Alexandria Renew Enterprises

Request for Proposals for:

Solids Master Planning Services - Wastewater

RFP 21-015

July 27, 2021

AlexRenew will be accepting proposals in hand at the AlexRenew Environmental Center located at 1800 Limerick Street, Alexandria, VA 22314, Attn: Maryam N. Zahory, Purchasing Agent, on or before **4:00 P.M.** EDT Monday, **September 27, 2021**.

An optional in-person pre-proposal conference will be held at **1:00 P.M.** EDT on Tuesday, **August 17, 2021**. The purpose of this conference is to allow potential respondents an opportunity to present questions and obtain clarification relative to any facet of this solicitation and to tour the Water Resource Recovery Facility (WRRF).

Respondents who wish to attend the pre-proposal meeting must pre-register by sending an email with the subject: RFP 21-015 Pre-Proposal Conference to **purchasing@alexrenew.com** by **4:00 P.M.** EDT on Tuesday, **August 10, 2021**. Email shall contain the firm's name and the name(s) and email addresses of the individuals who would like to participate in the meeting. A maximum of (3) three people may attend from each firm.

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List of Exhibits

* To be completed by respondent and included with the RFP response.

Section 1. Purpose and Vison

General

The intent of this Request for Proposal (RFP) is to solicit Professional Solids Master Planning Services related to the creation of a Solids Master Plan (Master Plan) for the AlexRenew Water Resource Recovery Facility (WRRF). The Master Plan shall provide a roadmap for solids management over a 20 year planning period and be in accordance with the values set forth in AlexRenew's 2040 vision (Exhibit A).

Solids in the context of this RFP shall include any solids generated as part of the wastewater treatment process such as grit, screenings, and biosolids. Solids management shall include solids capture, processing, handling, transportation, disposal and/or reuse. The Master Plan shall also address the management and/or beneficial re-use of any byproducts generated during solids processing, such as gas and/or odors. It shall also address the impacts of current and future permitting requirements, the evolving regulatory landscape, and climate change in the context of solids handling and disposal. Finally, it shall address how all recommended solutions shall be implemented, including timing, phasing, and staff resource requirements.

The successful respondent will be responsible for evaluating the WRRF's current solids handling process in its entirety and working iteratively and collaboratively with AlexRenew (Exhibit B) to determine the best solids processing and management plan for AlexRenew and its stakeholders. The final solution may involve enhancing the current solids handling process or replacing it with one that is able to ensure system reliability and resiliency over the planning horizon.

Planning Process

The Master Planning process shall be **adaptive** (not fixed or linear) and focus on creating a **custom** solids management solution unique to AlexRenew and its specific drivers. The process shall encourage **creative** and **forward thinking** about multiple possible futures (not just current conditions) and be **iterative** to facilitate the consideration of these futures.

In addition, a diverse group of AlexRenew staff, across all levels of the organization, will be involved in the Master Planning process. Therefore, the process must be **inclusive** of diverse internal stakeholder feedback and participation. The successful respondent shall be able to effectively communicate with and educate a diverse group of internal stakeholders on possible solids handling solutions and technologies throughout the planning process.

Planning Document

The Master Plan be a long-term adaptive planning document that provides a framework for successfully managing AlexRenew's Solids. It shall do the following:

- *Define* AlexRenew's Solids Management (SM) ***Strategy & Goals***
- *Identify* and evaluate ***challenges/potential risks*** to successful SM

- Present ***near and long term BM solutions*** that support AlexRenew's vision, mission, goals, and strategic objectives over a 20 year planning horizon
- Assess ***organizational readiness*** (e.g., financial, process, technology, and staffing) with respect to solution implementation
- Provide ***a roadmap to solution implementatio***n (e.g., methodology, program development, procurement options, triggers, timing etc.)

Capital Improvement Plan

AlexRenew dedicates a portion of its $721 million 10-year Capital Improvement Plan (CIP) to solids management projects, including the Master Plan and the design and construction of associated facilities. The Master Plan will help inform the project planning and prioritization process so that the execution of capital projects can support the vision for an optimized solids management program. Information on our current CIP plan can be found in our FY21 Operating and Capital Budget document located here: https://alexrenew.com/who-we-are/budget-and-reports

Expression of Interest

Firms interested in this work must submit a proposal demonstrating their expertise and experience in the area of solids management and related matters such as facility design, operation, permitting, sustainability, and others. This demonstration shall include a proven portfolio of related work, strong project management skills, and strong technical competence in wastewater planning, design, and engineering, with an emphasis on solids. Only one contract for these services will be awarded.

Contract Structure

The contract will be structured in the form of a Professional Services Agreement (PSA) with the scope of the Master Plan defined and agreed to via a Task Order (TO) under the PSA. Work under this contract may also require traditional engineering design services to meet near term goals or to ensure continued performance of the existing solids processing system while the Master Plan is under development. If needed, design work will be handled via additional TOs under the PSA. The successful candidate will also be required to collaborate and share information with AlexRenew's other Engineering consultants or contractors.

Section 2. Background

Established in 1952 by the Alexandria City Council, AlexRenew's chartered mission is to intercept and clean wastewater and protect public health and the environment. AlexRenew is governed by a five-member citizen Board of Directors appointed by Alexandria City Council and is a political subdivision of the Commonwealth of Virginia, created under the Virginia Water and Waste Authorities Act. AlexRenew is an independent, special-purpose government unit with administrative and fiscal independence from the City of Alexandria. AlexRenew serves more than 300,000 people in the City of Alexandria and parts of Fairfax County, Virginia. It currently maintains capital assets valued at approximately $750 million and treats approximately 38 million gallons per day (MGD) of wastewater at its WRRF, located in Alexandria, Virginia.

AlexRenew maintains one of the most advanced wastewater treatment facilities in the United States, on a 35-acre site within walking distance of Old Town Alexandria. AlexRenew's treatment processes include preliminary and primary treatment, Biological Nutrient Removal (BNR), chemical addition for phosphorous removal, and UV disinfection. Treated effluent is discharged into Hunting Creek and eventually flows into the Potomac River, which is part of the Chesapeake Bay watershed. AlexRenew also produces Class A Exceptional Quality Biosolids, which are land applied throughout the Commonwealth of Virginia. Exhibit C includes copies of the WRRF site plan and the WRRF individual liquids- and solids- processing schematics for additional detail on the assets and treatment technologies comprising AlexRenew's WRRF.

While the City of Alexandria owns the majority of the collection system, AlexRenew owns and operates large interceptors and trunk sewers, which comprise approximately 18 to 20 miles of gravity flow pipe. Two (2) miles of this pipe are located in Old Town Alexandria and carry combined sewage flows. The remaining 16 to 18 miles are separate sewer system. AlexRenew also maintains several pump stations. These off-site pump stations have a total capacity of about 24 MGD. Exhibit C provides a summary of the major assets that comprise AlexRenew's interceptor system.

Under the RiverRenew Program, AlexRenew acquired the assets associated with the City's existing combined sewer overflow (CSO) outfalls in June 2018 and is developing and implementing a CSO mitigation program, which will significantly reduce CSO discharges into the City's waterways. AlexRenew will own and operate the RiverRenew assets upon completion of this program in 2025. See https://riverrenew.com/ for additional information on RiverRenew.

AlexRenew is committed to being an environmental steward, good neighbor, and industry leader in the day-to-day work of making dirty water clean. A copy of AlexRenew's 2040 Vision and its Community Benefit Policy are included in Exhibit A. As denoted by the vision, AlexRenew has a strong commitment to innovation, environmental stewardship and sustainability. AlexRenew aims to improve the overall performance of the WRRF, while optimizing resource efficiency and managing costs and risks in a responsible manner. AlexRenew expects its service providers to perform their work in alignment with this vision, environmental and sustainability goals and the community benefit policy.

Section 3. Solicitation Method and Competition Intended

This solicitation is issued using the Competitive Negotiation procurement process as defined and authorized in the Virginia Public Procurement Act (VPPA) § 2.2-4302.2.(4). The Contract resulting from this solicitation shall be subject to the terms and conditions as set forth herein, or elsewhere in AlexRenew and Commonwealth of Virginia rules and regulations. The content of the proposals and the identity of the offerors are not public record until a Notice of Award has been issued. The opening of proposals is therefore not public.

It is AlexRenew's intent that this Request for Proposal (RFP) permits competition. It shall be the Respondent's responsibility to advise the Purchasing Agent in writing if any language, requirement, specification, etc., or any combination thereof, inadvertently restricts or limits the requirements stated in this RFP to a single source. The Purchasing Agent must receive such notification no later than fifteen (15) days prior to the date set for acceptance of proposals.

Section 4. Minimum Qualification Requirements

AlexRenew is seeking an experienced, innovative, thought leader with a demonstrated ability to build relationships with diverse stakeholders within a wastewater utility or authority. Firms should be able to tap into domestic and international industry talent and experience through academia, research, partnerships or the like. Teaming with others to deliver a successful Master Plan for AlexRenew is encouraged. Previous experience working for AlexRenew is not required.

Interested engineering firms should have at least ten (10) years of wastewater treatment facility experience and be registered to provide engineering services in the Commonwealth of Virginia through the Virginia Department of Professional and Occupational Regulation. Professional experience/knowledge should be in the following areas:

- The planning, design, construction, operation, and permitting of municipal solids handling projects at advanced wastewater facilities;
- Developing strategic and effective wastewater project implementation plans;
- Experience with/knowledge of proven and emerging solids handling technologies;
- A demonstrated ability to create and adhere to an effective quality control plan;
- Experience with and in depth knowledge of the Virginia Department of Environmental Quality (VDEQ) and the Environmental Protection Agency (EPA) permitting requirements to include existing and emerging regulatory trends and requirements;
- Experience analyzing and addressing the impacts of climate change on wastewater facilities;
- Experience analyzing and incorporating sustainability measures into wastewater facilities; and,
- Experience with effectively communicating technical concepts to both industry professionals (all levels of experience) and the general public in written, visual, and verbal formats, as well as experience educating industry professionals and others on technical and regulatory concepts.
- Experience developing and executing procurement strategies in the wastewater sector

Section 5. Scope of Services

All proposals must be made on the basis of and either meet or exceed the requirements contained herein. All respondents must be able to provide engineering and other professional services to complete the development of the Master Plan. Specialties may include, but are not limited to, general civil engineering, mechanical, electrical and plumbing (MEP) engineering, architectural services, wastewater engineering, land surveying, hydraulics engineering, hydrology, environmental studies, public communications, community engagement and outreach, cost estimation, scheduling, project- and portfolio-management services, process troubleshooting, and permitting.

The scope of services for this solicitation is intended to provide for professional engineering services in support of the development and implementation of a Master Plan. However, AlexRenew reserves the right to solicit separately for professional engineering services related to any solids projects identified as part of the master planning process (or elsewhere) if it deems this approach to be in the best interest of AlexRenew.

All services shall be performed in compliance with industry standards of practice and all federal, state, and local laws, ordinances and regulations including EPA, Virginia Department of Environmental Quality (VDEQ), Virginia State Health Department, VOSH (Virginia Occupational Safety and Health Agency) and OSHA rules and regulations. The services to be provided shall include but not be limited to the following:

- Development of a Master Plan for the identified planning period and in accordance with AlexRenew's values and 2040 vision.
- Professional involvement throughout all phases of the plan development including but not limited to development of programs, preparation of reports, preparation for and participation in briefings and presentations to staff groups, citizen groups, AlexRenew's Board, and Federal or State agencies as appropriate.
- Other types of professional and non-professional services of a nature consistent with the intent of this RFP as so directed by AlexRenew.
- Follow-on solids system design work, evaluations (including bench- and/or pilot- studies), alternative analysis, reports and recommendations, cost and time estimates, scopes of work to form the basis for future capital projects and/or projects to improve, repair or replace existing assets, preparation of bid documents (including drawings in latest AutoCAD version and specifications), bidding services, commissioning, O&M support and field investigations and/or inspections.

Section 6. Instructions for Preparing and Submitting Proposals

Respondents shall respond to the RFP with a written proposal in the format outlined below.

Proposal Organization and Contents

The proposal shall include at a minimum the following sections, arranged in the specified order:

Section A. Executed Cover Sheet

Section B. Table of Contents

Section C. Introductory Letter

Section D. Project Understanding and Management Approach

Section E. Proposed Project Team

Section F. Related Project Experience

Section G. RFP Checklist

Section H. Proposal Form

Section I. Resumes

Section J. Sample Solids Master Planning Scope

Unnecessarily elaborate materials beyond that sufficient to present a complete and effective proposal are not desired. Elaborate artwork, expensive paper, bindings, visuals, and other presentation aids are not required.

Proposal Sections

Information on what is to be included in each proposal section is explained below.

Section A: Executed Cover Sheet

Complete Exhibit E and include as the first page of the proposal.

Section B: Table of Contents

Include a Table of Contents outlining the contents of the proposal that allows for at least three (3) levels of content to address the proposal's level of detail.

Section C: Introductory Letter (3 page limit)

Include a dated cover letter indicating the firm's understanding of and interest in the work required under this RFP, summarizing the key components addressed within the Proposal. This document shall be legally binding by a person authorized to represent the firm. Please include name, address, telephone number, email and title for each of these persons. Provide any information that distinguishes your firm from its competition and any additional information applicable to this RFP that might be valuable in assessing the proposal. Explain any concerns respondent may have in maintaining objectivity in recommending the best solution. All potential conflicts of interest must be disclosed (see Exhibit G).

Section D: Project Understanding and Management Approach

1. Provide a brief narrative demonstrating the respondent's understanding of the Master Plan project requirements. To the extent possible, relate specific experience of the respondent's firm and Key Personnel to the project understanding and approach.
2. Provide a discussion on the methodology the respondent will use to successfully manage the project and provide engineering and planning services for the Master Plan. Attention to the following areas must be provided in the approach:
    - Approach to organizing the work and the rationale for proposed staffing plan/organizational chart in Section E
    - Approach to developing, maintaining and meeting project schedule
    - Quality assurance and quality control approach
        - Methods to ensure accountability in quality review documentation
    - Communication Plan for working with AlexRenew on this project
        - Include proposed lines of communication

   - Describe benefits of proposed communication methods

- Engaging & educating AlexRenew's diverse personnel as appropriate. Refer to the AlexRenew Organizational Chart (Exhibit B)
   - Include information on how the firm plans to effectively engage and educate staff with diverse backgrounds, education levels, technical ability, and experience levels.

Section E: Proposed Project Team

1. Provide a one-page organizational chart illustrating the respondent's team structure and information on the entities comprising the respondent's team. One-page organizational chart may be 11" by 17" if necessary, to clearly identify the respondent's team structure. Key Personnel shall be clearly identified.
2. At a minimum, the respondent shall demonstrate the ability to staff the following three (3) Key Personnel roles with experienced personnel:

- Master Plan Manager:
   - Responsible for managing all aspects of the planning program.
   - Must be familiar with and passionate about the wastewater sector but does not need to have an extensive design/technical background.
   - Must be an emotionally intelligent collaborator and a connector; able to generate ideas as well as pull ideas from others.
   - Must be an exceptional listener and an effective communicator.
   - Must stay with the program for its duration.
   - Must be highly organized and able to pay attention to detail.
   - Must be empowered to bring in the resources needed to deliver a successful Master Plan.
- Wastewaters Sector Subject matter Expert:
   - Responsible for bringing extensive local/global industry knowledge into the planning processes
   - Must be an acknowledged/proven industry leader
   - Must have experience with the implementation of solids projects
   - Must be familiar with industry drivers, stressors, regulations, and practices
   - Must be able to teach/educate AlexRenew staff on sector drivers, stressors, regulations, and practices (or be able to facilitate this)
- Organizational Readiness/Implementation Advisor:
   - Responsible for bringing practical implementation experience, knowledge, and options to the master planning process.

- Must be able to lead the development of an implementation strategy/vision
- Must be able to lead the identification and analysis of implementation options
- Must be familiar with a variety of procurement tools and understand how to leverage them to achieve the desired implementation outcomes
- Must be able to assess AlexRenew's ability to implement the range of possible solutions and to craft appropriate implementation plans

These three (3) Key Personnel roles are summarized in Table 1. Table 1 is intended to capture the critical team roles required to produce a successful Master Plan. The respondent may, where it deems appropriate, identify up to three (3) additional Key Personnel, provided that their roles and responsibilities are clearly defined and the respondent deems them important to crafting a successful Master Plan. Key Personnel are expected to stay with the project over the life of the contract.

Table 1. Summary of Key Personnel Experience

Key Personnel Role	Firm/Staff Name	Office Location	Years of Experience	Years with Entity	Reference Project(s)	Reference 1	Reference 2
Role	Firm/Staff name	City, State	Total years of experience	Total years with entity	Project name	Name • Title • Address • Phone Email	Name • Title • Address • Phone Email
Master Plan Manager	" "	" "	" "	" "	" "	" "	" "
Wastewater Sector Subject Matter Expert	" "	" "	" "	" "	" "	" "	" "
Master Plan Organizational Readiness/Implementation Advisor	" "	" "	" "	" "	" "	" "	" "
Other (specify)	" "	" "	" "	" "	" "	" "	" "

3. In addition to the organizational chart, provide a summary of all Key Personnel (required and proposed) as outlined in Table 1. Respondents may modify Table 1 to reflect any combining or splitting of positions but shall adhere to the given format of the table as closely as possible to facilitate comparisons during proposal evaluation. Repeat rows as necessary to cover all positions respondent deems as Key Personnel.
4. Provide information that demonstrates direct experience with advanced wastewater treatment plant solids master planning, facility studies, rehabilitations, upgrades, and expansion projects for each of the proposed Key Personnel, including subcontractors. Mandatory information to be provided for each Key Personnel includes:

- Role
- Qualifications (technical and/or soft skills)
- Reference project(s)
- Total years of experience and years with current entity
- A minimum of two (2) references with name, title, address, email, and phone number
- Full resumes provided in an appendix highlighting experience in the proposed role. Include only two-page resumes for Key Personnel (see Table 1) and one-page resumes for all other personnel. Provide their credentials and experience that demonstrate their qualifications to perform the assigned role(s) under the Master Plan.

<u>Section F. Related Project Experience</u>

1. Provide a summary of the reference projects as outlined in Table 2 below, one row for each project.
    - Include project descriptions for a minimum of (5) five projects completed by the respondent that are in progress or have been completed within the last ten (10) years that demonstrate direct experience in master planning as well as projects that demonstrate experience in the qualification areas listed in Sections 4 and 5 of this RFP. Solids master planning experience is strongly desired.
2. Include a description of the respondent ’s role (prime, subconsultant) on each submitted project. For work as a subconsultant, identify the respondent ’s scope of work and subcontract value.
3. Identify proposed personnel who worked on each project along with their role and responsibilities. Include at least two (2) projects where there is significant involvement from Key Personnel proposed on this project.
4. Include a minimum of one (1) reference contact with name, title, address, email, and phone number for each project in Table 2 below. References must have direct knowledge of performance of the submitting respondent and/or the Key Personnel associated with the reference project. Respondent authorizes AlexRenew to verify any and all information contained in the respondent ’s submittal from references contained herein and hereby releases all those concerned providing information as a reference from any liability in connection with any information they give.

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Table 2. Summary of Related Project Experience

Project Name	Owner	Construction Dates	Key Personnel	Reference
1.	Identify project owner	MM/DD/YYYY – MM/DD/YYYY	Name Title/Role on Project Responsibilities	Name • Title • Address • Phone • Email
2.	Identify project owner	MM/DD/YYYY – MM/DD/YYYY	Name Title/Role on Project Responsibilities	Name • Title • Address • Phone • Email
3.	Identify project owner	MM/DD/YYYY – MM/DD/YYYY	Name Title/Role on Project Responsibilities	Name • Title • Address • Phone • Email
4.	Identify project owner	MM/DD/YYYY – MM/DD/YYYY	Name Title/Role on Project Responsibilities	Name • Title • Address • Phone • Email
5.	Identify project owner	MM/DD/YYYY – MM/DD/YYYY	Name Title/Role on Project Responsibilities	Name • Title • Address • Phone • Email

Section G: RFP Checklist

Complete Exhibit F and include in the proposal.

Section H: Proposal Form:

A fully completed and signed proposal form must be included (see Exhibit G).

Section I: Resumes:

Two-page resumes for all Key Personnel in Table 1 (including any additional Key Personnel identified by the respondent) and one-page resumes for all other support personnel including subcontractors.

Section J: Sample Solids Master Planning Scope:

1. Respondent shall submit a Sample Solids Master Planning Scope (Scope) in AlexRenew's standard task order format (See Exhibit H). To the extent possible, the Scope shall be specific to the process

proposed for the creation of the AlexRenew Master Plan. The purpose of the high-level sample scope in this section is to help AlexRenew gain a deeper understanding of how the respondent will approach the master planning process. The actual project scope will be developed and negotiated with the successful respondent after contract award.

2. The Sample Scope shall include:
   - Proposed potential tasks, subtasks and/or workshops and associated goals and deliverables, explaining their rationale.
   - Proposed project schedule that identifies the sequence in which tasks will be executed, the interrelationship between tasks, their duration, key milestones and deliverables.

Proposal Length and Size Requirements

Maximum proposal length shall not exceed 30 page-equivalents.

The Executed Cover Sheet, Table of Contents, Introductory Letter, RFP Checklist, Proposal Form, and Resumes will not count toward the 30 page limit. However, the Introductory Letter shall not exceed three (3) pages total.

Pages shall be 8.5” by 11” with minimum of 0.5” margins and a minimum font size of 11 point. One double-sided 8.5” by 11” page shall count as two pages toward the page number limit. Pages 11” by 17” in size will count as two pages toward the page number limit. AlexRenew encourages the use of recycled products, therefore, it is urged that proposals be submitted on paper made from or with recycled content and printed on both sides, with the exception of any 11” by 17” pages, which should only be printed on one side.

Trade Secrets/Proprietary Info

Trade secrets or proprietary information submitted by the respondent shall not be subject to the Virginia Freedom of Information Act (Virginia Code § 2.2-3700 et seq.); however, the respondent shall (i) invoke the protections of this section prior to or upon submission of the data or other materials, (ii) identify (in writing) the data or other materials to be protected, and (iii) state the reasons why protection is necessary.

A respondent shall not designate as trade secrets or proprietary information (a) an entire proposal; (b) any portion of a proposal that does not contain trade secrets or proprietary information; or (c) cost and, prices (to the extent provided). References may be made within the body of the proposal to proprietary information; however, all information contained within the body of the proposal not labeled proprietary or otherwise not meeting all three of the requirements of Virginia Code § 2.2-4342 shall be public information in accordance with Virginia Code statutes.

Section 7. Submission Instructions

A. Each firm shall submit the following in a sealed package labeled as instructed in Paragraph B, below:

- Hard Copies: One (1) original and six (6) copies of the proposal. The original proposal shall be clearly marked as "original".
- Soft/Digital Copy: One (1) exact digital copy of the original proposal on a Universal Serial Bus (USB) flash drive and, if protection has been sought for proprietary information, one (1) redacted digital copy with the requested redactions. Digital copies shall be in searchable PDF format and all proposal sections (i.e., Sections A through I) shall be bookmarked.

B. Proposals must be delivered to the following physical address in a sealed box no later than the time and date deadline specified in this solicitation and labeled as follows:

Attn: Maryam Zahory
Purchasing Agent
Alexandria Renew Enterprises
1800 Limerick Street
Alexandria, VA 22314
Ref: RFP 21-015

Timely submission of the proposal is solely the responsibility of the respondent. Proposals received after the specified date and time will be rejected. Electronically submitted proposals or those submitted unsealed will not be accepted.

C. Changes to the RFP, in the form of addenda, may be issued between the RFP release and submission dates. Receipt and incorporation of all addenda into the proposal submission must be acknowledged. Addenda acknowledgements will become additional pages to the Executed Cover Sheet and will not count toward the total page count.

Section 8. Anticipated Procurement Schedule

AlexRenew anticipates conducting the proposal and contract award processes in accordance with the milestones set forth below. These milestones are subject to revision and AlexRenew, at its sole discretion, reserves the right to modify the milestones as it finds necessary.

The following schedule is anticipated for the procurement:

1. Issue RFP: July 27, 2021
2. Pre-Proposal Meeting: August 17, 2021 at 1:00 PM
3. Last day for questions on the RFP to be submitted to AlexRenew: September 7, 2021 at 4:00 PM
4. Proposals submitted to AlexRenew: No later than 4:00 pm EDT on September 27, 2021
5. Interview Shortlist Notifications: Week of November 8, 2021 (Nov 11)
6. Interviews: Week of December 6, 2021
7. Workshop Shortlist Notifications: Week of December 20, 2021
8. Workshop: Week of January 17, 2022
9. Notification of Selected Respondent: Week of January 31, 2021

10. Negotiations: Week January 31, 2021 through week of February 28, 2022

11. Announce Project Award: March 16, 2022

12. Notice to Proceed: March 16, 2022

Process for Submitting Questions

All questions relating to this solicitation shall be submitted to the Purchasing Agent via email to purchasing@alexrenew.com.

For a question to be considered, the subject line of the email must state the following: “RFP No. 21-015 Questions”

Questions should be succinct and must include the submitter’s name, title, company name, company address, and telephone number. Prior to the award of a contract resulting from this solicitation, potential respondents are prohibited from contacting AlexRenew staff other than the Purchasing Agent.

No questions will be considered if they are submitted after September 7, 2021 AT 4:00 PM.

If any questions or responses require revisions to this solicitation as it was originally published, such revisions will be by formal addendum only. Offerors are cautioned that any written, electronic, or oral representations made by any AlexRenew representative or other person that appear to change materially any portion of the solicitation shall not be relied upon unless subsequently ratified by a written addendum to this solicitation posted on the AlexRenew website.

Section 9. Procurement/Evaluation Process and Basis of Award

A. Procurement Overview

The Master Plan procurement process consists of several steps and contains four evaluation phases as summarized in Table 3 below. More detailed information on the evaluation criteria and process can be found in the sections that follow.

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Table 3. Procurement Process Overview

Step	Purpose/Activity	Evaluation Outcome
Issue RFP	To publicly advertise AlexRenew's need for Solids Master Planning Services	N/A
Pre-Proposal Meeting	To review the RFP process and communicate AlexRenew's operating profile and organizational values to potential respondents and to allow potential respondents to tour the WRRF facility.	N/A
Evaluation 1: Initial Proposal Screening	To review proposals for responsiveness.	Elimination of non-responsive proposals
Evaluation 2: Detailed Proposal Review	To Evaluate & Rank Respondent Proposals	Oral Interview Shortlist
Evaluation 3: Oral Interview	To Evaluate & Rank Respondent Interviews	Workshop Shortlist
Evaluation 4: Workshop	To Evaluate & Rank Respondent Workshops	Final selection of the Respondent best suited to deliver AlexRenew's Solids Master Plan
Contract Negotiation	To successfully negotiate a contract with the selected respondent	N/A
Contract Award & NTP	To award the contact and issue Notice to Proceed.	N/A

B. Evaluation Criteria

Respondents and respondent submissions will be evaluated by an AlexRenew Selection Advisory Committee (SAC). The SAC will consist of a diverse group of AlexRenew staff. Generally, the SAC will consider the firm's overall suitability to provide the required services based on the merits of proposals received or the oral presentations and workshops given. It will also consider the comments and/or recommendations of the firm's previous clients, as well as other references such as the State licensing board. Selection criteria is summarized in Table 4 below. Points reset to zero after each shortlist.

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Table 4. Evaluation Criteria

Evaluation Round	Description	Total Points Available	Evaluation Criteria & Point Breakdown
1	Initial Proposal Screening	N/A	• "Acceptable/Responsive" or "Unacceptable/Not Responsive"
2	Detailed Proposal Review	100	• 35 points, Master Plan Team • 30 points, Related Project Experience • 35 points, Master Plan Understanding and Approach
3	Oral Interview	100	• 50 points, Scenario Based Question (Provided with Shortlist Notification) • 50 points, Live Question (Asked during the interview)
4	Workshop	100	• 50 points, Solids Master Plan Scope • 50 points, Vision of Partnership and Achieving the Requested Outcome

C. Evaluation Process

1. AlexRenew reserves the right to make on-site visitations to assess the capabilities of individual respondents and to contact references provided with the proposal.
2. AlexRenew's Purchasing Agent may arrange for discussions with firms submitting proposals, if required, for the purpose of obtaining additional information or clarification.
3. Respondents are advised that, in the event of receipt of an adequate number of proposals, which, in the opinion of the AlexRenew Purchasing Agent, require no clarifications and/or supplementary information, such proposals may be evaluated without further discussion. Consequently, respondents should provide complete, thorough proposals with the respondents most favorable terms. Should proposals require additional clarification and/or supplementary information, respondents should submit such additional material in a timely manner.
4. **Initial Proposal Screening.** Proposals which, after discussion and submission of additional clarification and/or supplementary information, are determined to meet the requirements of this RFP will be classified as "acceptable" or "responsive". Proposals found not to be acceptable will be classified as "unacceptable" or "not responsive" and no further discussion concerning the same will be conducted.
5. **Detailed Proposal Review.** In this round the SAC will evaluate each proposal based on the evaluation criteria presented herein. Once the SAC has evaluated each proposal, they will develop a composite rating which indicates the group's collective ranking of the highest rated proposals in a descending order. The rating will be used to select the respondents for further

consideration (i.e., the Oral Interview Shortlist). The shortlisted respondents will be invited to participate in the Oral Interview round.

6. Oral Interview. In this round, the SAC will conduct interviews of the top ranked respondents (usually the top three (3) to five (5) depending upon the number of proposals received). Shortlisted respondents will prepare and provide an oral presentation in response to a Scenario Based Question (SBQ). The SBQ will be provided with the shortlist notification. The oral presentation will be followed by a question and answer session.

   At the end of this round the SAC will evaluate the oral interviews and develop a composite rating which indicates the group's collective ranking of the presentations in a descending order. The rating will be used to select the offerors for further consideration (i.e., the Workshop Shortlist). The Workshop shortlist respondents will be invited to participate in the Workshop Round.

7. Workshop. In this round, the SAC will participate in two discussions with the top ranked respondents. Respondents will prepare and provide a two part oral presentation. Part 1 will focus on their proposed Master Planning Scope and Part 2 will focus on their Partnership Vision and how they will help AlexRenew achieve the requested planning outcomes. Each oral presentation will be followed by a discussion session. There will be a break in between the two sessions.

   At the end of this round the SAC will evaluate the workshops and develop a composite rating which indicates the group's collective ranking of the workshops. The highest ranking respondent will be invited to enter into contract negotiations with AlexRenew.

8. AlexRenew will enter into negotiations with the highest ranked respondent .
   a. The parties may negotiate changes in the proposal if deemed in the best interest of AlexRenew. Negotiations may include, but are not limited to:
      i. Contract Terms and Conditions (example Professional Services Agreement provided in Exhibit H)
      ii. Project scope
      iii. Proposed personnel
      iv. Pricing terms
      v. Contract start date

9. If a contract can be negotiated at terms and conditions considered fair and reasonable, the contract award shall be made to that respondent . Otherwise, negotiations with the respondent ranked first shall be formally terminated and negotiations will be conducted with the respondent ranked second, and so on through those respondents deemed fully qualified, responsible, and suitable until such a contract(s) can be negotiated at fair and reasonable terms and conditions.

10. Negotiations shall then be conducted with the respondent so selected. AlexRenew shall select the respondent which, in its opinion, has made the best value offer, and shall award the contract to that respondent .

11. Should AlexRenew determine, at its sole discretion that only one respondent is fully qualified, or that one respondent is clearly more highly qualified and suitable than the others under consideration following receipt and evaluations of proposals, AlexRenew may enter into negotiations with that respondent (s) without shortlisting or interviews.
12. When AlexRenew has made a decision to award the contract and successfully completed negotiation of the contract with such respondent , the result of such decision will be posted on the AlexRenew website.

Section 10. Miscellaneous Requirements

A. AlexRenew reserves the right to waive minor defects or variations from the exact requirements of the solicitation in a proposal insofar as those defects or variations do not affect the price, quality, quantity, or delivery schedule of the goods, services and/or construction being procured. If insufficient information is submitted for AlexRenew to properly evaluate the proposal by a respondent , AlexRenew reserves the right to require such additional information as it may deem necessary after the proposals are received, provided that the information requested does not change the price, quality, quantity, or delivery schedule for the goods, services, or construction being procured.

B. AlexRenew will not be responsible for any expenses incurred by a firm in preparing and submitting a proposal. All proposals shall provide a straightforward, concise delineation of the firm's capabilities to satisfy the requirements of this request. Emphasis should be on completeness and clarity of content.

C. Respondents who submit a proposal in response to this RFP may be required to make an oral presentation of their proposal. AlexRenew will schedule the time and location for such presentation(s).

D. The contents of the proposal submitted by the successful respondents and this RFP will become part of any contract awarded as a result of the Scope of Services contained herein. The successful firm will be expected to sign a contract with AlexRenew.

E. AlexRenew reserves the right to reject any and all proposals received by reason of this request, or to negotiate separately in any manner necessary to serve the best interests of AlexRenew. AlexRenew reserves the right to accept or reject proposals, waive informalities or irregularities therein and to contract as the best interest of AlexRenew may require in order to retain the firm that best meets the needs of AlexRenew, as expressed in this RFP. Selection of a proposal does not mean that all aspects of the proposal are acceptable to AlexRenew. AlexRenew reserves the right to negotiate the modification of terms and conditions with the offerors offering the best value to AlexRenew in conjunction with the evaluation criteria contained herein prior to the execution of a contract, to ensure a satisfactory contract.

F. Respondents should be aware that all Key Personnel identified in a respondent ’s proposal must remain on the respondent ’s team for the duration of the proposal process and, if the respondent is awarded a contract, the duration of the contract, so long as they remain employed by such respondent .

G. If extraordinary circumstances require a proposed change in Key Personnel during the evaluation process, it must be submitted in writing to AlexRenew’s Point of Contact, who, at their sole discretion, will determine whether to authorize a change. Unauthorized changes to the respondent's team at any time during the procurement process may result in elimination of the respondent from further consideration.

H. Notice of Award – NOA will be posted on AlexRenew's web site (https://alexrenew.com/business-opportunities)

I. Protests – Respondents may refer to Sections 2.2-4357 through 2.2-4364 of the Code of Virginia to determine their remedies concerning this competitive process.

J. No respondent who is permitted to withdraw a proposal shall, for compensation, supply any material or labor to or perform any subcontract or other work agreement for the person or firm to whom the contract is awarded or otherwise benefit, directly or indirectly, from the performance of the project for which the withdrawn proposal was submitted.

K. Debarment – Respondents shall indicate, in the space provided on the Proposal Form, whether or not it, or any of its principals, is/are currently debarred from submitting proposals to AlexRenew or any other state or political subdivision, and whether or not it is an agent of any person or entity that is currently debarred from submitting proposals to AlexRenew, or any other state or political subdivision. An affirmative response may be considered grounds for rejection of the proposal.

L. Authority to Transact Business – Any respondent organized as a stock or non-stock corporation, limited liability company, business trust, or limited partnership or registered as a limited liability partnership shall be authorized to transact business in the Commonwealth of Virginia as a domestic or foreign business entity if so required by Title 13.1 or Title 50 of the Code of Virginia, or as otherwise required by law. The proper and full legal name of the firm or entity and the identification number issued to the respondent by the Virginia State Corporation Commission must be written in the space provided on the Proposal Form. Any respondent that is not required to be authorized to transact business in the Commonwealth shall include in its bids a statement describing why the respondent is not required to be so authorized. AlexRenew may require a firm to provide documentation prior to award which: 1) clearly identifies the complete name and legal form of the firm or entity (i.e. corporation, limited partnership, etc.), and 2) establishes that the firm or entity is authorized by the State Corporation Commission to transact business in Virginia. Failure of a prospective and/or successful respondent to provide such documentation shall be grounds for rejection of the proposals or cancellation of the award. For further information refer to the Commonwealth of Virginia State Corporation Commission website at: www.scc.virginia.gov.

M. Interest in More than One Proposal and Collusion – Multiple proposals received in response to this solicitation from an individual, firm, partnership, corporation, affiliate, or association under the same or different names will be rejected. Reasonable grounds for believing that a respondent is interested in more than one (1) proposal for a solicitation both as a respondent and as a subconsultant for another respondent will result in rejection of all proposals in which the respondent is interested. However, a firm acting only as a subconsultant may be included as a subconsultant for two (2) or more respondents submitting a proposal for the work. Respondents rejected under the above provisions shall be disqualified if they respond to a re-solicitation for the same work.

N. News Releases – News releases concerning any resultant contract from this solicitation will not be made by a respondent without the prior review and written approval of AlexRenew.

O. Proposal Withdrawal Prior to Proposal Opening – No proposal may be withdrawn after it is filed with AlexRenew unless the respondent makes a request in writing to AlexRenew prior to the opening of Proposals.

P. Security Compliance – The respondent may, at any time, be required to execute and complete, for each individual respondent 's employee or agent, additional forms which may include non-disclosure agreements to be signed by respondent 's employees or agents acknowledging that AlexRenew information with which such employees and agents come into contact while at the AlexRenew site is confidential and proprietary. Any unauthorized release of proprietary or personal information by the respondent or an employee or agent of the respondent shall constitute a breach of its obligations under this Section and the contract.

Q. The respondent shall immediately notify AlexRenew, if applicable, of any Breach of Unencrypted and Unredacted Personal Information, as those terms are defined in Virginia Code 18.2-186.6, and other personal identifying information, such as data as date of birth, etc. The respondent shall provide AlexRenew the opportunity to participate in the investigation of the breach and to exercise control over reporting the unauthorized disclosure, to the extent permitted by law.

R. The respondent shall indemnify, defend, and hold the AlexRenew, their officers, directors, employees and agents harmless from and against any and all fines, penalties (whether criminal or civil), judgments, damages and assessments, including reasonable expenses suffered by, accrued against, or charged to or recoverable from AlexRenew, their officers, directors, agents or employees, on account of the failure of Consultant to perform its obligations pursuant this Section.

S. In accordance with Code of Virginia § 2.2-4343.1, AlexRenew does not discriminate against individuals or organizations in the performance of its procurement activity.

T. Late, unsealed, and electronic proposals will not be accepted.

U. Insurance Requirements – The Contractor shall secure and maintain all insurance required by law or this Contract. Please see Article 6 of the PSA in Exhibit H for specific insurance requirements.

V. Distribution of Solicitation Documents and Offerors Responsibilities Regarding Defective Solicitation Documents

W. Distribution of Solicitation Documents – The distribution of this Request for Proposals (RFP), all addenda, and responses to questions will be posted to the AlexRenew website https://alexrenew.com/business-opportunities and the Commonwealth of Virginia website http://www.eva.virginia.gov/pages/eva-i-buy-for-virginia.htm The date and time of posting on AlexRenew website shall be the date and time of the official issuance or notification of the RFP or any modification to the solicitation process. It is the responsibility of each offeror to check AlexRenew's website daily for posted notifications. AlexRenew will not consider modification of any date, time frame, or addendum due to late receipt of notification based on subsequent advertisements or posting at any location other than the AlexRenew's website.

   Offerors Responsibilities Regarding Defective Solicitation Documents – It is the offeror's responsibility to determine the accuracy and /or completeness of the solicitation Documents upon which it relied in making its proposal, and has an affirmative obligation to notify the Purchasing Agent immediately upon discovery of an apparent or suspected inaccuracy, error in, or omission of any pages, drawings, sections, addenda whose omission from the Documents was apparent from a reference or page numbering or other indication in the solicitation Documents.

Exhibit A
AlexRenew 2040 Vision and Community Benefit Policy

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2040 Vision

By 2040, we have effectively partnered with all watershed stakeholders to:

- Enable local citizens the opportunity to **embrace the best use of water resources and establish a personal connection with local waterways.**
- **Sustainably manage water as a single resource** through the entire water cycle.
- **Create a healthy environment and improve our quality of life** through the exceptional reclamation of used water resources.
- **Maximize use of multiple financial options** to continue our fiscal stability.

Strategic Outcomes

1. Operational Excellence

Continually enhance water resource and recovery procedures to provide exceptional quality products.

2. Public Engagement and Trust

Engage our community to help them to become informed consumers and supporters of clean water.

3. Watershed Stewardship

Facilitate collaboration to collectively manage and improve water resources.

4. Adaptive Culture

Establish an organization-wide commitment to exceptional outcomes through an enthusiasm for learning, adapting, and solving problems to achieve clean water.

5. Effective Financial Stewardship

Manage our financial resources to create an efficient and resilient organization that contributes to the health of the local economy.

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Alexandria Renew Enterprises Board Adopted Policy		
Title: COMMUNITY BENEFIT POLICY		
Date of Adoption: October 2014	**Date of Revision:**	**Page 1 of 2**

Alexandria Renew Enterprises affirms and commits to the goal of developing an inclusive and comprehensive community benefits program to better serve and foster our partnership with the communities in the City and to ensure that public benefits are shared across all communities.

Alexandria Renew acknowledges its responsibility to develop a community benefits program that is intentional in its participation and support programs and projects that are designed to benefit our City, is centrally coordinated within Alexandria Renew, applies to all of its operations and its activities in all service areas, and which is sustainable, transparent, measurable, and accessible by stakeholders and Alexandria Renew staff.

Alexandria Renew defines community benefits as those positive effects on a community that result from Alexandria Renew's operation and improvement of its wastewater services. Alexandria Renew seeks to be a good neighbor to all whose lives or neighborhoods are directly affected by its activities. Alexandria Renew has adopted a decision matrix analysis to guide its decisions, balancing Alexandria Renew's economic, environmental, employee, production and social equity goals, to promote sustainability and community benefits.

The Board of Directors of Alexandria Renew will devote sufficient resources to Alexandria Renew staff to achieve outcomes including:

(1) Workforce development, including coordination of internal and external workforce programs and strategic recruitment, training, placement, and succession planning for current and future Alexandria Renew staff to ensure a skilled and diverse workforce;
(2) Environmental programs and policies which preserve and expand clean, renewable water and energy resources, decrease pollution, reduce environmental impacts, and reward proposals for innovative and creative new environmental programs;
(3) Economic development resulting from collaborative partnerships which promote contracting with local companies, hiring local workers, and providing efficient, renewable energy at reduced costs;
(4) Support for arts and culture related to the Alexandria Renew's mission, goals and activities;
(5) Educational programs;
(6) Use of land in a way that maximizes health, environmental sustainability and innovative ideas;
(7) Diversity and inclusion programs and initiatives;
(8) In-kind contributions and volunteerism; and
(9) Improvement in community health through Alexandria Renew activities, services and contributions.

In application of this policy to Alexandria Renew's operations, projects and activities, Alexandria Renew staff shall:

Develop and update a budget and staffing plan to implement and sustain the Community Benefits Program.

Develop an implementation strategy to review, analyze and coordinate community benefits initiatives and integrate these initiatives into an agency-wide Community Benefits Program.

Develop and implement guidelines, metrics, and evaluation methodologies for existing and future community benefits initiatives.

Develop diverse and culturally competent communication strategies to ensure wide ranging discussion.

Exhibit B
AlexRenew Organizational Structure

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FY22 Approved Budget

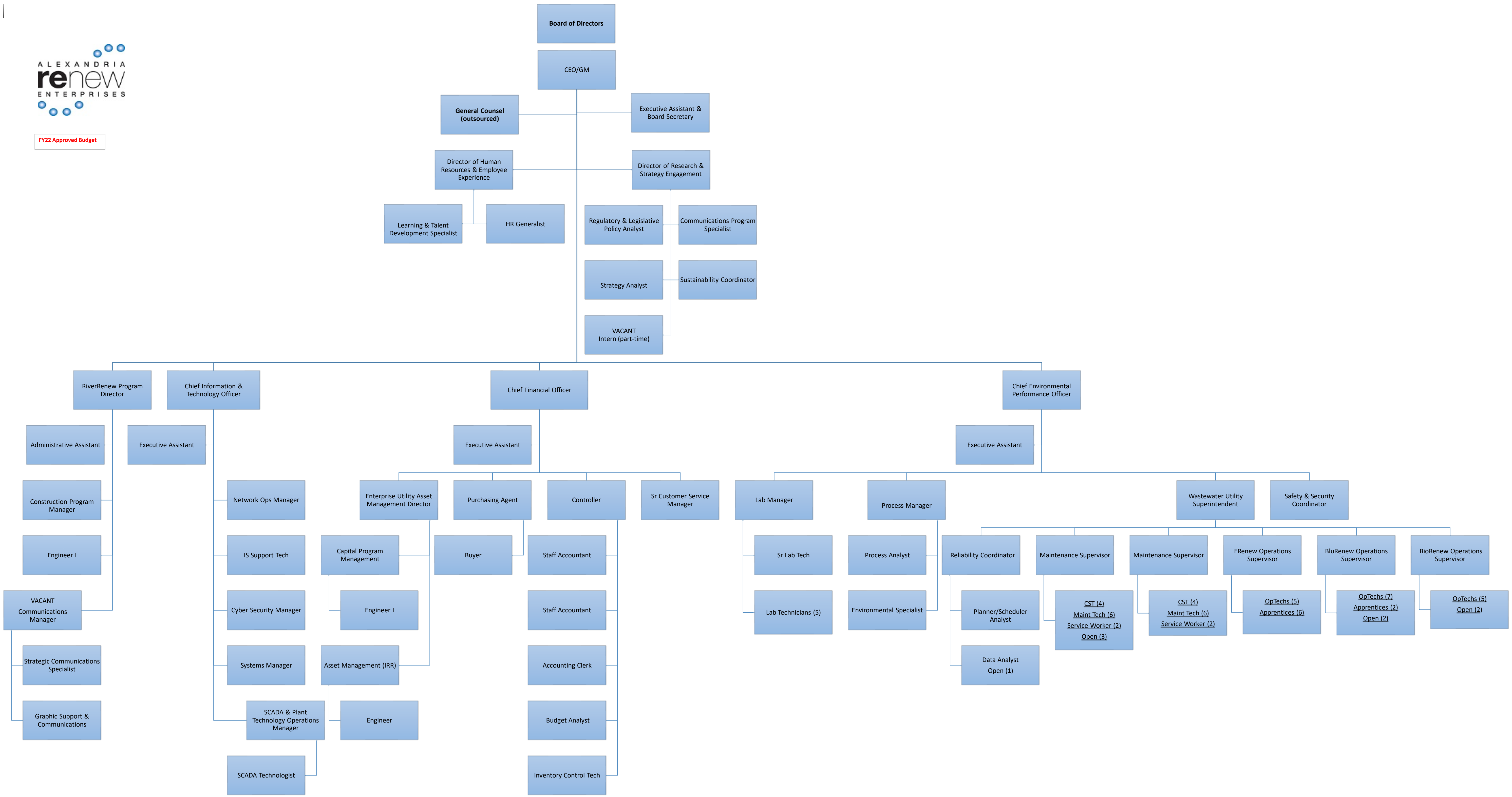

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Exhibit C
AlexRenew WRRF Treatment Process Schematics And Facilities

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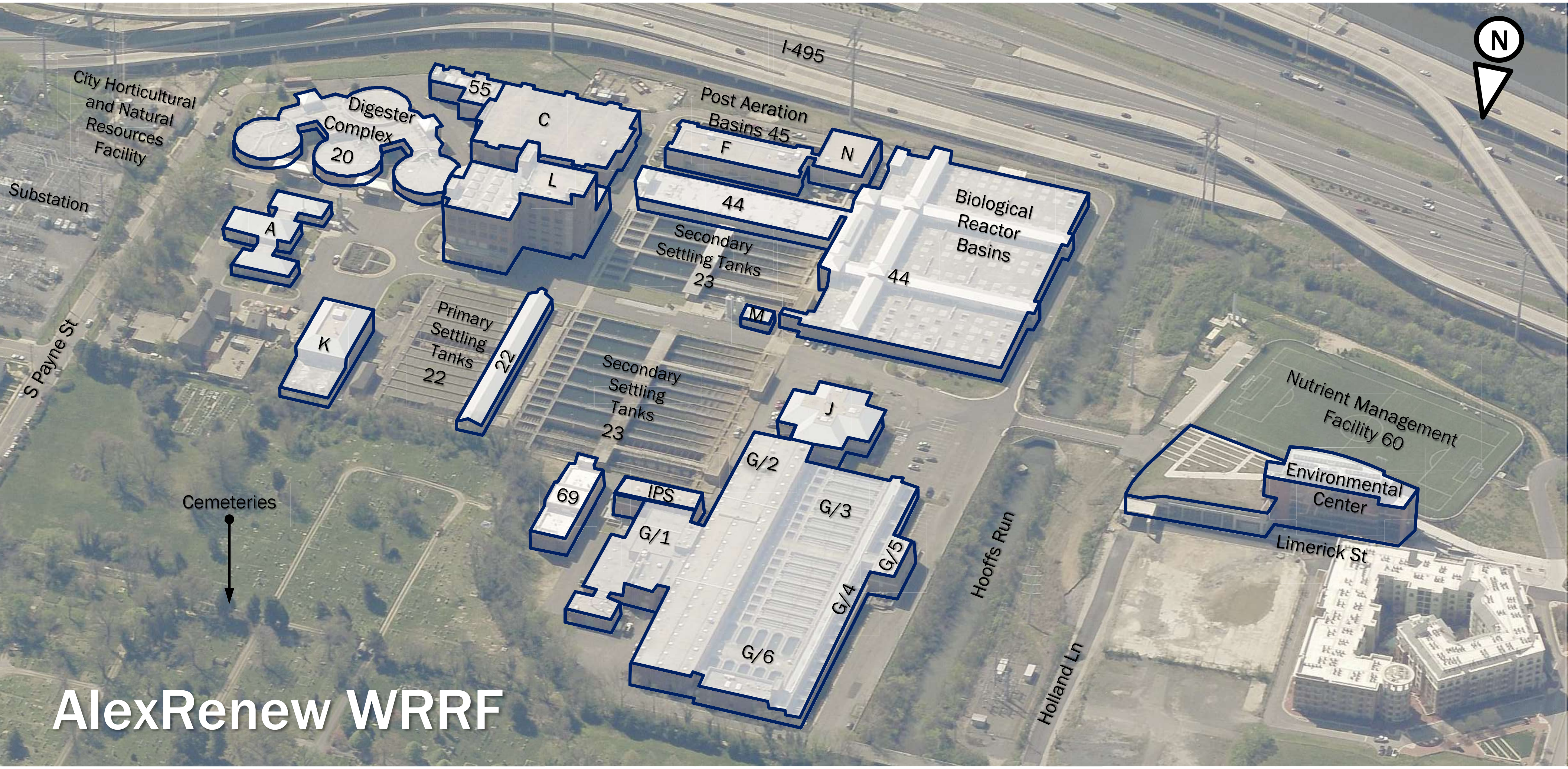
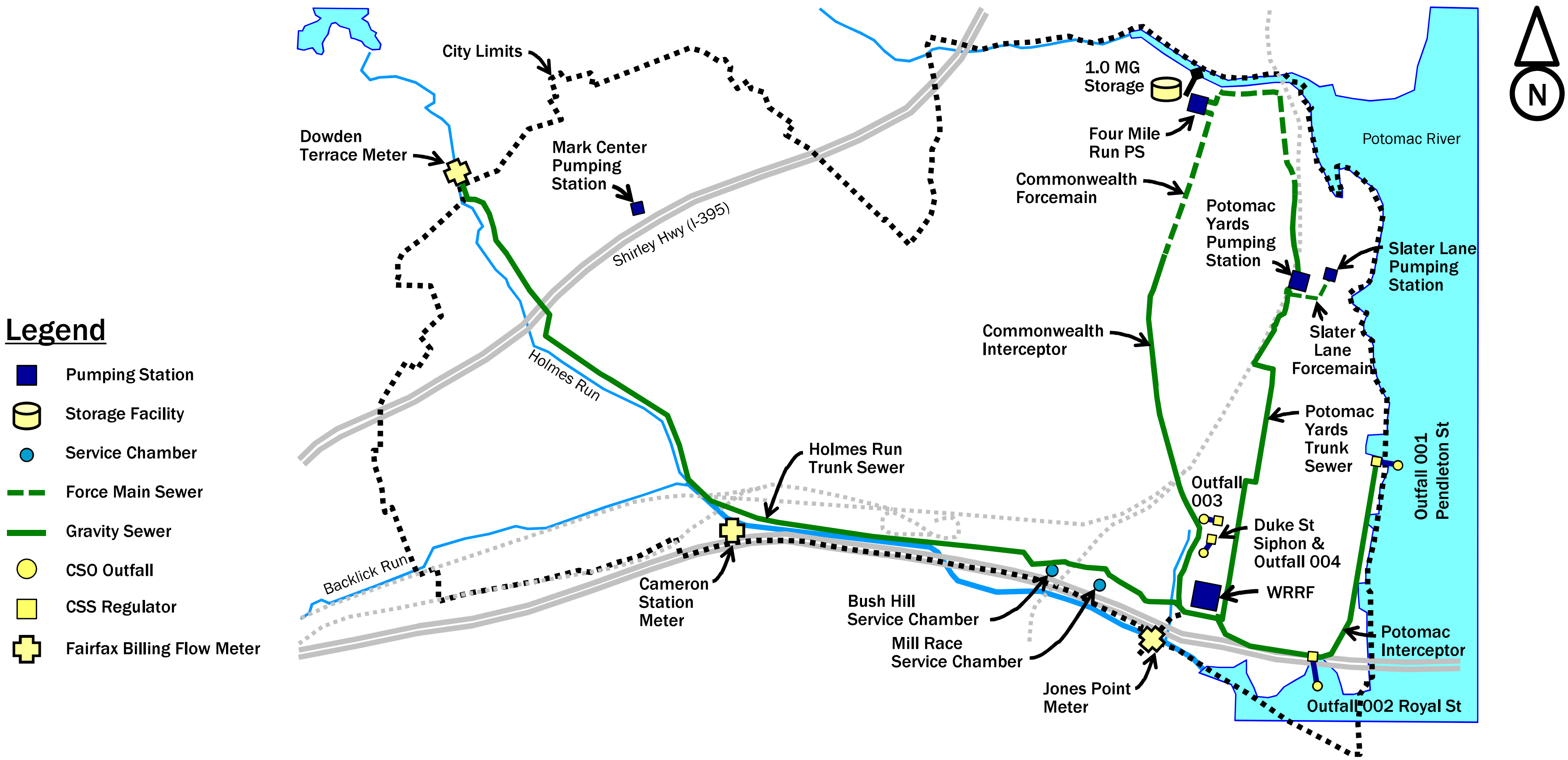

I-495
N
City Horticultural and Natural Resources Facility
Substation
Digester Complex 20
55
C
L
A
K
Post Aeration Basins 45
F
N
44
Secondary Settling Tanks 23
Biological Reactor Basins
44
M
Primary Settling Tanks 22
22
Secondary Settling Tanks 23
J
G/2
G/3
69
IPS
G/1
G/5
G/4
G/6
Nutrient Management Facility 60
Environmental Center
Limerick St
Hooffs Run
Holland Ln
S Payne St
Cemeteries
AlexRenew WRRF

AlexRenew WRRF Facilities

Facility Index	Facility Name
A	Main Building
C	Sludge Thickening Building
F	Process Air Compressor Building
G/1	Advanced Treatment Building
G/2	Carbon Column Building
G/3	Tertiary Settling Tanks
G/4	Filters
G/5	Wash Water Building
G/6	Filters
IPS	Intermediate Pump Station
J	Administration / Lab Building
K	Preliminary Treatment Building
L	Solids Processing Building
M	Methanol Building
N	UV Disinfection Building
20	Sludge Digester Complex
22	Primary Settling Tanks
23	Secondary Settling Tanks
44	Biological Reactor Basins
45	Post Aeration Basins
55	Pre-Pasteurization Building
60	Nutrient Management Facility
69	Centrate Pre-Treatment Complex

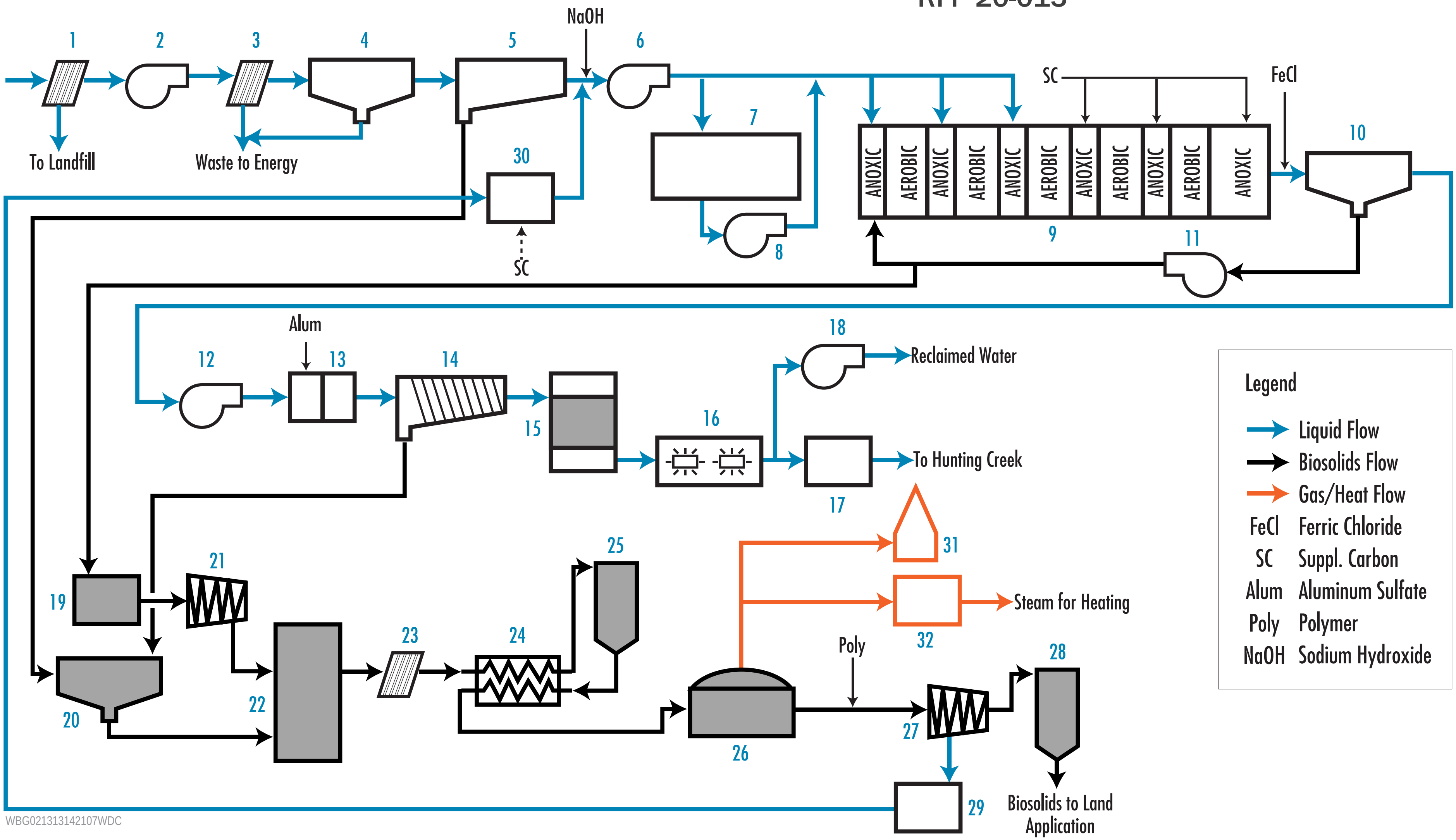
AlexRenew Interceptor System



AlexRenew Interceptor System Assets

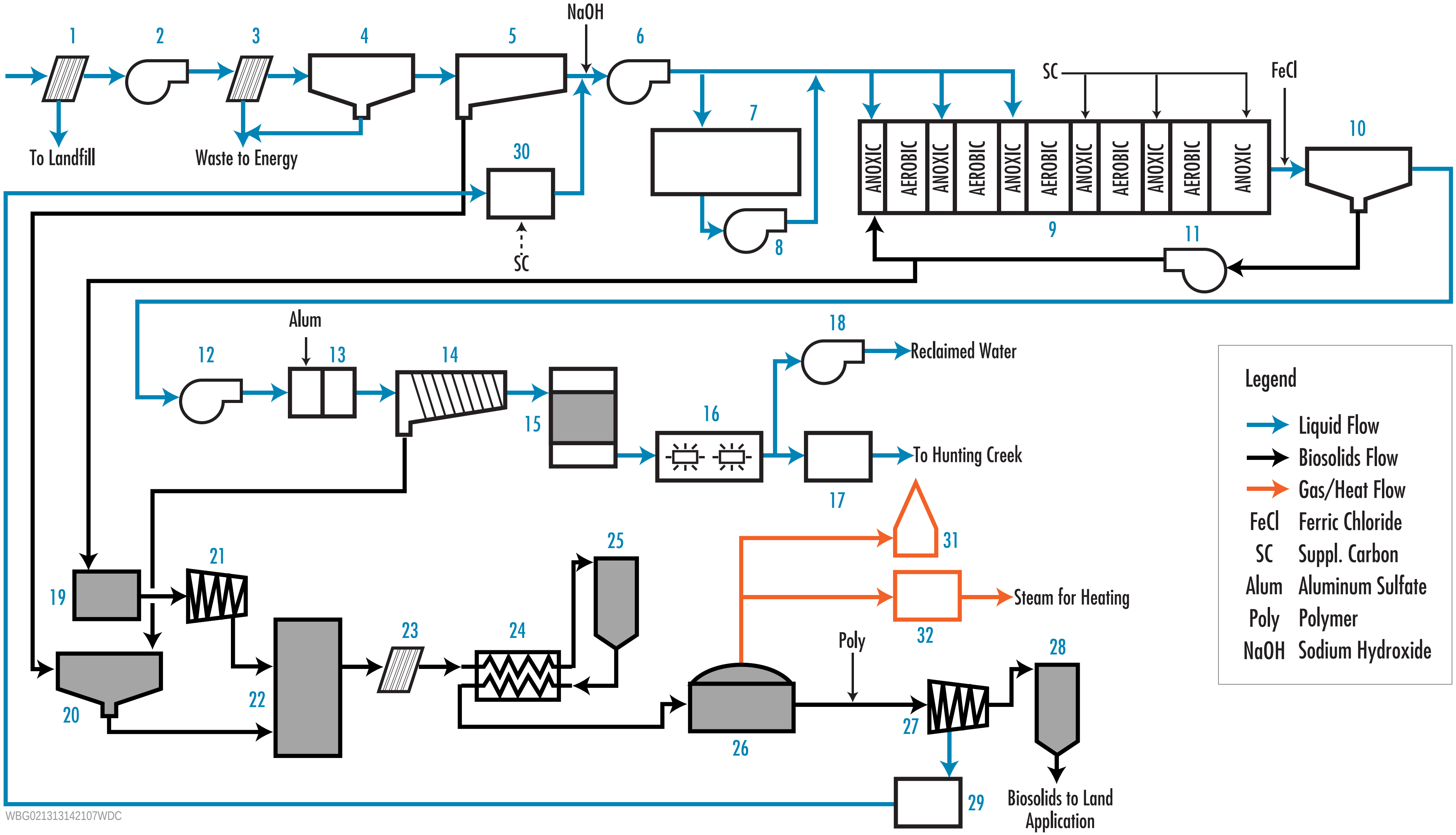
Asset Type	Name	Original Date of Service	Size or Capacity	Length (ft)	Original Material Type
Pump Station	Four Mile Run	1954	11 MGD		
Pump Station	Slater's Lane	1996	1.5 MGD		
Pump Station	Potomac Yards	2009	9.5 MGD		
Pump Station	Mark Center	2011	1.6 MGD		
Storage Facility	Four Mile Run Storage Tanks	2000	1 MG		
Service Chamber	Bush Hill	2002	250 GPM		
Service Chamber	Mill Race	2002	730 GPM		
Force Main Sewer	Commonwealth	1954	24"	4,600	RCP
Force Main Sewer	Slaters Lane	1996	12"	130	DI
Gravity Sewer	Commonwealth	1954	30" – 72"	16,400	RCP
Gravity Sewer	Holmes Run Trunk Sewer	1954	30" – 72"	22,500	RCP
Gravity Sewer	Potomac Interceptor	1954	36" – 42"	9,900	RCP
Gravity Sewer	Potomac Yards Trunk Sewer	2002	30"	8,700	PVC
CSO Outfall	Outfall 001 – Pendleton Street	1954			
CSO Outfall	Outfall 002 – Royal Street	1954			
CSO Outfall	Outfall 003 – King and West	1954			
CSO Outfall	Outfall 004 – Duke Street	1954			
CSS Regulator	CSS Regulator 001 – Pendleton Street	1954			
CSS Regulator	CSS Regulator 002 – Royal Street	1954			
CSS Regulator	CSS Regulator 003 – King and West	1954			
CSS Regulator	CSS Regulator 004 – Duke Street	1954			

C-3 AlexRenew WRRF Unit Process Information
RFP 20-015



Unit Processes

1	Coarse Screens	9	Biological Reactor Basins	17	Post-Aeration Channels	25	Pasteurization Tanks
2	Raw Sewage Pumps	10	Secondary Settling Tanks	18	Reclaimed Water Pumps	26	Anaerobic Digesters
3	Fine Screens	11	Return Activated Sludge Pumps	19	Raw Sludge Blending Tanks	27	Dewatering Centrifuges
4	Vortex Grit Chambers	12	Intermediate Pumps	20	Gravity Thickeners	28	Biosolids Silos
5	Primary Settling Tanks	13	Rapid Mix/Floc.Tanks	21	Thickening Centrifuges	29	Centrate Storage Tanks
6	Primary Effluent Pumps	14	Tertiary Settling Tanks	22	Thickened Sludge Eq. Tanks	30	Centrate Pre-Treat. Reactors
7	Nutrient Mgmt. Facility	15	Gravity Filters	23	Sludge Screenings Presses	31	Gas Flares
8	Nutrient Mgmt. Pumps	16	UV Disinfection	24	Heat Exchangers	32	Biogas Boilers

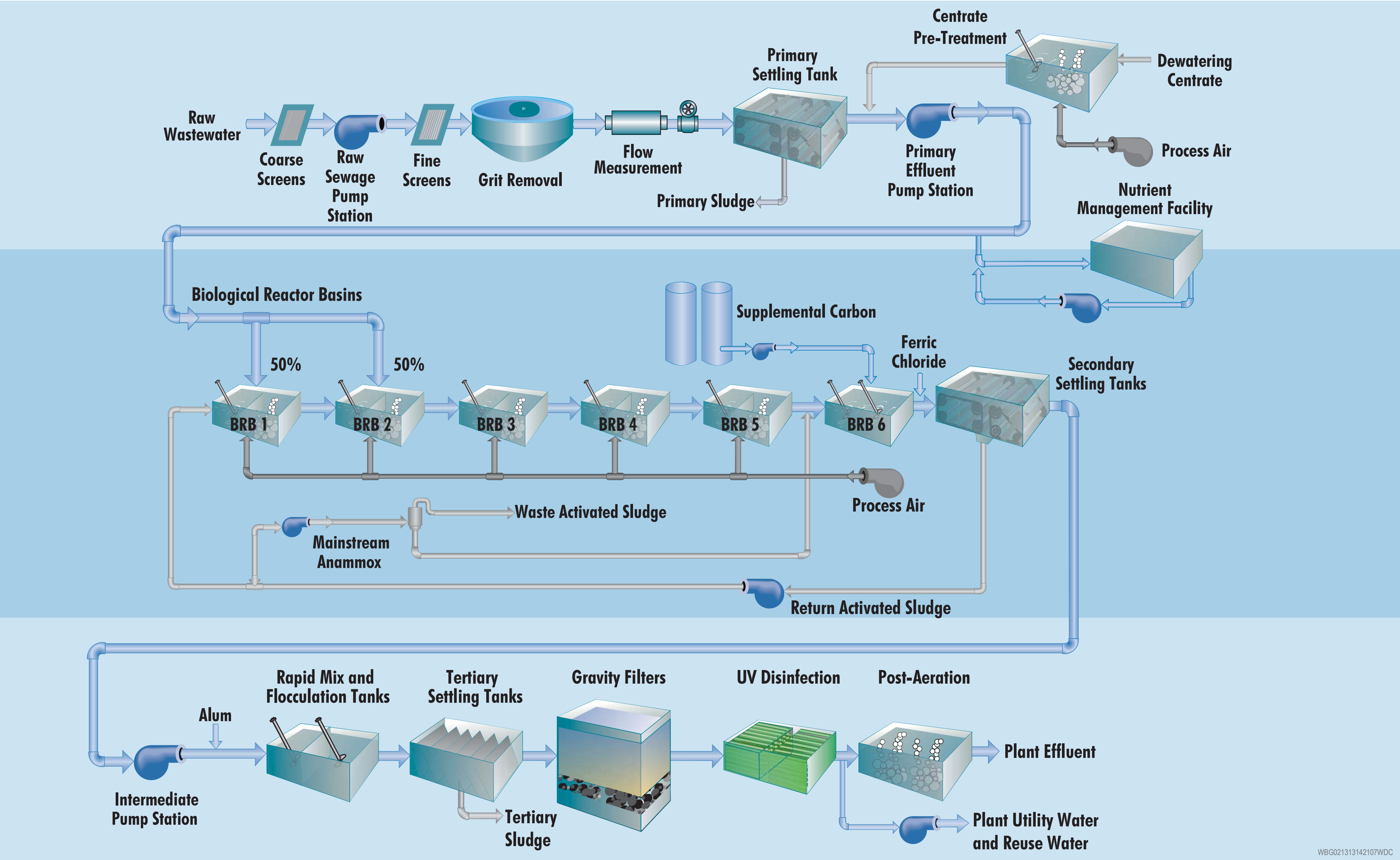


	Unit Process	Units		Capacity or Size	
1	Coarse Screens	2	x	60	MGD
2	Raw Sewage Pumps	6	x	30	MGD
3	Fine Screens	4	x	40	MGD
4	Vortex Grit Chambers	4	x	40	MGD
5	Primary Settling Tanks	8	x	6,228	sf
6	Primary Effluent Pumps	6	x	24	MGD
7	Nutrient Mgmt. Facility	4	x	4.5	MG
8	Nutrient Mgmt. Pumps	4	x	11	MGD
		4	x	3	MGD
9	Biological Reactor Basins	5	x	4.2	MG
		1	x	3.8	MG
10	Secondary Settling Tanks	6	x	23,240	sf

	Unit Process	Units		Capacity or Size	
11	Return Activated Sludge Pumps	12	x	5.9	MGD
12	Intermediate Pumps	6	x	37	MGD
13	Rapid Mix/Floc.Tanks	8	x	18	MGD
14	Tertiary Settling Tanks	8	x	25,200	sf
15	Gravity Filters	22	x	728	sf
16	UV Disinfection	6	x	23	MGD
17	Post-Aeration Channels	2	x	70	MGD
18	Reclaimed Water Pumps	2	x	350	gpm
		2	x	700	gpm
19	Raw Sludge Blending Tanks	3	x	0.016	MG
20	Gravity Thickeners	3	x	2,375	sf
21	Thickening Centrifuges	4	x	460	gpm

	Unit Process	Units		Capacity or Size	
22	Thickened Sludge Eq. Tanks	3	x	0.0153	MG
23	Sludge Screenings Presses	2	x	200	gpm
24	Heat Exchangers	3	x	100	gpm
25	Pasteurization Tanks	4	x	0.012	MG
26	Anaerobic Digesters	4	x	1.5	MG
27	Dewatering Centrifuges	3	x	200	gpm
28	Biosolids Silos	6	x	2,800	cf
29	Centrate Storage Tanks	2	x	0.039	MG
		2	x	0.028	MG
30	Centrate Pre-Treat. Reactors	2	x	0.4	MG
31	Gas Flares	2	x	260	scfm
32	Biogas Boilers	2	x	200	BHP

Schematic of AlexRenew WRRF's Liquid Treatment Processes



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Schematic of AlexRenew WRRF's Solids Treatment Processes

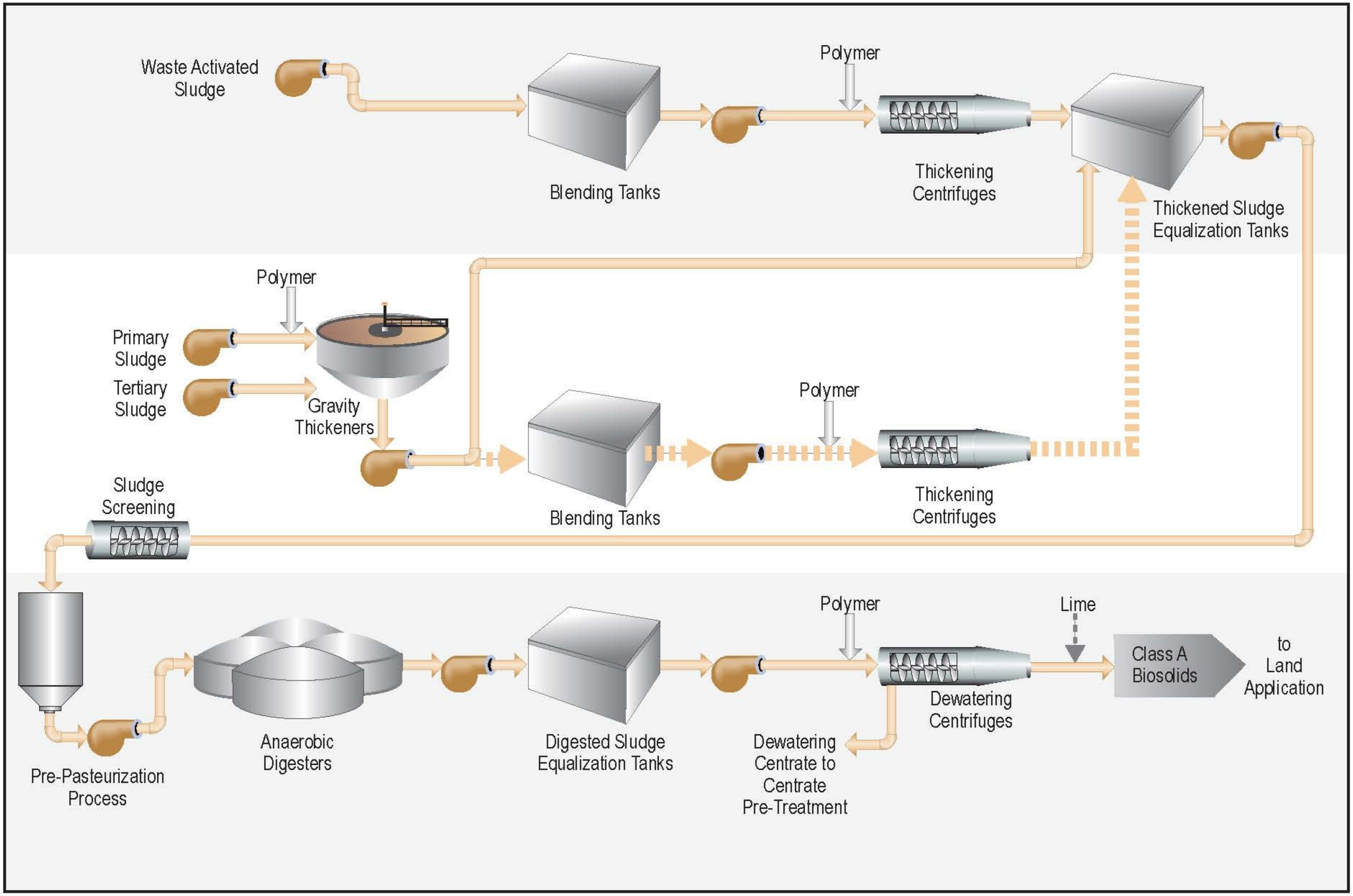

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Exhibit D
Previous AlexRenew Solids Studies

D-1 Biosolids Update to the Long Range Plan (Black and Veatch 2014)
D-2 Solids Handling and Energy Optimization Update to the Long Range Plan (CH2M, 2017)

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BIOSOLIDS UPDATE TO THE LONG RANGE PLAN

PREPARED FOR

ALEXANDRIA RENEW ENTERPRISES

17 DECEMBER 2014

Table of Contents

1 Introduction

1.1 PROJECT FRAMEWORK

The purpose of this Memorandum is to provide the basis for an update to the biosolids portion of the AlexRenew Long-Range Plan. The scope of the study is to identify the most suitable future biosolids programs for AlexRenew and to serve as a living document that establishes a road map for the utility in achieving a sustainable, dependable program. The scope and sequence of the work performed is presented in Figure 1-1.

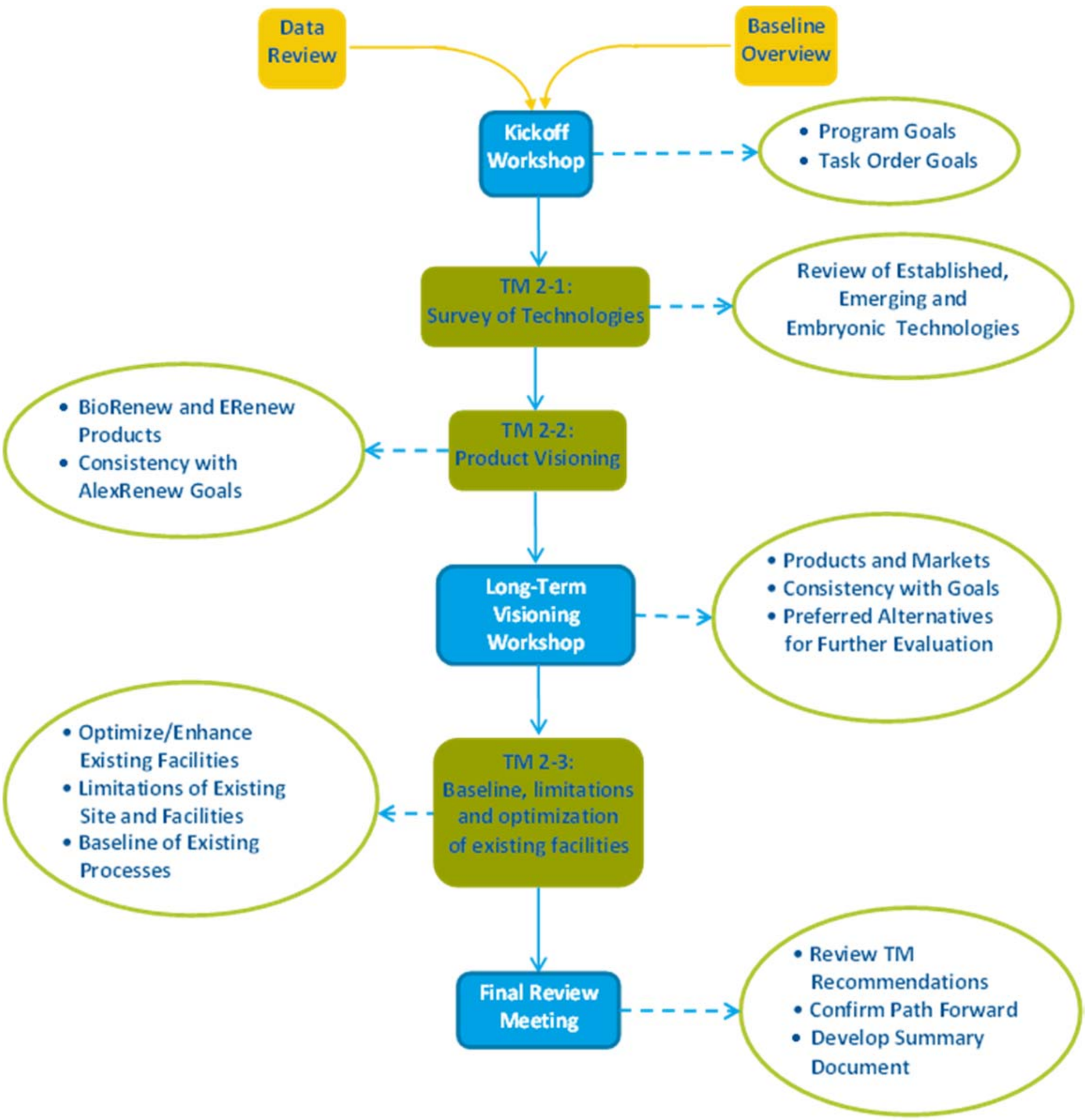

Figure 1-1. Project Workflow

1.2 PROJECT OBJECTIVES

Through the workshops, review of the Technical Memoranda and general discussions with key AlexRenew stakeholders, we have identified several key drivers that must be considered as part of the planning process. These include:

1. Serving as an integrated part of the community–
    a. Be seen as a visible, positive part of the community that serves as an investment and resource, rather than a cost center;
    b. Develop public/private or public/public partnerships, including research at the university level;
    c. Be a source for jobs and economic growth;
    d. Integrate elements of EcoCity Alexandria into goals and operations
    e. Minimize environmental impacts, including greenhouse gas emissions;
    f. Minimize negative community impacts such as: truck traffic, odors, and lighting.
2. "AlexRenew 2030" -- A central element to the utilities long-term vision is to transition from a waste treatment facility to a resource recovery facility that focuses on products and has a recognized brand in the community. Key subgoals include:
    a. Minimize or eliminate external land application;
    b. AlexRenew as energy self-sufficient;
    c. Develop recognizable brands.
3. Innovation – AlexRenew plans to continue being an industry leader and leveraging its location in an innovation corridor to provide technical advancements to the resource recovery industry.
4. Flexibility – Given uncertainties in regulations and markets, the biosolids system needs to provide flexibility to adjust to changing conditions.
5. Connection with other processes- Any changes within the biosolids system need to be tied together with existing and new processes and process impacts need to be understood. Likewise, impacts of new processes on biosolids system need to be incorporated into the plan.
6. Economic sustainability – In addition to other objectives, any solution should focus on long-term life-cycle costs and providing business stewardship for the rate payers and community.
7. Plant dependability/operability – As a critical element in the community's environmental infrastructure, all systems must be operable, dependable and robust.
8. Site Constraints – Any solution must recognize the limited site space available and plan accordingly.

2 Summary of Technical Memoranda and Recommendations

2.1 SURVEY OF BIOSOLIDS TREATMENT TECHNOLOGIES AND END-USE ALTERNATIVES

Technical Memorandum 2-1: Survey of Biosolids Treatment Technologies and End-Use Alternatives provides a comprehensive catalog of treatment technologies and the end-products they generate. The technologies and end-products were then combined into biosolids management systems, which were evaluated against AlexRenew's Decision Model Evaluation Criteria and ranked. A more qualitative analysis, including order of magnitude cost estimates and impacts on truck traffic, was also generated to assist with screening.

This document will serve as a reference for AlexRenew staff, as the "state-of-the-art" as of 2014. It is a single source for information on technologies that may be applicable in the future, the advantages and drawbacks of each technology and what triggers will impact their applicability for AlexRenew's consideration. This information will serve as a basis which can be updated as new technologies are developed.

2.2 PRODUCT VISIONING

Technical Memorandum 2-2: Product Visioning provides a comprehensive assessment of the end-use products that can potentially be generated by AlexRenew, now or in the future. Products were identified as "BioRenew" (biosolids-based product) and "ERenew" (energy-based product). Each product was evaluated against a set of criteria consistent with AlexRenew's goals and drivers. Systems were then developed that tie together BioRenew products, ERenew products and the technologies that generate each product. Each system was evaluated for marketability, branding potential, status of technology, use of existing assets and site suitability. This evaluation was then used to screen the list of systems into a more manageable set of options for further evaluation. These options were broken down into those seen as "promising technologies," which could be implemented based on known information, and "technologies to watch," which are less developed technologies recommended for tracking and possible research, pilot or demonstration testing.

This document includes an analysis of the potential end products currently generated from biosolids. The near term and long term markets are presented as well as the related marketing requirements. In addition, trigger conditions for the product are provided, indicating the status of the associated technologies, the product market, value and cost of generation. As these conditions change, the appeal of an end product may also change.

Figure 2-1 provides those systems that are more established and could be implemented in the near term, depending on the timeline determined by AlexRenew. Figure 2-2 presents systems that may meet AlexRenew's goals, but are recommended for tracking and possible support for additional research, pilot or demonstration testing, as they are not yet proven. The legend for the color coding in these tables can be found in Figure 2-3.

BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
			BioRenew	Erenew	BioRenew	Erenew			
Compost	MAD/Compost	Electricity/Hot Water							
Compost	MAD/Compost/HSW	Electricity/Hot Water							
Compost	MAD/Compost/HSW	Pipeline gas							
Compost	MAD/Compost/HSW	Vehicle Fuel							
Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Electricity/Hot Water							
Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Pipeline gas							
Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Vehicle Fuel							
High quality pellet	MAD/Pellet drying/HSW	Electricity/Hot Water							
High quality pellet	MAD/Pellet drying/HSW	Pipeline gas							
High quality pellet	MAD/Pellet drying/HSW	Vehicle Fuel							
Soil Blend	MAD/Pre-Past/HSW	Electricity/Hot Water							
Soil Blend	THP/MAD	Electricity/Hot Water							
Soil Blend	THP/MAD/HSW	Electricity/Hot Water							
Soil Blend	TPAD/HSW	Electricity/Hot Water							
Soil Blend	MAD/Pre-Past/HSW	Pipeline gas							
Soil Blend	THP/MAD/HSW	Pipeline gas							
Soil Blend	TPAD/HSW	Pipeline gas							
Soil Blend	MAD/Pre-Past/HSW	Vehicle Fuel							
Soil Blend	THP/MAD/HSW	Vehicle Fuel							
Soil Blend	TPAD/HSW	Vehicle Fuel							
Sulfur	Biogas sulfur recovery								
Worm Castings	MAD/Vermiculture	Electricity/Hot Water							
Worm Castings	MAD/Vermiculture/HSW	Electricity/Hot Water							
Worm Castings	MAD/Vermiculture/HSW	Pipeline gas							
Worm Castings	MAD/Vermiculture/HSW	Vehicle Fuel							

Figure 2-1. Promising Near-term Technologies

BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
			BioRenew	Erenew	BioRenew	Erenew			
Bio-char	Pyrolysis	Electricity/Hot Water							
Bio-char	Pyrolysis	H2							
Bio-char	HyBrTec	H2							
Bio-Oil	Pyrolysis	Electricity/Hot Water							
Bio-Oil	Pyrolysis	H2							
Bio-Oil	Algae cultivation on sidestream								
Cellulose	Fine straining/solids handling								
Struvite Fertilizer	Sidestream Struvite Precipitation								

Figure 2-2. Technologies to Watch

BioRenew product	ERenew Product	Market	Branding	Status of technology	Fits on site	Use of AlexRenew's existing stabilization assets
Beneficial Use of Product	Net Energy in excess of process	Existing near term market, easy to enter	Easy to brand, net offsite energy	Established	Fits on site with no demo required	Uses most of existing equipment
Little beneficial use	Unsure net energy	Small near term market, expect larger long term market, or difficult to enter	May be branded, but difficult/no offsite energy	Innovative	Fits, but with demolition	Uses some existing equipment
No Product	No energy recovery	No existing near term market, unknown long term market (or no product)	Unlikely to develop a brand	Embryonic	Will not fit	Uses little existing equipment

Figure 2-3. Biosolids Systems Coding Legend

2.3 BASELINE, LIMITATIONS AND OPTIMIZATION OF EXISTING CONDITIONS

Technical Memorandum 2-3: Baseline, Limitations and Optimization of Existing Conditions documents the historical solids production, identifies capacities of major biosolids process equipment and process limitations and provides recommendations for optimization of the existing treatment system.

Solids projections were developed based on flows presented in the Long Range Planning Report, Alexandria Advanced Wastewater Treatment Facility (2009) (hereafter referred to as the LRPR), developed as part of the State of the Art Nitrogen Upgrade Program (SANUP) and the historical average annual and maximum month solids production rates. The LRPR 2030 flow and ultimate flow are 44.9 and 54.0 mgd, respectively. Future solids production projections were based on the condition that future raw influent characteristics and operation of plant processes will result in a similar solids generation rate as are currently experienced. However, if there are changes in either the raw influent characteristics or plant process performance, the solids production rate can also change.

As shown in Figure 2-4, all of the existing processes have adequate capacity to support influent loads through 2030, using the O&M recommended duty/spare configuration, based on the LRPR influent flow projections. It should be noted that the gravity sludge thickener (GST) capacity shown reflects three GSTs in service, based on the concept that one of the two remaining out of service GSTs can be brought back into service if needed. Processes that may need capacity expansions to support the 2030 or design influent flows (44.9 mgd and 54 mgd, respectively) include gravity thickening, pre-pasteurization and anaerobic digestion.

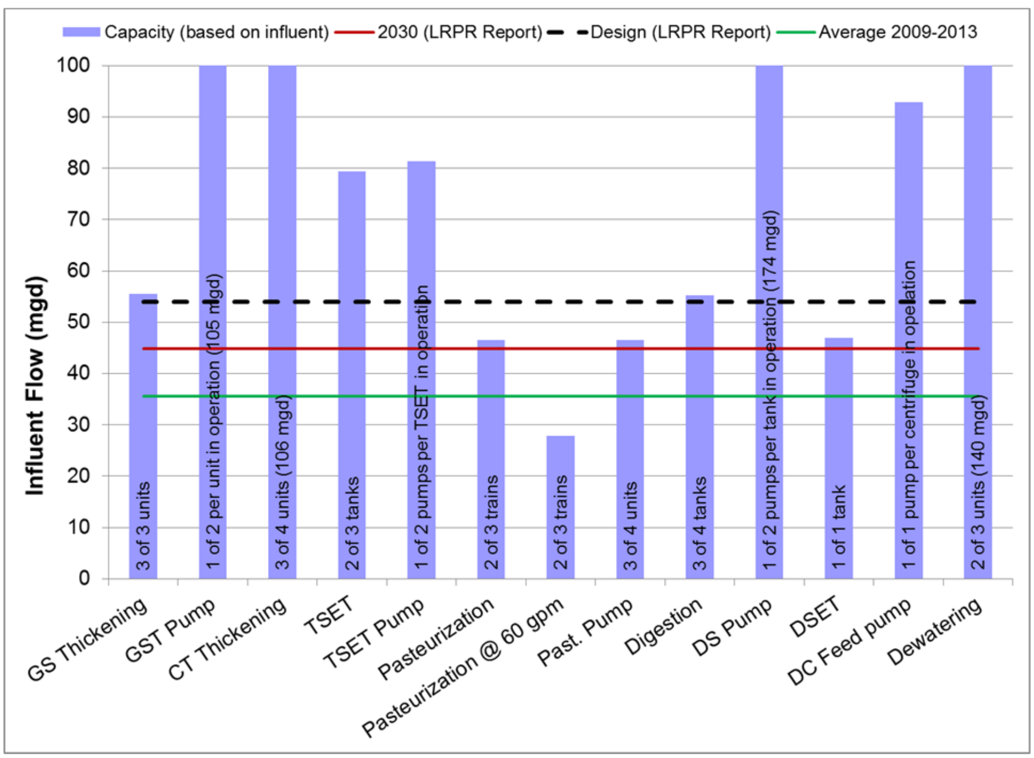

Figure 2-4 System Capacity Summary

3 Interim Steps

Through the investigations for the technical memoranda, as well as workshop discussions, it became clear that some additional information on capacity, solids handling, WAS drying, the feasibility of codigestion and the feasibility of CHP cogeneration will be beneficial before AlexRenew implements a Biosolids Long Range Plan. Understanding these elements will facilitate planning and future decision making and result in a more effective plan.

3.1 UNDERSTANDING PLANT CAPACITY

Through the analysis performed for Technical Memorandum 2-3 on the baseline capacities, as well as discussions with AlexRenew staff, it appears there are some gaps in knowledge related to the plant capacity. While capacity does not seem to be a critical limitation, it does need to be analyzed as changes are made at the plant. Four specific issues have been raised: data showing an unexpected loss of solids through the plant, limitations in screen press capacity, limitations in pre-pasteurization heat exchanger capacity and discrepancies between modeling data and historical data.

In review of the historical plant data and the mass balance, the mass balance will not close due to discrepencies in the mass of solids between the Primary Clarifiers and Digester Feed. Analysis indicates a range in loss between 4% and 28%. This may be an issue with sampling data, caused by discrepancies with grab samples, or it may be due to inaccuracies flow meter readings. In order to develop an accurate mass balance, essential for sizing solids equipment, this issue needs to be investigated further.

Discussion with plant staff indicates the screen press, upstream of the pre-pasteurization process, is designed to handle 7% solids but is currently limited to 5% solids. This limitation impacts the flow into the pre-pasteurization tanks and creates maintenance issues for plant staff. Huber, the press manufacturer, has indicated this limitation may be a control issue, rather than a limitation in the press capacity. It is recommended that this be investigated further and the controls modified, to eliminate this bottleneck in the solids capacity.

The pre-pasteurization heat exchangers have a design capacity of 100gpm each; however, historically, their performance is limited to around 60gpm each. As shown in Figure 2-3, this creates a limitation in the solids handling capacity at the plant. Over the past two years, AlexRenew has performed studies and field testing to understand what is causing the limitation at the heat exchangers, but that has not yet been determined. Investigation is ongoing and includes review of heating and cooling water supply, recirculation pump performance, and scaling within the heat exchangers, among other issues. If the capacity issues cannot be resolved, the pre-pasteurization process will continue to limit the overall solids handling capability at the plant. The capacity analysis in Technical Memorandum 2-3 is based on historical data provided by AlexRenew and looks at average and maximum month flows. Part of this analysis included determining the expected impact of implementing mainstream Anammox treatment on plant capacity. Comparing the values used in modeling the mass balance, to the historical values, there seem to be some discrepancies. Plant data indicates 8% TS at the Thickening Centrifuges (TCEN), while the modeling data uses 5% TS. Plant data indicates 55% VSr in the digester, while the modeling data for Anammox uses 67-73% reduction. If the modeling data is used for determining the plant capacity when Anammox is implemented, it results in different constraints through pasteurization and digestion. While these discrepancies do not result in significant differences, it is recommended to investigate this further as the mainstream Anammox modeling is refined and implemented.

3.2 PRIMARY CLARIFIER PERFORMANCE

Historically, AlexRenew limits the solids from the primary clarifiers to less than 1% TS. This results in a high flow rate to the gravity thickeners. While the gravity thickeners can handle this capacity, if AlexRenew decides to implement a different technology for primary thickening in the future, it may be advantageous to reduce the flow rate from the primaries, to allow installation of smaller equipment. It is recommended that AlexRenew work on improving the primary clarifier solids capture, so that the decision on primary thickening equipment is not being driven by a high flow rate of dilute solids. It is understood that AlexRenew is considering implementing Chemically Enhanced Primary Treatment (CEPT). This may improve the clarifier performance and will impact this decision.

3.3 DRYING OF WASTE ACTIVATED SLUDGE

One way to increase the plant capacity at pre-pasteurization and digestion would be to bypass the WAS stream around the digester and dry it separately. As shown in Figure 3-1 this would provide additional capacity in critical processes.

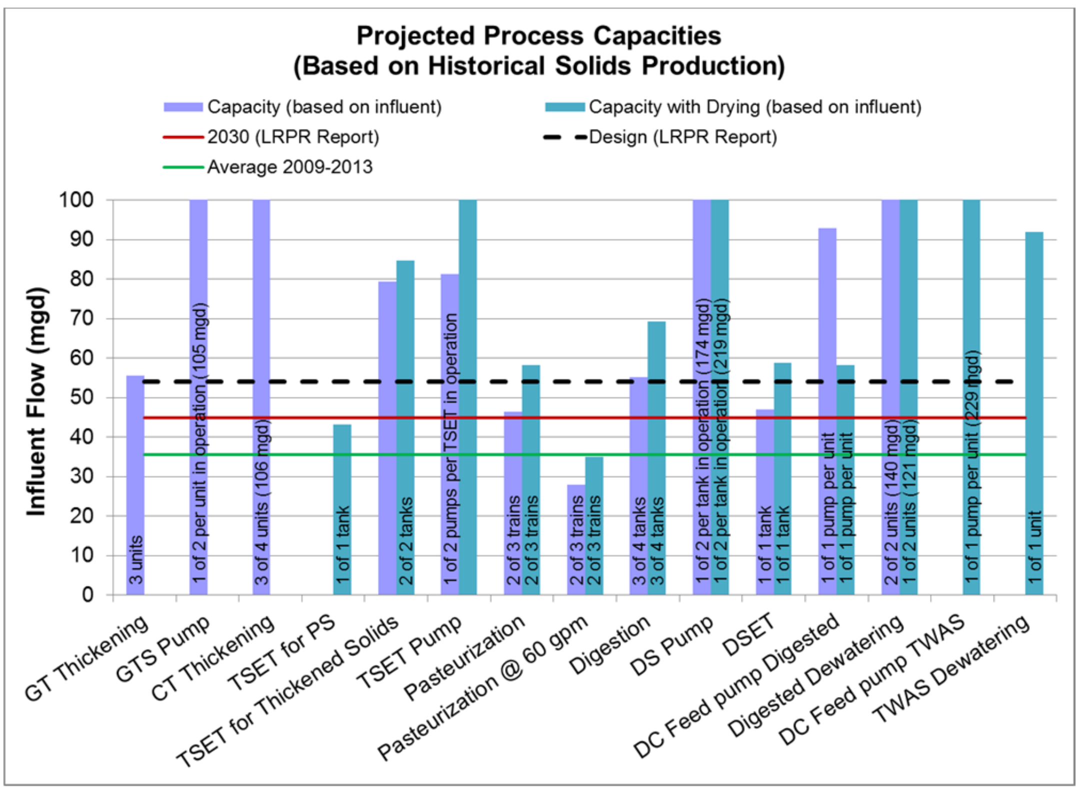

Figure 3-1. Capacity With and Without WAS Digestion

Pilot testing of WAS drying equipment would allow AlexRenew to test the efficiency of the system and evaluate the quality of dried, undigested WAS. This testing could be used to determine the dewaterability of primary sludge and WAS as separate systems, either through bench scale testing, pilot testing or both. By producing a dried product, on a pilot scale, AlexRenew also could study the marketability of the product before committing to it. There are multiple manufacturers of low temperature dryers that could be used for WAS drying. If AlexRenew is interested in this technology, it is recommended that a study is performed, with bench scale and pilot testing to determine operability, real-world performance, technology options and sizingDue to the goals of the AlexRenew process, drying will always be a technology worth considerationas part of a long range plan. If an undigested WAS product proves not to be a viable alternative for AlexRenew, this information will allow for the development of a long range plan with more certainty when evaluating whether to include or exclude a potential technology.

3.4 CODIGESTION FEASIBILITY STUDIES

As discussed above, the technologies reviewed in TM 2-1 and recommended for further investigation in TM 2-2 produce an energy product. However, to produce sufficient energy to generate an ERenew product , codigestion with high strength waste (HSW will be required. Before selecting a specific biosolids treatment technology, it is recommended to do a feasibility study on the use of HSW to fully understand the available system capacity, the impact of delivery on the plant, and the potential HSW sources and their energy potential. AlexRenew could team with a research facility, such as Virginia Tech, to do this investigation.

Based on the current capacity analysis, the digesters have approximately 170,000 gpd of capacity available for the addition of HSW. However, if AlexRenew wants to minimize additional traffic to 5 additional trucks per day, this limits the HSW to 25,000 gallons, which is likely not sufficient to produce net energy. Additional HSW could be brought in through a dedicated forcemain with a transfer station elsewhere, or by increasing the energy content of the influent through the inclusion of additional food waste or FOG. Finding a reliable HSW source will be critical to the success of codigestion.

3.5 CHP COGENERATION STUDY

AlexRenew's existing system and the interest in power generation and sustainability make it a perfect candidate for CHP cogeneration. Before the system is implemented in full scale, it is recommended that a study be performed to look at the sizing, configuration and economics of cogeneration with the current system (pre-pasteurization), with WAS drying and with codigestion alternatives. The study should also consider the potential for mixing digester gas with natural gas for peak shaving and load management. Depending on the biosolids technologies considered and other market drivers, AlexRenew may also want to look into the combination of natural gas power production and digester gas fuel production, to see the impact this has on the economics and marketability of an ERenew product.

ALEXANDRIA RENEW ENTERPRISES

TECHNICAL MEMORANDUM 2-1: SURVEY OF BIOSOLIDS TREATMENT TECHNOLOGIES AND END-USE ALTERNATIVES

PREPARED FOR

ALEX RENEW

3 MARCH 2014

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Building a world of difference.

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1 Objectives

The purpose of this Task Order is to provide the basis for an update to the biosolids portion of the AlexRenew long-range plan. The scope of the Task Order is to identify the most suitable future biosolids program for AlexRenew and to establish a road map for the utility in achieving a sustainable, dependable program.

More specifically, the planning effort will:

- Serve as a roadmap for future decision making;
- Identify long-term biosolids management alternatives;
- Continue to diversify the portfolio of reliable biosolids management options;
- Allow for operations redundancy;
- Incorporate sustainability principles and reduce environmental impact; and,
- Provide cost-efficient technologies.

The objectives of this technical memorandum (TM 2-1) are to provide: a survey of alternatives for biosolids treatment, processing and end-use; and a sound basis for identifying and selecting alternatives for further evaluation. Process descriptions and a summary of the preliminary decision model results are provided in this TM. Subsequent evaluation will be conducted for the shortlisted alternatives/systems, as identified with AlexRenew staff.

2 Current Biosolids Management System

AlexRenew treats thickened and blended primary sludge, waste activated sludge (WAS), and tertiary sludge through pre-pasteurization and mesophilic anaerobic digestion (MAD) followed by centrifuge dewatering to produce Class A dewatered cake. Biogas generated in the digestion process fuels the steam boilers for the pre-pasteurization system and building heating. Digester gas supplies about 90% of the energy needed for heating during the summer months, but only about 30% during the winter months. Excess biogas is combusted in the waste gas flares. The digester gas flared ranges from 0 to 10% in the winter months up to 20 to 30% in the summer months. Figure 2-1 illustrates the existing anaerobic digestion treatment system with pre-pasteurization.

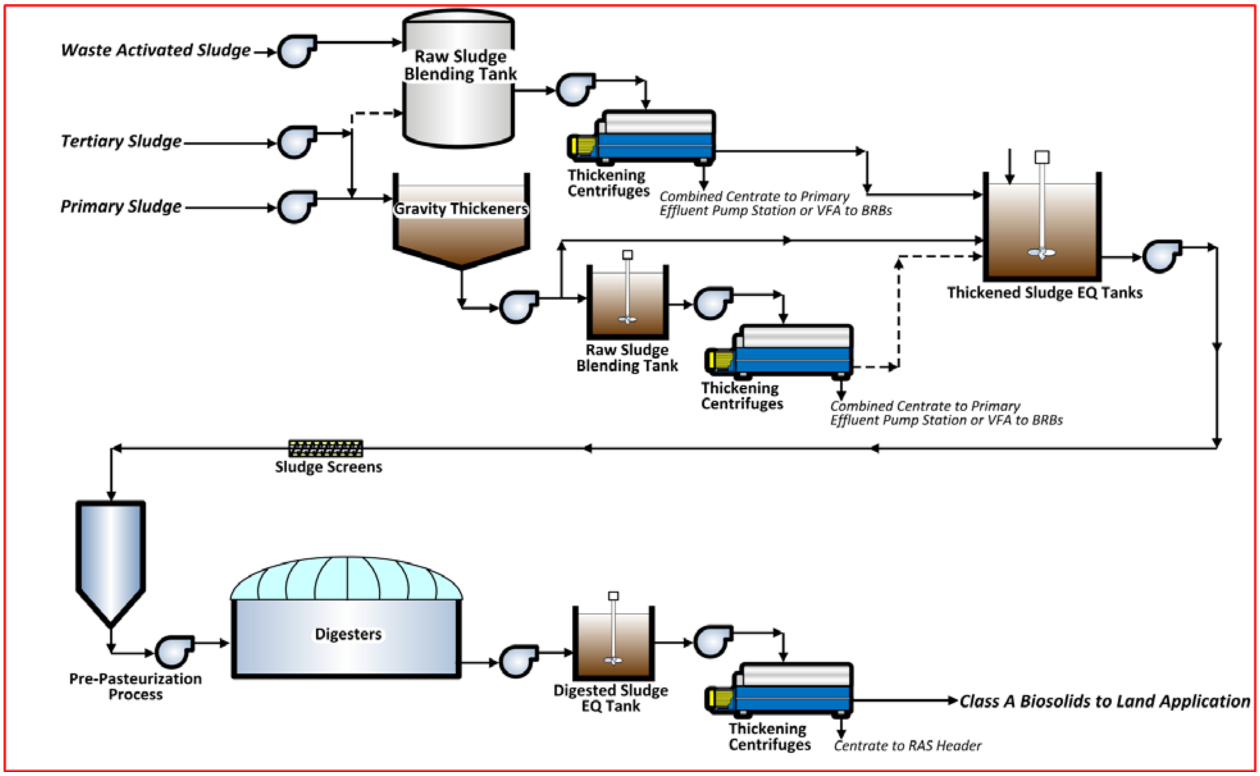

Figure 2-1. Existing Anaerobic Digestion at AlexRenew

3 Biosolids Management Systems

A biosolids management *system* is a combination of treatment technologies, end-uses of products generated by the treatment process, such as biosolids products, energy products (biogas, electricity), and other recovered resources (such as recovered nutrients), marketing, public relations, and monitoring– not the technology or treatment process alone.. The type of treatment process(es) used directly impacts the quality and quantity of biosolids-related products. Biosolids management systems are typically developed by first identifying desired end-products and uses and then determining treatment technologies that can produce the target end-products. In many cases, a variety of treatment technologies can be used to produce similar end-products. For example, dewatered biosolids cake suitable for bulk land application can be generated using stabilization processes including aerobic digestion, MAD, or alkaline stabilization, among others. Each of these technologies has benefits and drawbacks, which must be weighed against one another when selecting treatment solutions.

The following major steps are used to identify biosolids management system solutions:

1. Identify desirable biosolids products and uses. Inputs to this decision include organization value and goals, viable end-uses, and costs.

2. Identify treatment technologies to generate identified products.

3. Screen biosolids systems (end-use + technologies) to identify systems likely to be most suitable for the organization. Screening is based on organization-specific evaluation criteria.

4. Evaluate selected biosolids systems based on further refinement of equipment and facility requirements, costs, and technology refinements. Process enhancements may be incorporated into the evaluation at this stage, or applied to the recommended solution(s).

5. Develop an implementation strategy for the recommended solution(s). This strategy usually addresses implementation schedule, recommended research, pilot, or demonstration testing, and phasing costs.

As the first step in developing biosolids management system solutions, products and final use options must be identified. There is a wide range of biosolids products that can be generated through different treatment processes, with some of the most common products, uses, and stabilization technology categories listed in Table 3-1. Note that there are variations on many of the technologies listed in the table that are discussed in Appendix A. The value and suitability for each product is specific to an organization's overarching policies and goals, as well as location, size, and budget.

Table 3-1. Common Biosolids Treatment Products, Uses and Corresponding Treatment Technologies

PRODUCT	USE	STABILIZATION TREATMENT TECHNOLOIES
Class B liquid	Bulk land application	MAD, alkaline stabilization
Class A liquid	Bulk land application	Thermophilic digestion, thermal hydrolysis, MAD with pre-pasteurization, alkaline stabilization (includes variations)
Class B cake	Bulk land application	MAD (with or without enhancements), alkaline stabilization
Class A cake	Bulk land application; feedstock for soil blend product	Thermophilic digestion, thermal hydrolysis, MAD with pre-pasteurization, chemical stabilization (BCR Neutralizer)
Class A dry product	Bulk land application; sale or distribution as organic fertilizer or for use in landscaping; energy substitute for coal in certain industrial applications	Thermal drying, solar drying (with or without MAD)
Compost/vermiculture castings	Bulk land application; sale or distribution as organic fertilizer or for use in landscaping	Composting, vermiculture (with or without MAD)
Ash	Landfill; constituent in cement production; soil amendment for phosphorus benefits	Incineration, gasification, super critical water oxidation
Bio-char or bio-oil	Energy substitute; soil amendment	Pyrolysis (includes variations)

PRODUCT	USE	STABILIZATION TREATMENT TECHNOLOIES
Biogas[1]	Combust for heat or power generation; clean and use as CNG, LNG, or pipeline quality gas	Anaerobic digestion (MAD, thermophilic digestion, thermal hydrolysis), gasification/pyrolysis (with additional gas conditioning)
Hydrogen	Use for power generation in fuel cells	Pyrolysis (includes variations)
Struvite pellets[2]	Sale or distribution as replacement to commercial fertilizer	Precipitation technology

1 Note that treatment technologies to produce biogas also produce biosolids to be managed via one of the previously presented stabilization treatment technologies.
2 Struvite pellets are not a biosolids-derived product.

Biosolids treatment technologies are discussed in Appendix A, along with advantage and drawbacks. Comments on applicability to the AlexRenew facility are included for each of the technologies.

4 Evaluation Criteria

For the most useful results, evaluation criteria should be tailored to each organization. Criteria typically address sustainability, energy recovery, impacts on surrounding neighbors, versatility, ability to integrate into existing system, and costs. The relative importance of each criterion is specific to each organization.

AlexRenew has developed a Decision Model that defines criteria and importance (weighting), which is used across all programs and capital projects. This model provides a set of weighted criteria that rank alternatives with regard to People, Environmental Leadership, Efficiency, Community Awareness and Fiscal Responsibility. A summary of the Decision Model criteria is presented in Figure 4-1.

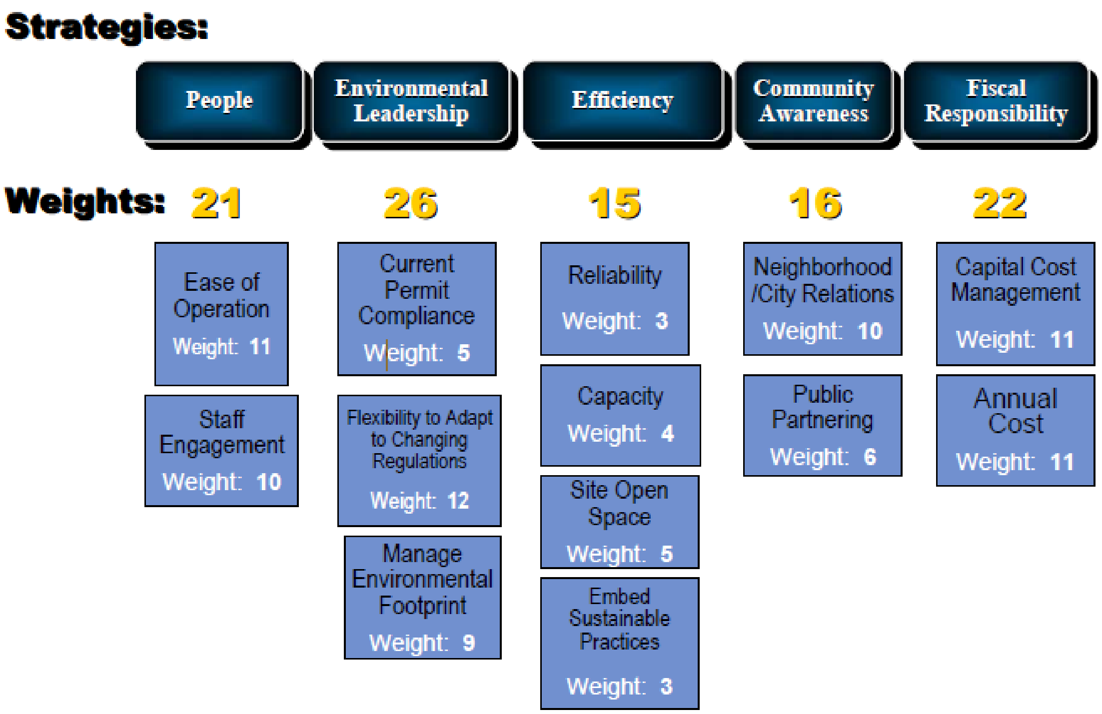

Figure 4-1. AlexRenew Decision Model Criteria

As a preliminary step to this evaluation, Black & Veatch reviewed the criteria in the Decision Model and noted that many of the criteria, as currently defined, did not significantly differentiate key attributes of the biosolids alternatives. A modification to the existing system was proposed with example scoring to assess impacts. While the modified scoring increased differentiation among the alternatives, the improvement was not considered significant enough to justify deviating from the standard model. Therefore the standard model, with only minor revisions, is proposed for this planning effort.

In addition to criteria detailed in the Decision Model, a list of program goals was developed during a Project Initiation Workshop In November 2013. Some key factors that pertain particularly to the Biosolids program include:

- **Products and Branding** – AlexRenew has set a goal of developing and leveraging the AlexRenew brand and its products (BlueRenew, E-Renew, BioRenew) as AlexRenew develops its vision/mission through 2030. Potential biosolids system impacts on this goal include a marketable biosolids product (BioRenew) and a renewable energy product (E-Renew).

- **Integration within the community** – AlexRenew wants to minimize negative impacts to the community such as truck traffic, odors, and lighting. However, the utility should be visible to the community as a resource management agency. The community should understand the value and the cost of wastewater treatment and the value of the renewable resources, as well as a means for creating jobs. This will favor alternatives that have a strong, positive public profile.

- **Innovation** - AlexRenew has been a leader in wastewater treatment innovation, with an ongoing responsibility to assist the industry to develop and identify options for resource recovery.

- **Flexibility** - Given the uncertainty of future regulations and markets, AlexRenew wants the flexibility in the future to modify processes and products.

- **Economic drivers** – AlexRenew has a focus on economic efficiency but also providing economic solutions/stimulus.

- **Plant dependability/operability** – This will always be a important factor in any technology evaluation.

- **Site Constraints** – The plant site is land limited; AlexRenew will not be able to acquire any additional land. No treatment processing will be allowed on the west site. Therefore any process must fit within existing footprints or performed off-site.

5 Biosolids Management System Survey Results

Conceptual biosolids management systems were developed based on products, end-uses, and supporting stabilization technologies listed in Appendix A. The current biosolids management process described in Section 2 is considered the “baseline” system, against which all other options were compared. Each system was scored using the AlexRenew Decision Model Evaluation Criteria described in Section 4. For purposes of this initial comparison, add-ons such as on-site power generation, resource recovery, or digester performance enhancements were not included in the system unless their inclusion was considered the more common configuration. Cost inputs were based on “order of magnitude” costs from industry experience, where available. Cost inputs for embryonic or emerging technologies that have little cost information were estimated. The overall scoring results of the initial evaluation using the Decision Model are summarized in Figure 5-1while detailed results of the evaluation are summarized in Appendix B.

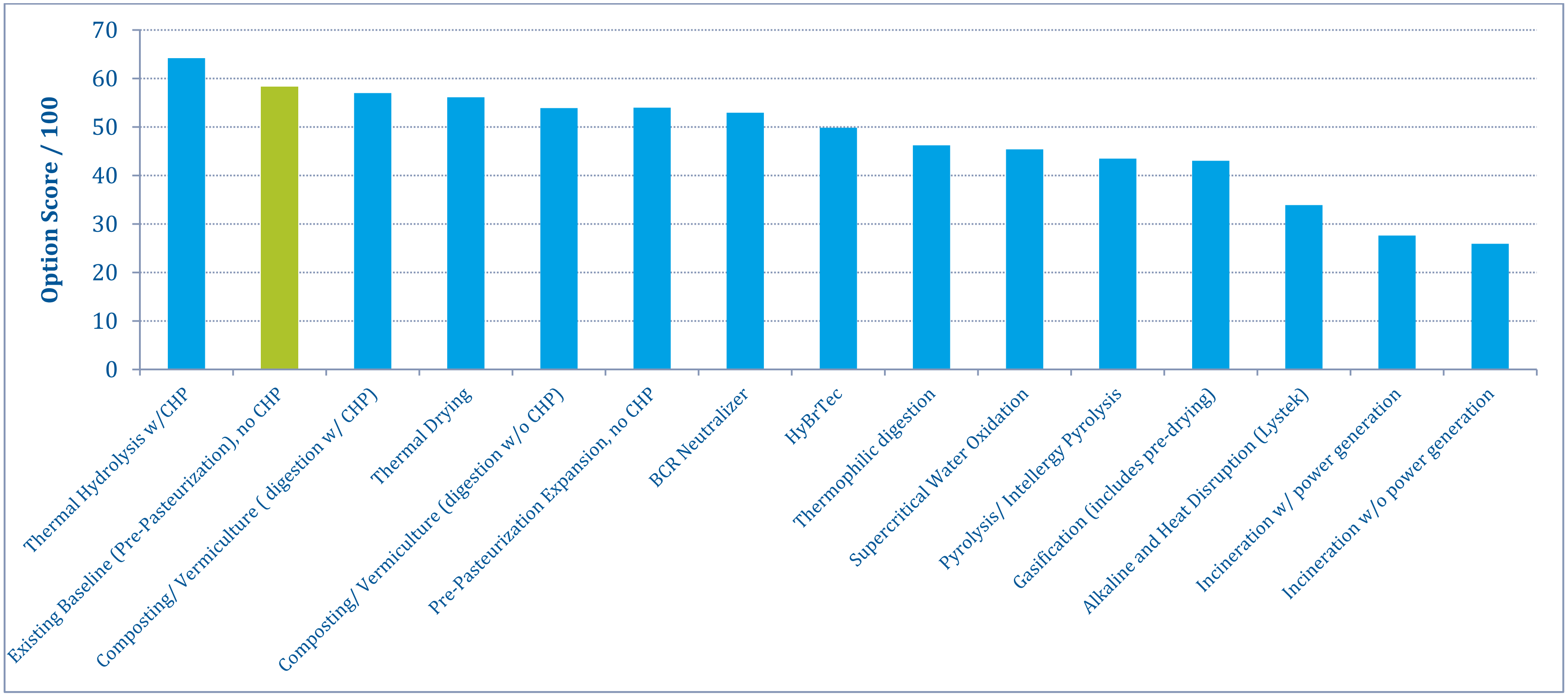

Figure 5-1. Initial Output of Decision Model.

Though many of the program goals identified during the Project Initiation Workshop are addressed in some of the criteria and sub-criteria of the AlexRenew Decision Model, they are included with many other criteria and therefore their impact to the overall score is somewhat muted. There are a few AlexRenew goals that will be significantly affected by the biosolids program. These include AlexRenew's capacity to fulfill two of its three product goals (Bio-Renew and E-Renew). To highlight these key program elements and the impact of various alternatives, a qualitative comparison is provided, along with the Decision Model results.

Figure 5-2 provides a summary of the product and energy characteristics, cost estimates, and truck traffic for the selected treatment systems and the existing baseline. Cost and truck traffic are shown as compared to the existing baseline. The comparisons are qualitative at this time and are used to signify major changes; small scale changes associated with a technology are hard to quantify at the screening phase.

		Biosolids Product	Energy Product	Ancillary Energy Recovery Technology	Cost	Community Awareness
Thermal Conversion	Incineration	Ash	Heat	Steam CHP	Capital - $$$ Annual - $$$	
	Gasification	Ash	Syngas/ Heat	CHP	Capital - $$$ Annual - $$$	
	Pyrolysis/Intellergy Pyrolysis	Biochar/Bio-oil	Syngas/ Heat /H_2	CHP	Capital - $$$ Annual - $$$	
	HyBrTec	Ash	H2, Power	Fuel Cell	Capital - $$$ Annual - $$$	
	Supercritical Water Oxidation	Ash, Gas Products (CO_2, N_2)	Heat	Steam CHP	Capital - $$$ Annual - $$$	
Digester Stabilization	Thermophilic Anaerobic Digestion	Class B Cake	Biogas	Biogas Use/CHP	Capital - $ Annual - $$	
	Pre-Pasteurization	Class A Cake	Biogas	Biogas Use/CHP	Capital - $$ Annual - $$	
	Thermal Hydrolysis	Class A Cake	Biogas	Biogas Use/CHP	Capital - $ Annual - $	
Non-Digester Stabilization	Composting/ Vermiculture with MAD	Class A Product	Biogas	Biogas Use/CHP	Capital - $ Annual - $$	
	BCR Neutralizer*	Class A Cake			Capital - $ Annual - $$	
	Thermal Drying	Dried Product	Biogas	Digestion/Bio gas Use	Capital - $$ Annual - $$$	
	Alkaline and Heat Disruption (Lystek)	Class A Liquid			Capital - $$ Annual -$$$	

*This process does not require the use of anaerobic digestion, but is compatible with anaerobic digestion and therefore has the potential to produce biogas

Beneficial product, net energy production
Possible net energy production - need to determine for specific condition
No beneficial product, no net energy production
Significantly less truck traffic than baseline
Similar truck traffic to baseline
Significantly more truck traffic than baseline

Figure 5-2. Product and Energy Comparison for Treatment Systems.

6 Recommendations

Based on the initial scoring shown in Figure 5-1 and Appendix B, the highest five scoring biosolids management systems are recommended to be carried forward and subjected to a more detailed evaluation. As shown in the bulleted list, two of the five options include composting, with and without biogas use for on-site power generation or conversion to "near natural gas".

- Class A biosolids cake for distribution or bulk land application, generated through thermal hydrolysis. Biogas use in CHP or cleaning to "near natural gas" quality for sale or use as vehicle fuel or pipeline injection.

- Class A biosolids cake for distribution or bulk land application, generated through continued pre-pasteurization. Biogas use in CHP or cleaning to "near natural gas" quality for sale or use as vehicle fuel or pipeline injection.

- Compost product for sale or distribution generated through off-site composting after on-site mesophilic anaerobic digestion. Biogas use in CHP or cleaning to "near natural gas" quality for sale or use as vehicle fuel or pipeline injection.

- Composting product for sale or distribution generated through off-site composting after on-site mesophilic anaerobic digestion. Biogas used for process or building heat only (no CHP or biogas sale) for sale or use as vehicle fuel or pipeline injection.

- Dried product for sale or distribution generated through on-site mesophilic anaerobic digestion and thermal drying. Biogas use in drying process, CHP, or cleaning to "near natural gas" quality for sale or use as vehicle fuel or pipeline injection.

The top five scoring management systems represent a selection of mature technologies that are aligned with the goals and constraints as outlined by AlexRenew. While some of the emerging/embryonic technologies and end products appear promising, the lack of available cost and performance data may have resulted in lower scores. These options should be tracked for future consideration when additional performance and cost information becomes available. In addition, options for implementing attractive emerging technologies should be considered as part of the evaluation of the selected management systems.

As the Decision Model is intended as a tool for stakeholder decision-making and consensus, scoring will be reviewed and revised with AlexRenew staff in a workshop setting prior to moving forward with further analysis of the shortlisted system alternatives.

ALEXANDRIA RENEW ENTERPRISES

TECHNICAL MEMORANDUM 2-1: SURVEY OF BIOSOLIDS TREATMENT TECHNOLOGIES AND END-USE ALTERNATIVES

Appendix A

End-product and Treatment Technologies

PREPARED FOR

ALEX RENEW

3 MARCH 2014

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1 Evaluated End-Products and Stabilization Technologies

This section provides overview information for end-use options and supporting biosolids and energy recovery stabilization technologies included in the evaluation. The choice of end-products often drives the selection of treatment technologies. A list of common end-products is presented in Table 1-1. AlexRenew currently generates a Class A dewatered cake, suitable for bulk land application or as a component of soil blending. While Class B land application is permittable in the regional area, AlexRenew staff indicated that moving from a Class A to a lower quality Class B product is unlikely. Consequently, processes that produce Class B liquid or cake were not considered for this evaluation. Products listed in Table 1-1 that were included in the evaluation are indicated by check marks. Processes and technologies that produce the identified products, as listed in the table, are discussed in the following sections.

Table 1-1. Common Biosolids Treatment Products, Uses and Corresponding Treatment Technologies

PRODUCT	USE	STABILIZATION TREATMENT TECHNOLOIES	CONSIDERED FOR ALEXRENEW
Class B liquid	Bulk land application	MAD, alkaline stabilization	
Class A liquid	Bulk land application	Thermophilic digestion, thermal hydrolysis, MAD with pre-pasteurization, alkaline stabilization (includes variations)	✓
Class B cake	Bulk land application	MAD (with or without enhancements), alkaline stabilization	
Class A cake	Bulk land application; feedstock for soil blend product	Thermophilic digestion, thermal hydrolysis, MAD with pre-pasteurization, chemical stabilization (BCR Neutralizer)	✓
Class A dry product	Bulk land application; sale or distribution as organic fertilizer or for use in landscaping; energy substitute for coal in certain industrial applications	Thermal drying, solar drying (with or without MAD)	✓
Compost/vermiculture castings	Bulk land application; sale or distribution as organic fertilizer or for use in landscaping	Composting, vermiculture (with or without MAD)	✓
Ash	Landfill; constituent in cement production; soil amendment for phosphorus benefits	Incineration, gasification, super critical water oxidation	✓
Bio-char or bio-oil	Energy substitute; soil amendment	Pyrolysis (includes variations)	✓

PRODUCT	USE	STABILIZATION TREATMENT TECHNOLOIES	CONSIDERED FOR ALEXRENEW
Biogas[1]	Combust for heat or power generation; clean and use as CNG, LNG, or pipeline quality gas	Anaerobic digestion (MAD, thermophilic digestion, thermal hydrolysis), gasification/pyrolysis (with additional gas conditioning)	✓
Hydrogen	Use for power generation in fuel cells	Pyrolysis (includes variations)	✓
Struvite pellets[2]	Sale or distribution as replacement to commercial fertilizer	Precipitation technology	✓

1 Note that treatment technologies to produce biogas also produce biosolids to be managed via one of the previously presented stabilization treatment technologies.
2 Struvite pellets are not a biosolids-derived product.

2 Stabilization and Enhancement Technologies

Stabilization includes a variety of technologies that are used to reduce volatility and odors, vector attraction, and pathogen content of solids. Stabilization can be achieved through chemical, thermal, or biological methods, or by using a combination of processes. Stabilization can be coupled with select treatment technologies to “enhance” the stabilization process. Many of these process enhancements improve stabilization performance or provide methods of energy or resource recovery. In most cases, enhancements are not expected to change the inherent quality of the products generated through the stabilization process.

The stabilization processes are stand-alone design options and were evaluated using the AlexRenew Decision Model. Process enhancements can be applied to appropriate stabilization processes to improve process or energy recovery efficiency or to produce additional biosolids treatment-related products. These will be further discussed as they relate to a given system or stabilization process.

Table 2-1. Evaluated Biosolids Stabilization Technologies and Enhancement Processes

STABILIZATION PROCESSES	ENHANCEMENT PROCESSES
Thermal Conversion Incineration Gasification Pyrolysis Supercritical water oxidation HyBrTEC™	**Gas Utilization/Energy Recovery** Engine generators Microturbines Fuel cells Biomethane production Conversion to methanol Thermoelectric technology
Anaerobic Digestion Stabilization (Class A Biosolids) Thermal hydrolysis with anaerobic digestion Pre-pasteurization with anaerobic digestion Thermophilic digestion	**Anaerobic Digestion Pre-Treatment** Microsludge™ OpenCEL Biocrack Crown Biogest Sonication

STABILIZATION PROCESSES	ENHANCEMENT PROCESSES
	Ozone/AOP Co-digestion
Non-Anaerobic Digestion Stabilization* Composting Vermiculture BCR Neutralizer™ Thermal drying Alkaline and heat disruption (Lystek™)	**Enhanced Digestion** Acid-Gas (2 phase) digestion Staged digestion Co-Digestion
	Resource Recovery Alkaline extraction of WAS Nutrient recovery

***These stabilization processes do not require mesophilic anaerobic digestion to meet Class A standards but can be coupled with digestion**

The following sections describe the stabilization technologies and enhancements, including status, benefits and drawbacks, considerations for AlexRenew, and potential triggers for implementation. Information on the technologies is based on engineering experience and industry information.

While many technologies may appear attractive in theory, implementation experience is vital to understand equipment complications and difficulties, performance, and cost. Consequently, the status of the technology is highly relevant to evaluations. The status of each of the technologies discussed in this appendix has been identified as embryonic, emerging, or mature, using the following criteria:

- Embryonic – Technologies in early development with testing at laboratory or bench scale. These technologies typically do not have demonstration scale testing. Performance and cost information for a full scale facility is unavailable. These technologies are not viable for near term implementation but near term decisions on the approach to solids management may preclude the future application of an embryonic technology.
- Emerging – Technologies that have been tested at a full-scale demonstration sites or have a limited number of full scale installations on wastewater solids. Technologies in wide use in other industries, but have not been applied to wastewater solids would also be considered emerging for the wastewater industry. Limited performance and cost information is available, but may have questionable applicability to other installations.
- Mature – Technologies that are widely used and have well-established performance and cost information.

2.1 STABILIZATION TECHNOLOGIES

Stabilization technologies listed in Table 2-1 are discussed in the following sections.

2.1.1 Thermal Conversion

Thermal conversion of biosolids is a process that completely or partially oxidizes the volatile fraction of the material, allowing for the recovery of energy from the released heat during the oxidation process or from gaseous or carbon-based end-products. Biomass thermal conversion technologies include incineration, which is well established, and more recent technologies such as gasification, and pyrolysis. Figure 2-1 illustrates the thermal conversion technology processes. Energy and moisture content of the feedstock are critical parameters for thermal conversion processes. Net energy production is only achievable if the energy that can be recovered from the heating value of the feedstock is greater than that required to drive off the moisture content in the feedstock (NACWA, 2010). Incineration, gasification, and pyrolysis differ from one another based on the amount of oxygen that is available during the thermal conversion process. The products of the conversion also differ, with incineration producing heat and ash, gasification producing synthetic gas (syngas) and ash, and pyrolysis producing char.

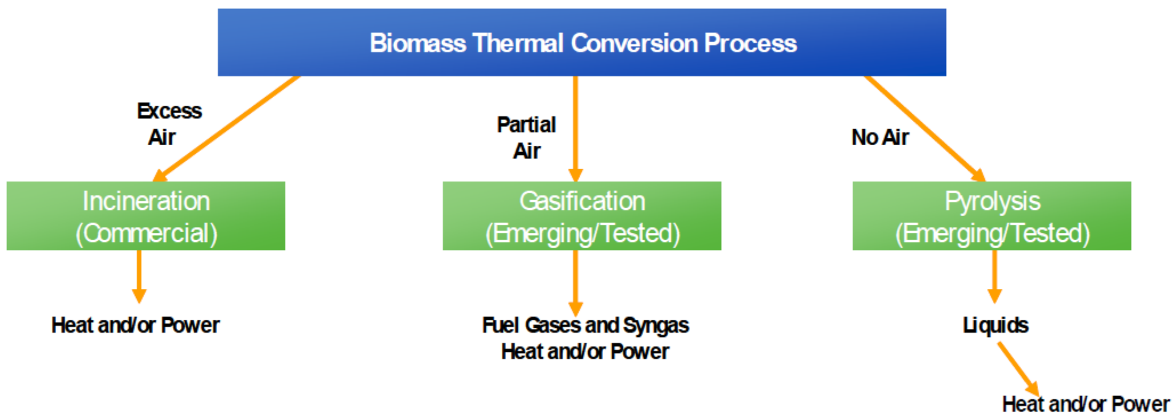


Figure 2-1. Biomass Thermal Conversion Technologies (NACWA, 2010)

The potential products from the evaluated technologies are: biochar for agriculture, or energy in the forms of heat, steam, steam to electricity, syngas, or solid fuel. Syngas is typically combusted to generate steam, or heat. Heat recovery and steam conversion to electricity in a steam turbine are the most commonly used methods of energy recovery. If the facility is large enough, it may be economical to use the syngas to fuel a gas turbine; however, there is a lack of performance data for syngas cleaning and use in gas turbines. Syngas may be converted into liquid vehicle fuels (ethanol, diesel, gasoline) via a variety of chemical catalysts, but these conversions have not been demonstrated utilizing biosolids, they have only been demonstrated utilizing dry solid fuels such as wood waste and crop residue. A few of the technologies produce a solid fuel that can be used on-site, or co-fired in an off-site location, such as a coal fired power plant or a cement kiln.

Biochar is essentially charcoal; it has a high carbon content (i.e. it is not ash) and a high sorptive capacity for plant nutrients which can be exchanged with plants and act as a reserve against leaching losses. It was discovered in strongly weathered soils in the Amazon and was key to those soils sustaining some degree of fertility. Interest in biochar production has grown in recent years; however, further research is needed to prove its agronomic value. Emerging research in Louisiana suggests that biochar has significant positive impacts on soil fertility.

2.1.1.1 Incineration

Technology Status: Mature

Incineration, also known as thermal oxidation, is the most common of the thermal conversion technologies with installations worldwide. During incineration, solids are burned in a combustion chamber with excess oxygen (O_2) to form carbon dioxide (CO_2) and water, with inert ash waste product. Dewatered biosolids, which have a high energy value, also have a high moisture content (typically between 70 and 80 percent moisture), which reduces the heating value of the wet sludge. During incineration the water must be evaporated before the volatile fraction can reach combustion temperatures. Combustion is an exothermic reaction during which the volatile material is destroyed, releasing hot gases. Thermal energy can be recovered from this released gas stream. The remaining inert fraction is reduced to ash. The combustion emissions include particulates, nitrogen oxides (NOx), carbon monoxide (CO), sulfur oxides (SOx) and metals including mercury (Hg), which must be removed using emission control systems. Ash is comprised mostly of inert material in the feedstock and is produced at a volume of approximately 10 percent to 15 percent of the feed (Kuchenrither et al., 2012).

There are various incineration technologies. While many existing installations used multiple hearth furnaces (MHIs), new installations predominantly use fluid bed incineration (FBI) because of the larger capacity and improved efficiencies. An FBI recovers heat from the off-gas which can be used for process heat or for power generation using steam turbines, as shown in Figure 2-2. While emission control technologies are available to meet regulatory requirements, permitting a new incinerator in a non-attainment zone such as Northern Virginia, can be difficult.

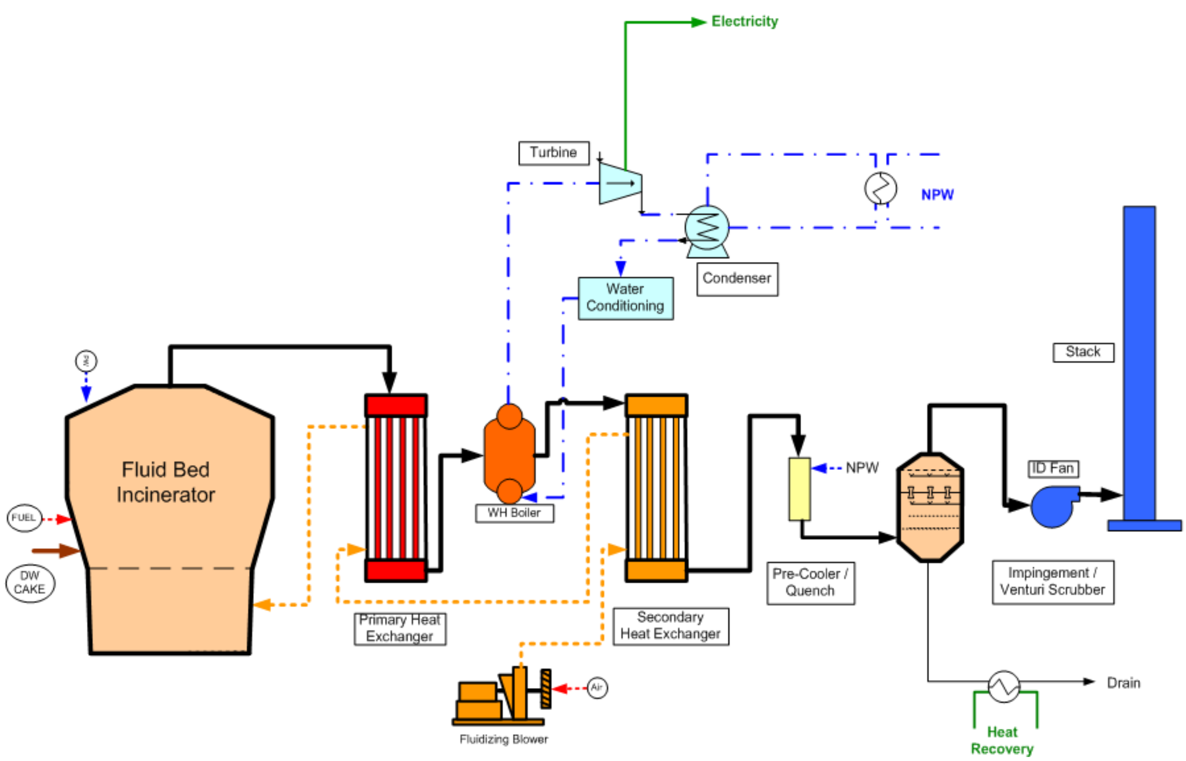


Figure 2-2. Fluidized Bed Incineration (FBI) Process with Energy Recovery

Advantages

Incineration is a mature technology, with well understood implementation requirements, costs, and operational issues. Incineration maximizes volume reduction, minimizing truck traffic for biosolids use/disposal. Incinerator ash is an inert, sterile material that can be landfilled or used beneficially in cement production. Incineration eliminates odors associated with biosolids hauling, storage, and use. Heat recovered from incineration can be used for process heating needs or converted to steam to generate electricity. The process does not have a high concentration ammonia recycle stream and would reduce the nitrogen loading to the liquid plant and reduce operating costs.

Drawbacks

Incineration is mechanically complex and capital intensive. Supplemental fuel is required if the biosolids feed does not have adequate energy for combustion. Permitting a new incineration facility can be difficult. The lack of a high concentration ammonia stream would reduce or eliminate the growth of Annamox bacteria in the new side stream reactor and may impact the ability of AlexRenew to pursue main stream Annamox.

Applicability to AlexRenew

Considerations relevant to AlexRenew specific to incineration include:

- Site considerations – Incineration has a significant footprint and therefore existing facilities would need to be removed or modified to allow construction of an incinerator. The most likely location would be in the current digestion area, which would create significant challenges for sequence of construction. Incineration is a large capacity process, which would support increased solids quantities within the existing site constraints. Off-site incineration can also be performed if a suitable site is available.

- Cost – Incineration would have a high capital cost and increased labor and maintenance as compared to the baseline system.

- End-product – The final product is ash. While ash is suitable for use as an ingredient for cement production or as a soil enhancement, the most common end-use for ash is landfill disposal. Ash will contain inert material, such as phosphorus, which may be recovered from the ash prior to disposal. The overall truck traffic for the site would decrease by at least 80%.

- Energy – While incineration has relatively little required electrical power input, an input of fuel will most likely be needed to drive combustion. Power generation through waste heat steam production/turbines is possible, although may have marginal cost benefits.

- Community Awareness – While incineration significantly reduces truck traffic at the plant, it has negative connotations based on emissions concerns with municipal solid waste incineration and therefore can result in pushback from neighbors. The permitting process for a new incineration facility can be complex. Incineration also reduces odor potential associated with cake hauling and land application.

Triggers

Common triggers for implementation of incineration are increased solids production with limited site available for process expansions, prohibitions or severe limits on truck traffic from the treatment plant, or limitations on beneficial use of a biosolids product.

2.1.1.2 Gasification

Technology Status: Emerging

Gasification is the partial oxidation of a carbon-rich, organically derived feedstock to a synthesis gas or "syngas" consisting primarily of hydrogen (H_2) and CO. The syngas also consists of lesser amounts of CO_2, water, methane (CH_4), higher hydrocarbons, and nitrogen (N_2). Figure 2-3 illustrates the gasification process from the MaxWest system (commercial supplier of biosolids gasification systems). Partial oxidation lies between the extremes of combustion and pyrolysis (no oxygen). In contrast to combustion, which works with excess oxygen to achieve the complete oxidation of the organic feedstock and the maximum generation of heat, partial oxidation operates at substoichiometric conditions, with the oxygen supply controlled, to produce both heat and a gaseous fuel. In most gasifiers, the heat released by burning about one-fourth of the fuel gasifies the remainder, producing syngas. The syngas can be combusted for heat generation (for the drying process or other use) or cleaned and used in power generation equipment, such as engine generators.

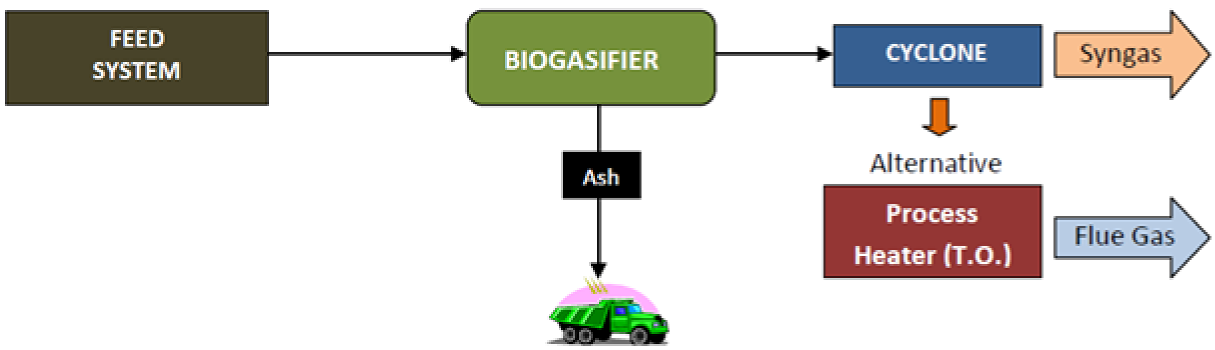


Figure 2-3. Gasification Process (MaxWest Environmental Systems)

Similar to incineration, the gasification produces an ash product that can be disposed in landfills or used beneficially, potentially in cement production. Also similar to incineration, gasification minimizes the volume of material from the biosolids process.

Gasification feedstock must have fairly low moisture content (approximately 40 percent or less, depending on energy content of the feed), typically requiring drying for biosolids-only feedstock. While a variety of configurations are available for gasification equipment, all biosolids gasifiers in current operation are fluid bed systems.

Gasification is a mature technology for coal and biomass feedstocks, but is still relatively new to biosolids treatment, with only a few full scale installations. A USEPA ruling in December 2013 determined that federal municipal biosolids incinerator emissions regulations do not apply to gasification systems.

Advantages

Gasification maximizes volume reduction, minimizing truck traffic for biosolids use/disposal. The resulting ash is an inert, sterile material that can be landfilled or used beneficially in cement production. Gasification eliminates odors associated with biosolids hauling, storage, and use. Heat recovered from incineration can be used for process heating needs or cleaned for use in a cogneration process for heat and power. Gasification emissions do not fall under the USEPA municipal biosolids incinerator emissions requirements, reducing emission control requirements and permitting issues. The process does not have a high concentration ammonia recycle stream and would reduce the nitrogen loading to the liquid plant and reduce operating costs.

Drawbacks

Gasification is an emerging technology for biosolids treatment, with limited cost information. Gasification requires a relatively dry feed stock, necessitating pre-drying prior to gasification, increasing cost and system complexity. In many cases, energy generated through the gasification process is required to operate the drying process, limiting net energy production. The remaining ash at the completion of the process has a low carbon content of less than 5% - 10%. The lack of a high concentration ammonia stream would reduce or eliminate the growth of Annamox bacteria in the new side stream reactor and may impact the ability of AlexRenew to pursue main stream Annamox.

Applicability to AlexRenew

Considerations relevant to AlexRenew specific to gasification include:

- Site considerations – Gasification has a significant footprint, requiring both pre-drying and the gasification process. Existing facilities would need to be removed/modified to support implementation of gasification, with the most likely location the current digestion area, which would create significant challenges for sequence of construction. Gasification would support increased solids quantities within the existing site constraints. Conversely, a gasification system could be installed off-site.

- Cost – Limited information is available on costs for full-scale gasification installations; however, gasification is a capital intensive process with fairly high capital costs.

- End-product – The final product is ash and is not as flexible for use as a biosolids product; it would most likely be landfilled. Ash will contain inert material, such as phosphorus, which may be recovered from the ash prior to disposal.

- Energy – The process creates syngas but as there is a pre-drying step; most, if not all, of the syngas and residual heat would be consumed in the drying process.

- Community Awareness – Gasification significantly reduces truck traffic at the plant. Based on recent regulatory rulings, gasification emissions are not subject to the incineration MACT requirements, which is expected to simplify permitting as compared to municipal biosolids incinerators. Gasification also reduces odor potential associated with cake hauling and land application.

Triggers

Anticipated triggers for gasification include end-use and biosolids product volume concerns, similar to incineration. Further restrictions on incinerator emissions requirements may make this an attractive alternative. Increased experience with biosolids-only systems is required for this technology to further develop cost and operation experience information. The development of enhanced dewatering systems capable of mechanically drying biosolids without the use of syngas would enhance the economic viability of the process.

2.1.1.3 Pyrolysis

Technology Status: Embryonic

Pyrolysis is the thermal conversion of carbonaceous biomass under high pressure and temperature and in the absence of an oxidizing agent. Pyrolysis is not only one of the three main thermal conversion processes, but also the preliminary step of combustion and gasification. Pyrolysis typically occurs at lower temperatures than either gasification or incineration. Three products are generated through pyrolysis: a liquid fuel or bio-oil, a solid char, and some combustible gas.

There are two main categories of pyrolysis: slow pyrolysis and fast pyrolysis. Depending on the technology used, the balance between biochar, bio-oil, and syngas produced varies. Fast pyrolysis, maximizes the production of bio-oil while slow pyrolysis maximizes the production of biochar (similar to charcoal). In pyrolysis, syngas is typically used to supply the energy for the reactor, and thus the two main products to market would be biochar and potentially a bio-oil, depending on the technology.

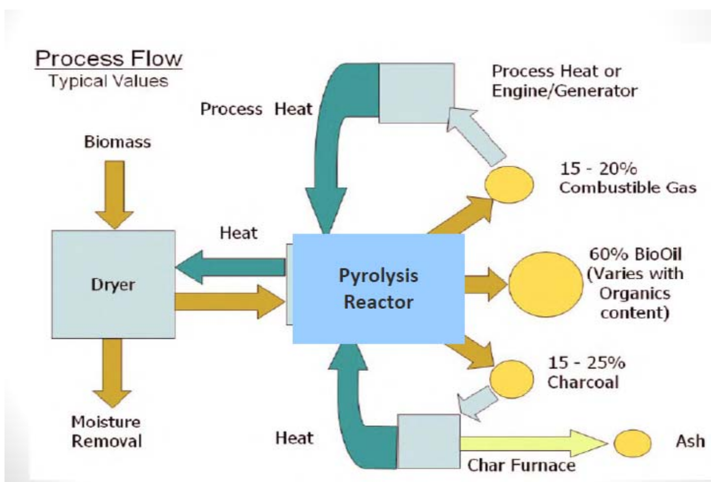


Figure 2-4. Pyrolysis Process (From B. Toffey, WaterJAM, 2012)

Intellergy uses a pyrolysis process to generate syngas. The syngas is further processed through a reforming step to generate hydrogen gas, which can be used directly or in a fuel cell for power generation. In the Intellergy pyrolysis process, approximately 85% of the material is converted to syngas. A pilot/demonstration scale facility is planned for the San Francisco Bay Area Biosolids to Energy Coalition. A flow diagram of the Intellergy process is shown in Figure 2-5.

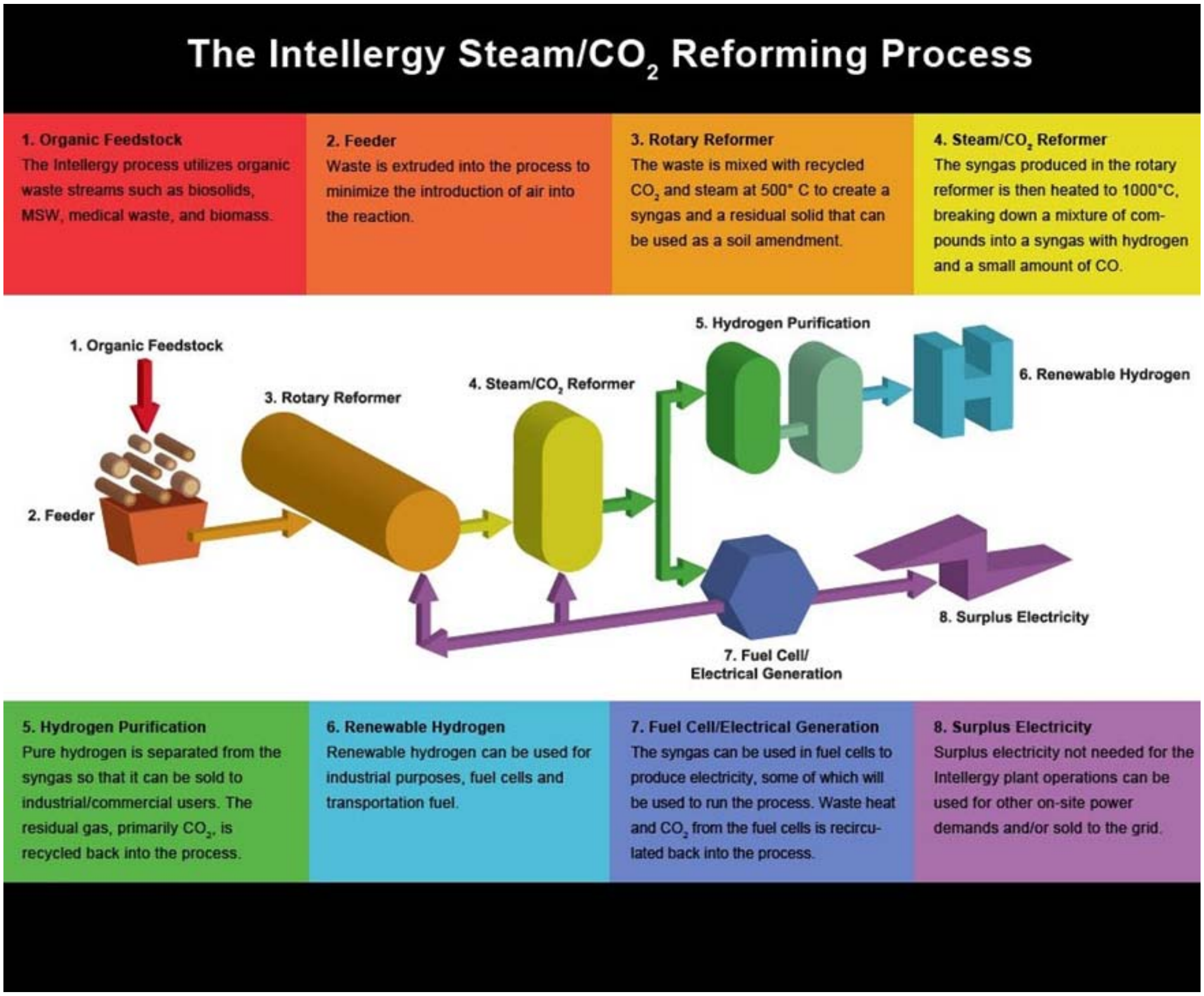


Figure 2-5. Intellergy Pyrolysis System (accessed from intellergy.com, 2014)

Advantages

The pyrolysis process generates a carbon rich product, which can vary in make-up between a bio-oil (fast pyrolysis), biochar, (slow pyrolysis), or various types of syngas or hydrogen (Intellergy process). Biosolids products will have value as energy sources or can be used as a soil supplement (biochar). Pyrolysis processes maximize volume reduction, minimizing truck traffic, and reduce odor potential. The process does not have a high concentration ammonia recycle stream and would reduce the nitrogen loading to the liquid plant and reduce operating costs.

Drawbacks

Pyrolysis is still a new technology for biosolids applications and has no demonstration or full-scale installations to date. Consequently, there is little information on system performance and costs. In addition, most pyrolysis processes require a relatively dry feed, necessitating a thermal drying step prior to the pyrolysis process. The lack of a high concentration ammonia stream would reduce or eliminate the growth of Annamox bacteria in the new side stream reactor and may impact the ability of AlexRenew to pursue main stream Annamox.

Applicability to AlexRenew

Considerations relevant to AlexRenew specific to pyrolysis include:

- Site considerations – The required footprint for pyrolysis (including the pyrolysis process and pre-drying) is large and will require siting in areas currently occupied by existing facilities, such as the digestion area which would create significant challenges for sequence of construction..
- Cost – This technology is in the embryonic stage and therefore there is little cost information available. Capital cost is likely to be high. While there is little operating information, it is likely to require significant attention and maintenance.
- End-product – The final product is a sterile bio-char, bio-oil, or electricity. Bio-char may be combusted or used as a soil amendment, while bio-oil can be used as a replacement for other types of fuel oils.
- Energy – Pyrolysis creates syngas which can be used to meet the energy or heating needs for the process or converted to hydrogen for power generation.
- Community Awareness - Pyrolysis reduces truck traffic at the plant, which would be a positive outcome. In addition, since pyrolysis generates an energy product that can be used by others, it may result in positive public perception. Pyrolysis also reduces odor potential associated with cake hauling and land application.

Triggers

Anticipated triggers for pyrolysis include end-use and biosolids product volume concerns, similar to incineration, and an increased desire and market for bio-oil and bio-char products. Since this technology is considered embryonic for the biosolids industry, increased experience with biosolids-only systems is required for this technology to further develop cost and operation experience information. The development of enhanced dewatering systems capable of mechanically drying biosolids without the use of syngas would enhance the economic viability of the process.

2.1.1.4 Supercritical Water Oxidation

Technology Status: Embryonic/Emerging

The supercritical water oxidation (SCWO) process oxidizes carbonaceous materials at high temperatures and pressures (>221 bar and 374 °C). These temperatures and pressures are "supercritical", at which liquid and vapor can coexist. Supercritical conditions increase the solubility of various solids, liquids, and gases. Products of the SCWO process are the gasses CO_2 and N_2 and inert solids. Energy from the oxidation process may be recovered and used as hot water or for steam production. A process flow chart is presented on Figure 2-6. The City of Orlando, FL constructed a demonstration pilot SCWO facility at its Iron Bridge WWTP in 2008, but is still addressing operating and design issues. Aquacritox has a demonstration facility in operation in Ireland. No cost or operating information is available for either facility; consequently, success and suitability at treating wastewater solids is not well known.

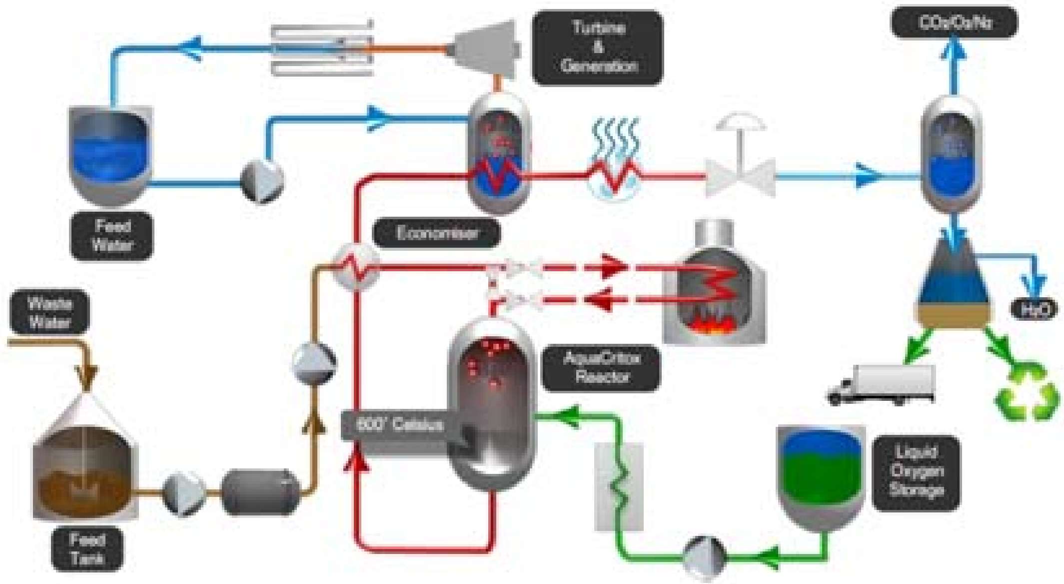


Figure 2-6. Process flow diagram for the SCWO (Courtesy of Aquacritox)

Advantages

The SCWO process achieves a very high destruction efficiency of organic material, minimizing mass and volume of the byproducts requiring disposal. The SCWO process also generates high quality gas suitable for sale. Unlike the other thermal conversion processes, a low moisture solid is not required for SCWO, eliminating the need for pre-drying or dewatering. The process does not have a high concentration ammonia recycle stream and would reduce the nitrogen loading to the liquid plant and reduce operating costs.

Drawbacks

While SCWO has a long history in certain industrial applications, it has little operating experience on wastewater solids. Consequently, performance and costs for a wastewater solids application are not well known. The SCWO environment can be very corrosive on the equipment and materials of construction, potentially resulting in high maintenance and replacement costs. Another challenge is heat exchanger fouling and scale build-up from the inert materials and salts produced. The lack of a high concentration ammonia stream would reduce or eliminate the growth of Annamox bacteria in the new side stream reactor and may impact the ability of AlexRenew to pursue main stream Annamox.

Applicability to AlexRenew

Considerations relevant to AlexRenew specific to SCWO include:

- Site considerations – The required footprint for SCWO is unknown, but may be required to be sited in areas currently occupied by existing facilities, such as the digestion area.
- Cost – This technology is in the embryonic/emerging stage and therefore there is little cost information available. Capital cost is likely to be high. While there is little operating information, it is likely to require significant attention and maintenance.

- End-product – This process produces gaseous products such as CO_2 and N_2. Ash will contain inert material, such as phosphorus, which may be recovered from the ash. A portion of the end-product would require disposal in a landfill.

- Energy – The energy balance of SCWO for wastewater solids treatment is not well known. While heat from the process can be used to generate steam and electricity, much of the energy recovered is expected to be consumed in the process itself.

- Community Awareness – SCWO will significantly reduce truck traffic at the plant, which would be a positive outcome. Since SCWO generates a gas by-product, which is much different than biosolids or energy products generated through other treatment technologies, product marketing/sale may result in positive community awareness. SCWO also reduces odor potential associated with cake hauling and land application.

Triggers

Anticipated triggers for SCWO include end-use and biosolids product volume concerns (similar to the other thermal processes) and a desire to generate end-products outside of the energy/fertilizer categories. Since SCWO is considered embryonic for the biosolids industry, increased experience with biosolids-only systems is required for this technology to further develop cost and operation experience information.

2.1.1.5 HyBrTec™

Technology Status: Embryonic

HyBrTec™ converts wastewater solids into hydrogen gas using thermochemical reactions. Hydrogen bromide (HBr) is produced from biosolids. Co-products are CO_2 and thermal energy. Electrolysis is used to disassociate the hydrogen into recyclable bromine and hydrogen. The hydrogen can be used to operate a fuel cell (for power production) or other uses. Pathogens and organisms are killed by bromination, producing a sterile ash with some unreacted carbon. Sulfur and nitrates are converted into sulfates and nitrogen in exothermic reactions that produce additional HBr. Sulfates are removed with the ash while nitrogen is off-gassed. At this time, few details are available about the HyBrTEC™ process, although a pilot/demonstration scale facility is planned for the San Francisco Bay Area Biosolids to Energy Coalition. A schematic of the process is shown in Figure 2-7.

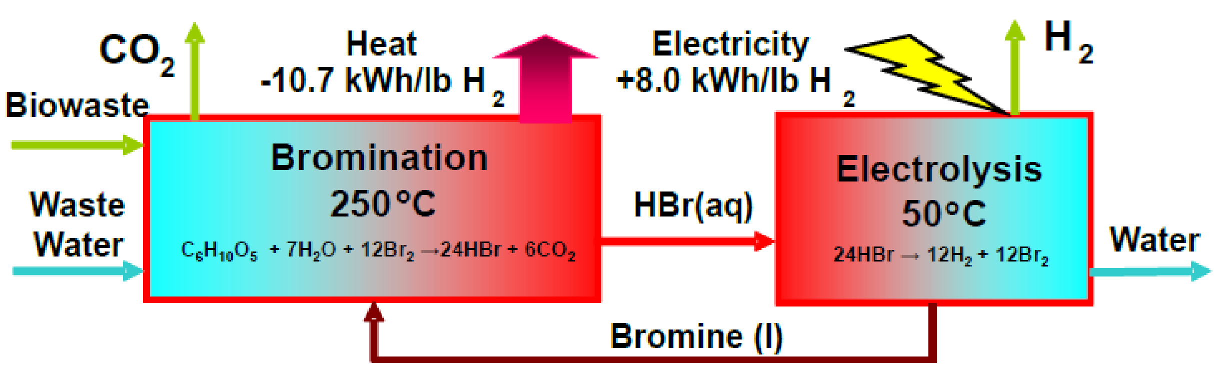


Figure 2-7. HyBrTec Process Schematic

Advantages

The HyBrTec™ process is reported to be able to operate with feed solids concentrations of 50 percent, reducing its dependence on pre-drying. However, since dewatered cake can typically only achieve solids concentrations of 25 to 35 percent, some drying would be expected. The process does not have a high concentration ammonia recycle stream and would reduce the nitrogen loading to the liquid plant and reduce operating costs.

Drawbacks

The HyBrTec™ technology is still in an embryonic stage; there is little process or operational data available. No information is available on the equipment footprint, costs, quality or quantity of the residue products, or potential disposal options or uses. The lack of a high concentration ammonia stream would reduce or eliminate the growth of Annamox bacteria in the new side stream reactor and may impact the ability of AlexRenew to pursue main stream Annamox.

Applicability to AlexRenew

Considerations relevant to AlexRenew specific to HyBrTec™ include:

- Site considerations – The required footprint for HyBrTec™ is unknown.
- Cost – This is an embryonic technology and therefore there is little cost information available. No information is available on operations and maintenance requirements.
- End-product – This process produces hydrogen gas, suitable for use for energy production through fuel cells. Residue quality and quantity are unknown.
- Energy – Net energy production is unknown, although the process produces hydrogen gas for use in fuel cells.
- Community Awareness – HyBrTec™ will reduce truck traffic at the plant, which would be a positive outcome. If the process has a net power production, loading power back to the grid would be expected to result in improved public relations. While operational information is limited, it would be anticipated that odors would be reduced with the HyBrTec system.

Triggers

Anticipated triggers for HyBrTec include end-use and biosolids product volume concerns. As this technology is in the embryonic stage, practical experience is required to further develop cost and operation experience information.

2.1.2 Stabilization Technologies

Biodegradation technologies use microbial action to convert organic material in the feedstock into biomass and products of metabolism, such as carbon dioxide and water. Biodegradation technologies include anaerobic and aerobic digestion, composting and vermiculture. Anaerobic processes generate CH_4 which can be combusted for heat or power or cleaned for use as a replacement to natural gas, and therefore have very different energy recovery potential as compared to non-anaerobic technologies.

2.1.2.1 Anaerobic Digestion Stabilization

Anaerobic digestion is a biochemical process that can stabilize many different types of organic material, generating CH_4 and CO_2 as products of the process. Digestion occurs in three basic stages – hydrolysis, acid formation, and methane formation. In conventional digestion, all three stages occur in the same vessel. Mesophilic anaerobic digestion (MAD) operates at temperatures between 30 to 38 ^{o}C. While volatile solids reduction (VSr) during MAD is a function of the feed solids characteristics and the digester effectiveness, MAD can typically achieve VSr ranging from 40 to 60 percent. Based on 40 CFR Part 503 requirements, biosolids treated through MAD for 15 days at a minimum temperature of 35^{o}C meets Class B pathogen criteria; consequently, a 15 day solids retention time (SRT) is often used as a basis of design for MAD. However, if the biosolids undergo further processing after digestion (such as thermal drying or composting), the Part 503 requirement is not required in the digestion process itself and the digestion process can be designed for slightly shorter SRTs, typically 12 to 15 days, depending on the feed characteristics, available tank volume, and gas production targets.

2.1.2.1.1 Anaerobic Digestion (with Pre-Pasteurization) – BASE CASE TECHNOLOGY

Technology Status: Mature

Pasteurization is an additional step in the anaerobic digestion process that involves heating the solids to 158°F (70°C) or higher and maintaining the temperature for at least 30 minutes before feeding the digesters. This results in pathogen reduction and meets the time and temperature requirement for Class A compliance. Pasteurization has not been shown to impact digestion performance, including VSr, biogas production, or dewaterability of digested solids.

Advantages

Pre-pasteurization with anaerobic digestion is the existing treatment process at AlexRenew and would require no changes to the current system, other than for capacity expansion. Pre-pasteurization ensures that biosolids meet Class A pathogen criteria.

Drawbacks

Pre-pasteurization has not been shown to improve digester performance. Biogas generated through the anaerobic digestion process is used to heat the pre-pasteurization process; there is no net output of energy.

Applicability to AlexRenew

In the SANUP Long Range Planning Report from 2009, it was indicated that the pre-pasteurization system would need to be expanded from two online units to three in order to maintain redundancy and meet the operating requirements for Class A biosolids at the design flow of 54 MGD due to higher than expected solids loading. Considerations relevant to AlexRenew specific to the expanded pre-pasteurization system include:

- Site considerations – Maintaining the existing pre-pasteurization system at higher than anticipated loading while ensuring redundancy and requirements for Class A biosolids would require an expansion in capacity.

- Cost – Upgrading the existing pre-pasteurization system would require a minimal capital investment compared to the installation of a new system.
- End-product – The final product is a Class A biosolids that can be land applied.
- Energy – Biogas is currently used in the pre-pasteurization treatment process. Natural gas is purchased for building heat and to supplement the biogas for pre-pasteurization as needed.
- Community Awareness – There would be no change to odors or truck traffic.

Triggers

Triggers are non-applicable as this is the current treatment system.

2.1.2.2 Thermal hydrolysis with Anaerobic Digestion

Technology Status: Mature

The thermal hydrolysis process (THP) is a high-pressure, high temperature pretreatment process, wherein biological cells in the sludge are ruptured during a sudden pressure release, making the contents bioavailable during anaerobic digestion. THP is offered by Cambi, Kruger (Exelys and Biothelys) and Lysotherm. Cambi and Kruger Biothelys are similar processes, and both are considered mature technologies based on the number of full scale installations. The Kruger Exelys is a continuous plug flow system, rather than a tank based system used by Cambi and the Biothelys process, and currently has one demonstration scale facility. Consequently, the Exelys system would be considered emerging at this time. Lysotherm has a single installation under construction in North America. It is a continuous plug flow process, but is designed to treat only WAS and therefore cannot generate a Class A cake without additional treatment.

The first step for THP systems is dewatering the sludge to 16 to 20 percent total solids. The following steps are specific to Cambi treatment. The dewatered solids are fed into a preheating tank, which uses recovered heat from the process to heat the solids. The preheated solids are fed to a second tank where high pressure steam is added to achieve temperatures of 300 to 320°F (150 to 160°C) and pressures of about 115 to 130 pounds per square inch (psi) (8 to 9 bar). After approximately 30 minutes of reaction time, the pressure is released (flashed) and the steam is recirculated to the first tank for preheating of the incoming raw solids. The hydrolyzed solids are cooled to 95°F (35°C), diluted, and fed to anaerobic digesters. Figure 2-8 illustrates the Cambi® process. Figure 2-9 shows an operational Cambi facility.

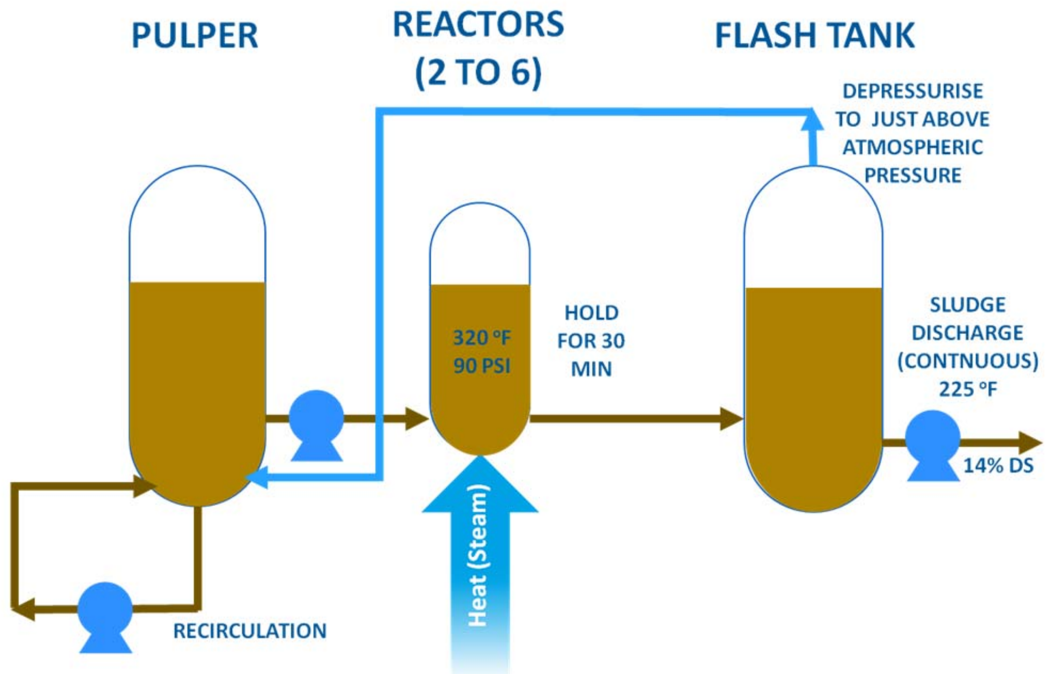


Figure 2-8. Cambi® Process Schematic

Figure 2-9. Cambi equipment at Davyhulme, UK.

The EXELYS process is a continuous system that operates in a temperature range of 285°F to 330°F and a pressure ranging from 130 to 220 psi. Progressive cavity pumps are used to feed the system from a dewatered sludge tank of hopper while steam is continuously fed to the bottom of the reactor. The steam transfers heat to the sludge, raising it to the required temperature for hydrolysis. A pressure pump maintains the pressure point for the system. The sludge is now at the necessary temperature and pressure and flows through the unit for the required time. Upon leaving the reactor, the sludge enters a heat exchanger where the sludge is cooled to the proper temperature for mesophilic digestion. The cooling water is subsequently used for heating incoming sludge. Figure 2-10 shows a configuration where the EXELYS system is used for the hydrolysis of the waste activated sludge (WAS) while the primary sludge is pasteurized in the existing pre-pasteurization tanks.

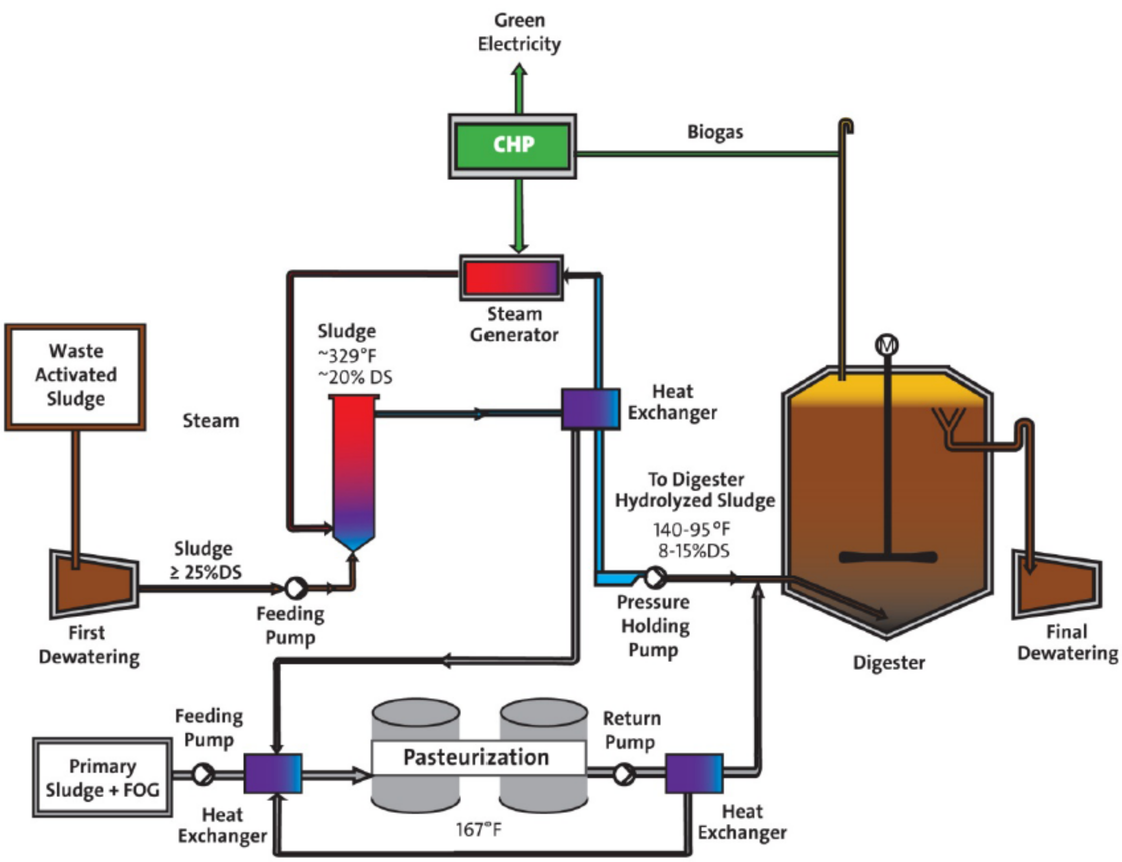


Figure 2-10. EXELYS Treatment for WAS with Pre-Pasteurization for Primary

Advantages

THP produces a more readily degradable sludge than conventional mesophilic anaerobic digestion, which allows increased digester loading, produces more biogas, increases cake dewaterability, and creates a stabilized biosolids product. THP meets Class A pathogen requirements based on time and temperature criteria. Digested solids that have undergone THP may be less odorous than conventionally digested material. Dewatered cake from THP commonly achieves 28 to 32 percent total solids using belt filter presses or centrifuges.

Based on THP experience in Europe, digesters receiving THP-treated sludge can operate at higher organic loading rates, without impacting digester stability due to variations in loading rates and/or the feed composition. Since the feed solids are dewatered to 16 percent total solids or greater, the higher organic loading rates result in significantly reduced digester volume requirements. The digesters achieve high VSr of 60 percent or greater, even at high loading rates, and biogas production increases by 40 to 50 percent. THP is also reported to destroy filamentous bacteria carried over from the activated sludge process, which helps reduce digester foaming and digestion process upsets.

Drawbacks

THP is a complex operation. The process operates at high pressures during the reaction phase. Depending on local regulations, a full-time certified boiler operator may be required. While THP increases biogas production as compared to conventional anaerobic digestion, some of the biogas is used to support the THP process, reducing the net biogas production by 10 to 15 percent. The temperatures associated with THP operation may result in colored centrate, which can interfere with ultraviolet (UV) disinfection of the liquid stream. The THP process also creates refractory Total Kjeldahl Nitrogen (TKN) which must be managed in order to meet the effluent total nitrogen limit. Improvement of the digestibility of primary solids from THP treatment is expected to be minimal.

Applicability to AlexRenew

THP is a proven and reliable technology. THP technology has a moderate capital costs, but is a good fit for installations requiring Class A treatment. The pre-pasteurization process would no longer be required to produce Class A biosolids, which would save AlexRenew from having to purchase supplemental natural gas. The existing digesters could be used for this process. THP has increased VSr and increased dewaterability which should lead to reduced polymer costs and more than a 25% reduction in hauling costs due to the higher cake solids. Other considerations relevant to AlexRenew specific to THP include:

- Site Considerations – This process has a moderate footprint and is expected to fit within the existing pre-pasteurization area, after demolition of the pre-pasteurization equipment, which will create challenges with the sequence of construction.
- Cost – THP requires a significant capital investment but there is likely to be a reduction in overall operating costs.
- End-product – The end-product is a Class A biosolids that is suitable for land application, similar to the current biosolids product generated by AlexRenew.
- Energy – Biogas produced in the digesters would be collected and combusted to produce energy with a net increase in biogas production as compared to current quantities.
- Community Awareness – There would be reduced truck traffic resulting from increased VSr and improved dewatering performance.

Triggers

Since THP generates a similar product as the current pre-pasteurization system, it has similar final use issues. However, since THP reduces digester volume requirements, it can help meet system expansion requirements with little additional footprint. In addition, it maximizes biogas production, which is attractive if combined heat and power (CHP) or biomethane generation is desired.

2.1.2.3 Thermophilic Digestion

Technology Status: Mature

Thermophilic anaerobic digestion includes one or more stages that are operated at thermophilic temperatures, ranging from approximately 122 to 140°F (50 to 60°C). Thermophilic digestion typically results in increased VSr and pathogen destruction. Depending on the configuration, thermophilic digestion can meet Class A criteria and most thermophilic digestion systems are designed to generate Class A solids. The temperature phased anaerobic digestion (TPAD) process uses a combination of thermophilic and mesophilic stages to optimize digester performance. Batch thermophilic tanks can be used to meet the Class A criteria by definition, reducing the requirement for pathogen measurement. A TPAD schematic is shown in Figure 2-11. Existing mesophilic digestion can be converted to a thermophilic process, but conversion often requires the addition of new heat exchangers, pumping and piping modifications, tank insulation, batch tanks, and potential modification to the existing biogas system. Thermophilic digestion processes have a higher odor potential and potentially reduced dewaterability as compared to mesophilic digestion.

In a continuous thermophilic digestion process the dewatered cake must be sampled for pathogens in order to demonstrate effective pathogen kill as the time temperature regulations do not apply on a continuous basis. The testing requirements can be significant, but Virginia Department of Environmental Quality (VDEQ) can limit testing after 2 years of continuous operation with 100% compliance.

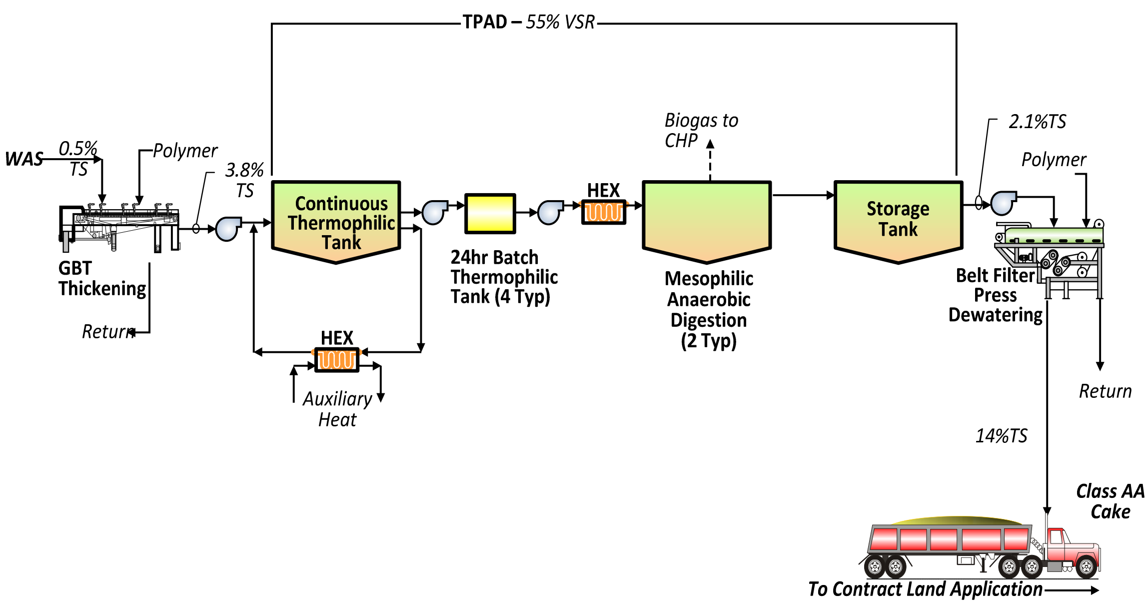


Figure 2-11. Temperature phased anaerobic digestion process

Advantages

Advantages of thermophilic digestion include Class A treatment, increased VSr and biogas production.

Drawbacks

Thermophilic digestion has greater heating energy requirements than mesophilic digestion and requires more heat exchange capacity, which can increase maintenance requirements. TPAD systems require additional tankage and pumping than a single stage mesophilic system.

Applicability to AlexRenew

Thermophilic digestion (specifically TPAD) can be used to increase biogas production and to decrease dewatered cake solids, as compared to the current pre-pasteurization system. A TPAD would be expected to meet Class A criteria. The pre-pasteurization process would no longer be required to produce Class A biosolids, which would save AlexRenew from having to purchase supplemental natural gas. This process would have moderate associated capital costs and while existing digesters would be reused, additional tankage would be required for batch tanks. The heat exchangers would need to be evaluated to determine whether additional exchangers would be required. Other considerations relevant to AlexRenew specific to TPAD include:

- Site Considerations – This process would require additional tankage for batch tanks and may have siting issues at the plant.
- Cost – TPAD requires a moderate capital investment. There would likely be little change in operating costs.
- End-product –The end-product is a Class A biosolids that is suitable for land application, similar to the current biosolids product generated by AlexRenew.
- Energy – Biogas production would be expected to increase over baseline but the TPAD treatment system would also have a larger input requirement. Biogas produced in the digesters would be expected to meet process requirements with potential for excess biogas in summer. The TPAD system does not require steam generation for digester heating and can utilize waste heat from a biogas driven combined heat and power unit. The digester gas production would allow energy generation while minimizing the addition of supplemental natural gas.
- Community Awareness – There may be slightly reduced truck traffic due to increased VSr.

Triggers

Since thermophilic digestion generates a similar product as the current pre-pasteurization system, it has similar final use issues. Thermophilic digestion would increase biogas production, which is attractive if CHP or biomethane generation is desired.

2.1.2.4 Non-Anaerobic Digestion Stabilization

Several stabilization options are available that do not require the use of anaerobic digestion. These include aerobic degradation processes, such as composting and vermiculture, thermal drying, and chemical stabilization processes. These technologies are discussed in the following sections. Note: each of these processes can utilize mesophilic anaerobic digestion to reduce odor potential and to minimize the mass of solids that must be stabilized in the following processes. In addition, mesophilic anaerobic digestion is capable of producing sufficient biogas to drive combined heat and power generation equipment without the requirement of purchased natural gas for digester heating. The use of the pre-pasteurization system would not be necessary for mesophilic anaerobic digestion as the following processes achieve Class A biosolids.

2.1.2.4.1 Composting

Technology Status: Established

Composting (Figure 2-12)is an aerobic biological process where microorganisms break down organic matter and their heat of respiration increases the temperature of the composting mass. The temperature during composting can be high enough to kill disease organisms; consequently, the compost product typically meets Class A pathogen criteria. After treatment, compost must be screened to remove large material. The final compost product is used widely in landscaping or as a soil amendment. Amendment, in the form of wood chips or other woody material, must be added to biosolids to increase porosity of the material during the composting process. Since it is an aerobic process, the composting solids must be aerated through mechanical turning or through mechanical aeration. Composting can generate significant odors which can impact surrounding neighbors. In addition, there is considerable truck traffic associated with the final product and with the amendment supply.

Figure 2-12. Composting Facility

Aerated static pile technology is the most common composting technology in North America. However, in-vessel technology, such as the Siemens IPS system, is more often used at new composting installations to reduce odor concerns. Odor control systems are provided for in-vessel composting operations to contain and treat the odors generated during the process. While odors are contained better by in-vessel systems, odor control is usually provided to treat the large volumes of air required for the composting process.

Advantages

Composting produces a marketable, desirable, high quality Class A biosolids. Since it requires woody material as amendment, community green waste can be used in the compost process, reducing costs for amendment purchase and providing a use for the City's green waste.

Drawbacks

Composting, especially in-vessel composting, can have high capital and operating costs. It is also a labor intensive process and requires considerable space. Odor potential from composting is significant.

Applicability to AlexRenew

Composting would be used following anaerobic digestion to produce Class A biosolids. The pre-pasteurization process would no longer be required to produce Class A biosolids, which would save AlexRenew from having to purchase supplemental natural gas. Since composting requires significant space, it cannot fit on the existing site. Off-site composting through contract operation and ownership may be a viable option. Anaerobic digestion would continue to operate; consequently, a CHP system could be installed to produce energy with the biogas. Other considerations relevant to AlexRenew specific to composting include:

- Site Considerations – This process cannot fit on the site and would need to be performed at an off-site or third party location.
- Cost – Capital costs can be expensive for an in-vessel system. Off-site composting may be suitable for windrow processes, which are less expensive. If the compost system is owned/operated by a contractor, final use costs would be expected to increase as compared to the current system.
- End-product –The end-product is high quality Class A compost, which is likely to have high demand and the potential for revenue.
- Energy – Biogas that is currently used in the pre-pasteurization process would be available for CHP, allowing for a net energy output. Additionally, this technology would eliminate the purchase of natural gas used in the pre-pasteurization process.
- Community Awareness – There would be no change to the current truck traffic. The compost could be sold as a branded product.

Triggers

Compost has greater flexibility in its end-use and may be an attractive option if Class A cake use becomes limited. Since it is likely to be owned/operated by a third party, it may also be attractive if AlexRenew wants to expand its capacity without increasing its installed equipment.

2.1.2.4.2 Vermicomposting

Technology Status: Emerging

Vermicomposting (Figure 2-13) is the process of using earthworms to decompose and stabilize the organic component of a waste. The earthworms break down the organic fraction of the waste material while producing a fine grain casting, or vermicast, which has shown to contain a high saturation of nutrients that are readily available for plant uptake, considered by some to be a more desirable organic fertilizer and soil conditioner than products from traditional composting. Vermicasts are expected to meet Class A pathogen requirements and would be suitable for sale or use as a landscaping or fertilizer product.

Figure 2-13. Vermicomposting

Vermicomposting generally occurs in a semi-continuous feed to a series of modular beds. Bed configuration and sizing is dependent upon feedstock, feed rate, and media necessary to maintain aerobic conditions. There is no need to regularly restock the earthworms as they remain in the beds while the feedstock is processed. Populations are naturally regulated based on food availability and size constraints. Regular monitoring of parameters such as temperature and moisture content is required and allow for the adjusting of solids flow into the system to optimize living conditions for the worms. Unlike conventional aerobic composting, vermiculture does not require thermophilic temperatures to achieve stabilization.

Advantages

The vermicompost process provides organic solids destruction without releasing objectionable odors and produces marketable Class A biosolids. The technology has low capital and operating costs.

Drawbacks

The process requires a fairly large footprint, similar to aerated static pile composting. The process also has some design and operational challenges in controlling the physical environment for the worms and thus optimizing the treatment process. Optimal conditions for worm growth include bed temperatures ranging from 59-77ºF (15-25ºC), sludge moisture content of 80-99 percent, and pH between 5.5 and 8.5. Worms are sensitive to heat and while they can tolerate colder temperature, many systems located in hotter climates require a cooling system to prevent earthworm death. Also, if the system is too dry, heat generated during degradation can elevate the bed temperature, requiring a cooling mechanism to keep the worm population alive. Aerobic conditions must be maintained throughout the active bed section. Waste feed rates must be adjusted based on worm population density.

Applicability to AlexRenew

Vermicomposting would be used in conjunction with anaerobic digestion to produce Class A biosolids. The pre-pasteurization process would not be needed and would therefore save AlexRenew from having to purchase natural gas for the process. Off-site vermicomposting through contract operation and ownership may be a viable option. Since anaerobic digestion is still used, a CHP system could be installed to produce energy with the biogas. Other considerations relevant to AlexRenew specific to vermicomposting include:

- Site Considerations – Due to the large footprint, the use of this technology would require either offsite or third party processing.
- Cost – Third party operation of the facilities would have low capital and maintenance cost. If the compost system is owned/operated by a contractor, final use costs would be expected to increase as compared to the current system.
- End-product – The end-product is a marketable, high quality Class A material that is likely to have high demand.
- Energy – A CHP system could be installed with this treatment scheme, allowing for the net production of energy. Additionally, this technology would eliminate the purchase of natural gas used in the pre-pasteurization process.
- Community Awareness – There would be no change in the vehicle hauling for transport of the cake to off-site facilities. The compost could be sold as a branded product.

Triggers

Vermicomposting has greater flexibility in its end-use than the existing biosolids and may be an attractive option if Class A cake use becomes limited; however, there are few installations in North America and cost information for a large scale facility is limited. If AlexRenew is interested in an off-site third party system, vermicomposting may be considered, but is likely to be less attractive than composting.

2.1.2.4.3 BCR Neutralizer ® Chemical Stabilization

Technology Status: Embryonic

BioChem Resources' Neutralizer® Process (Figure 2-14) is a two-stage acid-oxidative chemical treatment system. Thickened WAS at 4 percent total solids or less is dosed with chlorine dioxide for two hours. This step partially disinfects the sludge and raises the oxidation/reduction potential. Next, the sludge is acidified to a pH ranging from 2.2 to 3.0 and sodium nitrite is added and held for 6 hours. Under these conditions, nitrite speciates as nitrous acid, which penetrates the shell of helminth ova (Smith and Surampalli, 2007) providing pathogen kill, meeting Class A requirements. At the end of this step the pH is elevated to a desired level. The final solids product can be used as a liquid or dewatered.

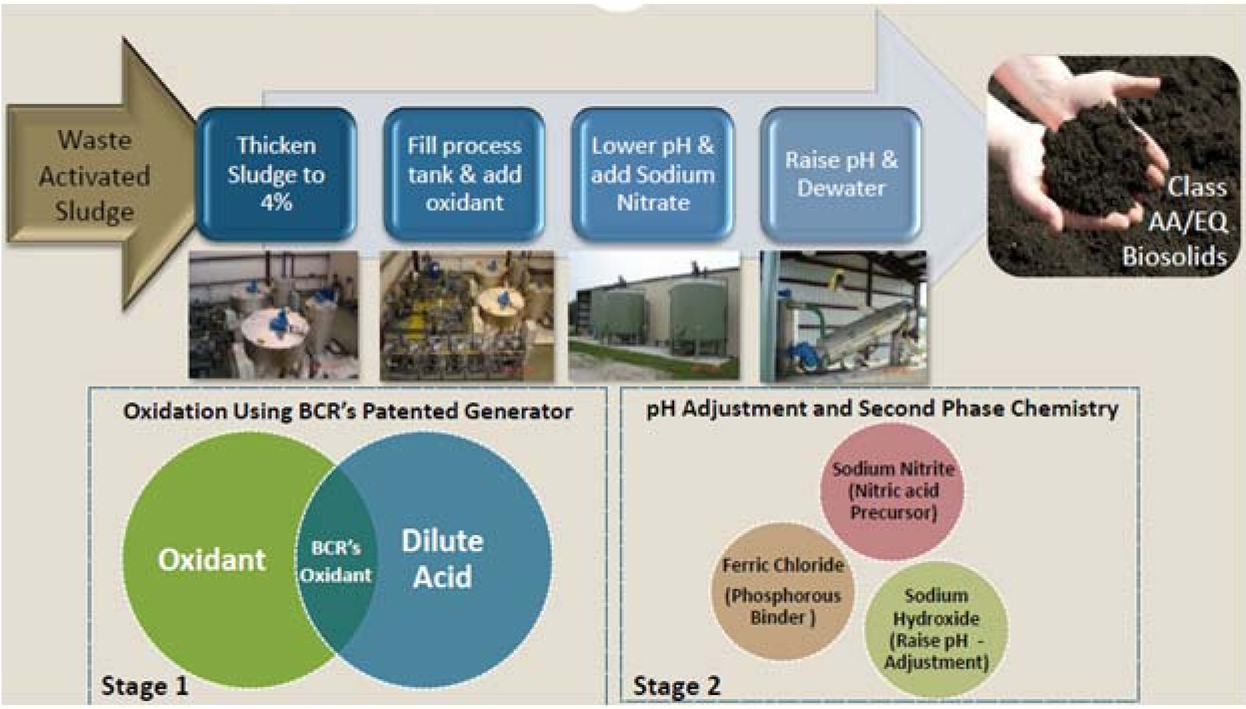


Figure 2-14. BioChem Resources' Neutralizer® (BCR Environmental)

Advantages

The Neutralizer® Process generates Class A biosolids and eliminates the need for anaerobic digestion. The final product is expected to be similar to the Class A material currently generated at AlexRenew.

Drawbacks

This process does not generate any usable energy. It is also still in the embryonic phase and therefore there is a lack of information and experience regarding operation and maintenance cost.

Applicability to AlexRenew

The Neutralizer® process creates a sterile, Class A biosolids without the need for digestion and pre-pasteurization. As the pre-pasteurization process would no longer be required to produce Class A biosolids, AlexRenew may realize savings from not having to purchase supplemental natural gas. Other considerations relevant to AlexRenew specific to the Neutralizer® process include:

- Site Considerations – This process is expected to have a small footprint and would be installed in the existing digester area.
- Cost – While there are relatively few full scale installations, low capital costs are expected. As the process requires chemicals, there will be an increased operations cost as compared to the current system. The addition of nitrous acid will increase the loading of nitrogen in the recycle streams and must be addressed as part of the operational costs of the system and capacity of the liquid system.

- End-product – The end-product is Class A biosolids, similar to the existing biosolids material.
- Energy – There is no expected net energy production. This technology would eliminate the purchase of natural gas used in the pre-pasteurization process.
- Community Awareness – There would be no change to truck traffic of processed solids or odors. There would be an increase in truck traffic associated with chemical deliveries and would require the storage of chlorine dioxide on site requiring additional community safety measures for addressing releases of chlorine gas.

Triggers

The BCR Neutralizer® process generates a product similar to the current dewatered cake and would have similar end-use concerns. A potential trigger may be the desire to eliminate digestion to make the area currently used for digestion available for other uses.

2.1.2.4.4 Thermal Drying

Technology Status: Mature

Thermal drying is the process of evaporating dewatered solids to generate a dried product, reducing the volume and weight of the solids. A simplified schematic is provided in Figure 2-15. Dewatered sludge at a solids concentration of approximately 18 to 25 percent total solids can be dried to a solids concentration of 90 percent through a process of raising the temperature of the wet solids such that the water is evaporated. The high temperature and time required for the drying process meet Class A pathogen criteria. The product is a stabilized, very low in water content (less than 10 percent), and high in organic content. Digester gas or waste heat may be used to help offset the large energy input requirements of the process. Thermal drying facilities have demonstrated reliable operation, but product must be protected from moisture to keep dry. Safety issues are a concern for thermal drying facilities due to increased potential of fire and explosions resulting from excess heat generated during storage. Storage volumes are typically limited to reduce safety risk. Thermal drying odor at treatment plants is controllable with thermal oxidizer equipment. Dust control for thermally dried product can be an issue at the treatment plant and for certain outlets which require dust free products and a defined pellet size.

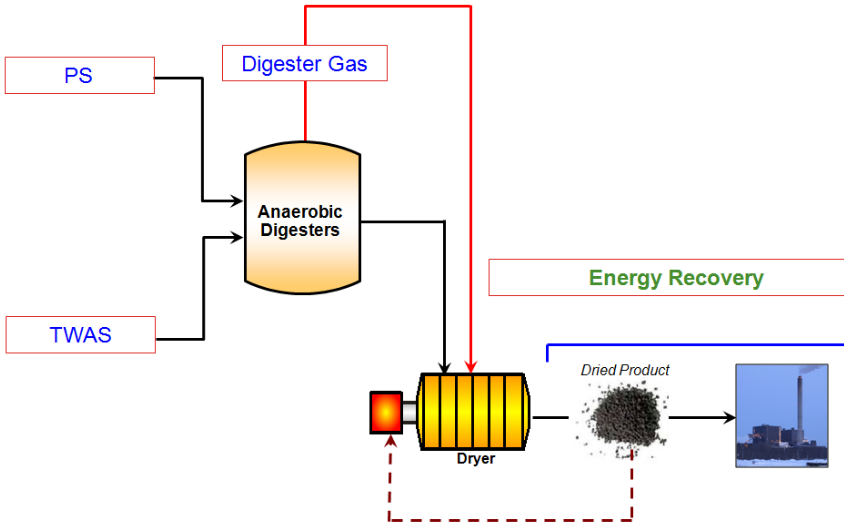


Figure 2-15. Thermal Drying Schematic

Advantages

Heat dried solids can be marketed as a fertilizer, soil conditioner, or fuel. The technology is well proven with multiple installations throughout the US. The volume and weight of the biosolids are greatly reduced, lowering handling and transportation costs.

Drawbacks

Thermal drying can be a complex process, depending on the drying technology. It also consumes most of the biogas generated through the digestion process and typically requires additional purchased natural gas to supplement the biogas supply. There is a safety element of concern with the drying process including the explosion potential of the dust and the potential for overheating and fires. The equipment is relatively complex and requires a qualified staff. The process has high capital and O&M costs. System maintenance can be extensive. Air emissions from the process require pollution control measures.

Applicability to AlexRenew

Thermal drying produces high quality granular or pelletized Class A biosolids without the need for pre-pasteurization. Other considerations relevant to AlexRenew specific thermal drying include:

- Site Considerations – This process has a fairly large footprint and would be installed in the existing pre-pasteurization area. Rotary drum drying facilities, which are more common for medium to large plants, may have difficulty fitting in the pre-pasteurization area.

- Cost – There would be a high capital cost associated with this process and increased operations costs associated with power and energy requirements for drying.

- End-product – The end-product is a granular or pelletized Class A product suitable for land application, soil blending, landscaping or combustion (in place of coal).

- Energy – Purchased energy requirements are expected to increase as compared to the current system. Biogas collected during anaerobic digestion would be used in the drying process.
- Community Awareness – There would be greatly reduced truck traffic due to large volume reduction in solids, as well as the potential for odor reduction. There may be public relations benefits associated with the sale or marketing of a high quality dry product.

Triggers

The most common trigger for thermal drying is a desire to convert from a biosolids cake product to a high quality product suitable for a variety of end-uses, with significantly reduced volume. Thermal drying consumes most, if not all, of the biogas generated through the digestion process, minimizing its availability for power or biomethane production.

2.1.3 Alkaline and Heat Disruption (Lystek)

Technology Status: Emerging

The Lystek® process uses a combination of heat, the addition of alkaline material, and high shear mixing to generate conditions for pathogen reduction. The process heats dewatered solids to 150 to 160°F (65 to 70°C), and increases the alkalinity of the material using potassium hydroxide. The solids are treated through a batch or semi-batch process. The end-product is a liquid, high-solids concentration biosolid that can be pumped. Lystek® reports to be able to operate at concentrations as high as 20 to 28 percent total solids. A schematic of the Lystek® process is shown on Figure 2-16.

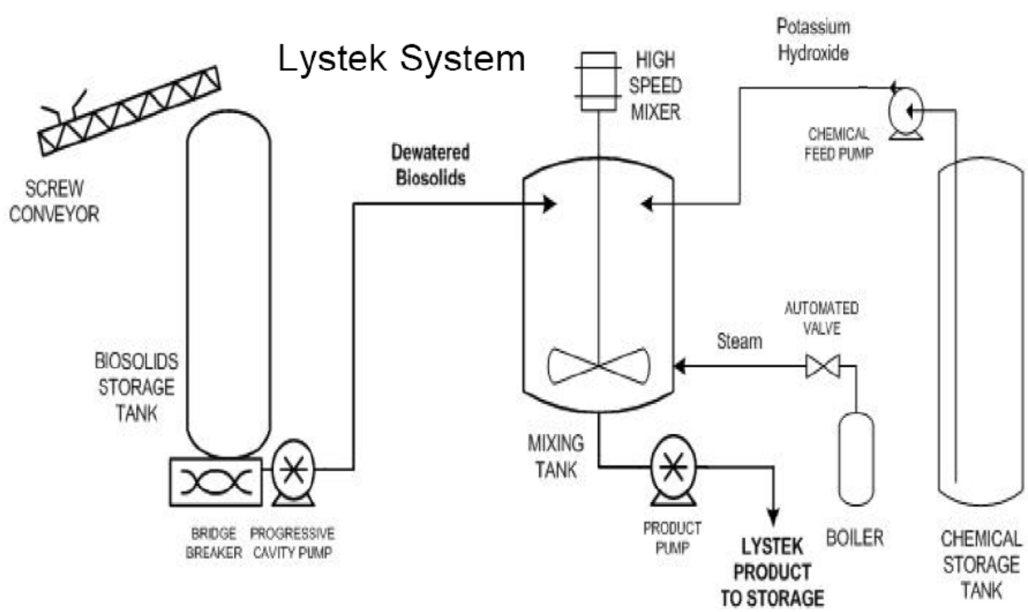


Figure 2-16. Lystek® Process Schematic

Advantages

The Lystek® process eliminates the need for anaerobic digestion. Lystek® reports that biosolids production can be reduced by 40 percent, based on pilot studies at the Saint Mary WWTP, with an increased VSr from 40 to 50 percent. The final product is a Class A biosolid with a reduced odor. The process is reported to drastically reduce solids viscosity, making the product pumpable with conventional equipment. Since this system is installed downstream of dewatering, it can be retrofitted into an existing system.

Drawbacks

One of the most significant drawbacks in this technology is that it produces a liquid product, which requires different hauling and application than dewatered cake. In addition, little full scale information is available regarding process performance or capital and operating costs. The Lystek® process requires both chemical and steam addition, increasing the complexity of the system. There is no large plant experience for this technology; the process was initially developed for the Guelph WWTP in Guelph, Ontario, which has a biosolids production of approximately 12 dry tons per day (dtpd).

Applicability to AlexRenew

Lystek® is most applicable to facilities that generate a liquid biosolids product. While the final product is a Class A biosolids, the liquid form limits the use for land application. The pre-pasteurization process would no longer be required to produce Class A biosolids, which would save AlexRenew from having to purchase supplemental natural gas. The Lystek® process is considered an emerging technology. Performance results from further testing and full scale operation should be monitored, along with system capital and operating costs. Other considerations relevant to AlexRenew specific to Lystek® include:

- Site Considerations – This process requires additional reactor tanks, storage tanks, and chemical feed. These could be constructed in the existing pre-pasteurization and digester areas. Sequence of construction would be very challenging.
- Cost – There is limited data regarding this emerging technology but there is a moderate expected capital and operating cost.
- End-product – The end-product is a liquid Class A biosolids that is suitable for land application.
- Energy – There is no expected net energy production. This technology would eliminate the purchase of natural gas used in the pre-pasteurization process.
- Community Awareness – There would be increased truck traffic due to a liquid product.

Triggers

The most common trigger for the Lystek® process would be a desire to free up space currently devoted to the anaerobic digestion process. Lystek® generates a liquid product, which is expected to be less suitable to hauling and land application in the region. Consequently, Lystek® is not considered to be a good fit for AlexRenew.

2.2 PROCESS ENHANCEMENTS

A variety of process enhancements can be coupled with specific stabilization technologies to improve performance and increase energy recovery. The process enhancements are not expected to dramatically change the inherent quality of the biosolids products. In cases where the process enhancements improve digester performance, the quantity of the biosolids product generated may be impacted. For example, process enhancements that increase volatile solids destruction in an anaerobic digester will concomitantly decrease digester solids production. The enhancements are described along with the expected benefits.

2.2.1 Gas Utilization and/or Energy Production

Biogas can be combusted to produce heat and electricity in CHP equipment. There are a number of CHP technologies, with varying levels of operating history and success. The heat can be recovered from the power generation units in the form of hot water or steam for use in process or building heat. CHP systems can have efficiencies that approach 80 percent if all the recovered heat is used.

The suitability of on-site CHP technologies varies with respect to size, fuel requirements, local air emissions requirements, efficiency, cost, and overall compatibility with the existing treatment processes. Biogas requires cleaning systems upstream of the combustion equipment for the removal of moisture, H_2S, and siloxanes, depending on the type of combustion system selected. A schematic of a complete gas cleaning process is depicted in Figure 2-17. Fuel cells are the most sensitive with regards to contaminated biogas while engine generators are the least sensitive.

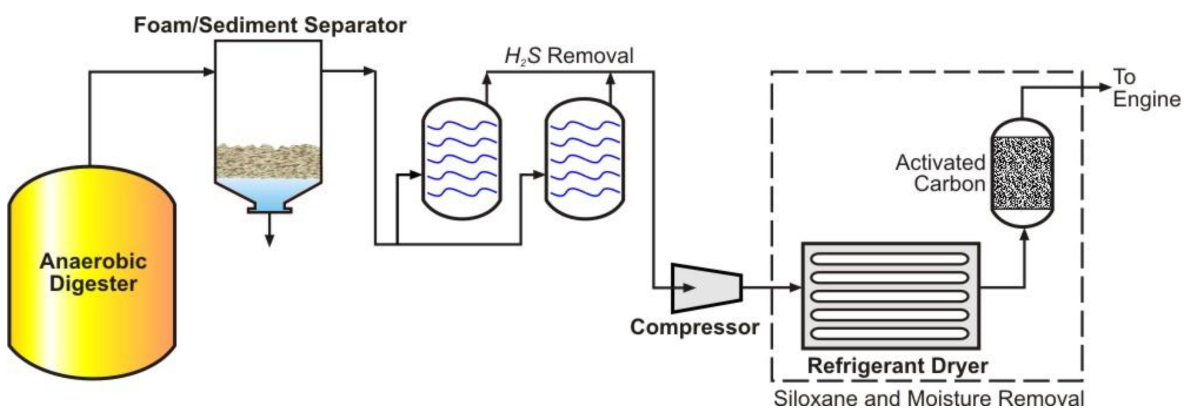


Figure 2-17. Biogas Cleaning for Power Generation

A number of selection factors come into place when evaluating cogeneration technologies including:

- Gas production rate for potential generation
- Potential air emissions and site restrictions
- Need for heat recovery to heat digesters
- Quality of gas or cleaning requirements
- Simple payback or life cycle benefits
- Renewable energy credit and GHG footprint

Figure 2-18 illustrates the selection factors for the three most common cogeneration technologies. Each technology is further described in the below sections.

Technology	Efficiency	Capacity	Reliability	Cleaning Requirements	Emissions	Cost
Engine Generators						$
Microturbines						$
Fuel Cells						$$$

	Technology excels at given criteria
	There are minor concerns/issues with criteria
	Technology has difficulty with given criteria

Figure 2-18. Cogeneration Technology Selection Factors

2.2.1.1 Engine generators

Technology Status: Mature

Engine generators are the most common choice for wastewater treatment plants desiring to use biogas as an energy resource at the plant. An engine generator is shown in Figure 2-19. Engine generators can have power efficiencies up to 40 percent or more, with capacities ranging up to 0.4 to 5 MW per unit. The waste heat from the generators (in the form of hot water) can be recovered and used for process or building heat. While power production is a function of carbon in the raw water, upstream treatment processes, and digestion effectiveness, most plants generate sufficient electricity to meet the biosolids processing power requirements and can offset some of the power requirements from the liquid treatment processes. Maintenance is relatively simple and can be performed by the plant staff.

Figure 2-19. Engine Generator

Advantages

Engine generators typically have the lowest cost of available power generation technologies and are the least sensitive to biogas contaminants. Engine generators have high power efficiencies relative to many other power generation technologies. Maintenance is typically performed by plant staff.

Drawbacks

Engine generators have greater exhaust emissions than other power generation technologies, which can be a concern in locations with strict emission limits. Downstream emissions control technologies can be included at an additional cost.

Applicability to AlexRenew

Engine generators are commonly used for on-site power generation and may be a good fit for AlexRenew if biogas utilization is being considered.

2.2.1.2 Microturbines

Technology Status: Mature

Microturbines (Figure 2-20) are small combustion turbines that operate at very high speeds, available in unit capacities of 260 kW or lower. Multiple units can be installed in parallel for higher capacity. They are available as modular packaged units that include the combustor, the turbine, the generator, and the cooling and heat recovery equipment. Because of the size limitations, microturbine units are attractive for small to medium sized plants. Early microturbines had fairly low energy efficiencies, typically 25 percent or less. Newer models report electrical efficiencies at 30 to 33 percent. Most microturbine maintenance is performed by the vendor and maintenance includes lining and fuel injector replacement approximately every two years and complete turbine replacement around every five years.

Figure 2-20. Microturbine installation (Sheboygan, WI)

Advantages

Microturbines have small footprints and require little maintenance from plant staff. They have reduced emissions as compared to engine generators.

Drawbacks

Microturbines have lower efficiencies when compared to engine generators. Microturbines are more sensitive to biogas contaminants than engine generators and therefore require higher levels of gas treatment and higher inlet pressures, ranging from 75 to 100 pounds per square inch gauge (psig), as compared to engine generators. The efficiencies are reduced further when operating at higher ambient temperatures (lower combustion air mass flow available). Capital costs are higher than for engine generators and there are few vendors, limiting model choice and competition.

Applicability to AlexRenew

Microturbines are a mature, robust on-site generation technology, with reduced emissions, which would be a good fit for the AlexRenew site. Higher costs and reduced power generation, as compared to engine generators, make them likely to be less cost effective than engine generators. However, AlexRenew may want to consider this technology for biogas utilization.

2.2.1.3 Fuel Cells

Technology Status: Emerging/Mature

While fuel cells using natural gas is a mature technology, the use of fuel cells for on-site power generation using biogas is a somewhat recent development, with relatively few operating installations. A fuel cell and associated gas cleaning equipment are shown in Figure 2-21. The hydrogen contained in biogas CH_4 is separated through a reforming process. The hydrogen is converted directly to electricity through an electrochemical reaction in the fuel cell stack, which is a group of fuel cells, consisting of an anode and a cathode separated by an ion-conducting membrane. The number of fuel cells in the stack determines the total voltage, and the surface area of each cell determines the total current. Similar to a battery, the electricity produced in a fuel cell is in the form of direct current (DC), which is converted to alternating current (AC) in an inverter.

Figure 2-21. Fuel cell and gas cleaning system (Turlock Irrigation District, CA)

Contaminants in the digester gas such as H_2S, moisture, and siloxanes must be removed prior to use in fuel cells to avoid damage to the plate stacks.

Fuel cells maintenance includes:

- Replacing the carbon in the pretreatment module two to four times annually.
- Conducting an annual shutdown for replacement of filters and for servicing other components such as blowers.
- Replacing fuel cell stacks every three to five years.
- Overhauling the fuel processor after five to ten years of use.

Advantages

Fuel cells have high power efficiency (over 40 percent), low emissions, and quiet operations. Unlike other combustion power generation systems, fuel cells can sustain high efficiency operations even under partial load conditions. As a result of these high operating efficiencies and lack of combustion, fuel cells emit fewer greenhouse gases per unit of power generated than for microturbines or internal combustion engines. The combustion-free process also produces fewer byproducts than other alternatives, resulting in less criteria air pollutant emissions (notably NO_X and SO_X).

Drawbacks

Disadvantages of fuel cells vary by type. High capital cost, long startup time, a short fuel cell stack life of three-to-five years (which increases O&M costs), high sensitivity to biogas quality, low power density, and power generation degradation over time resulting from corrosion and breakdown of cell components are the primary disadvantages of fuel cell systems and are the focus of research and development.

Applicability to AlexRenew

Fuel cells are not typically cost effective unless significant grant money or tariffs are available. Unless these funds are available to offset the capital and operating costs, fuel cells should not be considered at this time.

2.2.1.4 Biomethane Production

Technology Status: Mature

Biomethane generation is the process of cleaning and compressing biogas to generate “near” natural gas quality. The produced biomethane can be used in natural gas pipelines or for vehicle use as a replacement for compressed natural gas (CNG). There are a variety of cleaning technologies that remove CO_2, including pressure swing adsorption (PSA), membrane removal, or solvent removal. The cleaning process removes foam/sediment, CO_2, H_2S, water, and potentially siloxanes. Figure 2-22 shows one version of the biomethane cleaning process. Most cleaning and compression systems are packaged by a manufacturer.

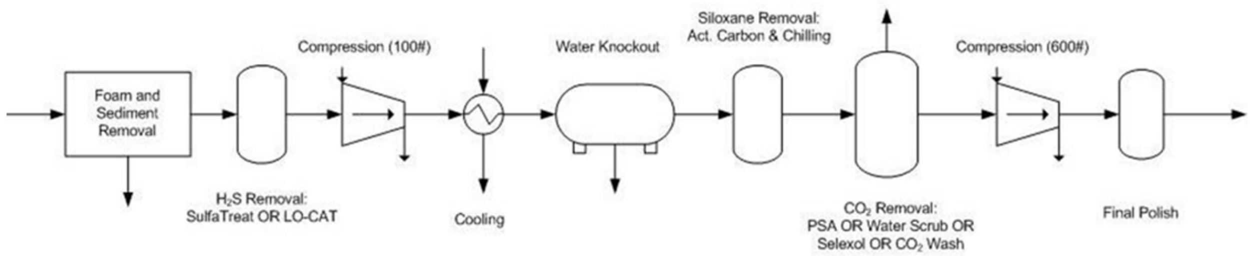


Figure 2-22. Biomethane treatment process

When treatment using solvents is utilized, the solvents are chosen to selectively absorb CO_2 but will typically remove other compounds as well such as H_2S. The removal process usually occurs as pressures exceeding 100 psi. The solvent can be regenerated by reducing the pressure (sometime at elevated temperatures).

PSA involves compressing the biogas to 100 – 150 psig and transporting the flow stream through an absorbent filled packed bed. The absorbent is selected for CO_2 removal and includes zeolites and carbon molecular sieves. Regeneration involves depressurizing the vessel and using dry regeneration gas. H_2S and siloxanes may also be removed during this process. This process is simpler than a solvent system.

Membrane removal of CO_2 uses semipermeable barriers with differential partial pressure to drive the separation process. This process requires biogas to be compressed to a pressure exceeding 150 psig. A 2-stage process is usually required to match the capture efficiency of the PSA. Waste gas from the first stage is recompressed and treated through a second stage. The membranes may be damaged by VOCs, H_2S, and particulates. This process is also characterized by a low capture when compared to the other options.

Gas cleaning requirements for vehicle use are less stringent than cleaning for pipeline injection. A biomethane system for vehicle use also requires storage and fueling facilities.

Advantages

Biomethane is similar to natural gas and therefore has a wide market for use. Increasing availability of CNG powered vehicles has also increased interest and demand for CNG, including biomethane based CNG. Renewable energy tariffs may be available to partially offset the cost of the system.

Drawbacks

The biomethane cleaning process does not generate heat; consequently, process and building heating must be provided using purchased energy. Biomethane treatment systems are expensive and have a relatively high power use. While biomethane is similar to natural gas, injection into natural gas pipelines may be difficult depending on pipeline ownership and injection requirements. The demand for biomethane use as CNG is driven by local and regional CNG vehicle needs, which may be less than CNG supply. In addition, CNG fueling stations locations must be convenient for the users, potentially requiring CNG transport to off-site stations.

Applicability to AlexRenew

Conversion to biomethane is growing in the wastewater treatment industry. As AlexRenew considers beneficial use for its digester biogas, biomethane generation should be considered as an alternative to on-site power generation.

2.2.1.5 Conversion to Methanol

Technology Status: Embryonic

Due to methanol's common use as a carbon source for denitrification, conversion of anaerobic digester gas to methanol is being researched as a viable alternative to the economically and energy intensive means of methanol creation through chemical catalysis. Taher and Chandran at Columbia University evaluated a biological process for achieving autotrophic conversion of CH_4 to methanol (CH_3OH). In the study, they employed ammonia-oxidizing bacteria (AOB) to selectively and partially oxidize CH_4 to CH_3OH. In fed-batch reactors using mixed nitrifying enrichment cultures from a continuous bioreactor, up to 59.89 ± 1.12 mg COD/L of CH_3OH was produced within an incubation time of 7 h, which is approximately ten times the yield obtained previously using pure cultures of Nitrosomonas europaea.

This process would utilize the methane gas created as part of the anaerobic digestion process to produce methanol that could be utilized as a supplemental carbon source in the denitrification process. There are several challenges that still exist with the concept. Methane oxidation to methanol by AOB has been found to be inhibited by ammonia (the primary substrate for the oxidative enzyme, ammonia monooxygenase, AMO) as well as the product, methanol, itself. Further, oxidation of methane to methanol by AOB was also limited by reducing equivalents supply, which could be overcome by externally supplying hydroxylamine (NH_2OH) as an electron donor.

A potential optimum design for promoting methane to methanol oxidation by AOB could involve supplying ammonia (needed to maintain AMO activity) uncoupled from the supply of ammonia monooxygenase and methane.

Advantages

Utilization of excess methane to produce methanol would reduce flaring of excess digester gas and produce a chemical that is currently purchased by AlexRenew and traditionally manufactured from fossil fuels (natural gas)

Drawbacks

There is no potential for energy production with the methane that is converted to methanol.

Applicability to AlexRenew

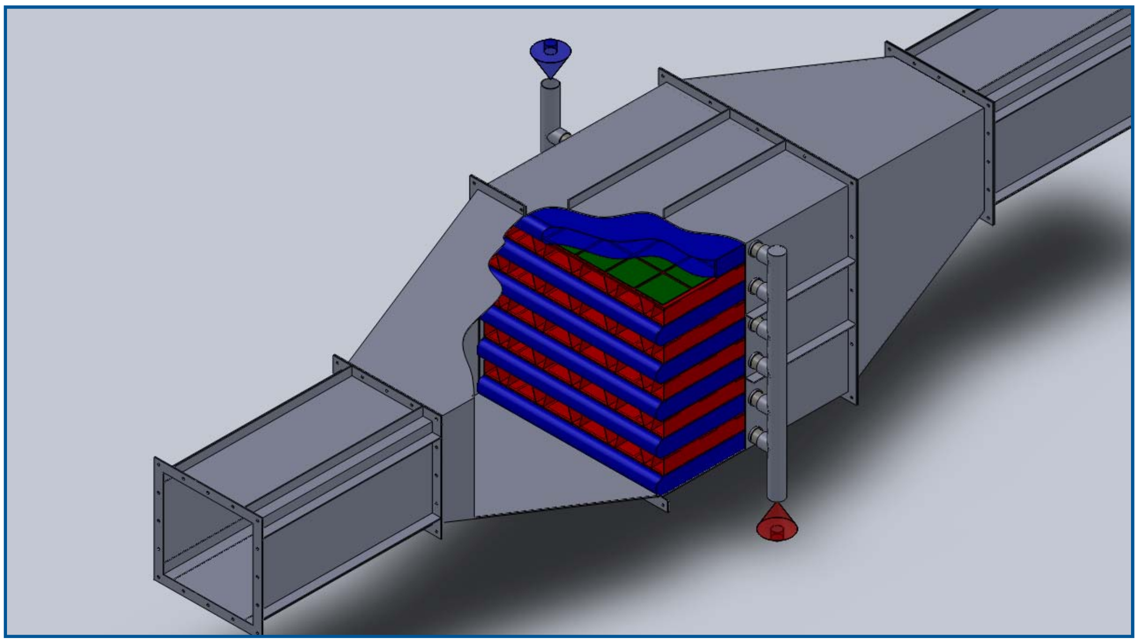
The process is still being developed at a conceptual and bench scale level and is not commercially viable at this time.

2.2.1.6 Thermoelectric Technology

Technology Status: Embryonic

Thermoelectric technology uses semiconductors to generate electricity from a temperature gradient. The semiconductors must have high electrical conductivity and low thermal conductivity. Historically, this technology has been used to power deep space satellites from radioisotope heat sources and has generally been cost prohibitive for use in other applications.

Thermoelectric technology can potentially convert a portion of waste heat from various processes into electricity (Figure 2-23) using silicone-based thermoelectric elements. Waste heat from biogas combustion (in boilers or CHP equipment) may be used with this technology to generate electricity.



Red – Exhaust gas hot side channels
Blue - Water cooled cold side channels
Green –Thermoelectric generator elements

Figure 2-23. Alphabet Energy Thermoelectric Generator

Advantages

Thermoelectric generators have no moving parts and are relatively simple.

Drawbacks

The technology is new to the commercial market, with unknown costs and performance. Waste heat from biogas combustion would not be available for its typical uses (anaerobic digestion, building heat).

Applicability to AlexRenew

Thermoelectric generation is still in its infancy in industrial applications. While it is not recommended for implementation at AlexRenew at this time, it should be monitored to identify costs and performance for potential future use.

2.2.2 Anaerobic Digestion Pre-Treatment

Anaerobic digestion pre-treatment includes an assortment of technologies that are targeted at improving digestion performance, either through increased VSr, reduced foaming, or improved dewaterability. While some digestion pre-treatment processes can meet Class A pathogen criteria, this section is limited to processes that do not result in changes to pathogen class (see Section 2.1.2 for Class A Anaerobic Digestion technology discussion).

2.2.2.1 Microsludge ™ Cell Lysis

Technology Status: Embryonic/Emerging

MicroSludge™ is a combined chemical and mechanical process, developed by Paradigm Environmental Technologies, that conditions thickened waste activated sludge (TWAS) prior to anaerobic digestion. In this process, TWAS is mixed with caustic soda (NaOH) using a high shear mixer, and then transferred to a conditioning tank. The conditioned TWAS is then passed through a gas/liquid separator and a fine filter before being transferred to one or more high-pressure homogenizers (cell disruptors). The cell disrupters are positive displacement pumps that force TWAS at very high pressure through a valve, where the pressure drops from 12,000 psi (827 bar) to about 50 psi (3 bar). The sudden pressure drop causes the cell membranes to rupture, releasing the contents of the cells into solution, which increases the digestibility of the sludge. A process flow diagram of the MicroSludge™ system is presented in Figure 2-24. The Microsludge™ process has been tested at several wastewater treatment facilities. Initial testing showed promise for improved VSr and biogas production. However, subsequent testing at different facilities has not been able to reproduce similar benefits.

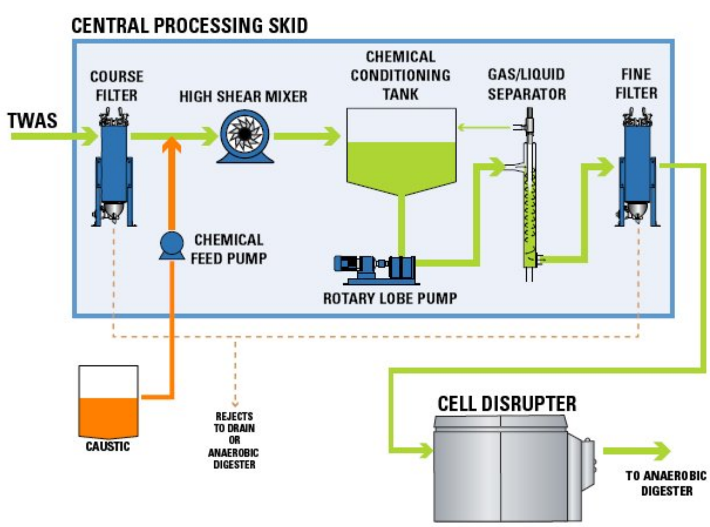


Figure 2-24. Microsludge™ treatment schematic (*Courtesy of Paradigm)*

Advantages

Microsludge™ is a simple process, readily retrofitted into existing facilities with small footprint requirements.

Drawbacks

Testing subsequent to the 2004 initial demonstration has not been able to replicate the original results. In addition, MicroSludge™ requires high doses of caustic soda, high pressure for homogenization, and may produce process odors.

Applicability to AlexRenew

Based on the current performance results for MicroSludge™ technology, it is not considered to be viable at this time. However, testing continues and if benefits can be identified, MicroSludge™ may warrant additional consideration.

2.2.2.2 OpenCEL® Cell Lysis

Technology Status: Embryonic/Emerging

OpenCEL® is a physical pretreatment technology that uses a rapidly pulsing, high-voltage electric field, typically between 15 to 100 kilovolts per centimeter applied on the order of 2 to 15 microseconds, to disrupt the cell walls. The applied electric field disrupts the lipid layer and proteins in the cell membranes, causing the cell to swell and eventually rupture and release the intercellular material for better digestion. The OpenCEL® system consists of step-up transformers for high-voltage power supply (480 volt alternating current to 30,000 volt direct current), capacitors for electrical energy storage, and a treatment chamber where an electrode assembly focuses the electrical pulses on the WAS stream. Figure 2-25 illustrates the components of the OpenCEL® system. The solids streamflows through a grinder pump upstream of the OpenCEL® process to reduce the particle size. Electric pulsing is based on the mass of solids to be pre-treated and therefore, the system can handle feed solids concentrations ranging from 4 to 8 percent total solids. One of the potential concerns with more dilute feed solids is the effect on charge ratio, which could affect electrical conductivity inside the treatment chamber.

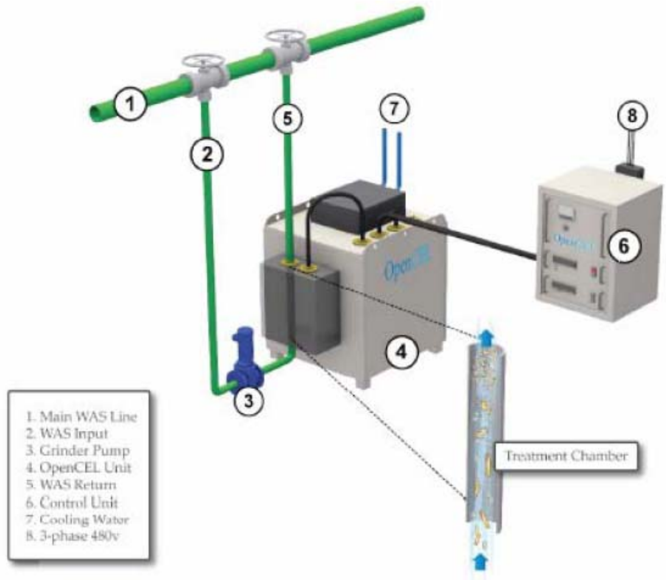


Figure 2-25. Components of the OpenCEL® System (Courtesy of OpenCEL®)

Testing performed at the Mesa, Arizona Northwest Water Reclamation Plant since early 2007 indicated improvements in VSr and biogas production, potentially up to 40 percent improvement. Since the OpenCEL® process also generates heat and raises the temperature of the digester feed sludge, an associated benefit is the reduction in heating energy required for the digestion process. The OpenCEL® process is undergoing performance testing at Racine, WI, Philadelphia, PA, and Orange County, CA. Performance information is not yet available for these installations.

Advantages

The OpenCEL® system is a relatively simple technology with a small footprint. The equipment has no moving parts and has little to no wear components. The primary maintenance on the system is the treatment chamber, which may have to be replaced as often as once every three years. According to OpenCEL®, replacement of the pretreatment chamber costs approximately $20,000 and can be accomplished in about 20 minutes. OpenCEL® typically provides a service contract so that the plant maintenance personnel do not have to work on the high voltage equipment.

Drawbacks

OpenCEL® currently only has performance data from a single full scale installation, limiting information on the broad applicability of the process at other sites. In addition, the full-scale system at Mesa is no longer in operation. There is also limited data on capital and operating costs for full-scale systems.

Applicability tor AlexRenew

While previous OpenCEL® test information showed promise, it has not yet been duplicated at other facilities. If future testing indicates improved digestion performance, it may warrant consideration.

2.2.2.3 BioCrack® Cell Lysis

Technology Status: Embryonic/Emerging

BioCrack® is a high voltage cell lysing technology by Vogelsang. The process, shown in Figure 2-26, begins with a mechanical shearing element or "rotacut" macerator. The macerator is used to both protect the internal electrodes from rocks or fibrous material as well as condition the sludge to increase surface area and improve the efficiency of the electro-kinetic disintegration. Next, the sludge is subjected to a pulsing electrical field created between electrodes to weaken cell walls.

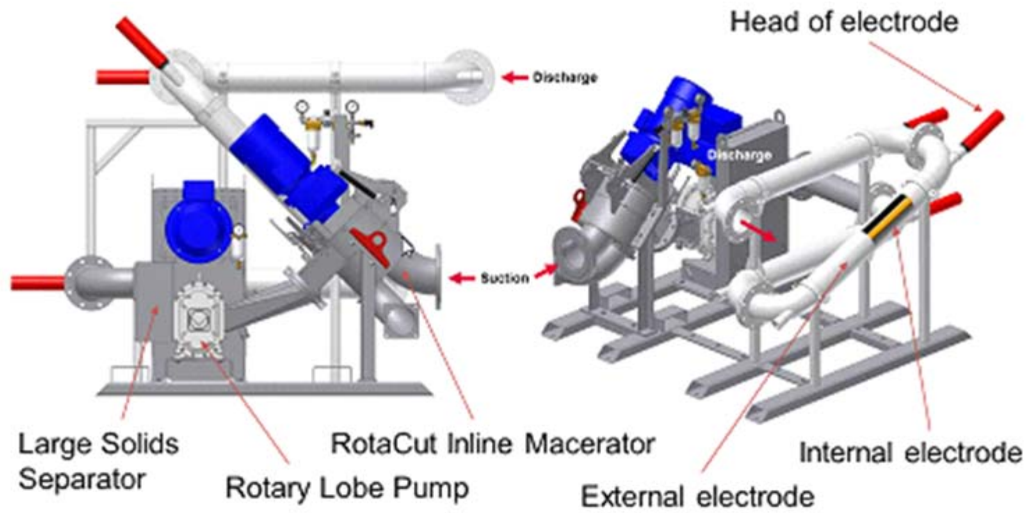


Figure 2-26: BioCrack System

There are no full scale installations of BioCrack®. Recent pilot testing of a portable BioCrack® unit at the Urbana Champaign Sanitary District was inconclusive.

Advantages

BioCrack® consumes less energy than OpenCEL®. It is a simple, small footprint technology that can be retrofitted into most anaerobic digestion systems.

Drawbacks

Performance of the BioCrack® technology is unknown. The study at Urbana Champaign showed no significant improvements in gas production or VSr.

Applicability tor AlexRenew

Based on the current performance results for BioCrack® technology, it is not considered to be a viable technology at this time. However, if testing continues and if benefits can be identified, it may warrant additional consideration.

2.2.2.4 Crown® Biogest Cell Lysis

Technology Status: Emerging

The Crown® disintegration system is a mechanical cell lysing system for TWAS and is used upstream of anaerobic digestion. The system consists of a high speed mixer, a homogenizer, two progressive cavity pumps, a recirculation tank, and a disintegration nozzle (Figure 2-27). Incoming sludge is mixed, homogenized, pressurized to 174 psi (12 bar) and forced through the disintegration nozzle where cavitation occurs due to the sudden pressure drop, causing the cell structure to rupture. The sludge is recycled three times through the process. While there are no North American Crown installations at this time, there are more than 20 installations worldwide.

Pretreatment through the Crown® system is reported to improve solids destruction and biogas production during anaerobic digestion, as well as reduce foaming potential by disrupting filamentous bacteria. According to the manufacturer, the system is appropriate for digester feeds with solids concentrations in the range of 3 to 8 percent total solids. For anaerobic digester applications, the manufacturer guarantees at least 20 percent increase in gas production and a 15 percent reduction in dry solids production. Plant data from existing installations show an average VSr and biogas increase of 28 percent and cake solid content increase of 18 percent.

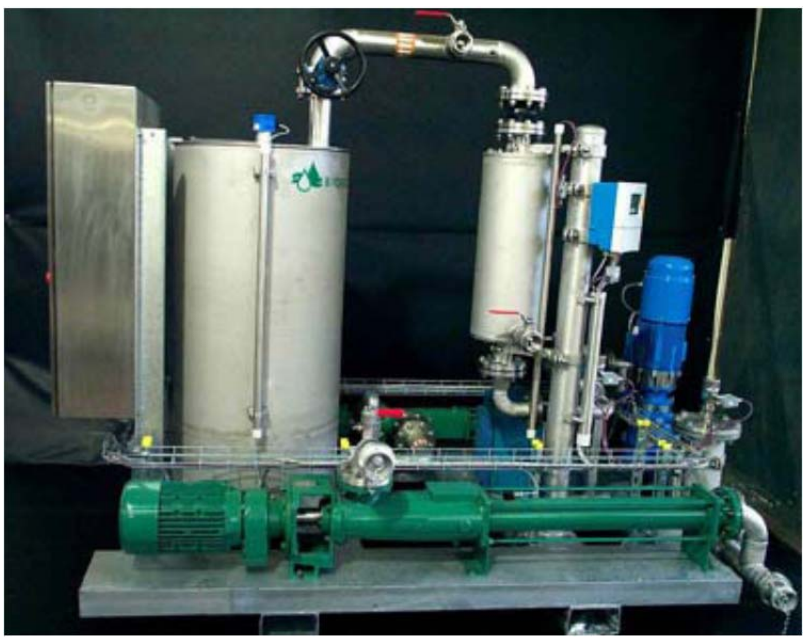


Figure 2-27. Crown® Disintegration System (Courtesy of BIOGEST®)

Advantages

The Crown® system has a relatively small footprint that can be easily retrofit into an existing process.

Drawbacks

The Crown® system is based on treating only 30 to 40 percent of the WAS in order to reduce total energy requirements. While this may be an optimal energy solution, 60 to 70 percent of the sludge is left untreated.

Applicability to AlexRenew

The Crown® process may be a viable solution as a simple, low cost method for increasing VSr and biogas production at AlexRenew in conjunction with mesophilic anaerobic digestion. Since there are no North American installations, there may be some risk associate with vendor maintenance and support.

2.2.2.5 Sonication Cell Lysis

Technology Status: Emerging

Sonication or ultrasound pretreatment works on the principle of cavitation, which is the formation, growth, and collapse of micro-bubbles. The implosion of these tiny bubbles produces "hot spots" in the liquid that release sufficient energy to disintegrate the bacterial cells in WAS. The ultrasound unit consists of a series of ultrasonic probes or horns that are configured in a flow-through vessel. As the WAS flows through the vessel, it comes in direct contact with the probes that transmit the ultrasonic waves to the solids, causing cavitation. The ultrasound units typically come in modules and can be incorporated into the existing WAS piping with minor modifications. Figure 2-28 shows a schematic of the ultrasound system configuration. A full scale sonication facility installed at the Subiaco WWTP (Perth, Australia) is no longer in use.

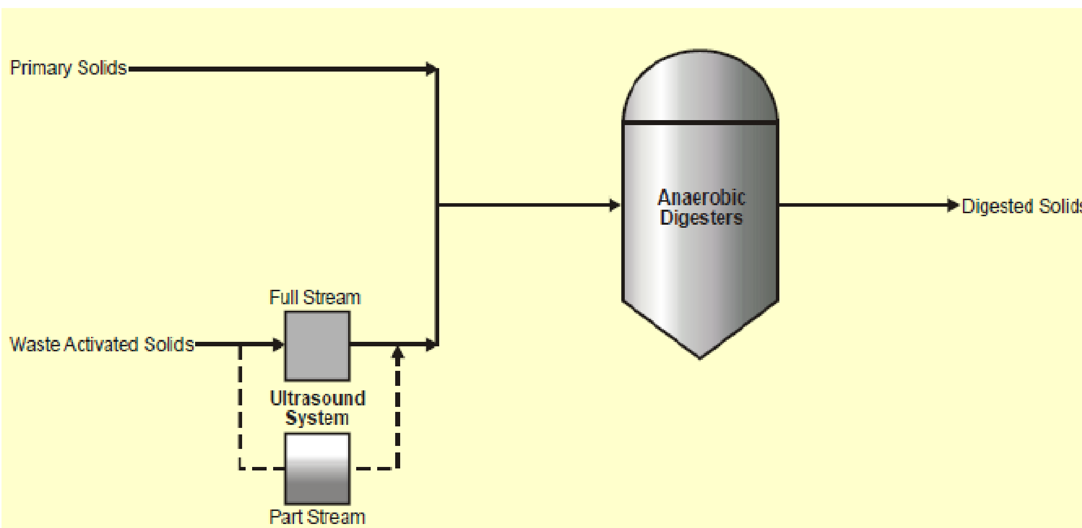


Figure 2-28. Ultrasound System Configuration

Advantages

Sonication research indicates that sludge rheology decreases after treatment, improving pumpability. Studies have also shown sonication has been shown to increase biogas production by 50 percent. Sonication is a small footprint technology and is fairly easy to retrofit into existing facilities.

Drawbacks

While sonication research indicates an increase in biogas production, it has not shown a similar increase in VSr. Dewaterability may be degraded as a result of the sonication process and filamentous bacteria, which can affect digester foaming, do not appear to be affected by the treatment.

Applicability to AlexRenew

Based on current research and full scale performance, sonication is not recommended for consideration at AlexRenew.

2.2.2.6 Ozonation

Technology Status: Embryonic

The ozonation process oxidizes the refractory organic materials in WAS into biodegradable compounds that are amenable for digestion. The ozonation unit can be incorporated into existing recirculation loops of digesters and typically consists of an ozone generator, a reaction tank, and an ozone destruction facility to remove any residual ozone and oxygen from the liquid prior to recycling the solids into the digesters. Ozone treatment of return activated sludge (RAS) has also been shown in demonstration testing to improve digestion performance. Schematics of the digester ozonation is shown on Figure 2-29.

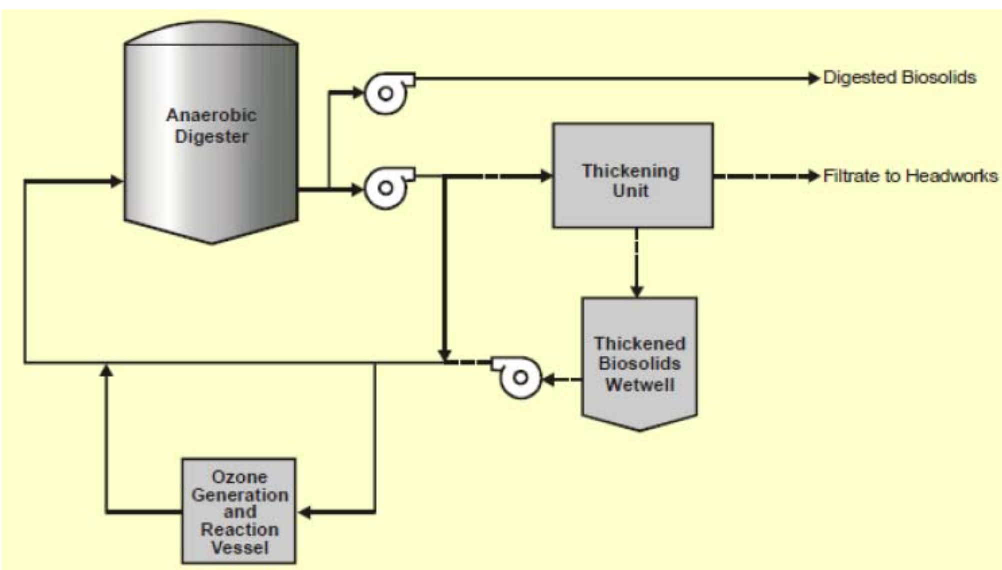


Figure 2-29. Ozonation System Configuration

In the ozonation process, it is critical to optimize the ozone dosage. At higher doses of ozone, the chemical oxygen demand (COD) in the raw solids may be completely converted to carbon dioxide, resulting in a reduction in the carbon source for methane formation. The inorganic constituents in the solids will be solubilized by ozone and returned to the headworks with dewatering return streams, potentially increasing nutrient load on the liquid process. Full-scale tests in Japan in 2002 through 2004 showed higher VSr with partial ozonation of the digester contents and an increase in biogas production from 24 percent to 143 percent.

Advantages

The ozonation process is relatively simple, requiring few treatment steps. The benefits of ozonation include a reduction in total solids, as well as treatment of filamentous bacteria, which can also help reduce digester foaming. In addition, ozonation has also been found to convert sulfides to oxidized forms, reducing odors. Utilities that have or are installing oxygen systems may have excess oxygen production that can be used for ozone generation.

Drawbacks

Ozonation is a relatively new pretreatment technology with little published data regarding performance or costs. Existing data are limited to a few test installations.

Applicability to AlexRenew

Initial performance results from ozonation testing look promising, but there is little information on full-scale costs and benefits. Performance results and costs from additional testing should be monitored. Since ozonation is expected to be most beneficial through reduction in the quantity of solids being generated, increases to the final use and disposal costs for biosolids make ozonation more attractive.

2.2.3 Enhanced Digestion

The process of anaerobic digestion to stabilize wastewater solids involves three main stages: hydrolysis, volatile acid fermentation, and methane formation. The efficiency of each reaction step is affected by reaction time, temperature, pH, and other factors. The majority of anaerobic digestion systems currently in use at municipal WWTPs are configured as conventional MAD. In these systems, all stages of anaerobic digestion reactions occur in the same vessel operated at a mesophilic temperature range of approximately 90 to 100°F (32 to 38°C). Heating and mixing are normally provided to maintain uniform conditions in the digester. In a conventional MAD operation, secondary digesters are normally included to provide storage for digested sludge as well as biogas. Digesters are sized to provide sufficient detention time to allow solids stabilization. To achieve Class B biosolids, a minimum SRT of 15 days is required for MAD per 40 CFR Part 503. Though single stage digestion at a constant temperature has been the most popular practice adopted by WWTPs, enhanced anaerobic digestion schemes operating at multiple stages and temperatures can be implemented to improve digester performance.

2.2.3.1 Acid-gas (2 phase) Digestion

Technology Status: Mature

Acid-gas digestion (Figure 2-30) provides separate tanks for the acidogenic and methanogenic bacteria, improving the overall performance of digestion process. The acid phase can be operated at thermophilic or mesophilic temperatures with a short SRT of 1.5 to 2 days, during which the substrates are hydrolyzed to produce volatile fatty acids (VFAs), which are utilized by methanogens to produce methane and carbon dioxide in the second phase.

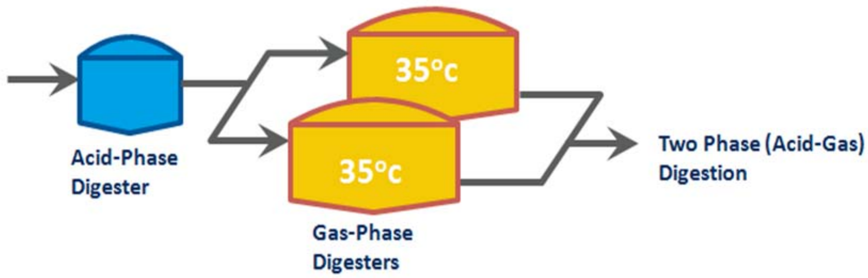


Figure 2-30. Acid-Gas (2 Phase) Digestion Process

Enzymic hydrolysis is a proprietary acid-gas digestion technology developed by Monsal. The system consists of multiple stage serial flow reactors, which provide the acid phase of the digestion process. The total SRT for the multiple reactors is two days or less. Several of the small reactors can be operated at thermophilic temperatures, which have been shown to meet Class A pathogen requirements. If thermophilic stages are included, the process becomes enhanced enzymic hydrolysis. The enhanced enzymic hydrolysis process claims to be more effective than conventional digestion in pathogen inactivation, which may be a function of the staged digestion process and reduced short circuiting.

Advantages

The separation of the anaerobic digestion phases is reported to improve solids reduction and increase gas production at some facilities. Acid gas digestion may also reduce potential for foaming, and provide improved pathogen inactivation.

Drawbacks

Acid-gas digestion is more complex than single stage digestion, requiring additional tankage and equipment. Other disadvantages of acid-gas digestion include the significant odors generated in the acid-phase reactor. Accumulation of VFAs in the acid reactor creates a low pH environment that can cause corrosion on the tank and equipment, increasing maintenance costs. Acid-gas systems concentrate heat requirements at the first tank in the system, which has a low detention time.

Applicability to AlexRenew

The benefits of acid-gas digestion appear to vary by installation, with most expected benefit related to decreased foaming potential and slightly improved pathogen reduction. Since AlexRenew has not experienced significant performance issues with the existing anaerobic digesters, acid-gas treatment is not expected to enhance the existing system and should not be considered at this time.

2.2.3.2 Two-Stage Digestion

Technology Status: Mature

Staged mesophilic digestion is a reconfiguration of the conventional parallel digestion process in order to achieve higher VSr and pathogen reduction, while avoiding the high capital costs associated with converting to thermophilic and other advanced digestion processes. In a staged operation, sludge is fed to the first digester. The digested sludge from the first digester is then transferred to the second digester for further stabilization. Such staged operation moves the process kinetics from complete mix toward plug-flow design. To minimize short circuiting, the first stage at a minimum must be operated in a semi-batch fill-and-draw configuration. Systems with overflow transfer will decrease short-circuiting, but will not eliminate it.

Advantages

Staged digestion reduces short circuiting and can therefore improve VSr and reduce pathogen content of the treated biosolids. Staged operation increases VSr an average of 5 percent as compared to parallel operation. At locations that have multiple digestion tanks, staged digestion is typically a relatively simple retrofit, requiring additional piping and pumping.

Drawbacks

Staged digestion increases the volatile solids loading on the first stage in the digestion process and must be considered in the digester volume design. In addition, fill-and-draw operation requires pumped transfer, which will increase system energy costs.

Applicability to AlexRenew

Two-stage digestion would be expected to moderately increase VSr and biogas generation, but potentially complicates digester operation. If the existing digester piping and pumping configuration can support two-stage digestion with few modifications, it may be suitable for use at AlexRenew. If major reconfiguration is required, the benefits do not appear to make it an attractive option.

2.2.3.3 Co-digestion

Technology Status: Mature

Codigestion of high strength wastes (HSW) with wastewater solids is becoming common in the United States, especially at plants that have extra capacity in their existing digestion facilities. Codigestion of organic wastes has the potential to increase biogas production and energy recovery. In many locations, tipping fees for accepting HSW can be collected. Although there are many bench-scale studies investigating various potential codigestion substrates, most full-scale codigestion applications in the United States have been focused on fats, oils and grease (FOG) codigestion. Codigestion typically requires truck unloading facilities, heated and mixed storage facilities and pumped transfer of the HSW into the digestion system.

Advantages

Codigestion increases biogas generation and may result in increased revenue from tipping fees. Codigestion may also have synergistic effects on the digestion of biosolids, increasing the VSr and biogas production.

Drawbacks

Digesting multiple feedstocks can increase the complexity of the digestion system and will reduce digester capacity for wastewater solids treatment. Acceptance of multiple feedstocks will also increase truck traffic to the plant. When accepting FOG, receiving facilities are subject to fouling and will require cleaning and maintenance. If significant competition exists in the area, lowered tipping fees may be required, which may not cover the capital and operating expenses of the acceptance system.

Applicability to AlexRenew

Codigestion typically has a fairly low capital cost and can be implemented with few modifications other than construction of receiving and storage facilities for HSW. If there is competition for HSW in the local area, the benefits of HSW codigestion will be limited to increased biogas production and providing a service to the generators of the HSW. If dependable HSW sources can be identified, codigestion should be considered for AlexRenew.

2.2.4 Resource Recovery

Resource recovery is the process of segregating valuable components of the wastewater for reuse. Recovered resources include organic material for land application, energy products from biosolids or biogas, nutrient (nitrogen and phosphorus) recovery, or other products. Processes that generate energy products and biosolids for land application have been discussed elsewhere in this appendix. Therefore, the discussion in this section is limited to the recovery of nutrients and other materials.

2.2.4.1 Nutrient Recovery

Technology Status: Emerging/Mature

Biosolids contain a number of nutrients, such as nitrogen and phosphorus, which are vital to agriculture systems and are some of the primary additives in commercial fertilizers. Several technologies are used to recover phosphorus and nitrogen in the form of struvite (magnesium ammonium phosphate), both to reduce the impact of nutrients in dewatering return streams on the liquid treatment process and to generate a product for beneficial use. Struvite precipitation processes are offered by Ostara, Multiform Harvest, ProCorp and Lysotherm. The Pearl® process offered by Ostara (Figure 2-31) uses an upflow reactor to form struvite from dewatering return streams. The precipitated struvite can be sold as a slow release fertilizer. The WASSTRIP® process is a modification of the Pearl® process that includes a WAS fermentation step upstream of digestion. Phosphorus released during fermentation is captured in the fermenter decant and combined with the digester return stream. The Multiform Harvest and ProCorp system is somewhat similar to the Ostara process, the primary differences are related to the size and density of the struvite crystals. The Lysotherm process recovers struvite prior to dewatering, reducing the potential for struvite formation on dewatering equipment. There are several full scale installations of phosphorus recovery systems in North America.

Figure 2-31. Ostara Pearl® Process at the Durham WWTP

Advantages

Struvite recovery reduces the phosphorus recycle and the ultimate loading on the liquid stream process. It is a relatively simple system and may be cost effective, depending on the phosphorus content of the WAS. In addition, controlled removal of struvite will reduce the potential for struvite accumulation on digester and dewatering equipment and pipes.

Drawbacks

Suitability of phosphorus recovery depends on the concentrations of phosphorus, ammonia, and magnesium in the sidestreams. It is typically only used at plants that utilize bio-phosphorus (Bio-P) removal. WASSTRIP fermentation and decant collection adds treatment processes and costs.

Applicability to AlexRenew

Phosphorus recovery is best suited to plants that have Bio-P removal processes in the liquid train. If testing indicates that the phosphorus and ammonia concentrations in the centrate or WAS would support economic phosphorus recovery, AlexRenew should consider converting to Bio-P and implementing phosphorus recovery in conjunction with their WAS thickening or digested sludge dewatering processes.

2.2.4.2 Alkaline extraction of WAS

Technology Status: Embryonic

Biosolids contain many different compounds, including various forms of polysaccharides and proteins, but also constituents of lipids, humic acids, and DNA. Polysaccharides and proteins can be used as emulsifiers and adhesives, suitable for use under a wide range of conditions. The commercial production of adhesives derived from microbial compounds is being studied for application in the lubricant, drug delivery, and cosmetic industries. Lipids found in the cellular material have high surface activity and have potential for use as commercial surfactants.

Laboratory research has been conducted to develop methods of extracting these compounds from WAS with a cation exchange resin (Garcia et al, 2010).

Advantages

Marketable products could be generated from waste sludge. Reduction in WAS would reduce load to the digesters and the quantity of biosolids products.

Drawbacks

This technology is still in the research phase so performance and costs are not available for a full-scale application. Removal of products from WAS is likely to reduce biogas generation and energy production potential.

Applicability to AlexRenew

As this research is still in the early stages, this technology is not ready for implementation. It may be worthwhile to monitor this technology as the research develops.

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ALEX RENEW

TECHNICAL MEMORANDUM 2-1: SURVEY OF BIOSOLIDS TREATMENT TECHNOLOGIES AND END-USE ALTERNATIVES

Appendix B

Scoring of Biosolids Alternatives

PREPARED FOR

ALEX RENEW

3 MARCH 2014

Scoring of Alternatives - Rough Cut Assessment to Identify Lead Options

Alex Renew Biosolids Options March 2014 User Input

Listed configurations reflect "standard" system package (e.g., if technology typically includes CHP, it's included in the configuration)

Criteria	Weight	Existing Baseline (Pre-Pasteurization), no CHP		Notes	Incineration w/o power generation		Notes	Incineration w/ power generation		Notes
People (21)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Ease of Operation	11	4	44	Moderate operator attention & maintenance assumed	0	0	Lots of operation & maintenance	0	0	Lots of operation & maintenance
Staff Engagement	10	6	60	Some opportunities for staff engagemen	6	60		6	60	
Total			**10.4**			**6.0**			**6.0**	
Environmental Leadership (26)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Current Permit Compliance	5	6	30	Class A process, possible regrowth	8	40	Sterile product, MACT control technology	8	40	Sterile product, MACT control technology
Flexibility to Adapt to Changing Regs	12	6	72	Meets Class A, but will need process mods if change to bulk land app policy	2	24	Expected to meet emission regs through 2020. Possible issues with GHGs	2	24	Expected to meet emission regs through 2020. Possible issues with GHGs
Manage Environmental Footprint	9	4	37		2	14		3	31	
Subsection for Enirvonmental Footprint	Max Grade or %									
1. Water Resources										
a) Minimize quantity of stormwater runoff	10	2		No change	2		Expect no change in stormwater run off.	2		Expect no change in stormwater run off.
b) Maximize quality of stormwater conveyed off site	10	2		No change	2		Expect no change in quality	2		Expect no change in quality
c) Maximize use of effluent on site for reuse	5	3		Assume some re-use of final effluent for process applications	3		Will be some re-use (e.g. poly dilution, cooling) but not much.	3		Will be some re-use (e.g. poly dilution, cooling) but not much.
2. Biosolids Management										
a) Ability to use biosolids as soil ammendment	4	4		Long term use of biosolids.	2		While use as soil amendment is possible, probably not likely. Could investigate	2		While use as soil amendment is possible, probably not likely. Could investigate
b) Project impact on biosolids quality	4	2		No change	0		Negative impact on quality - organic matter destroyed, nutrients wasted.	0		Negative impact on quality - organic matter destroyed, nutrients wasted.
3. Renewable Fuels										
a) Quantity of energy provided by renewable resources	10	7		Biogas used in pre-paseurization and digestion process	0			7		Will generate electricity to cover more than 5% of facility's power
4. Greenhouse Gas Emissions										
a) Degree of GHG variation against baseline	6				0			6		
i) Fuel use from stationary sources	15%	5		No change	10			10		
ii) Fuel use from mobile sources	5%	5		No change	10		Decrease - haulage for disposal reduced	10		Decrease - haulage for disposal reduced
iii) Indirect emissions - from electricity used	80%	5		No change	0			5		Assumed net neutral - power gen
Subtotal		5.0			2			6		
5. Chemical inputs / Additions										
a) Minimize number / quantity of chemicals	4	2		No change	0		Increased chemical use for emissions control	0		Increased chemical use for emissions control
b) Minimize quantities of hazardous / toxic substances	4	2		No change	2			2		
c) Maximize use of renewable / eco friendly chemicals	4	0		None used	0		None used.	0		None used.
6. Recognize need to minimize waste outputs										
a) Degree of waste stream impact	8	4		All biosolids beneficially used - no significant waste	0		Ash likely to be landfilled as waste	0		Ash likely to be landfilled as waste
Subtotal	69	28			11			24		
Total			**13.9**			**7.8**			**9.5**	
Efficiency (15)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Reliability	3	4	12	Failure is possible. Manage via multiple reactors and / or streams	4	12	Failure is possible. Likely to take out whole plant during equipment failure.	4	12	Failure is possible. Likely to take out whole plant during equipment failure.
Capacity	4	4	16		6	24	New system likely to provide some excess capacity	6	24	New system likely to provide some excess capacity
Site Open Space	5	8	40	No impact	4	20	Assumed new incinerator facility to replace existing sludge process.	4	20	Assumed new incinerator facility to replace existing sludge process.
Embed Sustainable Practices	3	8	24		4	12	Could meet EMS requirements, unlikely to meet any others.	4	12	Could meet EMS requirements, unlikely to meet any others.
Total			**9.2**			**6.8**			**6.8**	
Community Awareness (16)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Neighborhood/City Relations	10	6	60	No increase or decrease	2	20	Low perceived impact score; actual impact will be improved	2	20	Low perceived impact score; actual impact will be improved
Public Image	6	4	24	No impact	0	0	Definite negative impact - public generally not in favor of incinerators.	0	0	Definite negative impact - public generally not in favor of incinerators.
Total			**8.4**			**2.0**			**2.0**	
Fiscal Responsibility (22)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Capital Cost Management	11	10	110	Low investment requirements	0	0	High capital cost	0	0	High capital cost
Annual Cost	11	5	55	Likely reduction in operating costs	3	33	Expect increased power, reduced land app, increased labor	3	33	Expect increased power, reduced land app, increased labor
Total			**16.5**			**3.3**			**3.3**	
Total Score		**58**			**26**			**28**		

Scoring of Alternatives - Rough Cut Assess

Alex Renew Biosolids Options March 2014

User Input

Criteria	Weight	Gasification (includes pre-drying)		Notes	Pyrolysis/ Intellergy Pyrolysis		Notes	Supercritical Water Oxidation		Notes
People (21)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Ease of Operation	11	0	0	Lots of operation & maintenance	0	0	Little operating information - assumes significant attention/maintenance	0	0	Lots of operation & maintenance
Staff Engagement	10	10	100	New technology - lots of opportunity for staff involvement.	10	100	New technology - lots of opportunity for staff involvement.	10	100	New technology - lots of opportunity for staff involvement.
Total			**10.0**			**10.0**			**10.0**	
Environmental Leadership (26)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Current Permit Compliance	5	8	40	Sterile product, limited emission control requirements	6	30	Sterile product, unknown emissions issues	8	40	No emissions, sterile residue
Flexibility to Adapt to Changing Regs	12	6	72	Expected to meet emission regs and GHG regs	6	72	Expected to meet emission regs and GHG regs	8	96	
Manage Environmental Footprint	9	3	31		5	43		4	34	
Subsection for Enirovnmental Footprint	**Max Grade or %**									
1. Water Resources										
a) Minimize quantity of stormwater runoff	10	2		Expect no change in stormwater run off.	2		Expect no change in stormwater run off.	2		Expect no change in stormwater run off.
b) Maximize quality of stormwater conveyed off site	10	2		Expect no change in quality	2		Expect no change in quality	2		Expect no change in quality
c) Maximize use of effluent on site for reuse	5	3		Will be some re-use (e.g. poly dilution, cooling) but not much.	3		Will be some re-use (e.g. poly dilution, cooling) but not much.	3		Will be some re-use (e.g. poly dilution, cooling) but not much.
2. Biosolids Management										
a) Ability to use biosolids as soil ammendment	4	2		While use as soil amendment is possible, probably not likely. Could investigate P recovery.	2		Char could be used as soil ammendment.	0		
b) Project impact on biosolids quality	4	0		Negative impact on quality - organic matter destroyed, nutrients wasted.	0		Negative impact on quality - organic matter destroyed, nutrients wasted.	0		
3. Renewable Fuels										
a) Quantity of energy provided by renewable resources	10	7		Syngas used for pre-drying process	10		Expected net energy production through energy production or fuel production.	7		Recovered energy is used in process. No power generation
4. Greenhouse Gas Emissions										
a) Degree of GHG variation against baseline	6	6			6			0		
i) Fuel use from stationary sources	15%	5		Assumes syngas production meets energy requirements	5		Assumes syngas production meets energy requirements	5		Reported to use little total energy (recovered energy)
ii) Fuel use from mobile sources	5%	10		Decrease - haulage for disposal reduced	10		Decrease - haulage for disposal reduced	10		
iii) Indirect emissions - from electricity used	80%	5		Assumed net neutral - power gen	5		Assumed net neutral - power gen	0		Pumps, etc. for equipment
Subtotal		5.25			5.25			1.25		
5. Chemical inputs / Additions										
a) Minimize number / quantity of chemicals	4	0		Flue gas scrubbing chemicals, return liquor treatment.	2		Flue gas scrubbing chemicals, return liquor treatment.	2		
b) Minimize quantities of hazardous / toxic substances	4	2		Assumed no impact.	2		Assumed no impact.	2		
c) Maximize use of renewable / eco friendly chemicals	4	0		None used.	0		None used.	4		Generates CO2 for use
6. Recognize need to minimize waste outputs										
a) Degree of waste stream impact	8	0		Ash likely to be landfilled as waste	4		Residue likely to be beneficially used	4		
Subtotal	69	24			33			26		
Total			**14.3**			**14.5**			**17.0**	
Efficiency (15)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Reliability	3	2	6	Technology is not well proven at full scale - assumed high risk of failure.	2	6	Technology is not well proven at full scale - assumed high risk of failure.	0	0	Downgraded for emerging technology
Capacity	4	6	24	New system likely to provide some excess capacity	6	24	New system likely to provide some excess capacity	6	24	New system likely to provide some excess capacity
Site Open Space	5	4	20	Assumed new gasification facility to replace existing sludge process.	4	20	Assumed new pyrolysis facility to replace existing sludge process.	4	20	Assumes land available from digestion area
Embed Sustainable Practices	3	4	12	Could meet EMS requirements. Could produce fuel to off set fossil fuels.	4	12	EMS, increase value of ecosystem	4	12	EMS, increase value of ecosystem
Total			**6.2**			**6.2**			**5.6**	
Community Awareness (16)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Neighborhood/City Relations	10	8	80	Greatly reduced truck traffic, reduced odor potential. Complete re-build - construction traffic.	8	80	Greatly reduced truck traffic, reduced odor potential. Complete rebuild - construc	8	80	Greatly reduced truck traffic, reduced odor potential
Public Image	6	2	12		8	48	Could be perceived as +ve if correctly marketed - energy / fuel from waste.	8	48	
Total			**9.2**			**12.8**			**12.8**	
Fiscal Responsibility (22)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Capital Cost Management	11	0	0	High capital cost	0	0	Embryonic, little cost info but likely to be high	0	0	Embryonic, little cost info but likely to be high
Annual Cost	11	3	33	Emerging technology, reduced final use cost	0	0	Embryonic technology, reduced final use cost	0	0	Embryonic technology, reduced final use cost
Total			**3.3**			**0.0**			**0.0**	
Total Score		43			44			45		

Scoring of Alternatives - Rough Cut Assessi

Alex Renew Biosolids Options March 2014

User Input

Criteria	Weight	HyBrTec		Notes	Composting/ Vermiculture (digestion w/o CHP)		Notes	Composting/ Vermiculture (digestion w/ CHP)		Notes
People (21)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Ease of Operation	11	2	22	Lots of operation or maintenance	6	66	Assumed off-ste contracted operation.	4	44	Assumed off-ste contracted operation.
Staff Engagement	10	10	100	New technology - lots of opportunity for staff involvement.	2	20	Little staff engagment.	6	60	
Total			**12.2**			**8.6**			**10.4**	
Environmental Leadership (26)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Current Permit Compliance	5	8	40	No emissions, sterile residue	6	30	High quality, marketable Class A biosolids.	6	30	High quality, marketable Class A biosolids.
Flexibility to Adapt to Changing Regs	12	10	120		6	72	Compost is likely to be more flexibile to changing regulations than cake	6	72	Compost is likely to be more flexibile to changing regulations than cake
Manage Environmental Footprint	9	4	33		5	43		6	56	
Subsection for Enrivonmental Footprint	**Max Grade or %**									
1. Water Resources										
a) Minimize quantity of stormwater runoff	10	2		Expect no change in stormwater run off.	2		Stormwater for off-site is not ARE problem	2		Stormwater for off-site is not ARE problem
b) Maximize quality of stormwater conveyed off site	10	2		Expect no change in quality	2		No change providing composting facility carefully managed.	2		No change providing composting facility carefully managed.
c) Maximize use of effluent on site for reuse	5	5		Process requires wastewater	3		No change from existing	3		No change from existing
2. Biosolids Management										
a) Ability to use biosolids as soil ammendment	4	0		Ash product	4		Long term use of biosolids.	4		Long term use of biosolids.
b) Project impact on biosolids quality	4	0			4		More marketable than a Class A cake	4		More marketable than a Class A cake
3. Renewable Fuels										
a) Quantity of energy provided by renewable resources	10	10		Expected net energyy production	0			10		Cogen to Class B digesters could net a MW of power
4. Greenhouse Gas Emissions										
a) Degree of GHG variation against baseline	6	0			6			6		
i) Fuel use from stationary sources	15%	10			10		Eliminate purchase of natural gas for pre-past	10		Eliminate purchase of natural gas for pre-past
ii) Fuel use from mobile sources	5%	10			0		Increased vehicle hauling for cake and amendment	0		Increased vehicle hauling for cake and amendment
iii) Indirect emissions - from electricity used	80%	0		Information on net power use not available, but requries power input	5			10		
Subtotal		2			5.5			9.5		
5. Chemical inputs / Additions										
a) Minimize number / quantity of chemicals	4	0			2			2		
b) Minimize quantities of hazardous / toxic substances	4	2		Doesn't appear to use/generate hazardous substances	2		No real change.	2		No real change.
c) Maximize use of renewable / eco friendly chemicals	4	0			0		None used.	0		None used.
6. Recognize need to minimize waste outputs										
a) Degree of waste stream impact	8	4			8		Biosolids benefically used and recovers other waste streams (amendment). Red	8		Biosolids benefically used and recovers other waste streams (amendment). Red
Subtotal	69	25			33			43		
Total			**19.3**			**14.5**			**15.8**	
Efficiency (15)	**Weight**	**Grade**	**Score**		Grade	Score		Grade	Score	
Reliability	3	0	0	Downgraded for emerging technology	6	18	Low probability of failure - weather conditions only potential issue.	6	18	Low probability of failure - weather conditions only potential issue.
Capacity	4	6	24	New system likely to provide some excess capacity	4	16	Meets current capacity requirements (assuming still digested)	4	16	Meets current capacity requirements (assuming still digested)
Site Open Space	5	4	20	Assumes land available from digestion area	2	10	Must be an off site facility. No impact plant site.	2	10	Must be an off site facility. No impact plant site.
Embed Sustainable Practices	3	4	12	EMS, increase value of ecosystem	8	24	EMS, increase value of ecosystem (green waste beneficial use), no addl staffing	8	24	EMS, increase value of ecosystem (green waste beneficial use), no addl staffing
Total			**5.6**			**6.8**			**6.8**	
Community Awareness (16)	**Weight**	**Grade**	**Score**		Grade	Score		Grade	Score	
Neighborhood/City Relations	10	8	80	Greatly reduced truck traffic, reduced odor potential	6	60	No change in odors/truck traffic	6	60	No change in odors/truck traffic
Public Image	6	8	48		8	48	Better public image with higher quality product	8	48	Better public image with higher quality product
Total			**12.8**			**10.8**			**10.8**	
Fiscal Responsibility (22)	**Weight**	**Grade**	**Score**		Grade	Score		Grade	Score	
Capital Cost Management	11	0	0	Embryonic, little cost info but likely to be high	7	77	Little capital cost, assuming offsite 3rd party operation (no new facility)	7	77	Little capital cost, assuming offsite 3rd party operation (no new facility)
Annual Cost	11	0	0	Embryonic technology, reduced final use cost	5	55	Contract treatment/final use costs plus trucking	5	55	Contract treatment/final use costs plus trucking
Total			**0.0**			**13.2**			**13.2**	
Total Score		**50**			**54**			**57**		

Scoring of Alternatives - Rough Cut Assessı

Alex Renew Biosolids Options March 2014 User Input

Criteria	Weight	BCR Neutralizer		Notes	Thermal Drying		Notes	Alkaline and Heat Disruption (Lystek)		Notes
People (21)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Ease of Operation	11	4	44		4	44	Moderate operation & maintenance requirements.	2	22	Little operating information - assumes decent attention/maintenance
Staff Engagement	10	6	60	New technology would engage staff.	6	60	Some opportunity for engagement.	6	60	
Total			**10.4**			**10.4**			**8.2**	
Environmental Leadership (26)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Current Permit Compliance	5	6	30	Class A product would exceed baseline Class B criterion.	8	40	Dried product outlets less subject to nutrient limit issues	6	30	Class A biosolids
Flexibility to Adapt to Changing Regs	12	6	72	State of the art technology but may a little challenging to adapt if needed.	8	96		2	24	Liquid product may have less flexibility than solid product.
Manage Environmental Footprint	9	2	20		5	44		2	22	
Subsection for Enirvonmental Footprint	**Max Grade or %**									
1. Water Resources										
a) Minimize quantity of stormwater runoff	10	2		Expect no change in stormwater run off.	2		No change expected.	2		
b) Maximize quality of stormwater conveyed off site	10	2		Expect no change in quality	2		No change expected.	2		
c) Maximize use of effluent on site for reuse	5	3		No change from existing	3		Some re-use of final effluent.	3		
2. Biosolids Management										
a) Ability to use biosolids as soil ammendment	4	4		Long term use of biosolids.	4		Long term use of biosolids.	4		
b) Project impact on biosolids quality	4	2		Assumed no change from current Class A product.	4		Improved quality - dried product.	0		Liquid product
3. Renewable Fuels										
a) Quantity of energy provided by renewable resources	10	0			7		Biogas used for drying process	0		
4. Greenhouse Gas Emissions										
a) Degree of GHG variation against baseline	6	0			0			0		
i) Fuel use from stationary sources	15%	5		No change expected.	0			0		Requires steam input
ii) Fuel use from mobile sources	5%	0		Increase - more biosolids for disposal (no VSR)	10		Likely decrease due to smaller product volume.	5		High solids liquid - similar truck numbers
iii) Indirect emissions - from electricity used	80%	0		Assumed increase due to impacts of production of chemicals off site.	0		Increased power use for drying technology	5		
Subtotal		0.8			0.5			4.25		
5. Chemical inputs / Additions										
a) Minimize number / quantity of chemicals	4	0		Increased use of chemicals.	2		Assumed no impact. Would still require dewatering poly.	0		
b) Minimize quantities of hazardous / toxic substances	4	2		Assumed no impact.	2		No real change.	2		
c) Maximize use of renewable / eco friendly chemicals	4	0		None used.	0		None used.	0		
6. Recognize need to minimize waste outputs										
a) Degree of waste stream impact	8	0		Increase in quantity of solids for disposal (no VSR)	8		Reduction in volume.	4		
Subtotal	69	15			34			17		
Total			**12.2**			**18.0**			**7.6**	
Efficiency (15)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Reliability	3	4	12		2	6		2	6	Little operating history
Capacity	4	6	24		6	24		6	24	
Site Open Space	5	8	40	May reduce used site space through demo of pre-past and digesters	2	10	Assumes space available from pre-pasteurization area	6	30	Requires additonal reactor tanks, storage tanks, chem feed
Embed Sustainable Practices	3	4	12	EMS, needs more chemicals for process, does not require additional human reso	4	12	Could meet EMS requirements, Class A product.	4	12	EMS only (increased use of chemicals)
Total			**8.8**			**5.2**			**7.2**	
Community Awareness (16)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Neighborhood/City Relations	10	6	60	No change in odors/traffic	10	100	Greatly reduced truck traffic, reduced odor potential	2	20	Increased truck traffic for liquid product
Public Image	6	4	24		8	48	Better public image with higher quality product	2	12	Liquid product for bulk land app only
Total			**8.4**			**14.8**			**3.2**	
Fiscal Responsibility (22)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Capital Cost Management	11	7	77	Relatively low capital costs expected	4	44	Moderate capital cost (likely to be less than thermal conversion)	4	44	
Annual Cost	11	5	55	Increased costs for chemicals, may be minor	3	33	Increased labor, maintenance, energy costs, reduced final use costs	3	33	Higher costs than current cake program
Total			**13.2**			**7.7**			**7.7**	
Total Score		**53**			**56**			**34**		

Scoring of Alternatives - Rough Cut Assess

Alex Renew Biosolids Options March 2014 User Input

Criteria	Weight	Thermal Hydrolysis w/CHP		Notes	Thermophilic digestion		Notes	Pre-Pasteurization Expansion, no CHP		Notes
People (21)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Ease of Operation	11	4	44		6	66		4	44	Moderate operator attention & maintenance assumed
Staff Engagement	10	10	100	New technology / intersting to operate.	2	20		6	60	Some opportunities for staff engagement
Total			**14.4**			**8.6**			**10.4**	
Environmental Leadership (26)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Current Permit Compliance	5	8	40	Class A product with little chance of regrowth	6	30	Can reach Class A, but is less certain than current system	6	30	Class A process, possible regrowth
Flexibility to Adapt to Changing Regs	12	6	72		2	24		6	72	Meets Class A, but will need process mods if change to bulk land app policy
Manage Environmental Footprint	9	6	52		4	40		4	37	
Subsection for Enirovnmental Footprint	**Max Grade or %**									
1. Water Resources										
a) Minimize quantity of stormwater runoff	10	2		Expect no change in stormwater run off.	2			2		No change
b) Maximize quality of stormwater conveyed off site	10	2		Expect no change in quality	2			2		No change
c) Maximize use of effluent on site for reuse	5	5		Will be some re-use (e.g. poly dilution, final effluent dilution).	3		No change from existing	3		Assume some re-use of final effluent for process applications
2. Biosolids Management										
a) Ability to use biosolids as soil ammendment	4	4		Long term use of biosolids.	4			4		Long term use of biosolids.
b) Project impact on biosolids quality	4	4		Increase in dewaterability and reduction in odor.	2			2		No change
3. Renewable Fuels										
a) Quantity of energy provided by renewable resources	10	10		Will generate electricity to cover more than 5% of facility's power	7		Biogas used for digester heating	7		Biogas used in pre-paseurization and digestion process
4. Greenhouse Gas Emissions										
a) Degree of GHG variation against baseline	6	3			3					
i) Fuel use from stationary sources	15%	5			5			5		No change
ii) Fuel use from mobile sources	5%	5		Less mobile fuel than base case, but not as low as thermal conversion	5			5		No change
iii) Indirect emissions - from electricity used	80%	5		Assumed net neutral - power gen	5			5		No change
Subtotal		5.0			5			5.0		
5. Chemical inputs / Additions										
a) Minimize number / quantity of chemicals	4	2		Slightly less poly for dewatering	2		Slightly less poly for dewatering	2		No change
b) Minimize quantities of hazardous / toxic substances	4	0		High pressure steam	2			2		No change
c) Maximize use of renewable / eco friendly chemicals	4	0		None used.	0			0		None used
6. Recognize need to minimize waste outputs										
a) Degree of waste stream impact	8	8		Reduction in volume for disposal / beneficial use.	4			4		All biosolids beneficially used - no significant waste
Subtotal	69	40			31			28		
Total			**16.4**			**9.4**			**13.9**	
Efficiency (15)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Reliability	3	4	12	Failure is possible. Manage via multiple reactors and / or streams.	6	18		4	12	Failure is possible. Manage via multiple reactors and / or streams
Capacity	4	8	32	Will increase capacity of existing digestion tankage	4	16		4	16	
Site Open Space	5	4	20	Moderate footprint, expected to fit in existing site (replace pastuerization)	4	20	Needs additional tankage for batch tanks	6	30	
Embed Sustainable Practices	3	4	12	EMS, reduction in chemical use (poly)	4	12	EMS only	8	24	
Total			**7.6**			**6.6**			**8.2**	
Community Awareness (16)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Neighborhood/City Relations	10	8	80	Reduced truck traffic	6	60		6	60	No increase or decrease
Public Image	6	4	24		4	24		4	24	No impact
Total			**10.4**			**8.4**			**8.4**	
Fiscal Responsibility (22)	**Weight**	**Grade**	**Score**		**Grade**	**Score**		**Grade**	**Score**	
Capital Cost Management	11	7	77	Moderate capital costs, reuse existing digestion	7	77	Moderate capital costs, reuse existing digestion	7	77	Low investment requirements
Annual Cost	11	7	77	Reduced final use, energy costs	5	55	No major change in costs - slight decrease with reduced solids production	5	55	Likely reduction in operating costs
Total			**15.4**			**13.2**			**13.2**	
Total Score		**64**			**46**			**54**		

ALEXANDRIA RENEW ENTERPRISES
TECHNICAL MEMORANDUM 2-2: PRODUCT VISIONING

PREPARED FOR

ALEXANDRIA RENEW ENTERPRISES

7 MARCH 2014

BLACK & VEATCH
Building a world of difference.

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APPENDIX

1 Introduction

1.1 PROJECT OBJECTIVES

The purpose of this Task Order is to provide the basis for an update to the biosolids portion of the AlexRenew long-range plan. The scope of the Task Order is to identify the most suitable future biosolids program for AlexRenew and to establish a road map for the utility in achieving a sustainable, dependable program. Based on discussions with key AlexRenew stakeholders, specifically during our project initiation workshop, we have identified several key drivers that must be considered as part of the planning process. These include:

a. "AlexRenew 2030" -- A central element to the utilities long-term vision is to transition from a waste treatment facility to a resource recovery facility that focuses on products and has a recognized brand in the community. Key subgoals include:

   - Minimize or eliminate external land application
   - AlexRenew as energy self-sufficient

b. An integrated part of the community –minimize negative impacts such as: truck traffic, odors, and lighting. Also be seen as a visible, positive part of the community

c. Innovation – AlexRenew plans to continue being an industry leader and leveraging its location in an innovation corridor to provide technical advancements to the resource recovery industry

d. Flexibility – Given uncertainties in regulations and markets, the biosolids system needs to provide flexibility to adjust to changing conditions

e. Economic sustainability – Focus on long-term life-cycle costs and providing business stewardship for the rate payers and community.

f. Plant dependability/operability – As a critical element in the community's environmental infrastructure, all systems must be operable, dependable and robust.

g. Site Constraints – Any solution must recognize the limited site space available and plan accordingly.

1.2 PROJECT FRAMEWORK

The Task Order is being executed as a series of Technical Memoranda and workshops, which will allow AlexRenew to begin with a long-term, open-ended visioning of all the potential ways of managing biosolids and developing products. Through this task order, an increasingly rigorous screening process will allow AlexRenew to focus in on the most promising systems that will both produce high level products and meet the other drivers outlined above. Figure 1-1 provides an overview of the workflow and the elements of each portion of the project:

PROJECT OVERVIEW

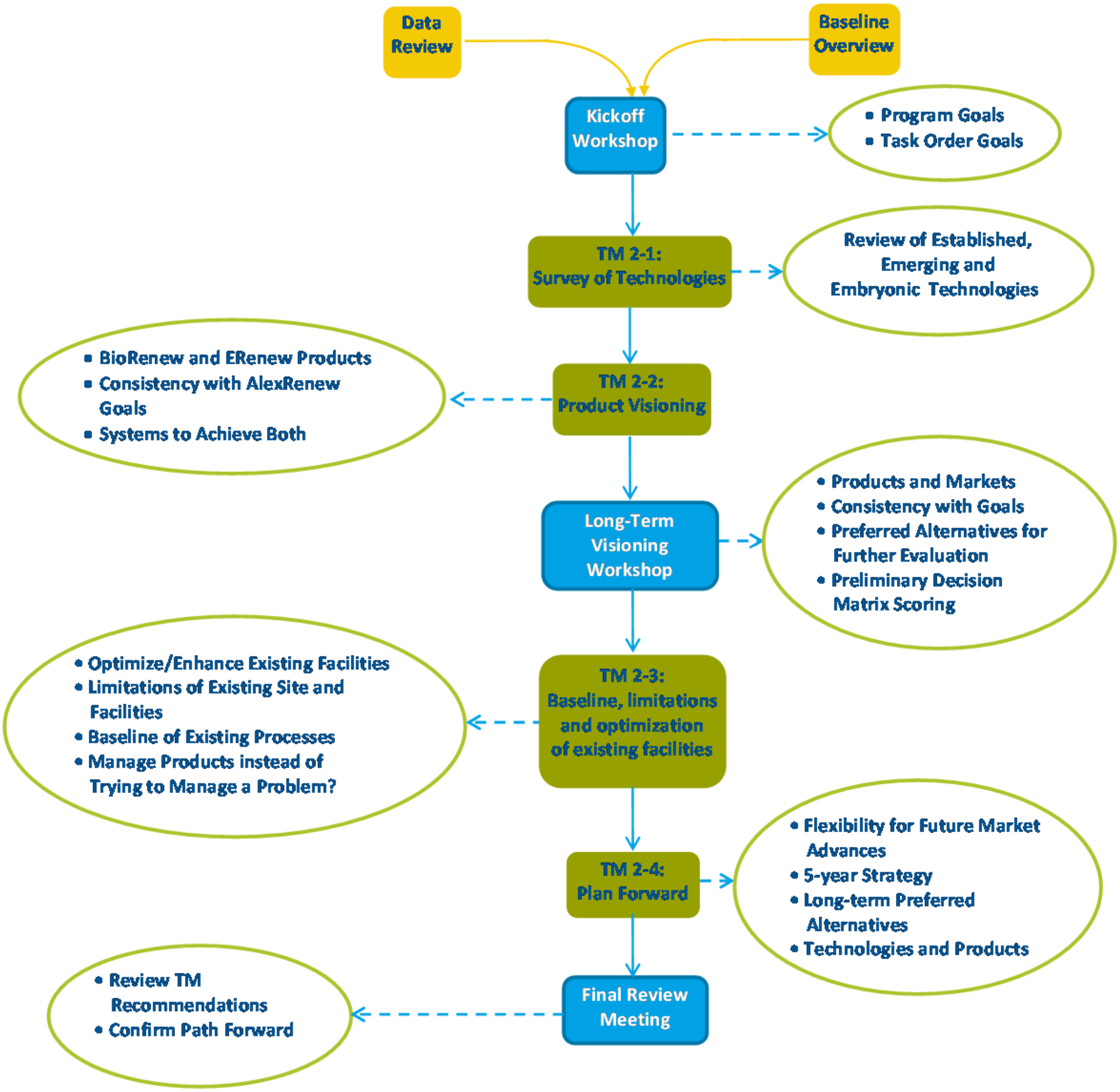

Figure 1-1. Project Workflow

1.3 APPROACH

The focus of TM 2-2 is to:

- Determine the products (both BioRenew and ERenew) that can potentially be generated by AlexRenew now, or in the future;
- Evaluate each product against a set of criteria that is consistent with AlexRenew's goals and drivers;
- Develop a comprehensive list of systems that tie together BioRenew products, ERenew products and the technologies needed to generate each; and
- Provide a recommendation for an initial screening to focus on the most promising systems.

The comprehensive set of products considered in this Technical Memorandum is presented in Figure 1-2, including both the BioRenew and the ERenew products that can be generated through the biosolids system. In the first part of the Technical Memorandum these are discussed as individual products with emphasis on their individual characteristics (market potential, branding ability, etc.). In the second part of the Technical Memorandum, they are considered as products of particular technologies and systems. This is an important consideration, as many of the products are mutually exclusive, due to the type of technologies required.

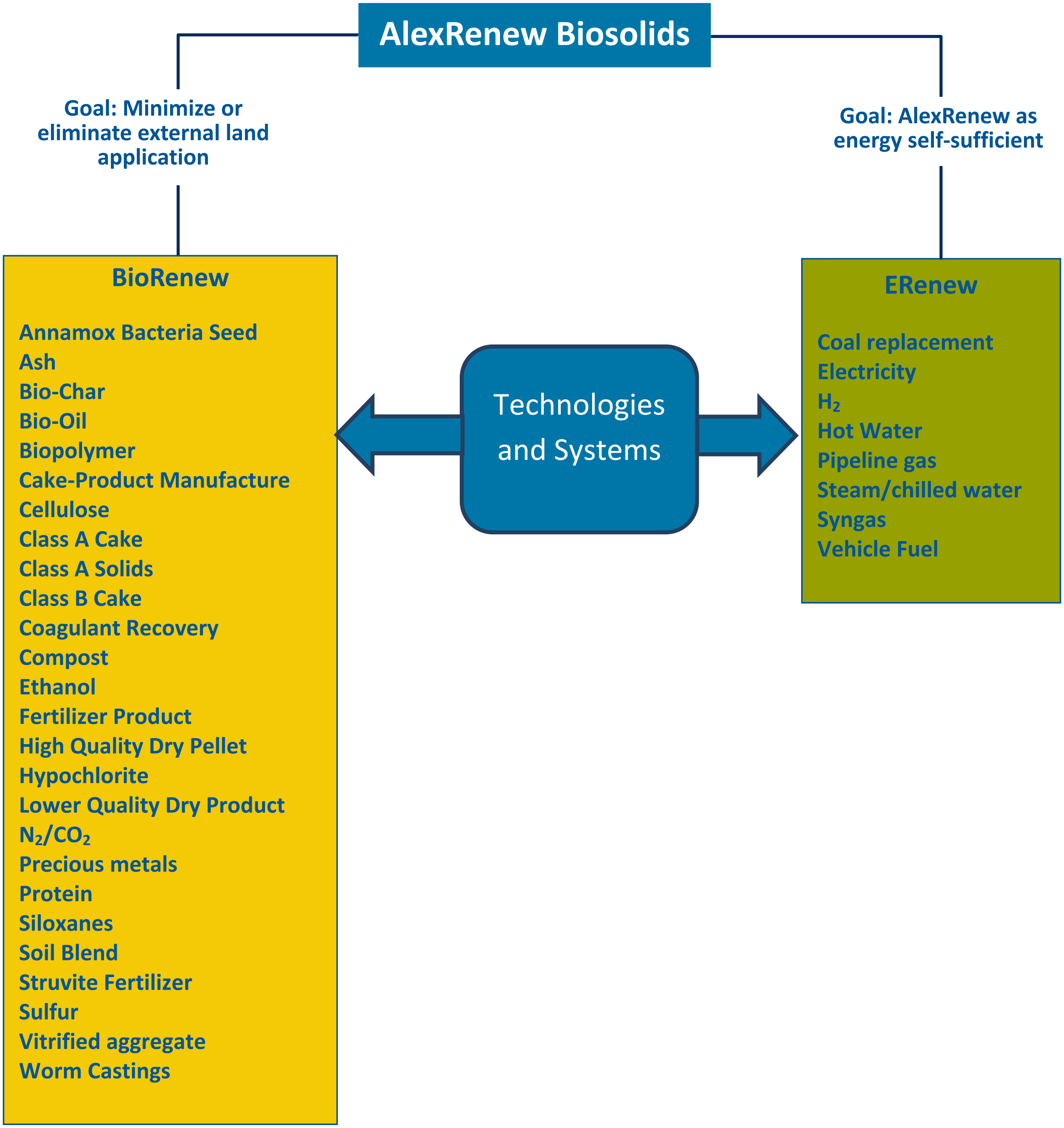

Figure 1-2. Potential Resource Products

It should be noted that the purpose of this Technical Memorandum is on long-term visioning and that many of the products and technologies presented are currently embryonic or even conceptual and therefore do not lend themselves to precise evaluation in terms of cost, space requirements and operating history. We have therefore focused on a few, critical goals for this initial screening:

1. The existing and potential market for each product.
2. The potential for each product to represent a clear “brand” as perceived by AlexRenew customers, stakeholders and the public at large.
3. The compatibility of products (i.e.: the ability of AlexRenew to produce both a BioRenew and ERenew product and to move towards the twin goals of reducing or eliminating bulk land application and moving towards energy self-sufficiency).

2 Potential Products

An internal workshop was conducted with an expert panel on product generation and distribution to identify possible BioRenew and ERenew products, based on existing and developing technologies and research. The product assessments are presented in Appendix A.

Each of the products was analyzed to identify the following:

- Product Market
  - Product Market Outlets (Near Term and Long Term)- Markets for each BioRenew and ERenew product were identified, considering both current and potential future markets.
  - Marketing Requirements - The capability for branding each product was reviewed based on the ease of product public relations and identifiable commercial value. One of the considerations was whether the end user would be able to identify the product as being produced by AlexRenew; in the case of many of the ERenew products, the product could be sold to utilities, but product identification from the end user may be challenging. For both BioRenew and ERenew, considerations were made as to whether marketing would be done by AlexRenew or 3rd party.
  - Sale Price- The Value to AlexRenew or Wholesaler. Sale prices are listed for products that have an existing market, or a market exists for a similar product. Prices for products that are conceptual or in embryonic stages of development are unknown.
- Stabilization/Treatment Process Required-The stabilization process or technologies that can produce the product.
- Trigger Conditions for the Product – The current conditions for technology status, product market, value, and generation costs are identified as a baseline for discussion. Trigger conditions that would make generation of each specific product more attractive, are also identified. The trigger conditions include:
  - Technology Status- current status considers whether the technology is identified as Established, Innovative or Embryonic, following the USEPA guidelines:

Established – technologies implemented in many locations or have been available and implemented in North America for more than 5 years.

Innovative – technologies that have been tested at a demonstration scale, are available and implemented in at least some locations in North America, or have some degree of initial use (i.e., implemented in less than 1 percent of rehabilitation/replacement projects throughout North America).

Embryonic - technologies in the development stage and/or have been tested at laboratory, bench, or pilot-scale only.

"Needed" conditions identify technical changes that may drive decisions to implement a different biosolids treatment technology, such as capital costs associated with rehabilitation of the existing biosolids system, further development of innovative or embryonic technologies, or regulatory conditions.

  - Product Market- This considers the status of the current market for competing products and required market changes to make the product more attractive in the future, such as increased market for renewable energy, increased costs for competing products in the same market, or reduced supply of a competing product.
  - Product Value- This considers product value in terms of public perception or possible end users and conditions that would increase the actual or perceived value.
  - Cost of generation- This considers the relative cost to AlexRenew for generating the end product and associated marketing or distribution costs. The future costs are associated with changes in the costs of generation of the identified product or competing products/technologies.

- Excluded Products- This identifies any end products that cannot be produced simultaneously with the product being reviewed. For example, a dried product may consume all of the generated biogas and therefore exclude the production of an ERenew product.
- Required Modifications to the Existing AlexRenew Processes- This identifies any existing equipment that would need to be taken off-line, modified, expanded or demolished, as well as any new equipment to be installed.

A summary of some of the key product findings is presented in Table 2-1. Based on discussions with AlexRenew, having a marketable, branded product is seen as a driver in the appeal of an end product. Thus, the market and branding potential, as well as associated sale price and suitability to 3rd Party production are summarized for each end product. While various combinations of AlexRenew and 3rd Party production and handling are possible options for most of the products, the most likely or common scenario is listed for each product.

Table 2-1. Potential BioRenew and ERenew Products

PRODUCT	MARKET POTENTIAL	BRANDING POTENTIAL	PRICE	3RD PARTY PRODUCTION/ HANDLING
BIORENEW				
Class B Cake	Currently well established; Reduced market expected from increased regulatory restrictions	Poor branding potential	-$35.75/wet ton	Marketing – 3rd party Production - AlexRenew
Class A Cake	Currently well established; Reduced market expected from increased regulatory restrictions	Poor/limited branding potential	-$30.75/wet ton	Marketing – 3rd party Production - AlexRenew
Class A Pellet (high quality dried product)	Both bulk and retail markets are well-established, effort required to enter regional/national market as AlexRenew brand	Good branding potential	Price varies from giving away bagged products to $40/dry ton	Marketing – 3rd party Production - AlexRenew
Class A Pellet (low quality dried product)	Established wholesale markets, effort required to enter regional market as AlexRenew brand	Good branding potential	Price varies, may be a cost to AlexRenew for final use, up to $26/dry ton	Marketing – 3rd party Production – AlexRenew
Class A Aerobic Compost Product	Well established wholesale and retail markets, effort required to enter regional market as AlexRenew brand	Good branding potential	Price can be up to $20/cubic yard	Marketing – 3rd party Production – offsite by 3rd party
Class A Anaerobic (Dry Digestion) Compost Product	Well established wholesale and retail markets, effort required to enter regional market as AlexRenew brand	Good branding potential	Price can be up to $20/cubic yard	Marketing – 3rd party Production – offsite by 3rd party
Soil Blend Product (similar to George's Old Town Blend)	Established wholesale and growing retail markets.	Established brand in Ag market. Good branding potential for retail markets	Currently given away. Potential for increased price in future, $10 - $30/cubic yard for TAGRO	Marketing – 3rd party or AlexRenew Production – offsite by 3rd party
Enhanced Fertilizer Pellets	Well established wholesale and retail markets, effort required to enter regional market as AlexRenew brand	Good branding potential	Retail price about $800/dry ton	Marketing – 3rd party Production – on-site 3rd party

PRODUCT	MARKET POTENTIAL	BRANDING POTENTIAL	PRICE	3RD PARTY PRODUCTION/ HANDLING
Organic Char	Emerging markets in coal industry, effort required to develop biosolids-based market	Difficult to brand; Potential PR benefit	Similar to current char prices, ~ $5/100 Btu	Marketing – 3rd party Production – on-site 3rd party
Recovered P Fertilizer Product	Established retail market for commercial sale	Propriety product - may difficult to brand.	Varies by vendor- can be up to $300/ton of phosphate	Marketing – 3rd party Production – on-site 3rd party
Recovered Nitrogen Gas	Established wholesale market for industrial gas products, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	Varies by quality- $0.02- $3/ 100 cubic foot	Marketing – 3rd party Production – on-site 3rd party
Recovered Carbon Dioxide Gas	Established wholesale market for industrial gas products, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	Varies by quality- $100/ton for industrial gas	Marketing – 3rd party Production – on-site 3rd party
Hydrogen	Established wholesale market for industrial gas products, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	$400- $600/tonne	Production – on-site 3rd party Production – on-site 3rd party
Ammonia	Established wholesale market, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	Varies by quality, $600/tonne wholesale ammonia	Marketing – 3rd party Production – on-site 3rd party
Annamox Bacteria (seed material)	Limited by current licensing agreements	Propriety material, difficult to brand	Varies by location- depends on cost of transportation	Marketing – 3rd party Production – AlexRenew
Liquid Class A Biosolids	Reduced market expected from increased regulatory restrictions	Poor branding potential	No current value, Final use cost varies by location, $2-$10/gal	Marketing – 3rd party Production – AlexRenew
Ash	Limited market, may be difficult to develop	Poor branding potential	No current value for ash product	Marketing – 3rd party Production – AlexRenew
Bio-polymer	Established market for polymer, no existing market for renewable polymers. May be difficult to develop.	Industrial product, difficult to brand; Potential PR benefit	$1-$5/lb active polymer, varies by type	Marketing – 3rd party Production – on site 3rd Party
Coagulant Recovery from Tertiary Solids	Established market for chemical coagulants, no existing market for renewable coagulants. May be difficult to develop.	Industrial product, difficult to brand; Limited PR benefit	Unknown	Marketing – 3rd party Production – on site 3rd Party
Precious Metals	Established market.	Industrial product,	Varies by metal	Marketing – 3rd

PRODUCT	MARKET POTENTIAL	BRANDING POTENTIAL	PRICE	3RD PARTY PRODUCTION/ HANDLING
		difficult to brand; Limited PR benefit	type	party Production – on site 3rd Party
Protein for Animal Feed	Limited market, would need to be developed	Industrial product, difficult to brand; Limited PR benefit	Unknown	Marketing – 3rd party Production – on site 3rd Party
Bio Oil	Limited market, would need to be developed	Industrial product, difficult to brand; Potential PR benefit	Equivalent to crude oil prices ($17/mmBtu)	Marketing – 3rd party Production – on site 3rd Party
Worm Castings	Established market, may be difficult to enter with branded product	Good branding potential	$0.80/lb retail sale	Marketing – 3rd party Production – offsite by 3rd Party
Algae for Animal Feed/Biofuel	Limited market, would need to be developed	Industrial product, difficult to brand; Potential PR benefit	Unknown	Marketing – 3rd party Production – on site by 3rd Party
Hypochlorite	Established wholesale market for products, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	$0.80-$1.00/lb, based on solution concentration, bulk product	Marketing – 3rd party Production – on site by 3rd Party
Pressed Biosolids Product (flower pots, etc.)	Limited market, would need to develop specialty market for recycled products	Good branding potential	Unknown	Marketing – 3rd party Production – off site by 3rd Party
Vitrified Aggregate Product	Established market for glass aggregate, would need to develop market for renewable product	Industrial product, difficult to brand; Potential PR benefit	$5-$6/ton for commercial grade glass aggregate	Marketing – 3rd party Production – on site by 3rd Party
Sulfur	Established wholesale market, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	$2 - $40/lb based on quality	Marketing – 3rd party Production – on site by 3rd Party
Ethanol	Established wholesale market, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	$2.00 - $2.50/gal	Marketing – 3rd party Production – on site by 3rd Party
Siloxanes Recovery	Established market for chemicals, would need to establish market for renewable version	Industrial product, difficult to brand; Potential PR benefit	$1-$2/lb industrial grade siloxanes (varies by type)	Marketing – 3rd party Production – on site by 3rd Party
Cellulose	Limited market, would need to establish as	Industrial product, difficult to brand;	Unknown quality, high quality pulp ~	Marketing – 3rd party

PRODUCT	MARKET POTENTIAL	BRANDING POTENTIAL	PRICE	3RD PARTY PRODUCTION/ HANDLING
	alternative to industrial pulps	Potential PR benefit	\$800/tonne	Production – on site by 3rd Party
ERENEW				
Electricity	Well established wholesale markets	Difficult to brand; Potential PR benefit	Same as retail power cost. \$0.06-\$0.15/ kWh	Marketing – AlexRenew Production – on site by AlexRenew
Biogas for Vehicle Fuel	Emerging for utility fleet vehicle; Embryonic for commercial sale	Good branding potential	Varies with technology \$2 - \$6/GGE	Marketing – AlexRenew Production – on site by AlexRenew
Pipeline Quality Biogas	Emerging market for pipeline injection and commercial sale	Difficult to brand; Potential PR benefit	\$8 - \$12/mmBTU	Marketing – AlexRenew Production – on site by AlexRenew or 3rd Party
Syngas	Emerging wholesale market for industrial gas	Industrial product, difficult to brand. Potential PR benefit	Similar to heating value ~ \$5/mmBtu	Marketing – 3rd Party Production – on site by 3rd Party
Hot Water	Limited offsite market; Mostly for on-site use	Difficult to brand	Similar to heating value ~ \$5/mmBtu	Marketing – AlexRenew Production – on site by AlexRenew
Steam	Limited offsite market; Mostly for on-site use	Difficult to brand	Similar to heating value ~ \$5/mmBtu	Marketing – AlexRenew Production – on site by AlexRenew
Hydrogen	Well established industrial market, may be difficult to enter	Industrial product, difficult to brand; Potential PR benefit	\$400-\$600/tonne	Marketing – 3rd party Production – on site by 3rd Party
Chilled Water	Limited offsite market; Mostly for on-site use	Difficult to brand	Similar to heating value ~ \$5/mmBtu	Marketing – AlexRenew Production – on site by AlexRenew

Table 2-1 presents an extensive list of products that could be considered BioRenew products (that is, non-energy products produced through the biosolids system). All listed products have some market potential, although the existing markets may address similar products, generated through conventional industrial technologies (such as hydrogen or nitrogen gas markets). Many of the products listed in Table 2-1 have well established industrial markets, rather than biosolids based markets, with wide variation based on quality of the product. Consequently, costs listed in Table 2-1 reflect current wholesale or retail costs from the existing market. Positive prices indicate revenue; products that have little or no commercial value in the current market (such as cake or liquid for bulk land application) show a negative price for end use.

Products that can be easily recognized and/or are available to the public have good branding potential. Products that are likely to compete in an industrial market and be handled through wholesalers (industrial chemical production, precious metal extraction) are expected to have a low profile from a branding perspective. For these products, development of a “brand” would be limited to public information provided by AlexRenew, but will likely have public relations benefits. Other products such as soil blend products, compost, worm castings and dried pellets have a better potential for public marketing as biological products and potential for being viewed by the utility customers and public at large as a recognized brand.

Table 2-1 also includes ERenew products, although the potential for marketing and branding is somewhat different for these products. Most of the ERenew products are wholesale products that would be used by an existing utility. While minimal effort would be required to market the product to the utility, ERenew products would not be available for retail purchase, reducing visibility of the brand. As with the bulk BioRenew products, AlexRenew would have to develop the “brand” through a public information program.

Also, as noted in the following section, depending on the overall system and the type of ERenew product, the energy may be used on the plant site and will not result in the net production of an energy product.

3 Biosolids System Options

The products identified in Section 2 were combined into systems, with each system identified by BioRenew product, ERenew product, and system technology. The list of system options is presented in Table 3-1. Each system option includes products that can be generated, along with a summary evaluation of marketability, branding potential, status of technology, use of AlexRenew’s existing equipment assets, and site suitability. Each of these parameters was color coded, based on the concepts listed in Figure 3-1. Biosolids Systems Coding Legend.

Additional definition and description of potential technologies were provided in Technical Memorandum 2-1 (previously issued). Abbreviations for technologies included in Table 3-1 are listed in Table 3-2. Note that technologies with the additional notation of “HSW” reflect codigestion of imported waste (such as grease trap waste or food waste) in the plant’s digesters to increase energy production. The amount of HSW added to the system is assumed to result in a net energy production to support export to the power grid. An evaluation of the availability of HSW or capacity of the existing digesters to accommodate HSW will need to be performed to confirm viability of these systems.

Table 3-1. Biosolids Systems Options

System	BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
				BioRenew	ERenew	BioRenew	ERenew			
1	Ammonia	Distillation, steam stripping, ion exchange								
2	Annamox Bacteria seed	Annamox sidestream treatment								
3	Ash	Gasification	Electricity							
4	Ash	Incineration	Electricity							
5	Ash	Gasification	Hot Water							
6	Ash	Incineration	Hot Water							
7	Ash	Gasification	Steam/chilled water							
8	Ash	Incineration	Steam/chilled water							
9	Ash	Gasification	Syngas							
10	Bio-char	Pyrolysis	Electricity							
11	Bio-char	Pyrolysis	H2							
12	Bio-char	HyBrTec	H2							
13	Bio-char	HyBrTec	Hot water							
14	Bio-Oil	Pyrolysis	Electricity							
15	Bio-Oil	Pyrolysis	H2							
16	Bio-Oil	Algae cultivation on sidestream								
17	Biopolymer	Fermentation, other processes								
18	Cake-product manufacture	Cake pressing/molding process								
19	Cellulose	Fine straining/solids handling								
20	Class A cake	MAD/Pre-Past/HSW	Electricity							
21	Class A cake	THP/MAD	Electricity							
22	Class A cake	THP/MAD/HSW	Electricity							
23	Class A cake	TPAD	Electricity							
24	Class A cake	TPAD w/HSW	Electricity							
25	Class A cake	MAD/Pre-Past/HSW	Pipeline gas							
26	Class A cake	THP/MAD	Pipeline gas							
27	Class A cake	THP/MAD/HSW	Pipeline gas							
28	Class A cake	TPAD	Pipeline gas							
29	Class A cake	TPAD w/HSW	Pipeline gas							
30	Class A cake	MAD/Pre-Past/HSW	Vehicle Fuel							
31	Class A cake	THP/MAD	Vehicle Fuel							
32	Class A cake	THP/MAD/HSW	Vehicle Fuel							
33	Class A cake	TPAD	Vehicle Fuel							
34	Class A cake	TPAD w/HSW	Vehicle Fuel							
35	Class A cake	MAD/Pre-Past								
36	Class A Solids	MAD/Lystek	Electricity							
37	Class A Solids	MAD/Lystek/HSW	Electricity							
38	Class A Solids	MAD/Lystek	Pipeline gas							
39	Class A Solids	MAD/Lystek/HSW	Pipeline gas							
40	Class A Solids	MAD/Lystek	Vehicle Fuel							
41	Class A Solids	MAD/Lystek/HSW	Vehicle Fuel							
42	Class B Cake	MAD	Electricity							
43	Class B Cake	MAD/HSW	Electricity							
44	Class B Cake	MAD	Pipeline gas							
45	Class B Cake	MAD/HSW	Pipeline gas							

System	BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
				BioRenew	ERenew	BioRenew	ERenew			
46	Class B Cake	MAD	Vehicle Fuel							
47	Class B Cake	MAD/HSW	Vehicle Fuel							
48	Coagulant Recovery	Unknown								
49	Compost	MAD/Compost	Electricity							
50	Compost	MAD/Compost/HSW	Electricity							
51	Compost	Dry Digestion/HSW	Electricity							
52	Compost	MAD/Compost	Pipeline gas							
53	Compost	MAD/Compost/HSW	Pipeline gas							
54	Compost	Dry Digestion/HSW	Pipeline gas							
55	Compost	MAD/Compost	Vehicle Fuel							
56	Compost	MAD/Compost/HSW	Vehicle Fuel							
57	Compost	Dry Digestion/HSW	Vehicle Fuel							
58	Ethanol	Hydrolyis, distillation, fermentation								
59	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Electricity							
60	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Pipeline gas							
61	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Vehicle Fuel							
62	Fertilizer Product	MAD/Fertilizer (Vitag)								
63	High quality pellet	MAD/Pellet drying/HSW	Electricity							
64	High quality pellet	MAD/Pellet drying/HSW	Pipeline gas							
65	High quality pellet	MAD/Pellet drying/HSW	Vehicle Fuel							
66	High quality pellet	MAD/Pellet drying								
67	Hypochlorite	Microbial fuel cells/unknown								
68	Lower quality dry product	MAD/Modular Drying/HSW	Electricity							
69	Lower quality dry product	MAD/Modular Drying/HSW	Pipeline gas							
70	Lower quality dry product	MAD/Modular Drying/HSW	Vehicle Fuel							
71	Lower quality dry product	MAD/Modular Drying								
72	N2/CO2	SCWO	Electricity							
73	N2/CO2	SCWO	Hot Water							
74	Precious metals	Thermal conversion/acid leaching								
75	Protein	Unknown								
76	Siloxanes	Unknown								
77	Soil Blend	MAD/Pre-Past/HSW	Electricity							
78	Soil Blend	THP/MAD	Electricity							
79	Soil Blend	THP/MAD/HSW	Electricity							
80	Soil Blend	TPAD	Electricity							
81	Soil Blend	TPAD/HSW	Electricity							
82	Soil Blend	MAD/Pre-Past/HSW	Pipeline gas							
83	Soil Blend	THP/MAD	Pipeline gas							
84	Soil Blend	THP/MAD/HSW	Pipeline gas							
85	Soil Blend	TPAD	Pipeline gas							
86	Soil Blend	TPAD/HSW	Pipeline gas							
87	Soil Blend	MAD/Pre-Past/HSW	Vehicle Fuel							
88	Soil Blend	THP/MAD	Vehicle Fuel							
89	Soil Blend	THP/MAD/HSW	Vehicle Fuel							
90	Soil Blend	TPAD	Vehicle Fuel							
91	Soil Blend	TPAD/HSW	Vehicle Fuel							

System	BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
				BioRenew	ERenew	BioRenew	ERenew			
92	Soil Blend	MAD/Pre-Past								
93	Struvite Fertilizer	Sidestream Struvite Precipitation								
94	Sulfur	Biogas sulfur recovery								
95	Vitrified aggregate	Vitrification								
96	Worm Castings	MAD/Vermiculture	Electricity							
97	Worm Castings	MAD/Vermiculture/HSW	Electricity							
98	Worm Castings	MAD/Vermiculture	Pipeline gas							
99	Worm Castings	MAD/Vermiculture/HSW	Pipeline gas							
100	Worm Castings	MAD/Vermiculture	Vehicle Fuel							
101	Worm Castings	MAD/Vermiculture/HSW	Vehicle Fuel							
102		MAD/Pellet drying	Coal replacement							
103		MAD/Modular drying	Coal replacement							

BioRenew product	ERenew Product	Market	Branding	Status of technology	Fits on site	Use of AlexRenew's existing stabilization assets
Beneficial Use of Product	Net Energy in excess of process	Existing near term market, easy to enter	Easy to brand, net offsite energy	Established	Fits on site with no demo required	Uses most of existing equipment
Little beneficial use	Unsure net energy	Small near term market, expect larger long term market, or difficult to enter	May be branded, but difficult/no offsite energy	Innovative	Fits, but with demolition	Uses some existing equipment
No Product	No energy recovery	No existing near term market, unknown long term market (or no product)	Unlikely to develop a brand	Embryonic	Will not fit	Uses little existing equipment

Figure 3-1. Biosolids Systems Coding Legend

The concepts presented in Table 3-1 are further described as follows:

BioRenew product – Possible BioRenew products that could be generated through a given system were identified and coded based on beneficial use potential. While some products, such as Class B cake for bulk land application, can be land applied, they are considered to have little value to AlexRenew based on their long term goals and therefore were qualified as "little beneficial use". Products new to the wastewater industry but with established markets, such as nitrogen gas or recovered siloxanes, were qualified as "beneficial use of product" since there is an established beneficial use.

ERenew product – Possible ERenew products that could be generated through a given system were identified and coded based on "net" energy potential –that is, energy in excess of operating the biosolids treatment/energy production processes. Systems with a known energy production, but unsure or unlikely of net energy production were coded yellow. No consideration to outside markets was addressed through this parameter.

Market –A red box indicates either no product is generated, or there is no current market for the product. A yellow box indicates that a market exists, but it may be difficult for AlexRenew to break into an established market. For example, there is a market for pipeline natural gas, but as a result of limitations imposed by many natural gas transmission companies, it can be difficult to inject cleaned biogas into an existing gas transmission line. Another example is compost, which is a well established market, but can be difficult to enter as a result of existing competition. Consequently, a yellow box does not indicate that the market is unavailable; rather, that it may take considerable effort to become established. Entering difficult markets can be facilitated through the use of wholesalers who are already functioning in the target market.

Branding Capability– While some products have strong markets, such as a Class A cake, or a potential beneficial use, such as hot water, it is likely to be difficult to develop an identifiable brand that the public recognizes. ERenew products were also categorized based on the expectation for off-site use; that is, ERenew products that are likely to be consumed entirely by the plant (such as on-site electricity generation) will have less public visibility and may be more difficult to brand. Systems that include HSW co-digestion may be able to produce enough energy to support off-site exports and therefore are considered more attractive.

Status of Technology– The status of each system technology was identified as Established, Innovative, or Embryonic. Systems coded as Innovative or Embryonic may be considerations for research or pilot testing if the BioRenew and ERenew products appear attractive.

Fits on Site– The required footprint of system was considered to determine if it could fit on the AlexRenew site. Some of the systems are expected to fit with differing amounts of required demolition of existing biosolids stabilization equipment. For example, thermal drying is expected to fit within the existing gravity thickening area, and would therefore require some demolition. Gasification would fit on site if a portion of the existing anaerobic digestion system were removed. Other systems, such as composting or vermiculture, cannot fit on site, but may be viable with an off-site location.

Use of Existing Assets– Each system was considered in view of its compatibility with existing biosolids stabilization equipment. Systems that continue to use anaerobic digestion and pre-pasteurization are typically coded green, while systems that would abandon pre-pasteurization are coded yellow. Systems that abandon anaerobic digestion are coded red.

Table 3-2. Technology Abbreviations

ABBREVIATION	DEFINITION
MAD	Mesophilic anaerobic digestion
Pre-Past	Pre-pasteurization
HSW	(Codigestion of) High strength waste
THP	Thermal hydrolysis
TPAD	Temperature phased anaerobic digestion (with thermophilic stage)
SCWO	Supercritical water oxidation

4 Recommended System Options for AlexRenew

Table 3-1 can be used as a tool for screening the potential systems available to AlexRenew in the long-term to a more manageable set of options for further evaluation. Key elements are the ability of systems to produce both BioRenew and ERenew products and the ability to promote a strong brand for both. Some systems which provide a strong product in one area (for instance drying will produce high-quality dried pellets) will not produce a product in the other (drying will not produce net energy and therefore has no ERenew product and will not further the goal of energy self-sufficiency). Similarly, a process such as gasification will produce a high quality energy product, but will not produce a BioRenew product that will lead to a strong brand.

Based on this rationale, several of the most promising alternatives (near term and long term) are identified by a yellow highlight of the system number. These are based on a somewhat subjective view of the conditions presented and should be reviewed and verified with key AlexRenew stakeholders.

As indicated in Table 3-1, bulk land application systems, while well established in the region and suitable for near term solutions, are not expected to maximize the value of the BioRenew product and have not been identified for longer term strategies. Conversely, several of the products and technologies included in this analysis are not well established and the technologies are still undergoing significant development. Future development may improve their ability to meet AlexRenew's long-term goals and therefore have been identified as promising options. For instance, technologies such as pyrolysis and HyBrTec do not currently produce net energy (all the energy produced is needed in the process itself to heat and dry the biosolids). However, research and development are on-going to improve the energy balance. In the future, these systems may prove to be energy attractive, generating a net ERenew product, suitable for branding. In addition, some of the solutions (algae cultivation, fine straining/solids handling and biogas sulfur recovery) may be applied to the sidestream or liquid side, so multiple system options could potentially be implemented in parallel.

The promising systems are further categorized into "near term" and "technologies to watch" strategies, listed in Table 4-1 and Table 4-2. Products and technologies identified in Table 4-2 are recommended for tracking and possible support for additional research, pilot, or demonstration testing. In the meantime, the near term system options can be implemented until the feasibility of the long term solutions is better understood.

Table 4-1. Promising Near Term Technologies Options

System	BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
				BioRenew	ERenew	BioRenew	ERenew			
49	Compost	MAD/Compost	Electricity							
50	Compost	MAD/Compost/HSW	Electricity							
53	Compost	MAD/Compost/HSW	Pipeline gas							
56	Compost	MAD/Compost/HSW	Vehicle Fuel							
59	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Electricity							
60	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Pipeline gas							
61	Fertilizer Product	MAD/Fertilizer (Vitag)/HSW	Vehicle Fuel							
63	High quality pellet	MAD/Pellet drying/HSW	Electricity							
64	High quality pellet	MAD/Pellet drying/HSW	Pipeline gas							
65	High quality pellet	MAD/Pellet drying/HSW	Vehicle Fuel							
77	Soil Blend	MAD/Pre-Past/HSW	Electricity							
78	Soil Blend	THP/MAD	Electricity							
79	Soil Blend	THP/MAD/HSW	Electricity							
81	Soil Blend	TPAD/HSW	Electricity							
82	Soil Blend	MAD/Pre-Past/HSW	Pipeline gas							
84	Soil Blend	THP/MAD/HSW	Pipeline gas							
86	Soil Blend	TPAD/HSW	Pipeline gas							
87	Soil Blend	MAD/Pre-Past/HSW	Vehicle Fuel							
89	Soil Blend	THP/MAD/HSW	Vehicle Fuel							
91	Soil Blend	TPAD/HSW	Vehicle Fuel							
94	Sulfur	Biogas sulfur recovery								
96	Worm Castings	MAD/Vermiculture	Electricity							
97	Worm Castings	MAD/Vermiculture/HSW	Electricity							
99	Worm Castings	MAD/Vermiculture/HSW	Pipeline gas							
101	Worm Castings	MAD/Vermiculture/HSW	Vehicle Fuel							

Table 4-2. Technologies to Watch

System	BioRenew Product	Technology	ERenew Product (net energy)	Market		Branding Capability		Status of Technology	Fits on site	Use of existing assets
				BioRenew	ERenew	BioRenew	ERenew			
10	Bio-char	Pyrolysis	Electricity							
11	Bio-char	Pyrolysis	H2							
12	Bio-char	HyBrTec	H2							
14	Bio-Oil	Pyrolysis	Electricity							
15	Bio-Oil	Pyrolysis	H2							
16	Bio-Oil	Algae cultivation on sidestream								
19	Cellulose	Fine straining/solids handling								
93	Struvite Fertilizer	Sidestream Struvite Precipitation								

[1]Struvite fertilizer is identified as a Technology to Watch because it requires conversion to bio-P treatment in the liquid stream, which isn't currently feasible with Mainstream Anammox Treatment.

Appendix A BioRenew & ERenew Product Assessment

BioRenew Products

Product	**Class B cake (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk land application • Mine Reclamation • Silviculture • Offsite incineration	*Long Term* • Similar outlets from Near Term with greater limitations potentially
Marketing Requirements	• Wholesaler marketing (little effort required by ARE) • Develop ARE brand	
Sale Price	• $0 (end use cost to ARE)	
Stabilization/Treatment Process Required	• MAD (Class B) • Alkaline stabilization • Aerobic digestion • Combination of MAD/Aerobic digestion	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established (many installations) • MAD already in place	• Desire for energy neutrality • Capital renew requirement for pre-past system • Existing system no longer meets pathogen reduction • Desire for offsite processing
Product market	• Stable market currently, subject to future changes	• Higher fertilizer cost • User acceptance • Higher demand for Blue Plains like material (alkaline stabilized material)
Product value	• Relatively low product value to public • Higher product value to farmers for N and P	• Increase fertilizer price • Reduced GHG/ Carbon sequestration • Perceived value for organic fertilizer
Cost of generation	• Relatively low cost of production • Cost to ARE (current cost of	• Very high Pre-pasteurization • Higher value for digester gas

Product	Class B cake (BioRenew)	
	$35.75/wt from Synagro)	• Energy cost increase
Excluded Products	• Energy products are limited to biogas-based products • Class A product	
Required Modifications to Existing AlexRenew Processes	• No modifications required • Pre-pasteurization could be taken off-line	

Product	Class A cake (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk land application • Silviculture • Mine Reclamation • Raw material for some other product • Offsite incineration	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing (little effort required by ARE) • Market branding by ARE	
Sale Price	Zero in VA market. $5-10 in New England market	
Stabilization/Treatment Process Required	• MAD (Class B) with pre-past • MAD with THP • Alkaline stabilization • Lystek with dewatering • BCR with dewatering • TPAD • MAD/THP/DLD • MagnaPro	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established (many installations) for pre-past, THP, TPAD, alk stab, • Less well established for BCR and Lystek	• Desire for energy neutrality • Capital renew requirement for pre-past system • Existing system no longer meets pathogen reduction • Mass and volume reduction
Product market	• Stable market currently, more versatile to future regulatory changes	• Pre- pasteurization removed from Class A list
Product value	• Relatively low product value to public • Higher value to farmers for N and P replacement	• Increase fertilizer price • Reduced GHG/ Carbon sequestration • Increased value for

Product	Class A cake (BioRenew)	
		organic fertilizer
Cost of generation	• Relatively low cost of production (slightly higher than Class B cake) • Cost to ARE (current cost of $30.75/wt from Synagro) • Price increase expected with potential changes to VA land application permit rates (2015?)	• Increase cost of transport • Increased cost of energy • Increased biogas value
Excluded Products	• Energy products are limited to biogas-based products	
Required Modifications to Existing AlexRenew Processes	• Capital renew requirement for pre-past system for continued operation • Various modifications with other technologies	

Product	Liquid Class A (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk land application • Silviculture • Raw material for some other product	*Long Term* • Similar outlets as Near term • May face increasing liquid land application restrictions
Marketing Requirements	• Wholesaler marketing (little effort required by ARE) • Market branding by ARE (may be difficult for liquid product)	
Sale Price	Zero in VA market.	
Stabilization/Treatment Process Required	• MAD (Class B) with pre-past • MAD with THP • Alkaline stabilization • Lystek • BCR • TPAD • MAD/THP/DLD • MagnaPro	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established (many installations) for pre-past, THP, TPAD, alk stab, • Less well established for BCR and Lystek	• Desire for energy neutrality • Capital renew requirement for pre-past system • Existing system no longer meets pathogen reduction
Product market	• Stable market currently, more versatile to future regulatory changes than Class B, but typically less desirable than cake	• Pre- pasteurization removed from Class A list • Desire to retain moisture for bulk application
Product value	• Relatively low product value to public • Higher value to farmers for N and P replacement	• Increase fertilizer price • Reduced GHG/ Carbon sequestration • Increased value for organic fertilizer

Product	**Liquid Class A (BioRenew)**	
Cost of generation	• Relatively low cost of production (slightly higher than Class B cake), but higher cost of application • Price increase expected with potential changes to VA land application permit rates (2015?)	• Increase cost of transport • Increased cost of energy • Increased biogas value
Excluded Products	• Energy products are limited to biogas-based products	
Required Modifications to Existing AlexRenew Processes	• Capital renew requirement for pre-past system for continued operation • Various modifications with other technologies • De-commissioning of dewatering system	

Product	Ash (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Landfill disposal • Cement production additive • Use in emissions control systems • Soil additive (for P, other metals) • Raw material for other products	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing (little effort required by ARE) • Market branding by ARE (may be dependent on outlet) – difficult for industrial raw material	
Sale Price	• Zero in VA market. • Disposal costs from landfill disposal	
Stabilization/Treatment Process Required	• Incineration (can incorporate digestion) • Gasification	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established (many installations)	• Desire to de-commission digestion • Capital renew requirements for pre-past and digestion system.
Product market	• Little demand for ash	• Reduced markets for biosolids-related products • Increased market for agricultural P or ash-based raw material
Product value	• Little product value to public • Little value for ag use or industrial use	• Increase fertilizer price • Increased cost of materials competing with ash-based materials
Cost of generation	• ~ \$300 - \$600/dt for incineration	• Increase cost of transport • Increased cost of

Product	Ash (BioRenew)	
		biosolids end use
Excluded Products	• If anaerobic digestion is de-commissioned, energy products are limited to heat recovery based products • Can generate biogas-based products with digestion retained	
Required Modifications to Existing AlexRenew Processes	• Potential de-commissioning of digestion • De-commissioning of pre-pasteurization • Construction of incineration or gasification system	

Product	**Vitrified Aggregrate (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Raw material for other products (roofing shingles, reflective coatings)	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing to industry uses(little effort required by ARE) • Market branding by ARE (may be dependent on outlet) – difficult for industrial raw material	
Sale Price	• $5-$6/ton (glass aggregrate)	
Stabilization/Treatment Process Required	• Vitrification (typically requires drying prior to vitrification process)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established for other industries; innovative for wastewater industry	• Desire to de-commission digestion • Capital renew requirements for pre-past and digestion system
Product market	• Established market for glass • Competes with glass recycling market	• Reduced markets for biosolids-related products • Increased demand for recycled aggregate
Product value	• Little product value to public • Value limited to industrial users	• Increased value for recycled materials
Cost of generation	• Unknown	• Better defined costs for technology (capital and O&M) • Increase cost of transport • Increased cost of biosolids end use • Reduced energy cost for vitrification process
Excluded Products	• If anaerobic digestion is de-commissioned,	

Product	Vitrified Aggregrate (BioRenew)
	energy products are limited to heat recovery based products • Can generate biogas-based products with digestion retained
Required Modifications to Existing AlexRenew Processes	• Potential de-commissioning of digestion • De-commissioning of pre-pasteurization • Construction of incineration or gasification system

Product	Siloxanes (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Raw material for industrial use	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing to industry uses(little effort required by ARE) • Market branding by ARE (may be dependent on outlet) – difficult for industrial raw material	
Sale Price	• $1 - $2/lb based on type (industrial quality)	
Stabilization/Treatment Process Required	• Siloxanes recovery equipment	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – little existing research on recovery processes	• Suitable technology for integration with ARE processes
Product market	• Established market for siloxanes for industrial use	• Increased demand for renewable siloxanes
Product value	• Value limited to industrial users	• Increased value for renewable product
Cost of generation	• Limited information on siloxanes recovery technology/costs	• Definition of costs for technology (capital and O&M) • Increased cost for siloxanes removal from biogas
Excluded Products	• Unknown	
Required Modifications to Existing AlexRenew Processes	• Construction of siloxanes recovery system (unknown technology)	

Product	Annamox (Biorenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Seed material- Limited by licensing agreements by DEMON vendor	*Long Term* • Seed material for other DEMON process
Marketing Requirements	• Market through World Water Works (little effort required by ARE)	
Sale Price	Unknown- seed material provided by World Water Works	
Stabilization/Treatment Process Required	• Side-stream DEMON process	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Relatively established- installations in Europe, emerging in North America	• Robust DEMON system in operation at ARE
Product market	• Small, but growing	• Chemical cost of methanol and similar products increase (increased implementation of DEMON)
Product value	• Varies with licensing agreements with World Water Works – currently unknown	• Increase in cost of alternative nitrogen removal processes (other than DEMON)
Cost of generation	• Cost associated with transporting the annamox bacteria	• Increased costs associated with transportation
Excluded Products	• None	
Required Modifications to Existing AlexRenew Processes	• Seed harvesting system from DEMON process	

Product	**Sulfur (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Raw material for industrial use	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing to industry uses(little effort required by ARE) • Market branding by ARE (may be dependent on outlet) – difficult for industrial raw material	
Sale Price	• $2 - $40/lb based on quality	
Stabilization/Treatment Process Required	• Biogas sulfur recovery equipment	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established for other industries; innovative for wastewater industry	• Biogas cleaning process
Product market	• Established market for sulfur produced as oil/gas byproduct	• Increased demand for renewable sulfur
Product value	• Value limited to industrial users	• Increased value for renewable product
Cost of generation	• Limited information on full scale sulfur recovery systems from biogas	• Better defined costs for technology (capital and O&M) • Higher costs for oil/gas sulfur recovery
Excluded Products	• Products generated without anaerobic digestion	
Required Modifications to Existing AlexRenew Processes	• Construction of biogas cleaning system	

Product	Algae for Biofuels and Co-Products(BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Animal feed • Bio-oil	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Wholesaler marketing to animal feed industyr uses(little effort required by ARE) • Market branding by ARE (may be dependent on outlet) – difficult for industrial raw material	
Sale Price	• Unknown for animal feed	
Stabilization/Treatment Process Required	• Algae cultivation system on sidestreams	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative, typically targeted at industrial producers	• Development of robust, small footprint technology • Potential decommissioning of DEMON sidestream process
Product market	• Developing market for bio-oil. • Limited markets in ARE area for animal feed	• Increased demand bio-oil or other algae by product
Product value	• Limited	• Increased value for renewable energy product
Cost of generation	• Limited information on full scale systems and oil recovery	• Better defined costs for technology (capital and O&M) • Higher costs for fossil-fuel based oils
Excluded Products	• Struvite-based nutrient recovery products	
Required Modifications to Existing AlexRenew Processes	• Modification of sidestream treatment process	

Product	Cake Products (flower pots, etc.)(BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Retail sale	*Long Term* • Similar outlets as Near term
Marketing Requirements	• Market branding by ARE • Marketing by specialty wholesalers/retailers	
Sale Price	• Unknown	
Stabilization/Treatment Process Required	• 3rd party manufacturing process	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative, likely to use established technology, little experience with biosolids	• Identification of processor willing to manufacture biosolids-based products
Product market	• Likely to be limited to small specialty market	• Increased demand for specialty renewable products
Product value	• Similar value to other products with similar use	• Increased value for renewable product
Cost of generation	• Unknown, expected to be higher than cost for similar, non-biosolids products	• Better defined costs for generation
Excluded Products	• Other biosolids-based products	
Required Modifications to Existing AlexRenew Processes	• No process modifications expected	

Product	Bio-Oil (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Wholesale to petro-chemical supplier	*Long Term* • Wholesale to petro-chemical supplier • Combustion in District Central Heating Plant • On-site refinery for liquid transportation fuels
Marketing Requirements	• Primarily a wholesale product that would require interaction with petro-chemical suppliers	
Sale Price	• Equivalent to crude oil on a per BTU basis ($17/mmBtu)	
Stabilization/Treatment Process Required	• Pyrolysis of biosolids • Sterilization of dewatered solids followed by bio-oil production by fermentation and oil separation (ethanol, butanol, succinic acid)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic	• Demonstration scale implementation • Desire to de-commission digestion and pre-past systems • Capital renew requirements for pre-past and digestion system.
Product market	• Crude oil market is established • Little market for bio-oil	• Increased market for renewable oil • Reduced markets for biosolids-related products
Product value	• Equal to crude oil prices on energy basis	• Increased incentives for renewable energy
Cost of generation	• Unknown	• Increase cost of transport
Excluded Products	• Limited biogas production expected, pyrolysis would not have a soil amendment by product	
Required Modifications to Existing AlexRenew	• Would eliminate all existing AlexRenew	

Product	Bio-Oil (BioRenew)
Processes	biosolids processes following dewatering

<table>
<tr><td>Product</td><td colspan="2">Class A pellet (high quality digested, dried product) (BioRenew)</td></tr>
<tr><td>Product Market</td><td colspan="2"></td></tr>
<tr><td>Outlets (near term/long term)</td><td>Near Term
• Bulk land application
• Wholesale to ag market
• Retail sale
• Fuel
• Bulk sale to fertilizer blenders
• Sale to soil blenders</td><td>Long Term
• Raw material for some other processes
• Similar to near term outlets</td></tr>
<tr><td>Marketing Requirements</td><td colspan="2">• Wholesaler marketing (little effort required by ARE)
• Additional work required for ARE to establish “brand”
• Raw material industry wholesaler
• Bio products wholesaler</td></tr>
<tr><td>Sale Price</td><td colspan="2">• Varies
• Leesburg –for Town distribution on fields, give bagged product away.
• Derry Township $10/dt for bulk pickup
• $10-25/dt in New England (based on time of the year)
• $9/40 lb bag Louisville
• $30-40/dt Automation Nation</td></tr>
<tr><td>Stabilization/Treatment Process Required</td><td colspan="2">• MAD (Class B)
• Rotary drum dryer or other pelletizing dryer</td></tr>
<tr><td>Trigger Conditions for Product</td><td>Current</td><td>Needed</td></tr>
<tr><td>Technology status</td><td>• Established (many installations)</td><td>• Capital renew requirement for pre-past system</td></tr>
<tr><td>Product market</td><td>• Stable market currently, more versatile to future regulatory changes
• Strongest market in local area – difficult to establish regional/national market as commercial fertilizer</td><td>• Public perception for a higher quality product
• User desire for a higher quality product
• Reduced mass volume
• Pathogen regulation
• Reduction of bulk land application</td></tr>
</table>

Product	**Class A pellet (high quality digested, dried product) (BioRenew)**	
	replacement	market
Product value	• Low to mid-range product value, depending on end use	• Relative cost of other fertilizers go up • Raw ingredients cost go up • Value of fuel go up • Emissions from fuel get restricted
Cost of generation	• Relatively high cost of production, based on equipment and energy use	• Very high cost associated with cake end uses • Avoided cost of digestion expansion
Excluded Products	• Energy products limited to biogas-based products • May consume most/all of generated biogas in thermal drying process unless additional feedstock included in digestion process	
Required Modifications to Existing AlexRenew Processes	• Installation of thermal drying equipment • Can de-commission pre-past system	

<table>
<tr><th>Product</th><th colspan="2">Class A product (low quality dried product) (BioRenew)</th></tr>
<tr><td>Product Market</td><td colspan="2"></td></tr>
<tr><td>Outlets (near term/long term)</td><td>Near Term
• Bulk land application
• Wholesale to ag market
• Less versatility than a pelletized product</td><td>Long Term
• Raw material for some other processes
• Similar to near term outlets</td></tr>
<tr><td>Marketing Requirements</td><td colspan="2">• Wholesaler marketing (little effort required by ARE)
• Additional work required for ARE to establish “brand”</td></tr>
<tr><td>Sale Price</td><td colspan="2">• Low (may have end use cost to ARE)
• $26/dt for flash dried product (Houston)</td></tr>
<tr><td>Stabilization/Treatment Process Required</td><td colspan="2">• MAD (Class B)
• Modular dryer (belt, paddle, etc.)</td></tr>
<tr><td>Trigger Conditions for Product</td><td>Current</td><td>Needed</td></tr>
<tr><td>Technology status</td><td>• Established (many installations)</td><td>• Waste heat available
• Capital renew requirement for pre-past system</td></tr>
<tr><td>Product market</td><td>• Stable market currently for bulk application
• Possible market with soil blenders
• More versatile to future regulatory changes, less versatile than pellet product</td><td>• Public perception for a higher quality product
• User desire for a higher quality product
• Reduced mass volume
• Pathogen regulation
• Reduction of bulk land application market</td></tr>
<tr><td>Product value</td><td>• Low to mid-range product value, depending on end use
• City of Houston gets $6/dt for flash dried product (portion of sale price)</td><td>• Relative costs of other fertilizers increase
• Raw ingredients cost go up
• Value of fuel go up
• Emissions from fuel get restricted</td></tr>
</table>

Product	**Class A product (low quality dried product) (BioRenew)**	
Cost of generation	• Relatively high cost of production, based on equipment and energy use	• Very high cost associated with cake end uses • Avoided cost of digestion expansion
Excluded Products	• Energy products limited to biogas-based products • May consume most/all of generated biogas in thermal drying process	
Required Modifications to Existing AlexRenew Processes	• Installation of thermal drying equipment • Can de-commission pre-past system	

Product	**Class A Aerobic Compost Product (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk land application • Wholesale to ag market • Retail sale • Higher value horticultural blend • Soil blend • Mine reclamation	*Long Term* • Erosion prevention • Stormwater runoff
Marketing Requirements	• 3rd Party marketing (McGill or Synagro, etc.) • Additional work required to establish ARE "brand" • Concern with 3rd party treatment combined with ARE "brand"	
Sale Price	• Varies • New England- up to $ 20/cy	
Stabilization/Treatment Process Required	• MAD (Class B) • Off-site compost system (AlexRenew owned/operated) • 3rd Party compost facility (McGill or Synagro)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established (many installations)	• Capital renew requirement for pre-past system
Product market	• Stable market currently • Can be difficult to enter market for a new brand (significant effort for high value product from ARE)	• Diminished supply of compost (increased demand) • Reduced reliance of biosolids cake product • Phosphorus limit on land application restricted • Higher need for treating co-composting products
Product value	• High value for high quality product	• Higher value for high quality compost product • Incentives e.g. DOT use for road side vegetation product • Carbon credits
Cost of generation	• Relatively high cost	• Reduced cost of

Product	Class A Aerobic Compost Product (BioRenew)	
	of production for ARE-owned system • Mid-range cost for 3rd party composting system (windrow based) • Synagro contract indicates \$48.75/wt	production • Higher value for recovered energy currently used for pre-past • Lower cost for bulking agent
Excluded Products	• Energy products limited to biogas-based products	
Required Modifications to Existing AlexRenew Processes	• None for 3rd party composting (can de-commission pre-past) • Construction of off-site composting facility for ARE owned system	

Product	**Class A Worm Castings (Vermiculture) BioRenew**	
Product Market		
Outlets (near term/long term)	*Near Term* • Wholesale to ag market • Retail sale (bagged product) • Higher value horticultural blend • Soil blend	*Long Term* • Similar to Near Term • Erosion prevention • Stormwater runoff
Marketing Requirements	• 3rd Party marketing • Additional work required to establish ARE "brand" • Concern with 3rd party treatment combined with ARE "brand"	
Sale Price	• $0.80/lb retail sale	
Stabilization/Treatment Process Required	• May require pathogen equivalency determination • Off-site vermiculture system (ARE owned/operated) • 3rd Party facility	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Mature concept, few installations (mostly small-scale installations)	• Capital renew requirements for pre-past system • Technology suitability for local climate • Scalable installations
Product market	• New market for ARE region	• Reduced reliance of biosolids cake product • Phosphorus limit on land application restricted
Product value	• High value for high quality product	• Reduced supply of peat and other potting soil ingredients • Carbon credits for renewable fertilizer product
Cost of generation	• Medium to high cost of production for ARE-owned system	• Reduced cost of production • Higher value for recovered energy currently used for

Product	Class A Worm Castings (Vermiculture) BioRenew	
		pre-past
Excluded Products	• Energy products limited to biogas-based products	
Required Modifications to Existing AlexRenew Processes	• None for 3rd party vermiculture process (can de-commission pre-past) • Construction of off-site facility for ARE owned system	

Product	Class A Anaerobic (Dry Digestion) Compost Product (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk land application • Wholesale to ag market • Retail sale • Higher value horticultural blend • Soil blend • Mine reclamation	*Long Term* • Erosion prevention • Stormwater runoff
Marketing Requirements	• 3rd Party marketing (Synagro?) • Additional work required to establish ARE “brand” • Concern with 3rd party treatment combined with ARE “brand”	
Sale Price	• Varies • New England- up to $ 20/yd	
Stabilization/Treatment Process Required	• Off-site dry digestion/compost system (AlexRenew owned/operated) • 3rd Party compost facility (Synagro or P3)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative – new to biosolids, some food waste dry digestion facilities	• Capital renew requirement for pre-past system and anaerobic digestion • Demonstration of robust operation • Available off-site location
Product market	• Stable (Expect to be similar to conventional composted product) • Can be difficult to enter market for a new brand (significant effort for high value product from ARE)	• Other feedstocks requiring digestion (food waste, organic MSW, etc.)
Product value	• High value for high quality product	• Higher value for organic compost material • Higher value for biogas/biogas

Product	Class A Anaerobic (Dry Digestion) Compost Product (BioRenew)	
		related recovered energy • Associated value with removing organic waste from landfills
Cost of generation	• Expect relatively high cost of production for new system	• Better defined capital and O&M cost for technology • High value in tipping fees from outside wastes (food waste, organic MSW)
Excluded Products	• Energy products limited to biogas-based products from the dry digestion process	
Required Modifications to Existing AlexRenew Processes	• None for 3rd party composting (can de-commission pre-past) • Construction of off-site composting facility for ARE owned system	

Product	**George's Old Town Blend (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Wholesale to ag market • Retail sale • Bulk land application • Silviculture • Mine Reclamation	*Long Term* • Similar outlets as near term
Marketing Requirements	• 3rd Party marketing • ARE brand established – additional/ continuing branding requirements • Concern with 3rd party treatment combined with ARE "brand"	
Sale Price	• Currently given away for public relations benefit • TaGro - $10/cy for bulk, $30/cy for potting soil	
Stabilization/Treatment Process Required	• Class A cake (pre-past, THP, TPAD) • Soil blending facility (either 3rd party or owned/ operated by ARE)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established – soil blending is a well established practice	• Facility/location availability for blending operation
Product market	• Stable - ARE has invested effort in developing brand. May need additional effort to expand market for highest value product.	• Increased demand for soil blend product • Reduced reliance of biosolids cake product • Phosphorus limit on land application restricted
Product value	• High value for high quality product	• Higher value for high quality soil product
Cost of generation	• Low to moderate with continued pre-past. Synagro cost of $35.75/wt • Higher costs for alternate Class A treatment technology	• Higher cost for cake end use
Excluded Products	• Energy products limited to biogas-based products from the anaerobic digestion	
Required Modifications to Existing AlexRenew Processes	• None for 3rd party soil blending with pre-past • Construction of TPAD or THP system if pre-past	

Product	George’s Old Town Blend (BioRenew)
	is de-commissioned

Product	Fertilizer (Vitag or Other) (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Wholesale to ag market • Wholesale to fertilizer retailers • Retail sale	*Long Term* • Similar to near term
Marketing Requirements	• 3rd Party marketing • ARE provided marketing to compete with commercial organic fertilizers (such as Milorganite)	
Sale Price	• Similar to Milorganite (~$800/dt retail)	
Stabilization/Treatment Process Required	• MAD • Nutrient enhancement/drying facility (ARE owned or 3rd party owned)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Relatively established – nutrient addition/drying systems have been in market for over a decade • Vitag less well established technology	• Capital renew requirement for pre-past system
Product market	• Stable – would need significant ARE effort to break into existing market	• Increased demand for organic fertilizer • Reduced opportunity for cake end use • Reduced mass/ volume rqmts • Pathogen reduction rqmts
Product value	• High value for high quality product	• Relative cost of other fertilizers go up • Carbon emissions from commercial fertilizers are restricted
Cost of generation	• High – includes nutrient addition and thermal drying step	• Very high cost associated with cake end uses • Avoided cost of construction of additional digestion

Product	Fertilizer (Vitag or Other) (BioRenew)	
		expansion
Excluded Products	• Energy products limited to biogas-based products from the anaerobic digestion • Likely to consume most or all of biogas in thermal drying step unless additional HSW is digested	
Required Modifications to Existing AlexRenew Processes	• Construction of nutrient addition/drying facility • Can de-commission pre-past	

Product	Organic Char (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Soil amendment for land application • Coal replacement (Innovative)	*Long Term* • Soil amendment for land application • Coal replacement • Electrodes for capacitors
Marketing Requirements	• Bioproducts marketing to industry (coal replacement, raw material) • 3rd party marketing to ag users • ARE marketing to ag users (expected to require significant effort to establish)	
Sale Price	• Unknown for ag use/raw material • Similar to coal based on energy content (~$5/1000 Btu)	
Stabilization/Treatment Process Required	• Pyrolysis	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic/Innovative. New to biosolids industry	• Robust technology with known costs • Capital renew requirement for pre-past system or digestion
Product market	• New – no existing biosolids pyrolysis facilities in operation, little information on market potential	• Reliable demand as ag product • Increased demand for renewable energy in place of coal
Product value	• Low value for ag product • Unknown/low value for coal replacement (little demand)	• Higher energy costs for coal (increased demand for coal replacement) • Higher value for carbon sequestration
Cost of generation	• High – requires construction of pyrolysis facility. Little information on actual capital or O&M costs	• Better defined costs for technology (capital and O&M) • Very high cost associated with cake end uses • Avoided cost of digestion

Product	Organic Char (BioRenew)
Excluded Products	• Not well suited for use with anaerobic digestion – no biogas available for eRenew product
Required Modifications to Existing AlexRenew Processes	• Construction of pyrolysis facility • Can de-commission pre-past and MAD

Product	Recovered P fertilizer (Ostara, Multiform Harvest) (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Commercial fertilizer for retail sale	*Long Term* • Similar as near term
Marketing Requirements	• Market through Ostara or Multiform Harvest (little effort by ARE to develop markets)	
Sale Price	• Can vary with market price for phosphate • Contracts with vendors typically undervalue phosphate benefit • ~$300/ton	
Stabilization/Treatment Process Required	• Proprietary P crystallization technology (Ostara, Multiform Harvest) • Requires bio-P liquid stream treatment • Requires anaerobic digestion for P release or co-settling for P release	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Relatively established – several full scale installation in operation	• Higher cost for sidestream treatment – drives struvite recovery • Implementation of bio-P treatment
Product market	• Stable, but growing – competes with chemical fertilizer	• Increased demand for renewable fertilizer
Product value	• Market price for P ($480/ton for di-ammonium phosphate)	• Increased value for renewable fertilizer – cost premium
Cost of generation	• Essentially $0 (considering payback from reduced metal salt addition)	• No change • Becomes more attractive with higher iron salt costs
Excluded Products	• Other N or P based products from sidestream	
Required Modifications to Existing AlexRenew Processes	• Addition of P crystallization system	

Product	Recovered N2 (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Industrial gas products market	*Long Term* • Similar to near term outlets
Marketing Requirements	• Wholesaler for marketing to industry	
Sale Price	• Varies by quality ($0.02 to $3.00/100 cf)	
Stabilization/Treatment Process Required	• Supercritical water oxidation • Gas capture/compression • (Gas capture from denitrification not included in biosolids evaluation)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic for biosolids – demonstration facility in Ireland. Implementation issues at Orlando • Embryonic for N2 recovery from SCWO	• Robust SCWO system for biosolids • Capital renew requirement for digestion and pre-past system
Product market	• Established industrial market	• Continued industrial market • Desire for biosolids-based N2 • Pressures to eliminate agricultural biosolids product
Product value	• Market price (see Sale Price above)	• Recognized value for biosolids-based N2
Cost of generation	• High – unproven technology, unknown capital and O&M costs.	• Well developed costs for capital and equipment for SCWO • Higher costs for biosolids-based product generation/ end use
Excluded Products	• Biogas from anaerobic digestion • Biosolids agricultural product (cake, dried product, etc.)	
Required Modifications to Existing AlexRenew Processes	• De-commissioning of MAD and pre-past • Construction of SCWO facility	

Product	Recovered N2 (BioRenew)	
Product	**Recovered CO2 (BioRenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Industrial gas products market	*Long Term* • Similar to near term outlets
Marketing Requirements	• Wholesaler for marketing to industry	
Sale Price	• Varies by quality (~ $100/ton for industrial grade)	
Stabilization/Treatment Process Required	• Supercritical water oxidation • Gas capture/compression • CO_2 separation from biogas cleaning process or combustion emissions	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• SCWO embryonic for biosolids – demonstration facility in Ireland. Implementation issues at Orlando • CO_2 separation equipment Established for gas cleaning industry. No installations in biosolids market	• Robust SCWO system for biosolids • Capital renew requirement for digestion and pre-past system (for SCWO implementation)
Product market	• Established industrial market	• Continued industrial market • Desire for biosolids-based CO2 • Pressures to eliminate agricultural biosolids production (SCWO driver)
Product value	• Market price (see Sale Price above)	• Recognized value for biosolids-based CO_2
Cost of generation	• High – unproven technology, unknown capital and O&M costs (SCWO) • High for CO_2 capture from gas	• Well developed costs for capital and equipment for SCWO • Higher costs for biosolids-based product

Product	Recovered N2 (BioRenew)	
	cleaning or combustion	generation/ end use
Excluded Products	• Biogas from anaerobic digestion (for SCWO) • Biosolids agricultural product (cake, dried product, etc.) (from SCWO)	
Required Modifications to Existing AlexRenew Processes	• De-commissioning of MAD and pre-past (for SCWO) • Construction of SCWO facility • Construction of CO_2 recovery and compression equipment (for digester gas based system)	

Product	Recovered CO2 (BioRenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Industrial gas products market	*Long Term* • Similar to near term outlets
Marketing Requirements	• Wholesaler for marketing to industry	
Sale Price	• Varies by quality (~ $100/ton for industrial grade)	
Stabilization/Treatment Process Required	• Supercritical water oxidation • Gas capture/compression • CO_2 separation from biogas cleaning process or combustion emissions	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• SCWO embryonic for biosolids – demonstration facility in Ireland. Implementation issues at Orlando • CO_2 separation equipment Established for gas cleaning industry. No installations in biosolids market	• Robust SCWO system for biosolids • Capital renew requirement for digestion and pre-past system (for SCWO implementation)
Product market	• Established industrial market	• Continued industrial market • Desire for biosolids-based CO2 • Pressures to eliminate agricultural biosolids production (SCWO driver)
Product value	• Market price (see Sale Price above)	• Recognized value for biosolids-based CO_2
Cost of generation	• High – unproven technology, unknown capital and O&M costs (SCWO) • High for CO_2 capture from gas cleaning or	• Well developed costs for capital and equipment • Higher costs for biosolids-based product generation/ end use

Product	Recovered CO2 (BioRenew)
	combustion
Excluded Products	• Biogas from anaerobic digestion (for SCWO) • Biosolids agricultural product (cake, dried product, etc.) (from SCWO)
Required Modifications to Existing AlexRenew Processes	• De-commissioning of MAD and pre-past (for SCWO) • Construction of SCWO facility • Construction of CO_2 recovery and compression equipment (for digester gas based system)

Product	**Ammonium salt (Biorenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk chemical suppliers	*Long Term* • Similar to Near Term outlets
Marketing Requirements	• 3rd party wholesaler to industrial chemical uses • May be able to develop an ARE brand, but may be limited to positive PR	
Sale Price	• Varies- based on type of ammonium salt and cost of natural gas • $600/tonne for wholesale ammonia	
Stabilization/Treatment Process Required	• CASTion (Flash vacuum distillation) • Steam stripping • Ion exchange	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established in industrial production • Pilot scale (NYC) for wastewater system	• Full scale demonstrations for wastewater systems
Product market	• Established market for ammonium salts	• Market for bio-sourced nitrogen • Carbon credits
Product value	• Market price (see Sale Price above)	• Offset cost of generation • Increased use for bio-based nitrogen compounds
Cost of generation	• Little information on costs for production from wastewater	• Better understanding of capital and O&M costs for the process • Costs must offset by product value
Excluded Products	• May interfere with production of struvite-based products	
Required Modifications to Existing AlexRenew Processes	• Decommissioning of DEMON • Flash Vacuum Distillation and ancillary chemical recovery equipment • Ion exchange column and regeneration system	

Product	**Hypochlorite (Biorenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk chemical suppliers	*Long Term* • Similar to Near Term outlets
Marketing Requirements	• 3rd party wholesaler to industrial chemical uses • May be able to develop an ARE brand, but may be limited to positive PR	
Sale Price	• Varies- based on solution strength • ~$0.80 - $1.00/lb	
Stabilization/Treatment Process Required	• Microbial fuel cells	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – research level only	• Full scale demonstrations for wastewater systems
Product market	• Established market for hypochlorite – industrial outlets	• Market for bio-sourced hypochlorite • Carbon credits
Product value	• Market price (see Sale Price above)	• Offset cost of generation • Increased use for bio-based chemical compounds
Cost of generation	• Little information on costs for production from wastewater	• Better understanding of capital and O&M costs for the process • Costs must offset by product value
Excluded Products	• May interfere with production of biogas based products if energy is removed using microbial fuel cells	
Required Modifications to Existing AlexRenew Processes	• Addition of microbial fuel cell technology (unknown equipment requirements)	

Product	**Ethanol (Biorenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk chemical supplier • Petro-chem	*Long Term* • Similar to Near Term Outlets
Marketing Requirements	• 3rd party wholesaler to chemical market • Additional work required for ARE to establish "brand" – may be limited to positive PR	
Sale Price	• ~$2.00- $2.50/gallon of Ethanol	
Stabilization/Treatment Process Required	• Extensive chemical treatment/conversions • Hydrolysis • Fermentation • Distillation	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – small scale testing	• Demonstration testing for biosolids • Capital renew associated with continued pre-past and digestion
Product market	• Established – competes with corn (or other renewable source) based ethanol	• Increased value of non-food based bio-ethanol • Increased cost of food products used in ethanol production
Product value	• Market price (see Sale Price above) • Significant use as renewable vehicle fuel	• Offset cost of generation • Increased availability of incentives for bio-ethanol
Cost of generation	• Little information on costs associated with wastewater ethanol production • Expected to be higher than corn-based ethanol due to scale and feedstock suitability	• Better developed capital and O&M costs • Costs must be offset by product value
Excluded Products	• Biosolids-type products	

	• Other ERenew products
Required Modifications to Existing AlexRenew Processes	• Addition of ethanol production equipment (fermentation and distillation processes) • De-commissioning of digestion and pre-past systems

Product	BioPolymer/BioPlastics (Biorenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Bulk chemical supplier • Plastics producers	*Long Term* • Similar to Near Term outlets
Marketing Requirements	• 3rd Party wholesaler to industrial market • Additional work required to establish ARE "brand"	
Sale Price	• $1-$5/lb active polymer	
Stabilization/Treatment Process Required	• Significant chemical/physical treatment • Fermentation	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – little active research	• Further research with demonstration testing for wastewater applications • Capital renew to existing pre-pasteurization system
Product market	• Growing market for bio-plastics • Stable, highly competitive market for polymers	• Increased desire for non-food sourced plastics or polymers • Increased desire for bio-degradable plastics • Reduced markets for organic biosolids products • Carbon credits
Product value	• Similar value to fossil-fuel based polymers and plastics	• Increased incentives for bio-degradable plastic or non-fossil fuel based plastics/polymers • Increased cost of fossil fuel based plastics
Cost of generation	• Unknown	• More developed costs for capital and O&M • Cost offset by

Product	BioPolymer/BioPlastics (Biorenew)	
		product value
Excluded Products	• Energy products limited to biogas-based products from the anaerobic digestion	
Required Modifications to Existing AlexRenew Processes	• Extensive addition of specialized equipment	

Product	**Precious Metals (Biorenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Precious metals market	*Long Term* • Similar to Near Term
Marketing Requirements	• 3rd party marketing to industrial uses	
Sale Price	• Varies- Very high (depends on metal)	
Stabilization/Treatment Process Required	• Thermal conversion (incineration/gasification) • Acid leaching and precipitation	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic in municipal waste management • Non-existent in wastewater	• Fundamental research • Desired conversion to Thermal process • Capital renew to pre-past system
Product market	• Established market for metals, varying metal availability	• Reduced markets for organic biosolids products
Product value	• Varies with metal type, based on supply and mining costs	• Increased demand with reduced availability of precious metal
Cost of generation	• Little known cost for capital and O&M for metal recovery • Well established costs for incineration	• More developed costs for capital and O&M • Cost offset by product value
Excluded Products	• Biogas ERenew products • Biosolids product for ag use	
Required Modifications to Existing AlexRenew Processes	• Incinerator/ thermal conversion process • Reactors and metal recovery	

Product	Cellulose (Biorenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Soil amendment • Bulk pulp and paper (low quality pulp)	*Long Term* • Similar to near term • Combustion for energy production
Marketing Requirements	• 3rd Party wholesaler to paper industry • Direct sale to energy producer/cement kiln • 3rd party wholesaler to ag product industry	
Sale Price	• Unknown – high quality wood pulp ~ $800/tonne	
Stabilization/Treatment Process Required	• Ultra-fine screens • Washing/treatment	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – little current research on removal/ treatment for wastewater	• Modification to existing screening • Demonstration testing
Product market	• Unknown, but likely to be difficult to compete with higher quality pulp	• Stable market for renewable pulp • Increased demand for alternative energy sources
Product value	• Low – driven by volume of product and little demand for renewable cellulose	• Increased desire for renewable feed stock for combustion or pulp • Incentives for cellulose based products
Cost of generation	• Unknown	• Known capital and O&M costs • Cost must be offset by product value
Excluded Products	• None expected	
Required Modifications to Existing AlexRenew Processes	• Installation of ultra-fine screens • Washing/further treatment	

ERenew Products

Product	**H2 (BioRenew/ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • On site power generation through fuel cells • Sale as H2 gas	*Long Term* • Similar to near term • Sale as vehicle fuel
Marketing Requirements	• Wholesaler for industrial gases	
Sale Price	• \$400-\$600/tonne (industrial grade, retail)	
Stabilization/Treatment Process Required	• Gasification w/gas treatment • Pyrolysis • HyBrTec	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic processes for syngas cleaning and HyBrTec	• Robust technology to generate H2 • Capital renew requirement for pre-past system and digestion
Product market	• Established market for industrial H2	• Desire for renewable H2 production • Increased H2 demand for vehicle fuel
Product value	• Market price (see above)	• Price to offset generation costs • RIN/RECs for renewable fuel
Cost of generation	• Unknown, undeveloped technology for biosolids	• Higher costs associated with end use of biosolids products • Reduced costs for H2 production
Excluded Products	• Biogas from anaerobic digestion • Conventional biosolids cake/dried product	
Required Modifications to Existing AlexRenew Processes	• Addition of H2 generation and conversion technologies • Decommissioning of pre-past, digestion	

Product	**Electricity (ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • On site power use • Sale to power grid	*Long Term* • Similar to near term outlets
Marketing Requirements	• No marketing required for on-site use or sale to grid. PR recommended to maximize benefit to ARE.	
Sale Price	• Retail/wholesale power cost (~ $0.06/kWh)	
Stabilization/Treatment Process Required	• Anaerobic digestion with CHP • H2 product with CHP • Steam product with CHP	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Established Process – technology options with varying implementation history	• Improved CHP technologies • Improved gas cleaning technologies • Reduced need for biogas combustion for process rqmts • Capital renew requirement for pre-past system
Product market	• Expect full consumption of power on-site • Potential difficulties in putting power on the grid (power company restrictions)	• Easy access for wheeling power or adding to the grid
Product value	• Retail/wholesale power	• Higher value for renewable energy • RECs for renewable fuel
Cost of generation	• Typically $0.06 to $0.15/kWh	• Generation cost and RECs at or below cost of power purchase
Excluded Products	• Technologies that do not include biogas generation or waste heat or that consume biogas/heat	
Required Modifications to Existing AlexRenew Processes	• Addition of CHP equipment	

Product	**Electricity (ERenew)**
	• Syngas production technology with gas cleaning and CHP • Waste heat production with CHP

Product	Biogas for vehicle fuel (ERenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • Utility/city vehicle fleet • Commercial sale	*Long Term* • Similar to near term outlets, increased demand
Marketing Requirements	• No marketing required for city fleet use • ARE or 3rd party marketing for commercial sale	
Sale Price	• Varies, similar to gasoline costs based on energy content (~ $4.00-$5.00/GGE)	
Stabilization/Treatment Process Required	• Anaerobic digestion with gas cleaning • Fueling system	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative Process for biosolids – technology options with varying implementation history • Lower cost systems have poor capture (~ 60%)	• Reduced need for process heat (associated with pre-past or other process) • Capital renew requirement for pre-past system • Improved capture for lower cost cleaning technologies
Product market	• Developing market, driven by fleet size	• Adequate demand to consume production
Product value	• Similar to natural gas, with some RIN value	• Increased demand for renewable vehicle fuel • Increased RIN value/availability
Cost of generation	• $2 to $6/GGE (varies with technology)	• Similar or less than natural gas conversion per GGE
Excluded Products	• Power generation • Combustion/steam technologies	
Required Modifications to Existing AlexRenew Processes	• Addition of biogas cleaning equipment • Fueling system	

Product	**Pipeline quality biogas (ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Commercial sale • Pipeline injection	*Long Term* • Similar to near term outlets. Expected increase in demand
Marketing Requirements	• Wholesale to utilities – little marketing required. PR recommended to maximize value to ARE.	
Sale Price	• Retail/wholesale natural gas cost (~ $6/ mmBtu)	
Stabilization/Treatment Process Required	• Anaerobic digestion with gas cleaning • Compression/pipeline injection system	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative Process for biosolids – technology options with varying implementation history	• Reduced need for on-site biogas use (heat/power) • Capital renew requirement for pre-past system • Improved technology to reduce generation costs
Product market	• Sale to utility – limited based on utility acceptance and rules	• Open access to utility pipeline injection • Increased demand for renewable based energy
Product value	• Similar to natural gas, with some RIN value if used as vehicle fuel	• Higher value for renewable energy to offset generation costs
Cost of generation	• $8 to $12/mmBtu	• Similar to cost of natural gas, including REC value
Excluded Products	• Power generation • Combustion/steam technologies	
Required Modifications to Existing AlexRenew Processes	• Addition of biogas cleaning equipment • Compression and pipeline injection system	

Product	**Syngas (ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • Heat from combustion of syngas • H2 (from steam reforming)	*Long Term* • Similar to near term outlets, with greater demand anticipated
Marketing Requirements	• Wholesaler for industrial gas (for H2)	
Sale Price	• Market price for H2 ($400-$600/tonne, industrial grade, retail) • Heat price similar to cost of generating hot water (on energy basis)	
Stabilization/Treatment Process Required	• Gasification • Steam reforming (for H2 production)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Innovative process for biosolids	• Robust system/ equipment • Capital renew requirement for pre-past system and digestion
Product market	• No current established market for syngas • Established market for H2 industrial gas	• Increased demand for heat from renewable resources • Increased demand for H2 from renewable resource • Increased difficulty for beneficial biosolids use
Product value	• Similar to value of heat from natural gas combustion • H2 value similar to industrial price	• Higher value for renewable energy • Availability of financial incentives
Cost of generation	• Limited information from single gasification installation (cost of gasification system offset by eliminated natural gas purchase – no Syngas sale)	• Reliable information on capital and O&M costs

Product	Syngas (ERenew)	
	• Unknown cost of steam reforming for H2 production	
Excluded Products	• Biogas from anaerobic digestion • Biosolids products for ag use or similar	
Required Modifications to Existing AlexRenew Processes	• Addition of gasification equipment • Addition of steam reforming equipment for H2 production	

Product	Hot Water (ERenew)	
Product Market		
Outlets (near term/long term)	*Near Term* • On site use for pre-pasteurization system/bldg heat • Adjacent off-site use	*Long Term* • Similar to near term outlets
Marketing Requirements	• Marketing effort by ARE to identify potential users • May be able to develop positive PR from offsite use	
Sale Price	• Similar to cost associated with natural gas based heat generation	
Stabilization/Treatment Process Required	• Combustion process (thermal conversion, biogas combustion)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Varies – Established for many technologies	• Capital renew requirement for pre-past system and digestion • Little need for on-site heat
Product market	• Little off site market	• Demand for heat adjacent to ARE site
Product value	• Similar to heat generation through conventional energy sources	• Increased value for renewable energy heat source
Cost of generation	• Relatively low with conventional heat recovery equipment	• Low cost system or heat recovery in conjunction with other process
Excluded Products	• Biogas for fuel or pipeline (if heat is recovered from biogas combustion) • Biosolids product for ag use (if heat is recovered from biosolids conversion)	
Required Modifications to Existing AlexRenew Processes	• Additional boiler capacity/upgrades • Biosolids conversion equipment/heat recovery • De-commissioning of pre-past system	

Product	**Steam (ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • On site use for heat for power generation • Adjacent off-site use	*Long Term* • Similar to near term outlets
Marketing Requirements	• Marketing effort by ARE to identify potential users • May be able to develop positive PR from offsite use	
Sale Price	• Similar to cost associated with natural gas based steam generation	
Stabilization/Treatment Process Required	• Combustion process (thermal conversion, biogas combustion)	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Varies – Established for many technologies	• Capital renew requirement for pre-past system • Little need for on-site steam
Product market	• Little off site market	• Demand for steam adjacent to ARE site
Product value	• Similar to steam generation through conventional energy sources	• Increased value for renewable energy steam source
Cost of generation	• Relatively low with conventional heat recovery equipment	• Low cost system or steam recovery in conjunction with other process
Excluded Products	• Biogas for fuel or pipeline (if heat is recovered from biogas combustion) • Biosolids product for ag use (if heat is recovered from biosolids conversion)	
Required Modifications to Existing AlexRenew Processes	• Additional boiler capacity/upgrades for steam production • Biosolids conversion equipment/heat recovery • De-commissioning of pre-past system	

Product	**Electricity from Microbial Fuel Cell (ERenew)**	
Product Market		
Outlets (near term/long term)	*Near Term* • On site power use • Sale to power grid	*Long Term* • Similar to near term outlets
Marketing Requirements	• No marketing required for on-site use or sale to grid. PR recommended to maximize benefit to ARE.	
Sale Price	• Retail/wholesale power cost (~ $0.06/kWh) • Possible premium for energy credits	
Stabilization/Treatment Process Required	• Microbial Fuel Cell on liquid treatment	
Trigger Conditions for Product	**Current**	**Needed**
Technology status	• Embryonic – ongoing research mostly focused on liquid stream rather than solids	• Further research on solids • Demonstration testing
Product market	• Established – potential difficulties in putting power on the grid (power company restrictions) • Expect full consumption of power on-site	• Easy access for wheeling power or adding to the grid
Product value	• Retail/wholesale power price	• Higher value for renewable energy • RECs for renewable fuel
Cost of generation	• Unknown capital and O&M costs	• Development of known capital and O&M costs • Generation cost and RECs at or below cost of power purchase
Excluded Products	• Consumes energy associated with biogas based products	
Required Modifications to Existing AlexRenew Processes	• Extensive – possible decommissioning of some liquid treatment equipment; reengineering of existing liquid treatment flow scheme.	

ALEXANDRIA RENEW ENTERPRISES

TECHNICAL MEMORANDUM 2-3: BASELINE, LIMITATIONS, AND OPTIMIZATION OF EXISTING CONDITIONS

PREPARED FOR

ALEXANDRIA RENEW ENTERPRISES

26 NOVEMBER 2014

BLACK & VEATCH
Building a world of difference.

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ABBREVIATION	DEFINITION
% TS	Percent total solids
Btu/hr	British thermal unit per hour
CEPT	Chemically enhanced primary treatment
DSET	Digested sludge equalization tank
EQ	Equalization
gpm	Gallons per minute
gpm/sf	Gallons per minute per square foot
GST	Gravity sludge thickener
HEX	Heat exchanger
HLR	Hydraulic loading rate
kWh	Kilowatt hours
lb/MG	Pound per million gallon
LRPR	Long Range Planning Report
mgd	Million gallons per day
MJ	Megajoules
PEW	Plant effluent water
ppd	Pound per day
ppd/kcf	Pounds per day per 1000 cubic feet
pph/sf	Pounds per hour per square foot
SLR	Solids loading rate
SRT	Solids retention time
TM	Technical memorandum
TSET	Thickened sludge equalization tank
VS	Volatile solids
WAS	Waste activated sludge

1 Introduction

1.1 PROJECT OBJECTIVES

The purpose of this Task Order is to provide the basis for an update to the biosolids portion of the AlexRenew long-range plan. The scope of the Task Order is to identify the most suitable future biosolids program for AlexRenew and to establish a road map for the utility in achieving a sustainable, dependable program.

1.2 PROJECT FRAMEWORK

The Task Order is being executed as a series of Technical Memoranda (TM) and workshops, which will allow AlexRenew to begin with a long-term, open-ended visioning of all the potential ways of managing biosolids and developing products. Through this task order, an increasingly rigorous screening process will allow AlexRenew to focus in on the most promising systems that will both produce high level products and meet the other drivers discussed in previous technical memoranda. In order to establish a framework for near and medium-term decisions, an evaluation of the existing processes capacities and limitations was conducted. These findings are summarized in this Technical Memorandum.

1.3 APPROACH

The focus of TM 2-3 is to:

- Document historical solids production and identify projected solids production
- Identify capacities of major biosolids process equipment
- Determine biosolids system process limitations based on capacity of existing equipment
- Provide recommendations for optimization of existing biosolids treatment system, based on both operational changes and equipment modification.

2 Solids Production

AlexRenew solids production was developed using plant historical data and future plant influent flow estimates from the Long Range Planning Report, Alexandria Advanced Wastewater Treatment Facility (2009) (hereafter referred to as the LRPR), developed as part of the State of the Art Nitrogen Upgrade Program (SANUP).

2.1 HISTORICAL SOLIDS PRODUCTION

The historical solids production values were identified using plant operating data from January 2009 through October 2013. Data evaluated includes plant influent and effluent characteristics, solids production, biosolids process parameters, and energy use. Historical plant solids production is summarized in Table 2-1. Maximum month solids production rates were based on plant operations in November 2012, which corresponds to the month with the maximum monthly average total solids production. Since the influent flows associated with maximum month solids production can vary significantly year to year based on rain events, the maximum month solids production has been normalized to the average annual influent flows. It should be noted that the November 2012 condition corresponds with the greatest total quantity of solids (combined primary solids, WAS [waste activated sludge], and tertiary solids), not necessarily the month with the maximum production of each of the types of solids. The maximum monthly average tertiary solids production occurred in December 2009 (13,620 ppd) and the maximum monthly average WAS production occurred in February 2011 (32,800 ppd). Since tertiary solids are combined with primary solids prior to thickening, the maximum combined primary and tertiary solids production of 69,030 ppd, which occurred in November 2012, results in the maximum solids load on gravity thickening. The historical maximum month WAS production, which occurred in February 2011, was 2 percent greater than the value listed in Table 2-1, and is therefore not expected to impact the results of the capacity evaluation. It should be noted that the total solids production is approximately 20 percent greater than the reported digester feed solids. While some solids are lost through thickening processes, a 20 percent difference is fairly large. Discussions with plant staff were not able to identify the reason for the difference. Consequently, the higher value associated with the individual solids streams (primary solids, WAS, and tertiary solids) was used for the evaluation, which is a conservative approach.

Table 2-1. Historical Plant Solids Production (2009 – 2013)

PARAMETER	UNIT	AVERAGE ANNUAL CONDITIONS	MAXIMUM MONTH CONDITIONS (NOVEMBER 2012)[1]
Flow	mgd	35.6	35.6
Primary solids	ppd lb/MG	41,490 1,165	62,380 1,752
Waste Activated Sludge	ppd lb/MG	27,170 763	32,200 904
Tertiary Solids	ppd lb/MG	8,380 235	6,660 187
Total Solids	ppd lb/MG	77,040 2,164	101,240 2,844

[1]Solids production rates normalized to average influent flow over data set

2.2 PROJECTED SOLIDS PRODUCTION

Solids projections were developed based on flows presented in the LRPR and the historical average annual and maximum month solids production rates. The LRPR 2030 flow and ultimate flow are 44.9 and 54.0 mgd, respectively, as listed in Table 2-2. Future solids production projections were based on the condition that future raw influent characteristics and operation of plant processes will result in a similar solids generation rate as are currently experienced. However, if there are changes in either the raw influent characteristics or plant process performance, the solids production rate can also change. Projected solids production is presented in Table 2-2.

Table 2-2. Projected Plant Solids Production

PARAMETER	UNIT	2030 PROJECTION		ULTIMATE PROJECTION	
		Average Annual	Maximum Month	Average Annual	Maximum Month
Flow	mgd	44.9	44.9	54.0	54.0
Primary solids	ppd lb/MG	52,325 1,165	78,670 1,752	62,930 1,165	94,620 1,752
Waste Activated Sludge	ppd lb/MG	34,270 763	40,610 904	41,215 763	48,840 904
Tertiary Solids	ppd lb/MG	10,565 235	8,395 187	12,710 235	10,100 187
Total Solids	ppd lb/MG	97,160 2,164	127,680 2,844	116,860 2,164	153,565 2,844

Solids production and capacity evaluations were also performed for treatment conditions anticipated using mainstream Anammox. The solids quantities for this evaluation were based on projections generated by CH2M-Hill and provided by ARE staff. The production estimates and capacity evaluation are presented in the Appendix.

3 Existing Biosolids Treatment System

The existing biosolids treatment system consists of gravity thickening for primary and tertiary solids, centrifuge thickening for WAS, pre-pasteurization of all solids, anaerobic digestion, and centrifuge dewatering. A schematic of the process is shown on Figure 3-1. The schematic illustrates "normal operation"; for simplicity, back-up functions designed into some of the tanks and pumping/valving systems have been removed from the schematic.

Historical performance information from 2009 through 2013 is presented in Table 2-1. The average annual performance corresponds to the average annual solids loads. The maximum month performance or loading information listed in Table 2-1 occurred during the month with the highest load on each specific process. The month during which the maximum loading occurred is also listed in Table 2-1.

Generally, the equipment is within typical loading rates. The gravity thickener hydraulic loading rate is relatively high at the maximum loading conditions. The anaerobic digesters appear to have considerable extra capacity, operating at 30 day SRT and 76 ppd/kcf volatile solids loading rate, but note that all four digester tanks appear to be operating as primary digesters, with no tank operating as a spare. Centrifuge thickening and dewatering performances are good with respect to expected values.

Table 3-1. Historical Plant Performance (2009-2013)

PARAMETER	UNIT	AVERAGE ANNUAL	VALUE AT MAXIMUM LOAD[1]	MONTH WITH MAXIMUM LOAD/LOADING RATE
Primary Solids Concentration	% TS	0.22	0.27	Nov 2012
WAS Concentration	% TS	0.50	0.59	Feb 2011
Tertiary Solids Concentration	% TS	0.11	0.09	Dec 2009
Gravity Thickener Loading Rate[2]	gpd/sf pph/sf	680 10	809 15	Aug 2009 Nov 2012
Gravity Thickened Solids Concentration	% TS	3.9	3.7	Nov 2012
WAS Thickening Centrifuge Loading Rate	gpm pph	464 1,132	578 1,366	Aug 2010 Feb 2011
Thickened WAS Concentration	% TS	8.7	8.2	Feb 2011
Solids to Pre-Pasteurization	gpd	175,150	208,200	Jun 2010
Anaerobic Digestion SRT[3] Anaerobic Digestion VS[3] loading	days ppd/kcf	30 76	20[4] 102	Jan 2010 Jan 2010
Digestion Volatile Solids Reduction	%	52	50	Jan 2010
Dewatering Centrifuge Loading Rate	gpm pph	127 1,723	213 2,835	Oct 2009 Oct 2009
Dewatered Cake Concentration	% TS	28	27	Oct 2009

[1]Value at maximum month average condition, where maximum month reflects maximum average monthly load on specific process.
[2]Two GSTs in service
[3]Four digester tanks in operation as primary digesters
[4]Minimum SRT

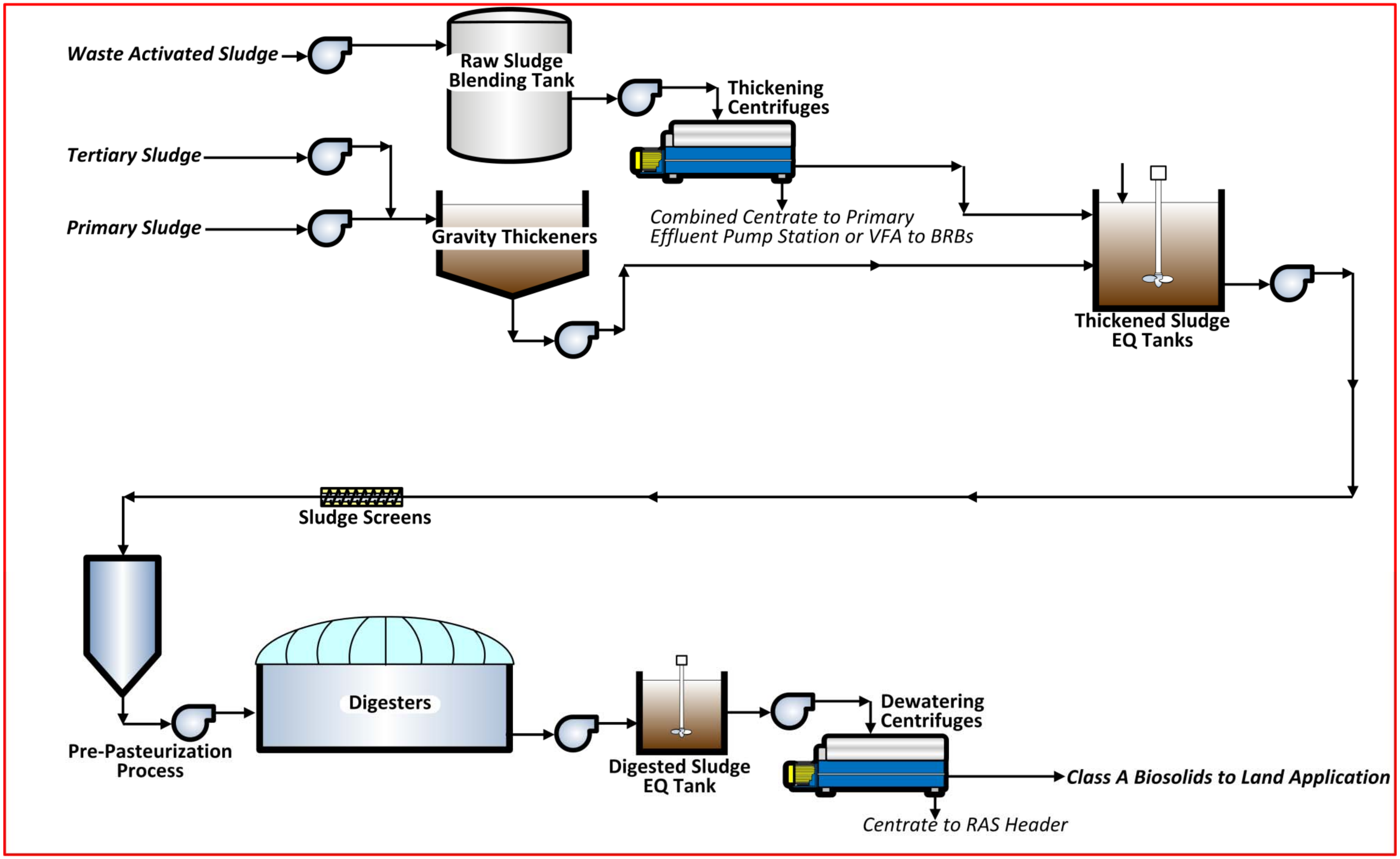

Figure 3-1. Biosolids Process Schematic

3.1 PROCESS EQUIPMENT AND MAJOR UNIT CAPACITIES

Capacities for the major biosolids treatment processes were developed based on information provided in O&M manuals and the LRPR. A summary of the unit and total capacities for the biosolids treatment processes is presented in Table 3-2. Most plant processes were assumed to have at least one spare unit, to ensure continued performance in the event of equipment shut down or maintenance. However, a few of the processes at AlexRenew do not follow the "single spare" concept, as follows:

- Gravity sludge thickeners – of the five gravity sludge thickeners (GST) installed, two are permanently out of service (GST 2 and GST 4). The remaining three GSTs operate as three duty, no spare units for backup.

- Gravity thickened sludge pumps – each GST is equipped with one duty and one spare thickened sludge pump. Four of the pumps are effectively out of service since the GSTs they support are out of service, resulting in six pumps available (one duty/one spare per train) to support the three available GSTs. Based on a two duty, 1 spare configuration for the GSTs, two of the thickened sludge pumps (one per duty GST) would be considered duty pumps.

- Thickened sludge pumps – each Thickened Sludge EQ Tank (TSET) is supported by two thickened sludge pumps (one duty, one standby). During normal operation, two TSETS are in use, each supported by a single duty pump.

- Digested sludge transfer pumps – each digester is equipped with two digested sludge transfer pumps (one duty, one standby). During normal operation, all digester tanks are in service, with one transfer pump per digester (four total) in service. However, since the digestion system is designed with a duty capacity of three digester tanks (with one tank out of service), three transfer pumps (one per duty tank) are considered duty pumps.

- Digested sludge EQ tank – a single Digested Sludge EQ Tank (DSET) is available; however, Raw Sludge Blending Tank 3 can be used to back up the DSET if necessary.

Table 3-2. Major Unit Capacities

PROCESS	NUMBER OF UNITS		UNIT CAPA-CITY	UNITS	TOTAL CAPACITY		UNITS	CAPACITY SOURCE INFO
	TOTAL	DUTY			TOTAL	DUTY		
Gravity Sludge Thickener (GST)[1]	5	3	800	gpd/sf	9,503,000	5,702,000	gpd	O&M Manual
Gravity Thickened Sludge Pump[2]	10	3	120	gpm/pump	864,000	518,400	gpd	O&M Manual

PROCESS	NUMBER OF UNITS		UNIT CAPACITY	UNITS	TOTAL CAPACITY		UNITS	CAPACITY SOURCE INFO
	TOTAL	DUTY			TOTAL	DUTY		
Thickening Centrifuge	4	3	450	gpm/ unit	2,592,000	1,944,000	gpd	LRPR
Thickened Sludge EQ Tank (TSET)	3	2	171	gpm/ tank	738,720	492,480	gpd	O&M Manual
Thickened Sludge Pump	6[3]	2	175	gpm/ pump	756,000	504,000	gpd	O&M Manual
Pre-Pasteurization System and Pump	3	2	100	gpm/ pump	432,000	288,000	gpd	O&M Manual
Non-Potable Water for Pre-Pasteurization	3	2	270	gpm/ HEX	810	540	gpm	Vendor
Anaerobic Digester	4	3	1.5[4]	MG	456,000[5]	342,000[5]	gpd	Class B Rqmt
Anaerobic Digester	4	3	140	ppd VS/kcf	128,000	96,000	ppd VS	B&V Standard
Digested Sludge Transfer Pump	8[6]	3	250	gpm/ pump	1,440,000	1,080,000	gpd	O&M Manual
Digested Sludge EQ Tank (DSET)[7]	1	1	202	gpm	290,880	290,880	gpd	O&M Manual
Dewatering Centrifuge Feed Pump	3	2	200	gpm	864,000	576,000	gpd	LRPR
Dewatering Centrifuges	3	2	4,700	pph/ unit	338,400	225,600	ppd	LRPR

[1] 2 units out of service. Units can be brought on line if needed; 3 units in service all considered to be "duty" units.
[2] 4 units out of service (1 duty/1 spare for each GST out of service)
[3] Maximum of 3 pumps in operation (1 per train, 3 trains)
[4] Volume excludes cone
[5] Based on 15 day SRT for Class B (40 CFR Part 503)
[6] Maximum of 4 pumps in operation (1 per train, 4 trains)
[7] Unit capacity calculated using 80 min detention time in the EQ tank

3.2 PROCESS/EQUIPMENT LIMITATIONS

The existing treatment equipment has duty and standby capacity for most treatment processes. Exceptions include the GSTs and the DSET.

The plant has five gravity thickeners, of which three are operational (GST 1, GST 3, and GST5). Based on the O&M manual, GST4 and GST5 were intended to be used to backup other functions. GST4 was identified as the backup for thickeners GST1 through GST3, providing three duty plus one spare GST. GST4 was also described as providing storage for WAS/secondary scum during normal operation. GST5 was identified to act as a storage tank for the dewatering centrifuges centrate prior to pumping back to the dewatering centrate storage tanks. With GST2 and GST4 permanently out of service, the backup functions provided by GST4 and GST5 are no longer available.

While not identified in Table 3-2, the non-potable water from the plant effluent water system limits performance of the pre-pasteurization/digestion system. The pre-pasteurization system uses effluent water to cool the treated sludge prior to anaerobic digestion, to a target temperature of 98 to 103 ^{o}C. During an investigation conducted in 2013, the effluent water system did not have adequate flow to support all competing uses, limiting the flow to the pre-pasteurization cooling heat exchangers. At the time of this TM, plant staff are investigating solutions for providing the necessary cooling water to the pre-pasteurization system. According to plant staff, the pre-pasteurization system is currently limited to a flow of 60 gpm per train, based on several factors including availability of plant cooling water. At the 60 gpm limit, the pre-pasteurization system capacity corresponds to a plant influent flow of approximately 28 mgd at maximum month conditions (36 mgd at average conditions).

3.3 SYSTEM CAPACITY SUMMARY

The capacity for the existing biosolids treatment system was estimated based on solids projections listed in Table 2-2 and the unit capacity information presented in Table 3-2. As shown in the figure, all of the existing processes have adequate capacity to support influent loads through 2030, using the O&M recommended duty/spare configuration, based on the LRPR influent flow projections. It should be noted that the GST capacity shown in Figure 3-2 reflects three GSTs in service, based on the concept that one of the two remaining out of service GSTs can be brought back into service if needed. Many of the processes, with the exception of pre-pasteurization, are expected to have adequate capacity to support influent loads through the 54 mgd design condition identified in the LRPR.

The GST capacity limit is based on providing one spare GST. If one of the operational GSTs is considered a “spare” unit, and only two duty GSTs are available, the influent plant flow is limited to 37 mgd, which does not meet the 2030 or design influent flow requirements. If the plant staff are comfortable operating without a spare GST, the capacity increases to 56 mgd.

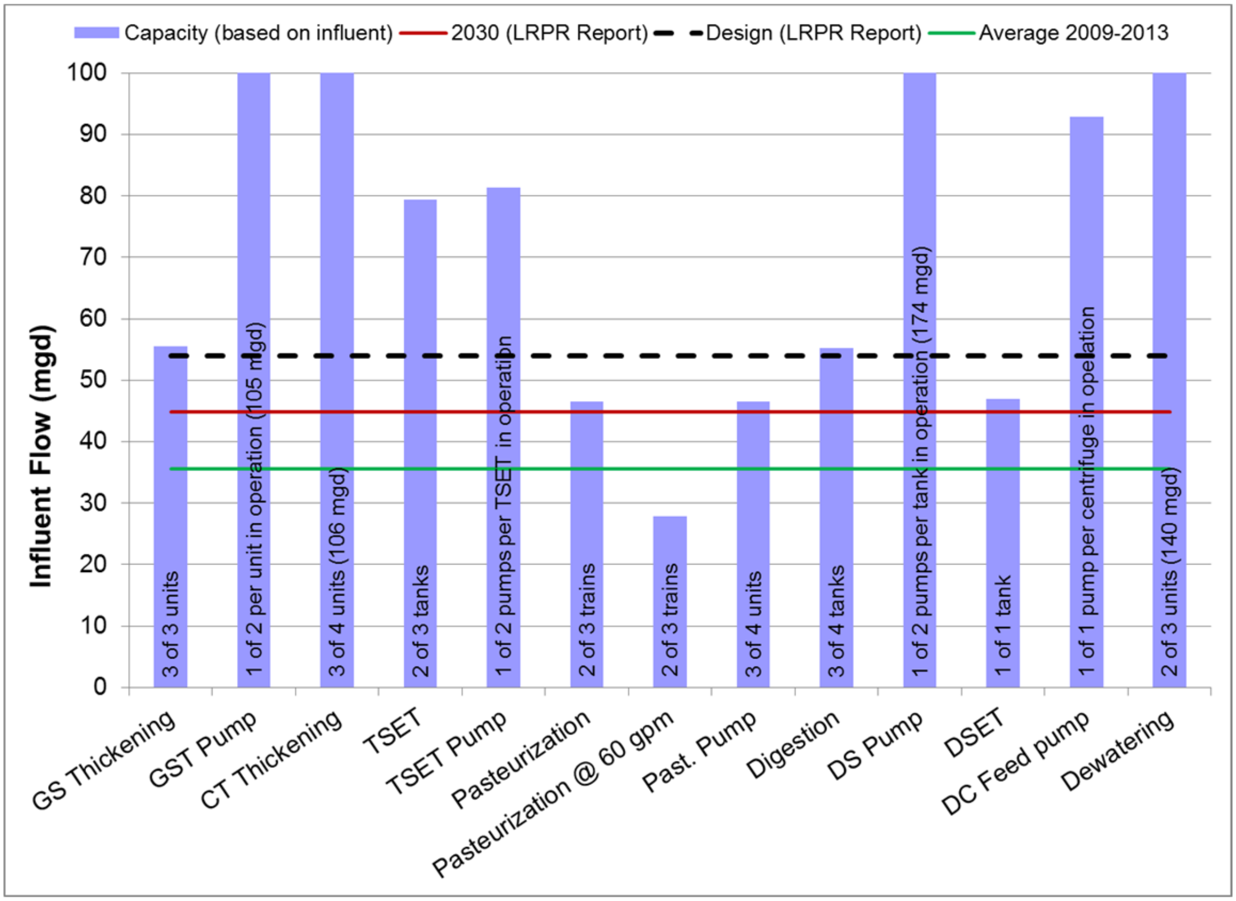

Figure 3-2. System Capacity Summary

While most of the processes are expected to have adequate capacity to support influent loads through 2030 and many of the processes should have capacity through the planning period, the existing equipment is expected to need upgrades and/or replacement as a result of age and wear. Typically, mechanical equipment is expected to have a life of approximately 20 years, although the life can be extended through rebuilds and refurbishment. Concrete structures (digester tanks, buildings, etc.) can have useful lives of up to 50 years.

Processes that may need capacity expansions to support the 2030 or design influent flows (44.9 mgd and 54 mgd, respectively) include gravity thickening, pre-pasteurization and anaerobic digestion.

4 Optimization of Existing Equipment

4.1 OPERATIONAL MODIFICATIONS

The plant primary sludge concentration (0.22 percent TS on average) is much lower than the typical range of 1 percent to 3 percent TS. While the downstream gravity thickeners perform well, thickening the combined primary and tertiary solids to 4.0 percent TS, the low primary solids concentration (and the resulting high hydraulic load on the GSTs) limits the GST capacity. Increasing the primary solids concentration allows the GSTs to operate at the solids loading limit, rather than the hydraulic loading limit. Based on the plant historical data, increasing the primary solids concentration from 0.22 to 1 percent TS will increase the duty GST capacity (2 GSTs) from a plant influent flow of 34 mgd to 44 mgd, respectively. Higher solids concentrations can often be achieved by increasing primary clarifier sludge blankets (within limits) and/or reducing frequency or duration of primary sludge removal.

As shown in Table 3-1, the anaerobic digesters are underloaded as compared to their design capacity. Consequently, plant staff may consider taking each digester tank off line every five years to clean, inspect and maintain. This will extend the life of the existing digester equipment and covers and should have minimal impact on performance.

Previous investigations into the pre-pasteurization heat exchangers indicated that regular cleaning of the sludge side and hot water side will maximize heating and cooling efficiency of pre-pasteurization system. Required cleaning frequency for the various pre-pasteurization can be established using a “baseline” clean performance and tracking heat exchanger performance.

4.1.1 Plant Energy Use

An evaluation was performed of the energy use and recovery for the existing treatment system using E-Sankey diagrams, which provide information for the energy contained in the raw influent and solids, electricity and fuel use in the buildings or processes, and fuel generation (in the form of biogas). The results are shown for average current and future conditions in Figure 4-1 and Figure 4-2. In the E-Sankey diagrams, the width of the line indicates quantity, allowing a quick visual comparison of energy use and production among processes. For example, in Figure 4-1, which represents the average annual condition, the electricity used by the biological reactor basins is 37,870 kWh/day as compared to the electricity used by the thickening centrifuges at 7,332 kWh/day. Consequently, the electricity line to the biological reactor basins is approximately five times wider than the line to the thickening centrifuges. As shown in Figure 4-1, approximately half of the total fuel use is for building heat (151,480 MJ/day), with the remainder being used in the pre-pasteurization system (173,517 MJ/day). Fuel is supplied through a combination of biogas (212,158 MJ/day) and purchased natural gas (194,088 MJ/day). It should be noted that fuel and energy usage varies by season and winter conditions will require more purchased fuel than average conditions.

As shown in Figure 4-2, increased raw influent flow increases energy requirements for most of the end uses. A significant exception to this is the building heat requirement, which is expected to remain relatively stable regardless of plant influent flow. As shown in Figure 4-2, the building heat energy requirement remains the same as in current conditions. Consequently, while the pre-pasteurization energy requirement increases by 26 percent, the increase is accommodated by the increased biogas production expected at higher influent flows and loads, resulting in an increase in purchased natural gas of less than 1 percent.

Process modifications that increase solids capture in the primary clarifiers (such as chemically enhanced primary treatment or CEPT) or increase biogas production (such as thermophilic digestion, thermal hydrolysis pre-treatment, or digestion of high strength waste), can have a large impact on plant energy use. Other biosolids modifications to consider that will have less significant impacts include replacing digester mixing with low energy mixers or using a lower energy thickening option in place of centrifuges, such as rotary drum thickeners or gravity belt thickeners. However, options to reduce energy consumption need to be reviewed in conjunction with their impact on process performance, to avoid “unintended consequences”. As an example, replacing thickening centrifuges with an alternate thickening technology may reduce power requirements, but may also result in lower thickened solids concentrations than the current 8 percent from the centrifuges, which will impact pre-pasteurization and digester capacities.

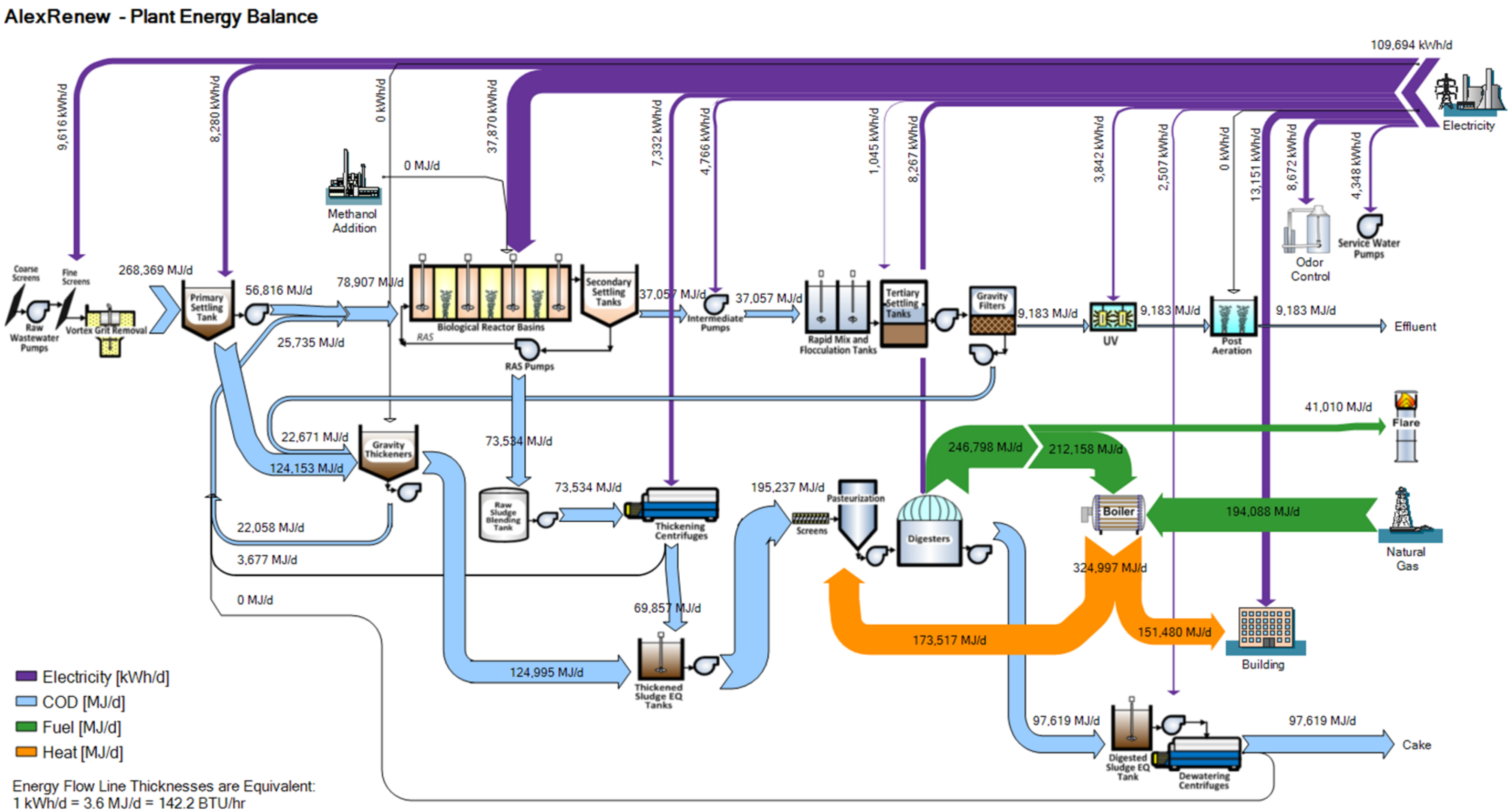

Figure 4-1. E-Sankey Current Average Annual Conditions

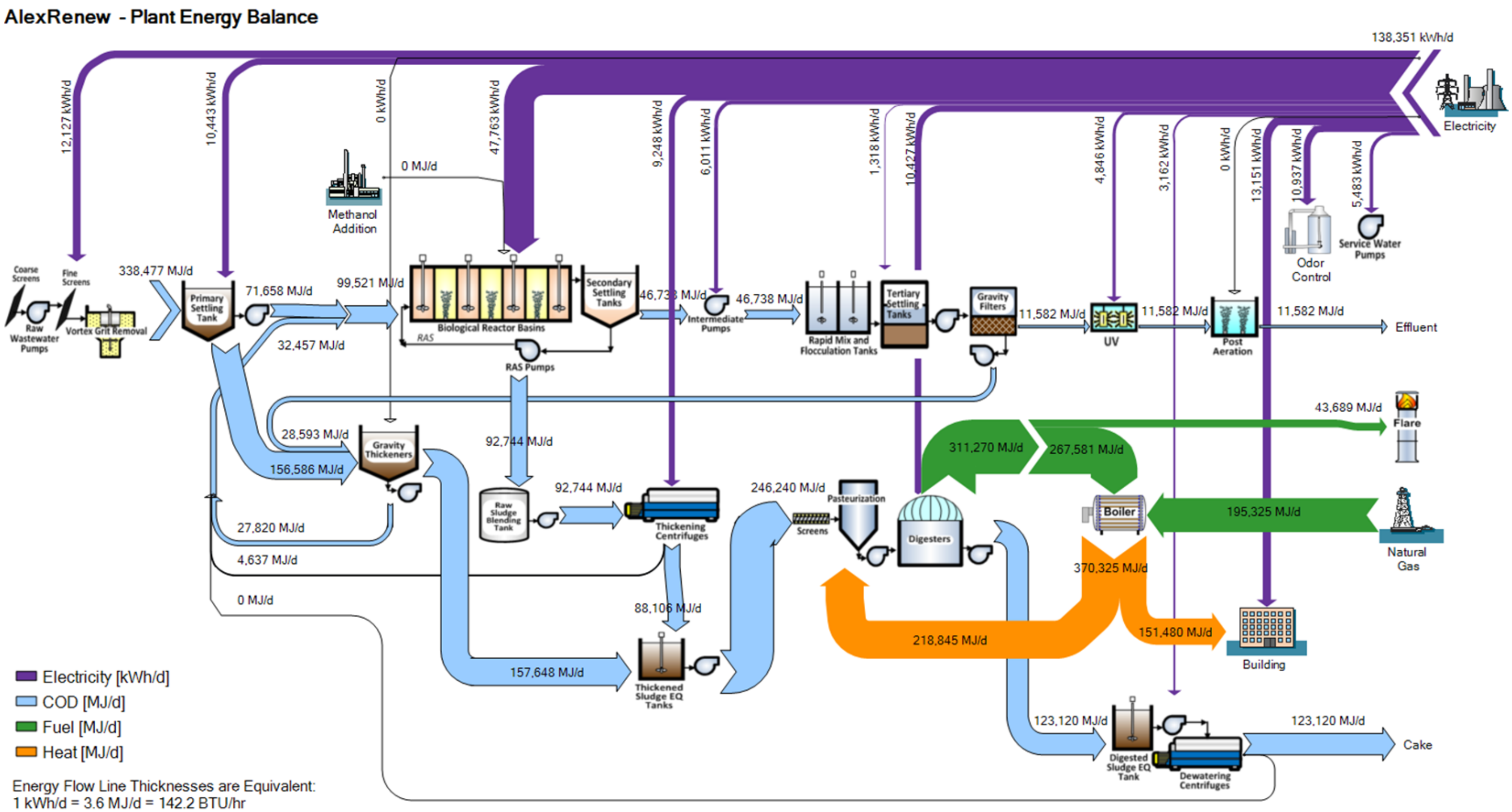

Figure 4-2. E-Sankey Future (2030) Average Conditions

4.2 EQUIPMENT MODIFICATIONS

As discussed in Section 3, the existing gravity thickening has capacity limitations. Two of the five GSTs are permanently out of service, limiting capacity. The thickening capacity for primary and tertiary solids can be expanded by repairing/rehabilitating the out of service GSTs or by replacing the existing GSTs with mechanical thickening equipment, such as gravity belt thickeners, rotary drum thickeners, or thickening centrifuges. Since thickening equipment capacity is based on both hydraulic and solids loading rates, increasing the primary sludge concentration from the historical value of approximately 0.3 percent TS to 1 percent or higher will reduce the required thickening capacity. The capability to operate the primary clarifiers at a higher solids concentration (and potentially deeper sludge blanket) should be investigated to determine if primary clarifier/primary sludge equipment, including clarifier mechanisms, primary sludge pumps, and piping, can support higher solids concentrations in the primary sludge.

As discussed in Section 3.2, the plant effluent water system is impacting the pre-pasteurization cooling capability during summer months, resulting in higher than desired temperatures in the anaerobic digesters and subsequent reductions in digester performance. The plant staff are investigating options to address cooling water flow to the pre-pasteurization system.

5 Summary

The existing plant processes have capacity to support plant growth through 2030 (44.9 mgd). To meet the design condition (54 mgd), expansions are also expected to be required for pre-pasteurization. At the 54 mgd condition, GST and anaerobic digestion will be at capacity. The GST capacity evaluation is based on operating three GSTs, and the concept that one of the out of service units can be brought back into service rapidly. The pre-pasteurization capacity is based on the vendor rated flows of 100 gpm per train. If the flows cannot be increased above the current 60 gpm per train, pre-pasteurization capacity is limited to approximately 28 mgd at maximum month conditions.

Operational modification recommendations include investigating increasing primary solids concentrations to reduce hydraulic loading rates on the GSTs, establishing a cleaning frequency requirement for the pre-pasteurization heat exchangers, and establishing a digester cleaning/maintenance schedule to extend digester equipment life.

The processes with significant energy consumption include the biological reactor basins, pre-pasteurization, and building heat. Processes that increase biogas production, including CEPT, enhanced digestion (thermophilic digestion or thermal hydrolysis), or digestion of high strength waste, will reduce the purchased natural gas requirement. Other biosolids modifications to consider that will have less significant impacts include replacing digester mixing with low energy mixers or using a lower energy thickening option in place of centrifuges.

Appendix

The capacity of the AlexRenew plant was evaluated based on mainstream Anammox treatment (without CEPT). The evaluation used solids production estimates developed by CH2M-Hill, provided by AlexRenew staff. The Anammox solids estimates were limited to current flows at average annual conditions. To estimate solids production at maximum month conditions, the historical maximum month to average annual solids production ratios were applied to the average annual solids production values. The estimated solids quantities for mainstream Anammox treatment are presented in Table A-1.

Table A-1. Estimated Solids Production with Mainstream Anammox Treatment (Without CEPT) (2013 Plant Flow)

PARAMETER	UNIT	AVERAGE ANNUAL CONDITIONS	MAXIMUM MONTH CONDITIONS[1]
Flow	mgd	35.6	35.6
Primary solids	ppd lb/MG	62,700 1,761	94,060 2,642
Waste Activated Sludge	ppd lb/MG	26,490 744	31,520 885
Tertiary Solids	ppd lb/MG	8,400 236	6,640 186
Total Solids	ppd lb/MG	97,590 2,741	132,210 3,714

[1]Maximum month conditions calculated by Black & Veatch based on plant historical maximum month to average annual ratio of 1.5 (primary solids), 1.19 (waste activated solids), and 0.79 (tertiary solids).

Solids projections were developed based on applying the unit solids production rates listed in Table A-1 to future flow conditions. The estimated unit process capacities are shown in Figure A-1. As shown in Table A-1, the mainstream Anammox projections indicate higher primary solids quantities than have been experienced historically, which increase solids loadings on all processes that treat primary solids (gravity thickening, pre-pasteurization, digestion, and dewatering). The corresponding capacities, based on plant influent flow, are consequently reduced. Based on Anammox related solids production projections, the two pre-pasteurization duty trains will not meet current pre-pasteurization load requirements and gravity thickening capacity will be exceeded at the 40 mgd influent flow condition.

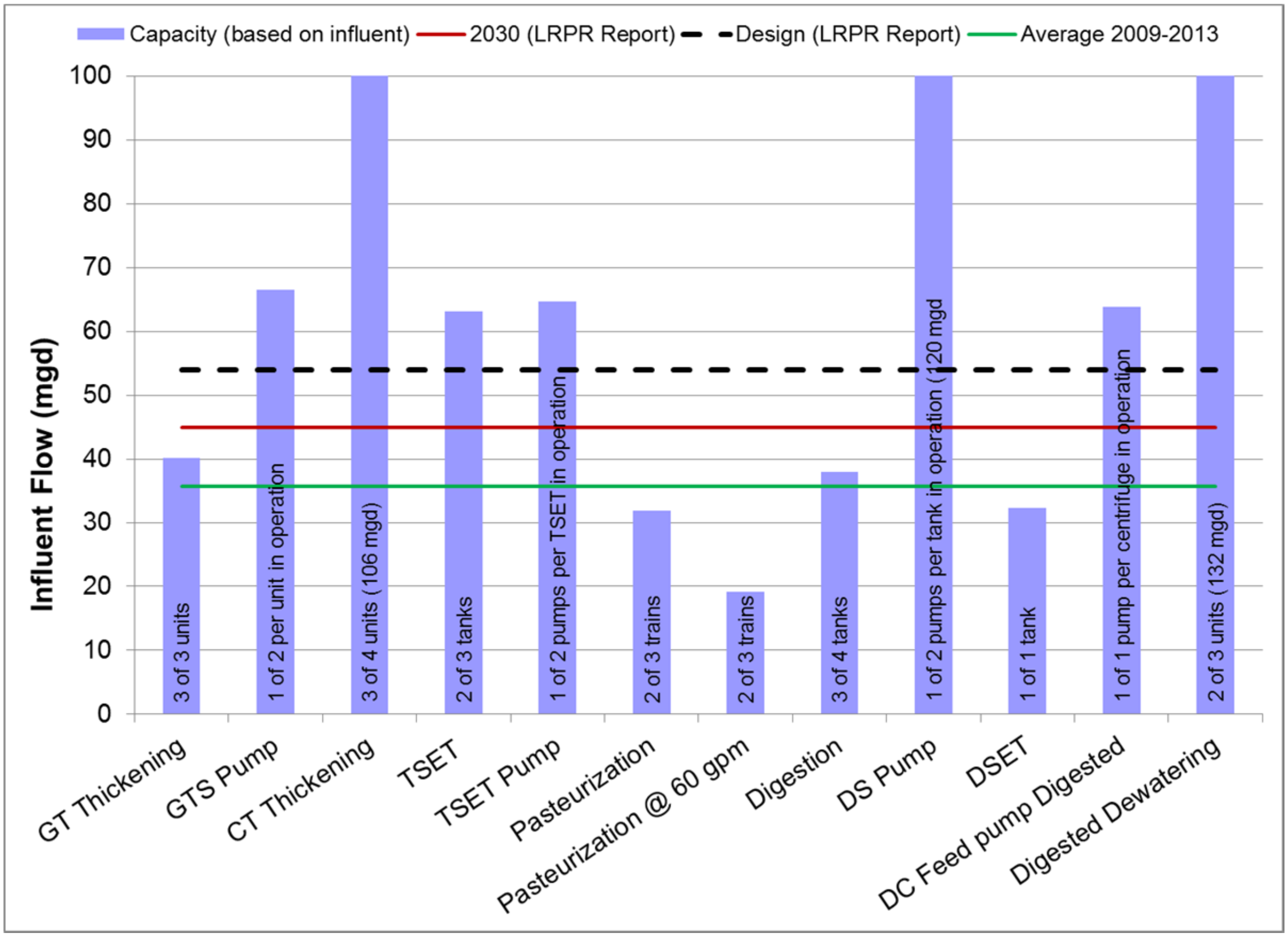

Figure A-1. System Capacity Summary with Mainstream Anammox Treatment

Final Report

Solids Handling and Energy Optimization Update to the Long Range Plan

Alexandria Renew Enterprises

January 2017

FINAL

Solids Handling and Energy Optimization Update to the Long Range Plan

Prepared for

Alexandria Renew Enterprises

January 2017

Executive Summary

In response to stringent nutrient removal regulations enacted by the Commonwealth of Virginia in 2006, AlexRenew underwent a comprehensive long range planning process. The long range planning effort was intended to consider immediate needs, as well as future drivers and AlexRenew's organization goals, in order to develop an implementation strategy through 2030. The planning process took place in 2007 and 2008 and, at that time, drivers included new lower total nitrogen (TN) effluent limits as well as opportunities presented by emerging technologies to increase efficiencies and reduce operating costs. The Long Range Planning Report (LRPR) (CH2M, May 2009) summarized the planning process and resulting strategy. AlexRenew implemented selected liquids treatment projects as part of the State-of-the-Art Nitrogen Upgrade Program (SANUP), which included the following improvements:

- Additional pumping and storage capacity for supplemental carbon and also increased flexibility to accommodate different sources of carbon (SANUP Package A)
- Centrate pretreatment (CPT) facility to reduce the nitrogen loading to the secondary treatment process (SANUP Package B)
- Nutrient management facility (with provisions for a future wet weather pump station) to reduce the peak diurnal nitrogen mass loadings to the secondary treatment process (SANUP Package C)
- Additional biological reactor volume to increase the removal of nitrogen (SANUP Package D)

In addition to the SANUP improvements, AlexRenew implemented the Anammox process in the mainstream biological system in order to take advantage of advances in nutrient removal technology. AlexRenew also constructed a new reclaimed water system to promote beneficial reuse of treated plant effluent and is currently upgrading the ultraviolet (UV) disinfection system and process air blowers.

Update to the Long Range Plan

The 2009 LRPR included recommendations for future projects, including improvements to the solids handling system, which could be triggered by future conditions. However, solids improvements were not enacted as part of the SANUP improvements. In 2016, with most of the liquids treatment process upgrades completed, AlexRenew decided to update the Long Range Plan in order to determine the next set of upgrades at the facility, focusing on solids handling and energy optimization.

The planning process in 2016 was similar to the process in 2008, where a workshop-based approach encouraged participation and buy-in from all levels of the AlexRenew organization. Figure ES-1 illustrates the adopted planning steps. The planning horizon in 2016 was extended from 2030 (2008 effort) to 2040, with consideration of an assumed build-out condition in 2060.

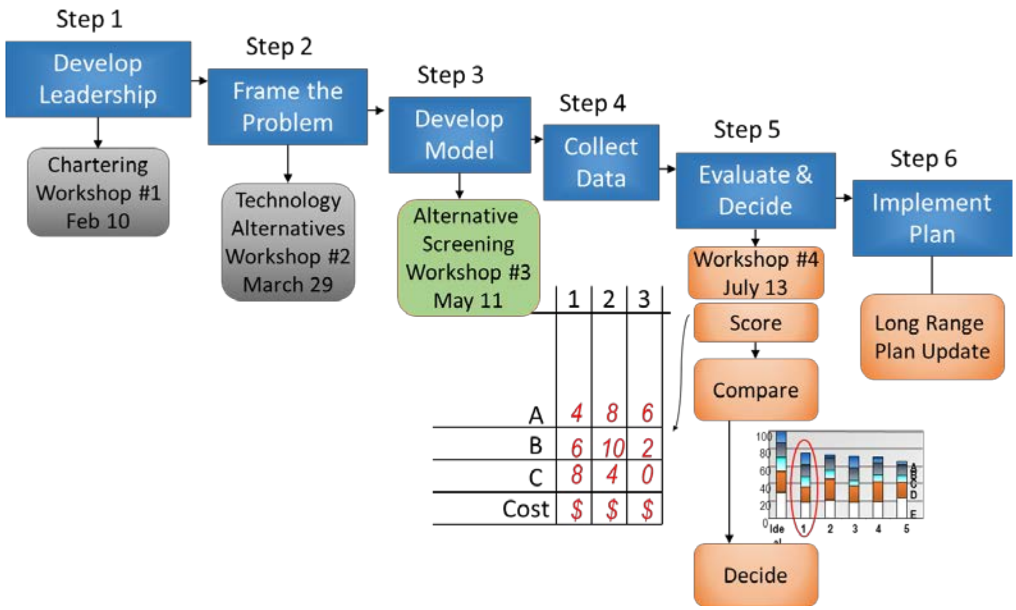

Figure ES-1. 2016 Long Range Planning Process

The project team developed new boundary conditions using the possible future nutrient limits established in the original 2008 LRPR, AlexRenew's Board 2040 vision, and an assessment of the drivers and opportunities on the planning horizon (2040). Table ES-1 summarizes the boundary conditions.

TABLE ES-1
Boundary Conditions for 2016 Long Range Planning at AlexRenew

Boundary Condition	Elements
Most Restrictive Limits (2040)	• Ban on land application of biosolids and/or potentially all land-based uses of biosolids. • Limits on nutrient effluent discharge concentrations down to LOT levels: – TN = 1 mg/L – TP = 0.01 mg/L • Monitoring and limits on microconstituents in the biosolids and the liquids • GHG caps
Sustainable Practices	• Trend towards energy neutrality • Recover resources (water, energy, nutrients) • No net increase in air emissions onsite • Manage risk associated with biosolids use/disposal • Reclaimed water – develop partnerships to use 5 MGD capacity • Site constraints – Available footprint at WRRF is limited for future development (none on West Plant Site)
Board Directives/Community Engagement	• Support Board 2040 vision and outcomes • Partner with supportive developers, such as Carlyle Partners • Focus on local community stewardship – solutions to enable: – City to grow – No net increase in odor/air emissions/light/noise/traffic – Remain neutral on visual impacts of future additional facilities compared with existing

Current Conditions and Basis of Design

As part of the planning process, the project team took a comprehensive look at all the plant's unit processes in order to identify areas where changes or upgrades could be implemented in an integrated fashion. New basis of design conditions were developed using updated facility influent flow and loading data, as well as updated growth projections from the City of Alexandria and Fairfax County. The solids production estimates were updated based on current facility operations, which include the recently completed SANUP upgrades.

Development of Technology Pathways to an Envisioned Future

To manage the inherent uncertainty of predicting conditions in 2040, the project team identified a series of plausible future scenarios and different technology pathways corresponding to the planning horizon. This included collectively generating a framework for the envisioned future towards which the pathways would lead. Figure ES-2 illustrates the interrelationship between three concepts:

1. Where we want to go: The envisioned future
2. How we know we have arrived: Technology attributes
3. What will get us there: Technology pathways

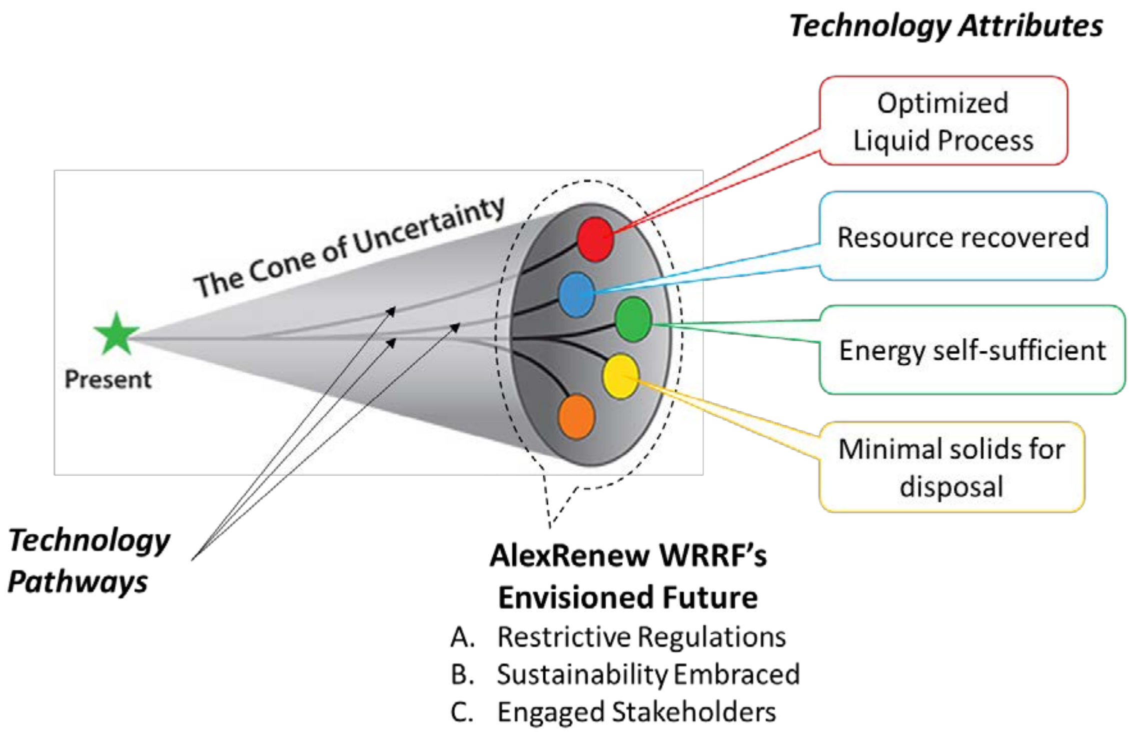

Figure ES-2. Technology Pathways to the Envisioned Future

The project team then evaluated established, innovative, and embryonic solids handling technologies and assembled a number of pathways that AlexRenew could implement in the future. The project team scored the pathways using an updated version AlexRenew's custom decision model, originally developed for the 2008 planning process. Amongst the four different alternatives considered, Anaerobic Digestion with Thermal Conversion of Organics and Waste Activated Sludge Conditioning received the highest score. Figure ES-3 illustrates the process.

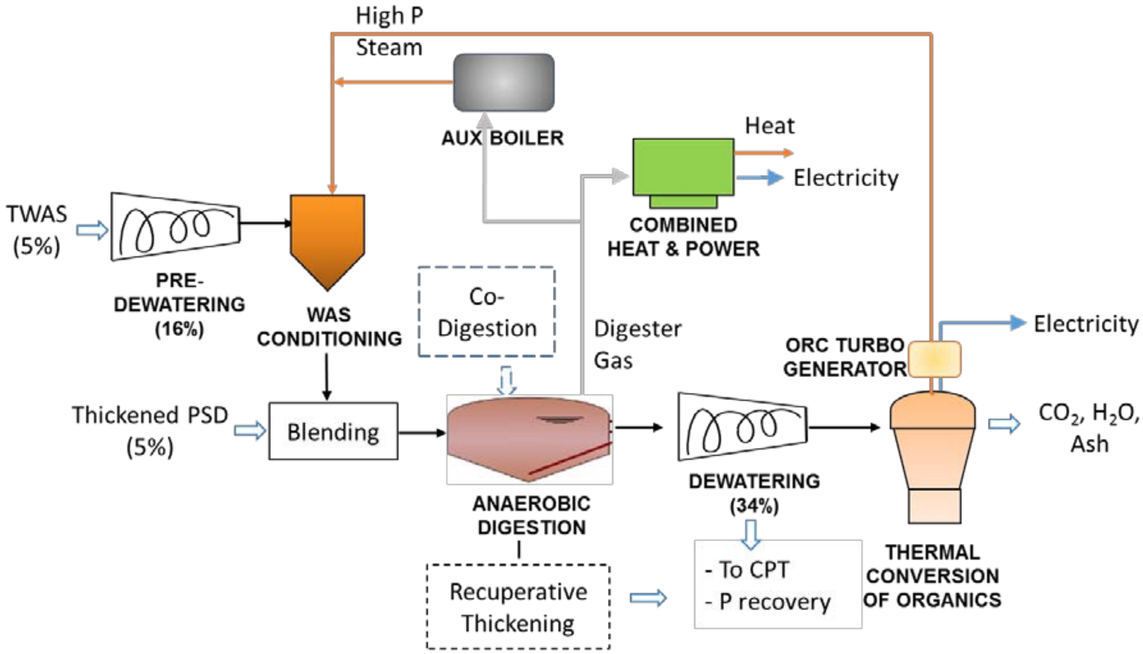

Figure ES-3. Highest Scoring Technology Pathway

The technology pathway exercise yielded the following conclusions:

- Anaerobic digestion provides benefits in energy recovery and solids reduction, and therefore should remain a core technology at AlexRenew either on its own or as part of a combined pathway.
- Thermal conversion of organics (TCO), in combination with combined heat and power (CHP) production using digester gas, recovers approximately 50 percent more energy (as electricity and available heat) than drying.
- TCO significantly reduces the final product (approximately 60 percent reduction compared to drying).
- Thermal hydrolysis of Waste Activated Sludge (WAS) increases biogas generation in the anaerobic digestion process by 7 percent, compared to digestion of sludge that has not been pre-treated. If thermal hydrolysis is applied to the digested sludge, biogas generation is increased by 15 percent.
- All technologies studied are viable at AlexRenew and can be accommodated in the existing footprint.

The team also discussed some of the potential barriers to short-term implementation of some of the pathway components, which included:

- TCO had the highest score, but implementation of the reference technology (fluidized bed incineration) requires air permitting and has a very high capital cost.
- The reference technology for sludge conditioning, thermal hydrolysis, requires installation of a high-pressure steam system. This system may negatively affect health and safety onsite. In addition, the high-pressure steam system needs to be operated by specially trained and certified personnel, which AlexRenew would need to hire or contract out. Both options would increase operational costs.
- Drying technology does not produce as much energy as TCO. While it reduces the final product volume, it is still considerable and needs marketing in order to be distributed commercially as a fertilizer or soil amendment.

- Implementation of CHP is not cost-effective under current conditions. However, if biogas production is boosted by sludge conditioning and/or co-digestion, the economics may become more favorable.

The recommended approach is to keep all the technologies as viable future alternatives in the long-term and continue to evaluate their applicability at AlexRenew in the short-term.

Phased Implementation Plan The alternatives developed and scored as part of the 2016 long range planning process represent the technology pathways to an envisioned long-term future for AlexRenew. However, in the absence of an immediate driver or trigger, AlexRenew requested a menu of options that can be phased to prepare for the future as it unfolds. As a result, the next step in the planning process was to develop short-term, medium-term and long-term projects that AlexRenew can prioritize and implement as needs arise, and adapt as needed if critical priorities change. Figure ES-4 illustrates three planning horizons considered in this implementation plan: short-term (5 - 10 years); medium-term (10 - 20 years); and long-term (20 - 40 years).

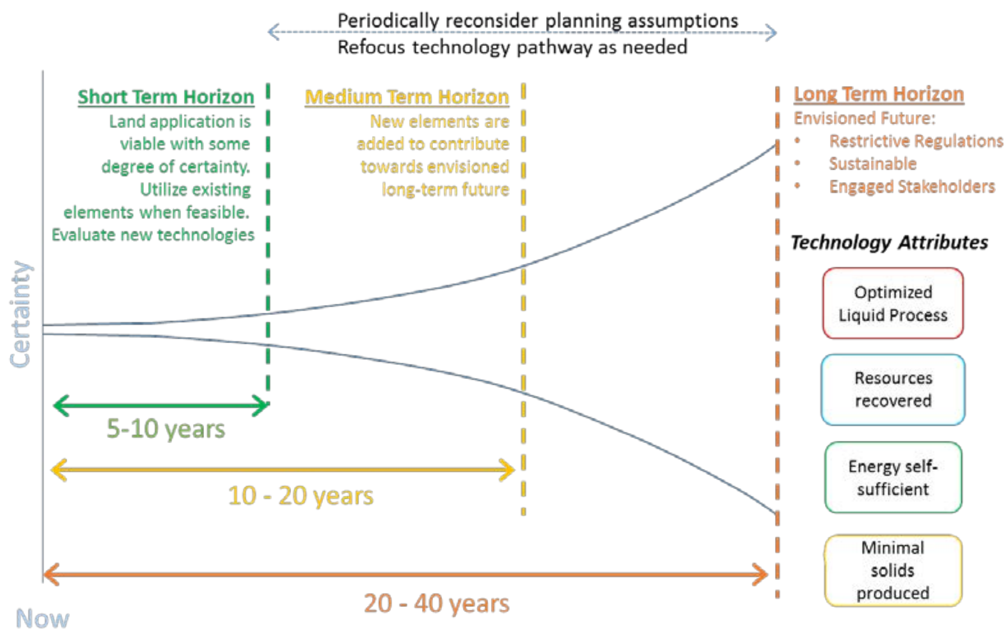

Figure ES-4. AlexRenew Water Resources Recovery Facility Planning Horizons

The project team developed multiple approaches to enable AlexRenew to adapt to the future as it unfolds in accordance with their organizational goals and values. All projects are summarized in Tables ES-2, ES-3 and ES-4. A more detailed description of each project is included in Section 4.3.

TABLE ES-2
Summary of Short-Term Projects

Project Number	Project or Study
S.1a	Pre-Pasteurization Improvements
S.2b	Pre-Pasteurization Business Case Evaluation
S.2	Gravity Thickening Evaluation
S.3	Digestion Evaluation
S.4	Solids Handling Building L Evaluation
S.5	Preliminary Treatment Evaluation
S.6	Primary Treatment Evaluation
S.7	Primary Effluent Pump Station

TABLE ES-3
Summary of Medium-Term Projects

Project Number	Project or Study
M.1	Combined Heat and Power (Study/Implement)
M.2	Co-Digestion/FOG (Study/Implement)
M.3	Biological Phosphorus Removal and Recovery (Study/Implement)
M.4	Strategies for Land Application Restriction/Ban
M.5	Sludge Conditioning Demonstration Study
M.6	Onsite Energy Use/HVAC Evaluation

TABLE ES-4
Summary of Potential Long-Term Projects

Project Number	Project or Study
L.1	Implement Thermal Organics Conversion
L.2	Implement Drying
L.3	Implement Sludge Conditioning
L.3	Implement Other Emerging Resource Recovery Technologies

Future Considerations

AlexRenew is well positioned to evolve and adapt in order to face yet fully defined future challenges and capitalize on opportunities as the organization continues its journey as a utility of the future. The planning process identified several issues that could change the direction and/or components of the recommended long range plan, as such should be closely monitored by AlexRenew:

- Changes in flows and/or loads
- Changes in regulatory requirements for biosolids management
- Regulation of microconstituents in the liquids and/or in the biosolids flow streams
- Regulation of greenhouse gas (GHG) emissions

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Acronyms and Abbreviations

%	percent
>	greater than
°F	degrees Fahrenheit
AADF	Annual Average Design Conditions
AD	Anaerobic Digestion
AFD	Adjustable Frequency Drive
AlexRenew	Alexandria Renew Enterprises
BAC	Biological Activated Carbon
BOA	Basic Ordering Agreement
BOD	Biological Oxygen Demand
BOD_5	Biochemical Oxygen Demand – 5-day test
BRB	Biological Reactor Basins
CEPT	Chemically Enhanced Primary Treatment
cfm	cubic feet per meter
CFR	*Code of Federal Regulations*
CHP	combined heat and power
City	City of Alexandria
CPT	Centrate Pretreatment
DS	Digested Sludge
FOG	Fats, Oils and Grease
ft	Foot or Feet
gal	Gallon
GHG	greenhouse gas
gpc	gallons per capita
gpd	Gallons per day
gph	Gallons per Hour
gpm	Gallons per Minute
HEX	heat exchanger
HVAC	Heating, Ventilation and Air Conditioning
I&C	Instrumentation and Control
IFAS	Integrated Fixed-film Activated Sludge
LED	Light Emitting Device
lbs/day	pounds per day
LOT	Limit of Technology
LRPR	Long-range Planning Report
MBTU	one thousand British Thermal Units
mg	Milligram
mg/kg	milligram per kilogram
mg/L	Milligram per Liter
MG	Million Gallons
MGD	Million gallons per day
mL	milliliter

MLSS	Mixed Liquor Suspended Solids
MW	megawatt
N:P	Nitrogen to Phosphate ratio
N/A	not applicable
NH_3	Ammonia
NH3-N	Ammonia Nitrogen
nm	nanometer
NMF	Nutrient Management Facility
O&M	Operations and Maintenance
OP	orthophosphate
ORC	Organic-Rankine Cycle
PCB	Polychlorinated Biphenyl
PEPS	Primary Effluent Pump Station
PF	peaking factor
PLC	Programmable Logic Controller
PSD	Primary Sludge
RAS	Return Activated Sludge
RW	reclaimed water
SANUP	State-of-the-Art Nitrogen Upgrade Program
sf	Square foot
SOA	state of the art
SRT	Solids Retention Time
SWD	Side Water Depth
TCO	thermal conversion of organics
TKN	Total Kjeldahl Nitrogen
TN	Total Nitrogen
TP	Total Phosphorus
TS	Total Solids
TSD	Tertiary Sludge
TSS	Total Suspended Solids
TWAS	Thickened Waste Activated Sludge
UV	Ultraviolet
VSS	Volatile Suspended Solids
WAS	Waste Activated Sludge
WRRF	Water Resources Recovery Facility

SECTION 1

Purpose and Background

The purpose of the Solids Handling and Energy Optimization Update is to update and revise, as needed, the original Long Range Planning Report (LRPR) (CH2M, May 2009), developed for Alexandria Renew Enterprises (AlexRenew). The impetus for this project was a need to revisit the biosolids solutions outlined in the Long Range Plan, the need to stay ahead of regulatory drivers, and the opportunity to take advantage of technological advancements to improve the efficiency of the AlexRenew Water Resources Recovery Facility (WRRF).

1.1 Background: 2008 Long Range Plan

The need to upgrade the plant to comply with Enhanced Nutrient Removal limits, set to change in 2011, presented the opportunity to create and implement a comprehensive, long-range planning process that would prepare AlexRenew for the future. The objective of the planning process was to develop a scope of work for the next set of facility upgrades that were in line with AlexRenew's 2030 mission and vision, and balance the different drivers that AlexRenew faced at that time and in the future. An LRPR was produced, summarizing and documenting the planning process and the resulting selected components for implementation (design and construction) to comply with the 2011 regulatory drivers and respond to anticipated challenges through the year 2030.

The main drivers in AlexRenew's decisions regarding the need for upgrade of existing facilities and/or addition of new facilities in the future were identified as follows:

- Regulations, including the 2011 nutrient-removal requirements.
- Future regulations that would likely require further nutrient reduction and removal of microconstituents.
- Limits or bans on land application of biosolids and/or all land-based uses of biosolids.
- Opportunities for application of sustainable practices including beneficial reuse of effluent water and biosolids, as well as contributions to community recreation and education.

These drivers were combined into a set of boundary conditions that guided and framed the decision-making process during the development of the LRPR. Table 1-1 summarizes the boundary conditions that were used.

A six-step decision-making and planning process was used to evaluate technical and process alternatives, develop treatment scenarios, and determine preferred approaches to achieving AlexRenew's vision and goals. Following the thinking-and-learning culture of the AlexRenew organization, the long-range planning process used workshops as a hands-on approach at each phase of the process. The workshops ensured that all participants were engaged, and promoted communication, understanding and contribution in the planning process. An AlexRenew-specific decision matrix criteria tool was developed for screening of process-alternative scenarios, and used to document all technologies considered.

TABLE 1-1
Boundary Conditions for 2009 Long Range Planning at AlexRenew

Boundary Condition	Elements
2030 Most Restrictive Limits and Sustainable Practices	Limits on nutrient effluent discharge concentrations down to LOT levels: • TN = 1 mg/L • TP = 0.01 mg/L
	Limits on the discharge of PCBs and microconstituent removal
	Ban on land application of biosolids and/or potentially all land-based uses of biosolids
	Reuse of plant effluent water for irrigation in city parks (5 MGD between March and November)
2011 Requirements	Limits on nutrient effluent concentrations to take effect in 2011 down to SOA levels: • TN = 3 mg/L • TP = 0.18 mg/L
	Continuing production of Class A Exceptional Quality Biosolids and alternative reuse options to bulk land application

Note:
LOT = Limit of Technology
mg/L = milligram per liter
MGD = million gallons per day
PCB = Polychlorinated Biphenyls
SOA = State of the art
TN = Total Nitrogen
TP = Total Phosphorus

AlexRenew selected a combination of strategies to meet the 2011 boundary conditions. The program, called the State-of-the-Art Nitrogen Upgrade Program (SANUP), provided additional pumping and storage capacity for supplemental carbon, additional biological reactor volume to increase the removal of nitrogen, a nutrient management facility (with a future wet weather pump station) to reduce the peak diurnal nitrogen mass loadings to the Biological Reactor Basins (BRBs), and a Centrate Pretreatment (CPT) facility to reduce the nitrogen loading to the BRBs. Together, these upgrades resulted in a robust nitrogen removal system with enough flexibility to meet the required effluent TN concentration of 3 mg/L at the design annual average flow of 54 MGD.

The plant's existing tertiary settling tanks and filters were designed to meet an effluent concentration TP limit of 0.18 mg/L at the design annual average flow of 54 MGD and therefore no modifications were needed to meet the TP goal for 2011.

The approach selected to meet the 2030 goals for nitrogen, phosphorous, and microconstituent removal was to enhance the existing biological reactor system using Integrated Fixed-film Activated Sludge (IFAS) technology and to use ozone and biologically activated carbon (BAC) adsorption followed by tertiary membranes. The IFAS provides additional biological nitrogen removal below a TN of 3 mg/L. The ozone and BAC processes reduce the nonbiodegradable fraction of the nitrogen in order to meet a (future) TN limit of 1 mg/L. These processes also help remove different types of microconstituents. The tertiary membranes would enhance total phosphorous removal. Because nutrient and microconstituent removal technology was expected to evolve, AlexRenew left open the possibility of selecting different processes if they are proven more beneficial or feasible in the future.

The plant's solids treatment process was designed to produce Class A Exceptional Quality biosolids for land application in the short and intermediate-term. Sludge drying was selected as the reference technology to be implemented in the future, in the event that land application of biosolids is restricted or banned. The dried pellets have a variety of uses, including as soil amendment products and in waste-to-energy applications. However, as there were no immediate biosolids land application restrictions and new technologies are constantly being developed and refined, AlexRenew decided to revisit the final technology selection at a later date.

In addition to the strategies mentioned herein, the Long Range Plan also outlined several future improvements that could be triggered by regulatory or sustainability drivers. These include an upgrade to the Ultraviolet Disinfection (UV) System and water reuse, which were designed and constructed as separate projects from SANUP. Mainstream Anammox, which was not part of the 2009 Long Rang Plan, was also implemented as part of the SANUP nitrogen reduction strategy.

Table 1-2 summarizes the recommended improvements that resulted from the 2009 Long Range Plan. The bolded items were implemented as part of SANUP or subsequent projects.

TABLE 1-2
2009 Long Range Plan – Summary of Completed and Proposed Improvements

Phase	Package	Driver	Improvements	Implemented
Phase 1	***Package A***	***Liquids Treatment – SOA Limits***	***Supplemental Carbon Facility Improvements***	***Yes***
	Package B	***Liquids Treatment – SOA Limits***	***CPT***	***Yes***
		Liquids Treatment – SOA Limits	***Final Effluent Flow Measurement and UV Level Control Gates***	***Yes***
Phase 2	***Package C***	***Liquids Treatment – SOA Limits***	***Nutrient Management Facility (and Future Wet Weather Pump Station)***	***Yes***
Phase 3	***Package D***	***Liquids Treatment – SOA Limits***	***BRB 6***	***Yes***
	Package E	Solids Treatment – Class A	Prepasteurization (4th Train)	No
		Solids Treatment – Class A	Recuperative Thickening	No
Future Improvements Driven by Changes in Effluent Requirements		***Facility Improvement***	***UV Facility – Technology Modifications***	***Yes***
		Sustainable Practice	***Water Reuse***	***Yes***
		Biogas Reuse Opportunity	Cell Lysis	No
		Biogas Reuse Opportunity	Co-Generation Equipment	No
		Biosolids Reuse (No Land Application)	Centrifuge Thickening (to replace Gravity Thickeners)	No
		Biosolids Reuse (No Land Application)	Dryer Facility (including gas treatment compressors)	No
		TN = 1 mg/L	IFAS	No
		TN = 1 mg/L, TP = 0.01 mg/L or microconstituents	Ozone & BAC/Fine Screens/Rapid Mix & Floc/Tertiary Membranes	No
		TN = 1 mg/L, TP = 0.01 mg/L or microconstituents	Demolition of the Administration/Laboratory Building	No

1.2 2016 Planning Process

SANUP items implemented and constructed by 2016 focused primarily on the liquids train of the plant. Improvements to the solids train were deferred. In the intervening years since the LRP was produced, advancements in solids treatment technologies and waning support for land application of biosolids in surrounding jurisdictions has prompted AlexRenew to revisit their solids handling and reuse practices. In addition, AlexRenew's goal of being an industry leader in resource recovery (water, energy, nutrients) has been driver to explore new and innovative technological advances in resource recovery as part of the long-range planning process.

AlexRenew and the City of Alexandria (City) have worked collaboratively to mitigate sewer overflows during wet weather events. The proposed solution, as described in the *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* (CH2M, November 2010) adds new storage for wet weather flows and increases the peak instantaneous flow at the WRRF. Peak flows will be treated through preliminary and primary treatment and then stored in the Nutrient Management Facility (NMF), as capacity is available, to mitigate impacts to secondary and tertiary treatment. Flows that cannot be stored in the NMF will be released at a relocated combined sewer overflow (CSO-004). Existing preliminary and primary treatment facilities will need improvements in order to accommodate the higher flows.

The planning process in 2016 was similar to the process in 2008, where a workshop-based approach encouraged participation and buy-in from various levels of the AlexRenew organization. Figure 1-1 illustrates the adopted planning steps. The planning horizon in 2016 was 2040 (same as in the 2008 plan) with an assumed build-out condition in 2060.

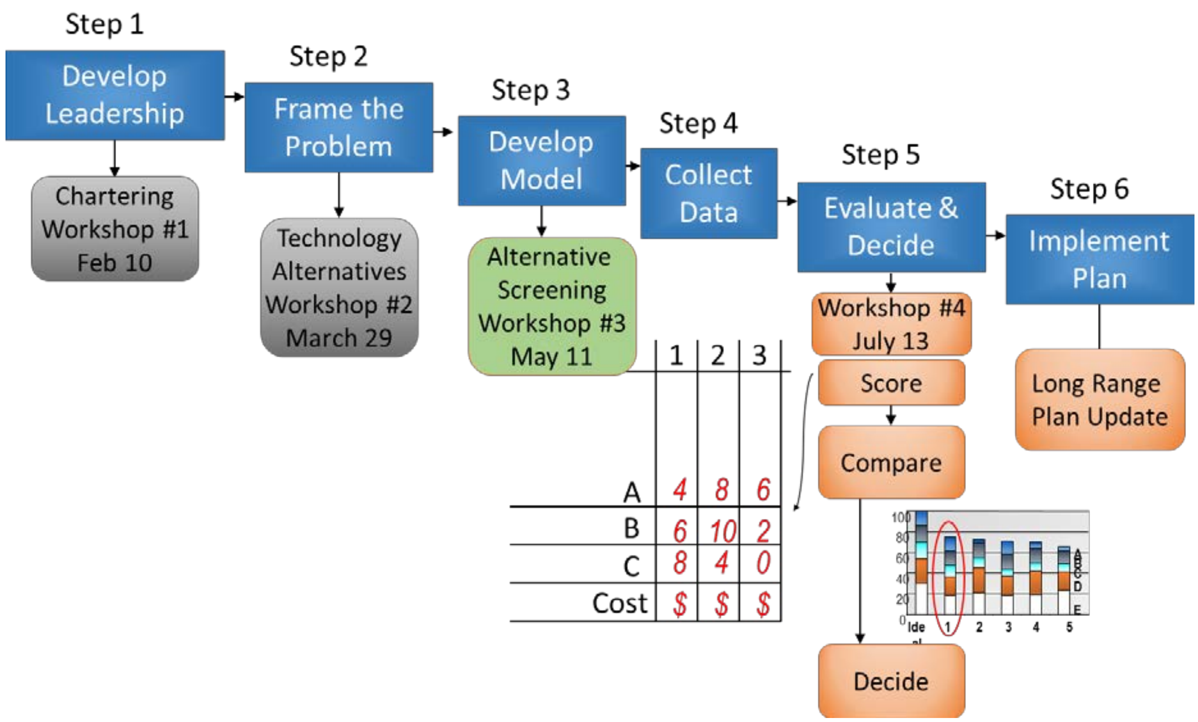


Figure 1-1. 2016 Planning Process

The first step was to review the previous planning documents and understand the current state of the facility, including historical influent flows and loads and system performance to-date. During the chartering workshop, a team exercise was conducted which scanned the planning horizon for future drivers, opportunities and trends. The second workshop focused on reviewing established, innovative and embryonic technologies and developing technology pathways to achieve the envisioned future. At the third workshop, the team screened the pathways and selected alternatives for future consideration. Data was then collected on the selected pathways, including a preliminary flow diagram, equipment sizing, layout, and cost estimates (capital and Operations and Maintenance [O&M]). The data was presented at the fourth workshop, where the alternatives were scored against the decision criteria by AlexRenew staff. The scoring process allowed the project team to understand the advantages and disadvantages of the proposed alternatives. Along the way, the project team identified several short and medium-term projects that AlexRenew could consider for implementation, as needed, in response to internal or external triggers, and could be phased in advance of a more significant upgrade. This approach enables development and maximizes AlexRenew's benefit from evolving technologies. These short and medium-term projects are further described in Section 4 of this Long Range Plan update.

The meeting notes from each of these workshops, including all presentation slides, are included in Appendix A.

1.3 Alignment with AlexRenew's Board 2040 Vision

In recent years, AlexRenew's Board has developed a new vision for the organization with a 2040 horizon:

"AlexRenew's 2040 Vision is to serve as a catalyst and be effectively partnered with all of its watershed stakeholders to:

- Enable Local citizens the opportunity to establish a personal connection with local waterways so that local streams are fishable and swimmable
- Support a healthy and resilient local economy through stable rates, supported by diversifying revenue and maximizing resource recovery
- Create an informed citizenry regarding the importance of water so that water stewardship is achieved through personal organizational actions."

As a part of the 2040 Vision, the Board expects transparency and financial stability. AlexRenew is committed to keeping rates low, leveraging partnerships, as well as meeting infrastructure needs, which include wet weather and wastewater treatment. Meeting these goals require effective planning. The 2040 Vision provided guidance in developing the goals and boundary conditions for the Long Range Plan Update.

1.4 Horizon Scanning: What can we see coming?

Looking towards the future, AlexRenew needs to evaluate how it manages biosolids treatment and disposal, how evolving regulation impacts liquids treatment, and how net energy consumption can be optimized while recovering resources from the treatment process.

1.4.1 Biosolids Regulations

Trends are showing that new regulations on biosolids are forthcoming, at both the Federal and State levels. These regulations are evolving to produce limits that are more stringent on land application of biosolids and the reduction of microconstituents in biosolids. In the Commonwealth of Virginia, citizen groups are lobbying legislators to tighten regulations, particularly around land application.

Restrictions on Land Application

The neighboring state of Maryland has enacted new requirements on land application of biosolids. Beginning in the winter of 2016 to 2017, no biosolids application to agricultural land in Maryland will be allowed during the winter months. In addition, the Phosphorus Site Index is being phased out, and the more restrictive Phosphorus Management Tool will be phased in over the next 7 years based on soil Phosphorus Fertility Index Value. The effect of this regulation is limiting the amount of biosolids that can be applied to the soil based on the phosphorus content of the biosolids in order to prevent over-application of phosphorus in the soil and consequent runoff into the Chesapeake Bay. This limitation will require farmers to supplement the land-applied biosolids with additional nitrogen fertilizer to achieve the desired Nitrogen to Phosphate (N:P) ratio in the soil required for crop growth. This in turn makes the economics of using land-applied biosolids less favorable for farmers.

Combined, these regulations will result in limited availability of land in Maryland for biosolids and will push land appliers to look for sites in Virginia, which will drive up costs. In addition, citizen groups will likely push for similar regulations in Virginia as more “out-of-state” biosolids start coming in. In conclusion, land capacity for biosolids is finite and shrinking, and the outlook for land application in the next 5 years for the Commonwealth of Virginia is uncertain.

Microconstituents

Public awareness and concern over microconstituents has increased in both the Unites States and Europe. Where microconstituents were once not easily quantified by laboratories, testing methods have progressed making these compounds much easier to measure. For this reason, the potential exists for implementation of regulations focused on limiting microconstituents. In the Chesapeake Bay watershed, the next step in nutrient reduction is likely reducing nonpoint sources. Therefore, at the WRRFs (like AlexRenew), it is likely that microconstituents will be regulated before more stringent nutrient limits are imposed.

1.4.2 Liquids Treatment

New liquid treatment technologies allow facilities to remove nitrogen with lower air (that is, electrical power consumption) and supplemental carbon requirements. This in turn provides the opportunity to capture more of the influent carbon and transform it into energy from the biogas generated in the anaerobic digesters. At AlexRenew, Mainstream Anammox is being implemented to reduce aeration requirements and the need for carbon supplementation for nitrogen removal. The carbon will be captured in the primary sludge using ferric chloride and/or polymer in the Primary Clarifiers and this carbon will be redirected to the digesters, where it will be converted to digester gas and potentially to electricity and/or heat. Implementation of Chemically Enhanced Primary Treatment (CEPT) will increase total sludge production by approximately 15 percent.

Another liquid treatment advancement is the implementation of biological phosphorus removal and subsequent recovery using technologies such as Ostara. These technologies intentionally produce struvite, which has beneficial uses as a slow release fertilizer and other commodities.

1.4.3 Energy Optimization

AlexRenew is committed to sustainability and the use of renewable energy sources in its plant operations. Several studies and energy audits of the plant have quantified the plant’s energy usage and developed projects to reduce and optimize energy use. The studies and audits show that combined heat and power (CHP), as well as, maintenance and upgrades to the existing heating, ventilation, and air conditioning (HVAC) systems and real-time electrical power monitoring will help AlexRenew move closer to their goal of energy neutrality. In addition, AlexRenew is committed to reducing the environmental impact of its operations by reducing greenhouse gas (GHG) emissions. This can be achieved by reducing consumption of purchased electricity, which contributes about 80 percent of the current emissions.

1.4.4 Resource Recovery

The resource recovery market is growing, with demand for products derived from wastewater treatment byproducts such as phosphorus, in the form of struvite, leading the growth. Energy by-products (such as, hot water and steam, biodiesel, bio-oil, or biogas) are also important. AlexRenew recognizes that byproducts produced through the plant’s various treatment processes have inherent value that may be monetized if they can be produced in large enough quantities. AlexRenew wants to leverage these potential resources as part of their commitment to sustainability and the environment.

1.5 Boundary Conditions

New boundary conditions were developed using the possible future nutrient limits established in the original LRPR, AlexRenew's Board 2040 vision, and an assessment of the drivers and opportunities on the planning horizon (2040). The boundary conditions are summarized in Table 1-3.

TABLE 1-3
Boundary Conditions for 2016 Long Range Planning at AlexRenew

Boundary Condition	Elements
Most Restrictive Limits (2040)	• Ban on land application of biosolids and/or potentially all land-based uses of biosolids. • Limits on nutrient effluent discharge concentrations down to LOT levels: – TN = 1 mg/L – TP = 0.01 mg/L • Monitoring and limits on microconstituents in the biosolids and the liquids • GHG caps
Sustainable Practices	• Trend towards energy neutrality • Recover resources • No net increase in air emissions onsite • Manage risk associated with biosolids use/disposal • Reclaimed water – develop partnerships to use 5 MGD capacity • Site constraints – Available footprint at WRRF is limited for future development (none on West Plant Site)
Board Directives/Community Engagement	• Support Board 2040 vision and outcomes • Partner with supportive developers, such as Carlyle Partners • Focus on local community stewardship – solutions to enable: – City to grow – No net increase in odor/air emissions/light/noise/traffic – Remain neutral on visual impacts of future additional facilities compared with existing

Current Conditions and Basis of Design

2.1 Flows and Loads: Historic, Current and Projected Design Criteria

2.1.1 Purpose and Methodology

The purpose of studying the historic flows and loads at the AlexRenew WRRF is to determine the design criteria that will guide the evaluation of the proposed future upgrades to the facility. The design criteria has been generated at various occasions in the past, including as part of the Long Range Planning effort in 2007 and again, as part of the *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* in 2009 to 2010. Updating the historical data and design criteria periodically is important because the AlexRenew WRRF influent loadings, in particular, have exhibited high variability from year-to-year as illustrated in Figure 2-1.

The methodology used for evaluating the data and determining the design criteria is as follows:

- Collect and evaluate historical plant data. Determine annual average, maximum month and peak loadings for all parameters: flow, total suspended solids (TSS), Biological Oxygen Demand (BOD), Ammonia (NH_3), Total Kjeldahl Nitrogen (TKN), TP and Biosolids production. Calculate Peaking Factors for maximum month and peak loadings compared to annual average data.
- Collect and evaluate historical population data for the service area.
- Determine per-capita contributions for each of the parameters by dividing the annual average loadings by the population served.
- Use population projections from the service area jurisdictions (the City and Fairfax County), to determine future loading curves to the design year (2040) and to the build-out condition (2060).
- Use the population projections, the per-capita loadings and the peaking factors to determine the projected facility influent flows and loads at the design year (2040) and the build-out condition (2060).

2.1.2 Historical Data and Basis of Design

Figure 2-1 illustrates the historical data from 1992 to present. The data has had a high degree of variability from year-to-year in particular for the TSS and BOD loadings. The annual average flow at AlexRenew has remained relatively stable, with less than 10 percent variation from year-to-year during the period analyzed (with the exception of 2003, which had historical storms). The TSS loadings went up by more than 50 percent between the early 1990s and the mid-2000s but some of this increase may be attributed to changes in influent flow sampling location and methodology. The BOD loadings went up by 20 to 30 percent during this time. Water use during this time was reduced because of new water saving features in plumbing fixtures and appliances. This period also saw an increase in use of industrial-scale food-waste disposal units by hotels and restaurants. These units allow more food waste to be drained down to the sewer and reduce solid waste (garbage) disposal costs for the establishments.

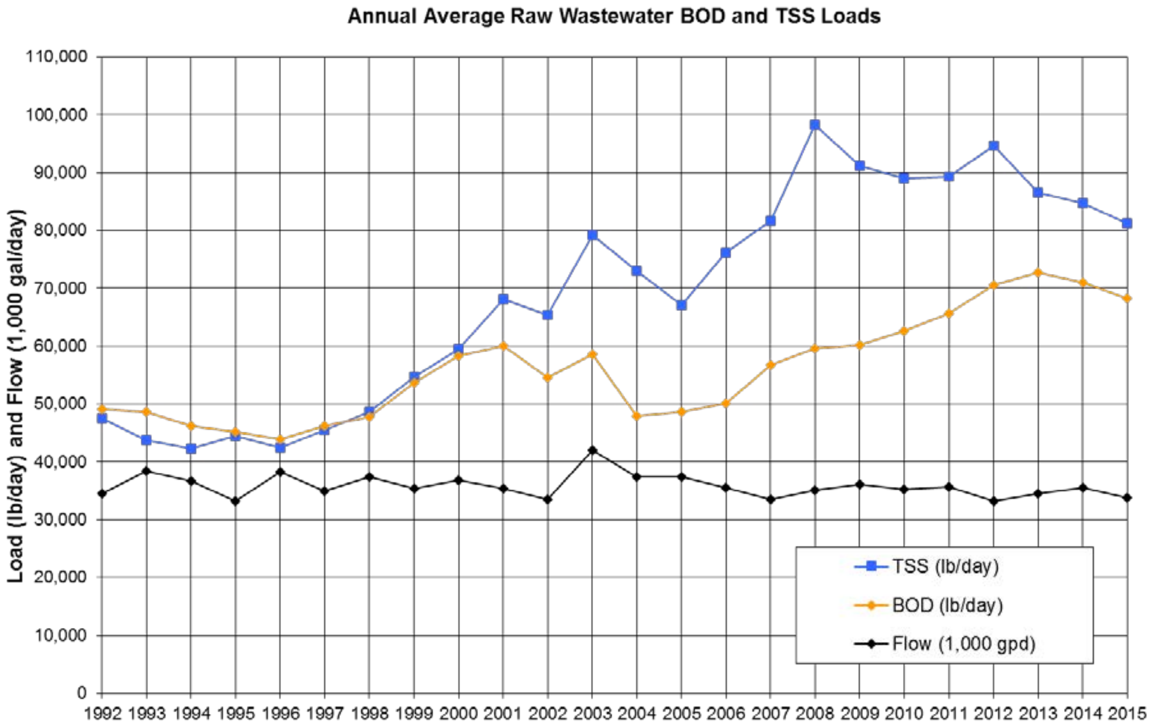


Figure 2-1. AlexRenew WRRF Annual Average Raw Influent Flows and Loads: 1992 to 2015

Figure 2-2 shows that for the last 8 years (the period from 2007 to 2015), the annual average influent TSS loadings coming into the WRRF have stabilized. The annual average biosolids hauled out of the WRRF have also been stable during this period.

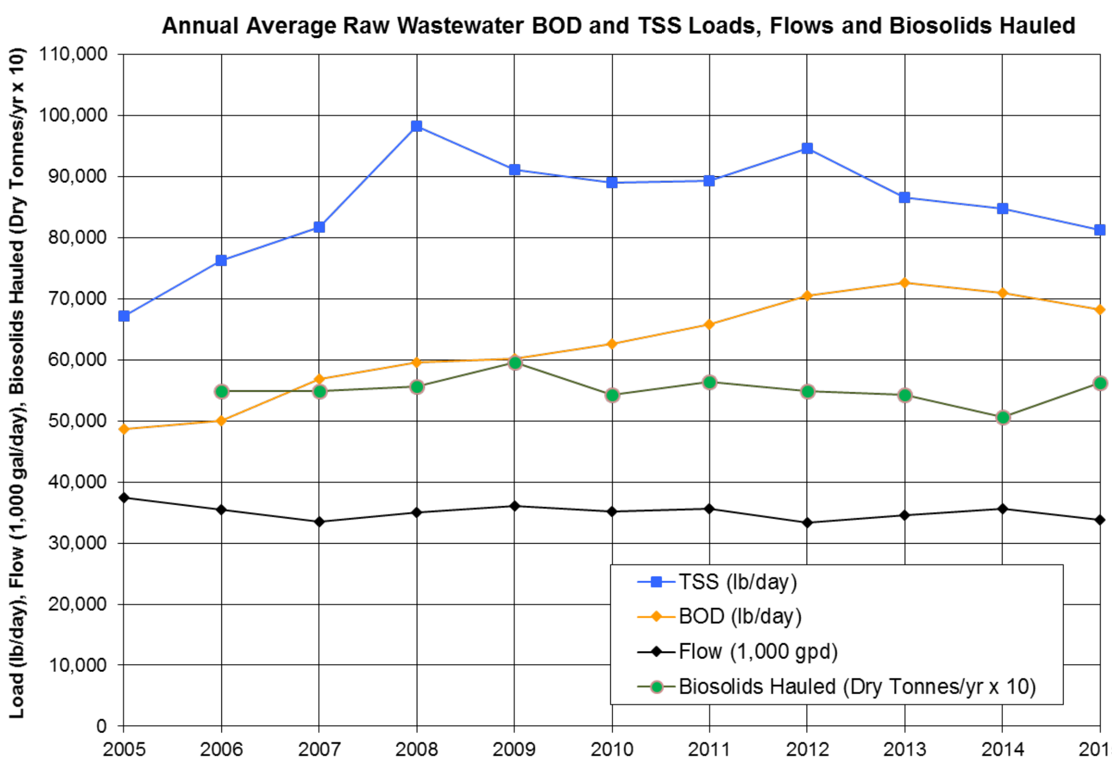


Figure 2-2. AlexRenew WRRF Annual Average Raw Influent Flows and Loads and Biosolids Hauled: 2005 to 2015

Therefore, the proposed time period of analysis for the flows and loading evaluation is the period of 2007 to 2015. This is the data period that was used to determine the annual average flows and loadings and the corresponding peaking factors.

2.1.3 Population Data

Population data from the City and Fairfax County was used to determine the current and projected future population. Figure 2-3 shows current and future population projections. The source of these projections are:

- The City: Metropolitan Washington Council of Governments Population and Household Forecasts, Round 9.0 (dated March 2016)
- Fairfax County: Fairfax County Demographic Report 2015 (dated January 2016)

Per the Fairfax County Demographic Report, the projected population in the AlexRenew sewer shed area will grow by 0.7 percent per year through the year 2040. However, this report does not project to 2060. For the purposes of this study, a rate of growth of 1 percent per year from 2040 to 2060 was used to match the City's growth projections. This likely provides a slightly more conservative estimate of the total service population in 2060. The 2060 total population is estimated at 480,000 compared to 460,000 if a rate of 0.7 percent per year is used (for the Fairfax County portion), for a net difference of approximately 4 percent.

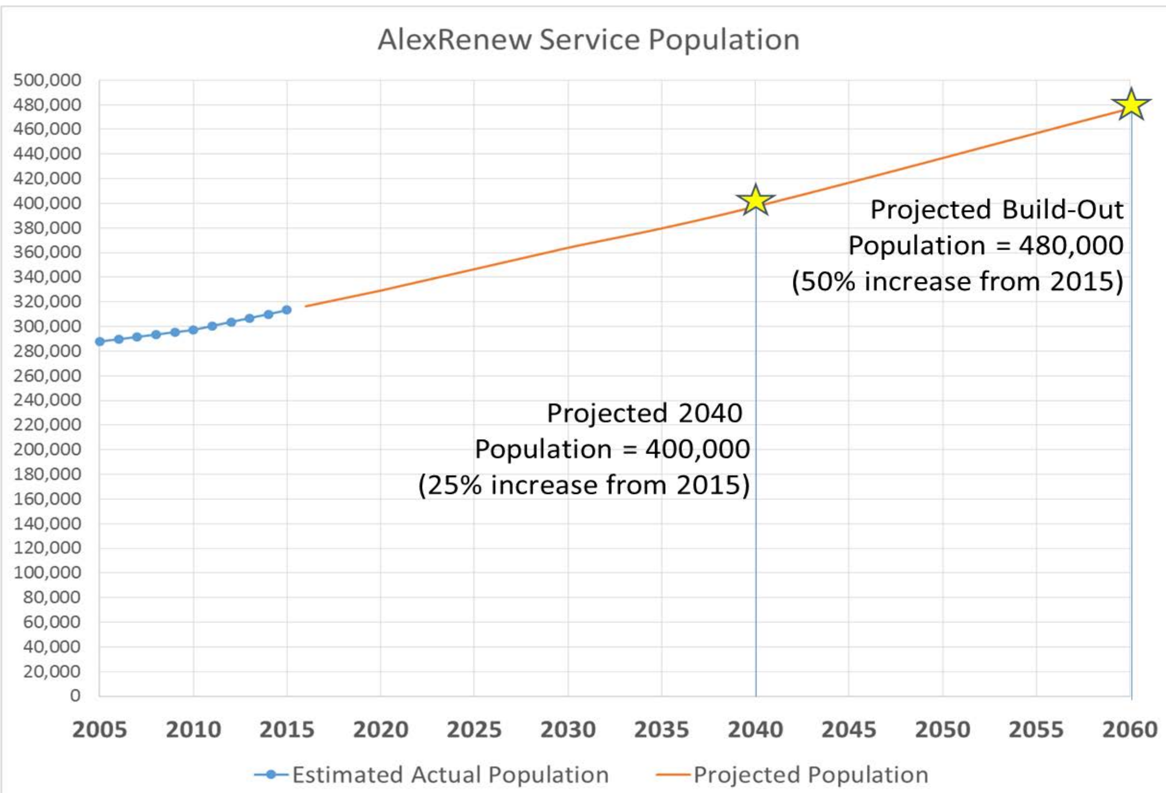


Figure 2-3. AlexRenew Service Population Projection through 2060

2.1.4 Per Capita Loadings and Design Criteria

Per capita loading contributions are determined by dividing the flows and loads by the population. The peaking factors are then applied to the average values to arrive at maximum month loadings. Table 2-1 illustrates the values used for this evaluation.

TABLE 2-1
Projected Population and Design Loadings for 2040 and 2060

	Population	Flow (MGD)	Loadings (lbs/day)					
			TSS	BOD_5	TKN	NH_3	TP	OP
2007-2015 Annual Avg. Loadings	~300,000	35	88,000	65,000	12,000	6,400	1,900	700
Per Capita Loading [a]		120 gpc	0.29	0.22	0.040	0.021	0.006	0.002
2040 Loadings	400,000	48	117,593	86,524	15,954	8,445	2,493	935
Build-Out Annual Avg. Loadings (~2060)	**480,000**	**58**	**141,000**	**104,000**	**19,100**	**10,100**	**3,000**	**1,100**
Max Month PF[a]			1.32	1.21	1.20	1.11	1.28	1.17
Max Month Design Loadings			186,000	125,000	22,900	11,200	3,800	1,300

Note:

[a] Per capita loadings and peaking factors are calculated using the 2007-2015 data set.

BOD_5 = Biochemical Oxygen Demand – 5-day test

gpc = gallons per capita

lbs/day = pounds per day

OP = Orthophosphate

PF = peaking factor

2.2 Liquids Treatment

The liquids treatment at the AlexRenew WRRF was the focus of the 2009 LRPR. Figure 2-4 illustrates the current liquid treatment process at AlexRenew WRRF, including the facilities added as part of the SANUP. This section describes the current state of the liquids treatment processes in comparison to the 2009 evaluation.

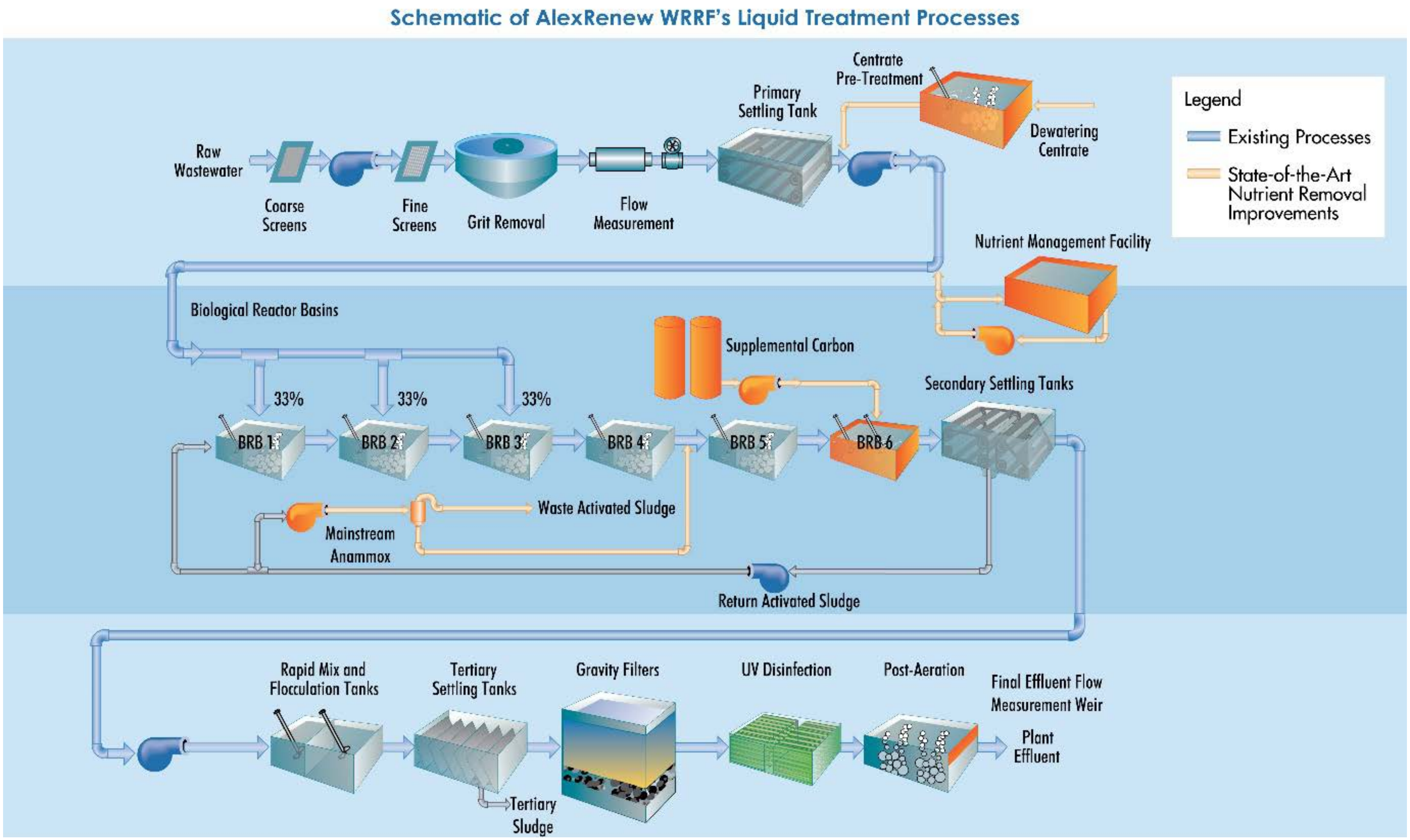


Figure 2-4. Liquids Treatment Processes at AlexRenew WRRF

2.2.1 Preliminary Treatment

Preliminary treatment at AlexRenew consists of two facilities: (1) Building A, which houses the coarse screening equipment ahead of the raw sewage pump station, and (2) Building K, which houses the fine screening, grit removal, and flow-splitting functions before primary treatment. Both of these facilities were constructed and placed into operation in the early 2000s.

Table 2-2 summarizes the Preliminary Treatment System and basis of design.

TABLE 2-2
Preliminary Treatment System– Design Criteria

Unit Process	Description	Design Basis
Coarse Screening	Number of Units	2[a]
	Type	Mechanically cleaned climber bar screen
	Channel Size (Width x Depth, ft)	6 x 8
	Hydraulic capacity, each unit (MGD)	60
	Bar Spacing (inches)	3
Fine Screening	Number of Units	4[b]
	Type	Belt lift
	Screen Channel Size (Width x Depth, ft)	6 x 9.5 x 6
	Hydraulic capacity, each unit (MGD)	40
	Bar Spacing (inches)	1/4
Grit Removal	Number of Units	4[b]
	Type	Vortex Grit Chambers
	Hydraulic Capacity Each Unit (MGD)	40
Conveyors	Number of Units (each type)	Screenings (2) Grit (2) Transfer (2) Truck Loading (2)

Notes:
a. System is designed to operate with one unit in service and the second as a standby.
b. System is designed to operate with three units in service and the fourth as a standby.

Coarse Screening

The coarse screening facility has been in service since 2005 and the equipment performs well. The system does not require any updates or upgrades.

Fine Screening

The fine screens, located in Building K, were first placed in service in 2001. These Parkson Aqua-Guards units are not very efficient in removing rags or trash. Debris that passes through the screens causes problems in downstream processes.

Grit Removal

Following fine screening, grit is removed in the vortex grit removal chambers also located in Building K and placed in service in 2001. These units perform well and are effective in removing grit from the system. However, one of the units (Grit Chamber #2) is out of service because of a broken propeller shaft that requires a crane for lifting and removal. The grit is pumped with recessed impeller pumps to the grit washer/classifier where the grit is dewatered and then dumped on the conveyer system for loading on the trucks for disposal.

Chemical Addition

Ferric chloride is added to the downstream end of the grit removal effluent channel to aid in solids and BOD removal in the primaries. This chemical addition point is used to implement CEPT, which allows for greater capture of the carbon in the influent. The ferric chloride lines clog easily and do not effectively split the chemical among the units in service. The chemical delivery system needs to be investigated and redesigned, as needed. In addition, the chemical supplier/vendor pool should be evaluated to determine if a different source of chemical can provide a cleaner product with less impurities.

Another option is to use polymer to aid in settling. The facility has polymer addition points into the pipes that carry the flow into the primary settling tanks, which can provide better flow distribution. Jar tests should be conducted to select type of polymer and dose and to determine efficacy.

Grit and Screening Truck Conveyors and Truck Loading

The Preliminary Treatment facility has a system of eight screw conveyors that collect the fine screens and the grit and combine the material before discharging it into one of two truck bays. The conveyors were originally installed in 2001, although they have been refurbished since. The conveyors are effective in moving the material through the facility but they experience a lot of wear and tear. In 2015, the average amount hauled from the Screening and Grit facility was 3,000 lbs/day.

Scum Removal, Treatment and Storage

Building K also houses a scum concentrator and a scum-holding tank. These units receive a combination of primary and secondary scum and treat the scum before disposal onto the truck bays. The system performs adequately but it is messy and generates odors.

Hydraulic Capacity

The sizing criteria for the Preliminary Treatment facility is the peak instantaneous flow. The existing facility has four treatment trains and each train was sized to treat 40 MGD for a total facility capacity of 120 MGD with three trains in operation and one stand-by unit.

The *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* analyzed the feasibility of increasing the flow through the existing Preliminary Treatment facility by 8 MGD. The analysis concluded that by giving AlexRenew the option to route the filter backwash directly into the primary settling tanks during high-flow periods, this additional flow could be accommodated. A new pipe and two control valves are needed to provide this flexibility.

2.2.2 Raw Sewage Pumping

The raw sewage pump station consists of six pumps that draw out of a common wetwell. The pumps are rated for 21,000 gallons per minute (gpm) each. The system was originally constructed in the 1950s but the pumps have been replaced since, most recently in 2006. Table 2-3 lists the capacity of the raw sewage pumping station.

TABLE 2-3
Raw Sewage Pump Station – Design Criteria

Unit Process	Description	Design Basis
Raw Sewage Pump Station	Number of Units	6
	Type	Centrifugal with AFD
	Firm Hydraulic Capacity (MGD)[a]	116

Notes:
a. System is designed to operate with five units in service and one as a standby.

AFD = Adjustable Frequency Drive

The *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* analyzed the feasibility of increasing the flow through the raw influent pump station facility by 8 MGD, from 108 MGD to 116 MGD. The analysis concluded that the pump station has the capacity to accommodate this additional flow.

2.2.3 Primary Treatment

Primary treatment consists of eight rectangular primary settling tanks. Primary sludge is removed using primary sludge pumps and routed to gravity thickening. Table 2-4 lists the characteristics of the system.

TABLE 2-4
Primary Treatment – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Primary Settling	Number and type	8 rectangular tanks	6 tanks normally in service
	Length x Width x SWD	173 x 36 x 9 ft	
	Total settling tank area per tank (sf)	6,228	6,228
	Hydraulic Loading Rate – average (gpd/sf)	1,200	900
	Hydraulic Loading Rate - maximum day (gpd/sf)	2,400	1,833

Note:
gpd/sf = gallons per day per square feet
sf = square foot
SWD = Side Water Depth

The primary treatment process is effective and performs well. The primary sludge pumps were originally installed in the 1970s but have been refurbished since. Four of the pumps (plunger type) are not operable. Implementation of CEPT is expected to increase the amount of primary sludge that is produced at the facility. Therefore, expansion of the primary sludge pumping capacity is needed.

An evaluation of the sludge collection and pumping system is recommended to determine how to improve the efficiency and efficacy of the sludge removal/thickening process. This could include implementation of AFDs on the primary sludge pumps (they currently run continuously at a steady flow) and sludge blanket monitoring to better automate the sludge withdrawal.

2.2.4 Primary Effluent Pumping

The primary effluent pump station was constructed in the early 2000s and placed into operation in 2003. This pump station lifts the plant effluent to the biological reactor basins and also to the Nutrient Management Facility. Table 2-5 lists the characteristics of this pump station.

TABLE 2-5
Primary Effluent Pump Station – Design Criteria

Unit Process	Description	Design Basis
Primary Effluent Pump Station	Number of Units	6[a]
	Type	Centrifugal with AFD
	Firm Hydraulic Capacity (MGD)[a]	120

Notes:
a. System is designed to operate with five units in service and one as a standby.

An analysis of this pump station was performed in 2015, which concluded that the pumps need to be upsized in order to comply with the peak instantaneous flow requirements of the *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation*. Upsizing the pumps would require replacement of the pumps with larger sizes and larger motors. The proposed upgrade is described in the Primary Effluent Pump Station (PEPS) Evaluation Report (CH2M, February 2016).

2.2.5 Secondary Treatment

Secondary treatment was the focus of the 2008 Long Range Plan, which sought to upgrade the system in order to comply with new regulatory drivers. As a result, the SANUP program was implemented and completed in 2016. See Section 1.1 for a complete description of the upgrades. Table 2-6 shows the design criteria and performance of the biological nutrient removal system for the operating year 2015.

TABLE 2-6
Secondary Treatment – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Biological Reactor Basins	Number of Units	6	5 in Step-Feed
	BRB 1 – 5: Anoxic Zone Volume, Each Unit	0.8 MG (19% of Total)	
	BRB 1 – 5: Swing Zone Volume, Each Unit	0.5 MG (12% of Total)	
	BRB 1 – 5: Aerobic Zone Volume, Each Unit	2.9 MG (69% of Total)	
	BRB 1 – 5: Total Reactor Basin Volume, Each Unit	4.2 MG	
	BRB 6 Total Anoxic Volume	3.8 MG	
	Operating Depth	24-27 ft (25 ft average)	
	Solids Retention Time (days)	12 (min)	17.1 (avg)
	Average MLSS (mg/L)	3,500	3,100
	Number of Process Air Compressors	5	Max 2 in operation
	Air flow capacity per unit (cfm)	16,600	16,600
	Total air flow capacity (cfm)	83,000	33,200
Secondary Settling Tanks	Number and type	6 rectangular [5 in service]	
	Length x Width x SWD	280 x 83 x 11 ft	
	Area each (sf)	23,240	
	Total area (sf)	116,200	
	Surface Overflow Rate – average (gpd/sf)	390	298
	Surface Overflow Rate- maximum day (gpd/sf)	800	600
	RAS solids concentration (mg/L)	7,000 – 9,000	7,000 – 9,000
	Solids Mass loading Rate – average (lbs/d/sf)	20	13
	Solids Mass loading Rate - maximum day (lbs/d/sf)	40	27.3
	Maximum RAS Flow (MGD)	70	70
	RAS Flow % of BRB Influent Flow	100%	74%
	WAS Flow (MGD)	1.2	0.7
Supplemental Carbon Storage and Feed System[b]	Methanol, Average Feed rate	18 mg/L	20.5 mg/L
	Number of Storage Tanks	2	
	Volume, each	24,500 gal	
	Working Volume, each	23,350 gal	
	Size, each	12 ft diameter, 30 ft tall, 27.5 ft liquid level	
	Chemical Metering Pumps, Number of Units	6 (5 in service, 1 spare)	
	Capacity, per BRB Basin	3 – 124 gph (2976 gpd)	
	Total Pumping Capacity	620 gph	

TABLE 2-6
Secondary Treatment – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Nutrient Management Facility	Number of Nutrient Management Tanks	4	
	Volume, each tank	4.5 million gal	
	Total volume	18 million gal	
	Nutrient Management Pumps		
	High Capacity Pumps, Number and Capacity	4; 7,740 gpm (11 MGD)	
	Low Capacity Pumps, Number and Capacity	4; 1,935 gpm (2.8 MGD)	
	Divert Flow Range (min-max)	1.2 to 44 MGD	
	Return Flow Range (min-max)	1.2 to 44 MGD	

Notes:
a. Range of monthly averages. b. Supplemental carbon system is designed to store and feed methanol, ethanol, sugar water, glycerol, proprietary products.
% = percent
cfm = cubic feet per minute
gal = gallon
gph = gallons per hour
MG = million gallon
MLSS = mixed liquor suspended solids
RAS = returned activated sludge
WAS = waste activated sludge

In addition to the SANUP improvements, AlexRenew also implemented the Mainstream Anammox process in the secondary biological reactors. This refinement of the biological process allows for nitrogen removal using less air and less carbon than the traditional nitrification/denitrification process. The approach at AlexRenew is to seed Anammox granules from the sidestream treatment into the mainstream process. The Anammox granules are selectively retained in the system by using hydrocyclones on the WAS flow stream which return the heavier particles back into the reactors and waste the lighter material. Hydrocyclones have also shown to improve the settling properties of the mixed liquor. The aeration system control in the BRBs has been modified to induce transient anoxia (rapid change from aerobic to anoxic conditions) in the first two reactors in step-feed with the goal of removing more of the ammonia via the deammonification pathway.

In 2015, AlexRenew reduced the final effluent TN by 1 mg/L compared to the 2007 condition (4.8 mg/L in 2007 and 3.8 mg/L in 2015). Annual methanol use has been reduced by 18 percent and the aeration system currently runs with only one process air compressor in service.

Other improvements to the secondary treatment system currently in progress include:

- Evaluation of the existing process air compressor system for replacement of the existing units. The existing process air compressors have been operating since 2003 and the units are over-sized for the new air requirements. The evaluation is considering installation of smaller and more energy-efficient units in order to take advantage of the process optimization efforts, such as Mainstream Anammox.
- Automation of supplemental carbon dosing based on nitrite/nitrate concentration in the effluent. The goal is to optimize the process and reduce chemical use.
- Investigation on feasibility and benefits of biological Phosphorus removal at AlexRenew. A preliminary investigation was conducted as part of this project and the conclusions are summarized in Appendix B.

2.2.6 Tertiary Treatment

The tertiary treatment processes at AlexRenew consist of an alum rapid mix and flocculation system followed by tertiary settling tanks with inclined settling plates, mono media filters, UV disinfection channels and post-aeration tanks. Table 2-7 lists the design criteria and current operation of the tertiary treatment processes for the operating year 2015.

TABLE 2-7
Tertiary Treatment – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Tertiary Settling	Number of Tanks	8	6 in service
	Effective Settling Area, per tank	25,200 sf	25,200
	Total Settling Area	201,600	151,200
	Hydraulic Loading Rate (gpm/sf)	0.1 – 0.5	0.2
	Alum Dosage (as $Al_2(SO_4)_3$)	50 – 75 mg/L	18 mg/L
Filtration	Number and type	22 units, sand and gravel support	
	Total area per filter (sf)	728 sf	
	Number filters in-service	20	20
	Total filter area in-service (sf)	14,560	14,560
	Hydraulic loading rate - average daily (gpm/sf)	2.6	1.8
	Hydraulic loading rate - maximum month (gpm/sf)	6	3.8

The tertiary treatment system is currently performing very well. The final effluent TSS concentration in 2015 averaged 0.8 mg/L, which is well below the permit limit of 6 mg/L. The final effluent TP concentration in 2015 averaged 0.08 mg/L, which is also well below the permit limit of 0.18 mg/L. Table 2-8 shows average annual and maximum monthly concentrations in the final effluent for 2015. The tertiary treatment system produces an effluent with very low BOD, TSS, TP and NH_3 concentrations. The tertiary treatment system has enough capacity to treat the design flows and mass loads with adequate redundancy.

TABLE 2-8
Final Effluent Concentrations

Parameter	Units	2015 Annual Average
BOD_5	mg/L	0.5
TSS	mg/L	0.8
TP	mg/L	0.08
TKN	mg/L	1.0
NH_3	mg/L	0.2

2.2.7 Ultraviolet Disinfection

AlexRenew's UV disinfection system, located in Building N, is currently being upgraded. The original UV system, which was designed in 1998 and placed in service in 2000, was nearing the end of its useful life and needed to be replaced. The new UV system, which is currently under construction, will provide improved energy efficiency, improved reliability, and reduced maintenance. The hydraulic capacity remains unchanged with a peak flow of 115 MGD.

The new system offers variable power between 60 and 100 percent, for enhanced energy efficiency. Ballasts will be located above the channel walls, offering improved flood resistance. Automated lamp cleaning, with o-ring wipers, can be conducted while systems are in operation, thus reducing maintenance requirements and cost.

System design parameters are shown in Table 2-9.

TABLE 2-9
Ultraviolet Disinfection System – Design Criteria

Unit Process	Description	Design Basis
UV Disinfection	Manufacturer, Model and Lamp Type	Trojan UV3000 Plus Low Pressure, High Intensity Amalgam Lamps
	Peak Flow	115 MGD
	Average Flow	54 MGD
	Minimum Flow	20 MGD
	Max Effluent TSS	9 mg/L
	UV Transmittance	65% at 253.7 nm
	No. of Channels	6
	Channel Dimensions (Length x Width x Depth) (ft)	60 x 6.25 x 6.6
	SWD in UV Channel	4 ft
	Final Effluent 30-day geometric mean *e coli*	126 #/100 mL

Note:
nm = nanometer
mL = milliliter

2.2.8 Reclaimed Water

A dedicated reclaimed water (RW) system was commissioned in 2014 in Building F, adjacent to the W3 Pump Station. The RW system includes a reclaimed water pumping station, an in-line UV disinfection system for enhanced pathogen kill, and a bulk filling station.

The UV system is designed to achieve Level 1 RW standards, which is the highest grade and offers the widest range of possible uses. Designed uses include the bulk filling station, landscape irrigation, water features/aquarium, toilet flushing, and cooling towers. Carlyle Plaza Partners have been identified as a future reclaimed water residential and commercial user. A 16-inch main has been provided from the Main Plant Site to Holland Lane, with planned future expansion.

The RW system capacity will be phased in over time. Phase 1 is complete, with two additional future phases to achieve buildout:

- Phase 1 – 2 MGD firm capacity (largest pump unit out of service) - Complete
- Phase 2 – 4 MGD firm capacity
- Phase 3 – 6 MGD firm capacity

TABLE 2-10
Reclaimed Water System – Design Criteria

Unit Process	Description	Design Basis
Reclaimed Water Pump Station (Phase 1)[a]	Number of Units	2 at 350 gpm 2 at 700 gpm
	Type	Centrifugal with AFD
	Firm Hydraulic Capacity (MGD)	2
In-line UV System	Number of Units	3 trains, (2 duty, 1 standby)
	Average Design Flow (MGD)	1.2
	Peak Design Flow (MGD)	2.0
	Design UVT	65% at 254 nm

a. Phase 2 – replace 350 gpm units with 1,400 gpm units. Phase 3 – replace 700 gpm units with 1,400 gpm units.

Twin hydro-pneumatic surge tanks are provided to balance usage demands and protect the system. A sodium hypochlorite dosing function is provided as needed to prevent the buildup of organics downstream. The Reclaimed Water Bulk Filling Station is located on the south side of Building 44 (BRBs).

2.3 Solids Processes and Equipment Assessment

The focus of the 2016 Solids Handling and Energy Optimization Upgrade to the Long Range Plan is the solids treatment processes, including an assessment of their current condition and the capacity. Figure 2-5 contains a flow diagram of the existing solids treatment processes at AlexRenew WRRF.

2.3.1 Projected Future Solids Handling Loadings

Analysis of flows and loads into the plant predict an increase in solids, BOD and nutrient mass loadings in the future as the service population grows. This means that additional capacity will be needed in order to maintain the redundancy required to reliably produce Class A biosolids under the future design conditions.

In the short-term, operational changes, such as implementation of Mainstream Anammox and CEPT will also affect the sludge production. CEPT is expected to increase primary sludge production by 38 percent, decrease WAS by 35 percent and increase overall sludge production by 15 percent. The sludge production was calculated using the BioWin plant model (see Appendix C). Figure 2-6 shows the predicted maximum month mass loadings and the resulting estimated sludge production.

Figure 2-7 summarizes the capacity of the key solids handling unit processes (in terms of annual average influent flow to the WRRF) and the projected time-frame when each unit process will be at capacity.

The capacity was estimated based on adding the impacts of CEPT, which is projected to increase the overall solids at the WRRF by about 15 percent. The capacity is also based on meeting the design criteria under maximum month conditions (using a peaking factor of 1.2).

Figure 2-7 indicates that the unit processes that will reach capacity in the short-term are the gravity thickeners and the pre-pasteurization heat exchangers. The digester capacity will have to be addressed in the medium-term horizon. The thickening and dewatering centrifuges have sufficient capacity for the foreseeable future.

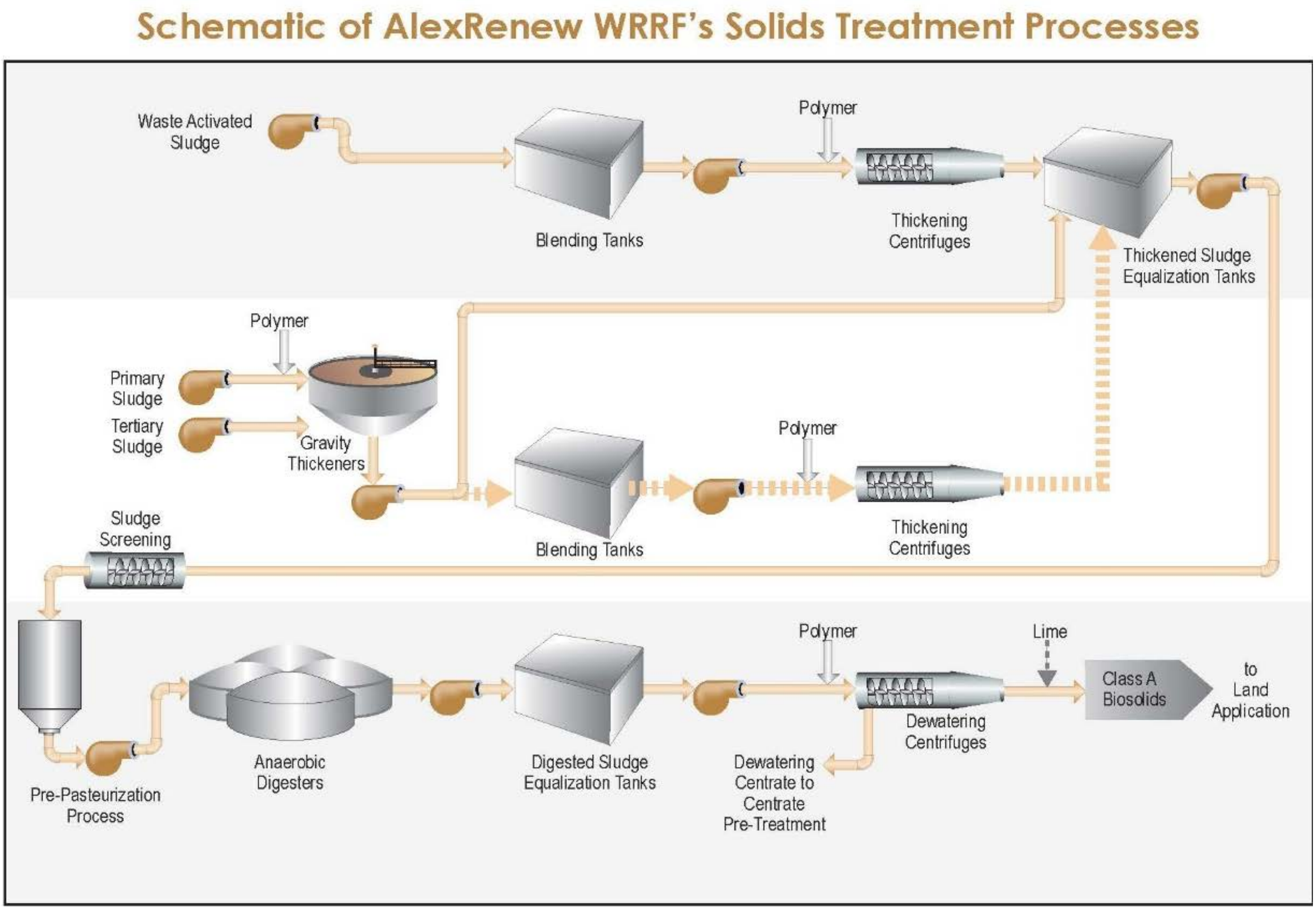


Figure 2-5. Solids Treatment Flow Stream at AlexRenew WRRF

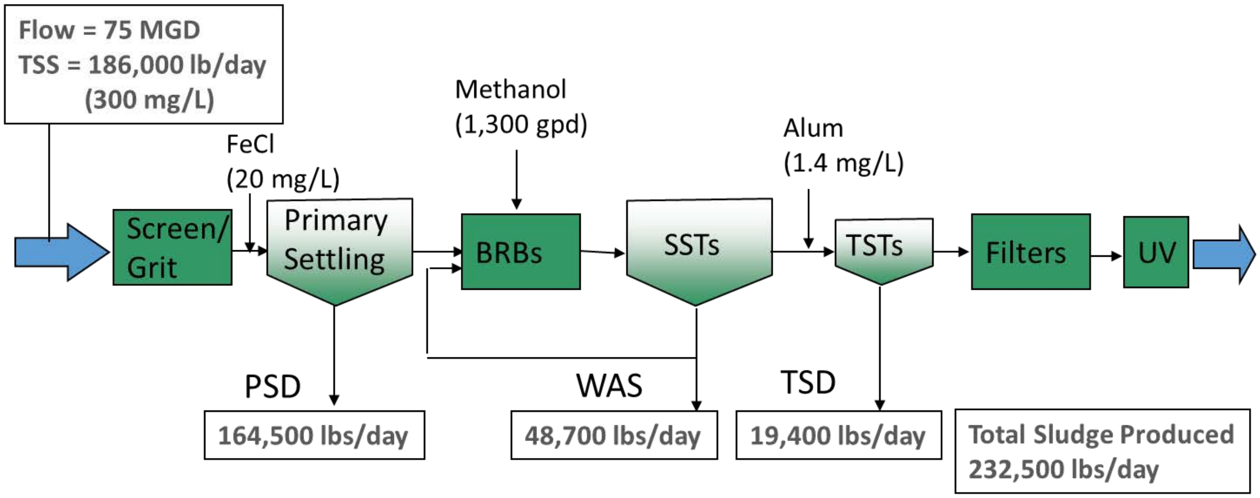
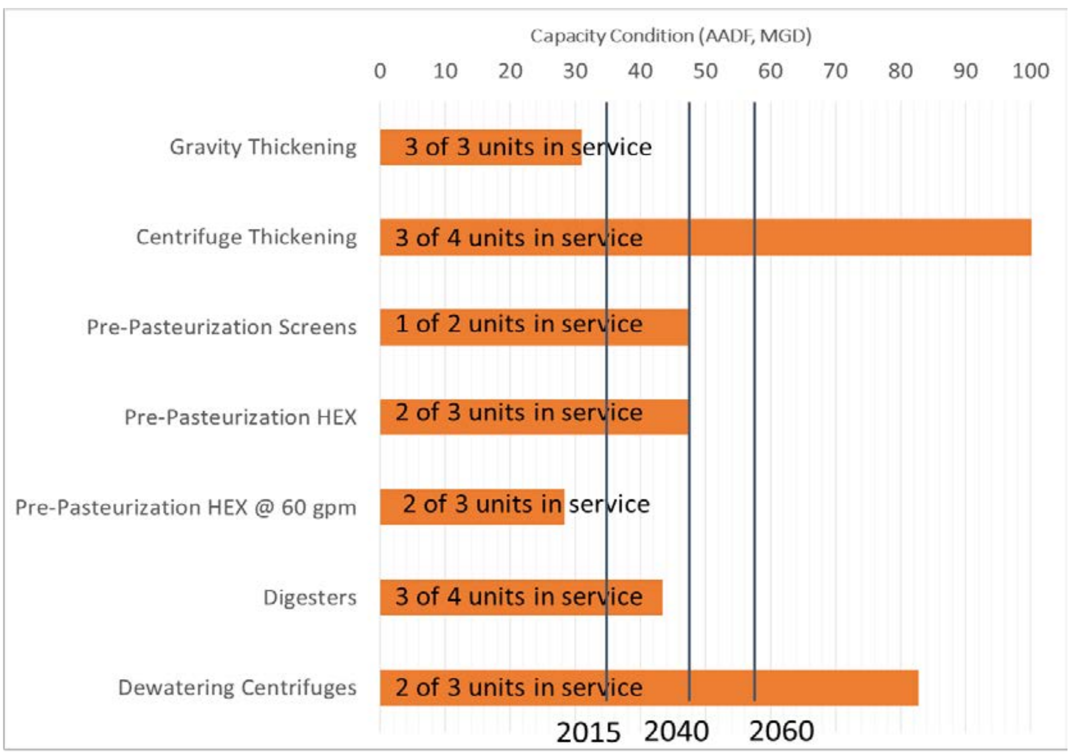


Figure 2-6. Overall Plant Mass Balance at Design Maximum Month Conditions (75 MGD)



* Based on 2015 data and adding projected impacts of CEPT:
38% increase in PSD, 35% decrease in WAS, 15% increase in overall solids

Figure 2-7. Solids Handling Unit Process Capacity

2.3.2 Gravity Thickening

The gravity thickener system currently consists of three tanks that co-thicken Primary Sludge (PSD) and Tertiary Sludge (TSD). The original system consisted of a total of five tanks, but two of the tanks were decommissioned in 2007. Table 2-11 lists the original design criteria and current performance of the gravity thickeners.

TABLE 2-11
Gravity Thickeners – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Gravity Thickening	Number of units	5 (3 available for treatment, 2 decommissioned)	3 usually in service
	Diameter and SWD	55 ft, 10 ft	
	Surface Area, each unit (sf)	2,375	
	Total settling tank area (sf)	7,175	7,175
	Total Sludge Flow to Gravity Thickener (gpm)	2,800	2,600
	Hydraulic Loading Criteria (gpd/sf)	400-800	528
	Feed Solids Concentration	0.24%	0.18%
	Percent Capture	85%	--[a]
	Underflow (gpm)	145	64
	Underflow TS	4%	4.5%
	Overflow TSS (mg/L)	380	117

Notes:
a. Mass balance around the Gravity Thickeners using data available is off by about 40%, therefore an accurate percent capture cannot be calculated.

TS = total solids

Process Performance

The thickener overflow is returned to the PEPS and from there it is pumped into the biological reactor basins. The overflow contains consistently low solids concentration, averaging around 117 mg/L for the year 2015 with no major spikes (peak concentration was 340 mg/L). The low solids content in the overflow indicates good process performance and good solids capture. Polymer can be added to the gravity thickeners to further improve the performance of the system.

System Condition

The gravity thickener tanks are in good condition and are in the process of being taken out of service and cleaned one at a time. The internal mechanisms function well. The thickened sludge pumps are over 30 years old, and they are currently being refurbished. Even though the pump suction was replaced in 2007, the system continues to experience loss of pumping capacity due to clogging of the pump suction.

Capacity

Based on the projected sludge production with CEPT, the gravity thickeners will reach full capacity (as defined by the design maximum hydraulic loading rate of 800 gpd/sf) at current flows and loads. The system capacity can be increased by refurbishing the two gravity thickeners that are currently out of service and this approach will provide adequate redundancy at the design condition. However, the gravity thickening process currently occupies a large footprint at a location on the site that could be more optimally used with a different unit process. Therefore, a full evaluation of the gravity thickening alternatives is recommended including developing an alternative that moves the process to another location with potentially a different technology (such as centrifuges, gravity belt thickeners or others).

2.3.3 Thickening Centrifuges

The centrifuge thickening system currently consists of four installed centrifuges to treat WAS. Two of these centrifuges normally operate and two are redundant Table 2-12 lists the design criteria and current performance of the thickening centrifuges.

TABLE 2-12
Thickening Centrifuges – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Centrifuge Thickening	Number of units	4[a]	2 in service
	Hydraulic capacity, each centrifuge	460 gpm	
	Total Sludge Flow to Centrifuge Thickening (gpm)	1,375	493
	Hydraulic loading per centrifuge (gpm)	460	246
	Feed Solids (%)	0.8	0.57
	Polymer Dose (lbs dry pol/dry ton feed)	8	1
	Percent Capture	95%	95%
	Thickened Sludge TS	4%	5%

Notes:
a. Four centrifuges are currently installed, with the ability to install two additional (future) units when needed.

Process Performance

The centrate being returned to the primary effluent pump station has low solids content (134 mg/L average in 2015) indicating good solids capture in the process.

System Condition

The mechanical thickening system includes the raw sludge blending tanks, the pumps and grinders that feed the thickening centrifuges and the centrifuges. The system was placed into service in 2003 and has received regular maintenance. There are no significant deficiencies and the system has additional service life.

Capacity

Treatment of the WAS flows predicted at the design maximum month conditions as shown on Figure 2-6 will require two centrifuges in operation. Treatment of WAS and tertiary sludge combined will require three centrifuges in operation as per the original design. The existing system of four centrifuges will therefore have enough capacity to treat the design maximum month mass loadings and corresponding sludge flows with adequate redundancy.

2.3.4 Pre-Pasteurization

The pre-pasteurization process reduces the pathogens in the sludge to meet Class A requirements by heating the sludge to a target temperature of 158 degrees Fahrenheit (°F) and holding it at that temperature for a minimum of 30 minutes before being introduced to the digesters. The thickened sludge is first screened to remove trash and debris in order to protect the pre-pasteurization equipment. The screened sludge is then processed in one of three pre-pasteurization treatment trains. Each treatment train consists of two pumps and a heat exchanger that raises the temperature of the sludge to the desired set point. The sludge is held in one of four pre-pasteurization holding tanks for the necessary time period and it is then pumped back through the heat exchanger in order to transfer its heat back to the colder sludge coming in. The pasteurized sludge is cooled to a temperature of around 95°F before introduction to the digesters. Table 2-13 lists the design criteria and current performance of the pre-pasteurization process.

TABLE 2-13
Sludge Pre-Pasteurization System– Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Sludge Screening	Number of Units	2[a]	1 in operation
	Hydraulic capacity, each unit (gpm)	200	104
	Maximum Feed Solids (%)	6	4.7
Sludge Pre-Pasteurization	Number of treatment trains (heat exchangers)	3[b]	2 in operation
	Hydraulic capacity, each unit (gpm)	100	52
	Total hydraulic capacity (gpm)	200	104
	Maximum Feed Solids (%)	7	4.7
Sludge Holding Tanks	Number of Units	4[c]	3
	Working Volume per Tank (gal)	12,000	12,000

Notes:
a. System is designed to operate with one unit in service and the second as a standby.
b. System is designed to operate with two units in service and the third as a standby.
c. System is designed to operate with three units in service (fill, hold, discharge) the fourth as a standby.

Process Performance

The pre-pasteurization system was placed into service in 2005 and has consistently met the Class A requirements. However, equipment performance issues are currently limiting the capacity of the system.

System Condition

The screen presses, upstream of the pre-pasteurization process are designed to pass 200 gpm at 6 percent solids but are currently limited to about 120 gpm at 5 percent solids. The screens are also letting some trash and debris through that ends up reaching the centrate. This affects the centrate pre-treatment system where pump clogging has become a frequent issue.

The pre-pasteurization heat exchangers are designed for 100 gpm each, but are currently limited to about 60 gpm each due to difficulty in reaching the desired temperature.

Over the past three years, AlexRenew has performed several studies and field investigations to determine the cause of the limitation at the heat exchangers. These are summarized in the Pre-pasteurization System Evaluation, Heat Exchangers Recommendations (CH2M, January 2016). Some recent upgrades include:

- Pre-pasteurization tanks’ mixers were replaced in 2013-2014.
- Pre-pasteurization sludge and recirculation pumps are being refurbished (scheduling work such that a refurbished, shelf, sludge pump is available at all times).
- Pre-pasteurization heat exchangers: excessive recirculation is taking place during wintertime operation (sludge not heating to temperature set point), and feed to digesters not cool enough during summer time operation. Chemical cleaning is currently at the planning phase.
- Pre-pasteurization tank exhaust fan needs replacement and also a standby fan needs to be provided.

Capacity

At their current state, the pre-pasteurization heat exchangers have a total capacity of 60 gpm which would not be adequate to treat the projected increase in sludge due to CEPT implementation. If the heat exchangers and the sludge screens are restored to their design capacity, the pre-pasteurization system could provide enough capacity to treat the projected future sludge loads up to the 2040 design condition.

Beyond 2040, AlexRenew would have to determine if construction of additional pre-pasteurization capacity is needed depending on whether land application is still a viable option. In that case, two additional heat exchangers would be needed. The sludge holding tanks have enough capacity to provide the 30-minute holding time for flows up to the projected 2060 as-built design condition.

2.3.5 Digestion and Gas Production

The pasteurized sludge undergoes anaerobic digestion in four digester tanks. The design criteria and current performance for the digesters is listed in Table 2-14.

TABLE 2-14
Digesters – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Digesters	Number of units	4	4
	Diameter and SWD	95 ft, 28.5 ft (max)	95 ft, 25 ft
	Volume per unit (MG)	1.5	1.33
	Total Volume (MG)	6	5.3
	Hydraulic Retention Time	15 days, minimum	35 days (min) 40 days (avg)
	Operating Temperature (°F)	95 (mesophilic)	98.5
	Volatile Solids Reduction	40% minimum	55%

Process Performance

The anaerobic digesters were started up in September 2005 and have performed well since. The digesters provide better-than-design volatile solids reduction (55 percent) and gas production (14.3 cubic feet per pound volatile solids reduced).

System Condition

The anaerobic digesters were started up in September 2005 and have performed well since. The digesters have enough capacity to treat current flows and mass loads with one unit out of service.

Digesters are scheduled to be taken down and cleaned, one at a time, starting with Digester #4 which was last cleaned in 2009. Some recent updates and upgrades include:

- Process heat transfer packages valves are leaking, leaving plant staff unable to isolate the systems. These are being replaced.
- Pump seals are prematurely failing
- Digester gas compressors are being refurbished yearly.
- Recent inspection of the boiler in Building A discovered white type of residue on the fire side tubes, and also some scaling on the water side. Chemical cleaning is currently at the planning phase.

Capacity

The current digester system operates with all tanks in service. Currently one tank can be taken out of service for repairs while still maintaining the 15-day solids retention time (SRT) required in the system for Class A treatment under current maximum month conditions. Increased future mass loadings because of implementation of CEPT will translate into higher sludge flows that need to be treated in the digesters. Therefore, all four tanks will be needed under maximum month conditions as shown in Figure 2-6.

Adding another digester tank is not a viable option at AlexRenew (because of site constraints and cost), so other alternatives were explored. The selected approach to increase the capacity of the digester system is to implement a recuperative thickening system. This system uses rotary drums that draw a constant flow of sludge out of the digesters, thicken it to approximately 9 percent and then return the thickened sludge into the digester. This process increases the solids concentration inside the digester which in turn raises the digester SRT to the 15 days needed to meet Class A requirements under design maximum month mass loadings with three out of four digesters in service.

An increase in sludge mass being treated in the digesters will result in higher biogas production. AlexRenew's existing flares and dual-gas boilers have adequate capacity to handle the increase in biogas. AlexRenew is currently evaluating options for beneficial use of the biogas in order to reduce energy consumption at the plant and will develop a plan for implementation of technology to take advantage of the additional biogas as an energy source.

2.3.6 Centrifuge Dewatering

The digested sludge is dewatered using centrifuges. The design criteria and current performance for the centrifuges are listed in Table 2-15.

TABLE 2-15
Centrifuge Dewatering – Design Criteria

Unit Process	Description	Design Basis	Current (2015)
Centrifuge Dewatering	Number of units	3 [a]	1 in operation
	Hydraulic capacity, each centrifuge (gpm)	200	
	Total Sludge Flow to Centrifuge Dewatering (gpm)	260 (raw sludge) 200 (digested)	118 (digested)
	Hydraulic loading per centrifuge (gpm)	130 [b]	118
	Feed Solids (%)	3 to 7	3%
	Polymer Dose (lbs dry pol/dry ton feed)	20	14
	Percent Capture	95%	>95%
	Dewatered Cake % Solids	30%	28%

Notes:

a. Three centrifuges are currently installed, but provisions have been made to accommodate one future unit for a total of four units.

b. With two units in operation and one in standby.

Process Performance

The dewatering centrifuges were placed in operation in June 2003. The dewatering centrate is treated in the CPT. The centrate has low solids concentration (less than 100 mg/L) indicating good solids capture. The dewatered cake produced is 29 percent solids by weight, which also indicates very good performance. The dewatered cake is then placed into storage silos and loaded into trucks. Currently, dewatered biosolids are managed as Class A biosolids and applied to land for beneficial re-use.

System Condition

The centrifuge dewatering system has operated reliably since it was placed in to service. Some improvements performed by AlexRenew included changing the DCENs motors from alternating current to direct current.

In addition, startup of the centrate pre-treatment system led to optimization of the polymer feed. Polymer use in the dewatering centrifuges has been reduced by 30 percent.

Since the centrate pre-treatment system was started up in May 2015 excess debris and trash has been found in the centrate that is treated at the system. This has caused clogging at the hydrocyclone recirculation pumps. Screening options at the centrifuge should be further investigated to mitigate this issue.

Capacity

Recuperative thickening will also add capacity to the existing dewatering centrifuge system. By thickening the sludge inside the digester, recuperative thickening reduces the digester effluent flow that is then treated in the dewatering centrifuges. The existing system of three centrifuges will therefore have enough capacity to treat the design maximum month mass loadings and corresponding sludge flows with adequate redundancy.

2.3.7 Centrate Pre-Treatment

The centrate pre-treatment system was implemented as part of SANUP and began operation in DEMON™ mode in May 2015. The process treats the centrate produced by dewatering anaerobically digested sludge, which contains a high concentration of ammonia nitrogen. If returned to the main plant flow stream for processing, this added nitrogen load can contribute up to 20 percent of the nitrogen entering the BRBs. Reducing the nitrogen load from the centrate before it enters the BRBs helps the plant meet the effluent TN concentration limits more reliably. Implementing shortcut nitrogen removal processes to treat the dewatering centrate also allows for reduced reactor volume, aeration requirements, and supplemental carbon usage in the BRBs. The DEMON™ process used at AlexRenew relies on anaerobic ammonium oxidation (Anammox) bacteria that can oxidize ammonia anaerobically using nitrite as the oxygen donor. These bacteria form granules and have slow growth, so in order to increase their retention time in the system the contents of the reactor are pumped through solids separation cyclones that retain the heavier particles (including Anammox granules) in the process and waste the lighter biomass.

The process goal of the CPT system is to remove 90 percent of the ammonia and 80 percent of the TN in the centrate before it is returned to the BRBs. The system is designed to run in one of three process modes: Nitrification/Denitrification, Nitritation/Denitritation and DEMON™. The basis of design is Nitritation/Denitriation mode. The facility is currently running in DEMON™ mode.

The design criteria and current performance for the centrate pre-treatment system are listed in Table 2-16. The current performance data shown is average data for the DEMON™ process for 2016.

TABLE 2-16
Centrate Pre-Treatment – Design Criteria

Unit Process	Description	Design Basis [a]	Current (2016)[b]
Centrate Pre-Treatment	Number of Sequencing Batch Reactors	3	3
	CPT 1 and 2: Vol, Each Unit	0.4 MG	
	CPT 3: Volume	0.04 MG	
	In Service Units	2	1
	Number of Blowers	5	1
	CPT 1 and 2: Blower hp	75/150	1 blower
	CPT 3: Blower hp	30	N/A
	Air Flow (scfm)	2,950	1,100
	Number of Recycle Pumps (per reactor)	1	1
	Influent Centrate (million gallons per day)	0.276	0.100
	Influent Ammonia Concentration (mg/L)	1,230	1,242
	Reactor Loading (lbs NH_3/gal of reactor vol)	0.0035	0.0032
	Ammonia Removal (% of influent)	90	88
	TN Removal (% of influent)	80	77

Notes:

a. Nitritation/Denitritation mode

b. DEMON™ mode

Process Performance

The effluent from the CPT is returned to Control Structure 3, which is located downstream of the Primary Effluent Channel and upstream of the PEPS. Currently, the system is treating the entire dewatering centrate flow which averages 100,000 gpd. The average ammonia removal in 2016 was 88 percent and the average total nitrogen removal was 77 percent.

System Condition

The facility was commissioned in 2015 and most of the equipment is running well. The pumps used to recycle the reactor contents through the cyclones have been clogging frequently with trash. The trash is coming from the influent centrate and is probably passing through the sludge screens in the pre-pasteurization system. AlexRenew is currently working to refurbish and repair the pump impellers and to eliminate trash from the system and also considering replacing the pumps with a different type. In addition, three process air blower cores failed in 2016 and are being repaired. They will be reinstalled and retested in 2016 to insure that the impeller selection and programming are correct for the process application.

Capacity

The CPT is processing all of the centrate produced using only one of the reactors. The design criteria for the facility was based on treating the centrate produced at the design annual average condition using two reactors. Footprint to the north of the CPT is reserved for a future third reactor if additional capacity is needed.

2.4 Biosolids Management Today

AlexRenew treats primary sludge, WAS, and tertiary sludge to produce Class A dewatered cake.

The solids treatment processes include:

- Gravity thickening for primary sludge and co-thickening with tertiary sludge
- Centrifuge thickening for WAS
- Sludge pre-pasteurization for the combined primary and WAS solids stream
- Mesophilic anaerobic digestion
- Centrifuge dewatering of digested sludge

AlexRenew biosolids meet the requirements for Class A and Exceptional Quality ratings. Currently, dewatered biosolids land applied for beneficial re-use.

The screenings and grit removed at the head of the plant and from the sludge at the pre-pasteurization step are loaded onto trucks and sent to a landfill.

2.4.1 Quantity and Quality

AlexRenew processes solids 24 hours per day and 7 days a week. The average daily production is 60 wet tons/day or an annual average of approximately 22,000 wet tons/year. The average cake solids content is 28 percent total solids. The Class A Exceptional Quality biosolids produced at AlexRenew are subject to the *Code of Federal Regulations* (CFR), Title 40, Part 503 for pathogens reduction, vector attraction reduction, and heavy metals concentrations. The total nitrogen (as N dry weight basis) in the bulk biosolids is also recorded. Table 2-17 shows the monthly average allowable concentrations allowed by 503 and the actual monthly concentrations for solids produced by AlexRenew in 2015. In all cases, AlexRenew meets or exceeds the requirements.

TABLE 2-17
Monthly Average for Constituents Monitored in AlexRenew Biosolids in Calendar Year 2015

Month	Arsenic (mg/kg)	Molybdenum (mg/kg)	Zinc (mg/kg)	Lead (mg/kg)	Nickel (mg/kg)	Mercury (mg/kg)	Copper (mg/kg)	Cadmium (mg/kg)	Selenium (mg/kg)	Sludge pH
Monthly Avg. Limit	41	N/A	2,800	300	420	17	1,500	39	100	N/A
January	6	9	888	41	19	0.6	363	2	<5.0	8.9
February	6	7	777	31	20	1.3	326	2	<5.0	8.9
March	6	8	749	34	21	0.7	320	2	<5.0	8.9
April	6	8	773	44	23	0.5	318	2	<5.0	9
May	6	8	892	42	25	0.5	364	2	<5.0	9.1
June	7	9	877	41	26	0.8	349	2	<5.0	9
July	6	9	939	43	26	1.2	365	2	<5.0	8.9
August	9	10	1020	65	23	0.8	395	3	<5.0	8.9
September	8	10	1020	49	20	1.2	376	2	<5.0	8.8
October	8	12	946	47	19	0.6	351	2	<5.0	8.9
November	10.0	13.0	955	43	21.0	1.1	360	3.0	<5.0	9.2
December	10.0	12.0	934	38	21.0	0.5	392	3.0	<5.0	9.0

Note:
mg/kg = milligram per kilogram
N/A = not applicable

In addition, the biosolids land applier (Synagro) is required by the Virginia Department of Environmental Quality, to sample and test, on a dry weight basis, for TKN, phosphorus, potassium, sulfur, calcium, magnesium, sodium, iron, manganese, ammonia-nitrogen, organic nitrogen, chromium, total organic carbon, carbon to nitrogen ratio, and the Environmental Protection Agency 40 CFR Part 503 heavy metals (listed in Table 2-18).

2.4.2 Truck Traffic

AlexRenew currently land applies all of the biosolids produced at the plant. Trucks haul the biosolids to the land application sites. At the average daily production rate of 60 wet tons/day, 2 to 4 truckloads are picked up each day. AlexRenew limits biosolids hauling to weekdays only. Based on the production rate, trucks come to site 4 to 5 times per week, which translates to 8 to 20 trucks per week.

2.4.3 Disposal Costs

AlexRenew land applies all of the biosolids produced at the plant at various land application sites in Virginia. Figure 2-8 shows the various sites that were used in 2015. The average disposal cost is $35.75 per wet ton.

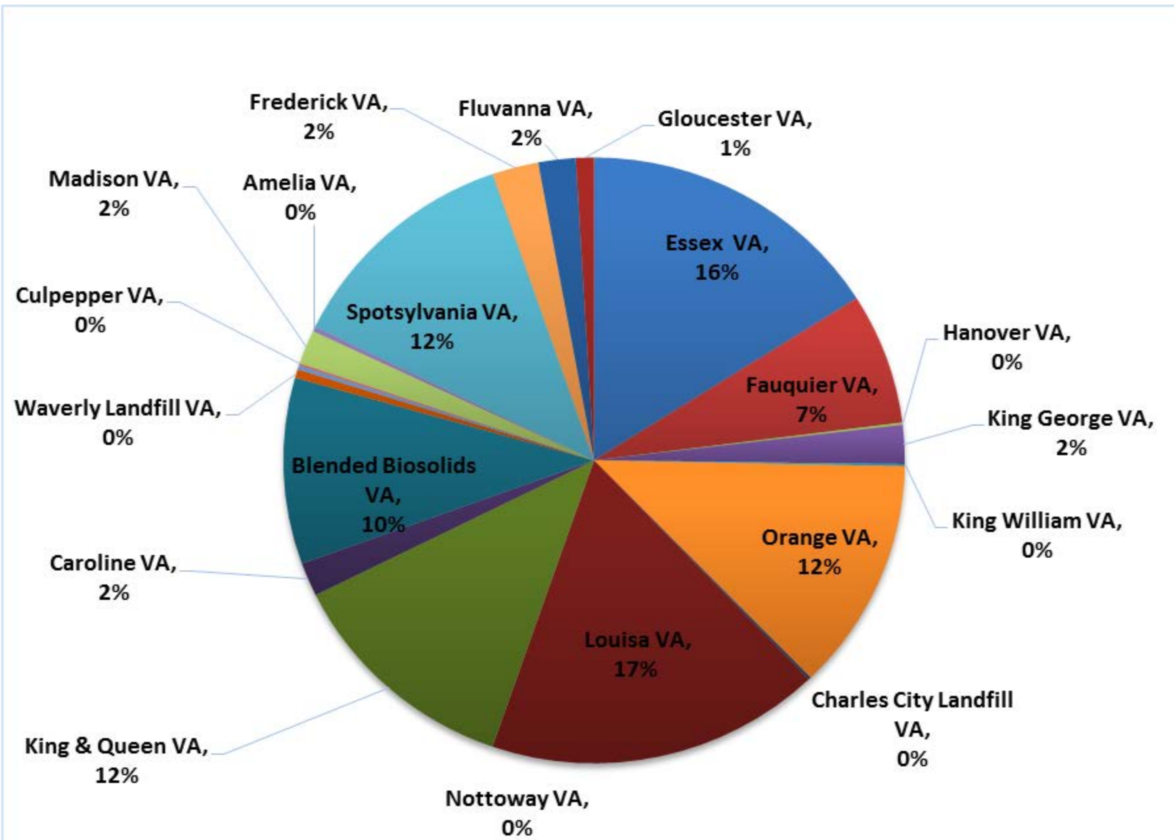


Figure 2-8. AlexRenew Biosolids Land Application Sites and Percentage Sent to Each Site in 2015

2.5 Energy Use at AlexRenew Water Resources Recovery Facility

AlexRenew has commissioned several studies to look at the energy usage at the plant. These studies include the *Energy Master Plan* (Greeley & Hansen, July 2014), several Energy Performance Contracts, and the *Alexandria Renew Enterprises Building Energy Analysis,* (CH2M, June 2016). These studies concluded that the main uses of electricity are pumping plant flow, aerating the BRBs and heating/cooling of buildings at AlexRenew. A new aeration system for the BRBs, optimized for energy efficiency and the addition of the NMF and CPT, is currently under design.

The *Energy Master Plan* (Greeley & Hansen, July 2014) contains a condition assessment of the existing electrical equipment and systems, and an energy usage analysis. Based on the energy analysis and condition assessment, the report recommends the following types of projects to improve energy usage and increase reliability:

- Upgrade variable frequency drives at all the major pumps stations
- Upgrade uninterruptable power supply units
- Upgrade electrical equipment including switchgear replacement
- Reduce the potential for arc flash
- Relocate one of the Dominion Virginia Power plant feeders
- Optimize onsite plant effluent water usage to reduce pumping

As part of the *Alexandria Renew Enterprises Building Energy Analysis* (CH2M, June 2016), CH2M conducted an energy analysis of the HVAC systems for nine building on the AlexRenew main plant site. The following areas of improvement, for the buildings evaluated (55, A, C, G1, G2, G5, J, K, and L) are noted in the report:

- Reprogram HVAC controls
- Operations and maintenance upgrades
- Installation of variable frequency drives
- Retro-commissioning of the existing HVAC systems
- Upgrades to the existing HVAC equipment
- Upgrades to the existing chillers in Building J

The report also evaluated the use of solar power at AlexRenew to offset power needs from the main grid. Based on the analysis of two different solar technologies, a solar power installation at AlexRenew has a long economic payback period – in excess of the lifespan of the solar array panels.

Previous work also looked at the use of hydroelectric turbines at locations in the plant where there are significant hydraulic drops. However, like solar power, the economic payback is too long to justify implementation. Wind turbines were also investigated, and it was determined that the plant is located in a low potential wind energy zone, therefore making this approach not feasible.

During the 2016 planning process, the following items were identified as potential options for reducing energy consumption for HVAC and lighting at the site:

- Addition of a third boiler than can run on biogas (dual gas boiler)
- Adding a second adsorption chiller
- Upgrading lighting with Light Emitting Device (LED) lighting

2.6 Site Utilization

AlexRenew is located at the edge of Old Town in Alexandria, Virginia and the site is significantly constrained. The main plant site is bordered to the east by the planning limits of the “Old and Historic” Planning District of Alexandria, with property values exceeding $1 million/acre. A national cemetery to the north contains historic survey monuments. The southern boundary includes Virginia Power easements and I-95, a major East Coast transportation route. Hoofs Run borders the west side of the Main Plant site.

With the addition of the West Plant Site for construction of the NMF, AlexRenew became a part of the South Carlyle Development Area as defined in the City’s East Eisenhower Small Area Plan .The City has defined the East Eisenhower corridor as a growth area and economic engine for the community.

Since the main plant site was already constrained, careful planning of the remaining available space was required. AlexRenew responded by acquiring the West Plant Site and selecting space saving technologies and processes to maximize site utilization. The SANUP program was designed to meet process needs within a limited footprint while maintaining space for future processes. The reclaimed water and ultraviolet disinfection projects also use repurposed space within existing facilities.

As discussed in the 2009 Long Range Plan, AlexRenew anticipates that several new, very stringent limits could be imposed on the plant effluent in the future. Liquids technologies selected to address these new limits include:

- Meeting a TN effluent limit of 1 mg/L and/or microconstituents:
  - Ozonation and BAC to be located in Building G (to remove refractory TKN and microconstituents)
  - Integrated Fixed-film Activated Sludge in the BRBs (to further reduce TN)
- Meeting a TP effluent limit of 0.01 mg/L:
  - Tertiary Membranes located in the footprint of the existing Administration/Laboratory Building

However, to accommodate 2016 long range planning solids to energy goals, the following areas could be re-configured to accommodate new solids processes:

- Building F: A new blower system for the BRBs is under design. If the new blowers are smaller than the current blowers, the remaining space may be available for use by other processes or equipment.
- Building L: Several processes contained in this facility are no longer used (for example, lime addition system). Additional analysis of the existing space is needed to understand how the existing equipment can be re-configured to provide space for future processes.
- Building C: The gravity thickeners are located in Building C and occupy a large footprint. Selection of a new process for thickening primary sludge may free up space in Building C for future solids, nutrient recovery or energy recovery processes.
- Building 20: Under the 2009 Long Range Plan, space was allocated in the digester building for recuperative thickening. The space is currently available.
- Building 55: Under the 2009 Long Range Plan, space for a fourth pre-pasteurization train was located in Building 55. This space is currently available, however it may have to house two pre-pasteurization trains to maintain adequate redundancy
- Building A: Under the 2009 Long Range Plan, space was allocated in Building A for co-generation equipment and/or boilers. The space is currently available.

Other future projects that may have onsite space needs include projects related to the wet weather management, including a wet weather storage tunnel with access shafts, a hydraulic grade-line control structure and a screening facility.

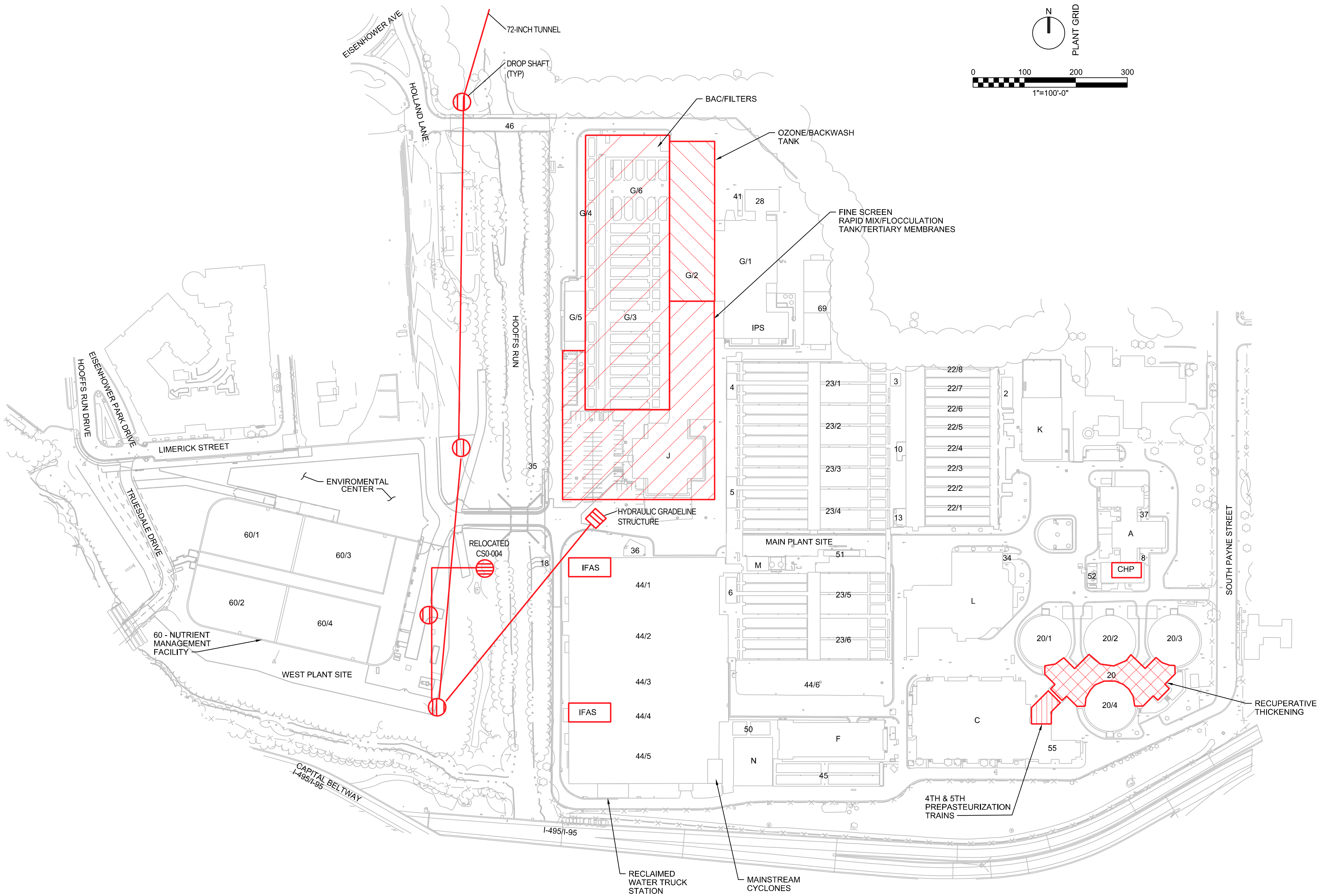


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FIGURE 3-1
PROPOSED IMPROVEMENTS THROUGH 2060
ALEXANDRIA RENEW ENTERPRISES
ADVANCED WASTEWATER TREATMENT FACILITY

XXXXXX.XX

ch2m:

2.7 Solids Handling Building (L) Assessment

An initial assessment of the Solids Handling Building (L) was conducted to determine, at a high-level, what space is currently unused or underutilized. Appendix D includes building floor plan drawings that indicate the space in Building L that could be available because either it is empty or the equipment in that space is not used. As the Appendix D drawings show, while there are pockets of usable space, they are insufficient for large pieces of equipment or new processes without major modifications of the existing equipment or processes. For example, as part of the 2016 long range planning effort, a sludge dryer was considered as a viable option in order to reduce the volume of biosolids generated. The dryer was sized using the established design criteria and vendor provided information indicated that the dryer(s) would need a footprint of 46 feet wide by 140 feet long by 40 feet tall. As the Appendix D drawings show, with the current equipment configurations there is no single space that can accommodate a dryer without relocation of the existing equipment.

A more in-depth analysis, including process and structural review, will be needed to determine viable approaches to repurposing spaces in Building L. The evaluation will also need to consider ways to replace existing processes with newer, more compact solutions.

SECTION 3

Planning Process and Alternative Evaluation

After assessing the future drivers and the current state of the facility, the next step was to develop plausible future scenarios and determine technology pathways to achieve the envisioned future. The planning process consisted of the following steps:

1. Envisioning Plausible Future Scenarios
2. Development of Technology Pathways to an Envisioned Future
3. Data gathering on the technology pathways
4. Scoring

3.1 Envisioning Plausible Future Scenarios

Envisioning the future for AlexRenew was conducted around three key elements: evolving regulations, embracing sustainability, and engaging stakeholders. Within that context, the project team developed a list of plausible future triggers and needs to determine the characteristics for a 2040 planning horizon. Table 3-1 lists the resulting characteristics

TABLE 3-1
Characteristics of an Envisioned Future

A. Evolving Regulatory Framework	B. Embraced Sustainability Principles	C. Engaged Stakeholders (Board and Community)
A-1: Ban on land application of biosolids and/or potentially all land-based uses of biosolids A-2: Limits on nutrient effluent discharge concentrations down to LOT levels A-3: Monitoring and limits on microconstituents in the biosolids and in the liquids A-4: GHG caps A-5: Air Emission Requirements A-6: "Integrated" Regulatory Frameworks (air, water, solids)	B-1: Trend towards energy neutrality and beyond B-2: No net increase in air emissions onsite B-3: Manage risk associated with biosolids use/disposal B-4: Reclaimed water – develop partnerships to utilize 5 MGD capacity B-5: Limited footprint at WRRF for future development B-6: Resource Recovery B-7: Climate change resiliency and adaptation B-8: Supply Chain considerations (life cycle assessments – where do chemicals come from and what's in them) B-9: Sustainable Infrastructure Rating System (Envision)	C-1: Support Board 2040 vision and outcomes C-2: Supportive development partner in Carlyle Partners C-3: Focus on local community stewardship – solutions to enable City to grow C-4: No net increase in odor/air emissions/light/noise/traffic C-5: Remain neutral on visual impacts of future additional facilities compared with existing C-6: Legislator advocacy C-7: Influence "Sector" Organizations (Water Environment Federation, Water Environment Research Foundation , National Association of Clean Water Agencies) C-8: New (revised) interaction between district and clients

3.2 Development of Technology Pathways to an Envisioned Future

The next step in the planning process was to develop various technology pathways to achieve the envisioned future outlined in Table 3-1. Figure 3-1 illustrates the interrelationship between three concepts:

1. Where we want to go: The Envisioned Future
2. How we know we have arrived: Technology attributes
3. What will get us there: Technology pathways

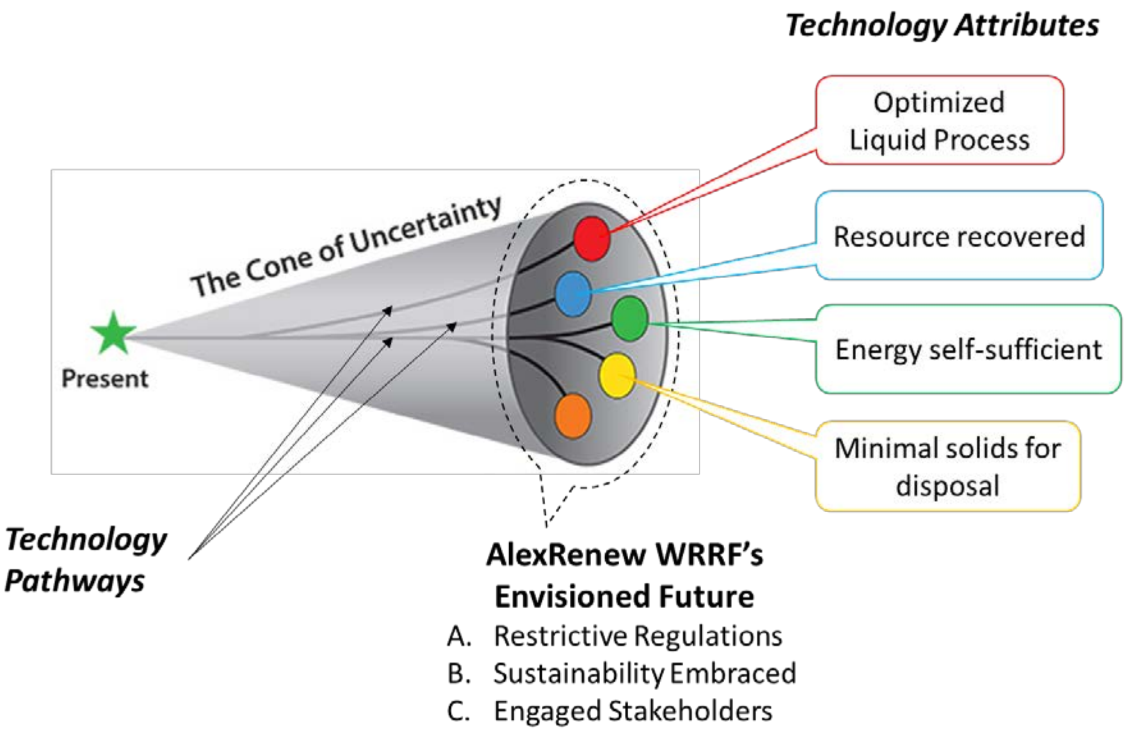


Figure 3-1. Technology Pathways to the Envisioned Future

The team used the technologies listed in Figure 3-2 to create various technology pathways. The goal was to use these technologies as references for the purposes of sizing and evaluating the pathways but with the understanding that as technologies advance and evolve, new options may be available in the future.

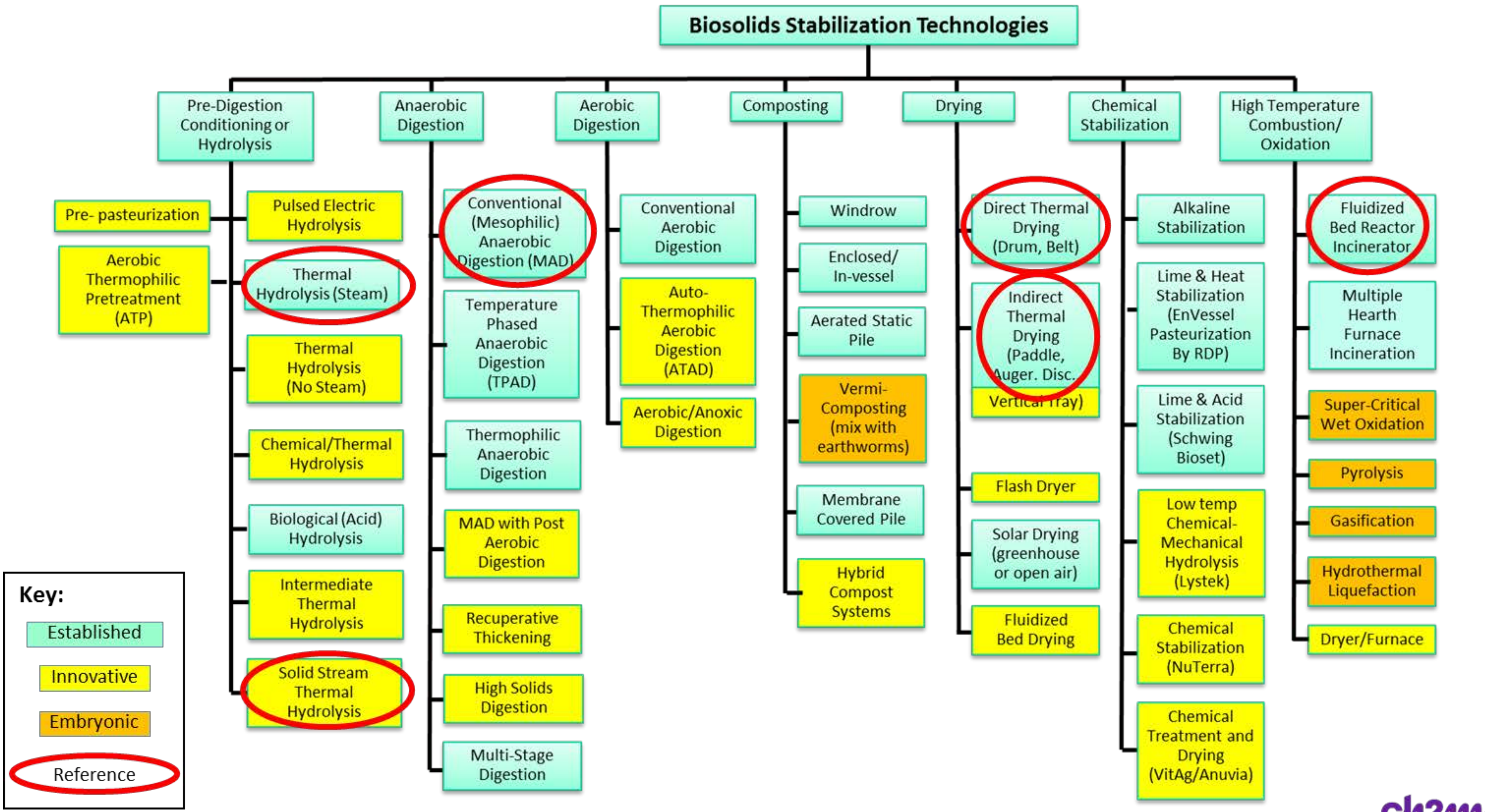


Figure 3-2. Biosolids Technologies

Out of the technologies listed on Figure 3-1, the following were screened out for consideration as the primary pathway at AlexRenew:

- Aerobic Digestion: Consumes (rather than generates) large amounts of energy
- Composting: Requires large footprint and there is risk of odors if neighbors are in close proximity
- Chemical (Alkaline) Stabilization: Material handling is challenging; high annual costs for lime and net increase in biosolids to be disposed

Three groups of technology pathways were created in a workshop setting and are summarized in Table 3-2. Group 1 focused on thermal oxidation, group 2 on anaerobic digestion and group 3 combined anaerobic digestion and thermal oxidation. A preliminary qualitative evaluation was conducted on these technology pathways and the general conclusion was that the Anaerobic Digestion pathway provides a great benefit in energy recovery and solids reduction and therefore should remain a core technology at AlexRenew either on its own or as part of a combined pathway. The group then voted on the top configurations for detailed evaluation that met the boundary conditions. The selected configurations are highlighted in red in Table 3-2.

TABLE 3-2
Possible Technology Pathways at AlexRenew Water Resources Recovery Facility

Group 1. TCO	Group 2. AD	Group 3. AD + TCO
1a. TCO with Partial Thermal Drying	**2a. AD with Thermal Drying**	3a. AD + TCO (no conditioning)
1b. TCO with WAS Conditioning	**2b. AD with WAS Conditioning and Drying**	**3b. AD + TCO + WAS Conditioning**
	2c. AD with post-digestion conditioning and Drying	**3c. AD + TCO + post-digestion conditioning**

Notes:
AD = Anaerobic Digestion
TCO = Thermal Conversion of Organics
Selected pathways for detailed evaluation.

3.3 Data Gathering

The project team generated process configuration flow diagrams for each of the selected technology pathways and performed a mass and energy balance in order to optimize each configuration. Equipment vendors provided preliminary sizing recommendations and estimates were developed for capital and O&M costs. The project team also found likely locations for the proposed processes on site and developed a feasible construction sequence that would maintain Class A Exceptional Quality biosolids.

The built-out condition (2060) was used to size the systems and to calculate the future energy profile, solids generated and O&M costs.

In order to develop the information for evaluation, the team agreed to use “reference technologies” as a stand-in for each process step. The reference technologies were selected if they are currently in use at AlexRenew for that function, and/or if they are considered typical by today’s industry standards. However, they could be replaced by a different technology in the future if new or better systems become available. Table 3-3 lists the reference technologies.

TABLE 3-3
Reference Technologies for Pathway Evaluation

Process	Reference Technology
PSD Thickening	Gravity Thickener
WAS Thickening	Centrifuge
Anaerobic Digestion	Mesophilic AD
Recuperative Thickening	Rotary Drum Thickener
Sludge (PSD, WAS, Dewatered Sludge) Conditioning	Thermal Hydrolysis (Cambi)
Sludge Dewatering	Centrifuge
Sludge Thermal Drying	Belt Dryer
TCO	Fluidized Bed Reactor
Phosphorus Recovery	Intentional struvite precipitation (Ostara)
CHP	Internal combustion engine (GE Jenbacher)
Energy Recovery from TCO	ORC Turbo Generators

ORC = Organic-Rankine Cycle

3.3.1 Pathway 2a – Anaerobic Digestion with Drying

This pathway was considered the "Baseline" pathway because it closely matches what had been the selected future solids handling alternative in the 2009 Long Range Plan. The characteristics of this pathway include:

- Abandon pre-pasteurization as the means of achieving Class A biosolids and use a belt thermal dryer to achieve a product with 90 percent solid content that can have beneficial reuse as fertilizer or a soil blend.
- Use the biogas from the anaerobic digesters in a CHP internal combustion engine to generate heat and electricity. The electricity generated can be used at the WRRF and the heat generated can heat the anaerobic digesters and the dryer.
- The minimum SRT in the digester can be reduced from the minimum of 15 days under all conditions to meet Class A biosolids to 15 days under average conditions and 12 days under maximum month conditions. In this scenario, the existing digesters would have enough capacity to treat the solids up to the 2060 design condition. Alternatively, recuperative thickening could be implemented to free up the footprint of one of the four digesters if the footprint is needed for other technologies.

Figure 3-2 illustrates the process flow diagram for Pathway 2a and Figure 3-3 illustrates the site layout and proposed construction sequence. Additional information, including more detail on the dryer facility can be found in Appendix A.

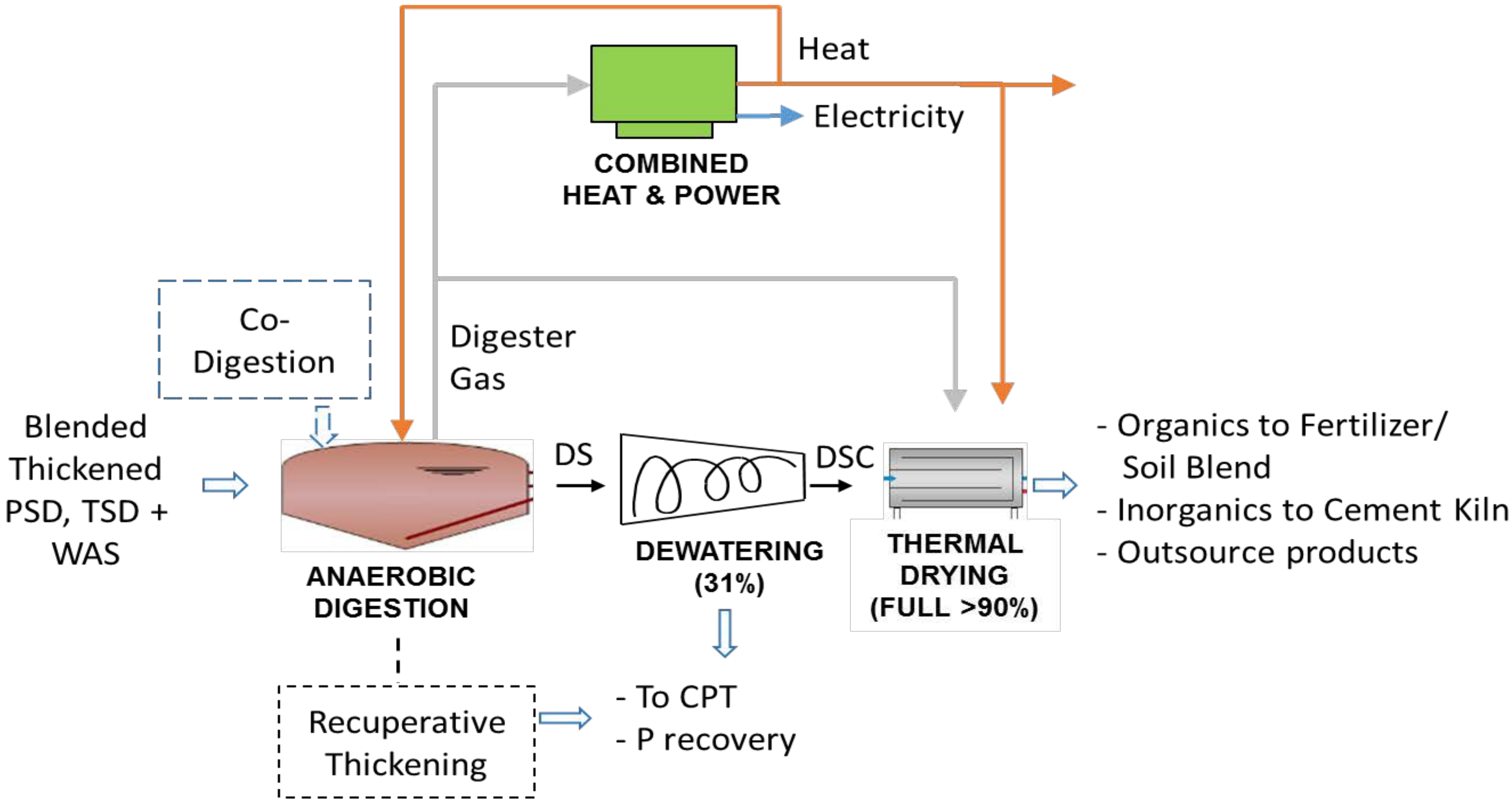


Figure 3-2. Pathway 2a Process Flow Diagram

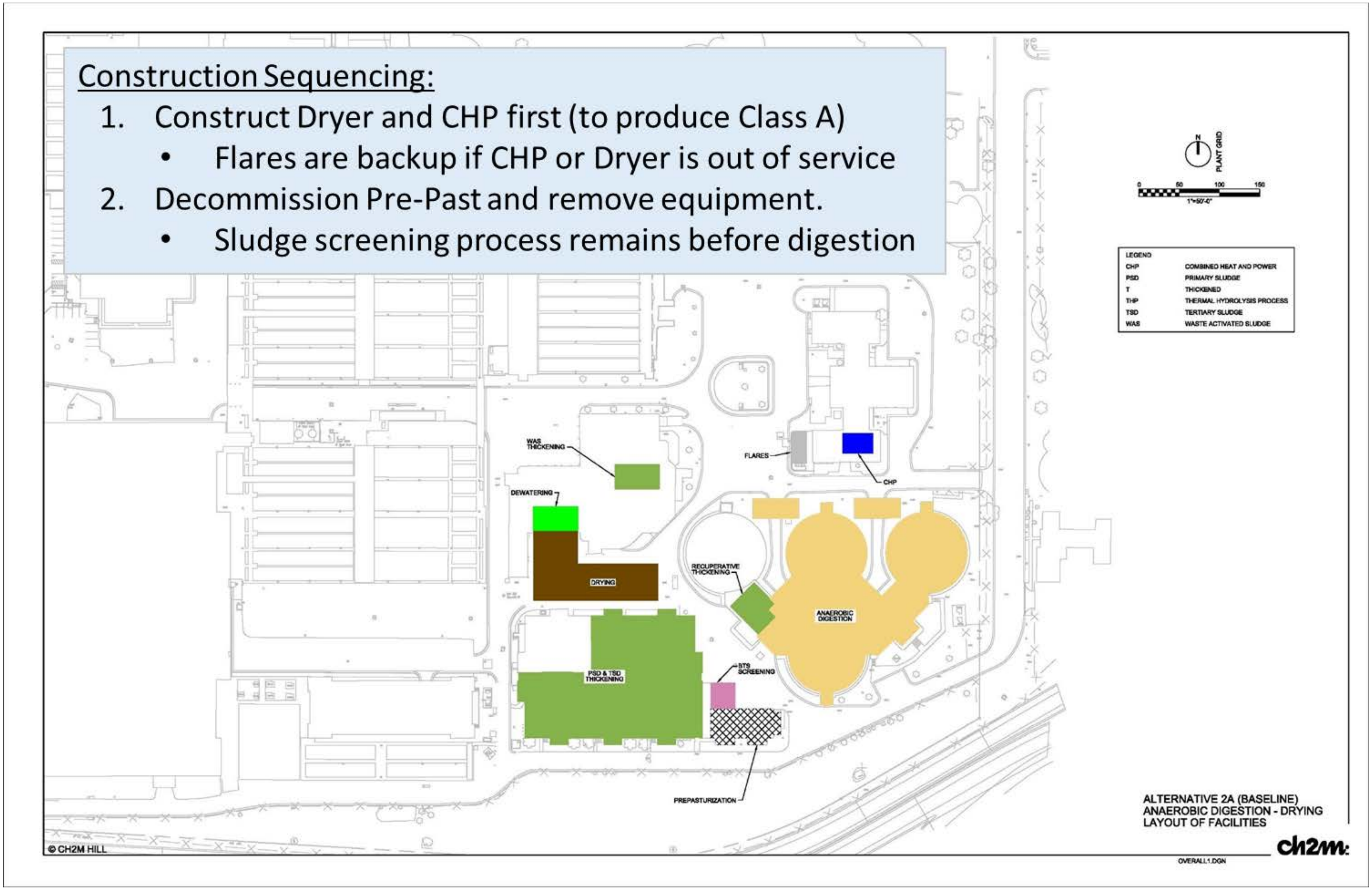


Figure 3-3. Pathway 2a Site Plan

3.3.2 Pathway 2b – Anaerobic Digestion with Waste Activated Sludge Conditioning and Drying

This pathway is the same as Pathway 2a but it adds WAS conditioning with the intent of improving biogas generation at the digesters, as well as improving the dewaterability of the digested sludge. In addition to the characteristics listed for Pathway 2a, this pathway offers the following:

- Implementation of WAS pre-dewatering to achieve a 16 percent solids influent to the WAS conditioning process (thermal hydrolysis). Since the feed to the digesters is thicker, the SRT is increased and the system can operate with only three digesters without using recuperative thickening.
- Implementation of WAS Conditioning increases dewaterability and results in dryer solids (assumed solids content increased from 32% to 34%) compared to alternative 2a.
- Volatile Suspended Solids (VSS) destruction in the digesters goes up (assumed from 61% to 66%) compared to alternative 2a.
- Digester gas production increases by 7 percent and heating requirement in the dryer decreases by 21 percent (because of less solids and drier cake) compared to alternative 2a.
- Electricity generation increases by 18 percent compared to alternative 2a.
- The new WAS conditioning system would be installed in the footprint of the existing pre-pasteurization facility. New sludge screening facilities for thickened WAS (TWAS) and thickened Primary Sludge and Tertiary Sludge (PSD+TSD) would have to be constructed. The TWAS facility could be constructed where the existing sludge screens are located in the Pre-Pasteurization building. The thickened PSD+TSD screening can be constructed in Building L.

Figure 3-4 illustrates the process flow diagram for Pathway 2b and Figure 3-5 illustrates the site layout and proposed construction sequence.

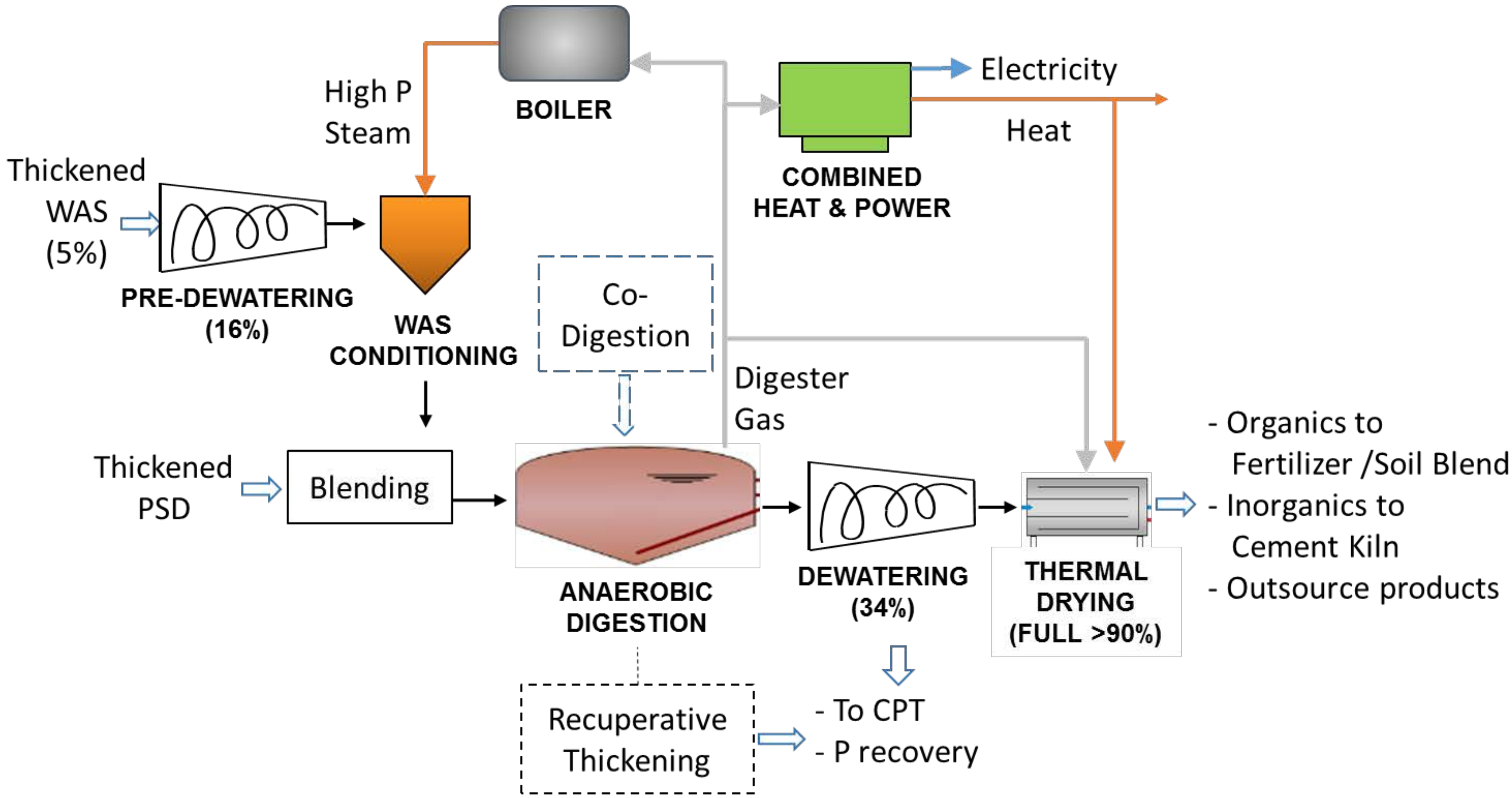


Figure 3-4. Pathway 2b Process Flow Diagram

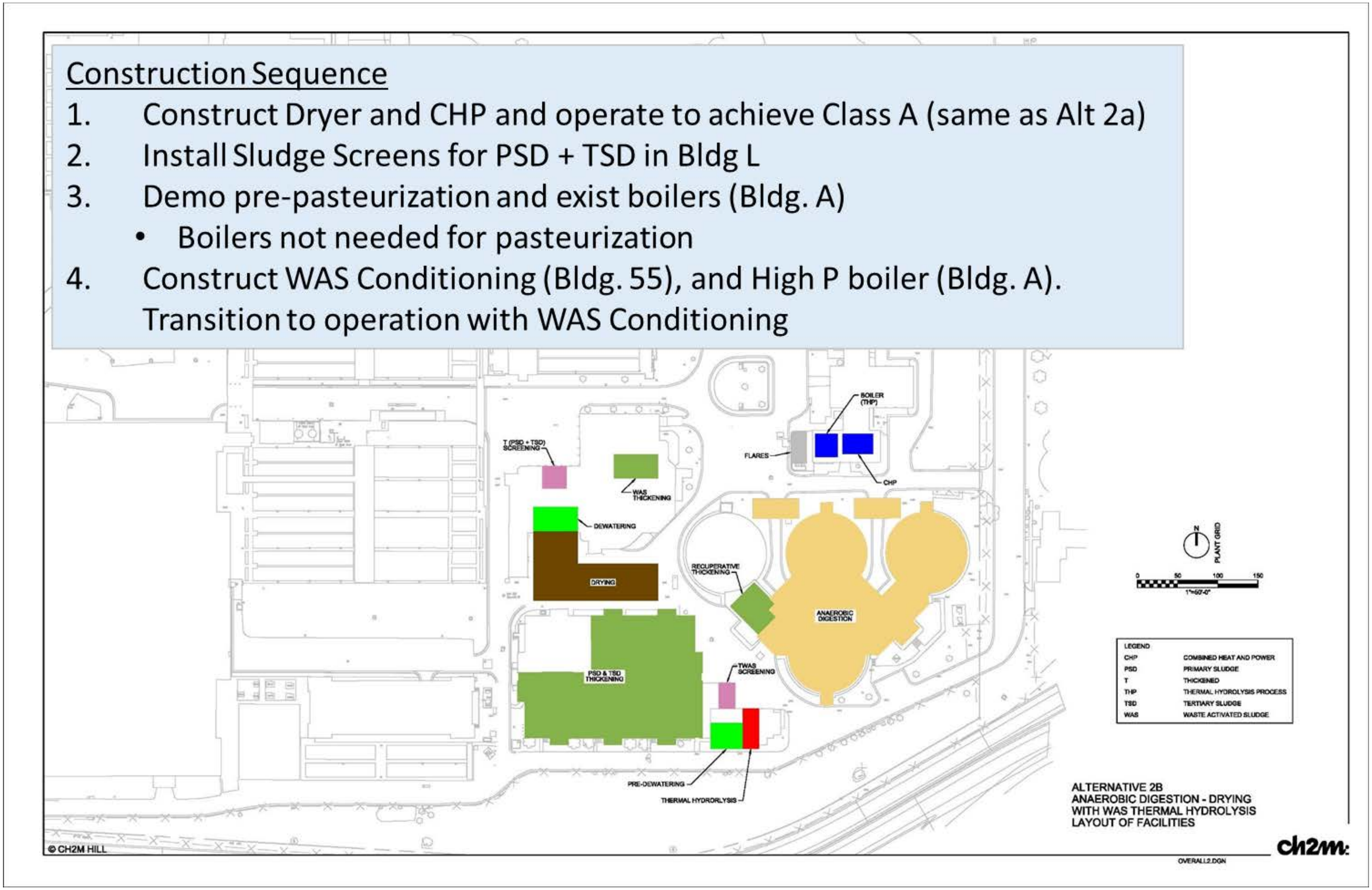


Figure 3-5. Pathway 2b Site Plan

3.3.3 Pathway 3b – Anaerobic Digestion with Thermal Conversion of Organics and Waste Activated Sludge Conditioning

This pathway is the same as 2b but it replaces drying with TCO. In addition to the characteristics listed for Pathway 2b, this pathway offers the following:

- Because no heat is needed for the dryer, more digester gas is available for CHP, so electricity production increases 47 percent. Heat recovered is also increased by 47 percent
- Energy (electricity and heat) will be recovered from TCO. As a result, total electricity production for alternative 3b is increased by 61 percent

Figure 3-6 illustrates the process flow diagram for Pathway 3b and Figure 3-7 illustrates the site layout and proposed construction sequence.

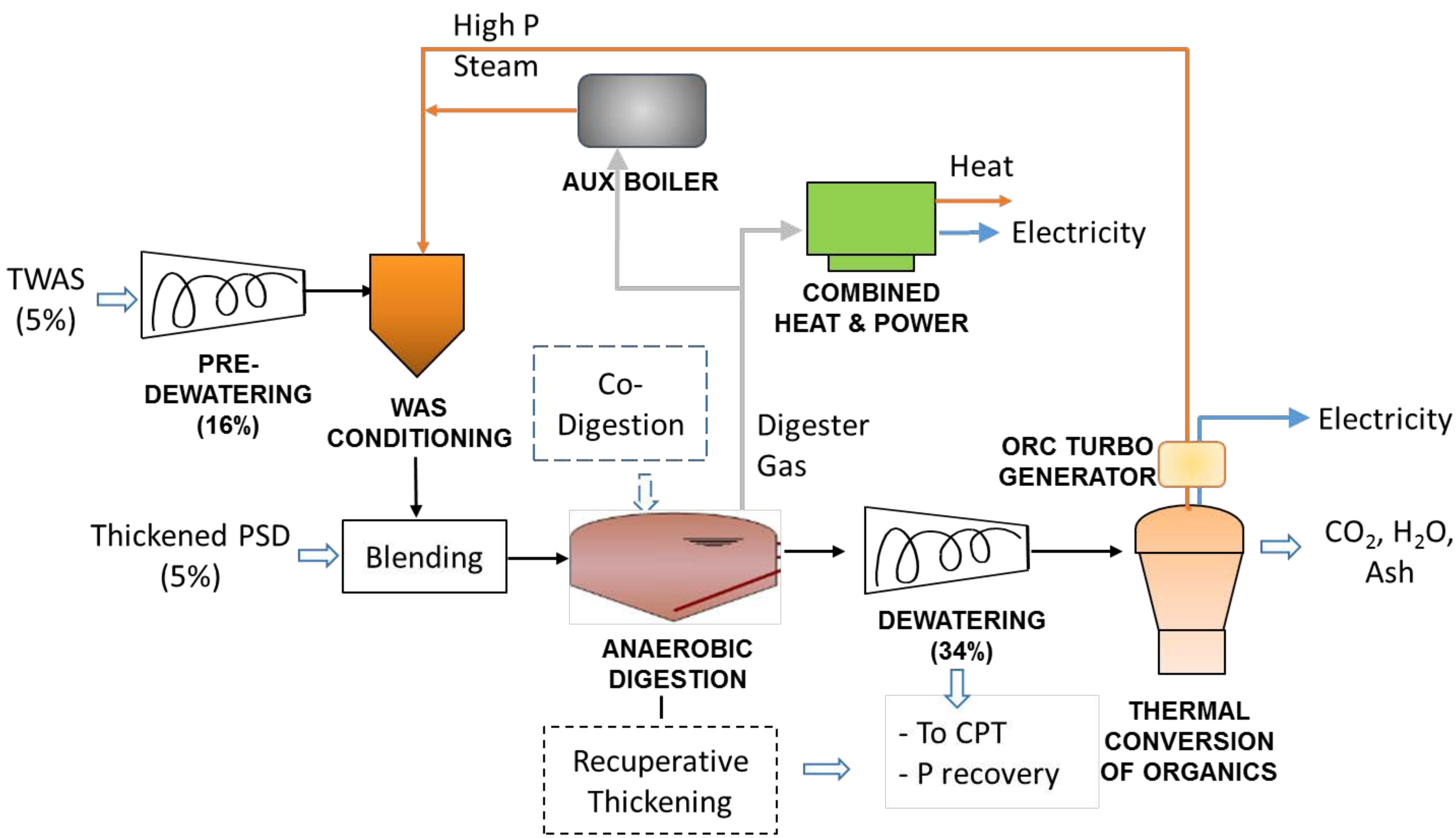


Figure 3-6 Pathway 3b Process Flow Diagram

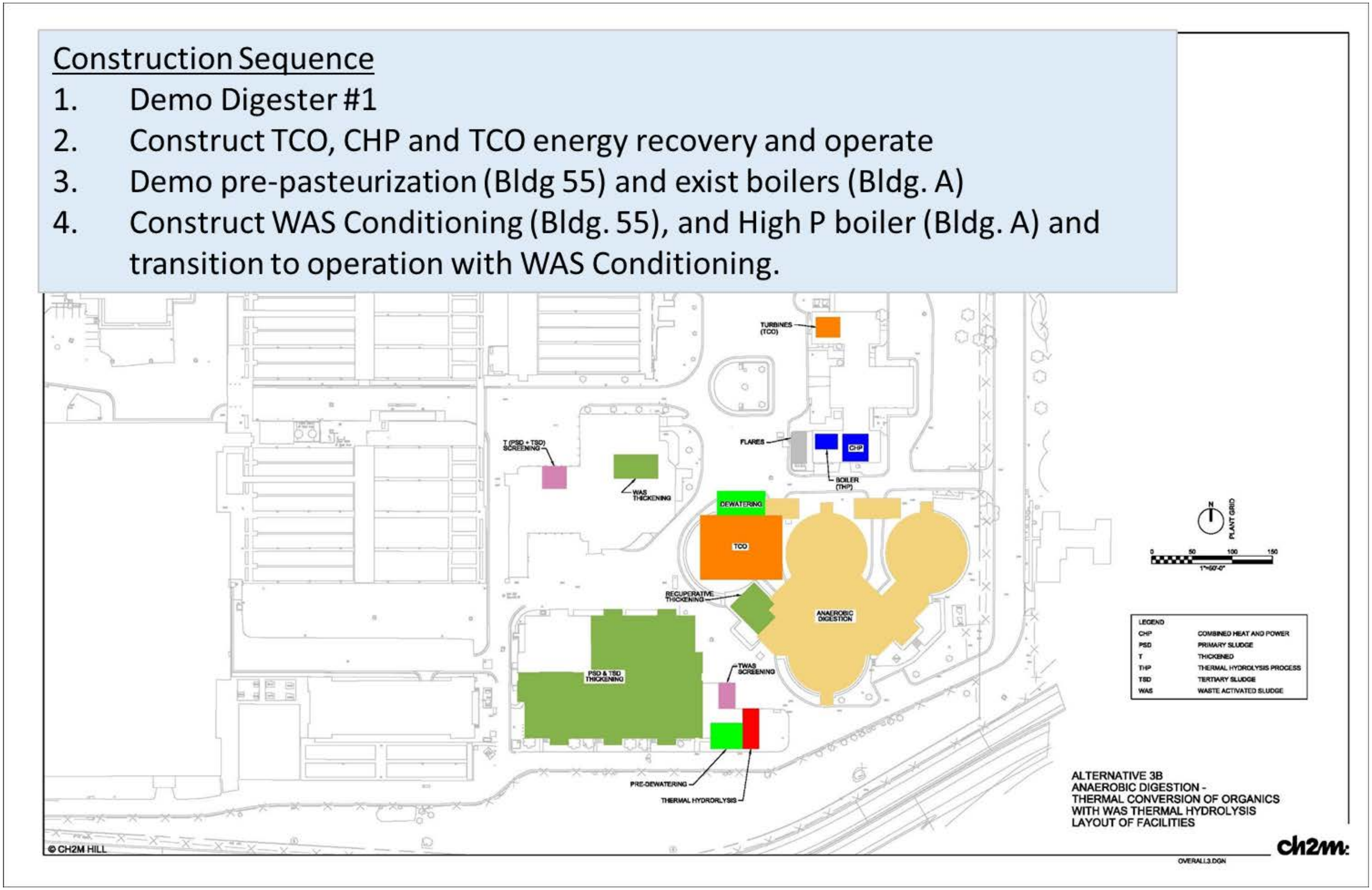


Figure 3-7. Pathway 3b Site Plan

3.3.4 Pathway 3c – Anaerobic Digestion with Thermal Conversion of Organics and Post-Digestion Conditioning

This pathway is similar to 3b but it places the sludge conditioning step (thermal hydrolysis) after digestion instead of before. The digested primary sludge is combined with TWAS and pre-dewatered to 17 percent solids prior to conditioning. The conditioned sludge is then dewatered and the dewatering centrate is recycled back to the anaerobic digester. This pathway has the following characteristics:

- More electricity production than 3b which is offset by more electricity consumption than 3b because of the extra dewatering step. The net amount of electricity available is about the same.
- More heat available (About 2 percent more than 3b)

Figure 3-8 illustrates the process flow diagram for Pathway 3c and Figure 3-9 illustrates the site layout and proposed construction sequence.

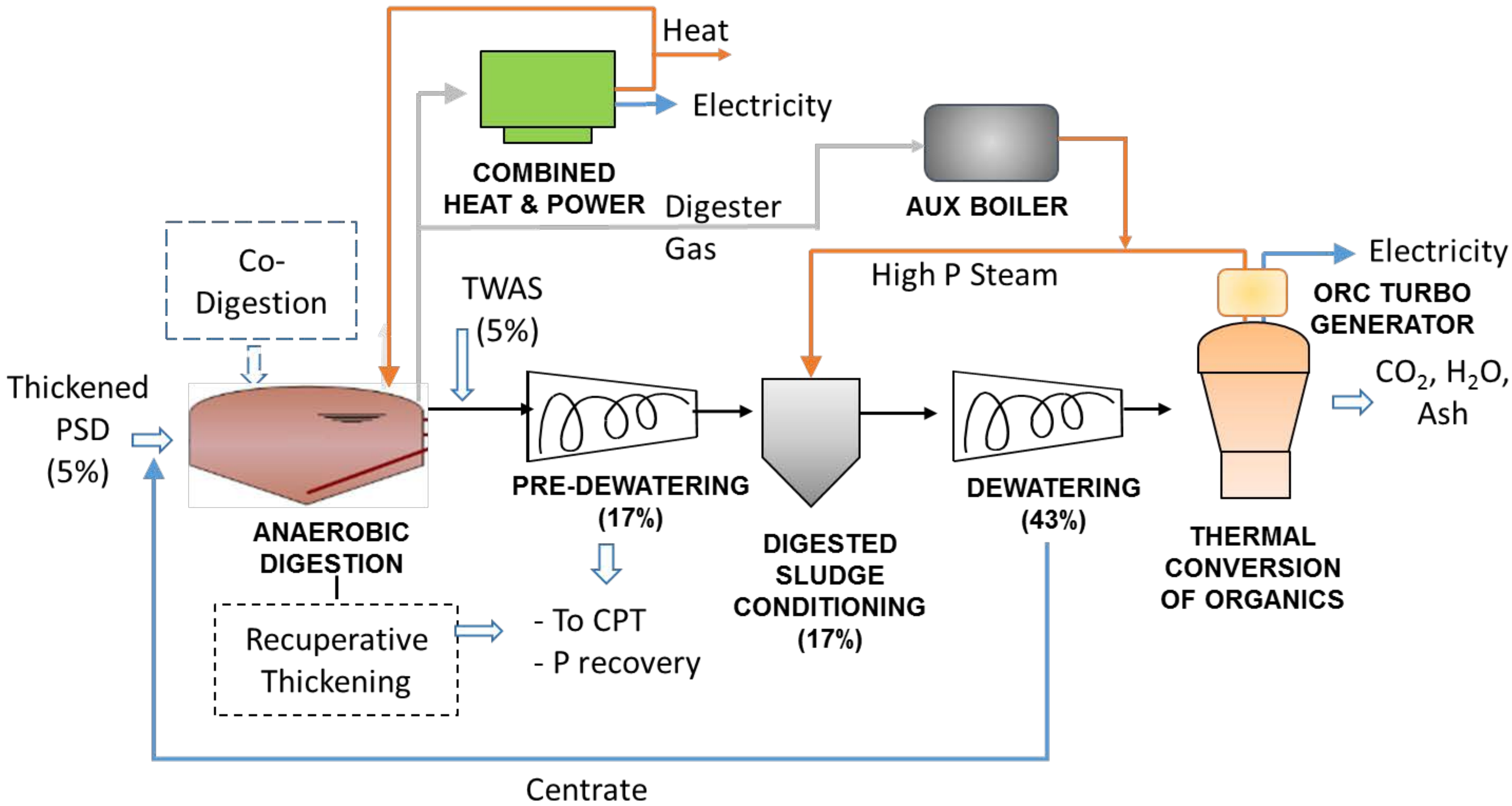


Figure 3-8. Pathway 3c Process Flow Diagram

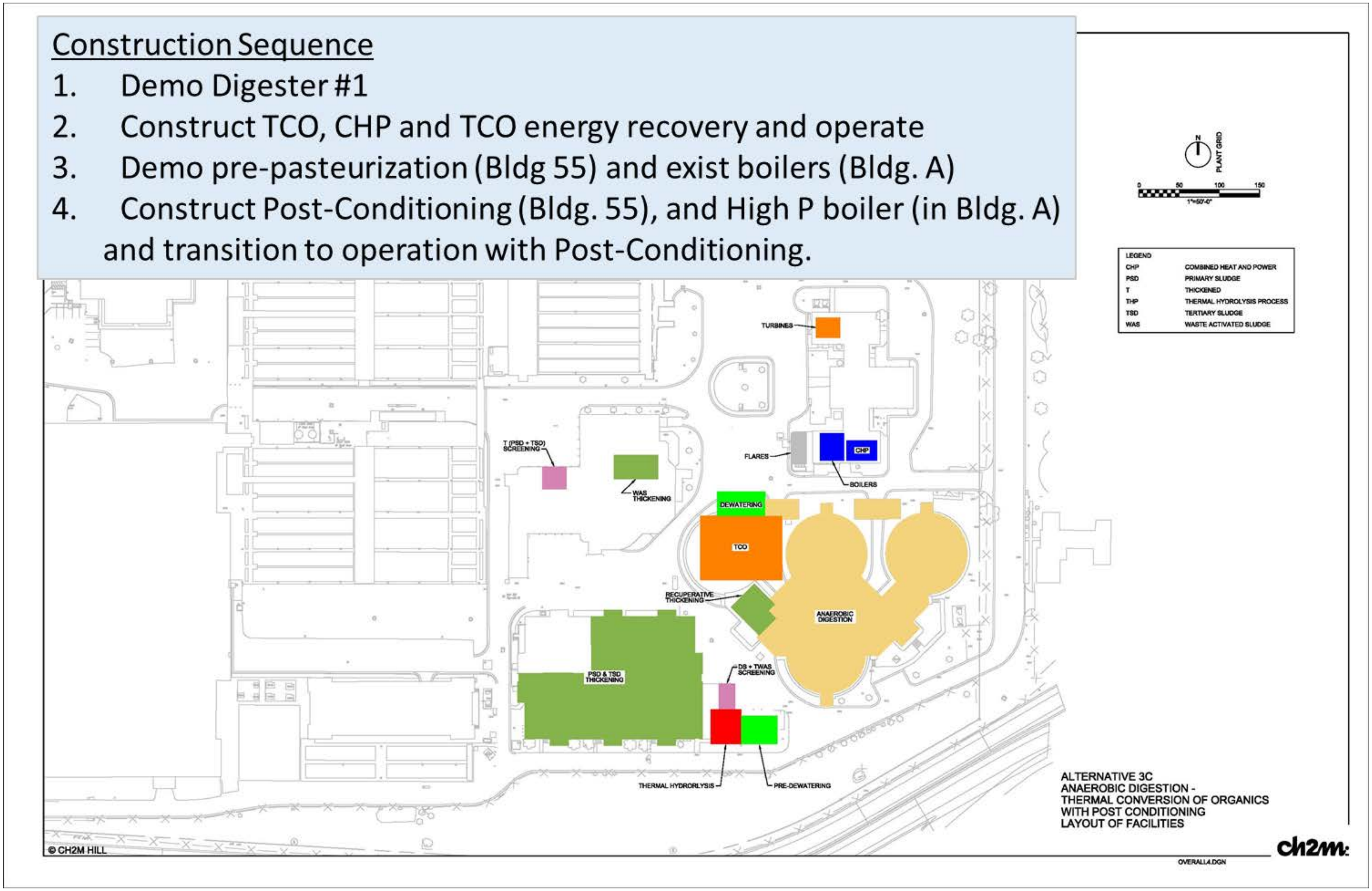


Figure 3-9. Pathway 3c Site Plan

3.3.5 Alternative Comparison

The four selected technology pathways were evaluated and data collected for comparison. Table 3-4 summarizes the final product generated, the amount of trucks per week and the energy produced (as electricity and hot water available) for each of the alternatives.

TABLE 3-4
Comparison of Final Product and Energy Generation at Annual Average Design Conditions (58 MGD AADF)

Parameter	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Final Product (dry tons per day)	42	38	16	16
Estimated Trucks/day	1.9	1.7	0.6	0.6
Electricity Generated, Net (MW)	1.8	2.2	3.5	3.5
% of Total Plant MW [a]	20%	25%	40%	40%
Available Hot Water (MBTU/day)	62	221	326	332
Total Available Energy (MBTU/day)	68	228	338	345

a. The total plant electrical demand in MW was estimated, for comparison purposes, by escalating 2015 plant annual average consumption in MW (~4.8) to design condition (~7.5 MW) in proportion to population growth and adding the energy consumption of the new processes for each alternative. Analysis does not take into account other energy efficiency / green energy projects on the liquids treatment or facilities.

AADF = Annual Average Design Conditions
DS = Digested Sludge
MBTU = one thousand British Thermal Units
MW = megawatts

The Group 3 alternatives (3b and 3c) significantly reduce (by almost 2/3) the final product and the truck traffic through the site compared to the Group 2 alternatives (2a and 2b). The Group 3 alternatives also produce considerably more electricity and hot water. Alternative 3c produces more electricity than 3b but it also consumes more electricity, so the net electricity production is the same.

The analysis estimated the additional GHG production for each alternative, using AlexRenew’s current GHG inventory methodology, and compared it to the projected future total entity-wide emissions. The resulting net GHG impact of each alternative is listed in Table 3-5.

TABLE 3-5
Comparison of Greenhouse Gas Emissions Impact at Annual Average Design Conditions (58 MGD AADF)

Parameter	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Estimated GHG Impact (tonnes CO_2e)	3784	1062	-2343	-2308
% of Total Entity-Wide Emissions [a]	8%	2%	-5%	-5%

a. The Total Entity-Wide Emissions at the design condition was calculated by escalating 2015 annual total emissions (~28,000 tonnes CO_2e) to design condition (~45,000 tonnes CO_2e) in proportion to population growth. Analysis does not take into account other GHG-reducing projects or initiatives.

Annual costs for operations and maintenance were estimated for each alternative and are listed in Table 3-6. The cost estimates are conceptual-level estimates and they are all in 2016 dollars for comparison purposes. The values in Table 3-6 should be considered about equivalent because they are within the accuracy of the estimate (+/- 20 percent).

TABLE 3-6
Comparison of Estimated Operation and Maintenance Annual Costs at Annual Average Design Conditions (58 MGD AADF)

Parameter	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Polymer	$1,037,000	$1,181,000	$1,181,000	$1,319,000
Solids Handling	$635,000	$443,000	$213,000	$213,000
Labor	$563,000	$1,048,000	$1,324,000	$1,365,000
Maintenance	$926,000	$1,276,000	$1,445,000	$1,668,000
Power	$25,000	($274,000)	($837,000)	($812,000)
Total	**$3,186,000**	**$3,674,000**	**$3,326,000**	**$3,729,000**

Construction costs were estimated for each of the alternatives and are summarized in Table 3-7. The cost estimates are conceptual-level estimates with an accuracy of +50/-30percent. The costs are all in 2016 dollars for comparison purposes. More detail on the cost estimates can be found in Appendix E.

TABLE 3-7
Comparison of Estimated Construction Costs (2016 Dollars)

Cost Element	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Primary + Tertiary Thickening	$97,800	$97,800	$97,800	$97,800
Screening Primary + Tertiary	-	$784,800	$784,800	$784,800
WAS Thickening	$4,350,400	$4,350,400	$4,350,400	$4,350,400
Screening Blended Sludge/WAS	$471,300	$384,700	$384,700	$384,700
Pre-Dewatering	-	$10,175,700	$10,175,700	$12,013,400
WAS Conditioning	-	$4,487,500	$4,487,500	-
Anaerobic Digestion	$97,800	$97,800	$97,800	$97,800
Recuperative Thickening	$2,788,000	$2,788,000	$2,788,000	$2,788,000
Post-Digestion Sludge Conditioning	-	-	-	$9,065,100
Dewatering	$3,526,900	$2,382,200	$15,152,600	$17,631,000
Drying	$20,059,600	$15,892,500	-	-
Thermal Conversion of Organics	-	-	$69,888,000	$69,888,000
TCO Turbines (power generation)	-	-	$3,416,400	$3,416,400
Boiler (High pressure steam)	-	$395,900	$395,900	$395,900
Combined Heat & Power	$7,411,700	$7,411,700	$9,244,200	$9,244,200
Biogas Flares	$19,600	$19,600	$19,600	$19,600
Pre-pasteurization (demolition)	$90,900	-	-	-
TOTAL	**$39,228,000**	**$49,276,000**	**$121,283,000**	**$130,177,100**

3.4 Scoring

AlexRenew staff scored the alternatives in a workshop setting, using the decision criteria model. The decision criteria model has been refined and updated by AlexRenew, and used in several projects since it was first created in 2008. The goal of the scoring exercise was to discuss the advantages and disadvantages of each alternative and rank them comparatively based on the decision criteria.

Figure 3-10 illustrates the decision criteria model used. The full decision model, with additional detail for each weighted element, is included in Appendix A.

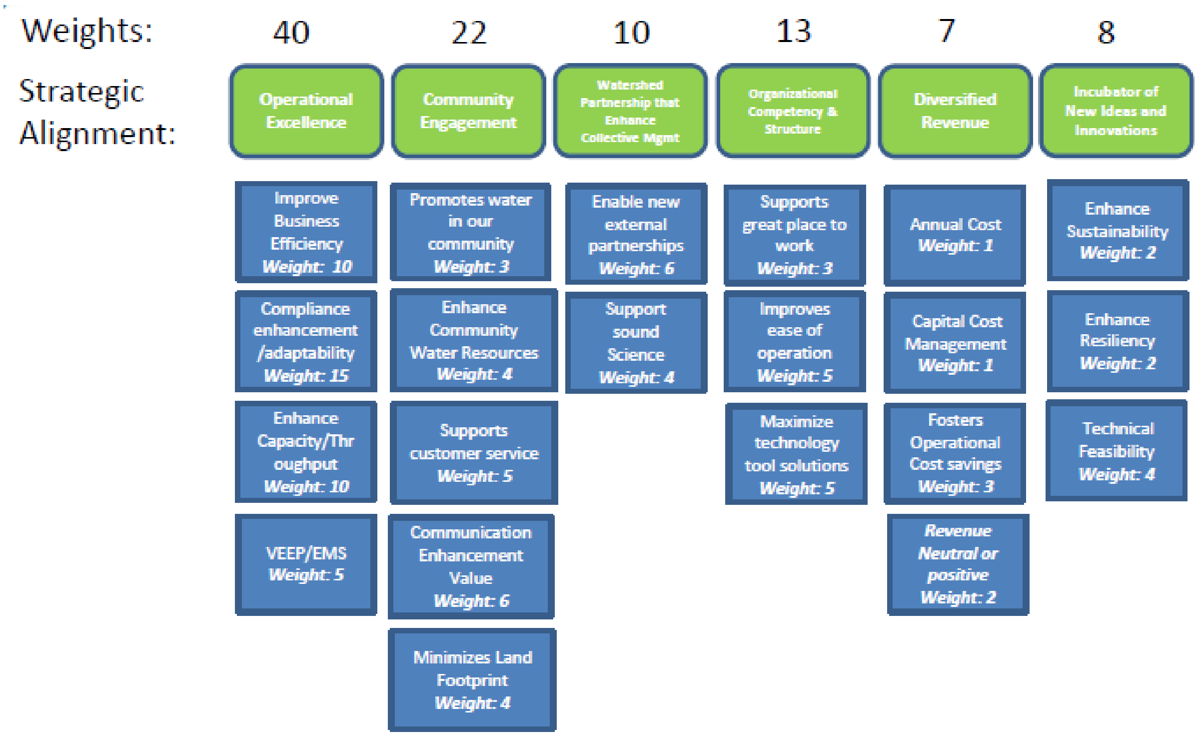


Figure 3-10. AlexRenew Decision Model

Figure 3-11 illustrates the results of the scoring.

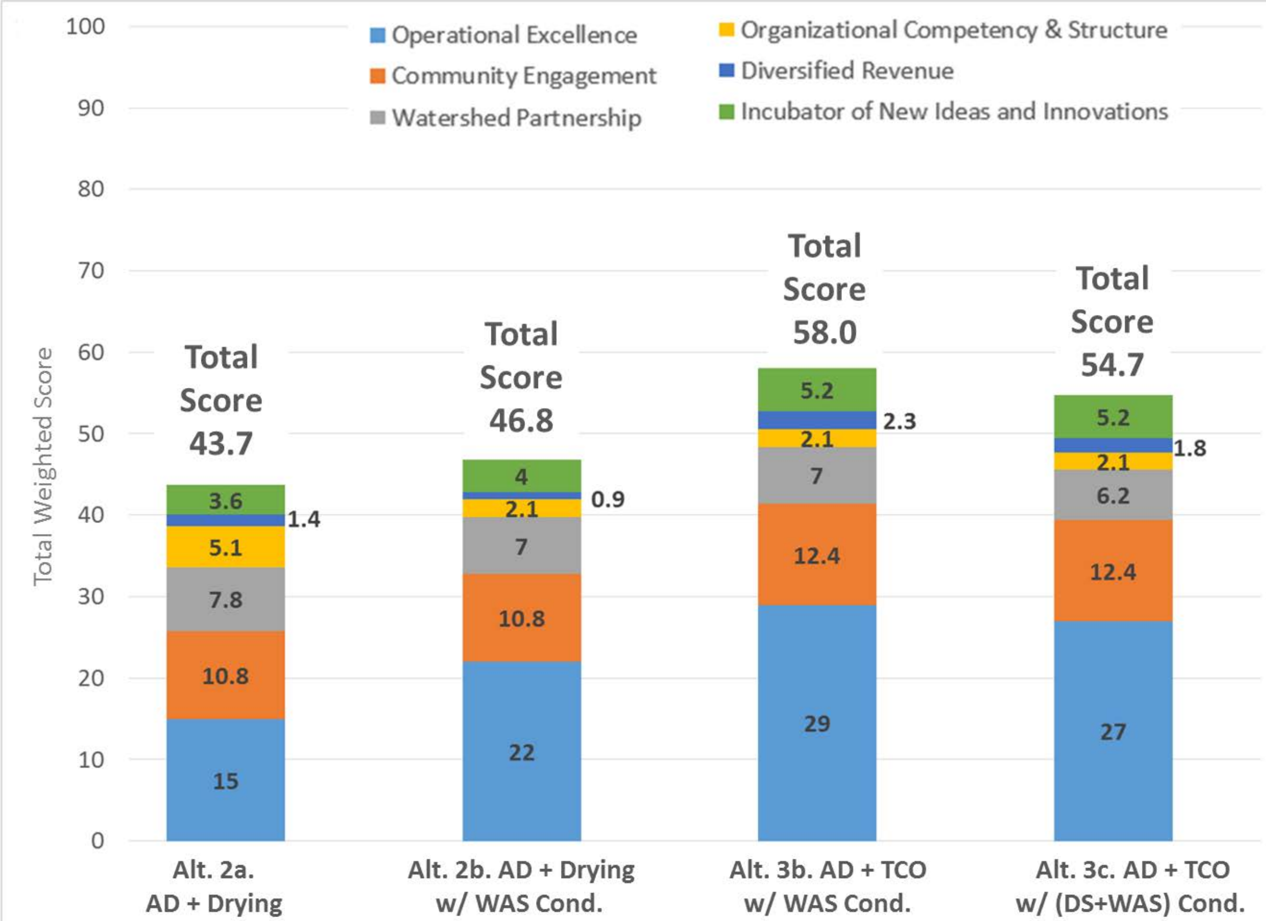


Figure 3-11. AlexRenew Technology Pathway Alternatives Scoring Results

Figure 3-11 shows that, in general, the Group 3 Alternatives (AD + TCO) scored higher than the Group 2 Alternatives (AD + Dryer). The Group 3 alternatives produce more energy, result in less final product and require less truck traffic, which contributed greatly to the operational excellence category. The group scoring also took into consideration the reduced footprint impact if a new TCO unit is constructed on the footprint of an existing digester.

There was a small difference between alternatives 3b and 3c. Alternative 3b scored higher than 3c because WAS conditioning is a more established technology than post-conditioning and it has a lower annual cost.

Alternative 2a scored the lowest because of its low energy efficiency and it has the highest amount of product/truck traffic. Alternative 2b scored higher than 2a because it has a better energy profile and uses state-of-the art technology (WAS conditioning).

3.5 Technology Pathway Evaluation Conclusions

The scoring exercise allowed the project team to thoroughly discuss and evaluate the advantages and disadvantages of the technology pathway alternatives. The following were key conclusions from the evaluation:

- Anaerobic digestion provides benefit in energy recovery and solids reduction and therefore should remain a core technology at AlexRenew either on its own or as part of a combined pathway.

- TCO in combination with CHP production using digester gas, recovers approximately 50 percent more energy (as electricity and available heat) than drying.
- TCO significantly reduces the final product (approximately 60 percent reduction compared to drying).
- Thermal hydrolysis of WAS increases biogas generation in the anaerobic digestion process by 7 percent, compared to digestion of sludge that has not been pre-treated. If thermal hydrolysis is applied to the digested sludge, biogas generation is increased by 15 percent.
- All technologies studied are viable at AlexRenew and can be accommodated in the existing footprint

The team also discussed some of the potential barriers to short-term implementation of some of the pathway components evaluated, which included:

- TCO had the highest score but implementation of the reference technology (fluidized bed incineration) requires air permitting and has a very high capital cost.
- The reference technology for sludge conditioning, thermal hydrolysis, requires installation of a high-pressure steam system. This system may negatively impact health and safety onsite. In addition, the high-pressure steam system needs to be operated by specially trained and certified personnel, which AlexRenew would need to hire or contract out. Both options would increase operational costs.
- Drying technology does not provide as much energy as TCO. While it reduces the final product volume, it is still considerable and needs marketing in order to be sold commercially as a fertilizer or soil amendment.
- Implementation of CHP is not cost-effective under current conditions. However, if the biogas production is boosted by sludge conditioning and/or co-digestion, the economics may become more favorable.

The recommended approach is to keep all the technologies as viable future alternatives in the long-term and continue to evaluate their applicability at AlexRenew.

Implementation Plan

4.1 Planning Horizons

The alternatives developed and scored as part of the planning process represent the technology pathways to an envisioned long-term future for AlexRenew. However, in the absence of an immediate driver or trigger, AlexRenew requested a menu of options that can be phased to prepare for the future as it unfolds. As a result, the next step in the planning process was to develop short-term, medium-term and long-term projects that AlexRenew can prioritize and implement as needs arise, and adapt as needed if critical priorities change. Figure 4-1 illustrates three planning horizons considered in this implementation plan: 5 - 10 years; 10 - 20 years; and 20 - 40 years.

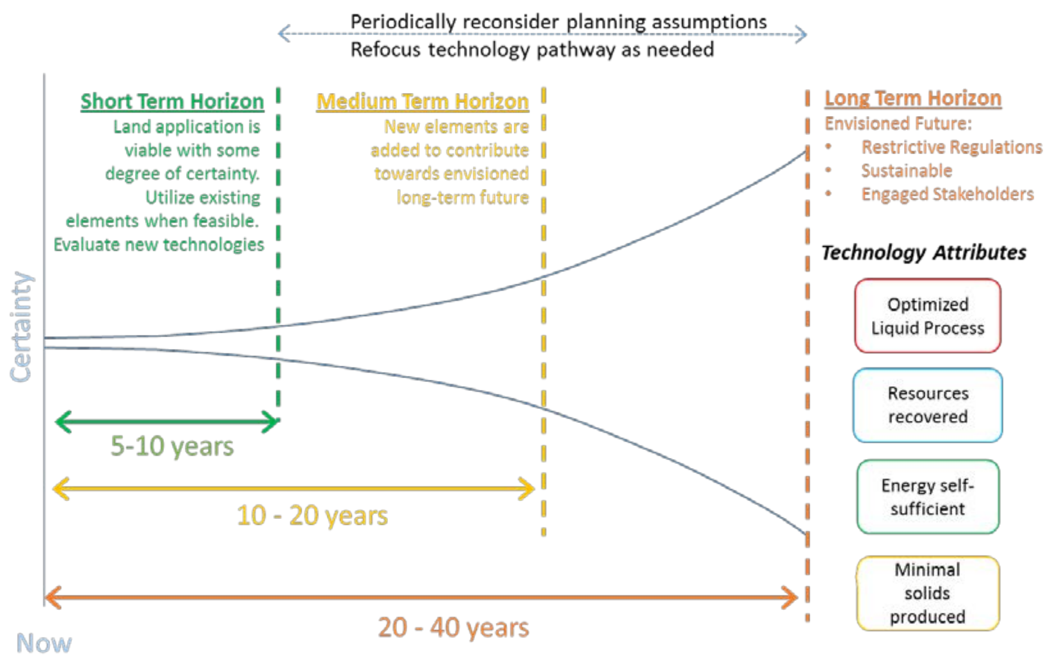


Figure 4-1. AlexRenew WRRF Long Range Planning Horizons

4.2 Proposed Projects

Tables 4-1, 4-2, and 4-3 summarize the array of proposed projects that were developed as part of the evaluation. A more detailed implementation plan for each project is included in Section 4.3.

TABLE 4-1
Summary of Short Term Projects

Project Number	Project or Study
S.1a	Pre-Pasteurization Improvements (already identified)
S.2b	Pre-Pasteurization Business Case Evaluation
S.2	Gravity Thickening Evaluation
S.3	Digestion Evaluation
S.4	Solids Processing Building L Evaluation
S.5	Preliminary Treatment Evaluation
S.6	Primary Treatment Evaluation
S.7	Primary Effluent Pump Station

TABLE 4-2
Summary of Medium Term Projects

Project Number	Project or Study
M.1	Combined Heat and Power (Study/Implement)
M.2	Co-Digestion/FOG (Study/Implement)
M.3	Biological Phosphorus Removal and Recovery (Study/Implement)
M.4	Strategies for Land Application Restriction/Ban
M.5	Sludge Conditioning Demonstration Study
M.6	Onsite Energy Use/HVAC Evaluation

Note:

FOG = Fats, Oils and Grease

TABLE 4-3
Summary of Potential Long Term Projects

Project Number	Project or Study
L.1	Implement Thermal Organics Conversion
L.2	Implement Drying
L.3	Implement Sludge Conditioning
L.3	Implement Other Emerging Resource Recovery Technologies

4.3 Summaries of Projects

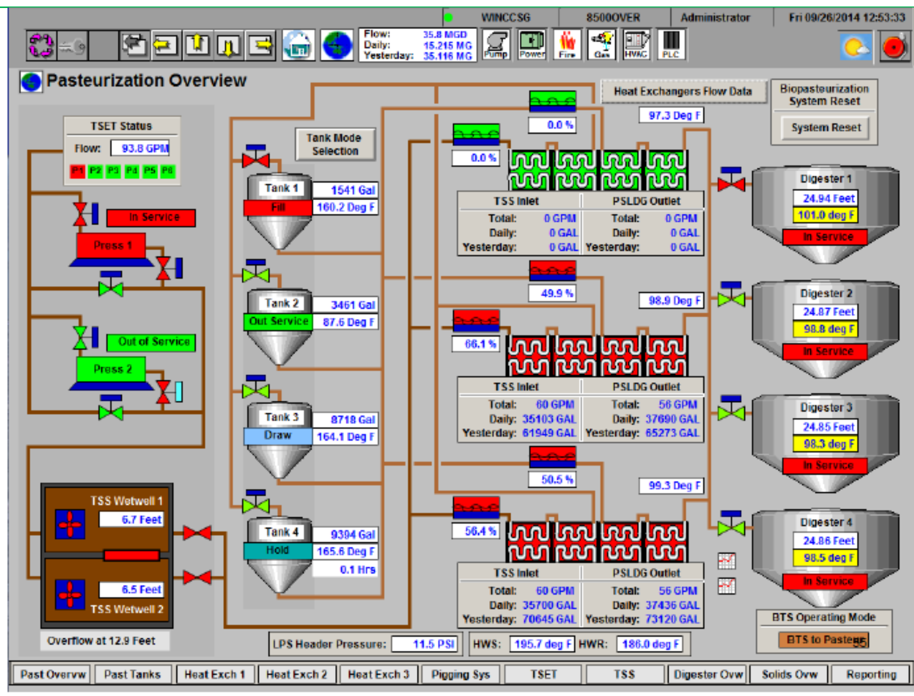
Implementation Plan – Short Term Projects

Project S.1a –Pre-Pasteurization Improvements

<table>
<tr><td>Project Description</td><td>This project consists of implementing the recommendations of previous investigations to improve performance of the pre-pasteurization system at AlexRenew.</td></tr>
<tr><td>Identified Deficiencies</td><td>

Pasteurized sludge does not cool to a low enough temperature to maintain the desired digester temperature in the summer.
Thickened screened sludge does not heat to the desired temperature for pasteurization in winter.
System only has one exhaust fan, which is nearing the end of its useful life. This unit is critical for operation of the system as this fan vents exhaust air out of the holding tanks. Whenever the fan is out of service, the entire pre-pasteurization system has to be placed on standby. A stand-by fan would reduce risk of non-compliance with Class A.

</td></tr>
<tr><td>Diagram</td><td>



</td></tr>
<tr><td>Recommended Improvements</td><td>

Perform chemical cleaning of all three heat exchangers (HEX) – both on the water side and the sludge side
Re-evaluate HEX performance after the cleaning is performed
Replace pressure regulating valves on the hot water supply system
If needed, work with Kruger to modify programming to allow all three HEX to be in operation at the same time in order to increase capacity

</td></tr>
</table>

Project S.1a –Pre-Pasteurization Improvements

	• Replace exhaust fan on pre-pasteurization holding tank ventilation system and add redundant fan (including modified piping). Design of the fan replacement is currently at the 60 percent complete level.
Duration/ Schedule	• HEX cleaning (to be scheduled First Quarter 2017) • HEX testing: 1 week • Regulating valve replacement: 8 weeks (including lead time for parts) • Fan replacement: 8 weeks to finalize design (including AlexRenew review and fix-up), 3 months for bidding, 6-month construction period. – Construction Cost Estimate: $163,000 • Kruger programming changes: 2-3 weeks
Triggers	This project is critical for reliable operation of the Pre-pasteurization system and for AlexRenew to achieve Class A (Exceptional Quality Biosolids) level of treatment. This project would be triggered if the current system is unable to or presents increased risk in meeting Class A Requirements.
Relationship to Other Projects	If HEX performance (heat transfer) does not improve and meet expectations after chemical cleaning then Pre-pasteurization Evaluation and Business Case (S.1b) project implementation should be considered.
List of Related Studies/Reports	• AlexRenew Basic Ordering Agreement (BOA) 14-017-2 Task Order WA2-2015-4, *Pre-pasteurization System Evaluation, Heat Exchangers Recommendations* – Draft, January 2016 • AlexRenew BOA 14-017-2 Task Order WA2-2015-4, *Pre-pasteurization Tank Exhaust System Replacement, Preliminary Design,* December 2015

Implementation Plan – Short Term Projects

Project S.1b – Pre-Pasteurization Business Case Evaluation

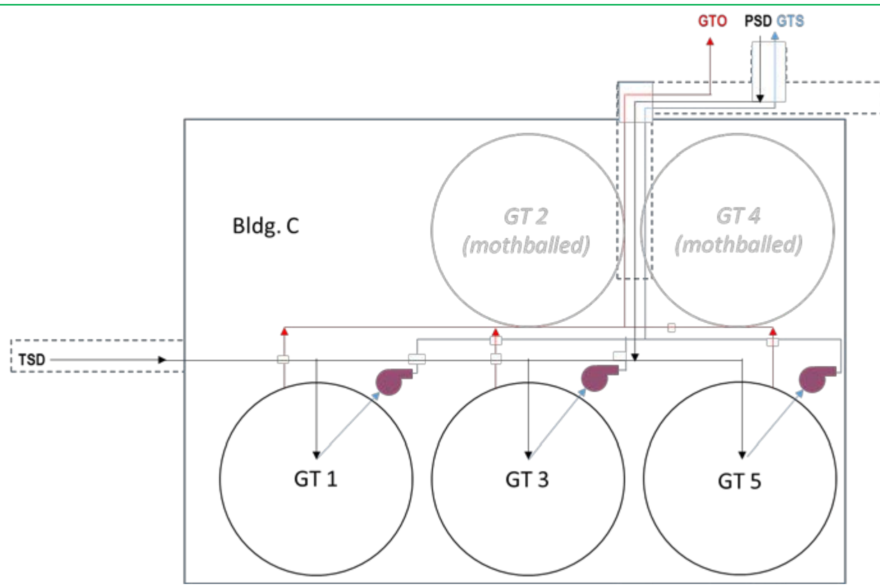
Project Description	Conduct comprehensive evaluation of Pre-Pasteurization system and potential modifications/replacement to achieve reliable performance if Project S.1 is not successful in doing the same.
Identified Deficiencies	• See Project S.1a • Sludge screens are not performing as designed and could limit throughput. The screens currently shut down on high pressure at sludge flows greater than 120 gpm at 5% TS (the design throughput is 200 gpm at 6% TS). In addition, debris gets through the screens and makes its way into the dewatering centrate.
Recommended Scope	Generate and evaluate alternatives for Pre-Pasteurization System to include: • Approaches for reliably heating the thickened sludge to the temperatures required for pasteurization. For example, steam addition. • Approaches for reliably cooling pasteurized sludge prior to digestion. For example, adding a cooling HEX that uses chilled water. • Complete replacement of the system (in-kind) • Sludge screening improvement and replacement options • "Do nothing" alternative that explores abandoning pre-pasteurization and producing Class B biosolids for land application as a short-term solution. Project shall include a business case evaluation that compares the short and long-term cost impacts of the various alternatives. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.
Estimated Duration/ Schedule	Evaluation: 6 to 9 months Design: 9 to 12 months Construction: 12 months
Triggers	This project should be considered for implementation if any of the following triggers are present: • Performance reliability issues persist after implementation of Project S.1a.

Project S.1b – Pre-Pasteurization Business Case Evaluation

	• Sludge production increases (because of CEPT or other factors) and the throughput capacity of the existing system is no longer sufficient • O&M spending on HEX cleaning and system troubleshooting increases
Relationship to Other Projects	• Pre-pasteurization Improvements (Project S.1a): This project will focus on first steps to improve HEX performance. If unsuccessful, then project S.2 could be triggered • Mainstream Anammox project – CEPT implementation may increase sludge production to the point that the pre-pasteurization process becomes a bottleneck. • Primary Treatment Evaluation (Project S.6) – Related to CEPT. Upgrades to primary sludge pumping could increase sludge production • Combined Heat and Power (Project M.1) – Abandoning pre-pasteurization may free up enough digester gas to improve the economics of electricity generation. • Co-digestion of food waste and/or FOG (Project M.2) may require additional capacity in the pre-pasteurization system in order to reduce pathogens from added feedstock and comply with Class A requirements • Strategies for Land Application Restriction/Ban (Project M.4) – if land application is no longer viable in the future, pre-pasteurization will not be needed to produce Class A. • Evaluation of sludge conditioning (Project M.5) which could replace pre-pasteurization with a different technology to produce Class A biosolids
List of Related Studies/Reports	• AlexRenew BOA 14-017-2 Task Order WA2-2015-4, Pre-pasteurization System Evaluation, Heat Exchangers Recommendations – Draft, January 2016 • AlexRenew BOA 14-017-2 Task Order WA2-2015-4, Pre-pasteurization Tank Exhaust System Replacement, Preliminary Design, December 2015 • Thickened sludge screen vendor (Huber) site visit report. Vendor came to site and rebuilt screen #1 on May 18, 2016.

Implementation Plan – Short Term Projects

Project S.2 – Gravity Thickening Evaluation

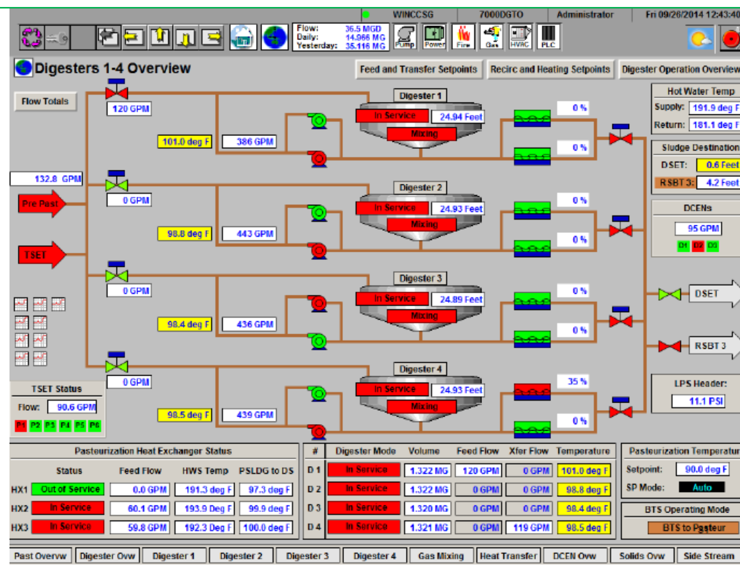
Project Description	Conduct comprehensive evaluation of the existing Gravity Thickeners and Building C and develop alternatives for refurbishment and replacement.
Identified Deficiencies	• Two out of the five Gravity Thickeners are currently out of service (mothballed), leaving only three units available for use. • Additional sludge generated by CEPT may exceed solids loading capacity of the available Gravity Thickeners • Thickened sludge pumps are being refurbished
Recommended Scope	Generate and evaluate alternatives for Gravity Thickening to include: • Develop alternatives for replacing gravity thickeners with other technologies. Include sizing and location of the new systems. • Assess cost and benefits of continued use of gravity thickeners and refurbishing Units 2 and 4 (currently mothballed) to meet future capacity. • Develop sampling and analysis protocol to determine why solids mass balance around Gravity Thickeners does not close (total influent solids exceed effluent solids by about 40 percent). • Evaluate alternatives for repurposing Sludge Thickening Building C space. Include structural, HVAC and electrical analysis. Project shall include a business case evaluation that compares the short and long-term cost impacts of the various alternatives. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.
Diagram	

Project S.2 – Gravity Thickening Evaluation

Duration/Schedule	• Evaluation and Report: 6 to 9 months • Design: 9 to 12 months • Construction: 12 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Aging equipment, piping, valves and/or other components. Excessive expenditure on O&M for this facility • Implementation of CEPT increases primary sludge volume and it exceeds capacity of existing system • Bans/restrictions on land application – Sludge Thickening Building C may be a desired location for a sludge dryer or another future technology
Relationship to Other Projects	• Mainstream Anammox – CEPT projections of future sludge loadings may require additional gravity thickening capacity • Solids Processing Building L Evaluation (Project S.4) – investigate if space is available in Building L for gravity thickener replacement technology. • Site Utilization – Sludge Thickening Building C footprint could be used for implementation of the other technologies under consideration such as: – FOG/Food Waste Receiving (Project M.2) – Phosphorus Recovery (Project M.3) – Sludge Conditioning Demonstration Study (Project M.5) – Thermal Oxidation (Project L.1) – Drying (Project L.2)
List of Related Studies/Reports	• Contract 1A As-Built Drawing and Gravity Thickening UPCP – these documents identify the changes made to the existing gravity thickening system to mothball Gravity Thickeners #2 and #4. • AlexRenew Building Energy Analysis – Task Order 20 Final Report, (CH2M, June 2016). This report included analysis of Building C and recommendations to improve energy efficiency.

Implementation Plan – Short Term Projects

Project S.3 – Digestion Evaluation

Project Description	Conduct comprehensive evaluation of the existing Anaerobic Digester Facility to identify deficiencies as well as opportunities for increased efficiency and capacity expansion.
Identified Deficiencies	• Process Heat Transfer Packages valves leak and pump seals fail prematurely. • Digester gas valves are difficult to operate (even when exercised frequently).
Recommended Scope	The evaluation shall include: • Evaluation of existing equipment including replacement options and cost • Capacity of the existing system to accommodate Co-Digestion/FOG addition • Evaluation of the facility and space utilization, including available space for other processes (such as recuperative thickening to increase SRT) • Evaluation of existing electrical and Instrumentation and Control (I&C) systems (motor control centers, transformers and programmable logic controllers [PLCs]) and their capacity to accommodate additional equipment.
Diagram	
Duration/Schedule	Evaluation: 16 weeks (Including a draft report and a final report)
Triggers	Anaerobic digestion process was validated during the 2016 Long Range Planning process as desirable to AlexRenew, now and in the near future, because of the many benefits it provides (biogas generation, VSS destruction, vector attraction destruction). Continued reliable operation of this process is a priority. This

Project S.3 – Digestion Evaluation

	project should be considered for implementation if any of the following triggers are present: • Excessive O&M spending replacing and/or refurbishing existing/aging equipment could trigger an overhaul • Increased biogas generation through Co-digestion/FOG or sludge conditioning
Relationship to Other Projects	• Pre-pasteurization Evaluation and Business Case (Project S.1a) – decision to keep or abandon pre-pasteurization would impact some of the digester equipment (heat exchangers) • Preliminary Treatment Evaluation (S.5) – improved fine screening may decrease the trash/debris that ends up in the digesters. • Primary Treatment Evaluation (S.6) – additional sludge generation because of CEPT may increase loadings to digesters and require recuperative thickening in order to maintain minimum SRT • Combined Heat and Power (Project M.1) – digester gas handling equipment may be affected • Co-digestion/FOG (Project M.2) – additional loadings to the digesters • Sludge Conditioning (L.3) – impact of sludge conditioning on digestion process
List of Related Studies/ Reports	No recent studies or reports have specifically evaluated the digester system at AlexRenew. Other studies have evaluated Combined Heat and Power and Co-digestion and those are referenced under those project descriptions (M.1 and M.2)

Implementation Plan – Short Term Projects

Project S.4 – Solids Processing Building L Evaluation

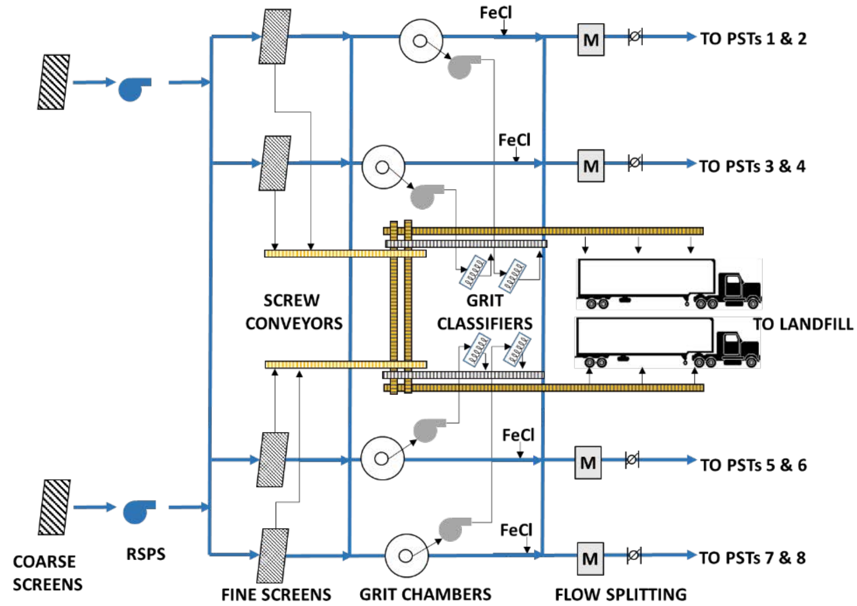
Project Description	Review and analysis of underutilized or unused space in the Solids Processing Building L and feasibility of repurposing the space for other unit processes. Structural evaluation of potential expansion options.
Identified Deficiencies	• Some unit processes currently housed in Building L are no longer used (for example, the lime addition system) • The building was constructed to meet specific needs, which increases the difficulty of repurposing spaces for new/different needs.
Proposed Scope	The evaluation shall include: • Detailed analysis of available space and potential uses • Review of existing equipment, processes and electrical and I&C systems to determine potential modifications to free up space. • Structural evaluation of existing building and potential options for increasing the footprint. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.
Diagram	See Appendix D for building drawings showing the available space developed as a preliminary evaluation.
Duration/Schedule	Study: 6 months
Triggers	This project should be initiated because of the following triggers: • As a first step to understand the space re-allocation that may be feasible in order to accommodate new processes in the future. Need to understand what processes can be housed in Building L. • Upgrades to the Primary Effluent Pump Station (see Project S.7)
Relationship to Other Projects	• Gravity Thickening Evaluation (S.3) – investigate the possibility of relocating the PSD and TSD thickening function to Building L. • PEPS Upgrade Project (S.7) – Location of new AFDs in the building • Drying (L.2) – Location of full or partial drying capacity in or adjacent to Building L. Modifications needed to re-purpose existing biosolids silos for dried product.
List of Related Studies/Reports	• Primary Effluent Pump Station Evaluation Report (CH2M, February 2016) • Primary Effluent Pump Station 60% Design (CH2M, June 2016)

Implementation Plan – Short Term Projects

Project S.5 – Preliminary Treatment Evaluation

Project Description	Conduct a comprehensive evaluation of the condition of the Preliminary Treatment System and the related facilities (Building K and Building A). The evaluation shall include alternatives for replacement or refurbishment of existing systems/equipment.
Identified Deficiencies	• Fine screens' removal efficiency is not optimal. A significant amount of trash/debris finds its way to downstream processes. • Fine screening control panels use outdated technology (switches and relays) instead of PLCs that can better optimize performance. • Grit removal chamber No. 1 is currently out of service because of a broken bottom mixer. Location and spatial requirements increase the difficulty in getting a crane in to pull out the long shaft. • Conveyors experience wear and tear. Transfer of material between conveyors is not optimal (material accumulates at the ends) • Ferric chloride addition to primary settling tanks is not effective. Existing piping clogs and does not feed evenly to the tanks.
Proposed Scope	The evaluation shall include: • Evaluation of existing equipment (coarse screens, fine screens, grit removal system, conveyors, scum concentrator, and chemical addition) including performance and condition. • Capacity of the existing facility to accommodate increased peak flows (per the City's Capacity Evaluation) • Evaluation of the facility and the space, including available space for replacement processes (different fine screening technology, for example) and electrical capacity • Structural evaluation and feasibility in moving large equipment in and out of the facility • Investigate different technologies for materials handling (belt conveyors, for example) and methods to optimize operations and reduce wear and tear (through control modifications to reduce run time, for example) • Investigate alternative methods for splitting the ferric chloride flow to achieve effective CEPT in the primary settling tanks. Project shall include a list of recommendations for upgrades/ refurbishment. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.

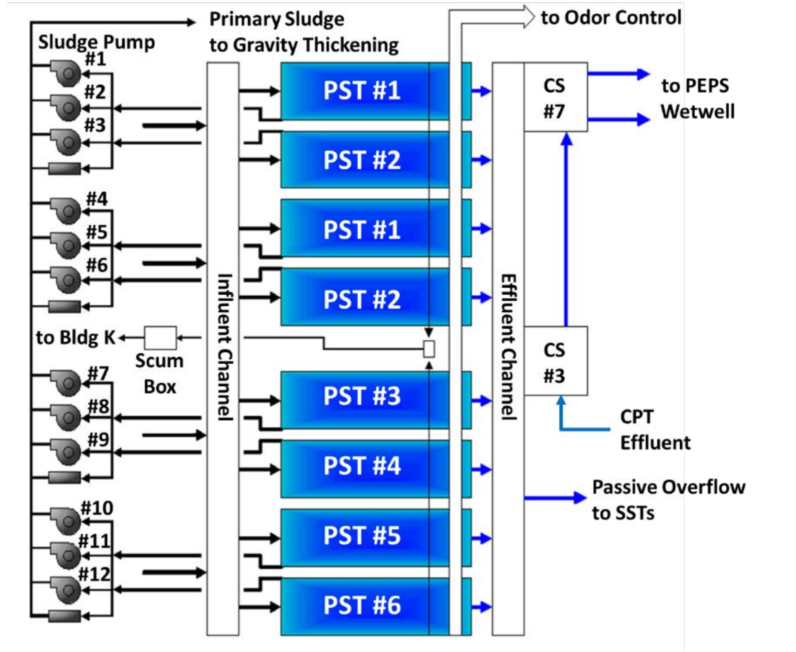
Project S.5 – Preliminary Treatment Evaluation

Diagram	
Duration/Schedule	• Evaluation and Report: 6 to 9 months • Design: 6 to 9 months • Construction: 12 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Increase in instantaneous peak flows to alleviate the City's collector system overflows. • O&M Cost increases because of trash/debris in downstream processes (for example in Centrate Pre-Treatment recycle pumps) • Excessive O&M costs to maintain Building K equipment (fine screens, grit systems, etc.)
Relationship to Other Projects	• Primary Treatment Evaluation (S.6): Improvements to ferric chloride addition will allow for implementation of CEPT and potentially increase primary sludge production • Pre-pasteurization Evaluation (S-1b): Improvements to the fine screening process in Building K could reduce the amount of trash found in the sludge and help the sludge screening process.
List of Related Studies/Reports	*City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* – Final Report, (CH2M, November 2010)

Implementation Plan – Short Term Projects

Project S.6 – Primary Treatment Evaluation

Project Description	Conduct a comprehensive evaluation of the condition of the Primary Treatment System (Primary Settling Tanks and related equipment).
Identified Deficiencies	• Existing primary sludge pumps are reaching the end of their useful life. • No instrumentation to measure sludge blanket • Primary sludge is very thin. Investigate how %TS can be optimized to improve subsequent thickening. • Redirecting filter backwash to the primary settling tanks is needed to provide additional capacity in Preliminary Treatment Building K.
Proposed Scope	The evaluation shall include: • Evaluation of existing equipment (flow splitting, chain-and-flight mechanisms, and sludge pumping) including performance and condition. • Capacity of the existing facility to accommodate increased peak flows (116 MGD per the City's Capacity Evaluation) • Evaluation of the facility and the space, including available space for replacement processes (new primary sludge pumps and piping, for example) and capacity of the existing electrical and I&C systems (motor control centers and PLCs) • Routing of filter backwash into primary settling influent channel to bypass Building K during high flow events. Include also measurement and automated controls. Project shall include a list of recommendations for upgrades/ refurbishment. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.

Diagram	
Duration/Schedule	• Evaluation and Report: 6 to 9 months • Design: 6 to 9 months • Construction: 12 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Implementation of CEPT will increase the primary sludge produced beyond the capacity of the existing system • Potential future bottlenecks with Gravity Thickening could trigger need for thicker PSD to reduce hydraulic loading
Relationship to Other Projects	• Gravity Thickening Evaluation (Project S.2): Implementation of CEPT will increase the primary sludge produced. • Preliminary Treatment Evaluation (Project S.5): Improvements to ferric chloride addition will allow for implementation of CEPT and potentially increase primary sludge production
List of Related Studies/Reports	*City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* – Final Report, (CH2M, November 2010)

Implementation Plan – Short Term Projects

Project S.7 – Primary Effluent Pump Station

Project Description	Upgrade the existing Primary Effluent Pump Station from a firm capacity of 120 MGD to 127 MGD. The Primary Effluent Pump Station Evaluation (CH2M, Jan. 2016)determined that the pump station could be upgraded to 127 MGD to accommodate the increased peak flows through the plant. The design for the upgrade was started in 2016 and it is currently 60 percent complete.
Identified Deficiencies	• The *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* – Final Report, (CH2M, November 2010)determined that an increase in flow to the pump station from 120 MGD to 127 MGD would be needed to accommodate the peak flows. The increase would reduce backups in the collection system and accommodate internal plant recycles. • The pump station contains six horizontal centrifugal pumps of equal size and is split into two equal sides, each containing a wetwell, three pumps, and a discharge header. The wetwells and the discharge headers are typically interconnected so that the two halves of the pump station operate as a single system. • The pump station was originally designed with a firm capacity of 120 MGD, with one pump out of service. • The existing pump station does not have enough pumping capacity to reliably handle the increase in flow. • The existing drives are obsolete, require significant maintenance and need to be replaced.
Recommended Scope	• The current design consists of replacement of the existing pumps with larger capacity units and transforming underutilized space on the ground floor of Building L (janitor's closet and a break room) into a new drive room to accommodate the larger drives for the new pumps. The location of the existing drives (Electrical Room 3) cannot accommodate the new, larger drives. • The current design is complete through the 60 percent design phase, including computational fluid dynamics modeling of the wetwell and the pump intakes. • Recommended path forward: Complete the design through Bid Documents.
Estimated Duration/ Schedule	• Design Completion: 3 to 6 months • Construction: 24 months

Project S.7 – Primary Effluent Pump Station

	• Construction Cost Estimate: $6.2 million (2016 dollars)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Failure of the existing pump drives • The City is required to reduce back-ups in the existing collection system and AlexRenew peak hydraulic flow needs to be increased.
Relationship to Other Projects	• Building L Evaluation (Project S.4) – investigate if the space allocated in Building L for the drives is adequate.
List of Related Studies/Reports	• AlexRenew BOA 16-017-2 Task Order WA2-2016-2, Primary Effluent Pump Station Evaluation (CH2M, February 2016) • *City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation* – Final Report (CH2M, November 2010)

Implementation Plan – Medium Term Projects

Project M.1 – Combined Heat and Power (CHP)

Project Description	Conduct a comprehensive evaluation of the feasibility of implementing a CHP system using digester gas at AlexRenew
Identified Deficiencies	• AlexRenew does not currently recover energy from digester gas. Use of digester gas to produce electricity and heat is one of the most efficient and commonly used paths towards AlexRenew's goal of energy neutrality. • A portion of the digester gas currently produced is not beneficially used (flared) • Implementation of Mainstream Anammox and capture of additional carbon in the primary sludge presents the opportunity to create more biogas and produce more energy while reducing power consumption in the liquid processes.
Recommended Scope	The evaluation shall include: • Evaluation of existing digester gas handling equipment and capacity to accommodate additional biogas production • Evaluation of technologies to convert biogas to energy (electricity and heat) • Requirements for gas pre-treatment • Evaluation of space available in the Main Building (A) (and/or other locations) for installation of proposed technologies. • Evaluation of existing electrical and heating systems to determine how best to use the electricity and heat produced. • Proposed phasing of project implementation to accommodate a scenario with pre-pasteurization (which uses additional biogas to heat up sludge to 140°F) and without pre-pasteurization. • Safety considerations regarding biogas handling and storage. • Possibility of using CHP system for back-up emergency electricity generation. • Economic evaluation (capital costs, annual costs and pay-back period estimates) Project shall include a list of recommendations for implementation. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria.

Project M.1 – Combined Heat and Power (CHP)

	Follow-up project would include design services (drawings, specifications) and construction of recommended alternative.
Estimated Duration/ Schedule	• Evaluation and Report: 6 to 9 months • Design: 6 to 9 months • Construction: 12 to 36 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Increase in the cost of purchased electricity. • Increased production of biogas (because of co-digestion, sludge conditioning, and/or carbon redirection) • Adoption of energy neutrality as a strategic objective • Increased value (above purchase price) for green electricity supplied back to the grid and/or availability of grants for construction of green power projects
Relationship to Other Projects	– Digester System Evaluation (Project S.3): This project will determine if the existing gas handling system is adequate for additional gas production. – Co-Digestion/FOG (Project M.2): Implementation of this project would increase the biogas production and the potential for heat and power generation. – Biological Phosphorus Removal and Recovery (Project M.3): Implementation of biological phosphorus removal would require carbon in the biological process therefore reducing the amount of carbon that is redirected to the digesters. – Sludge Conditioning (Projects M.5 and L.3): Sludge conditioning would result in increased biogas production and therefore increased potential for heat and power generation.
List of Related Studies/Reports	– *Energy Master Plan* (Greeley & Hansen, July 2014) – *Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014) – *Better Plants Program : CHP Analysis Summary Report* (Jim Freihaut, Penn State University, May 2016)

Implementation Plan – Medium Term Projects

Project M.2 – Co-Digestion/FOG

Project Description	Conduct a comprehensive evaluation of the feasibility of adding fats-oils-grease (FOG) or other types of waste (such as food waste, for example) as feedstock to better utilize existing digester capacity and increase digester gas production.
Identified Opportunities	• Current digester gas production is sufficient to meet heating needs, but not enough to also produce enough electricity to make a CHP system cost-effective (based on preliminary analysis and current electrical power costs). • AlexRenew has a goal of energy neutrality. Use of digester gas to produce electricity and heat is one of the most efficient and commonly used paths towards this goal.
Recommended Scope	The evaluation shall include: • Evaluation of existing digester system and the capacity to accommodate additional feed stock • Alternatives for feed stock (FOG, food-waste, plant/yard waste, and chicken waste) • Alternatives for location and design of receiving station • Identification of partnering opportunities with municipal or private entities (for example, waste collection companies, and the City). • Alternatives for mitigating potential nuisance odors and truck traffic • Impact to operations (trash and impurities the feed-stock, potential process disruptions, quality of the resulting biosolids and centrate) • Regulatory limits on food or organic waste disposal at landfills • Economic evaluation (capital costs, annual costs, potential income from tipping fees and pay-back period estimates) Project shall include a list of recommendations for implementation. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project could include design services (drawings, specifications) and construction of recommended alternative.

Project M.2 – Co-Digestion/FOG

Estimated Duration/ Schedule	• Evaluation and Report: 6 to 9 months • Design: 6 to 9 months • Bid Phase: 3 months • Construction: 12 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Increase in the cost of purchased electricity. • Opportunities for reducing the risk and negative impacts of co-digestion at AlexRenew (for example, if waste management company develops a program to deliver pre-screened and slurried product to site) • Increased value (above purchase price) for green electricity supplied back to the grid and/or availability of grants for construction of green power projects
Relationship to Other Projects	• Digester System Evaluation (Project S.3): This project will determine if the existing system has capacity for accommodating additional feed. • Combined Heat and Power (Project M.1): Implementation of this project would benefit from increased biogas production.
List of Related Studies/Reports	• *Energy Master Plan* (Greeley & Hansen, July 2014) • *Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Medium Term Projects

Project M.3 – Biological Phosphorus Removal and Recovery

Project Description	Conduct a comprehensive evaluation of the feasibility of implementing Biological Phosphorus Removal (Bio-P) and Recovery at AlexRenew.
Identified Opportunities	• Market opportunities to collect and sell phosphorus-rich material as fertilizer • Potential to reduce or eliminate consumption of ferric chloride • Potential to reduce the P content in the biosolids
Recommended Scope	The evaluation shall include: • Process modeling to determine process configuration and compliance with permit limits for TP. Process model should also be used to determine the N:P ratio in the biosolids. • Evaluation and comparison of technologies for phosphorus recovery (Ostara, Airprex and others) • Alternatives for system location and construction sequencing • Alternatives for mitigating potential nuisance odors and truck traffic • Economic evaluation (capital costs, annual costs and pay-back period estimates) Project shall include a list of recommendations for implementation, including a “do nothing” option. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project could include design services (drawings, specifications) and construction of recommended alternative.
Estimated Duration/ Schedule	• Evaluation and Report: 6 to 9 months • Design: 6 to 9 months • Construction: 12 months (depending on selected alternative) • Estimated preliminary cost: $6.5 - $8.0 Million
Triggers	This project should be considered for implementation if any of the following triggers are present: • Increase in the cost of ferric chloride (used for TP removal currently) • Carbon re-direction through CEPT is not needed to achieve the desired biogas production for CHP. This can be either because the effects of implementing a biogas-boosting technology (such as co-digestion or sludge conditioning)

Project M.3 – Biological Phosphorus Removal and Recovery

	produce so much biogas that the additional biogas produced by CEPT is negligible, or because CHP was not deemed feasible or economically viable.
Relationship to Other Projects	• Combined Heat and Power (Project M.1): This project will determine whether CHP is feasible and the amount of biogas needed to make this an economically viable project. • Co-Digestion/FOG (Project M.2): This project will determine whether increasing biogas production through co-digestion or FOG receiving is viable at AlexRenew. • Sludge Conditioning Demonstration Study (Project M.5): This project can potentially significantly increase the biogas produced at the digesters.
List of Related Studies/Reports	Appendix B – Implementation of Bio-P at AlexRenew WRRF TM *Nutrient Recovery Proposal* (Ostara, March 2014)

Implementation Plan – Medium Term Projects

Project M.4 – Strategies for Land Application Restriction/Ban

Project Description	Conduct a comprehensive evaluation of strategies for responding to a land application restriction or ban that would limit AlexRenew product reuse options. The strategies could be short-term (span 1-5 years) while capital projects are implemented, or longer term if opportunities are available.
Identified Deficiencies	• Regulatory pressure to limit land application in Virginia • Dependency on land application for beneficial reuse of biosolids • Lack of control of AlexRenew product
Recommended Scope	The evaluation shall include several viable alternatives for AlexRenew, some examples could be: • Partnerships with other utilities to send AlexRenew biosolids to incineration or drying facilities that may have excess capacity. • Landfilling • Expansion of the current soil amendment program or new opportunities for developing soil products offsite. • Partial drying (permanent onsite installation of temporary "skid mounted" unit) • Combinations of approaches if a single option is not sufficient to meet AlexRenew's needs. Project shall include a list of recommendations for implementation. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria.
Estimated Duration/ Schedule	• Evaluation and Report: 6 to 9 months
Triggers	This project should be considered for implementation if any of the following triggers are present: • New regulations are enacted that limit or ban land application • Cost of land application is significantly increased • Other beneficial reuse opportunities arise that are more cost effective and give AlexRenew better control over the product • New resource recovery technologies become viable, even if it is only for a portion of AlexRenew's biosolids

Project M.4 – Strategies for Land Application Restriction/Ban

Relationship to Other Projects	• Building L Evaluation (S.4): Investigate if partial drying is viable in Building L. • Thermal Oxidation (L.1): Thermal oxidation of organics eliminates 80 percent of the solids produced at the WRRF. • Drying (L.2): Drying also significantly reduces the biosolids generated and the product can more easily be marketed as a soil amendment. • Other Emerging Resource Recovery Technologies (L.3): Technologies such as Genifuel or gasification/pyrolysis could advance to the point where they could be viable at AlexRenew.
List of Related Studies/Reports	*Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Medium Term Projects

Project M.5 – Sludge Conditioning Demonstration Study

Project Description	Conduct a demonstration study on the viability and benefits of sludge conditioning at AlexRenew. Of particular interest may be technologies such as post-digestion thermal hydrolysis that show potential benefits but that have no full-scale installations to date.
Identified Deficiencies	• Current digester gas production is sufficient to meet heating needs but not enough to also produce enough electricity to make a CHP system cost-effective (based on preliminary analysis). • AlexRenew has a goal of energy neutrality. Use of digester gas to produce electricity and heat is one of the most efficient and commonly used paths towards this goal.
Recommended Scope	The evaluation shall include: • Survey of sludge conditioning technologies in the U.S. and installations currently in operation • Survey of potential partners for research and study (utilities) • Vendor proposals for pilot programs • Research plan with clear outline of goals, testing schedule and study duration (including end point) • Include study of centrate quality and impact to centrate pre-treatment system • Follow-on assistance during the demonstration project • Data collection and final report with conclusions and recommendations
Estimated Duration/ Schedule	• Survey and vendor proposals: 6 months • Pilot study: 12 months • Final report: 3 months
Triggers	This project should be considered for implementation if any of the following triggers are present: • Implementation of CHP • Better opportunities arise for disposal of biosolids with higher %TS content (offsite composting for example)
Relationship to Other Projects	• Digester System Evaluation (Project S.3): This project will determine if the existing system has capacity for accommodating additional biogas production. • Combined Heat and Power (Project M.1): Implementation of CHP would benefit from increased biogas production.
List of Related Studies/Reports	• *Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Medium Term Projects

Project M.6 – Onsite Energy Use/HVAC Evaluation

Project Description	Improve and expand upon the recommendations made in the *Energy Master Plan* (Greely & Hansen, 2014), the *Alexandria Renew Enterprises Building Energy Analysis* (CH2M, 2015) and during the 2016 long range planning process.
Identified Deficiencies	As part of the Energy Master Plan, the Building Energy Analysis and Solids to Energy planning process, several items were identified as potential opportunities for energy savings and optimization. Areas include HVAC controls and upgrades, as well as, upgrades of electrical equipment.
Recommended Scope	Based on the electrical analysis and condition assessments done to date, the following types of projects are recommended to improve energy usage and increase reliability: • Upgrade variable frequency drives at all the major pumps stations • Upgrade uninterruptable power supply units • Upgrade electrical equipment including switchgear replacement • Reduce the potential for arc flash • Relocate one of the Dominion Virginia Power plant feeders • Optimize W3 usage to reduce pumping Based on the energy analysis of the HVAC systems done to date, the following areas of improvement, for nine building (55, A, C, G1, G2, G5, J, K, and L), are recommended: • Reprogram HVAC controls • Operations and maintenance upgrades • Installation of variable frequency drives • Upgrades to water fixtures to reduce water use • Retro-commissioning of the existing systems • Upgrades to the existing HVAC equipment • Upgrades to the chillers in Building J The items identified during the 2016 long range planning process were: • Addition of a third boiler than can run on biogas (dual gas boiler) • Add a second adsorption chiller

Project M.6 – Onsite Energy Use/HVAC Evaluation

	• Upgrade lighting with LED lighting • Additional power monitoring equipment to collect real-time energy usage data.
Estimated Duration/ Schedule	Duration of design and implementation will depend on the items selected for upgrade and improvement
Triggers	This project should be considered for implementation if any of the following triggers are present: • Equipment reaching the end of its useful life • Organizational goal of energy self-suficiency and reducing O&M costs
Relationship to Other Projects	• Combined Heat and Power, M.1 • Co-Digestion/FOG, M.2 • Thermal Oxidation, L.1 • Drying, L.2
List of Related Studies/Reports	*Energy Master Plan,* (Greeley & Hansen, July 2014) *Alexandria Renew Enterprises Building Energy Analysis*– Task Order 20-2005, (CH2M, June 2016)

Implementation Plan – Potential Long Term Projects

Project L.1 – Thermal Conversion of Organics

Project Description	This long-range project would include a study of technologies that extract the energy from biosolids as heat and produce an inert product. Various alternatives would be evaluated and if deemed viable, could be implemented.
Identified Opportunities	• Reduction in the amount of biosolids hauled offsite. The reference technology (Fluidized Bed Reactor) would reduce the mass of solids produced by 80 percent. The resulting product is inert ash. • Energy recovery (in the form of heat) from the biosolids is possible • Beneficial use of heat can include conversion to electricity using ORC turbo generator
Recommended Scope	The evaluation shall include: • Evaluation and comparison of technologies for thermal conversion of organics (incineration, pyrolysis, gasification or others) • Compatibility and integration with other projects (Drying L.2 and/or Sludge Conditioning L.3). • Alternatives for system location and construction sequencing • Evaluation of air permitting process and system requirements to curb emission of air pollutants • Identification of reuse options • Economic evaluation (capital costs, annual costs and pay-back period estimates) Project shall include a list of recommendations for implementation, including a “do nothing” option. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project would include design services (drawings, specifications) and construction of recommended alternative. Project shall include a list of recommendations for implementation, including a “do nothing” option. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project could include design services (drawings, specifications) and construction of recommended alternative.

Project L.1 – Thermal Conversion of Organics

Estimated Duration/ Schedule	• Evaluation and Report: 12 months • Design: 12 to 18 months • Bid Phase: 3 months • Construction: 24 months (depending on selected alternative) Estimated preliminary capital cost: \$70 M for fluidized bed incinerator, \$3.4 M for ORC turbo generator
Triggers	This project should be considered for implementation if any of the following triggers are present: • Regulations that limit or ban land application • Cost of land application is significantly increased
Relationship to Other Projects	• Strategies for Land Application/Ban (M.4): This evaluation will determine viable options if land application is limited in the future • Drying (L.2): Drying also significantly reduces the biosolids generated and the product be marketed as a soil amendment. • Other Emerging Resource Recovery Technologies (L.3): Technologies such as Genifuel or gasification/pyrolysis could advance to the point where they could be viable at AlexRenew.
List of Related Studies/Reports	*Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Potential Long Term Projects

Project L.2 – Drying

Project Description	This long-range project would consist of implementation of a dryer project. Note that the highest scoring alternative in the selection process (Alternative 3b) included Thermal Conversion of Organics and not a dryer. However, dryer technology could provide benefits to AlexRenew in the future and therefore should be considered again.
Identified Opportunities	• Reduction in the amount of biosolids hauled offsite. The reference technology (Belt Dryer) would reduce the volume of solids produced by 70 percent. • Dried product provides increased flexibility and opportunities for beneficial reuse (fertilizer, soil blend, cement kiln feed)
Recommended Scope	The project shall include: • Evaluation and comparison of technologies for dying (belt, drum, etc) • Alternatives for system location and construction sequencing • Evaluation of air permitting process and system requirements to curb emission of air pollutants • Identification of reuse options • Economic evaluation (capital costs, annual costs and pay-back period estimates) Project shall include a list of recommendations for implementation, including a “do nothing” option. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project could include design services (drawings, specifications) and construction of recommended alternative.
Estimated Duration/ Schedule	• Evaluation and Report: 6 to 9 months • Design: 12-18 months • Bid Phase: 3 months • Construction: 18-36 months • Estimated preliminary capital cost: $15-20 M for a belt dryer.
Triggers	This project should be considered for implementation if any of the following triggers are present: • Regulations that limit or ban land application • Cost of land application is significantly increased

Project L.2 – Drying

Relationship to Other Projects	• Strategies for Land Application/Ban (M.4): This evaluation will determine viable options if land application is limited in the future • Thermal Conversion of Organics (L.2): Implementation of TCO technologies could eliminate the need for a dryer at AlexRenew • Sludge Conditioning (L.3): Implementation of sludge conditioning will alter the energy balance of the plant and will affect sizing and selection considerations for the dryer.
List of Related Studies/Reports	*Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Potential Long Term Projects

Project L.3 – Sludge Conditioning

Project Description	Implement recommendations of the Sludge Conditioning Demonstration Study (Project M.5)
Identified Opportunities	• Current digester gas production is sufficient to meet heating needs but not enough to also produce enough electricity to make a CHP system cost-effective (based on preliminary analysis). • AlexRenew has a goal of energy neutrality. Use of digester gas to produce electricity and heat is one of the most efficient and commonly used paths towards this goal. • Sludge conditioning can boost digester gas production and improve dewaterability
Recommended Scope	The project would consist of design services (drawings, specifications) and construction of recommended sludge conditioning alternative. The scope could cover the following: • Demolition of pre-pasteurization system • Construction of additional sludge screening equipment • Construction of ancillary treatment systems (pre-thickening or pre-dewatering, for example) • Construction of sludge pre-conditioning process Modifications to centrate pre-treatment system (if needed)
Estimated Duration/ Schedule	• Design: 9 to 12 months • Bid Phase: 3 months • Construction: 18 months (depending on selected alternative) • Estimated preliminary capital cost: $15 - $20 M for a thermal hydrolysis system, including pre-dewatering
Triggers	This project should be considered for implementation if any of the following triggers are present: • Implementation of CHP • Better opportunities arise for disposal of biosolids with higher %TS content (offsite composting for example)
Relationship to Other Projects	• Combined Heat and Power (M.1) – Implementation of sludge conditioning could greatly increase biogas production which in turn can be converted to heat and electricity in a CHP system. • Sludge Conditioning Demonstration Study (M.5) – This study will determine the viability of implementing sludge conditioning at AlexRenew and result in a technology recommendation.

Project L.3 – Sludge Conditioning

	• Dryer (L.2): Implementation of sludge conditioning will alter the energy balance of the plant and will affect sizing and selection considerations for the dryer (if implemented).
List of Related Studies/Reports	*Biosolids Update to the Long Range Plan* (Black&Veatch, December 2014)

Implementation Plan – Potential Long Term Projects

Project L.4 – Emerging Resource Recovery Technologies

Project Description	This project is a place-holder for emerging technologies that would recover resources from biosolids. These include bio-oil, bio-plastics and others currently under development.
Identified Deficiencies	• Diversified products would give AlexRenew flexibility for end-use • Potential revenue stream
Recommended Scope	The project could include: • Evaluation and comparison of resource recovery technologies • Pilot or demonstration study onsite • Development of alternatives for system location and construction sequencing • Economic evaluation (capital costs, annual costs and pay-back period estimates) Project shall include a list of recommendations for implementation, including a "do nothing" option. Project shall also include use of the AlexRenew decision model to screen alternatives against the strategic alignment criteria. Follow-up project could include design services (drawings, specifications) and construction of recommended alternative.
Estimated Duration/ Schedule	• Evaluation and Report: 12 months • Design: 12 to 18 months • Bid Phase: 3 months • Construction: 24 months (depending on selected alternative)
Triggers	This project should be considered for implementation if any of the following triggers are present: • Technology advances to the implementation phase
Relationship to Other Projects	• Biogas utilization: if the technology uses biogas (ie bio-plastics) then it would affect CHP (Project M.1) and Sludge Conditioning (Project L.3) • Liquid biosolids: if the technology uses liquid biosolids (ie bio-oil) then it would affect the solids mass balance and would affect all other projects.
List of Related Studies/Reports	None to date.

SECTION 5

Future Conditions

AlexRenew is well positioned to evolve and adapt in order to face yet fully defined future challenges and capitalize on opportunities as the organization continues its journey as a utility of the future. The planning process identified several issues that could change the direction and/or components of the recommended long range plan, and as such should be closely monitored by AlexRenew.

5.1 Changes in Future Flows and/or Loads

The AlexRenew service area is a vibrant urban community with planned growth in population and commercial activity. In the past 20 years, AlexRenew's influent loading concentrations have changed dramatically due to several factors, including use of water efficient fixtures, commercial food grinders, and other changes in the collection system. In addition, the City of Alexandria and Fairfax County have embarked in infrastructure improvement projects on the collection system that are also likely to affect the flows and loadings that arrive at the AlexRenew WRRF.

On an ongoing basis, AlexRenew should periodically evaluate the influent flow and loadings at the plant to monitor trends and evaluate the need for revisions to the design criteria at the facility. The City of Alexandria and Fairfax County should also provide periodic updates to their population projections.

5.2 Microconstituents

The 2008 long range planning process highlighted the potential for regulations that require WRRFs to remove microconstituents in the liquids stream. The approach for future treatment included ozonation followed by activated carbon as a tertiary treatment step, and space has been allocated for this process in Building G.

Microconstituents in the biosolids are also increasingly becoming a concern. Monitoring and reporting requirements are being enacted in Europe and could become a driver for restrictions on land-application. Research is currently being carried out in Europe as well to determine the fate of the microconstituents as they are removed from the liquid stream and carried into the solid stream.

5.3 GHG Regulations

Since 2005, AlexRenew has estimated the annual GHG emissions that result from its operations and tracks the GHG emission trends from year-to-year to monitor progress towards an institutional goal of 2% reduction in emissions per year. In the future, entities such as AlexRenew could face regulatory requirements to report GHG emissions, which could then lead to reduction requirements. On the other hand, opportunities may arise to exchange renewable energy credits in an open market. These regulatory drivers could make a future biosolids to energy project, using one of the technology pathway alternatives, more attractive for implementation.

5.4 Research and Partnerships

Like AlexRenew, many utilities in the U.S. and the world are working to find technologically viable alternatives for biosolids treatment that optimize resource capture. AlexRenew is currently participating in several research studies and forming partnerships to collaborate with the greater water resources recovery community to find solutions that will benefit all.

WERF Studies and Initiatives

AlexRenew is currently participating in several Water Environment Research Foundation (WERF) Studies::

- Toolbox for Mainstream Deammonification (STAR_N2R14): The goal of this study is to reduce energy and chemical costs by promoting nitrite shunt and deammonification in the mainstream process. The study also looks at optimizing BRB aeration and monitoring the resulting biological populations and biological activity.
- Balancing Flocs and Granules (U1R14): The goal of this study is to increase process capacity, maximize existing assets, and improve process reliability by improving the settleability of the sludge. The study also looks at monitoring the settling properties and the biological populations and activity in the flocs and granules.
- Impacts of Low-Energy, Low-Carbon TN Removal on Bio-P and Nutrient Recovery Processes (Proposed): The goal of this study is to reduce chemical costs and provide resource recovery opportunities by (1) promoting enhanced phosphorus removal and (2) investigating resource recovery opportunities.

In addition, AlexRenew is participating in initiatives to promote innovative technology through the Leaders Innovation Forum for Technology (LIFT). Currently these include:

- Biosolids to Energy Demonstration Project: This project is looking at new and evolving technologies, including pyrolysis, supercritical water oxidation, hydrothermal liquefaction, and gasification. The goal is to move these technologies from the emerging or experimental stage into practice by funding demonstrations with leveraged support from EPA and DOE. AlexRenew staff participated on a site visit to Vancouver, B.C. in February 2016 to tour the Genifuel demonstration project. This project uses hydrothermal liquefaction to create crude oil, using high pressure and temperature. The resulting material is a biocrude that can then be refined using conventional petroleum refining operations.
- Water Resource Recovery Test Bed Facility Network: The goal is to connect researchers, new technology providers and other innovators with potential facilities for piloting new technology. In this manner, the network seeks to help manage risk and accelerate development and adoption of new technologies.

Partnerships and Collaboration

Since 2013, AlexRenew has been collaborating with a Danish utility, Vand Center Syd (VCS), in various areas of common interest:

- Deammonification (sidestream and mainstream)
- Energy neutrality
- New products (reclaimed water and soil amendments)
- Institutional knowledge (Operational/Managerial) through staff exchange
- Sustainability
- Customer Relations
- Corporate Social Responsibility

VCS has various research and pilot projects underway and is interested in developing joint programs with AlexRenew. Currently they have a research project on steam drying and pyrolysis/gasification.

Appendix A
Workshop Materials and Meeting Notes

AlexRenew Solids Handling & Energy Optimization – Chartering Workshop – February 10, 2016

ATTENDEES:	Karen Pallansch/AlexRenew Sean Stephan/AlexRenew Janelle Okorie/AlexRenew Hong Yin/AlexRenew Johnnie Wallace/AlexRenew Steve Hill/AlexRenew Charlie Logue/AlexRenew Darel Stevens/AlexRenew Lisa Reynolds/AlexRenew Rickie Everette/AlexRenew Andre Yates/AlexRenew James Atkinson/AlexRenew	James Cummins/AlexRenew Eugene Singleton/AlexRenew Aster Tekle/AlexRenew David Hackworth/CH2M Dan Lynch/CH2M Glen Daigger/CH2M Tim Constantine/CH2M Rich Voigt/CH2M Paula Sanjines/CH2M Todd Williams/CH2M Marialena Hatzigeorgiou/CH2M Savita Schlesinger/CH2M
COPY TO:	Julian Sandino/CH2M File	
PREPARED BY:	Rich Voigt/CH2M	
DATE:	February 29, 2016	

Objectives

A Chartering Workshop for the Alexandria Renew Enterprises (AlexRenew) Solids Handling & Energy Optimization Project was held on February 10, 2016 at the AlexRenew Administration Building. Objectives were as follows:

- Introduction of Team Members and Project Scope
- Discussion of AlexRenew's Current Vision and Goals, particularly related to Strategic Planning
- Define Boundary Conditions and Strategic Outcomes

Summary

A summary, based on agenda topics, is provided below.

Introduction/Opening Remarks

Karen Pallansch provided remarks, which included:

- The original Long Range Planning (LRP) effort was an iterative process. When it started, we did not know what might result. Therefore we need to develop ideas knowing that they will be adapted.
- Our task is to bring ideas, curiosity, and creativity to develop solutions that will work for AlexRenew and the community.

- We need to solve current problems, but also look towards the future which may require us to adapt our plans.
- Our goal is to enable the community to thrive economically and grow. We need to provide the services that are needed for that growth.
- Since 2007, AlexRenew has become more engaged with the community it serves. AlexRenew is committed to the public interest and constitutional values. Integrating into the community is critical so they can take pride in what we do.
- Public workers are held to a high standard – which requires leadership.
- Financial stewardship/rate stability is a key metric (goal is to keep rate increases at 2% or less per year). Investing in planning will lead to sound financial decisions.

AlexRenew Vision & Goals

The AlexRenew Board 2040 Vision & Strategic Outcomes are included in Attachment 1.

Decision Model Overview

The current decision model was reviewed and is included in Attachment 2.

Regulatory Challenges and Opportunities

Discussion included the following:

- Maryland has enacted more stringent land application requirements which will push land appliers to look for sites in VA and drive up costs.
- Class B biosolids regulations and requirements may be adopted for Class A in the future, due to shrinking Virginia DEQ resources and staff
- Utilities and the Virginia Biosolids Council are involved in following legislation and regulations, focused on educating decision-makers
- More stringent land application requirements are likely in the next 5 years
- State of California is approximately 10-15 years ahead of the rest of the country with respect to biosolids, but on the same trajectory. Some counties are requiring Class A material. Land capacity for biosolids is finite and shrinking.

Political Challenges & Opportunities

Discussion highlights related to biosolids management:

- National Level – There is relatively little representation/backing for utilities to preserve/expand land application of biosolids due to (1) lack of public funding, (2) sensitive issue for portion of the public, (3) distrust of elected and public officials, and (4) lack of ownership of what is in the wastewater
- Virginia State Level – various citizens and citizen groups are passionate about biosolids and its constituents/effects on the public. The issue tends to draw a negative emotional response. Little to no relationships currently exist that would build trust and the personal connection needed to have productive dialogue. Legislative bills are put forth every year regarding biosolids. A budget amendment was proposed this session by the House to study the issue, which will take 2 years to complete. It is probable that land application will be restricted in Virginia within 5 years.

- Regional Level - AlexRenew tried to work with others to develop a regional solution to biosolids – but it was never endorsed/implemented for a variety of reasons – risks, siting, and other issues.
- Perceptions – a perception exists that urban citizens are exporting their biosolids/waste to rural communities. The Chesapeake Bay Foundation is making a significant push on legislators to tighten regulations around biosolids. However, there is not enough land available in the urban areas to use the material as fertilizer or soil amendment, even with a high level of treatment.

Opportunity: If land application is likely to be restricted in the future, utilities can fight it or move forward with alternative solutions/end uses/management methods for biosolids.

Related issues:

- Truck Traffic – The area surrounding the plant has changed, with additional high profile commercial and residential neighbors. Biosolids trucks passing through neighborhoods carries an 'ick' factor.
- City of Alexandria's Eco-City charter – need to review and embrace it's goals
- Air Pollution/Concerns – May not be able to consider incineration or storing methane on site. How do we market and dispel fear with these types of approaches? Note that the City experienced an industrial ethanol spill several years ago, and there is a heightened awareness of potentially harmful chemicals/compounds in close proximity to the public.
- Community Goals – Focus needs to be on adding community value – need to provide water, wastewater treatment, and trash disposal. If we can't solve these problems, the City can't grow. This team needs to meet the needs of a dense urban community, and understand City planning goals.
- AlexRenew Board Vision – The Board expects transparency and financial stability. AlexRenew is trying to keep rates low, as well as meet various challenges: (1) wet weather needs, (2) wastewater treatment needs, and (3) other infrastructure needs. The City has finite resources to meet all of these challenges. This requires effective planning.
- Biosolids: The challenge facing AlexRenew is that once the material is produced, it is not controlled by AlexRenew anymore. The fate of the material depends on contractors (Synagro) and farmers. One of the goals is to develop solutions that will enable AlexRenew to gain control of the product.
- Molybdenum – concentrations in biosolids have jumped 30 times over past levels, due to Ferric Chloride quality and variability. This is a serious quality issue.
- During the LRP, micro-constituents were not easily quantified by laboratories, but quantification methods have come a long way and these compounds are increasingly becoming a public concern (starting in Europe but also in the U.S.).
    - Potential exists for regulations around micro-constituents to be implemented before more stringent nutrient requirements.
    - In the Chesapeake Bay, the next step in nutrient reduction is probably reducing the non-point sources. Therefore, at the WRRFs, it is likely that micro-constituents will be regulated before more stringent nutrient limits are imposed.

Planning Horizon & Boundary Conditions

An overview of the past Long Range Planning effort, including the boundary conditions, was provided.

Draft boundary conditions were developed as follows:

Table 1. New (Draft) Boundary Conditions for Long Range Planning
2040 Planning Horizon

Boundary Condition	Elements
Most Restrictive Limits (2040)	Ban on land application of biosolids and/or potentially all land-based uses of biosolids Limits on nutrient effluent discharge concentrations down to Limit-of-Technology (LOT) levels: • TN = 1 mg/L • TP = 0.01 mg/L Monitoring and limits on micro-constituents in the biosolids and in the liquids Greenhouse gas (GHG) caps
Sustainable Practices	Trend towards energy neutrality No net increase in air emissions onsite Manage risk associated with biosolids use/disposal Reclaimed water – develop partnerships to utilize 5 mgd capacity Limited footprint at WRRF for future development
Board Directives/Community Engagement	Support Board 2040 vision and outcomes Supportive development partner in Carlyle Partners Focus on local community stewardship – solutions to enable City to grow No net increase in odor/air emissions/light/noise/traffic Remain neutral on visual impacts of future additional facilities compared with existing

Review of Solids Handling Data

Solids handling data used for the 2007 LRP and subsequent Task Order 11 (wet weather evaluation) were presented. Trends were shown, and a data set (2007-2015) was proposed for future planning use.

Other discussions included:

- AlexRenew averages 3 biosolids trucks per day, Monday through Friday
- Based on flow trends, AlexRenew may never meet the 54 mgd average annual daily flow number. But the plant will reach its load capacity, as BOD is increasing every year.
- Wet Weather – The City of Alexandria will provide offsite storage, as well as a deep tunnel for CSO-003 and -004.
- Screenings – Screening facilities may be added for combined sewers, upstream of remote pump stations, and other locations (for example the wet weather pump station in the NMF).
- Gravity thickeners (GTs) – mass balance does not close around the thickeners, off by almost 40%. The cause of the discrepancy is unknown, but may be due to (1) breakdown of solids while in the GTs, (2) grab sampling accuracy, and/or (3) other factors. Pumping for the GTs is an area that needs to be evaluated including the desired flow and percent solids. Currently solids are less than 1% coming into the GTs.

- Pre-pasteurization Update
    - A summary of studies and evaluations conducted in the past and currently underway was presented
    - Unresolved issue – Kruger had previously proposed rerouting the vent line from the tanks back to the digesters. This issued needs to be finalized.
    - Heat Exchanger Cleaning – a sample from the solids side of a heat exchanger was sent for analysis, which will determine the type of cleaning that is to be conducted
    - System controls – Kruger has also provided a quote to conduct programming changes to allow 3 heat exchangers to be put in service simultaneously (vs. current arrangement which always has one unit on standby)
- Energy Analysis – numbers for AlexRenew are in line with other facilities

Synthesis of Morning Discussion

The future is uncertain. We need to frame situations and possible futures (different kinds of futures).

Consider the following:

- Historically utilities have focused on minimizing capital expenditures. There needs to be a change in the industry mindset to being good financial stewards and practicing strategic investment. There is too much money chasing too few ideas. If solutions can reduce operating costs, the money is there to implement it.
- Resource Efficiency – create good products
- Regulations – The best regulation or target to meet is the one you set yourself – not what is imposed on you. Can't wait – need to decide what the right standards are/should be – and consider approaches to meet them.

Think strategically – things to think about:

- What to emphasize/do more of (ex. more digestion)?
- What to reduce/do less of (ex. reduce amount of WAS)?
- What do we eliminate (ex. prepast, gravity thickeners have provided great service, but maybe they aren't the future)?
- What do we add (something you don't currently have)?
- Need to find the game-changers!

Strategy Brainstorming

After a brief setup of the brainstorming sessions, groups were broken out into 3 categories – summaries of the findings are listed below:

Group 1: Minor Enhancements to Existing

- Process Improvement
    - Auto chemical dosing
    - Evaluate chemical vendors (Ferric), improve procurement/consistent quality of products
    - Bio-P in BRB (sections)
    - Auto "dirty" centrate diversion in Building L

- (Become a) Anammox seed sludge supplier – source of potential revenue
- Heat addition to Prepasteurization HEX
- Alternative thickening

- Equipment Improvements
  - Controls Optimization
  - Upgrade TCENs (AC drives, etc)
  - Primary Sludge Pumps – improve (VFDs or replacement) to reduce pumping time
  - Biogas backup generator
  - Reschedule maintenance
  - Electrical tie-overs to off-peak hours (testing, equip, switchover)
- Facility Improvements
  - Add third methane boiler
  - Add second absorption chiller
  - Additional LED lighting
  - Additional power monitoring to achieve collection of real time data

<u>Group 2: Today's Proven Advanced Technologies</u>

- What to do more of/add?
  - Produce more biogas/utilize more
    - CEPT
    - Add boiler/absorption chiller
    - Biogas to Clean Methane Gas (CMG)/pipeline quality
    - Combined Heat and Power to produce more steam or electricity
  - Volatile Solids Reduction (VSR)
    - Recuperative thickening
    - Thermal Hydrolysis (THP) before or after digestion
    - Chemical Hydrolysis
  - Water reuse – extend pipeline to more users
- What to reduce/eliminate?
  - Biosolids/trucks
    - VSR techniques above
    - Thermal drying
    - Fertilizer production
  - Energy consumption
    - Aeration
  - Methanol use

- Prepasteurization
- Gravity thickeners (or increase % solids)
- Reduce footprint

Group 3: Future Technologies

- Post Digestion Thermal Treatment & Thermal Oxidation
  - Basic setup:
    - Primary sludge (only) is digested to produce gas
    - Digester effluent solids are combined with WAS for thermal treatment, then incinerated to produce ash (landfill) and heat
  - Provides:
    - Energy recovery
    - P-recovery from ash
    - Other inorganics recovery from ash
  - Group feedback/discussion
    - Emissions cleanup technology is there
    - Adopted worldwide
    - PR issue
    - Will reduce biosolids volume by 90%
    - Incinerator would likely be a fluidized bed type (today's technology)
- Genifuel – "sludge to oil"
- Pyrolysis
- Gasification
- Note: Some embryonic technologies can't get to market and be profitable. If a utility is the only installation using a technology, they bear the cost of the R&D. If several utilities use the same technology, the cost is shared. Risk mitigation issue.

Industry Partnerships

A summary of related industry research and partnerships was presented

Parking Lot Issues

- Boundary Condition - We have a supportive development partner in Carlyle Partners
- Boundary Condition - No additional processes (treatment) on West Plant Site. Only available land on Main Plant Site is within fence line
- No lime (for treatment)
- Boundary Condition - Support Board 2040 vision and outcomes
- Metal recovery from sludge? Phosphorous/nutrient recovery?
- Fisher-Tropsch

- Covanta Alexandria – not viable - already reviewed (small area plan issues, site constraints/limit on intake – maxed out), and handling issues.
- Micro-constituents:
    - What is coming in (type/concentration range)?
    - What should we reasonably expect to be removing?
    - How do we test to confirm what's there?
    - Are they removed in biosolids?
    - What are we not removing – and is there a way to remove?

Action Items

Table 1. Action Items List

Item	Responsible Party	Target Due Date
Confirm all participants for next workshop – March 29 (invite Mike McGrath/Fairfax County)	Sean/Rich	February 19
Request latest City of Alexandria projections (population/flow)	Paula	February 19
Boundary Conditions – Review/Provide Feedback	All parties	February 19 (endorsement by end of February)
Proposed Loadings Period to use for Planning (2007-2015) – Review/Provide Feedback	All parties	February 19 (endorsement by end of February)
Status Prepasteurization Follow-up Items	Marialena/Steve	February 26
Brainstorm any technologies to be considered (Prep for next Workshop)	All parties	March 15

Attachments

1. AlexRenew Board of Directors 2040 Vision and Strategic Outcomes
2. AlexRenew Decision Model – Updated in 2015
3. Revised Presentation Slides
4. Meeting Agenda and Sign-in Sheet

ALEXANDRIA renew ENTERPRISES

2040 Vision

By 2040, we have served as a catalyst and are effectively partnered with all watershed stakeholders to:

- **Enable local citizens the opportunity to establish a personal connection with local waterways so that we can eat local fish and swim in local streams.**
- **Support a healthy and resilient local economy through stable rates, supported by diversifying revenue and maximizing resource recovery.**
- **Create an informed citizenry regarding the importance of water so that water stewardship is achieved through personal and organizational actions.**

Strategic Outcomes

1. **Operational Excellence**

   Enhance operational excellence to meet or surpass environmental requirements under all conditions.

2. **Community Engagement**

   Engage the communities we serve to increase understanding and commitment to water quality so that every person and organization demonstrates the important role he, she or they contribute to this effort.

3. **Watershed Partnerships that Enhance Collective Management**

   Create structural processes that enable partnerships to manage water as one resource.

4. **Organizational Competency and Structure**

   Improve and maintain the institutional competency of AlexRenew to achieve its long-range strategic objectives by enabling all levels of the organization to learn, adapt, and innovate.

5. **Diversified Revenue**

   Maximize additional revenue options through the sale of reclaimed products, credits, and other means to ensure financial stability while minimizing its impact on customers.

6. **Incubator of New Ideas and Innovations**

   Develop and implement innovative ideas and technologies to enhance resiliency and sustainability.

AlexRenew Decision Model

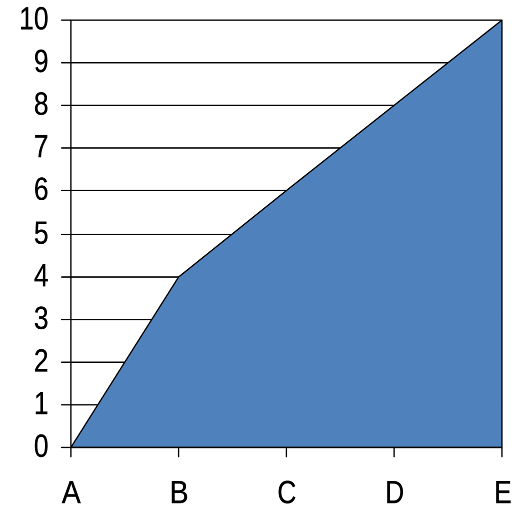
Weights:	40	22	10	13	7	8
Strategic Alignment:	**Operational Excellence**	**Community Benefit**	**Watershed Partnership**	**Organizational Competency & Structure**	**Investment Stewardship**	**Incubator of New Ideas and Innovations**
	Improve Business Efficiency ***Weight: 10***	Promotes water in our community ***Weight: 3***	Enable new external partnerships ***Weight: 6***	Supports great place to work ***Weight: 3***	Annual Cost ***Weight: 1***	Enhance Sustainability ***Weight: 2***
	Compliance enhancement /adaptability ***Weight: 15***	Enhance Community Water Resources ***Weight: 4***	Support sound Science ***Weight: 4***	Improves ease of operation ***Weight: 5***	Capital Cost Management ***Weight: 1***	Enhance Resiliency ***Weight: 2***
	Enhance Capacity/Throughput ***Weight: 10***	Supports customer service ***Weight: 5***		Maximize technology tool solutions ***Weight: 5***	Fosters Operational Cost savings ***Weight: 3***	Technical Feasibility ***Weight: 4***
	VEEP/EMS ***Weight: 5***	Communication Enhancement Value ***Weight: 6***			***Revenue Neutral or positive Weight: 2***	
		Minimizes Land Footprint ***Weight: 4***				

Operational Excellence

Improve Business Efficiency– Weight 10

1. Reduce Time & Costs
2. Meets or exceeds our permit requirements
3. Benefit our customer
4. Reduces/Eliminates redundancy in the business process
5. Promote safe environment

A. Has a negative impact on business efficiency (0)
B. Has a neutral impact on business efficiency (2)
C. Has a positive impact on business efficiency (6)
D. Has a significant positive impact on business efficiency and meets or exceeds compliance in 1 or more category (8)
E. Has a positive impact on business efficiency and meets or exceeds compliance in 2 or more categories (10)



Compliance Enhancement/Adaptability– Weight 15

1. Awareness and attainment of balance between multi media regulations
2. Processes that provide flexibility to incorporate technological advances and meet future regulations.

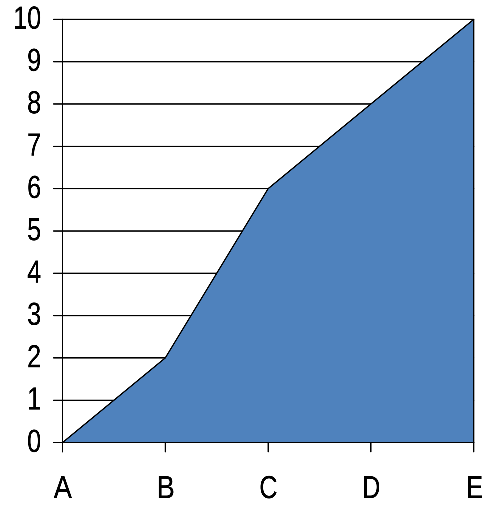
A. Will not help comply with future regulations (0)

B. Can adapt, but it is complex (2)

C. Can easily adapt (6)

D. State of the art technology today (8)

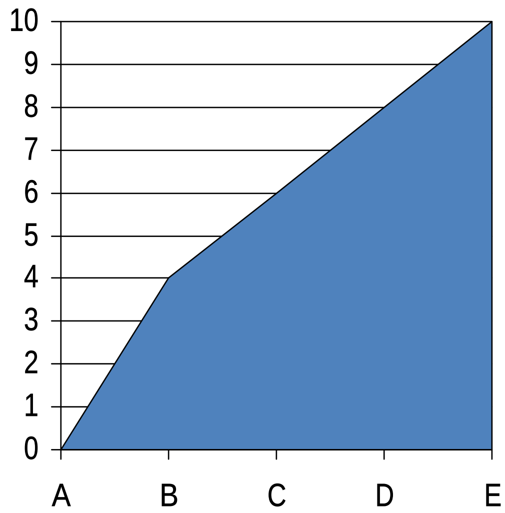
E. State of the art technology today with flexibility to adapt (10)



Enhance Capacity/Throughput – Weight 10

1. Increase or offset in hydraulic loading
2. Increase or offset in organic loading (liquids and solids)

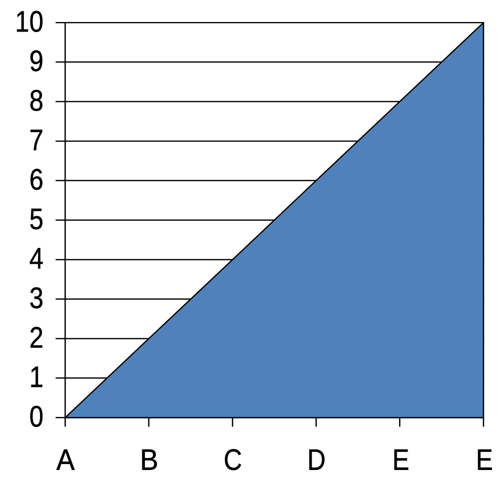
A. Current capacity will be reduced (0)
B. Meets current capacity requirements (4)
C. Capacity will be slightly increased (6)
D. Capacity will be moderately increased (8)
E. Capacity will be significantly increased (10)



VEEP/EMS- Weight 5

1. Support our VEEP and EMS programs
2. Aligns with the Environmental Policy and the EMS
3. Enhances our VEEP requirements
4. Aligns with our overall sustainability goals

A. Does not support our VEEP/EMS program (2)
B. Slightly supports our VEEP/EMS program (4)
C. Moderately supports our VEEP/EMS program (8)
D. Significantly supports our VEEP/EMS program (10)

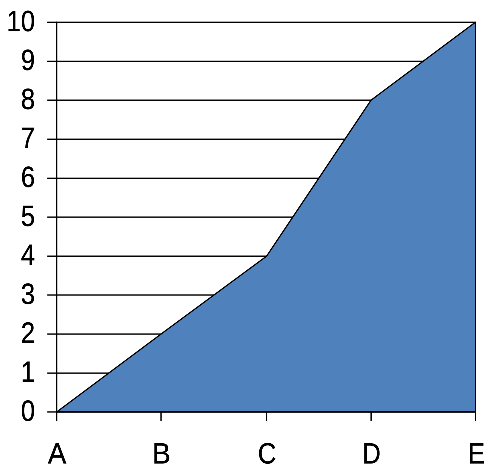


Community Benefit

Promotes Water In Our Community – Weight 3

1. Recognize water as truly valuable natural resource
2. Provides opportunity to create partnerships to support the environment, our causes and our products
3. Overall City Improvements (stream restoration, water reuse at parks, help City meet its environmental action plan, SP objectives and Cool Cities)
4. Recognized as efficient/effective public business
5. Includes the desires of ‘greener’ citizens

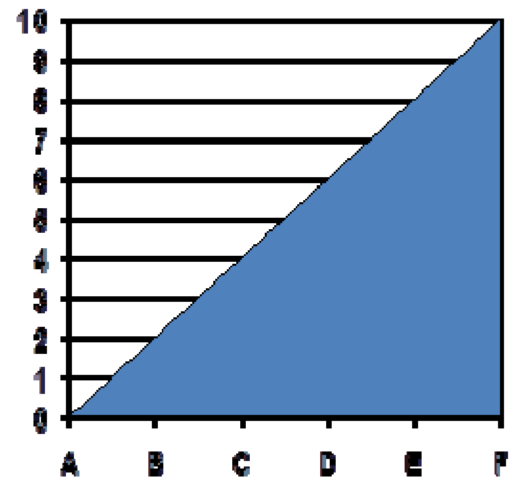
A. Negative impact on public image (0)
B. Potential negative impact on public image (2)
C. No impact on public image (4)
D. Moderate improvement in public image (8)
E. Significant improvement in public image (10)



Enhance Community Water Resources – Weight 4

1. Provides reduced nutrient loads into the local watersheds
2. Minimizes odor impact to the local watersheds
3. Enhances the quality of the watersheds for fishing and swimming
4. Creates an increase awareness in the community of cleaner watersheds (Potomac/Chesapeake)

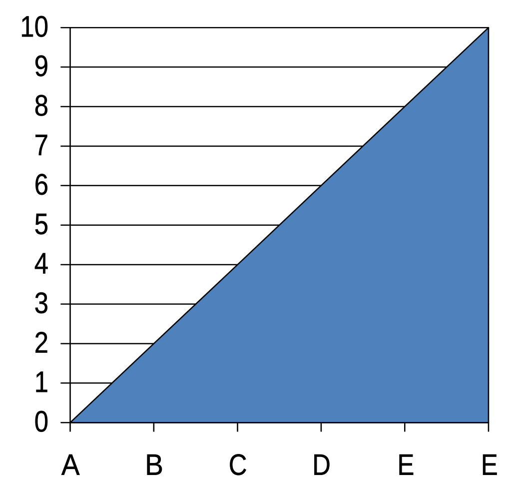
A. Negative impact on Community (0)
B. Slight negative impact on Community (2)
C. No impact on Community- neutral (4)
D. Slight positive impact on Community (6)
E. Very positive impact on Community (8)
F. Significant positive mpact on Community (10)



Supports Customer Service-Weight 5

1. Respond to customer/community issues in an expedient manner
2. Educate customers on water resource stewardship
3. Seamless customer payment options
4. Overall customer satisfaction

A. Significantly reduce the ability to provide customer service (0)
B. Slightly reduce the ability to provide customer service (2)
C. No impact on the ability to provide customer service – Neutral (4)
D. Slightly increases the ability to provide customer service (6)
E. Significantly increases the ability to provide customer service (8)
F. Exceptional customer service (10)



Communication Enhancement Value-Weight 6

1. Respond to customer/community issues in an expedient manner
2. Educate customers on water resource stewardship

A. Significantly reduce the ability to communicate our value (0)

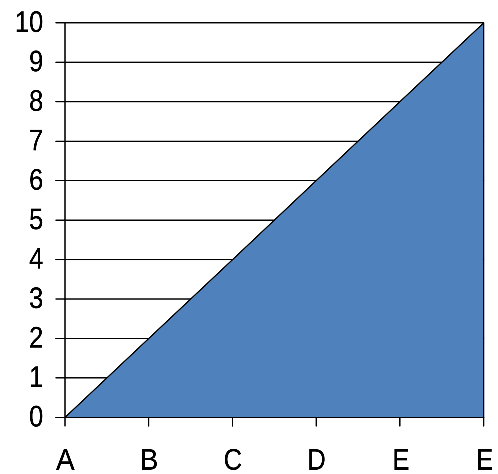
B. Slightly reduce the ability to communicate our value (2)

C. No impact on the ability to communicate our value – Neutral (4)

D. Slightly increases the ability to communicate our value (6)

E. Significantly increases the ability to communicate our value (8)

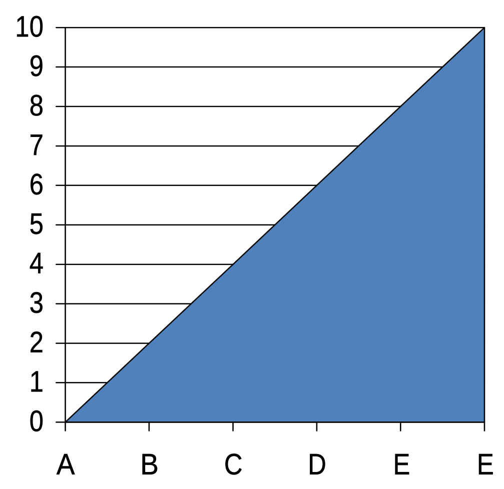
F. Exceptional ability to communicate our value (10)



Minimizes Land Footprint-Weight 4

1. Reduces or maintains community space required to operate
2. Aligns with development plans of the City

A. Significantly reduce the land footprint (0)
B. Slightly reduce the land footprint (2)
C. No impact on the land footprint Neutral (4)
D. Slightly increases the land footprint (6)
E. Moderately increases the land footprint (8)
F. Significantly increases the land footprint (10)

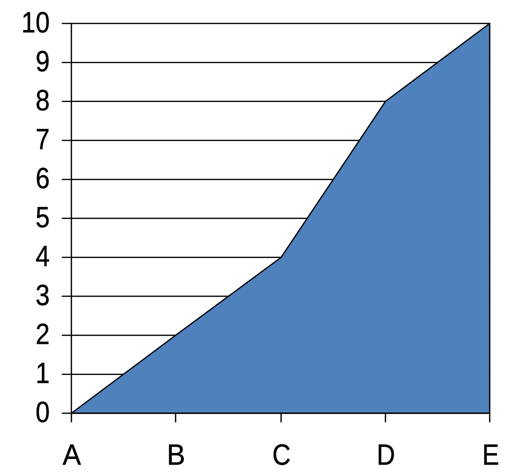


Watershed Partnership

Enable New External Partnerships – Weight 6

1. Provides opportunity to create partnerships to support the environment, our causes and our products
2. Overall City Improvements (stream restoration, water reuse at parks, help City meet its environmental action plan, SP objectives and Cool Cities)
3. Recognized as efficient/effective public business
4. Includes the desires of 'greener' citizens

A. Negative impact on public image (0)
B. Potential negative impact on public image (2)
C. No impact on public image (4)
D. Moderate improvement in public image (8)
E. Significant improvement in public image (10)



Support Sound Science – Weight 4

1. Impactful Watershed Research
2. Independently 3rd party verified technologies/processes
3. Adaptive lab practices to support watershed management changes
4. Align/Support Industry credited test methods
5. Aligned with new regulations

A. Severe negative impact to the treatment process (0)

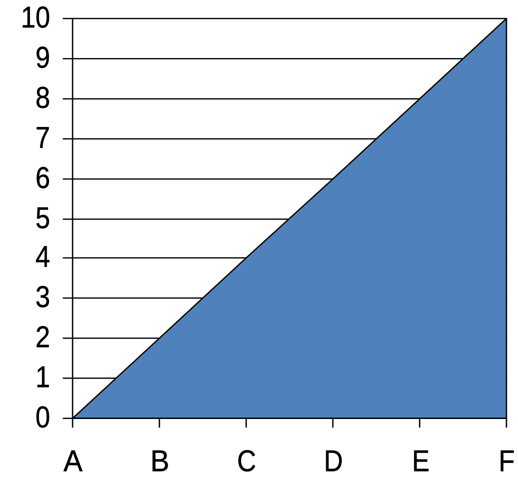
B. Moderate negative impact to the treatment process(2)

C. Slight negative impact on the treatment process (4)

D. No impact on the treatment process - neutral (6)

E. Slight positive impact to the treatment process (8)

F. Significant positive impact to the treatment process (10)



Organizational Competency & Structure

Support Great Place to Work – Weight 3

1. Creates safe environment
2. Utilizes technology to increase efficiency
3. Develop new learning opportunities
4. Increases employee engagement

A. Severe impact to the workplace environment (0)

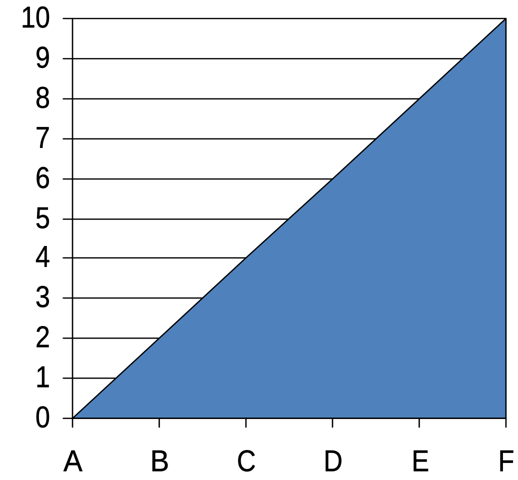
B. Moderate negative impact to the workplace environment (2)

C. Slight negative impact on the workplace environment (4)

D. No impact on the workplace environment - neutral (6)

E. Slight positive impact to the workplace environment (8)

F. Significant positive impact to the workplace environment (10)



Improves Ease of Operation – Weight 5

1. Improves the employees workflow
2. Reduces the number of units that need maintenance, required skill/knowledge level, training needed to learn/maintain skills, waste products/streams to monitor –
3. Accessibility of process controls, data and parameters for operation and automation
4. Adequate physical access for O&M activities -

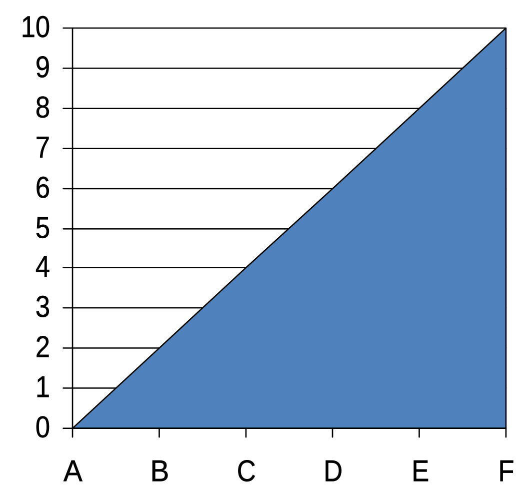
A. Does not improve employee workflow (0)

B. Slightly improves employee workflow (2)

C. Moderately improves employee workflow (4)

D. Significantly improves employee workflow (6)

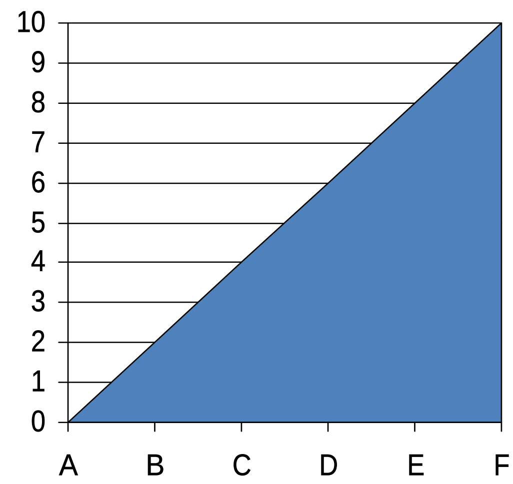
E. Automates employee workflow(10)



Maximize Technology Tool Solutions – Weight 5

1. Technology that increase operational efficiency
2. Communications enhancement/increase speed of data-decisions
3. Reduce daily work

A. Does not improve employee workflow (0)
B. Slightly improves employee workflow (2)
C. Moderately improves employee workflow (4)
D. Significantly improves employee workflow (6)
E. Automates employee workflow(10)



Investment Stewardship

Annual Cost – Weight 1

1. Operations Cost
2. Maintenance Cost
3. Improvement, replacement and renewal cost
4. Revenue generated
5. Other costs

A. Annual cost increase greater or equal to 15% from current annual cost (0)

B. Annual cost increase 11 to 15% from current annual cost (1)

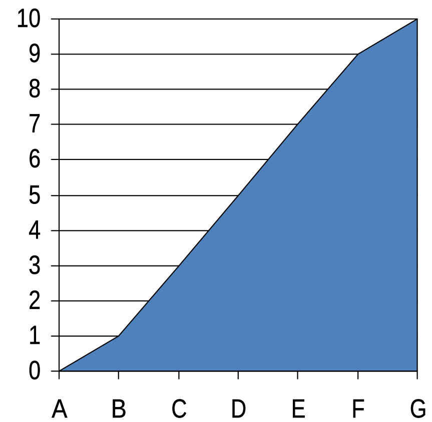
C. Annual cost increase 5 to 10% from current annual cost (3)

D. Annual cost change 0 to 5% from current annual cost, no rate change (5)

E. Annual cost decrease 5 to 10% from current annual cost (7)

F. Annual cost decrease 11 to 15% from current annual cost (9)

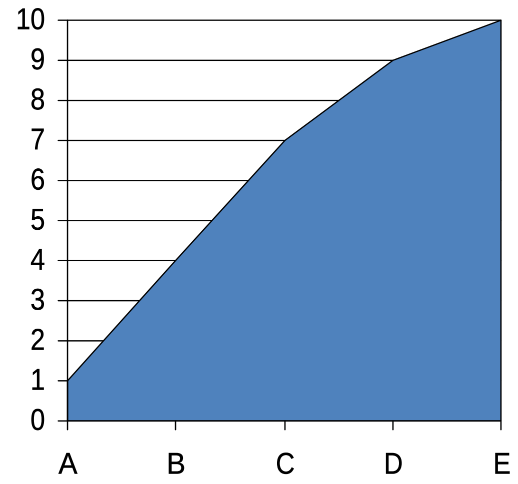
G. Annual cost decrease equal or greater to 15% from current annual cost (10)



Capital Cost Management – Weight 1

1. Magnitude of Capital Investment needed
2. Ability to finance
3. Reuse of resources available
4. Avoidance of stranded assets

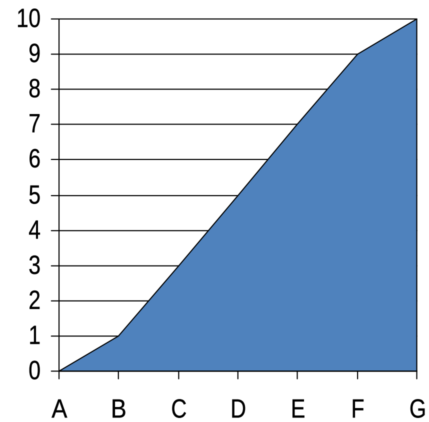
A. Greater than 30% higher than the least cost scenario (1)
B. Less than 30% higher than the least cost scenario (4)
C. Less than 20% higher than the least cost scenario (7)
D. Less than 10% higher than the least cost scenario (9)
E. Least cost scenario that is technically acceptable (i.e. meets boundary condition requirements) (10)



Fosters Cost Savings – Weight 3

1. Reduces Operations Cost
2. Reduces Maintenance Cost
3. Improvement, replacement and renewal cost
4. Revenue generation
5. Other costs

A. Does not deliver cost savings (0)
B. Delivers slight cost savings 2-5% (2)
C. Delivers moderate cost savings 5-10% (4)
D. Delivers significant cost savings over 10-20% (8)



Revenue Neutral or Positive- Weight 2

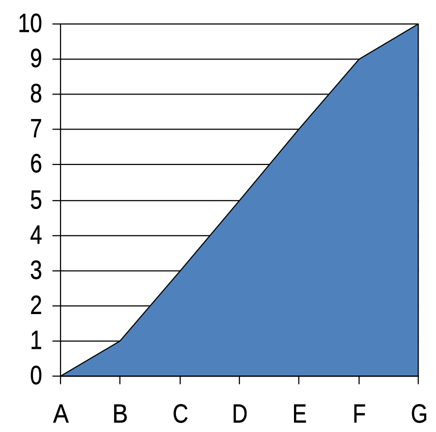
1. Create diversified revenue with resources
2. Delivers a positive impact to the local watershed
3. Maintains stable rates for our customers

A. Does not impact revenue (0)

B. Adds slight revenue (2)

C. Adds Moderate revenue (6)

D. Adds Significant revenue (10)

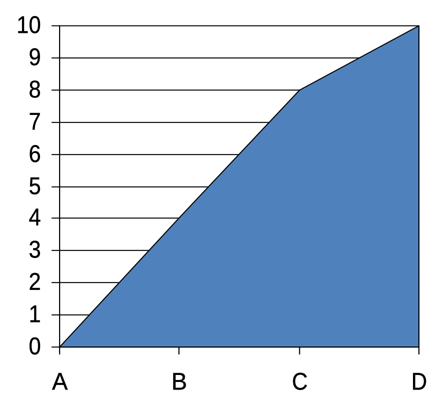


Incubator of new Ideas & Innovation

Enhance Sustainability – Weight 2

1. Meets LEED requirements where applicable
2. Meets Green Infrastructure requirements where applicable
3. Meet NBP EMS requirement
4. Meet ISO 14000 EMS requirements
5. Allows for flexibility to use environmental friendly chemicals in the future
6. Does no harm to the environment
7. Does not require additional human resources to manage process
8. Minimizes internal waste streams
9. Minimizes hazardous waste streams or uses
10. Reduce GHG emissions
11. Reduce KWh and natural gas usage

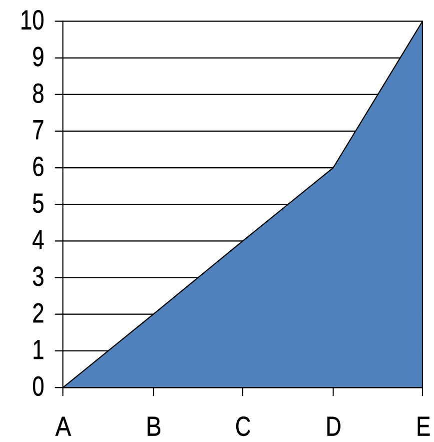
A. Meets none of the sustainable practices (0)
B. Meets two sustainable practices (4)
C. Meets four sustainable practices (8)
D. Meets six or more sustainable practices (10)



Enhance Resiliency – Weight 2

1. Robustness of the system – likelihood of failure and ability to handle variable loads and conditions
2. Redundancy – meets SCAT/regulatory requirements
3. Equipment meets life cycle expectations – minimize premature failures
4. Energy sources will be changing – process flexibility to absorb
5. Integration and risk assessment of new and emerging technologies
6. Secure and safe – continuously provides clean and safe products
7. Negative impact definition:
    a. High: Notification of regulators, permit compliance issues, health and safety, odor complaint, etc.
    b. Low: labor intensive cleanup/repair, spill within the plant, costly repair, etc.

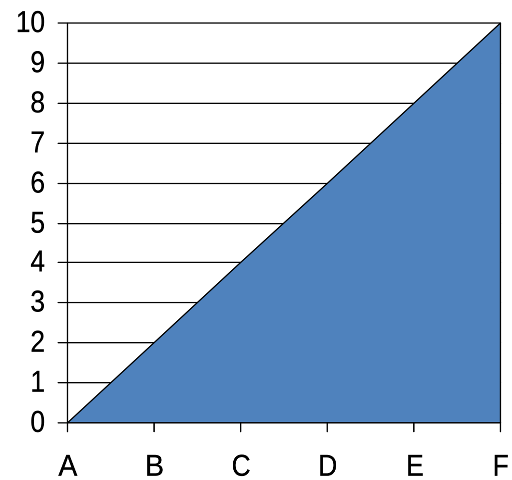
A. High probability of system failure and high negative impact (0)
B. Moderate probability of system failure and high negative impact (2)
C. Low probability of system failure and high negative impact (4)
D. Moderate probability of system failure and low negative impact (6)
E. Low probability of system failure and low negative impact (10)



Technical Feasibility– Weight 4

1. Amount of physical facility footprint required (including access roadways, truck bays, buffer zones, etc)
2. Impact of new process on site
3. Design maximizes site open space available for future

A. Large footprint required, lots of additional land needed, (0)
B. Moderate footprint required, some additional land needed (2)
C. Moderate footprint required, fits in existing site (4)
D. Small footprint required, fits in existing site (6)
E. No impact on existing site (8)
F. Reduces current site footprint (10)






Solids Handling and Energy Optimization Evaluation

Chartering Workshop

February 10, 2016

Revised per comments received at the Workshop

Agenda - Morning

- Welcome and Introductions
- AlexRenew Vision and Goals
- Regulatory Challenges and Opportunities
- Political Challenges and Opportunities
- Planning Horizon and Boundary Conditions
- Review of Solids Handling Data
- Synthesis of Morning Discussion

LUNCH!

Agenda - Afternoon

- Strategy Brainstorming
  - Current and Future Opportunities
  - Breakout Groups
  - Report out
- Industry Partnerships
- Wrap Up

ADJOURN!

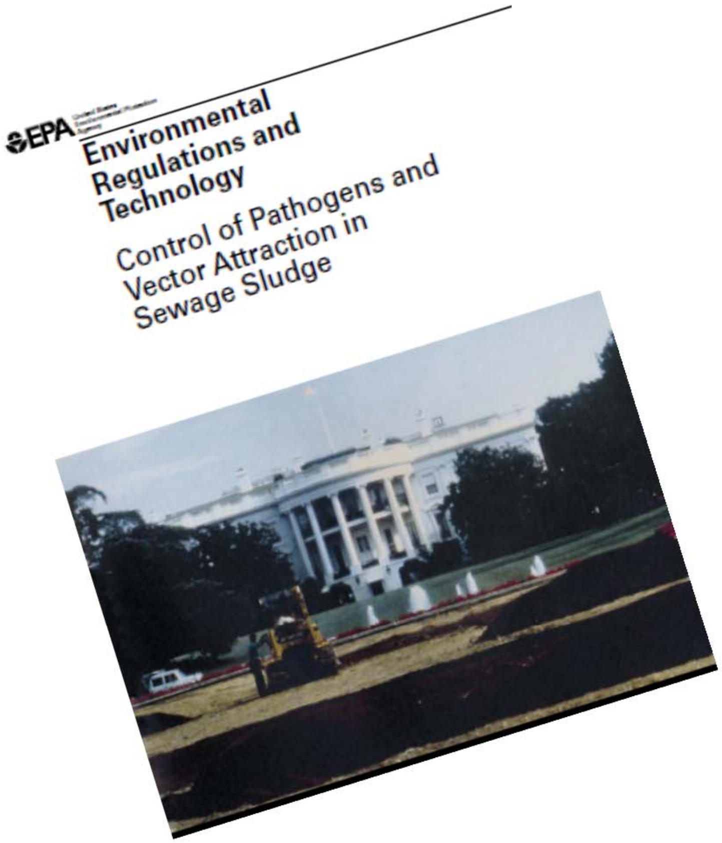
AlexRenew Vision and Goals

Presentation by Karen Pallansch and Sean Stephan

Regulatory Challenges and Opportunities

Presentation by Todd Williams/CH2M and Lisa Reynolds/AlexRenew

Federal Classifications of Biosolids



- Regulatory definition:
  - Class B: Less stringent pathogen standard
  - Exceptional Quality:
    - Lower metals concentrations
    - Vector attraction reduction
    - Class A: Additional pathogen reduction
- Benefits of Class A:
  - Additional flexibility
  - Still limitations
  - Positive public perception?
- Likely No New Regulations in Near Term (5 year horizon)
  - May add Molybdenum to federal list of monitored metals
  - 2013 biennial review draft is completed and under internal review

Concerns Identified in December 2010 Biosolids Summit (WEF, EPA)

- Fragmented, state-by-state regulatory framework that drifts from the Federal regulatory baseline
- More restrictive management practices such as fence-line setbacks and incorporation requirements; increased legal liability
- Greater uncertainty around the mid-term viability of technology and programmatic choices
- A substantial increase in management costs
- Greater complexity in obtaining and maintaining management options

New Maryland Regulatory Requirements

- Nutrient Management Plans updated by July 1, 2013 to comply with new regulations
- Beginning in July 1, 2015, the Phosphorus Site Index is phased out and the more restrictive Phosphorus Management Tool (PMT) is phased in over the next seven years based on soil Phosphorus Fertility Index Value (PFIV)
- Beginning in the Winter of 2016-2017, no nutrient application to agricultural land will be allowed in Winter
- Other restrictions such as the use of cover crops required from November 15 – March 1 each year

Impact of Maryland P-Based Limits on Land Application of Biosolids

- Low value to farmers because they will have to supplement N requirements with inorganic fertilizers
- Land area for biosolids application will decrease dramatically yet land requirement will increase
- Longer hauling distances will result
- Hauling out of state (to VA) will become more common
- Facilities will be converting to non-agricultural solutions
- More on-site storage will be needed

New Virginia Regulatory Requirements

Amendments Effective (Sept. 2013) VPA, VPDES, BUR:

- **Extended and New Setbacks (odor, public accessibility, reservoir, etc.)**
- Annual Financial Assurance Requirements
- **New Responsibilities for Certified Land Appliers**
- **New landowner agreements**
- Land apply only approved sources of biosolids
- **New Nutrient Management Plan Requirements**
- If soil potassium < 38 ppm, add potash
- Submit odor control plan within 90 days or prior to application, whichever is later.
- **New Signage Requirements**
- Notify DEQ and locality in writing within 24 hours before land application activity begins, including delivery (staging)
- Submit a staging plan for authorization, prior to overnight staging
- **Reduction or waiving of setback from occupied dwelling – need signature of occupant and landowner**

Regional/VA- Regulatory and Biosolids Use Trends

P Source	Florida	Pennsylvania Virginia	Most States
Mineral Fertilizer	1.0	1.0	
BPR Biosolids	0.8	0.8	
Alkaline or Conventionally Stabilized	0.4		1.0
Composted Biosolids	0.3	0.4	
Advanced Alkaline & Heat Dried	0.2		

Table 1: Select phosphorus source coefficients used in P indices

The P source coefficient (PSC) “quantifies the environmental availability of a P source relative to inorganic P fertilizer”, which has a PSC = 1.0

- Increasing public opposition
- Land application: P vs. N limiting
- VA may come under evaluation for even more P limits (proposed HB Budget Amendment) to require funding and study the issue for next two years
- Land appliers need more land base to adapt to tougher regulatory requirements
- More land area competition with out of state sources coming to VA

Other National Issues

- Pennsylvania Supreme Court Decision *Gilbert v. Synagro* (Dec 2015) ruled biosolids land application is normal activity under Right to Farm Act
- FDA finalized the Produce Safety Rule (Nov 2015)
- Public pressure continues to increase with well organized anti-biosolids groups to aid local concerned citizenry
- Paradigm shift in the industry in the past 5 years is gaining momentum to view WWTPs as WRRF's and find best use for biosolids

Regulatory and Policy Opportunities

- Biogas Opportunities Roadmap (USDA/EPA/DOE)
- Zero Waste and Organics Recovery Initiatives
- Policy shift toward Sustainability, lower GHG's
- Green Energy and Energy Independence Goals
- Emerging Technology Development through LIFT
  - 5 technology focus areas mostly align with AlexRenew focus areas
    - Deammonification
    - Phosphorus Recovery
    - Biosolids to Energy
    - Electricity from Wastewater
    - Pre-Digestion
- Plan now for future improvements that can accommodate emerging technologies

Political Challenges and Opportunities

Presentation by Karen Pallansch/AlexRenew

Planning Horizon and Boundary Conditions

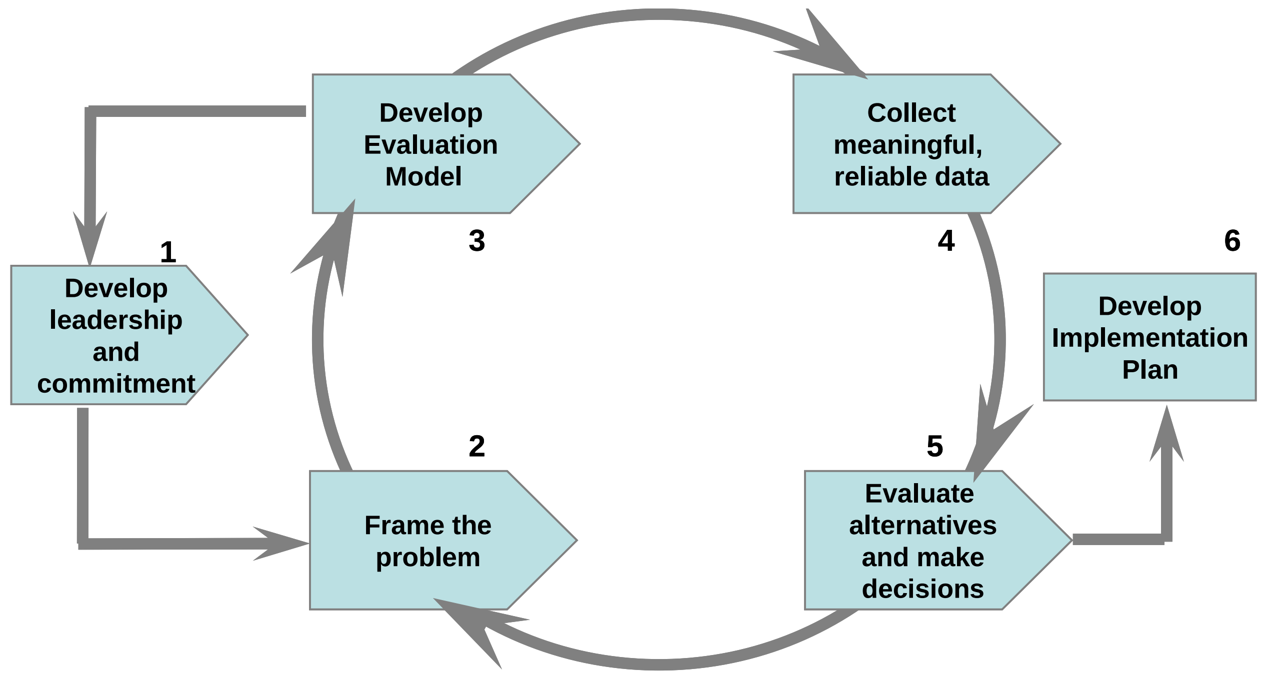
Presentation by Rich Voigt/CH2M

2007 Long Range Planning Effort

- Assessment of all drivers
- Assessment of all viable/applicable technologies and approaches
- Workshop-based, collaborative effort
- Output:
  - Boundary conditions
  - Phased approach to meet AlexRenew's 2011 and enable 2030 goals

2007 Long Range Planning Effort

Methodology:



2007 Boundary Conditions

Boundary Condition	Elements
2030 Most Restrictive Limits and Sustainable Practices	Limits on nutrient effluent discharge concentrations down to Limit-of-Technology (LOT) levels: • TN = 1 mg/L • TP = 0.01 mg/L
	Limits on the discharge of Polychlorinated Biphenyls (PCBs)
	Ban on land application of biosolids and/or potentially all land-based uses of biosolids
	Reuse of plant effluent water for irrigation in city parks (5 MGD between March and November)
2011 Requirements	Limits on nutrient effluent concentrations to take effect in 2011 down to SOA levels: • TN = 3 mg/L • TP = 0.18 mg/L
	Continuing production of Class A Exceptional Quality Biosolids and alternative reuse options to bulk land application

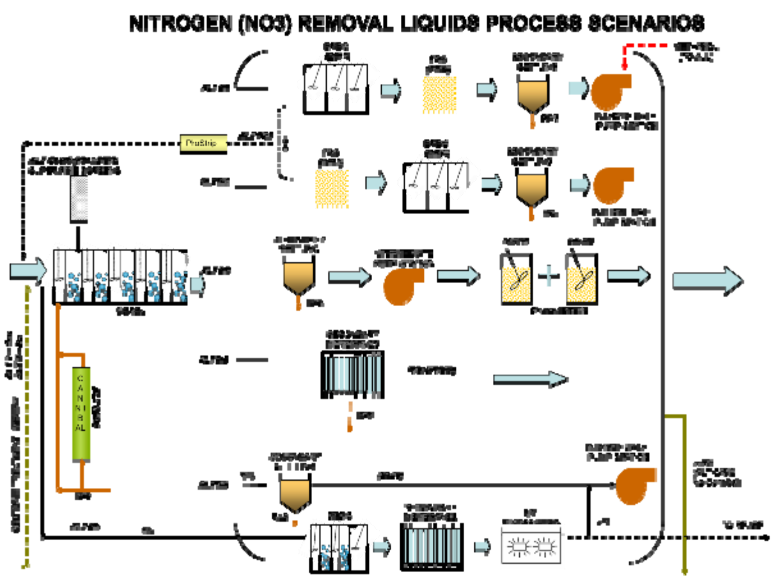
*Based on 54 mgd annual average daily flow (peak of 108 mgd)

2007 Decision Model

Strategies:

Strategies:	People	Environmental Leadership	Efficiency	Community Awareness	Fiscal Responsibility
Weights:	21	26	15	16	22
	Ease of Operation Weight: 11	Current Permit Compliance Weight: 5	Reliability Weight: 3	Neighborhood /City Relations Weight: 10	Capital Cost Management Weight: 11
	Staff Engagement Weight: 10	Flexibility to Adapt to Changing Regulations Weight: 12	Capacity Weight: 4	Public Partnering Weight: 6	Annual Cost Weight: 11
		Manage Environmental Footprint Weight: 9	Site Open Space Weight: 5		
			Embed Sustainable Practices Weight: 3		

2007 Long Range Plan Scenario Selection Process



Screened Against Boundary Conditions

Scenarios to be evaluated

Scored using Decision Model

Selected Scenario

- This process was conducted separately for the solids and liquids treatment trains
- Some selections were deferred

2007 Long Range Plan Outcomes- Liquids

- SANUP Program:
  - Pkg A: Supplemental Carbon
  - Pkg B: Centrate Pre-Treatment
    Final Effluent Flow Measurement
  - Pkg C: NMF
    - *Mainstream Anammox **
  - Pkg D: BRB6

The Decision Model was also used on these projects to select a preferred design alternative

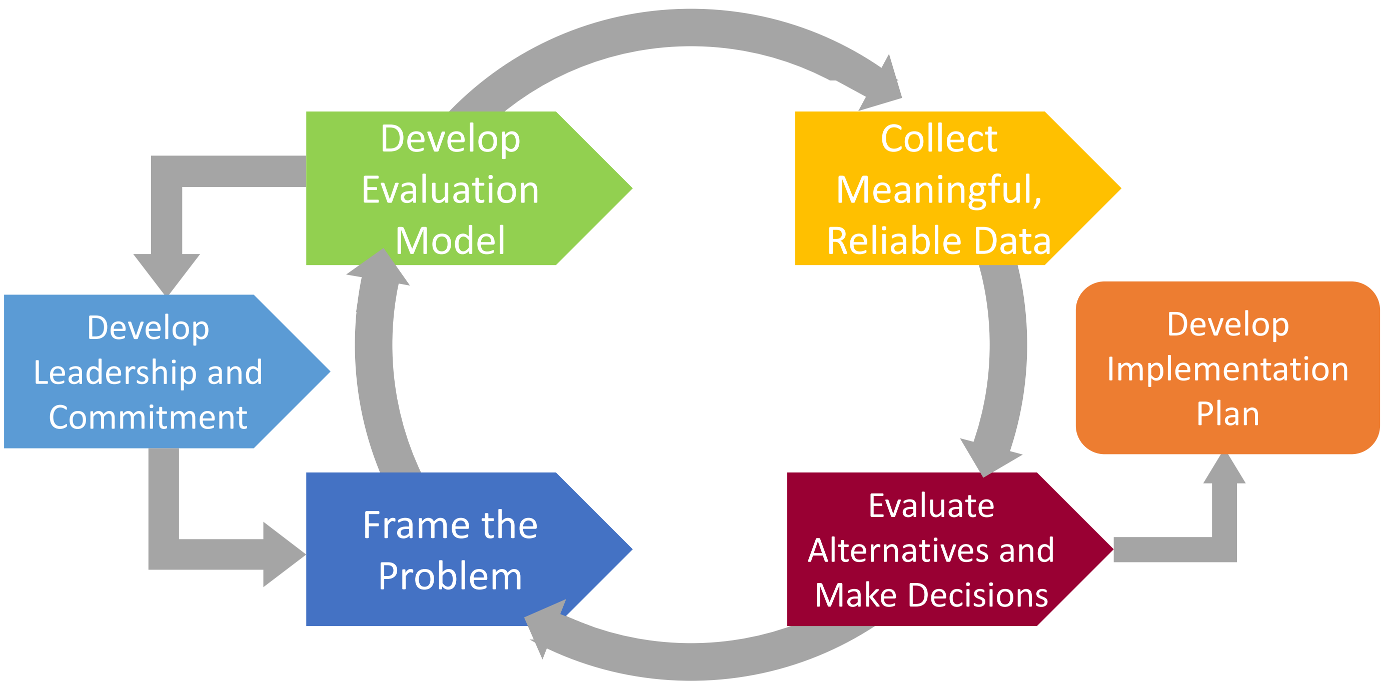
- Water Reuse
- Tertiary Treatment
  - Postponed decision on technologies to achieve a TN of 1 mg/L

** Not part of original Long Range Plan*

2007 Long Range Plan Outcomes - Solids

- SANUP Pkg E: Increase Capacity of Existing Solids Handling (deferred)
  - Additional pre-pasteurization train
  - Recuperative thickening to increase digester capacity
- Long-Term Biosolids
  - Highest scoring alternative to meet 2030 boundary condition was heat drying and combined heat and power
    - Decision was made to wait and see what new technologies and opportunities would materialize

2016 Solids Handling and Energy Optimization Planning



2016 Solids Handling and Energy Optimization Planning

Step 1
Develop Leadership
Chartering Workshop #1 Feb 10

Step 2
Frame the Problem
Technology Alternatives Workshop #2 March 29

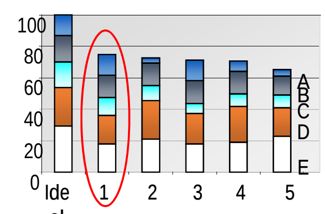
Step 3
Develop Model
Scenarios Workshop #3

Step 4
Collect Data

Step 5
Evaluate & Decide
Workshop #4
Score
Compare
Decide

Step 6
Implement Plan
Long Range Plan Update

	1	2	3
A	4	8	6
B	6	10	2
C	8	4	0
Cost	$	$	$



Planning Horizon

- What does the future look like?

Looking to the future ….

- It's all about managing water, carbon and resources (phosphorus, ammonia)
- Where is the energy market going?
  - Renewable subsidies
    - Green power value
    - Is combined heat and power the best use of carbon (w biogas)?
    - How can we better capture the energy value of the carbon recovered from wastewater? What is the next technology?
- Where is the resource recovery market going?
  - Demand for resources (phosphorus, ammonia, struvite)
- Where is the agricultural market going?
  - Demand for organics, macro and micro-nutrients
  - Regulations on micro-pollutants

Defining Plausible Future Planning Scenarios for AlexRenew

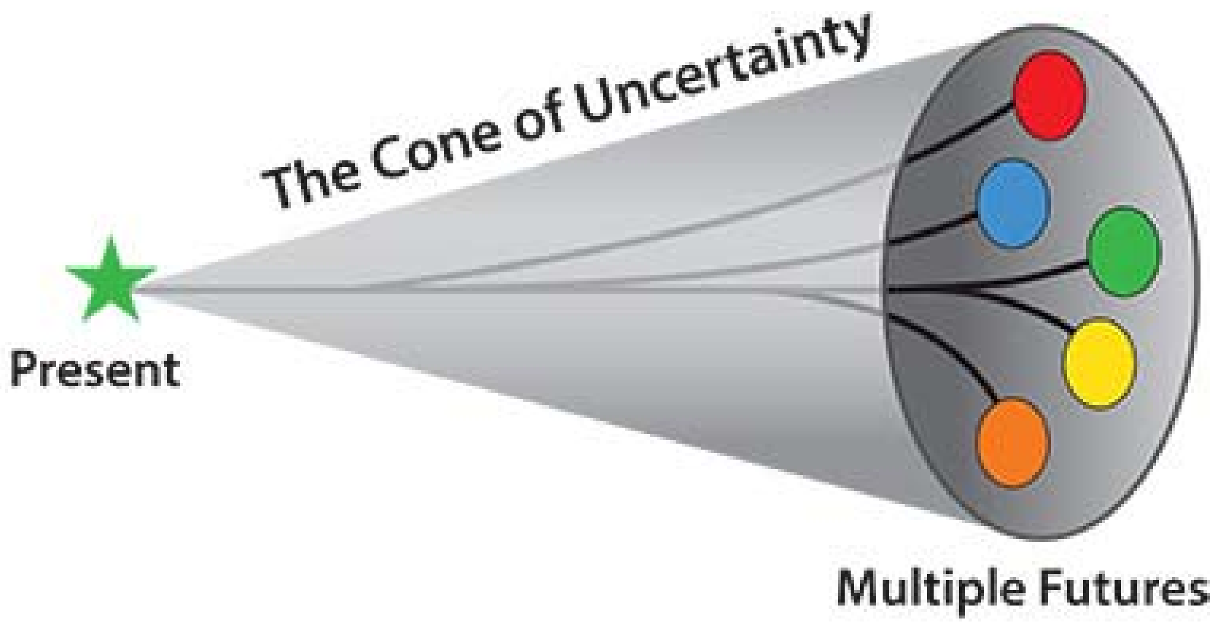


Image Source: Stratus Consulting and Denver Water, Embracing Uncertainty: A Case Study Examination of How Climate Change is Shifting Water Utility Planning, WUCA/AWWA/WRF/AMWA, May 2015

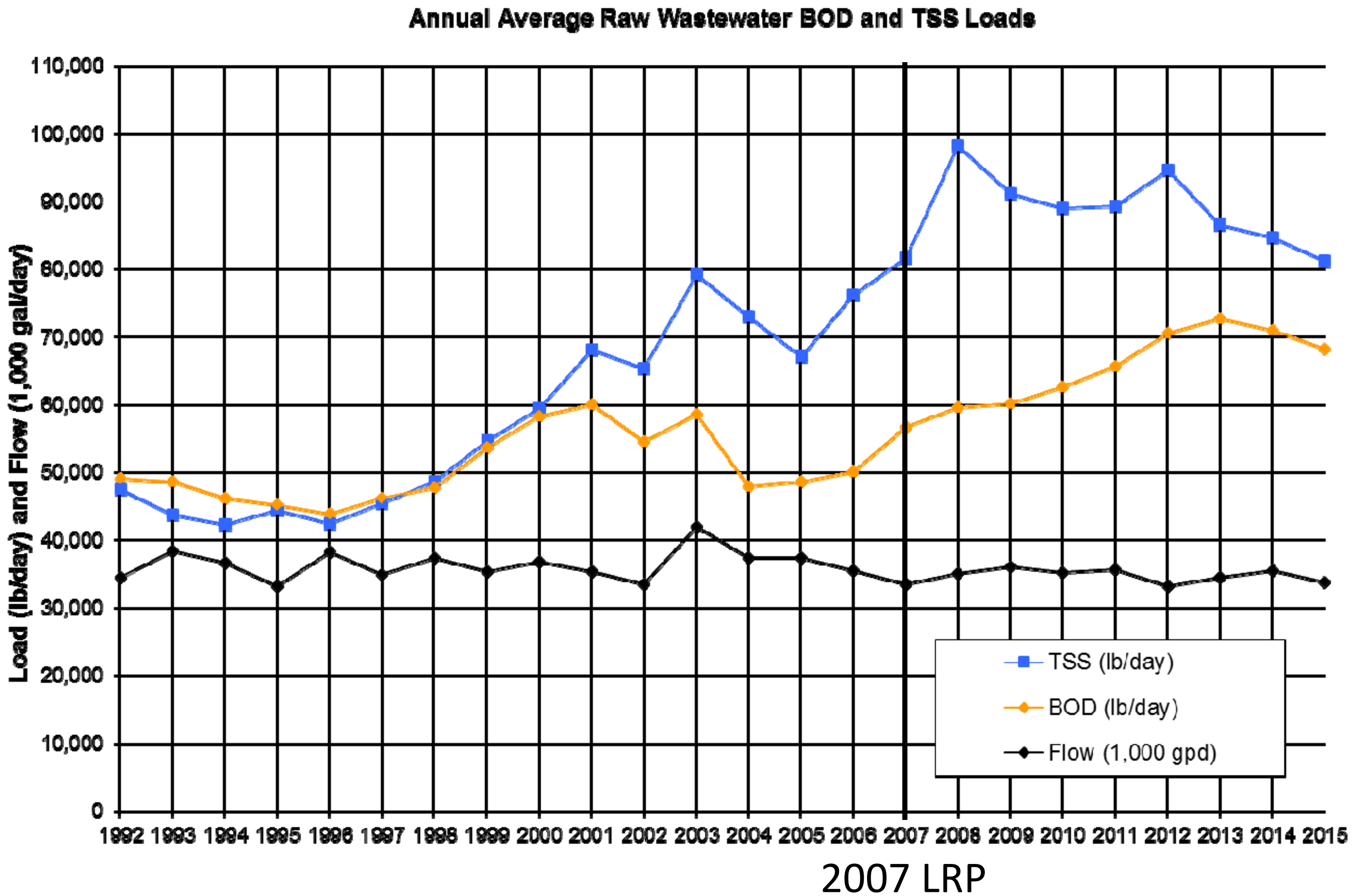
Open Discussion

- How should we determine boundary conditions?
  - AlexRenew vision and goals
  - Regulatory challenges and opportunities
  - Political challenges and opportunities
  - Site constraints
- What planning horizons should we consider?
  - Board Strategic Outcomes (2040)
  - Growth projections/build-out condition
  - Energy neutrality goal

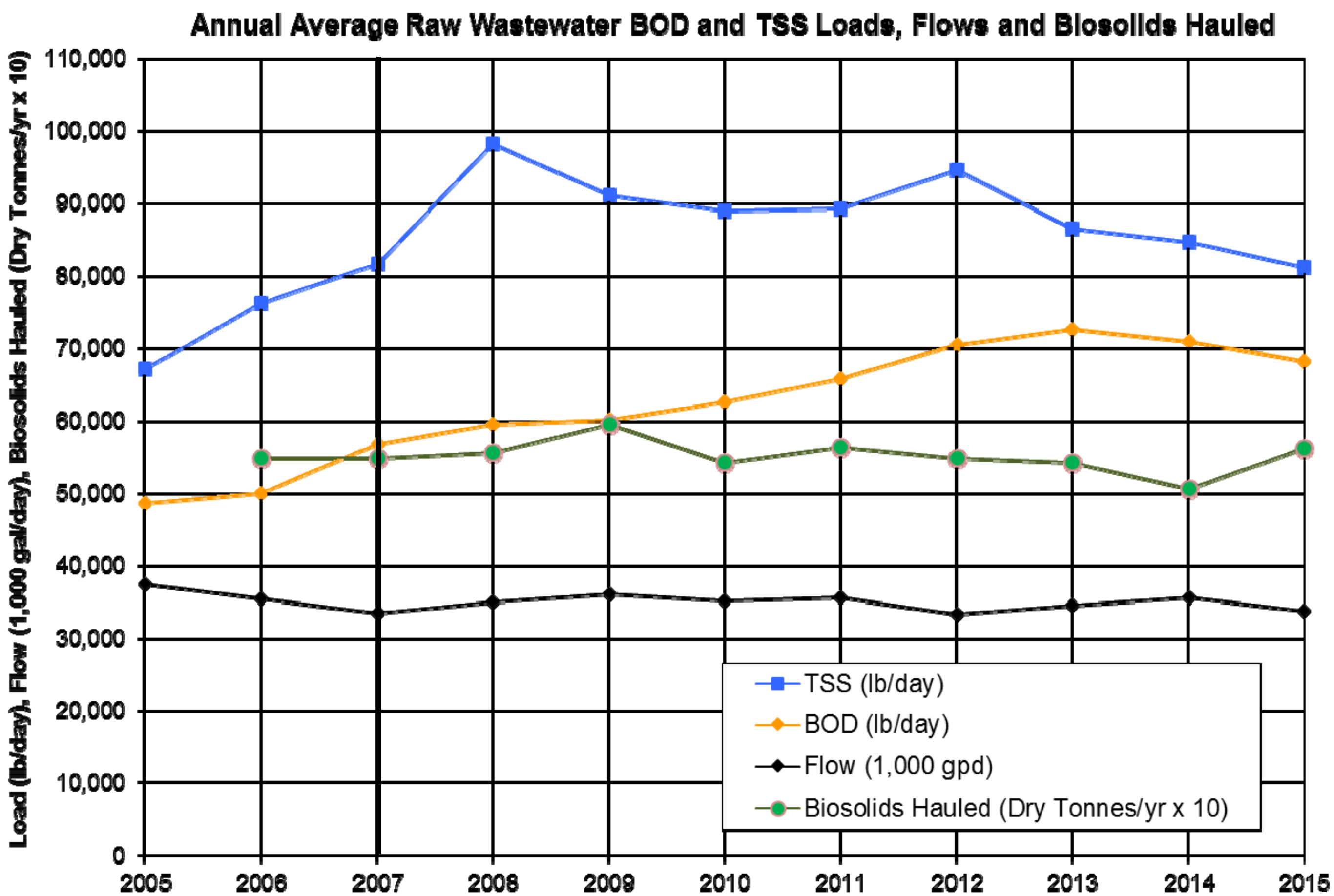
Review of Solids Handling Data

Presentation by Paula Sanjines/CH2M, Hong Yin/AlexRenew and David Hackworth/CH2M

Historical Loadings at AlexRenew



Historical Loadings at AlexRenew



2007 LRP

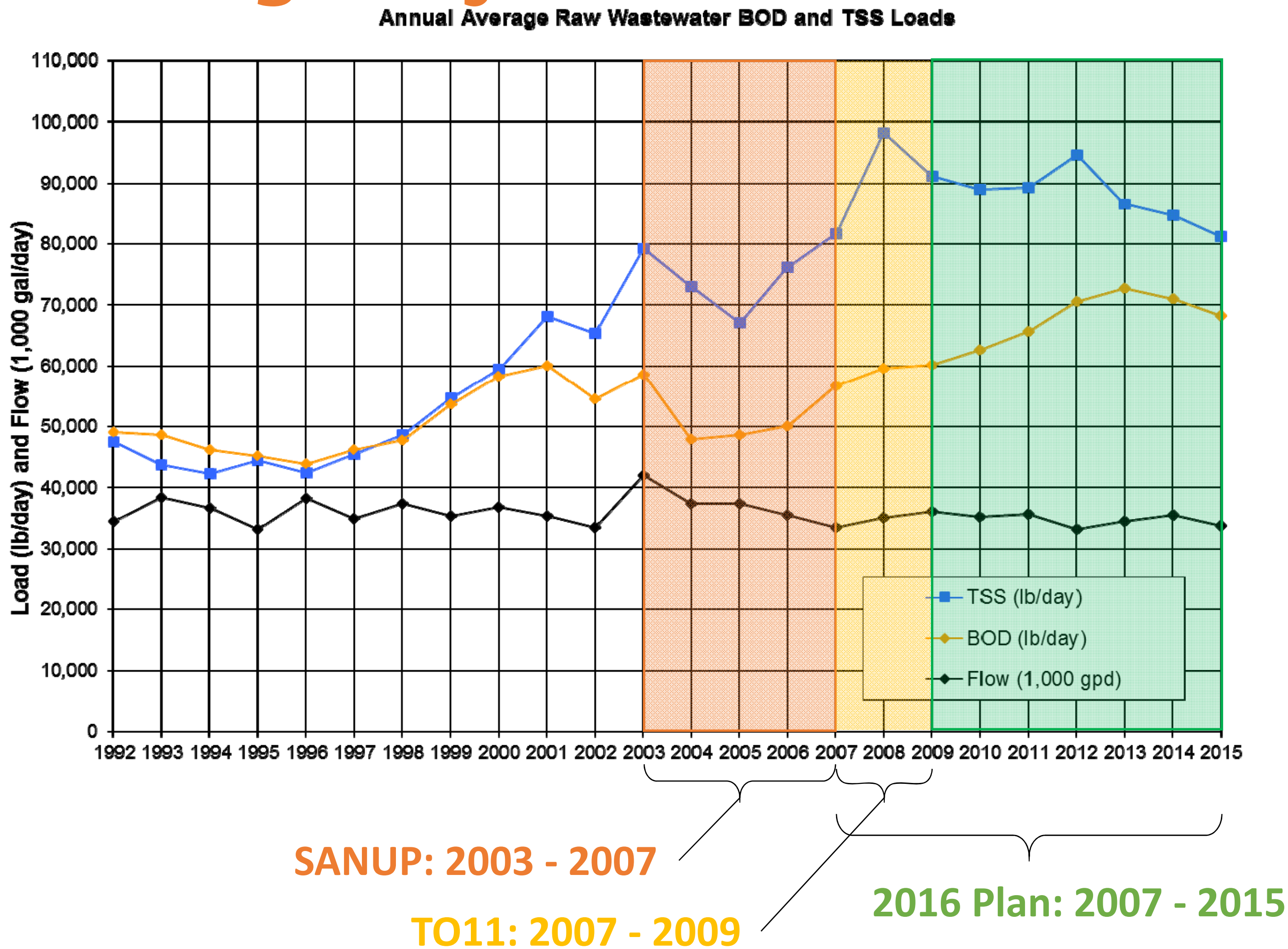
Historical Loading Trends

- 2005 to 2015 (last 10 years)

Component	Growth (avg % per year)
TSS	1%
BOD	4%
Ammonia	2%
TKN	2%
TP	0%
Flow	0%
Biosolids Hauled	0%

- Flows and Loads seem to have stabilized for now

Loading Projections: Time Periods



Loading Projections

- Loadings used for SANUP design (54 MGD Condition)

Original SANUP Loadings (2003-2007 Data)

	Population	Loadings (lbs/day)					
		TSS	BOD5	TKN	NH3	TP	OP
Per Capita Loading *		0.25	0.19	0.034	0.019	0.006	0.002
Orig. Annual Avg Design	**450,000**	**110,000**	**84,600**	**15,800**	**9,100**	**2,600**	**800**
Max Month PF *		1.4	1.3	1.2	1.1	1.4	1.3
New Max Month Design Loadings		154,000	110,000	19,000	10,000	3,640	1,000

- Revised Loadings per City of Alexandria Capacity Evaluation:

TO 11 Loadings (2007-2009 Data)

	Population	Loadings (lbs/day)					
		TSS	BOD5	TKN	NH3	TP	OP
Per Capita Loading *		0.30	0.19	0.038	0.020	0.007	0.002
SANUP Design (54 MGD)	450,000	133,828	87,180	17,026	9,141	2,942	1,052
Added Loadings	30,000	8,922	5,812	1,135	609	196	70
New Annual Avg Design	**480,000**	**143,000**	**93,000**	**18,200**	**9,800**	**3,100**	**1,100**
Max Month PF *		1.35	1.3	1.22	1.12	1.31	1.17
New Max Month Design Loadings		193,000	120,900	22,200	11,000	4,100	1,300

- *Per-capita loading increased in the evaluation period*
- *Added 30,000 estimated population at build-out (58 MGD AADF)*

Proposed Loading Projections for 2016 Planning Effort

- Use 2007-2015 Data Set and additional loadings per revised as-built condition (58 MGD)

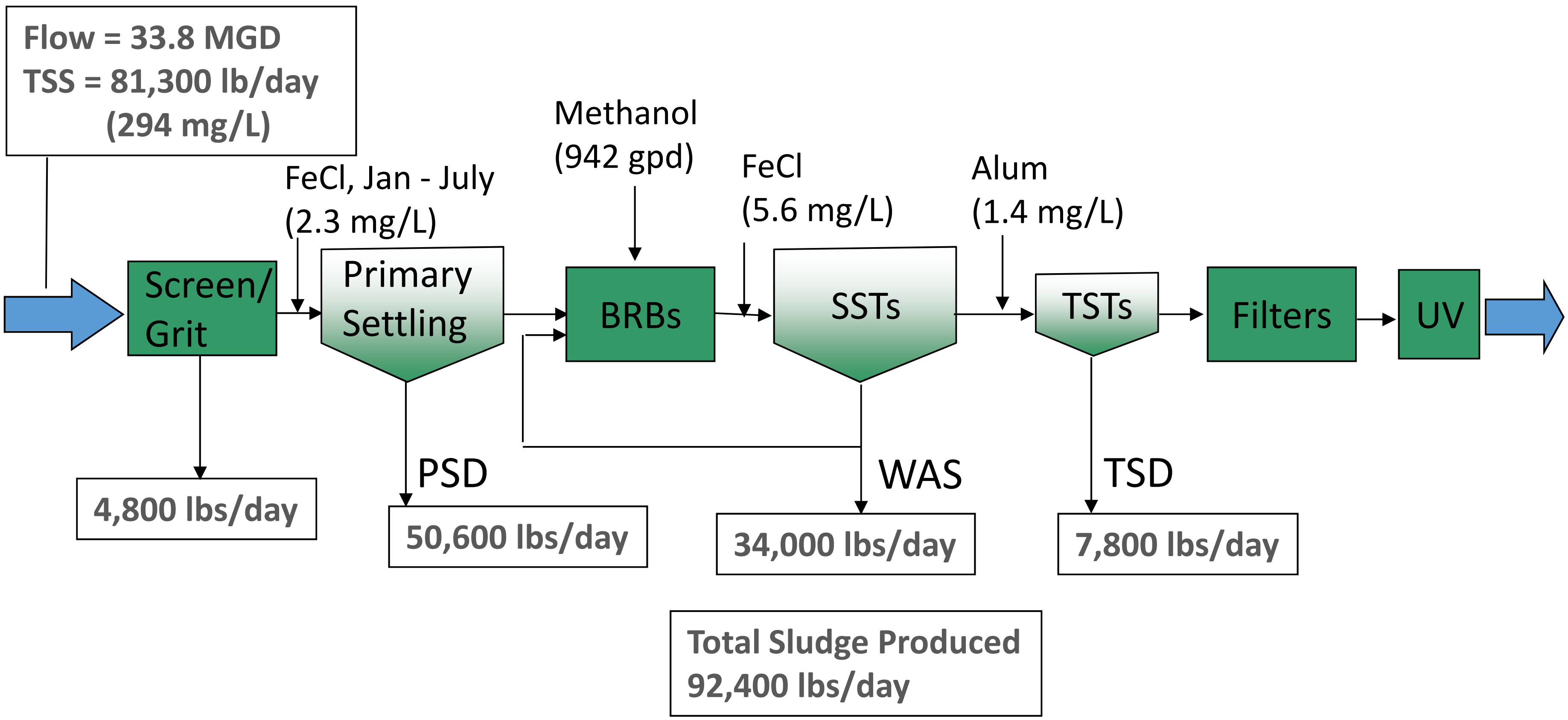
2016 LRP Loadings (2007-2015 Data)

	Population	Loadings (lbs/day)					
		TSS	BOD5	TKN	NH3	TP	OP
Per Capita Loading *		0.27	0.19	0.038	0.020	0.006	0.002
Design (54 MGD)	450,000	123,175	87,180	17,026	9,141	2,699	1,052
Added Loadings	30,000	8,212	5,812	1,135	609	180	70
New Annual Avg Design	**480,000**	**131,000**	**93,000**	**18,200**	**9,800**	**2,900**	**1,100**
Max Month PF *		1.32	1.21	1.20	1.11	1.28	1.17
New Max Month Design Loadings		173,000	112,000	21,800	10,900	3,700	1,300

* per-capita loading and peaking factors based on 2007-2015 data

- *Per-capita loadings the same as in City of Alex. Study, except for TSS and TP*

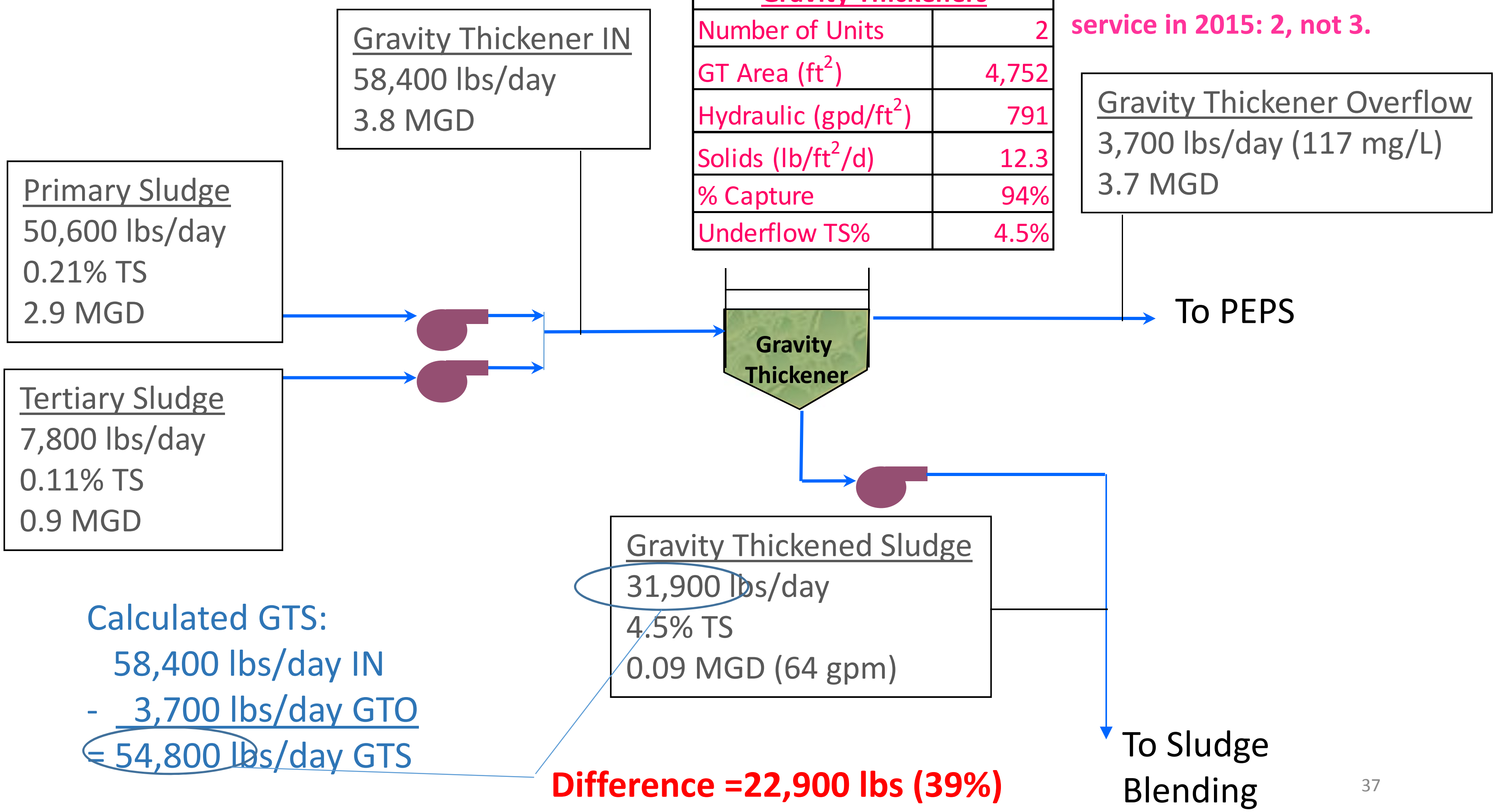
Current Plant Solids Mass Balance
2015 Annual Average Values



Gravity Thickening – 2015 Annual Avg.

Gravity Thickeners	
Number of Units	2
GT Area (ft^2)	4,752
Hydraulic (gpd/ft^2)	791
Solids ($lb/ft^2/d$)	12.3
% Capture	94%
Underflow TS%	4.5%

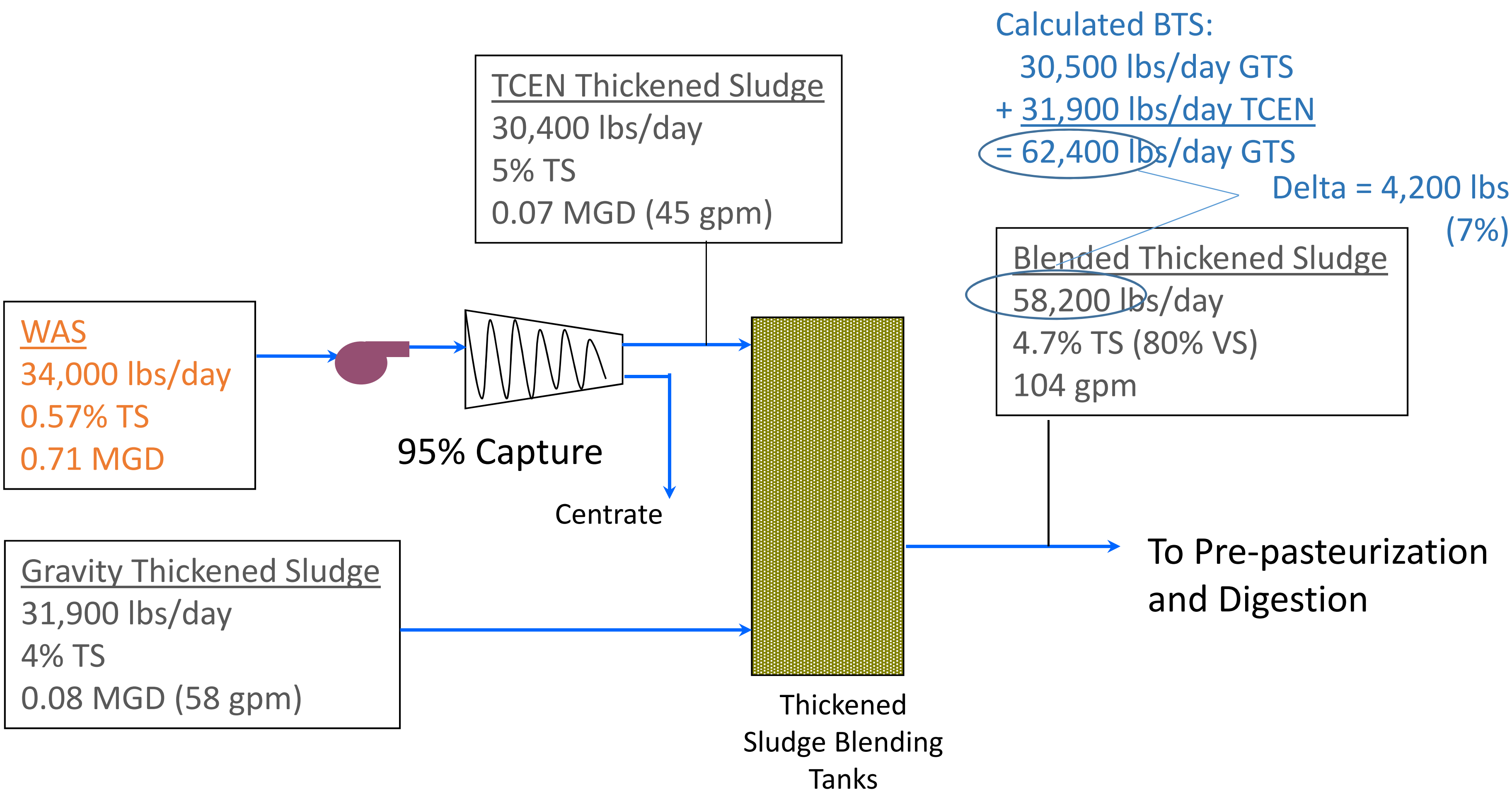
Revised number of units in service in 2015: 2, not 3.



Calculated GTS:
58,400 lbs/day IN
- 3,700 lbs/day GTO
= 54,800 lbs/day GTS

Difference =22,900 lbs (39%)

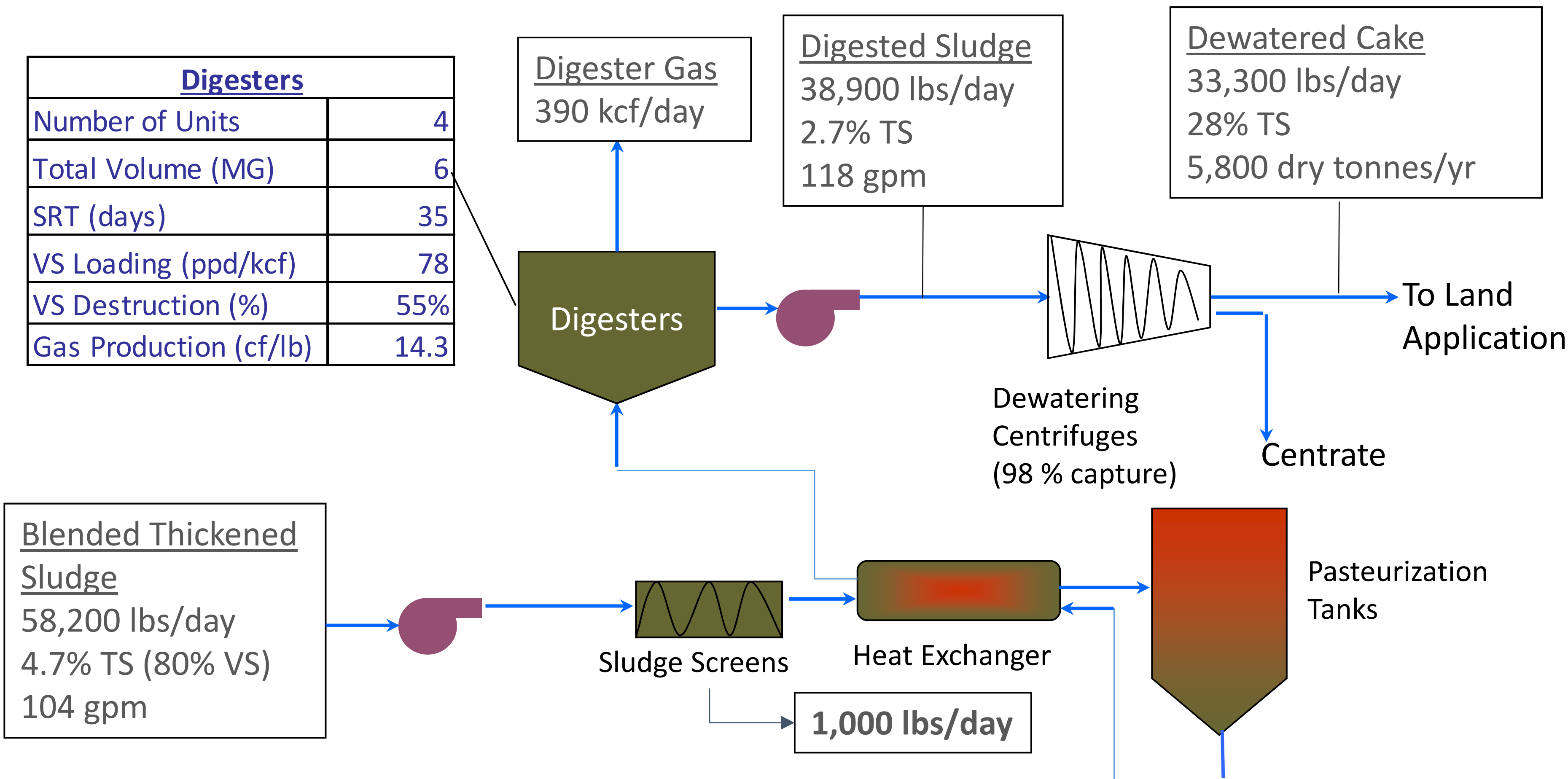
Thickening Centrifuges– 2015 Annual Avg.



Biosolids Mass Balance

Pre-Past/Digestion– 2015 Annual Avg.

Digesters	
Number of Units	4
Total Volume (MG)	6
SRT (days)	35
VS Loading (ppd/kcf)	78
VS Destruction (%)	55%
Gas Production (cf/lb)	14.3



- **Sludge screens are sized for 200 gpm each (2 units), but limited to 120 gpm**
- **Heat exchangers are sized for 100 gpm each (3 units – 1 is always standby) – current capacity is limited to 60 gpm**

Current Plant Solids Mass Balance

- Per the 2015 Annual Average values:
  - About 23,000 lbs/day of the solids generated are "unaccounted" for in the Gravity Thickeners
- Doing a "reverse" mass balance:
  - Starting from biosolids hauled (~5,500 dry Tons/year and stable since 2006) and working backwards
  - Would expect ~65,000 lbs/day in total sludge (PSD + WAS + TSD)
  - Compare to ~ 80,000 – 90,000 lbs/day in total sludge per actual plant annual average data (from 2009 to 2015)
  - About 20 - 30 % discrepancy in solids data
- What is going on?
  - Gravity Thickeners seem to be the source of the discrepancy
  - Investigate Primary Sludge flow metering and TSS sampling

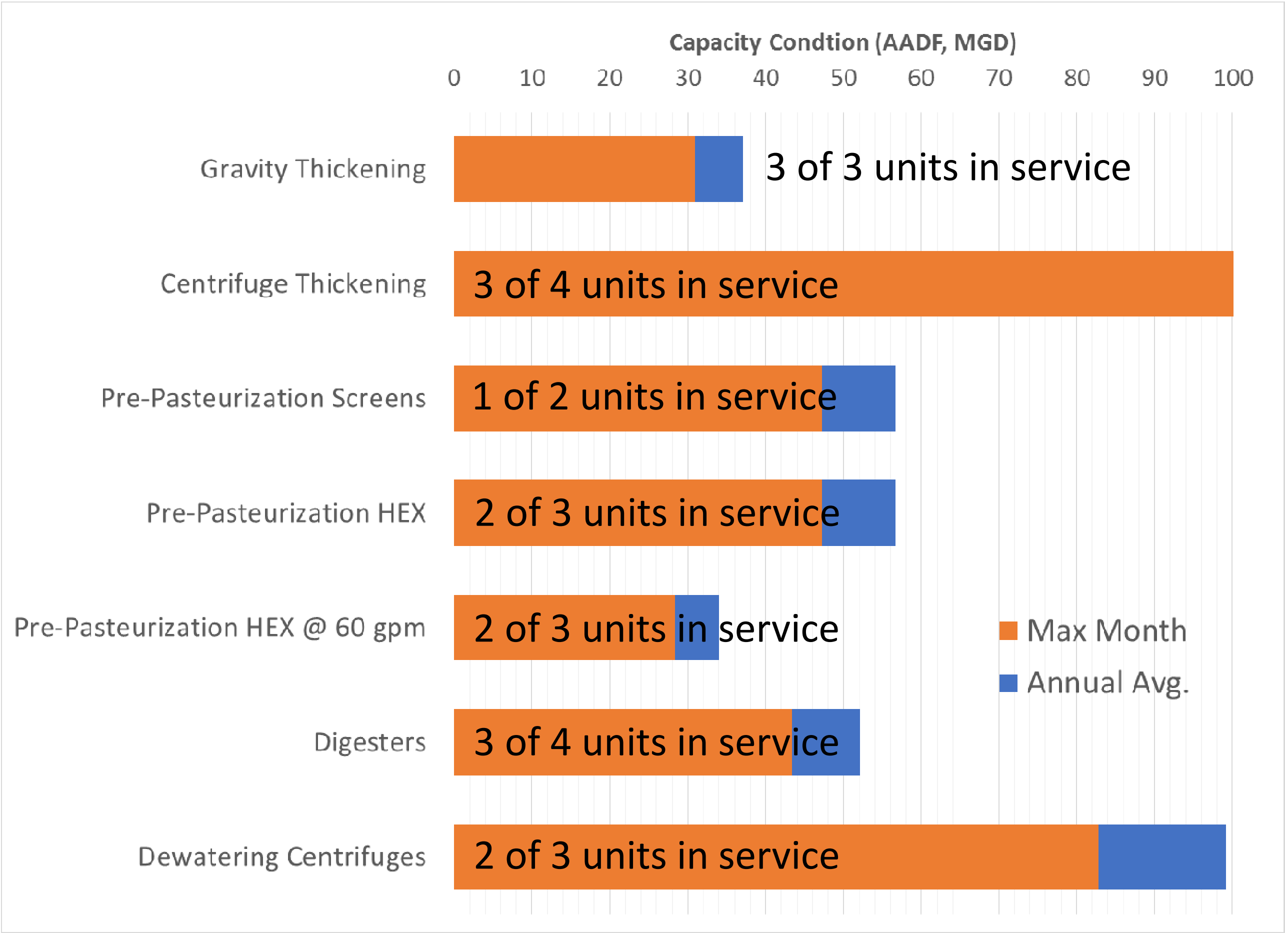
Chemically Enhanced Primary Treatment (CEPT) Trial Results

- CEPT (using ferric chloride) was implemented from January to August 2015
- Ferric dose to the PSTs was ~ 2.3 mg/L (615 gpd)
- During this period (compared to periods in 2014 and 2015 with no CEPT):
  - CBOD capture in PSTs increased from 44 to 56%
  - Primary Sludge (lbs/day) increased by about 15%
  - WAS (lbs/day) decreased by about 6% (methanol dose was also being reduced)
  - Total sludge generated (lbs/day) increased by about 10%

Chemically Enhanced Primary Treatment (CEPT) BioWin Model Results

- BioWin model was used to simulate actual plant conditions (2013 avg) with and without CEPT
- Model predicts:
  - 38% increase in PSD solids
  - 35% decrease in WAS solids
  - No change to TSD solids
  - Overall 15% increase in total solids (PSD + WAS + TSD)
  - Increased VSS destruction in digesters (61% vs. 55% currently)
- Increase in PSD Solids: Need to evaluate PSD and Gravity Thickening systems

Unit Process Capacity Assessment *



Max Month PF = 1.2

* Based on 2015 data and adding projected impacts of CEPT:
38% increase in PSD, 35% decrease in WAS, 15% increase in overall solids)

Screenings and Grit Production

- 2014 – 2015 Average:
  - 1,800 lbs/day from Coarse Screening
  - 3,000 lbs/day from Bldg K (Fine Screening, Grit & Scum)
  - 1,000 lbs/day from Pre-Pasteurization Screens
- Approximately 2 truck-loads per week
- Screenings capture could be improved
  - Screenings material is present in downstream processes
  - Bldg K screens have been in operation for 15 years
  - Improved capture would benefit all downstream processes (including mainstream Anammox cyclones)
  - 2009 Long Range Plan included finer screens (3 mm) for IFAS
- Solids handling system is equipped with grinder pumps to reduce impact of trash (let it pass through)

Pre-pasteurization System Update

- SANUP Task Order #1, 2013 to address:
  - tank vent safety concerns (gaseous concentrations)
- BOA Task Order #4, 2015 to address:
  - heat exchangers/system efficiency

  - Pre-pasteurization vent fan

Tank Vent Safety Concerns

- Concerns:
  - December 2009: Use of an oxygen/acetylene torch to cut the vent pipe caused flames in the piping
  - May 2010: Operators reported flames at the vent pipe elbow to the pre-pasteurization flare
  - July 2013: Discoloration of the vent pipe above the tanks observed
- Actions:
  - January 2010: B&V sample tests indicated gas concentrations below combustible levels
  - July 2013: Kruger issued letter citing safety concerns based on data collected and CH2M engaged to assist in addressing concerns
  - September 2013: CH2M sample tests indicated gas concentrations below combustible levels and TM issued with recommendations
  - Meeting with Kruger was held in October 2013 to review data and recommendations

Tank Vent Safety Concerns

- Recommendations (September 2013):
  - Exhaust fan should remain operational to ensure proper tank venting
  - 3 pre-pasteurization tanks should be used (instead of 4)
  - Tanks taken out of service should be cleaned
  - Flame arrester on the exhaust piping to the flare

Heat Exchangers

- Concerns:
  - Thickened sludge to pasteurization tanks not heating enough
  - Pasteurized sludge to digesters not cooling enough
- Actions:
  - January 2016: CH2M modeled heat exchangers and confirmed heat transfer inefficiencies, attributed to fouling
  - January 2016: Kruger site visit confirmed fouling
  - Oct 2015-Jan 2016: Evaluated recirculation pump operation
- Recommendations:
  - Perform chemical cleaning (sludge side)
  - Address recirculation pump operation (VFD/controls)
  - Modify programming to allow 3 heat exchanger trains in service
  - Conduct follow-up evaluation after cleaning
  - Confirm pressure regulating valve setting on W3 cooling water to each HEX, and Kruger PLC for W3 demand

Exhaust Fan

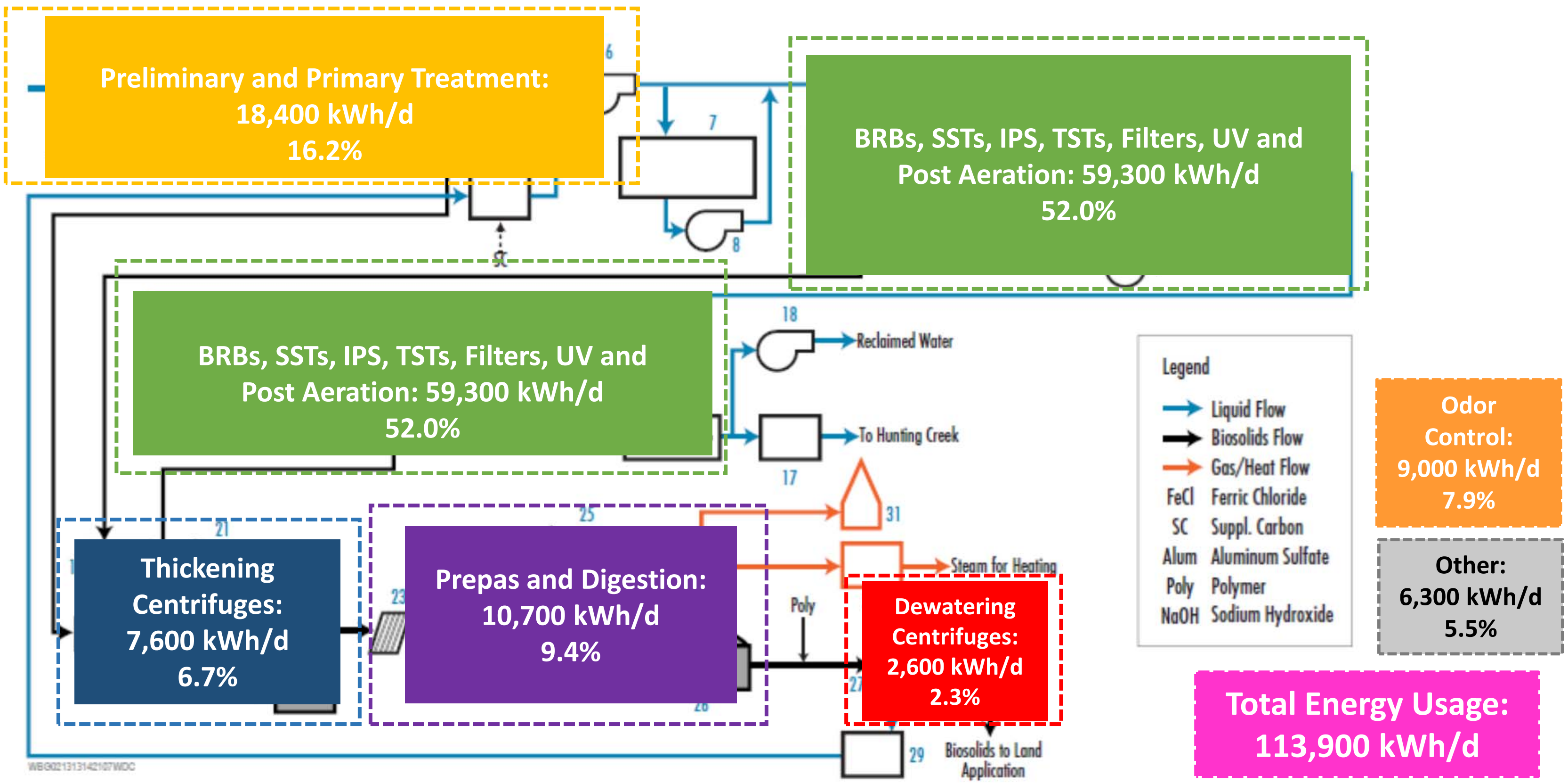
- Concerns:
  - Exhaust fan is critical
  - No redundancy
  - Existing unit is corroded
- Actions:
  - December 2015, issued preliminary design documents to replace the fan and provide a redundant installed fan (currently under review)

BOA TO#4 Miscellaneous Items

- Exhaust fan piping discoloration
- Odorous air damper not switching to route pasteurization tanks room air to Bldg L when exhaust fan fails
- Sludge screen clogging
  - Screen shuts down on high pressure

2015 Average Electrical Usage

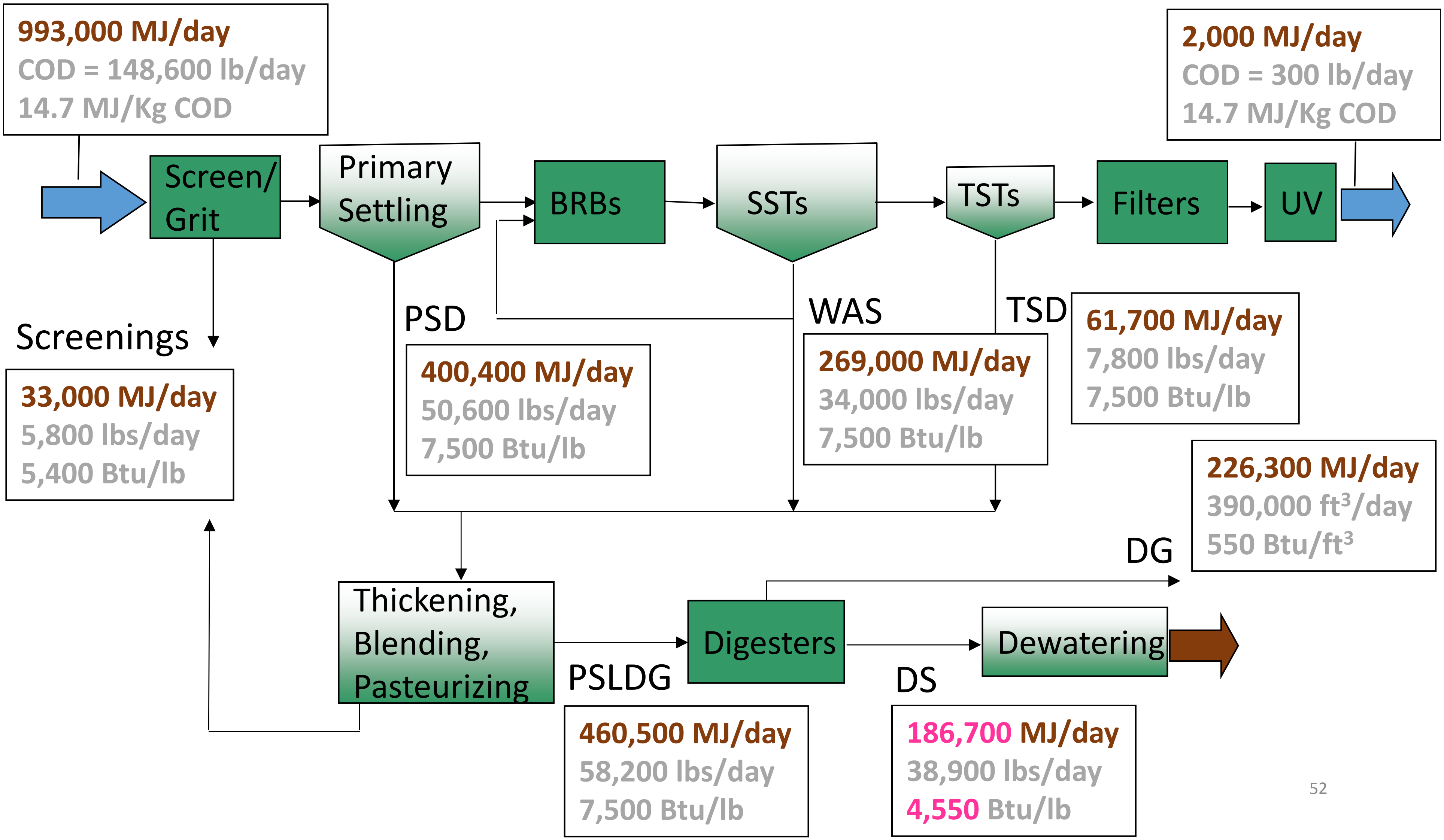
*NMF not included



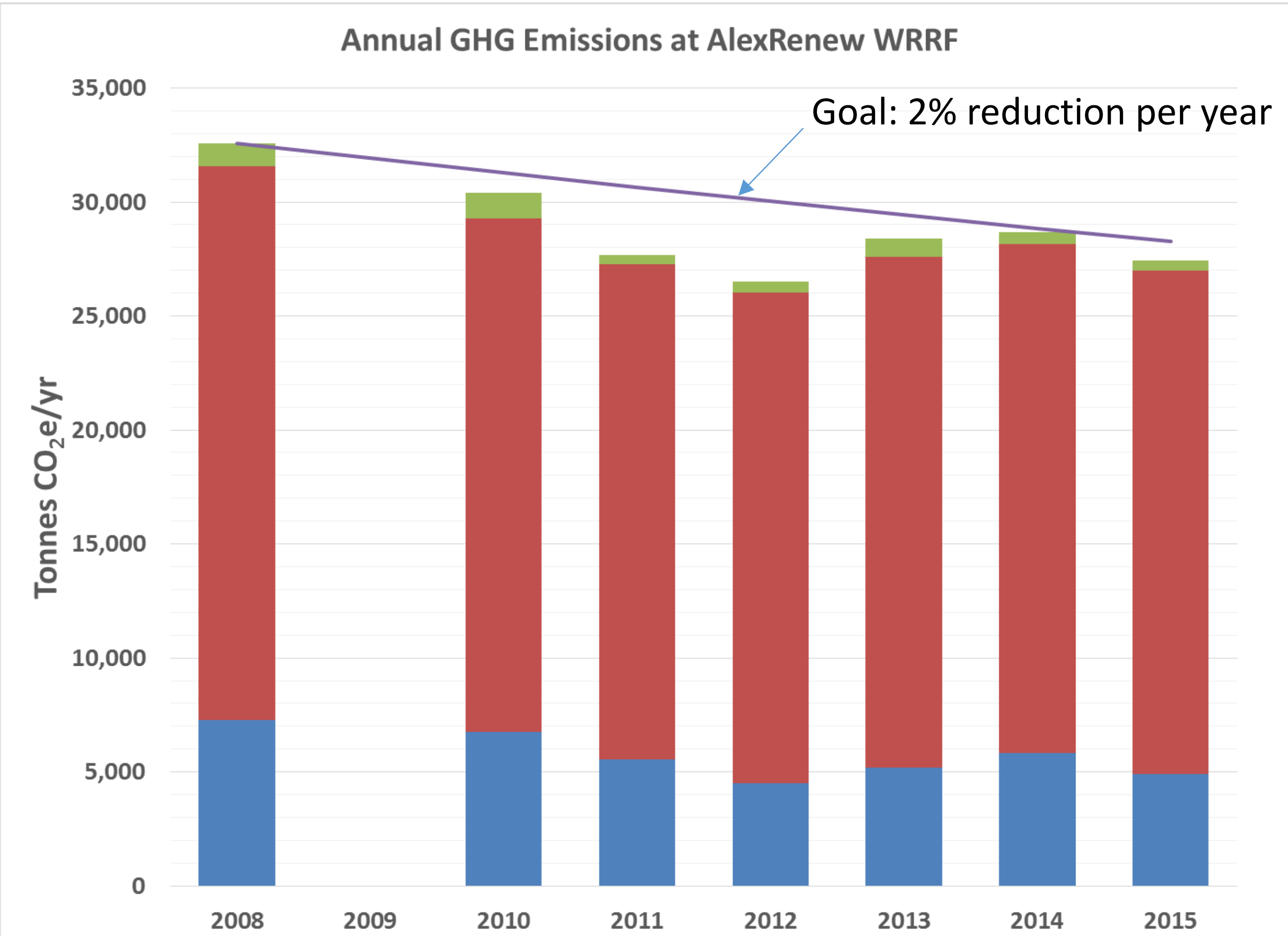
Unit Processes

1	Coarse Screens	9	Biological Reactor Basins	17	Post-Aeration Channels	25	Pasteurization Tanks
2	Raw Sewage Pumps	10	Secondary Settling Tanks	18	Reclaimed Water Pumps	26	Anaerobic Digesters
3	Fine Screens	11	Return Activated Sludge Pumps	19	Raw Sludge Blending Tanks	27	Dewatering Centrifuges
4	Vortex Grit Chambers	12	Intermediate Pumps	20	Gravity Thickeners	28	Biosolids Silos
5	Primary Settling Tanks	13	Rapid Mix/Floc.Tanks	21	Thickening Centrifuges	29	Centrate Storage Tanks
6	Primary Effluent Pumps	14	Tertiary Settling Tanks	22	Thickened Sludge Eq. Tanks	30	Centrate Pre-Treat. Reactors
7	Nutrient Mgmt. Facility	15	Gravity Filters	23	Sludge Screenings Presses	31	Gas Flares
8	Nutrient Mgmt. Pumps	16	UV Disinfection	24	Heat Exchangers	32	Biogas Boilers

2015 Plant Energy Value



GHG Inventory Trends



Scope 3 - Optional

- Employee Commuting
- Solids Hauling
- Chemical Manufacture
- Biosolids Disposal
- Use of Potable Water
- Fertilizer Avoidance
- Use of Reclaimed Water

Scope 2 – Indirect

- Electricity Use

Scope 1 – Direct

- Stationary Combustion
- Mobile Combustion
- Process Emissions
- Fugitive Emissions (Refrigerant)

Black & Veatch Biosolids Update to LRP

- B&V Effort/Report was completed in December 2014
- Key Elements in planning & evaluation process, similar to original LRP:
  - Baseline capacity evaluation
  - Issues to be addressed
  - Survey of treatment technologies and products

Scoring of Technologies

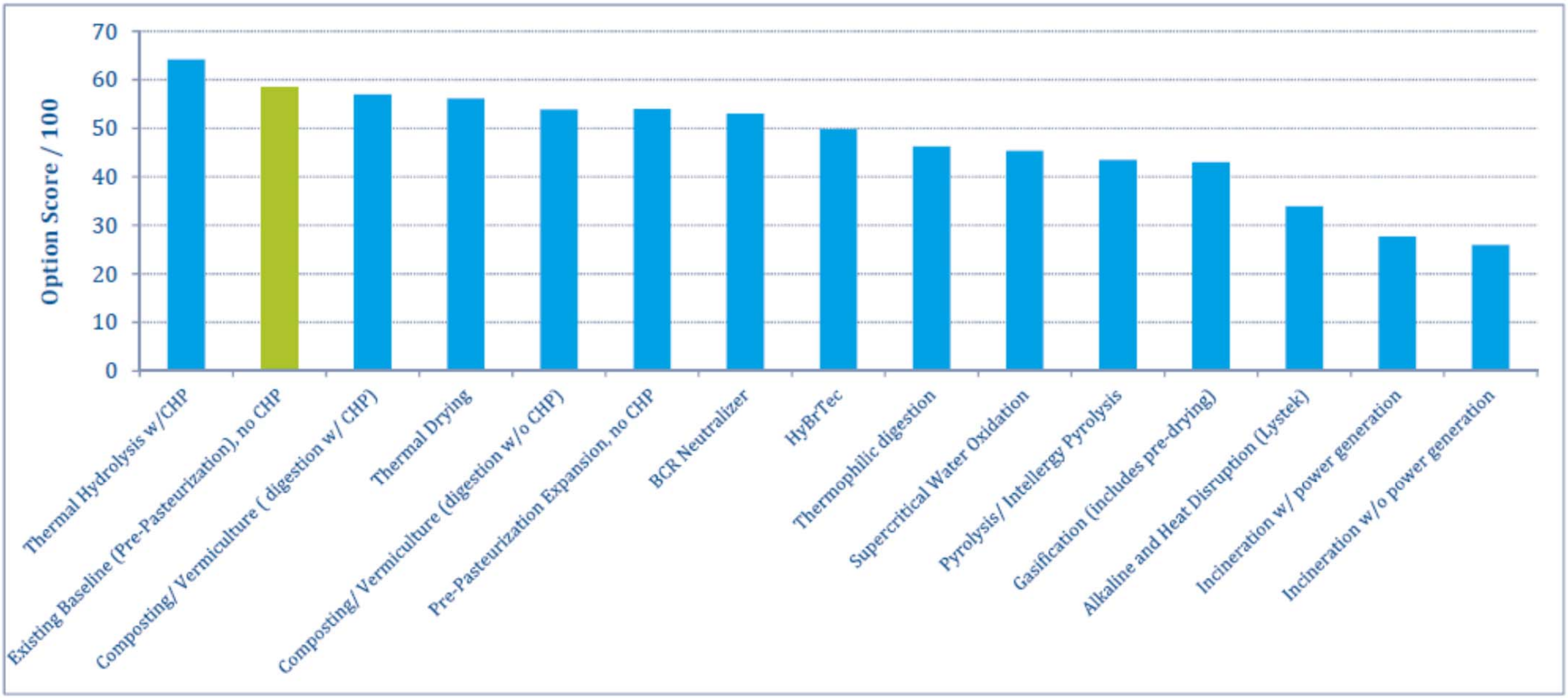


Figure 5-1. Initial Output of Decision Model.

Moving forward:

- Consider short-term capacity and outstanding issues
  - Those raised in B&V study
  - Other issues identified by the team
- Evaluate technologies for the future
  - Expand list as needed
  - Progressively screen technologies using boundary conditions and AlexRenew decision tool
    - Consider impacts to liquid processes, resource recovery
    - Develop scenarios composed of multiple technologies/processes

Synthesis of Morning Session

Guided discussion by Glen Daigger

Synthesis of Morning Session

- Boundary Conditions
  - Planning horizons
  - Regulatory drivers
  - Political drivers
- AlexRenew Vision

Lunch Break

Strategy Brainstorming

Group discussion, breakout groups, report out

Industry Partnerships

Presentation by Tim Constantine/CH2M

AlexRenew Participation in WERF Studies

Title	Goals	Activities	Partners
STAR_N2R14 Toolbox for Mainstream Deammonification	• Reduce energy costs • Reduce chemical costs	• Promote nitrite shunt and deammonification • Optimize BRB aeration strategy • Monitor biological populations and activity	• Columbia University • Ejby Mølle WWTP • Blue Plains WWTP • Strass WWTP • HRSD • NYCDEP • East Bay MUD • Singapore PUB • Union Sanitary District
U1R14 Balancing Flocs and Granules	• Increasing processing capacity • Maximize use of existing assets • Improve process reliability from better settling	• Improve SVI • Monitoring settling properties • Monitor biological populations and activity	• U. of Kansas • Ejby Mølle WWTP • Blue Plains WWTP • Strass WWTP • HRSD • Gregg Township • Tomahawk Creek
Proposed Impacts of Low-Energy Low-Carbon TN Removal on Bio-P and Nutrient Recovery Processes	• Reduce chemical costs • Improve process reliability • Resource recovery opportunities	• Promote enhanced phosphorus removal • Investigate phosphorus recovery opportunities	• Columbia University • Ejby Mølle WWTP • HRSD • Blue Plains WWTP • Chicago

AlexRenew Participation in WEF/WERF LIFT Initiatives

- Biosolids to Energy Demonstration Project
  - Site visit to Vancouver B.C in February 2016
- National Water Resource Recovery Test Bed Facility Network
  - Goal is to connect researchers, new technology providers and other innovators with potential facilities for piloting new technology to help manage risk and accelerate development and adoption

Collaboration with VCS Denmark

- In October 2015, Grace Richardson/AlexRenew participated in VCS' planning workshop
- Areas of collaboration:
  - Deammonification (sidestream and mainstream)
  - Energy neutrality
  - New products (reclaimed water and soil amendments)
  - Institutional knowledge (Operational/Managerial)
  - Staff exchange
  - Sustainability, customer relations, Corporate Social Responsibility
  - General knowledge sharing (joint papers to conferences)

Collaboration with VCS Denmark

- Nutrient Removal
  - Sharing data to improve mainstream process control
  - Sidestream bioaugmentation to mainstream - optimizing control from sidestream to mainstream
  - N_2O - generation and as process control
    - VCS currently researching and will share with AlexRenew
  - New technologies **MABR** for advanced aeration and DO control
    - **50-60% O2 transfer efficiency vs. 10-15% with standard methods**
    - VCS and AlexRenew both interested in more efficient aeration. Further develop potential joint pilot program.
  - Mainstream P recovery
    - VCS to share research projects/outcomes
- Solids
  - Effects of induced granulation on sludge
    - Develop joint protocol
  - Superheated steam drying + pyrolysis/gasification
    - VCS to share research project/outcomes

Next Steps/Action Items

Summary by Rich Voigt/CH2M

Adjourn

Alexandria Renew Enterprises Meeting Agenda

Facilitator: Dan Lynch	**Meeting topic**: ***Solids Handling & Energy Optimization Chartering Workshop (BOA WA2-2016-7)***
Meeting date: February 10, 2016	**Meeting start time**: 8:00 am
Minutes taken by: Rich Voigt	**Meeting end time**: 3:30 pm

I. Meeting Objectives:

1.	Introduction of Team Members and Project Scope
2.	Discussion of AlexRenew's Current Vision and Goals, particularly related to Strategic Planning
3.	Define Boundary Conditions and Envision Strategic Outcomes

II. Attendance:

Karen Pallansch	AlexRenew	James Cummins	AlexRenew
Sean Stephan	AlexRenew	Eugene Singleton	AlexRenew
Janelle Okorie	AlexRenew	David Hackworth	CH2M
Hong Yin	AlexRenew	Dan Lynch	CH2M
Johnnie Wallace	AlexRenew	Glen Daigger	CH2M
Steve Hill	AlexRenew	Tim Constantine	CH2M
Darel Stevens	AlexRenew	Rich Voigt	CH2M
Lisa Reynolds	AlexRenew	Paula Sanjines	CH2M
Rickie Everette	AlexRenew	Todd Williams	CH2M
Andre Yates	AlexRenew	Marialena Hatzigeorgiou	CH2M
James Atkinson	AlexRenew	Savita Schlesinger	CH2M

III. Discussion/Decision Items:

Start Time		Topics	Notes
	8:00 am	***Breakfast/refreshments***	
1.0	8:30 am	Welcome & Introductions (Karen)	
2.0	8:45 am	AlexRenew Vision & Goals (Karen/Sean)	• Discuss current organizational vision/goals and desired strategic outcomes (Karen) • Brief review of modified decision model criteria (Sean)
3.0	9:15 am	Regulatory Challenges and Opportunities (Todd/ Lisa)	• Regulatory Challenges facing industry – solids, energy, etc.
4.0	9:30 am	Political Challenges & Opportunities (Karen)	• Political Challenges

Alexandria Renew Enterprises Meeting Agenda

5.0	10:00 am	Planning Horizon & Boundary Conditions (Rich)	• Review planning process • Review past, current LRP boundary conditions • Determine boundary conditions moving forward
6.0	10:45 am	Review of Solids Handling Data (Paula/Hong/David)	• Review historic data, capacity/projections, and previous work • Prepasteurization system update • Review current energy balance at AlexRenew • Present GHG inventory trends (2013-2015)
7.0	11:30	Synthesis of Morning Discussion (Glen)	Discuss where we've been, where we are, new direction – set stage for afternoon brainstorming
	Noon	***Lunch***	
8.0	12:30 pm	Strategy Brainstorming	• Group discussion of current and future opportunities to generate energy, conduct resource recovery, and optimize treatment in alignment with AlexRenew Goals & Boundary Conditions (Tim – 20 mins) • Breakouts to discuss major strategies, including (40 mins): – Minor Enhancements to Existing – Today's Proven Advanced Technologies – Future Technologies • Report Out (Tim - 45 mins)
	2:15 pm	***Break***	
9.0	2:30 pm	Industry Partnerships (Tim)	• Presentation of current planning/initiatives/approaches and industry trends • Review of cooperative research/pilots/etc
10.0	3:00 pm	Wrap-up (Rich)	• Action Items • Next Steps
	3:30 pm	***Adjourn***	

Alexandria Renew Enterprises Meeting Agenda

Breakout Groups

<u>Group 1: Minor Enhancements to Existing (Location TBD)</u>
Hong Yin
Darel Stevens
Eugene Singleton
James Cummins
Steve Hill
Savita Schlesinger
Marialena Hatzigeorgiou
Paula Sanjines

<u>Group 2: Today's Proven Advanced Technologies (Location TBD)</u>
Sean Stephan
Johnnie Wallace
James Atkinson
Rickie Everette
David Hackworth
Todd Williams
Rich Voigt

<u>Group 3: Future Technologies (Location TBD)</u>
Janelle Okorie
Andre Yates
Lisa Reynolds
Tim Constantine
Glen Daigger

<u>Rovers</u>: Karen Pallansch, Dan Lynch

ch2m

ALEXANDRIA renew ENTERPRISES

AlexRenew Meeting Sign-in Sheet

Meeting Topic/Title:	**BOA WA2-2016-7 - Solids Handling & Energy Optimization - Chartering Workshop**
Location:	**AlexRenew Admin Building, Café**
Date:	**2/10/2016**

Name	Organization/Company
Rich Voigt	CH2M
James Atkinson	AlexRenew
William Yates	Alexrenew
Eugene L. Singleton	Alexrenew
Rickie Everette	AlexRenew
Darel G. Stevens	Alexrenew
Lisa Reynolds	Alex Renew
Tim Constantine	CH2M
Savita Schlesinger	CH2M
Todd Williams	CH2M
Johnnie Wallace	Alex Renew
James Cummins	Alex Renew E-shift
Charlie Logue	AlexRenew
Colen Duggar	CH2M
Steve Hill	Alex Renew
Sean Stephan	Alex Renew.
Aster Tekle	Alex Renew
Hong Yin	Alex Renew

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Name	Organization/Company
Mariolena Hatzigeorgiou	CH2M
David Hackworth	CH2M
Paula Sanjines	CH2M
Karen Pallansch	Alex Renew

MEETING SUMMARY

BOA WA2-2016-7

AlexRenew Solids Handling & Energy Optimization – Technology Pathways Workshop – March 29, 2016

ATTENDEES:	Karen Pallansch/AlexRenew	Mike McGrath/Fairfax Co DPWES
	Sean Stephan/AlexRenew	Sarah Motsch/Fairfax Co DPWES
	Janelle Okorie/AlexRenew	Chuck Longerbeam/Fairfax Co DPWES
	Steve Hill/AlexRenew	Ib Pedersen/VCS-Denmark
	Charlie Logue/AlexRenew	Ivan Volund/VCS-Denmark
	Darel Stevens/AlexRenew	Julian Sandino/CH2M
	Lisa Reynolds/AlexRenew	Dan Lynch/CH2M
	Andre Yates/AlexRenew	Glen Daigger/CH2M
	James Atkinson/AlexRenew	Tim Constantine/CH2M
	James Cummins/AlexRenew	Rich Voigt/CH2M
	Eugene Singleton/AlexRenew	Todd Williams/CH2M
	Chuck Phillips/AlexRenew	Marialena Hatzigeorgiou/CH2M
	Grace Richardson/AlexRenew	Savita Schlesinger/CH2M

COPY TO: Hong Yin/AlexRenew
Johnnie Wallace/AlexRenew
Rickie Everette/AlexRenew
Aster Tekle/AlexRenew
Paula Sanjines/CH2M
File

PREPARED BY: Rich Voigt/CH2M

DATE: April 11, 2016

Objectives

A workshop for the Alexandria Renew Enterprises (AlexRenew) Solids Handling & Energy Optimization Project was held on March 29, 2016 at the AlexRenew Administration Building. Objectives were as follows:

- Envisioning Plausible Future Scenarios
- Identifying Viable Pathways Toward an Envisioned Future
- Screening of Potential Alternative Process Configurations and Corresponding Unit Processes

Summary

A summary, based on agenda topics, is provided below.

Recap of Chartering Workshop

A brief recap of the chartering workshop, including draft boundary conditions, and review of action items and parking lot items, was conducted.

Confirmation of Planning Basis (Flows and Loads)

- Since the original Long Range Planning effort, a wet weather examination was undertaken. Outputs from that investigation indicated that the peak wet weather flow to be passed at the Water Resource Recovery Facility (WRRF) is important, and it relates to the provision of the NMF (diurnal balancing of nutrient loading, as well as integrated future wet weather pump station).
- Slides 12 and 13 - Population Projections
  - Projections should be extended on both graphs through 2060. But also note that this is a long way off in the future – and projections may not be accurate/things will change.
  - Projections should include population equivalents (flow, TSS, BOD, biosolids hauled per capita).
  - Fairfax County staff indicated that 1.5% annual population growth is a typical planning value. Note that under the existing AlexRenew Service Agreement, Fairfax County flow to Alexandria is capped at 32.4 mgd (average annual daily flow). City of Alexandria projections equate to a little over 1% annual population growth. This level of growth is significant and not typical of most urban areas. Discussion needs to focus on population equivalents and lbs/BOD, instead of being focused on flow (mgd). It may also be necessary to look at the service agreement(s) as they relate to loadings. Charts and loadings will be updated to include the Fairfax County population increase.
  - Flat flow growth is being seen in the industry (water conservation, attention to I/I, etc), as are increasing loads.
- Unit process capacities (as depicted on Slide 15, 'Unit Process Capacity Assessment') – 2040 and 2060 planning bars assume current technology, and we may be able to do better than that/technology will advance.
- Rainwater/stormwater impact during wet weather – has runoff from paved areas, etc. been considered? VCS-Denmark has seen these impacts and have some combined sewer systems.

Envisioning a Plausible Future

In order to envision a plausible future, we need to consider trends, provide strategic direction, and then reassess periodically (ever 10 years). A flexible approach is needed, because the future is uncertain and subject to change.

Industry-wide, there are some common trends/agreement:

- Managing water, carbon, and resources
- Managing energy, utility costs
- Resource recovery – capturing products with value
- Availability for land application is declining/will be restricted in the future

2040 Planning Horizon

<u>A: Evolving (instead of "Restrictive") Regulatory framework</u>

- Add A-5 - Air emission requirements
- Add A-6 – "Integrated" regulatory frameworks (air, water, solids), as they are possible in the future. As an example – wastewater and stormwater regulations could be merged and managed together. Note there is a tendency for people to over-predict short term changes, and under-predict long term changes.

<u>B: Embraced Sustainability Principles</u>

- Add B-8 – Supply Chain Considerations (life cycle assessments - where do chemicals come from, what's in them, etc.)
- Add B-9 – Envision?

C: Further Engaged stakeholders – Board, Community, and Clients

- Add C-6 – Legislator advocacy
- Add C-7 – "Sector" Organization (WEF, WERF, NACWA) Influence
- Add C-8 – New (revised) interaction between district and clients

Two perspectives to consider – (1) future is horrible, or (2) future is full of opportunities/good/it's just different – AlexRenew has already been doing outreach and future planning for years, and greater engagement to stakeholders is a positive – it can lead to more support

How Others are Positioning for the Future

VCS–Denmark (see attached presentation)

- VCS-Denmark's goals are to be energy (already achieved) and CO_2 (in progress) neutral by 2014. Electricity and Gas for heat are currently produced beyond their internal needs and generate revenue. N_2O emissions were not anticipated in prior work, but VCS-Denmark has responded by developing a partnership with an instrument manufacturer to develop and instrument to measure it. VCS-Denmark is now monitoring, measuring, and using modeling for N_2O.
- Leveraging R&D – VCS-Denmark's approach is to build things, test, adapt, and move forward. In addition, research by implementing and evaluating where it makes sense (trying things). These approaches have resulted in a high degree of engagement for employees (who feel challenged and empowered by CEO).
- VCS-Denmark is receiving biosolids and waste products from other plants and industrial users. As a result, production of electricity and heat has gone up, while consumption of same has been stable or minor decrease.
- Collaborative research with various parties is ongoing. VCS-Denmark is seeing enhanced/improved SVI with the use of cyclones. They are currently trying to quantify AOBs, NOBs, etc (qPCR), as well as track particle size.
- Current initiatives:
  - Microplastics – researching fate (water, solids)
  - Sludge reduction – pyrolysis: dry the solids, then use partial combustion to generate synthetic gas with BTU value. The resulting char has nutrient value and is very clean.
- Ejby Molle is likely to have a finite life span – the surrounding community may want it to be removed in the future. So VCS-Denmark is testing all available technologies and trying to develop solutions for that potential future condition.
- Integrated system management – VCS-Denmark is connecting models for sewers, plants, and receiving waters. Models can be used to screen project investments.

Fairfax County DPWES (see attached presentation)

- Fairfax County has used multiple hearth incinerators since inception of the Noman M. Cole, Jr. Pollution Control Facility (early 70s). The plant does not use digesters. Additional incinerators were added in the late 70s, and the incinerators were rehabilitated in the early 90s. Each incinerator is rated for 60 dry tons per day (dtpd), and the County is currently using about 45 dtpd of that capacity.

- Biosolids Program & Energy Project – The County looked at all viable/proven technologies, not emerging or embryonic ones. Peer group review included consultants, academia, and other utility owners. The shortlist of options included landfill, Fluidized Bed Incinerators (FBIs), Multiple Hearth Incinerators (MHIs), heat drying, combustion in a heat kiln, 3rd party processing, and other options. Peer review confirmed that no technologies were missed/no gaps, better risk analysis was needed, preferred value should value resource recovery, and the value benefit of self-reliance needed to be assessed/understood.
- A 20 year outlook was used to position for the future (may be beyond incineration, current system)
- Energy recovery – Proposed system includes Organic Rankine Cycle (ORC) Generator. The estimated payback is 10 years.

<u>Green Bay MSD (see attached presentation)</u>

Green Bay MSD is a utility similar in size to AlexRenew, with multiple clients. They adopted a solution that is a combination of various technologies/options that provides flexibility for an unknown future. Projections include generating 70% of the energy that will be needed to run the facility.

<u>Genifuel (see attached presentation)</u>

- Any carbon source + high heat, high Pressure → Makes Fuel
- A skid-mounted unit fits into a trucking container and processes up to 20 wet tons per day, wtpd (2 dtpd)
- There is no biochar or leftover product. But heavy metals, etc. are going somewhere – not consumed – they get concentrated and go into the blowdown.

<u>Summary Items to Consider (Glen Daigger)</u>

- Material handling issues with sludge are different compared to other feedstocks (sticky nature of sludge, trash and items in it – plastics, etc. – lack of uniformity vs. something like coal)
- Try to avoid transferring heat in/out of sludge (like Prepasteurization)
- A product has no value unless someone wants to buy it. The quantity of what we make is relatively low to the overall volume – so may not be significant to uses/can be difficult for them to take it. Example – phosphorous (Ostara) market has/had to be developed. A product needs to be of sufficient quality, quantity, timeliness, etc. Consider size of metropolitan area and are similar products produced that could define a market? AlexRenew is not a marketing firm – needs someone to help them develop or create and maintain a market (3rd party).

Defining Boundary Conditions

A brief overview of the AlexRenew Decision Model was provided

Identifying Alternative Technology Pathways Towards an Envisioned Future

An envisioned future for AlexRenew has 3 main attributes:

- Liquid processes have been optimized
- Residuals leaving plant have been minimized
- Resources are being recovered

The group reviewed Anaerobic Digestion as a warmup, prior to team breakouts.

General discussion was as follows:

- Energy neutrality – requires you to reduce your energy utilization, as well as produce more energy. Chemical energy (COD, BOD, etc) in wastewater is hard to capture. Heat energy in wastewater is easier to capture and may provide more value.
- General Considerations – Anammox reduces the need for carbon, allows different ways of thinking. Could use CEPT to remove carbon – the technology is in development. Another approach is to change the nature of sludges and their pumping requirements. Primary Sludge (PSD) and waste activated sludge (WAS) – are processed together at AlexRenew to produce Class A Biosolids. Prepasteurization is a step/process to getting to Class A. The only technical reason to digest PSD and WAS is because we need volatile solids reduction (VSR). In general, PSD when digested provides a 60-70% VSR, WAS is about 30%. WAS can be processed separately to make it more digestable.

<u>Technology Pathways/Considerations</u>

- Thermal Oxidation
- Anaerobic Digestion
- Outsourcing (ex. buying some incinerator capacity from Fairfax Co)
- Combo Incineration
- General Discussion:
  - Heat "harvesting"
  - Hydraulic profile "reconfiguration"
  - Prepasteurization "reconsideration" (only for Class A classification)
  - Optimized digestion: Primary sludge only
- Items that were screened out as the primary pathway for AlexRenew:
  - Aerobic Digestion - no
  - Composting – no
  - Chemical Stabilization - no

<u>Process Optimizations</u>

- Dewatering – Bucher "Twist" Press
- Thermal Drying (heat)
- Hydrolysis (biogas)
- Separate WAS and PSD stabilization/processing
- Sludge "micro-screening" (remove toilet paper)
- Oxidation embryonics – super-critical wet oxidation, pyrolysis, gasification, hydrothermal liquefaction
- Liquid Treatment Optimization/Positioning
  - Hydraulic profile "reconfiguration"
  - Bio-P conversion
  - Mainstream Deammonification implementation
  - Carbon redirection
    - CEPT

  - A/B (Bio-enhanced Primary)

- Need to consider the future but make sure we address the concerns of today.

<u>3 Products to Think About</u>

- Energy – Biogas, Heat
- Phosphorous – bio P, etc.
- Ash

Team Breakouts

Teams were broken up as follows:

- Team Nematodes
- Team Filaments
- Team Mites

Findings from the groups are summarized in the attached slides (graphical displays of output).

Note on Outsourcing: Different users want a different product to deal with (user-specific). Guideline – develop a path to have/keep the most control, and then use outsourcing options to supplement.

Parking Lot Issues

Stakeholder management – consider education, expectations for service and costs, etc. Folks spend much more on their cable or cell phone bill as opposed to their water bill - and view their water bill differently.

Action Items

Table 1. Action Items List

Item	Responsible Party	Target Due Date
Confirm Fairfax County Population, Flow Projection Data/Projections?	Mike McGrath	4/22/16
Confirm Boundary Conditions	All parties	4/22/16
Prepas Status	Marialena Hatzigeorgiou, Steve Hill	5/6/16
Centrifuge Status	Marialena Hatzigeorgiou, Steve Hill	5/6/16
Confirm next workshop Date – Find a date – week of May 9 or later	Sean Stephan, Rich Voigt	TBD

Attachments

1. Revised Presentation Slides
2. Team Breakout Outputs
3. Meeting Agenda and Sign-in Sheet

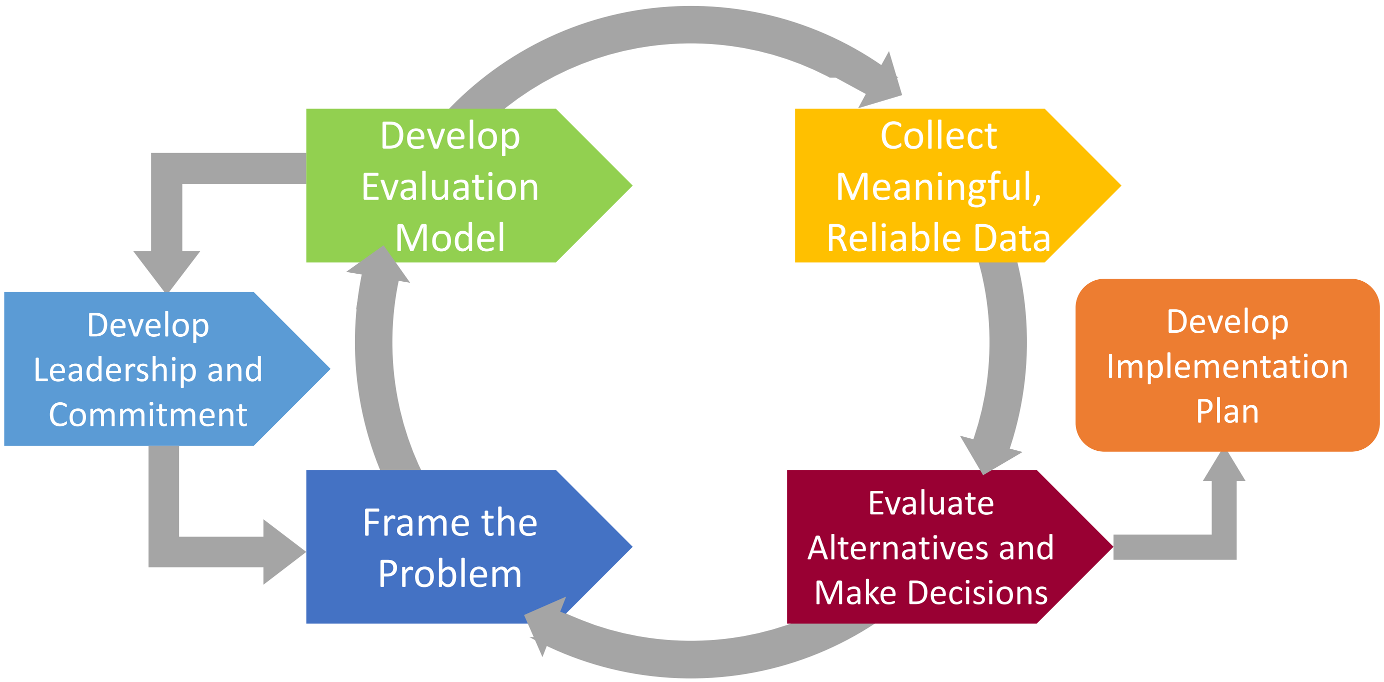
Solids Handling and Energy Optimization Evaluation

Workshop 2: Defining Viable Technology Pathways Towards an Envisioned Future

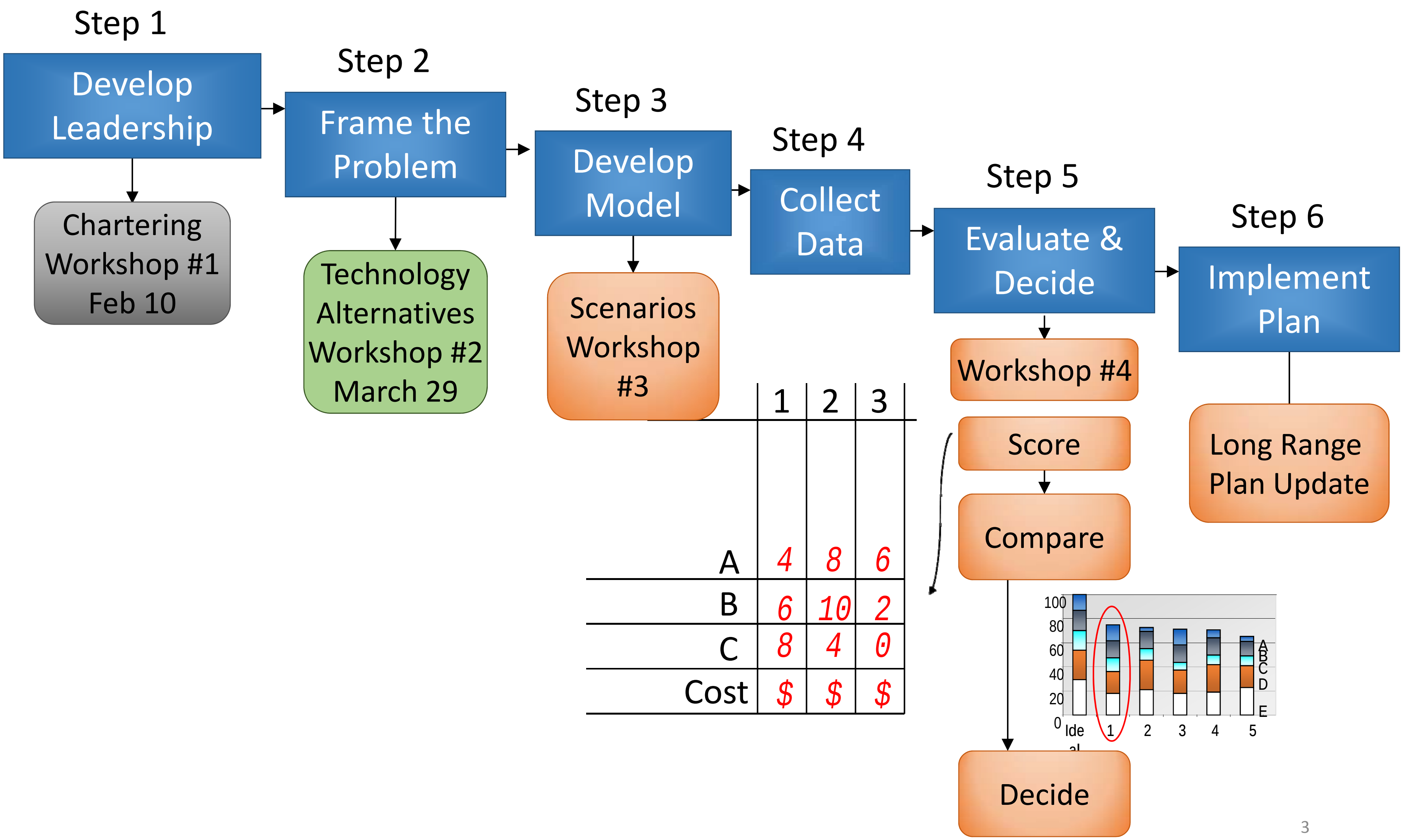
March 29, 2016

Revised per comments received at the Workshop

2016 Solids Handling and Energy Optimization Planning



2016 Solids Handling and Energy Optimization Planning



Workshop Objective – Framing the Problem

- Welcome and Introductions
- Defining success – Chartering Workshop summary
- Confirmation of Planning Basis
- Envisioning a plausible future
- How others are positioning for the future

LUNCH!!!!

- Defining boundary conditions – rules to plan by
- Identification of alternative pathways towards the future
- Configuring viable alternative process configurations: selection of unit process building blocks
- Next Steps – Develop & Evaluate Scenarios

Defining success – Chartering Workshop summary

Presentation by Rich Voigt

Recap of Chartering Workshop

- Brief review of where we've been (Long Range Plan/SANUP)
- Discussed challenges and opportunities:
  - Regulatory
  - Political
- Drafted new Boundary Conditions
- Reviewed historic and projected solids loading data
- Strategy brainstorming
  - Minor enhancements to existing facility
  - Today's proven advanced technologies
  - Future/embryonic technologies
- Reviewed industry partnerships

Draft Boundary Conditions (2040 Planning Horizon)

Boundary Condition	Elements
Most Restrictive Limits (2040)	Ban on land application of biosolids and/or potentially all land-based uses of biosolids Limits on nutrient effluent discharge concentrations down to Limit-of-Technology (LOT) levels: • TN = 1 mg/L • TP = 0.01 mg/L Monitoring and limits on micro-constituents in the biosolids and in the liquids Greenhouse gas (GHG) caps
Sustainable Practices	Trend towards energy neutrality Resource recovery No net increase in air emissions onsite Manage risk associated with biosolids use/disposal Reclaimed water – develop partnerships to utilize 5 mgd capacity Limited footprint at WRRF for future development (none on West Plant Site)
Board Directives/Community Engagement	Support Board 2040 vision and outcomes Supportive development partner in Carlyle Partners Focus on local community stewardship – solutions to enable City to grow No net increase in odor/air emissions/light/noise/traffic Remain neutral on visual impacts of future additional facilities compared with existing

Action Items

- Request latest City of Alexandria projections (population/flow)
- Review proposed loadings
- Consider draft boundary conditions/provide feedback
- Brainstorm technologies/pathways to be considered
- Status Prepasteurization items

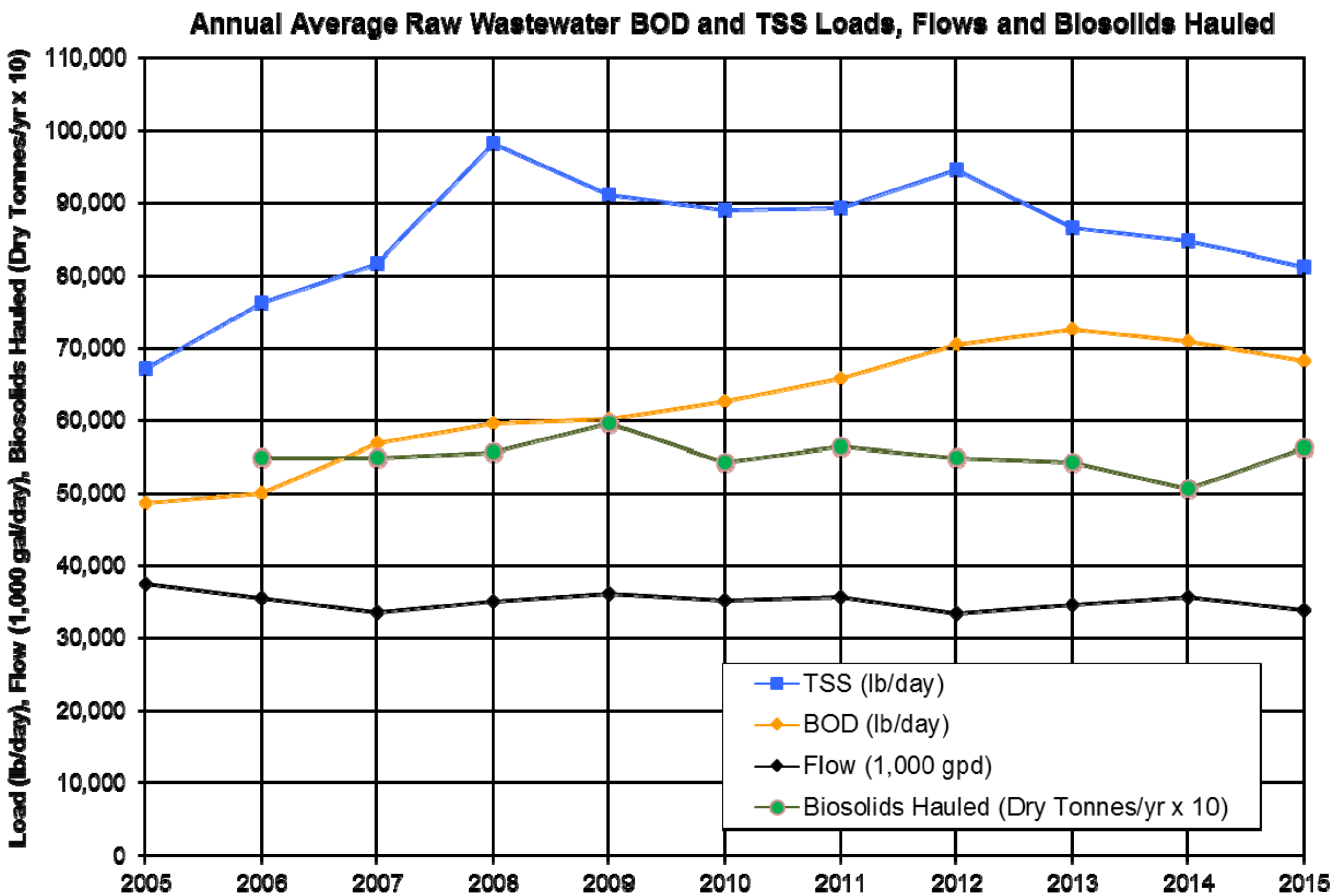
Review of Parking Lot Items

- Boundary Conditions (included):
  - Support Board 2040 vision and outcomes
  - Supportive development partner in Carlyle Partners
  - Metal recovery from sludge? Phosphorous/nutrient recovery?
  - No additional processes (treatment) on West Plant Site - only available land on Main Plant Site is within fence line
- Micro-constituents:
  - What is coming in (type/concentration range)?
  - What should we reasonably expect to be removing?
  - How do we test to confirm what's there?
  - Are they removed in biosolids?
  - What are we not removing – and is there a way to remove?
- Fisher-Tropsch
- No lime (for treatment)
- Covanta Alexandria – not viable - already reviewed (small area plan issues, site constraints/limit on intake – maxed out), and handling issues.

Confirmation of Planning Basis

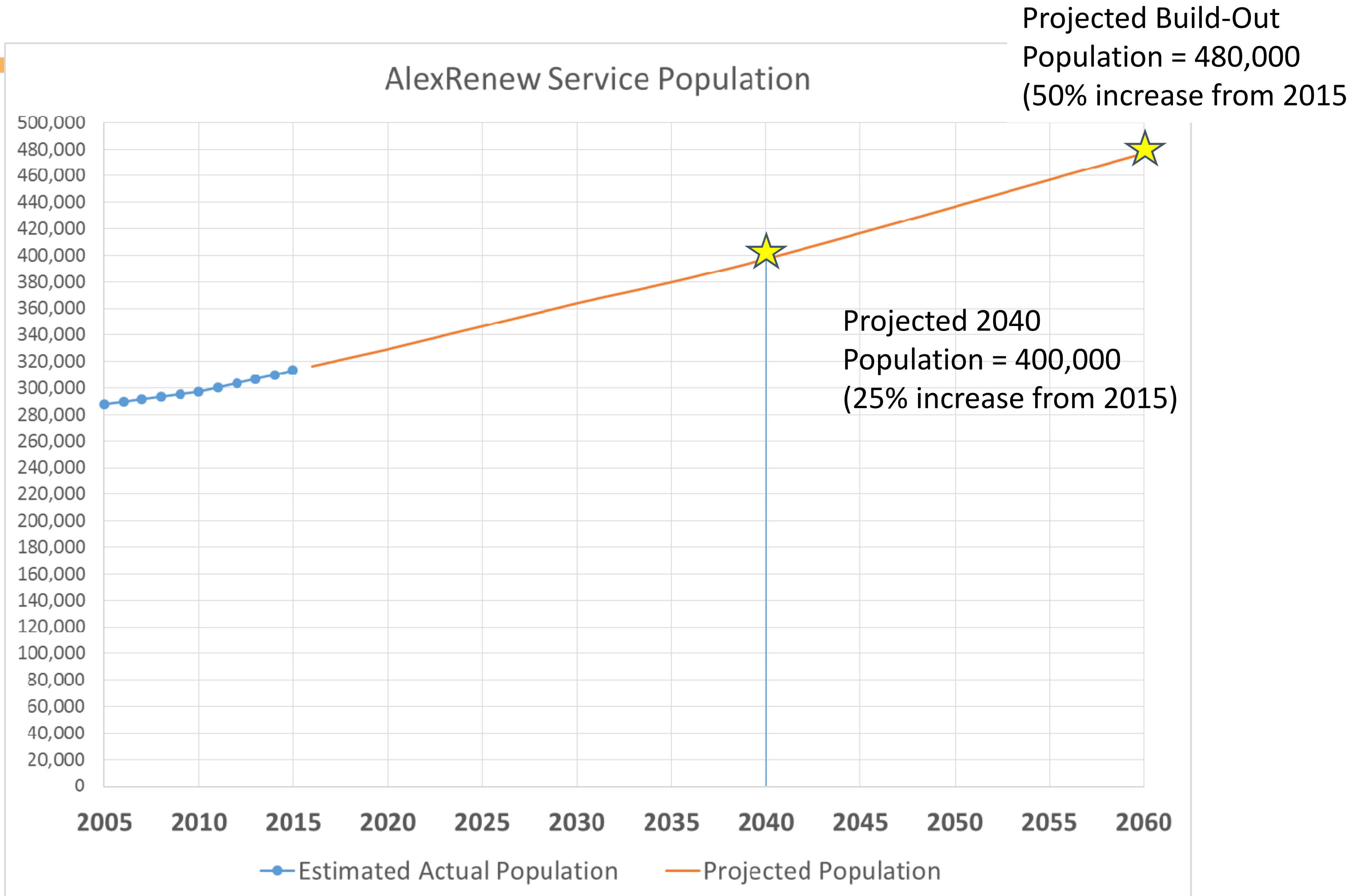
Presentation by Savita Schlesinger

Historical Loadings at AlexRenew 2005 - 2015 *



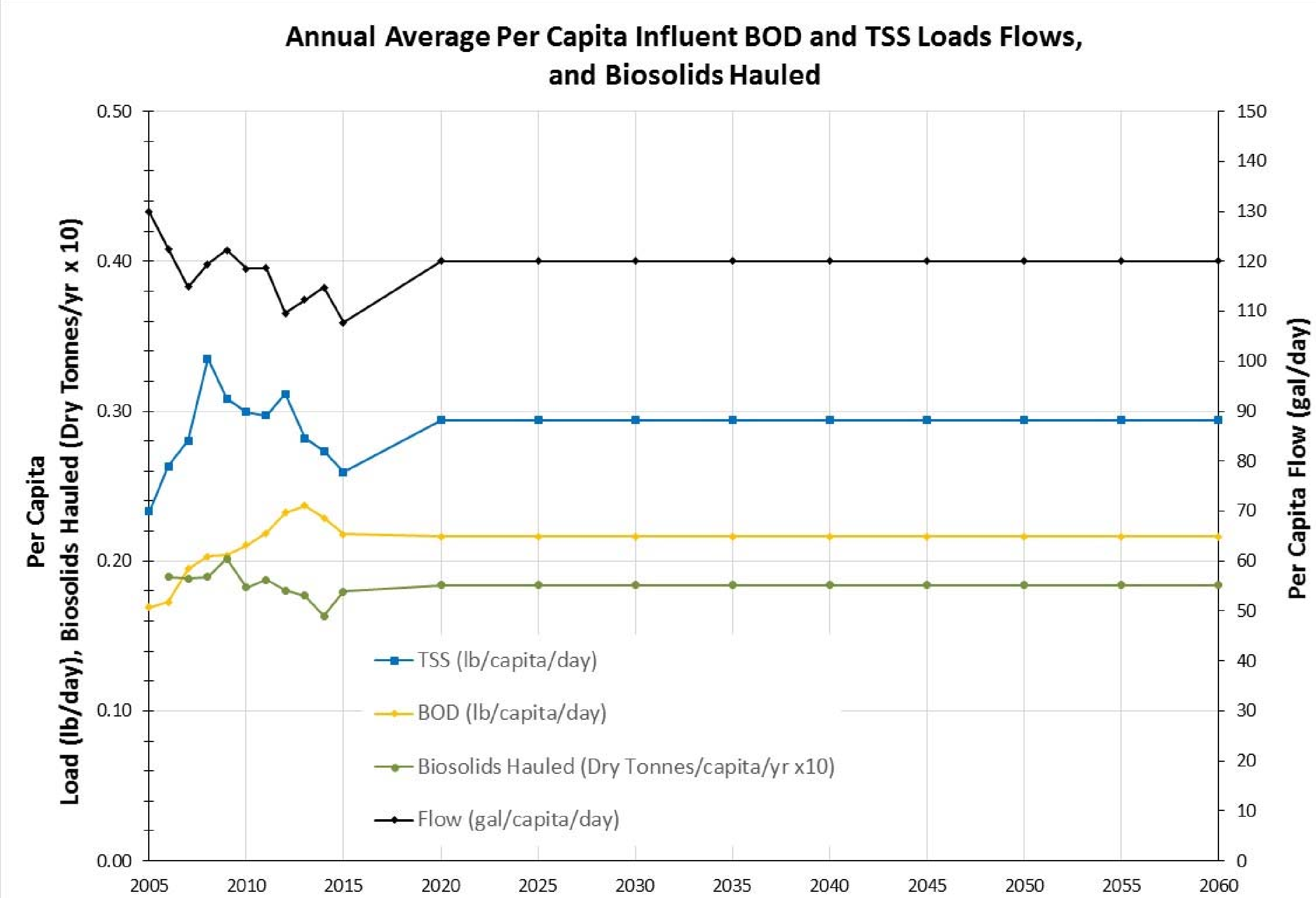
* From Chartering Workshop

AlexRenew Projected Population



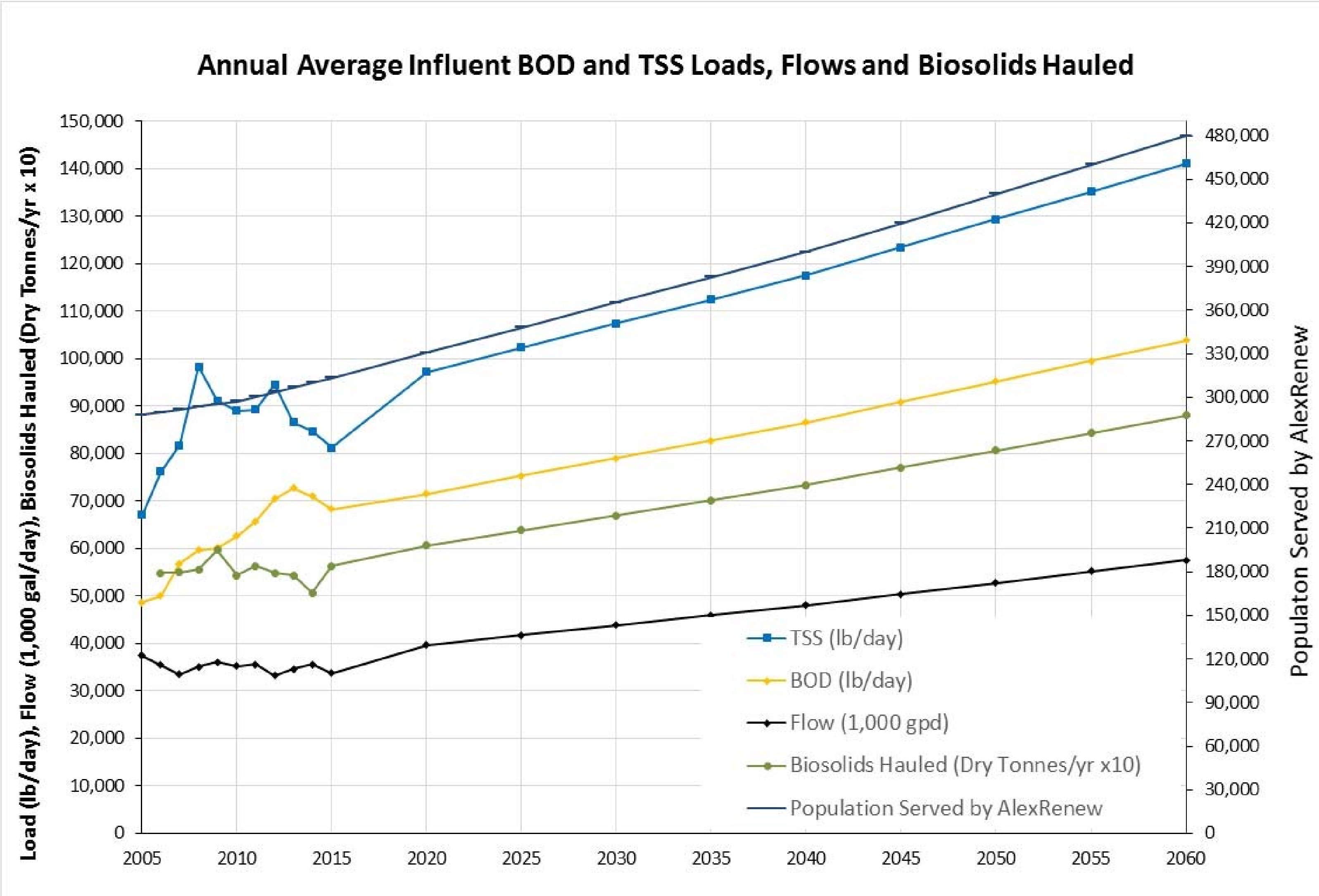
Updated Service Population Data obtained in 2016 from the City of Alexandria per MWCOG Round 9
Fairfax County has not updated their projections since 2009 (applied the last Census % increase for projection).

AlexRenew Population Equivalent Influent & Biosolids Hauled 2005 - 2060



Revised

AlexRenew Influent & Biosolids Hauled 2005 - 2060



Revised

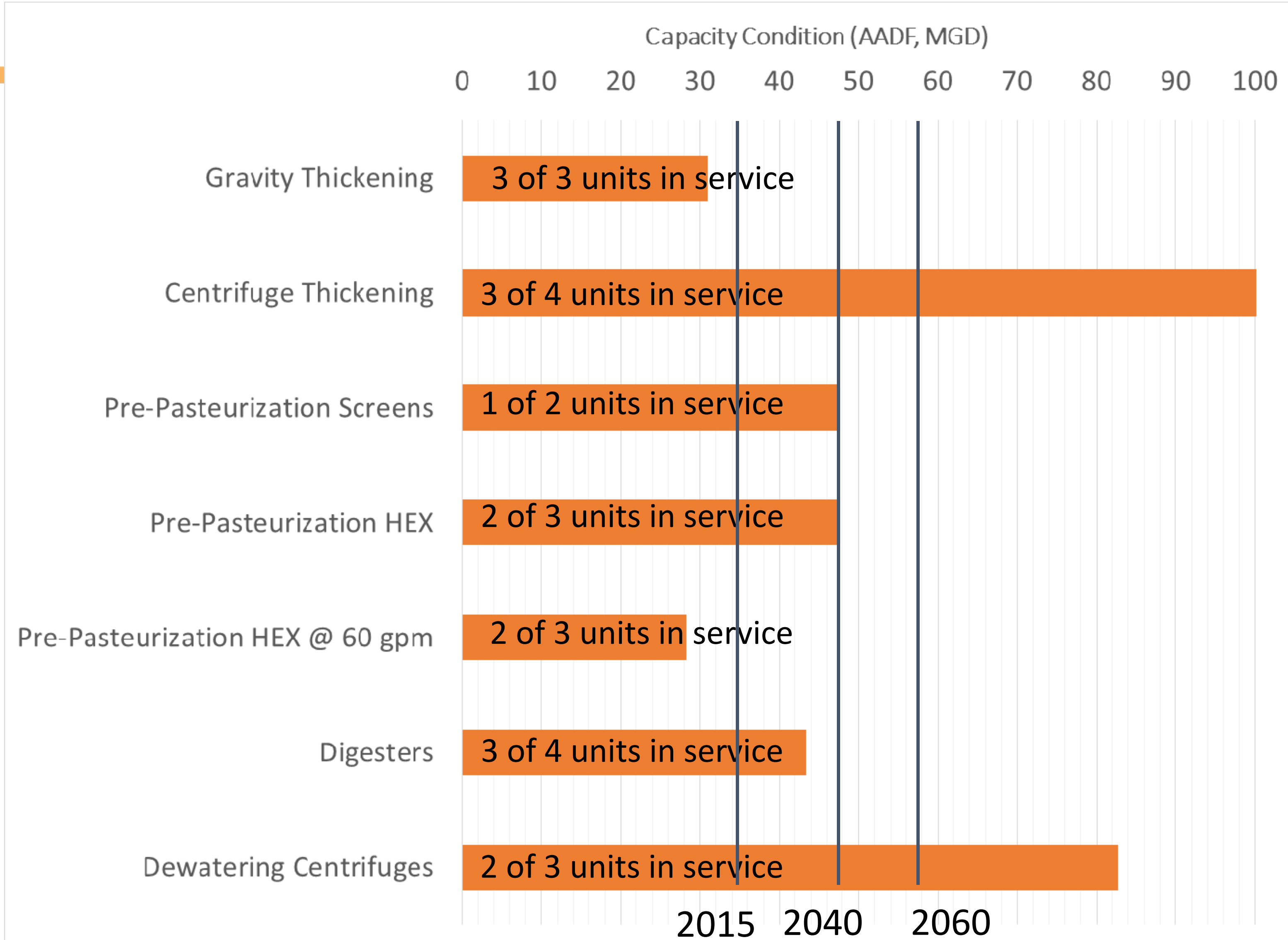
Proposed Loading Projections for 2016 Planning Effort

- Used 2007-2015 Data Set to determine historical Per-Capita Loadings and project out to 2040 and Build-Out Condition (~ 2060)

	Population	Flow (MGD)	Loadings (lbs/day)					
			TSS	BOD5	TKN	NH3	TP	OP
2007-2015 Avg. Loadings	~300,000	35	88,000	65,000	12,000	6,400	1,900	700
Per Capita Loading *		120 gpc	0.29	0.22	0.040	0.021	0.006	0.002
2040 Loadings	400,000	48	117,593	86,524	15,954	8,445	2,493	935
Build-Out Loadings (~2060)	480,000	58	141,000	104,000	19,100	10,100	3,000	1,100
Max Month PF *			1.32	1.21	1.20	1.11	1.28	1.17
Max Month Design Loadings			186,000	125,000	22,900	11,200	3,800	1,300

* per-capita loading and peaking factors based on 2007-2015 historical data

Unit Process Capacity Assessment *



* Based on 2015 data and adding projected impacts of CEPT:
38% increase in PSD, 35% decrease in WAS, 15% increase in overall solids

Envisioning a plausible future

Presentation and Group Discussion
Facilitated by Julian Sandino

Looking to the future ….*

- It's all about managing water, carbon and resources (phosphorus, ammonia)
- Where is the energy market going?
  - Renewable subsidies
    - Green power value
    - Is combined heat and power the best use of carbon (w biogas)?
    - How can we better capture the energy value of the carbon recovered from wastewater? What is the next technology?
- Where is the resource recovery market going?
  - Demand for resources (phosphorus, ammonia, struvite)
- Where is the agricultural market going?
  - Demand for organics, macro and micro-nutrients
  - Regulations on micro-pollutants

* From Chartering Workshop

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

A - Evolving Regulatory Framework

- A-1: Ban on land application of biosolids and/or potentially all land-based uses of biosolids
- A-2: Limits on nutrient effluent discharge concentrations down to Limit-of-Technology (LOT) levels: TN = 1 mg/L; TP = 0.01 mg/L
- A-3: Monitoring and limits on micro-constituents in the biosolids and in the liquids
- A-4: Greenhouse gas (GHG) caps
- A-5: Air emission requirements
- A-6: “Integrated” regulatory frameworks (air, water, solids)

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

B – Embraced Sustainability Principles

- B-1: Trend towards energy neutrality and beyond
- B-2: No net increase in air emissions onsite
- B-3: Manage risk associated with biosolids use/disposal
- B-4: Reclaimed water – develop partnerships to utilize 5 mgd capacity
- B-5: Limited footprint at WRRF for future development
- B-6: Resource recovery
- B-7: Climate change resiliency and adaptation
- B-8: Supply chain considerations (life cycle assessments)
- B-9: Envision?

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

C – Further Engaged Stakeholders – Board, Community, and Clients

- C-1: Support Board 2040 vision and outcomes
- C-2: Supportive development partner in Carlyle Partners
- C-3: Focus on local community stewardship – solutions to enable City to grow
- C-4: No net increase in odor/air emissions/light/noise/traffic
- C-5: Remain neutral on visual impacts of future additional facilities compared with existing
- C-6: Legislator advocacy
- C-7: “Sector” organization (WEF, WERF, NACWA) influence
- C-8: New (revised) interaction between district and clients

How others are positioning for the future

How others are positioning for the future

Presentations:

- **VCS:** Future challenges and R&D projects
- **Fairfax County:** Sludge incineration
- **Green Bay MSD:** Future-proofing through portfolio diversification (incineration and digestion and drying)
- **Genifuel**: sludge to oil embryonic technology

VCS

Workshop AlexRenew

Ivan Vølund
Head of Department, wastewater

Ib Pedersen
Teammanager, wastewater

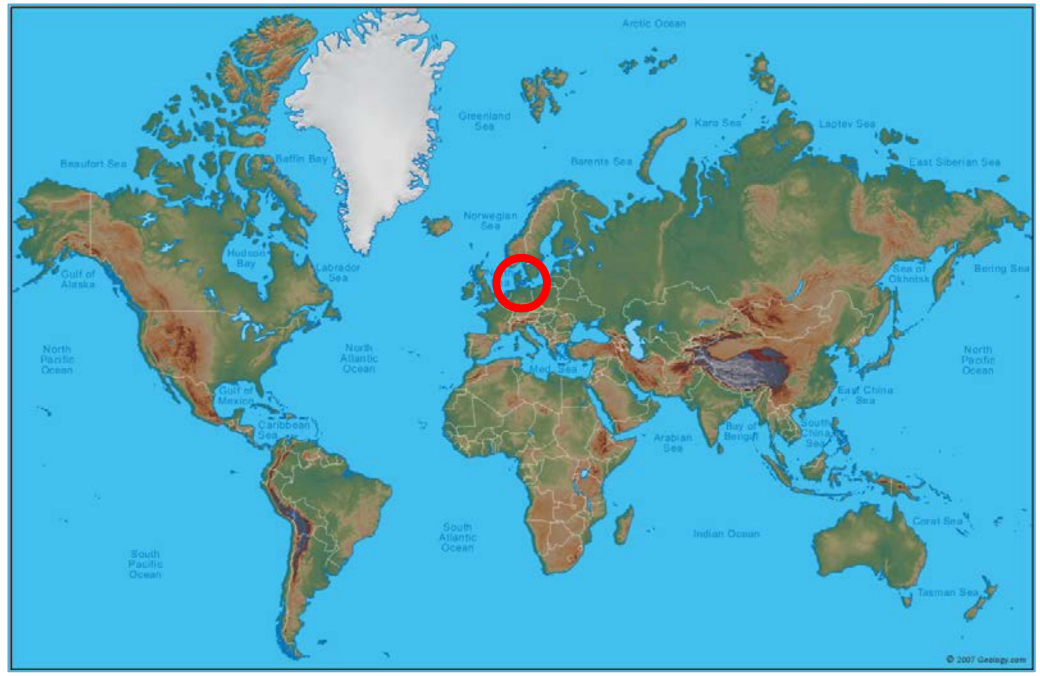
March 29th 2016

VCS Denmark
PRACTICAL WATER KNOWLEDGE

VCS Denmark

Main activities

- Production and distribution of drinking water
- Disposal and treatment of wastewater
- Operational services, training and consultancy on home and foreign markets



History

- In 1853 Odense Waterworks was established as the first in Denmark.
- In 1864 the first sewers were built.
- In 1907 the first wastewater treatment plant Ejby Moelle was built.
- In 1994 Odense Water Ltd. was established as a result of a merger between Odense Municipality's Water and Wastewater Departments.
- January 1st 2010 the name was changed from Odense Water to VCS Denmark
- January 1st 2011 VCS merged with Northern Funen Wastewater

Wastewater focus changes over time

Hygiene

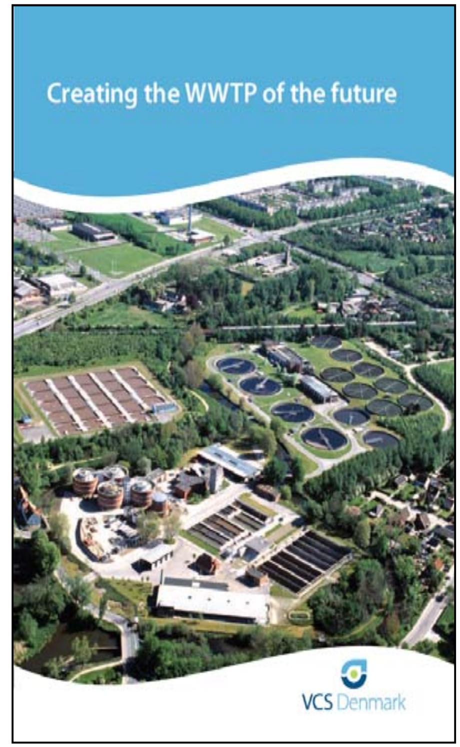
Environment

Climate and ressources

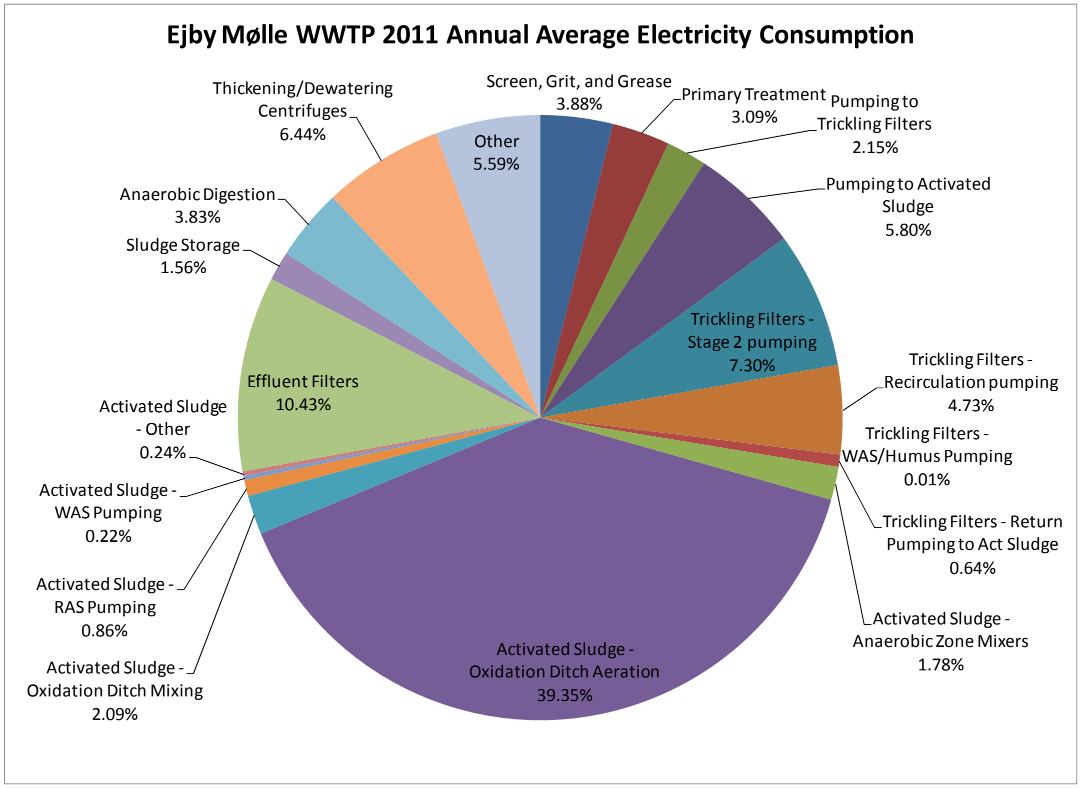
1800 | 1900 | 2000 | 2100

Ejby Moelle WWTP Optimization Project: Achieving net positive energy efficiency while complying with stringent effluent demands

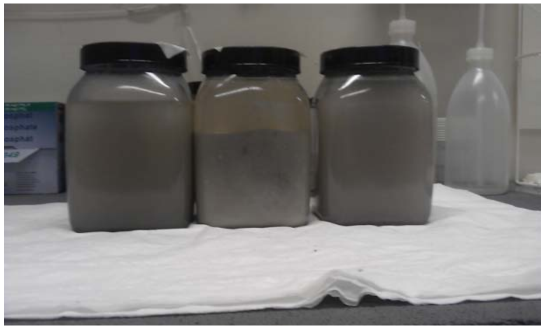
- Contribute towards achieving VCS's goal of energy self-sufficiency by 2014.
- Identify energy optimization opportunities. Concentrate on short-term, readily implementable actions – reduce energy consumption; increase energy generation.
- Identify and document longer term opportunities.



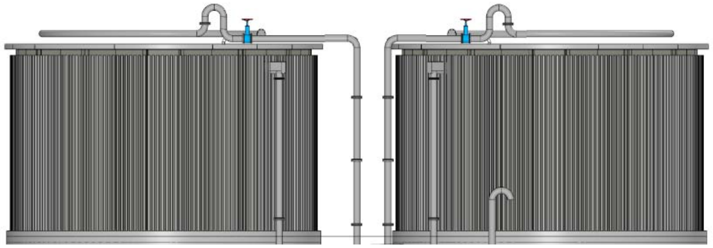
Availability of detailed historic energy consumption and generation data is key in the evaluation of optimization opportunities



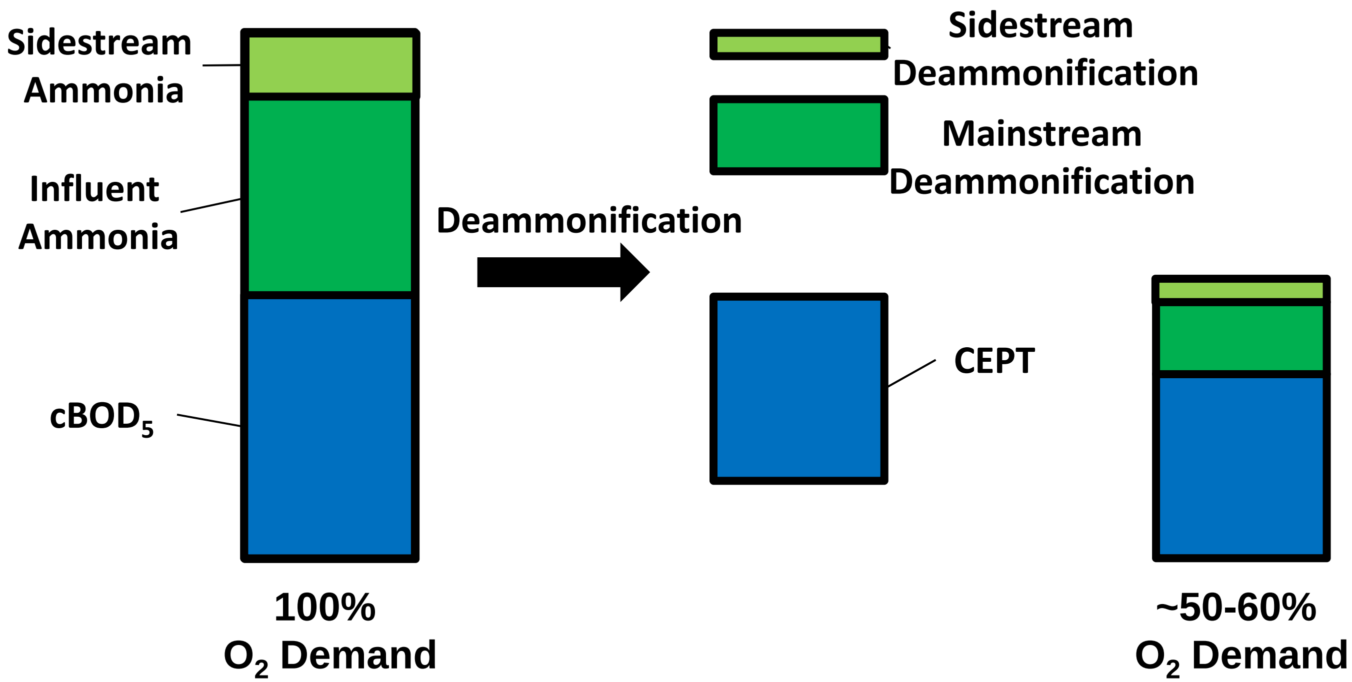
Short List



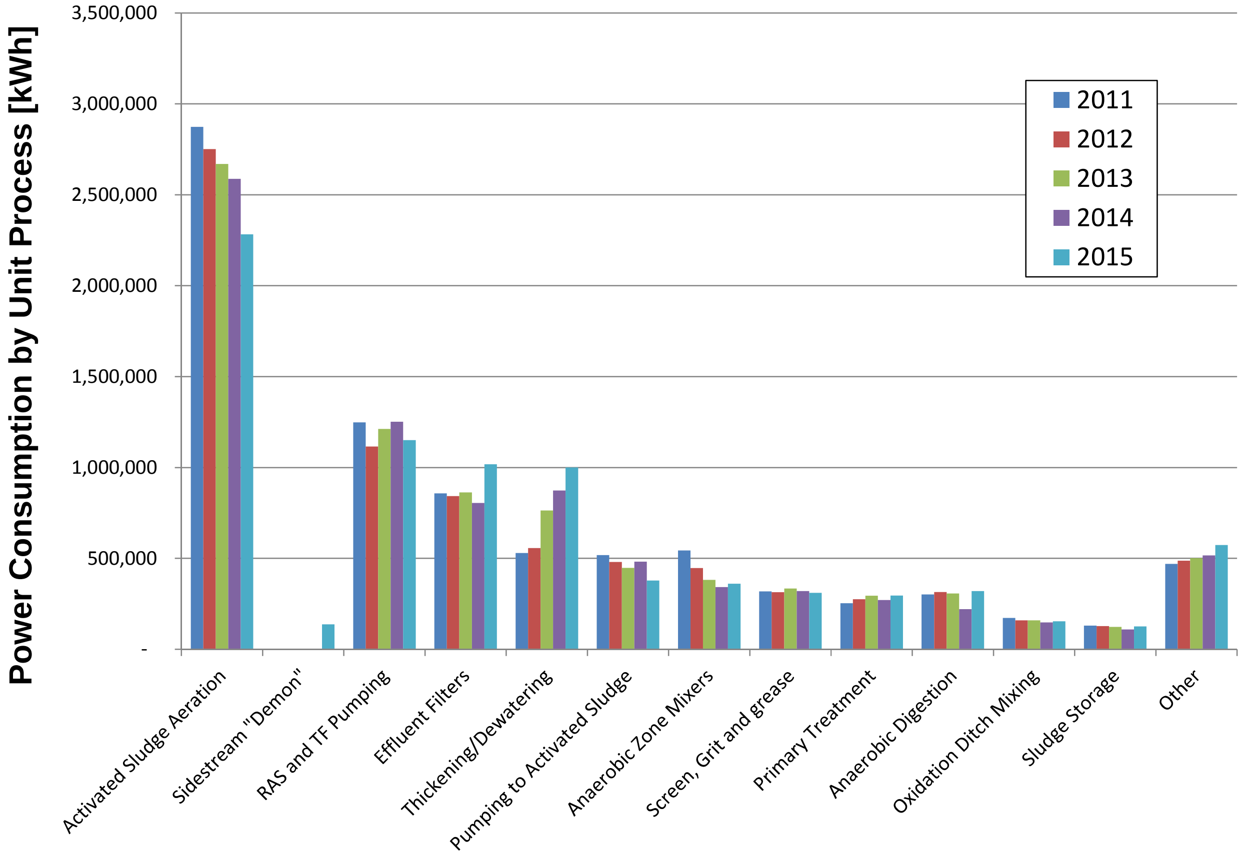
- Implement chemically enhanced primary treatment (CEPT)
- Decommission TF and convert TF clarifiers to CEPT for wet weather treatment
- Operate at shorter SRT in AS system
- Reduce effluent filtration operation to 12 hours per day
- Co-digestion of high-strength organic waste
- Implementing deammonification for N removal sidestream
- Implementing deammonifications for N removal mainstream
- Replace aeration system in oxidation ditch
- New CHP engine



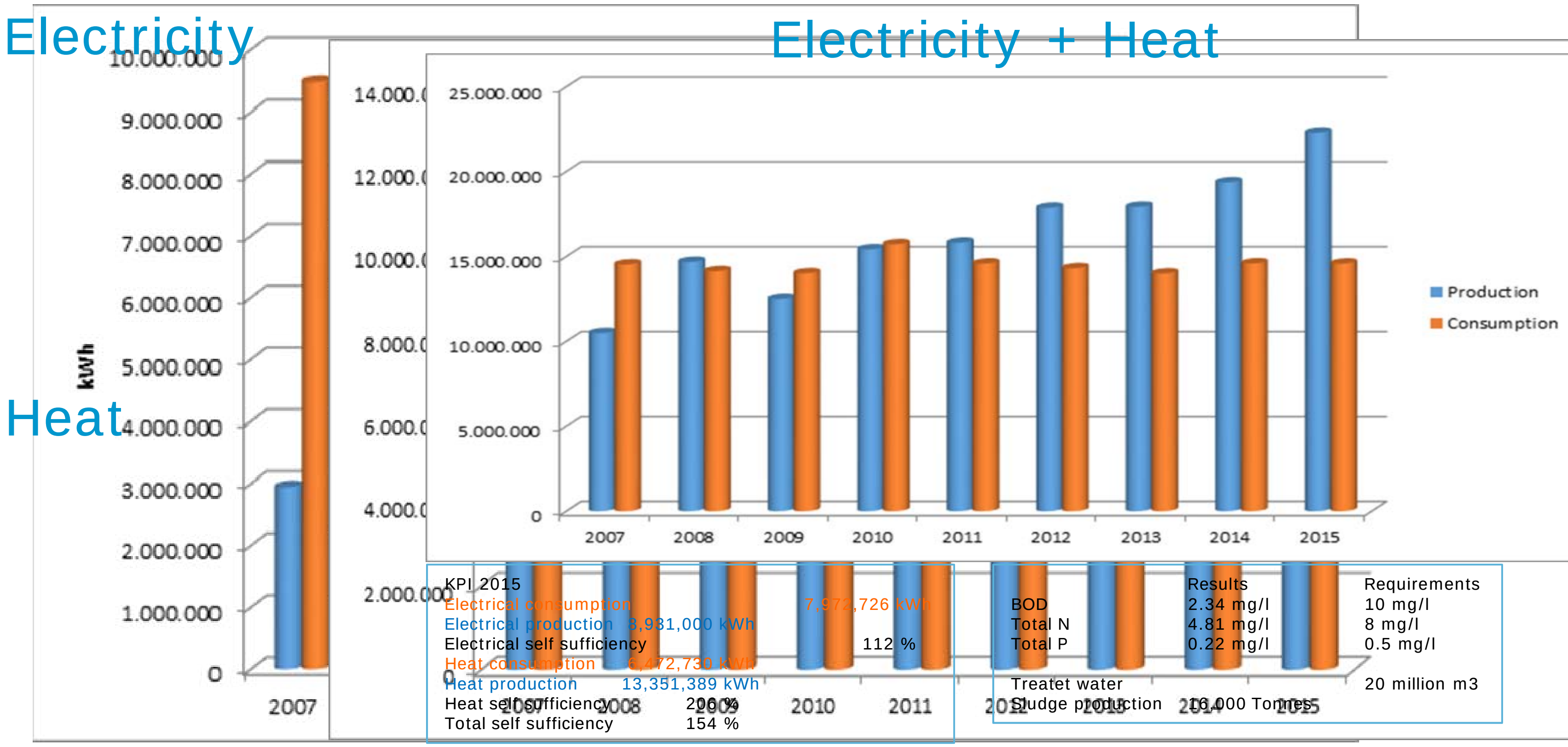
Why do mainstream deammonification?



Detailed Power Consumption Data Demonstrates Reduced Aeration from Deammonification



From Energy consumer to producer



KPI 2015	
Electrical consumption	7,972,726 kWh
Electrical production	8,931,000 kWh
Electrical self sufficiency	112 %
Heat consumption	6,472,730 kWh
Heat production	13,351,389 kWh
Heat self sufficiency	206 %
Total self sufficiency	154 %

	Results	Requirements
BOD	2.34 mg/l	10 mg/l
Total N	4.81 mg/l	8 mg/l
Total P	0.22 mg/l	0.5 mg/l
Treatet water		20 million m3
Sludge production	26,000 Tonnes	

Emissions
next step after energy neutrality

- 1 tonnes methane equivalent to 25 tonnes CO_2
- N_2O equivalent to 298 tonnes CO_2
- Former research on N_2O emissions from waste water very uncertain
- Some utilities makes CO_2 accounting without including N_2O and Methane
- At the moment no economic reasons for minimizing N_2O

Science for Environment Policy
DG Environment News Alert Service
European Commission

17 December 2009

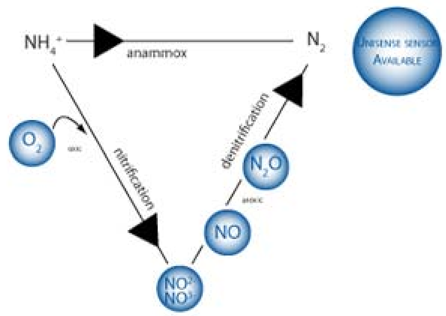
Nitrous oxide is now top ozone-layer damaging emission

According to new research, emissions of anthropogenic nitrous oxide (N_2O) are now causing more damage to the ozone layer than those of any controlled ozone depleting substance and this is projected to remain the case for the rest of this century. The study suggests that limiting N_2O emissions could help both the recovery of the ozone layer and tackle climate change.

Many ozone-depleting substances (ODS) have been phased out as a result of the Montreal Protocol[1] and are regulated by EU legislation[2]. N_2O is emitted from natural and anthropogenic sources, the latter including as a byproduct of agricultural fertiliser use and from fossil fuel combustion. Its role in ozone depletion has been known for some years and it is similar to CFCs in that it is stable when it is near the earth's surface but releases ozone-destroying active chemicals when transported into the stratosphere (between 10 and 50 km from the surface). However, N_2O is not defined as an ODS under the Montreal Protocol and, although it is a greenhouse gas (GHG) included in the basket of gases under the Kyoto Protocol, its emissions remain unregulated.

VCS actions related to emissions

- We know that nitrous oxide production occurs in nitrogen transformation.
- Control stategies that benefits energy production may cause more N2O.



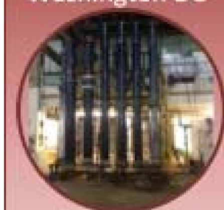
- VCS has participated in development of N2O meter with Unisense
- 2 students study N2O emissions in relation to different control strategies on sidestream and mainstream treatment.
- VCS talks to the EPA about regulation that gives benefits for utilities with a low footprint on emissions
- After working with energy and CO2 neutrality in former strategy, VCS now works with environmental footprint in latest 5 year strategy.

Principal Investigator
Belinda Sturm (University of Kansas)

Technical Co-Lead
Haydée De Clippeleir (DC Water)

Technical Advisory Committee
James Barnard (Black & Veatch), Joe Husband (Arcadis), Dave Kinnear and JB Neethling (HDR), Ron Latimer (Hazen&Sawyer), Dwight Houweling (CH2M HILL)

Blue Plains, Washington DC



Sudhir Murthy
Ahmed Al-Omari
(DC Water)
Beverly Stinson
(AECOM)

External selection
Screens at Pilot/bench–scale

James River, VA

Charles Bott
(HRSD)
Jose Jimenez
Pusker Regmi
(Brown & Caldwell)

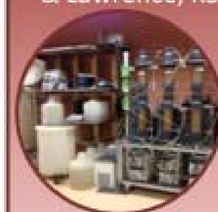
External selection
Cyclones at Full-scale

Strass, Austria

Martin Hell
(AIZ Waterboard)
Bernhard Wett
(ARAConsult)
Sabine Podmirseg
(Univ of Innsbruck)

External selection
Cyclones at Full-scale

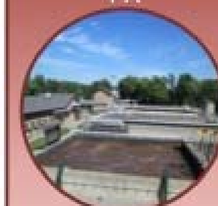
Tomahawk Creek & Lawrence, KS



Susan Pekarek
(Johnson County)
Andrew Shaw
(Black & Veatch)
Belinda Sturm (Univ Kansas)

Internal selection
Bench-scale SBRs with screens

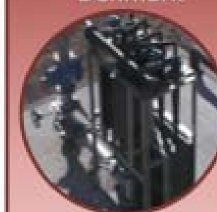
Gregg Township, PA



Floyd Koch (Gregg Township)
Wendell Kunjar
(Hazen & Sawyer)
Kevin Gilmore
(Bucknell Univ)

Internal selection
Full-scale SBR

Ejby Mølle, Denmark



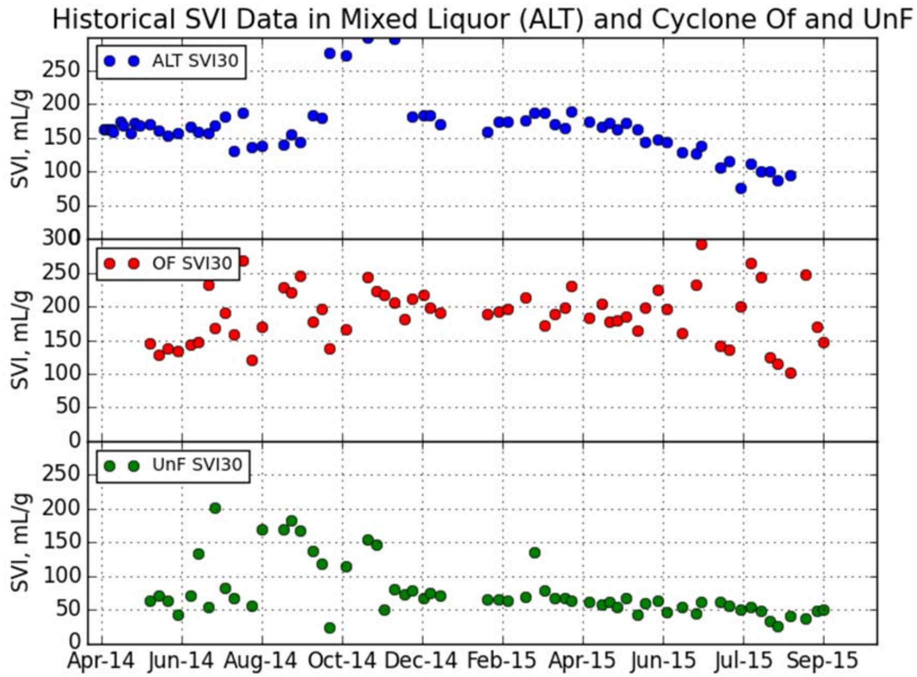
Per Nielsen
(VCS-Denmark)
Tim Constantine
Julian Sandino
(CH2M HILL)

External selection
Cyclones at Full-scale

Other Participating Utilities for Sampling & Conceptual Design Phase
Conceptual Design Lead: Joe Husband (Arcadis); Process Modeling Lead: Dwight Houweling (CH2M Hill)
Municipal Water Reclamation District of Greater Chicago, Others Pending

Collaborative Research Programme

- Activity testing to characterize the relative populations of AOBs, NOBs, and Anammox
- Genetic testing using qPCR to quantify populations of AOBs, NOBs, and Anammox
- SVI tests for assessing sludge settleability
- Petri dish image analysis for particle size tracking



Petri Dish Image Analysis

WAS Cyclone Overflow

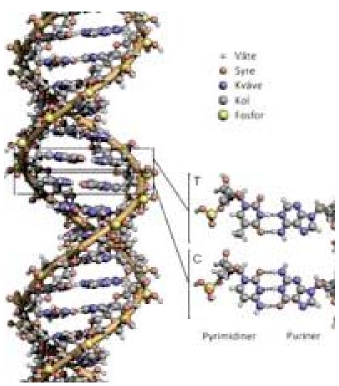
Particle Count: 82
Average Area: 0.02 mm^2

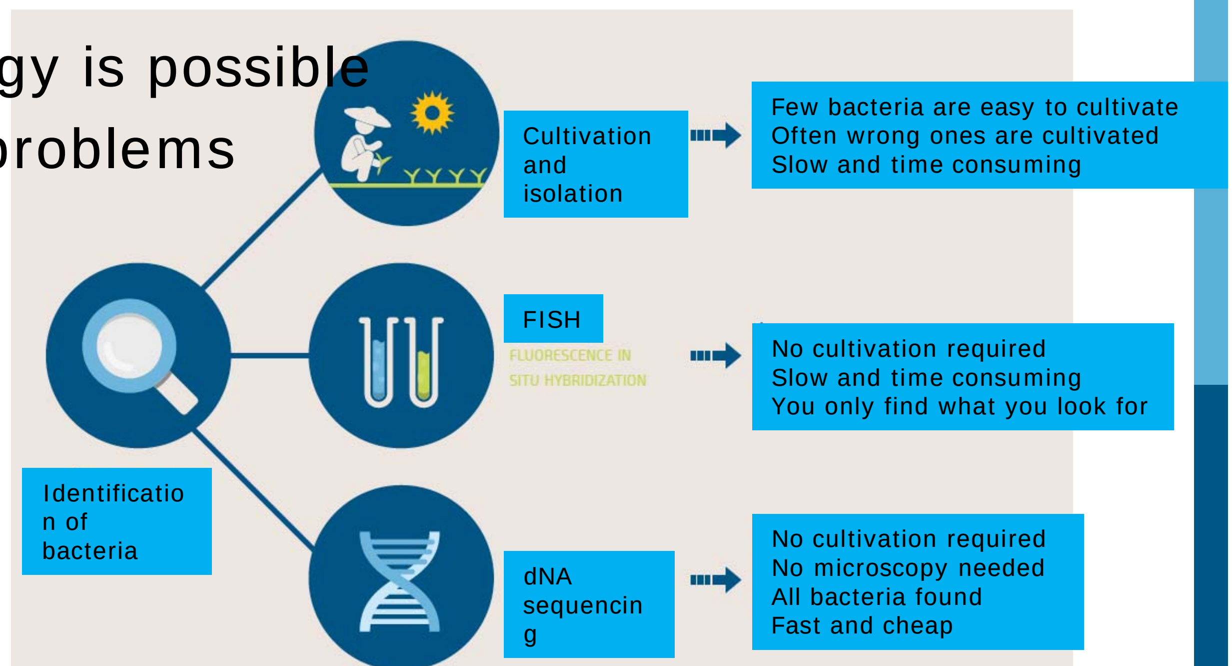
WAS Cyclone Underflow

Particle Count: 936
Average Area: 0.05 mm^2

qPCR

- Sludge analysis by Aalborg University
- Storage of sludge
- Customizing biology is possible
- Solutions for old problems





Microplastics

Separate sewer

App. 50%

App. 2/3

Direct discharge

App. 1/3

Stormwater reservoir

Degree of Treatment unknown

Combined sewer

App. 50%

Renseanlæg

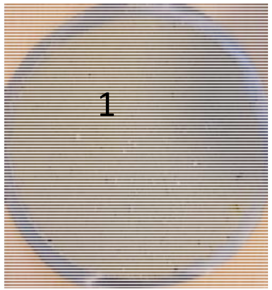
0,1 – 30% of microplastics discharged

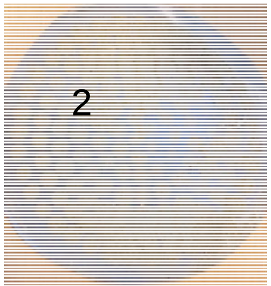
Biosolids to farmland

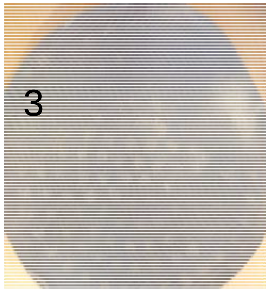
Microplastics

- German, Swedish and Norwegian research has some uncertainties about effect on microplastics from chemicals and heat used to separate microplastics from other materials and they are very time consuming.
- VCS participating in 2 researchprojects
  - Better ways to measure microplastics (inlet, outlet and biosolids)
  - Better ways to separate microplastics from the water together with controlling the carbon coming to the treatment plant.
- The first project has reduced time for purification from 3 weeks to 3 days and has achieved good results using spectroscopy based on laser.

1. H_2O_2
2. H_2O_2 + enzymes
3. H_2O_2 + enzymes +H_2O_2







Sludge reduction

- Superheated Steam Drying and Pyrolysis.
- The thermal energy is recoverable and suitable for district or process heating purpose.
- The residual biochar is rich on plant available phosphorus and is suitable as a fertilizer product within the agriculture industry.

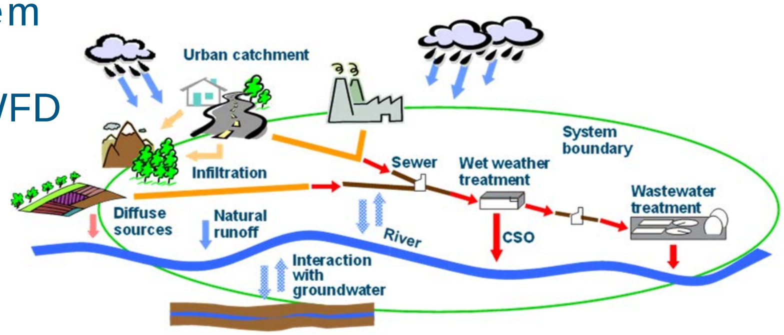
- SUBLIMATION means going from solid form to gas form without passing through the liquid phase. It is a Flash Pyrolysis system.
- SUBLIMATOR plants are able to convert all kinds of organic material into gas and activated carbon or BIOCHAR in a fast and efficient way without the use of bacteria or enzymes.
- A clean gas can be delivered to gas engine/turbine-generators or other uses.
- Activated carbon or BioChar is generated.


Billede 1 LxHxB 10x3x5 m

Oscar Company
- Rotary kiln
- May be able to perform pyrolysis

Integrated system management: connecting sewers, plants and receiving waters via a model

- Impact of planned collection system upgrades on WRRF?
- Impact of collection system CSOs & WRRF on river chemistry (DO, NH4) & WFD compliance?
- What is best grey-green infrastructure mix?
- Capital & operating costs?
- Climate change?
- Where to invest in data collection?

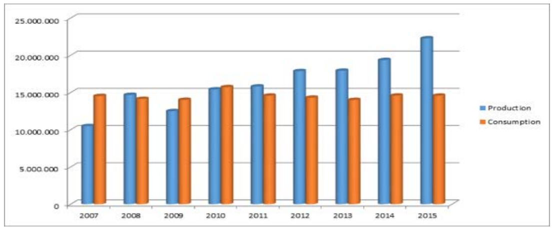


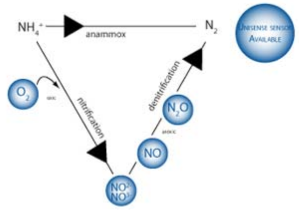
Other R&D projects

- Recover P - increase the P recovery from wastewater and transform it into high quality P products that can be used in agriculture and industry

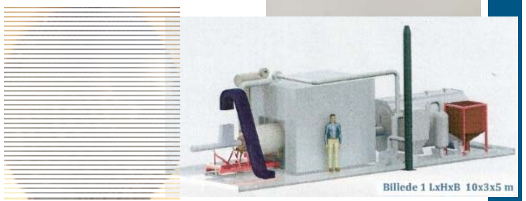
- BioCap - overall objective is to integrate underutilized biomass for energy production

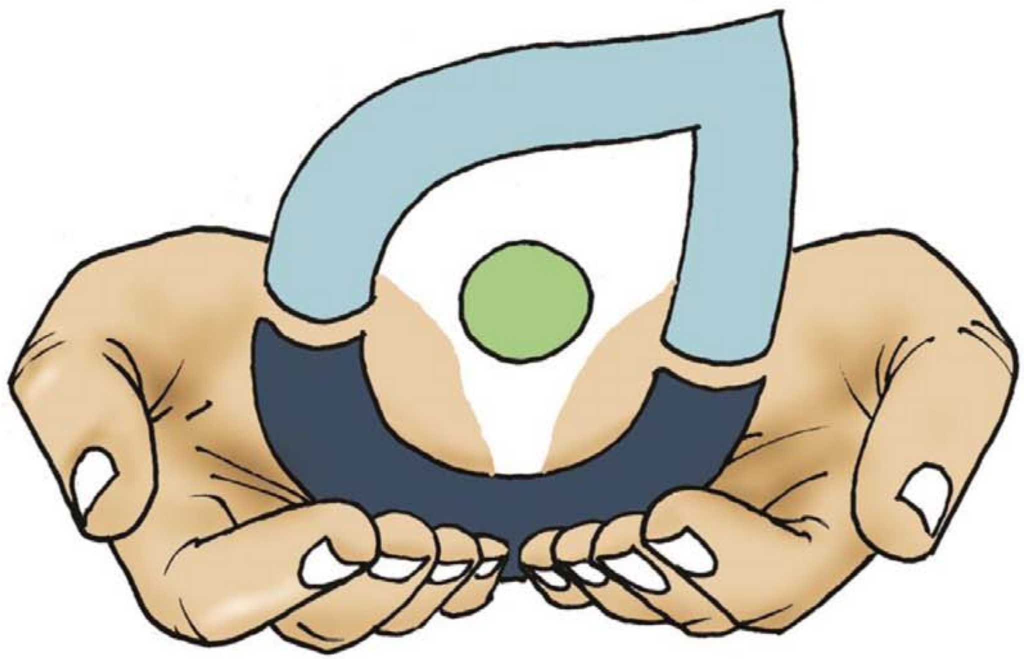
Summary and conclusions





- Energy and water is a big focus for VCS and we have reached more than 150 % self sufficiency at Ejby Mølle. It takes bigger plants to reach it all over, so centralizing treatment of waste water is part of our future as well as decentralized handling of rainwater.
- Emissions are correlated to energy neutrality and we believe the emissions some day will be taxed as well as our energy and effluent is taxed.
- More sophisticated treatmentplants. Automaticly run in less space and with selection of specific bacteria
- Biosolids contains lots of different substances, so on the long term we expect regulations, which means we need other solutions than end deposit at farmland.
- Biosolids also contains valuable substances and on the long run we'll see harvesting of more than just energy and phosphorus, for instance valuable carbons, rare earth elements and metals





VCS Denmark

PRACTICAL WATER KNOWLEDGE

Fairfax County DPWES

Biosolids Program & Energy Project Status Report

Noman M Cole Pollution Control Plant (NMCPCP)

February 3, 2015

Department of Public Works and Environmental Services

Working for You!

A Fairfax County, VA, publication

February 3, 2015

Outline

- Review previous update (Biosolids Program, February 2013)
- Biosolids Program Rehabilitation Project
- Energy Recovery

Looking for endorsement on proposed path forward for energy recovery

Overview of Findings (2012 Biosolids Study Peer Review)

- ⇨ Shortlisting and evaluation were robust and comprehensive
  - ⇨ No viable technologies were missed
- ⇨ Confirmed shortlisted alternatives, with exception of landfilling
  - ⇨ Not sustainable, long-term management option
- ⇨ Opportunities were identified within remaining 8 alternatives
- ⇨ Risk analysis not fully developed (e.g., phosphorus)
- ⇨ Preferred alternative should value resource recovery potential (e.g., energy, product) – not disposal
- ⇨ County recognition of value/benefit of “self reliance”
- ⇨ Long and short term strategies recommended

Recommendations

- **Short Term (now – 2030)**
  - Continue Multiple Hearth Furnaces (MHF) Program
    - Most economical, least unknowns, fewest risks
    - Established successful program
  - Consider energy recovery
    - Recover 1 mW (¼ of plant's energy requirements)
  - Costs already included in current rate recommendations
- **Long Term (beyond 2030)** :
  - Revisit biosolids program
    - Monitor – technologies, regulations, localities, etc.
    - Diversify – multiple options for stabilization and/or disposal
    - Position – lay groundwork for this phase

Biosolids Program Rehabilitation Projects

Three Construction Phases

1 – Scrubber Equipment

2 – Solids Processing Rehabilitation, Early Delivery

3 – Solids Processing Rehabilitation, Main Contract

Phase 1 – Scrubber Equipment

- **Scope**: Air scrubber equipment for four existing multiple hearth furnaces (MHF).
- **Schedule**: Now –> June 2016
- **Budget**: $ 6 million
- **Key Concepts/Aspects**:
  - Expedited to aid in ensuring with compliance with EPA SSI MACT regulations

Phase 2 – Early Delivery

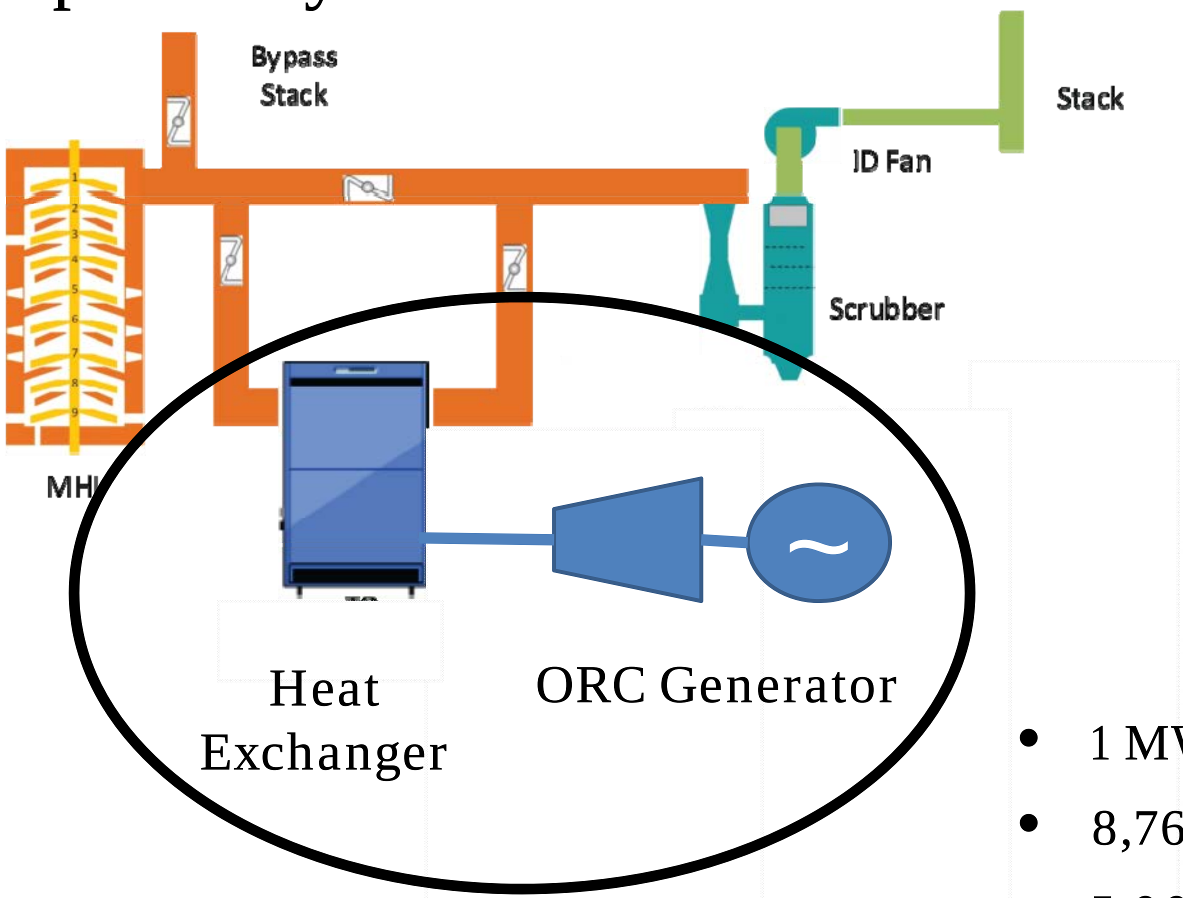
- **Scope**: Systems identified as highest risk (including: primary and scum system, sludge storage and mixing, lime addition system, odor control)
- **Schedule**: Now –> 2018
- **Budget**: $ 7 million
- **Key Concepts/Aspects**:
  – Systems selected based on infrastructure condition and risk associated with failure
  – Phasing aids in construction and financial planning

Phase 3 – Solids Processing Rehabilitation

- **Scope**: Remaining solids processing system rehabilitation and potentially energy recovery
- **Schedule**: Now –> 2020
- **Budget**: $ 78 million
- **Key Concepts/Aspects**:
  - Energy Recovery portion still being evaluated

Energy Recovery Evaluation

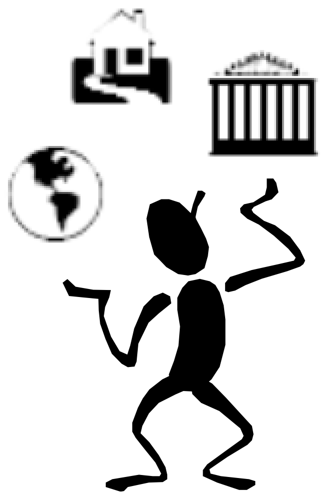
Proposed System



- 1 MW Renewable Energy
- 8,760,000 kwh
- 5,000 metric tons GHG reduction
- Equivalent to 1,000 homes

Energy Recovery – Decision Factors

- Production of renewable energy
- Reduction of greenhouse gases (GHGs)
- Impact on stakeholders, including ratepayers
- Environmental Policy
- Balancing Considerations
  - Practicing environmental stewardship
  - Exercising corporate stewardship
  - Building livable spaces



Energy Recovery Evaluation - Economic

- $12.7 million in additional capital cost
- $600,000 - $900,000 annual savings in energy costs
- Typical analysis: 3% discount rate, capital and O&M costs
- Goal: 10 year or less simple payback
- Multiple scenarios run:
  - Base Case
  - With higher energy costs
  - With and without grant funding ($1 million)
  - With additional solids from off site

Economic Evaluation Results: Payback time meets goal only if accepting biosolids received from off site

- What does "Off-site Biosolids" mean for the biosolids program at NMCPCP?
  - Maximize capital investment return of energy recovery equipment (use remaining 20% capacity)
  - One or two 30 cubic yard trucks per day coming into NMCPCP (compare to 25+ trucks of septage, chemicals & residuals)
  - Increases Regionalization of Wastewater Operations?

Energy Recovery Summary

- Energy recovery offers significant environmental benefits in a single project
- Economic Business case works with biosolids from offsite
- Other Factors need to be considered (regional cooperation, community)
- Wastewater Management Program perspective:
  - Without offsite solids – do not implement energy recovery at this time
  - With offsite solids – pursue with regional partners and report back to the board

Looking for endorsement on proposed path forward for energy recovery. Or …

Additional Information

For additional information, please contact:

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www.fairfaxcounty.gov/dpwes

Green Bay MSD

Selection of a Biosolids Management Approach to Meet GBMSD's Vision of Becoming a Leader in Sustainability

Tom Sigmund/GBMSD, Bill Angoli/GBMSD, Bill Desing/CH2M HILL

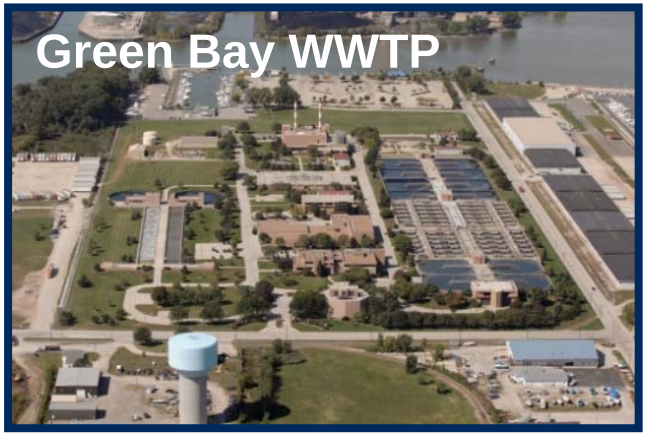
Central States Water Environment Association
83rd Annual Meeting

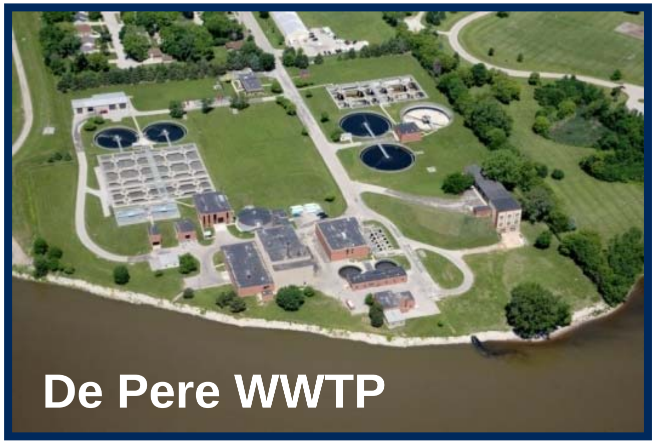
Green Bay Metropolitan Sewerage District
Cleaning Water Today For Tomorrow's Generations

CH2MHILL

GBMSD Facts

- Wastewater conveyance and treatment services
- 17 municipalities (219,000 pop) and 2 direct industrial customers
- Service area of 285 square miles
- Two WWTPs seven miles apart, discharging to Fox River
- Green Bay WWTP – 30 mgd, 45,300 lbs/day BOD
- De Pere WWTP – 8 mgd, 29,900 lbs/day BOD





GBMSD's Solids Management Challenges

- Two multiple hearth sludge incinerators (since 1975).
- Dewatered sludge contains more water (19-22% solids).
- Regulatory climate for air emissions is challenging.
- Addition of De Pere solids.
- Provide opportunities for GBMSD to partner with others on an innovative and sustainable approach to solids management.

Sustainability Emphasis Reflects Evolving GBMSD Role

- Wastewater management permit compliance
- Facilitation of economic development
- Efficient, reliable service delivery

Traditional Role

- Stakeholder engagement
- Holistic water quality approach
- Stormwater
- Environmental Stewardship

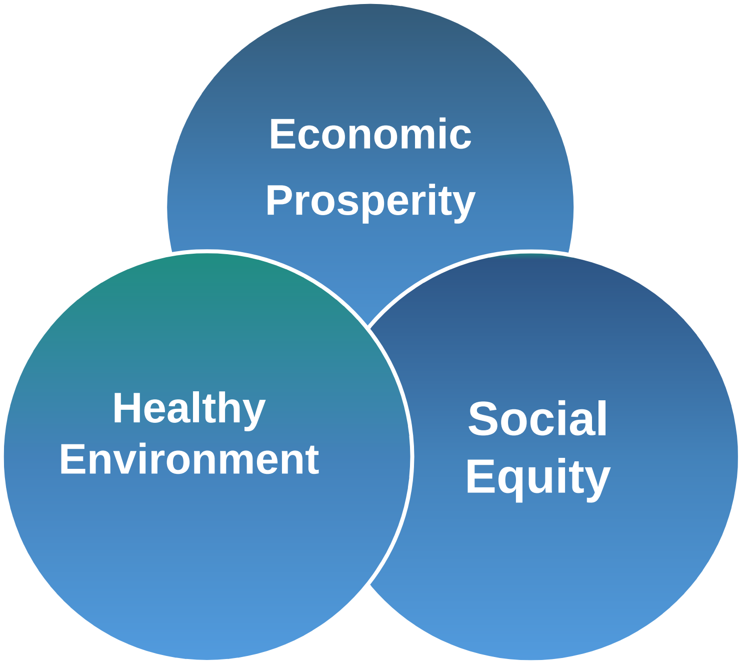
Emerging Role

- Affordability
- Social responsibility
- Sustainability
- Environmental Stewardship

Future Role

Solids Management Plan Vision Statement

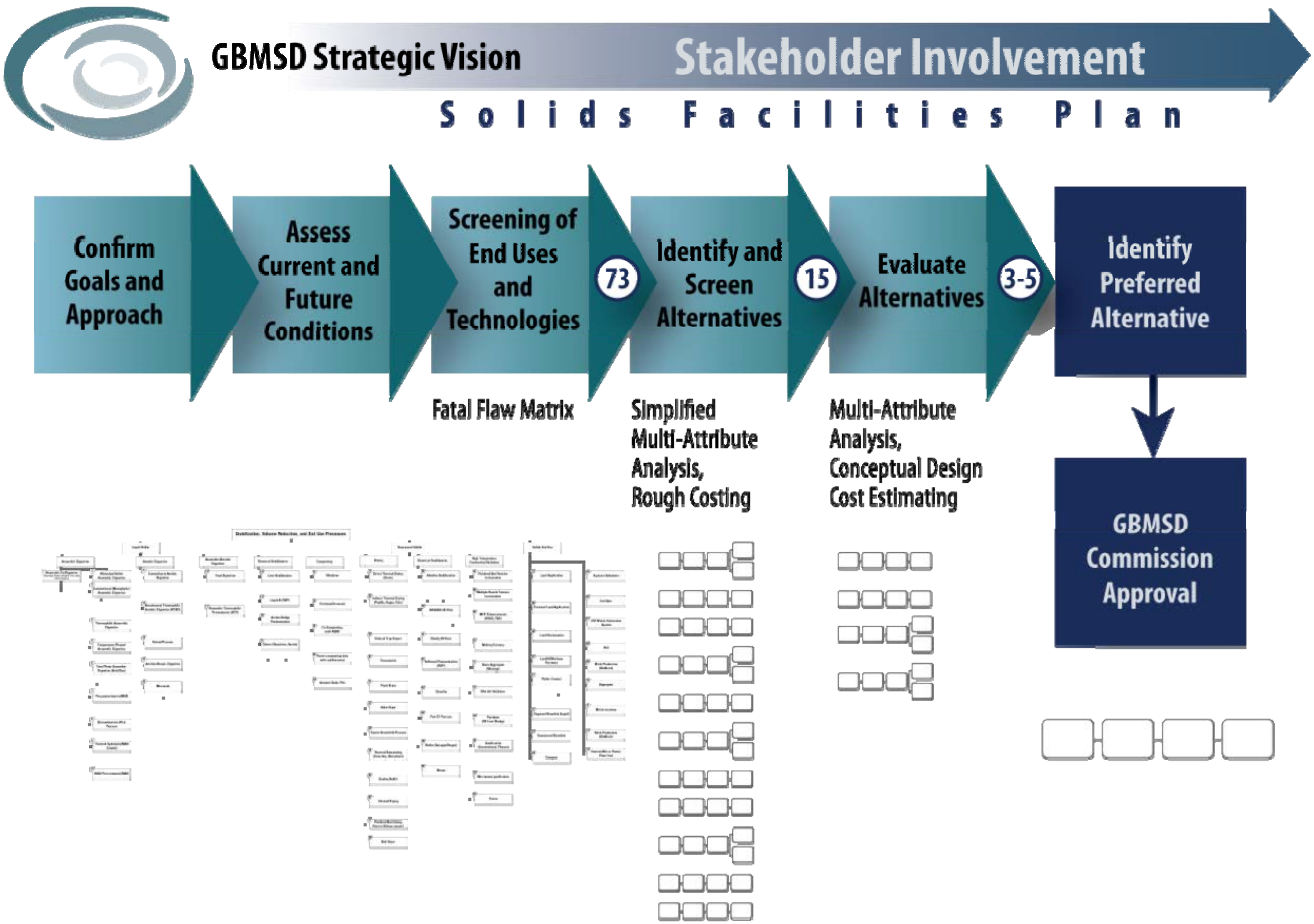
- Establish a regional Solids Management Plan using a sustainable approach for energy, air, and solids within the social, environmental, and economical values of our customers and stakeholders.



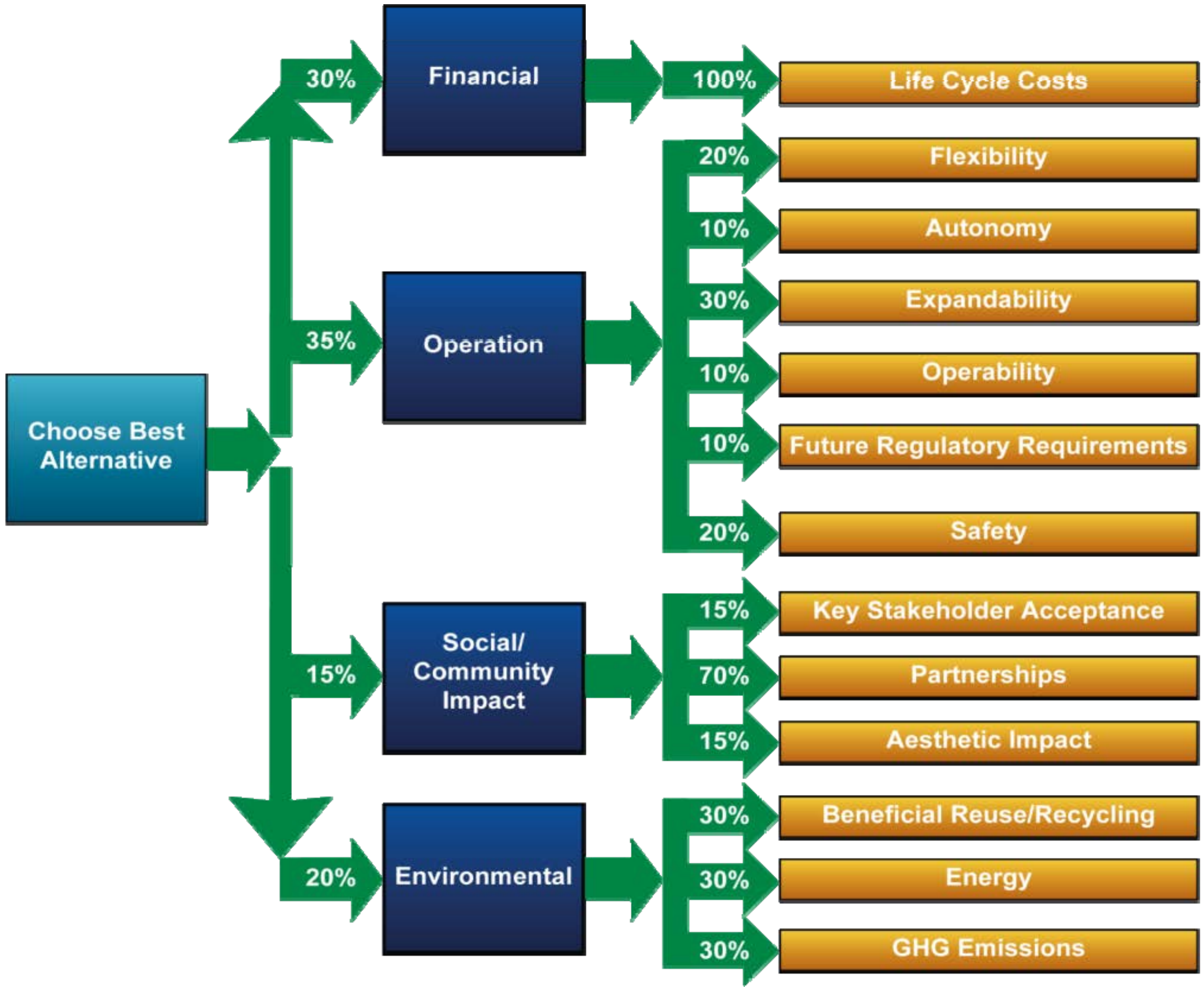
Solids Management System Fundamental Objectives

- **Financial:** Minimize the life-cycle costs.
- **Operations:** Safely performs at desired service levels and enables incremental expansion and re-alignment of process configurations under variable flow and load conditions.
- **Social/Community Impacts:** Promote stakeholder acceptance and support of partnering and education and limit adverse aesthetic impacts.
- **Environmental:** Minimize impacts on the environment by maximizing beneficial reuse/recycling and minimizing energy consumption and greenhouse gas emissions.

Project Approach

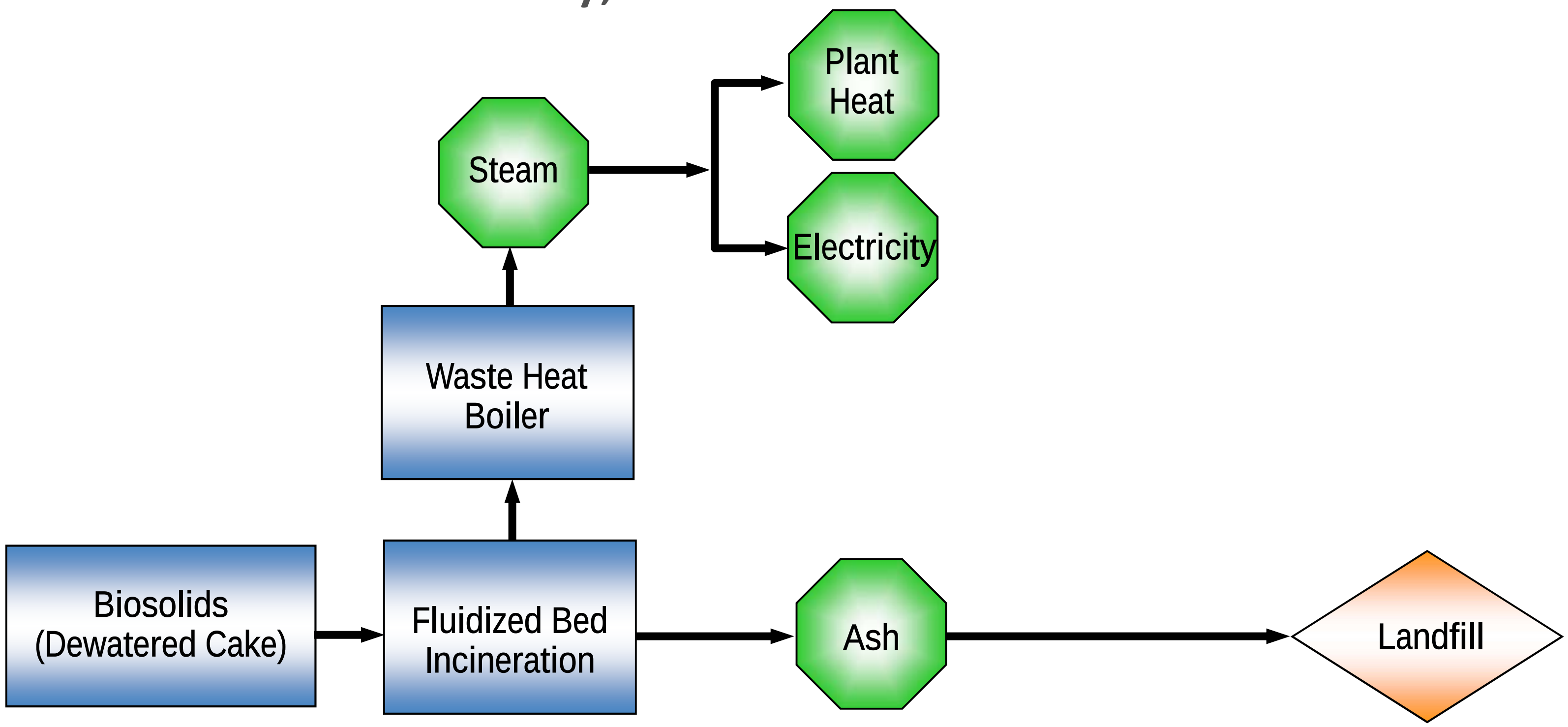


Multi-Attribute Utility Analysis used for Alternative Selection



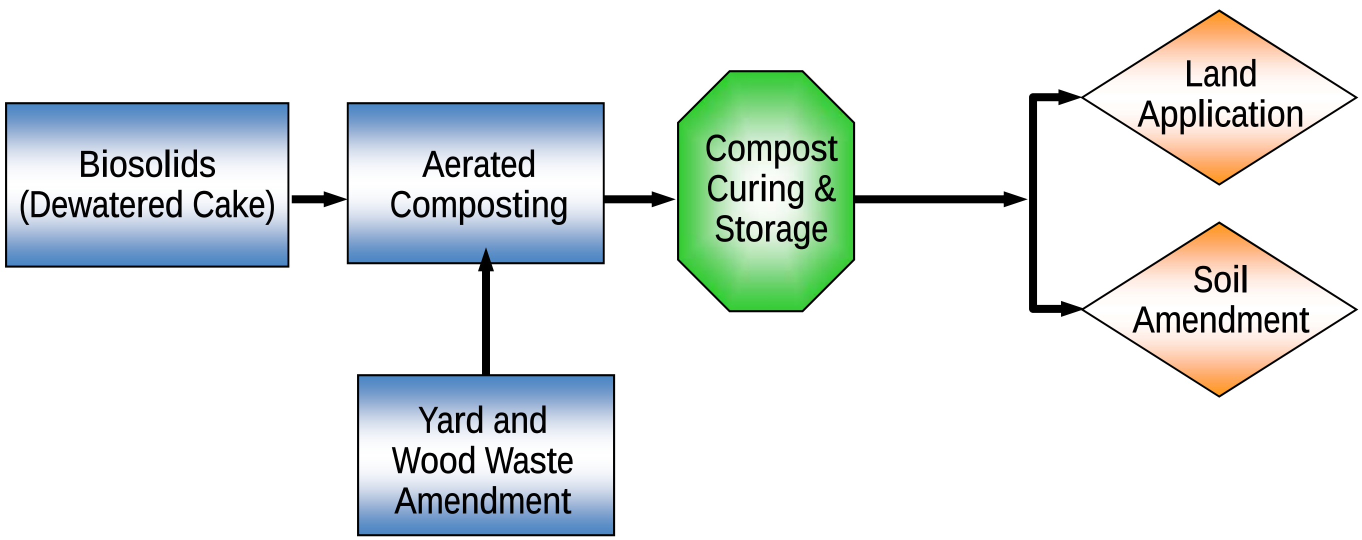
Alternative 2 – Incineration with Energy Recovery

- Main process – incineration
- Product – electricity, ash



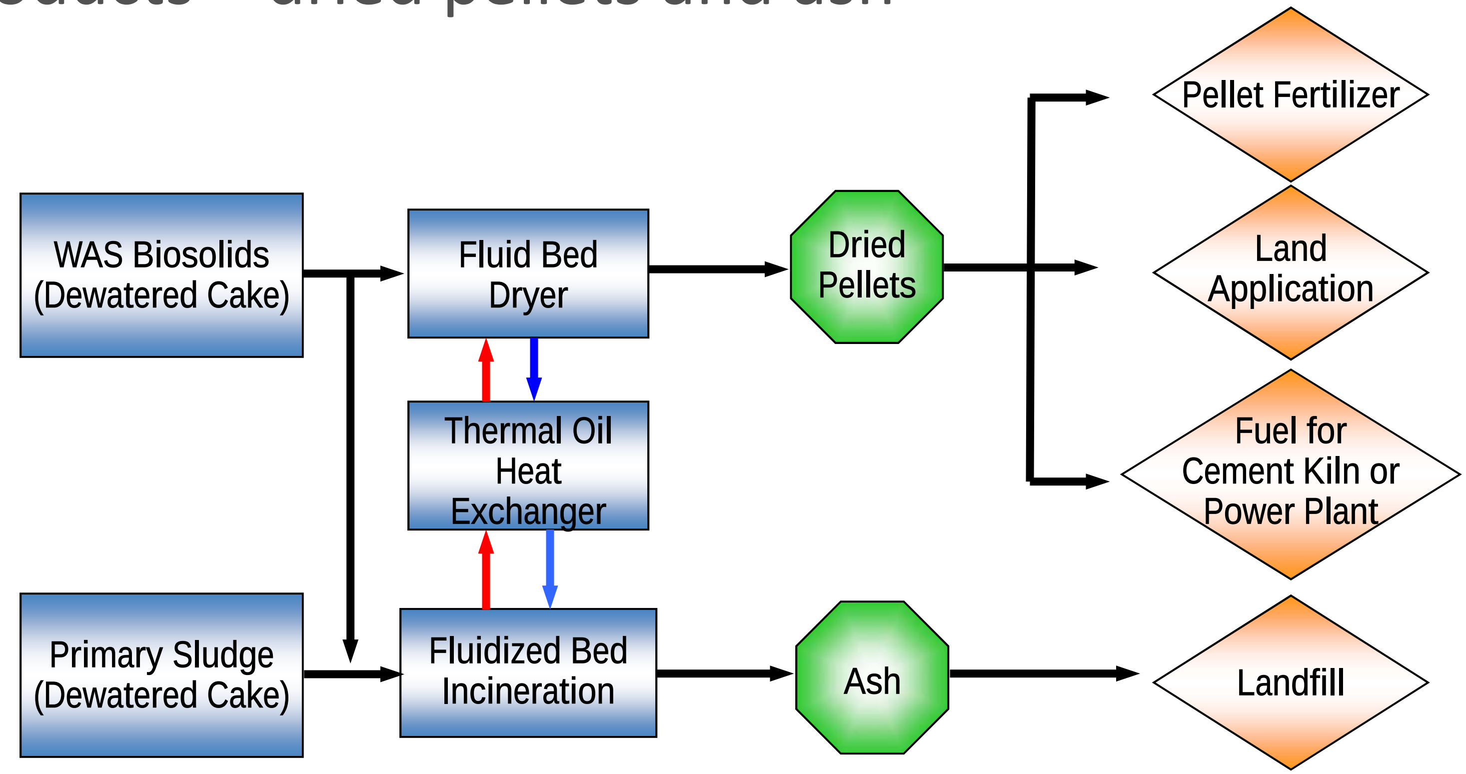
Alternative 11 – Conventional Composting

- Main process – composting
- Product – compost



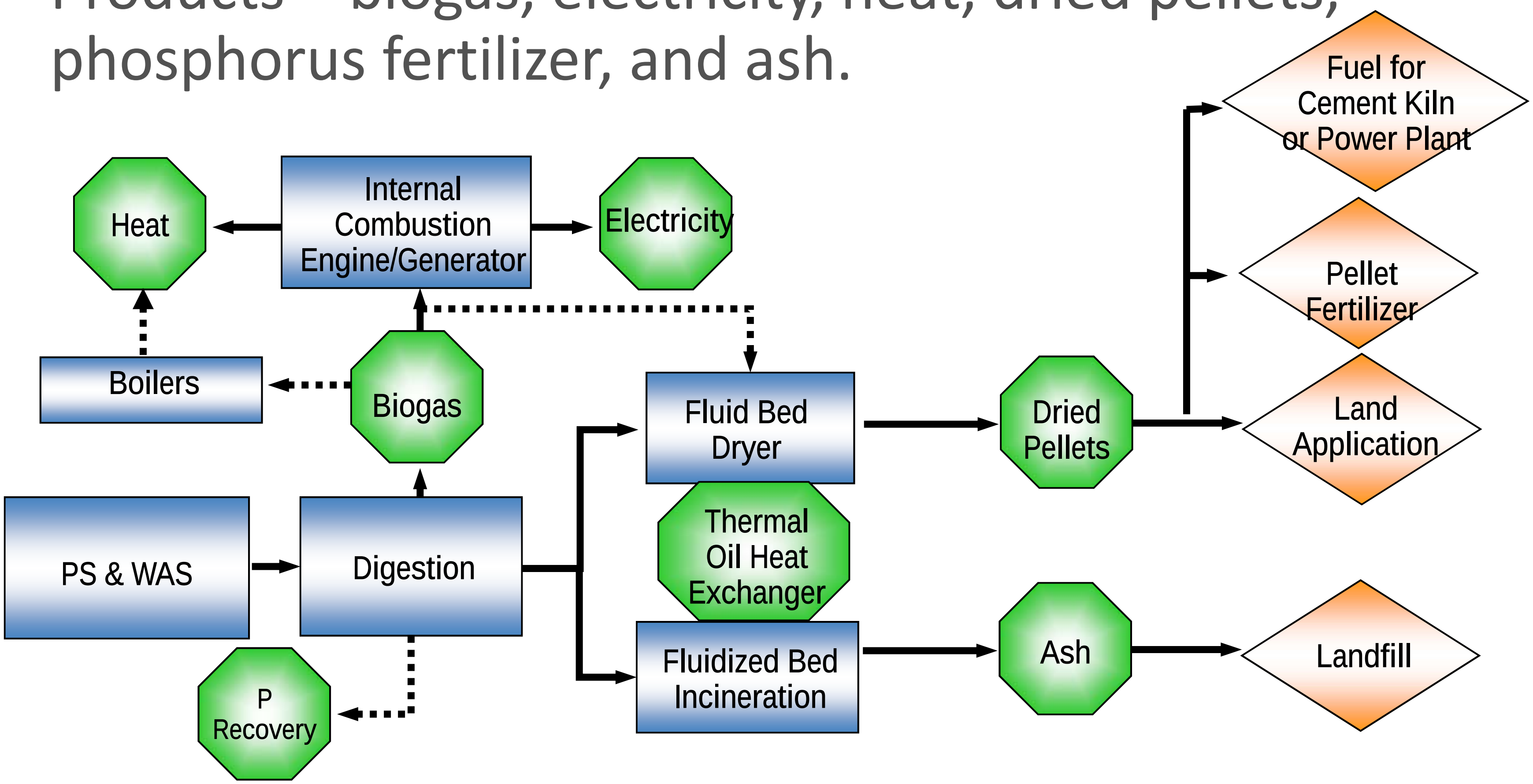
Alternative 14 – Incineration with Drying

- Main processes – drying and incineration
- Products – dried pellets and ash



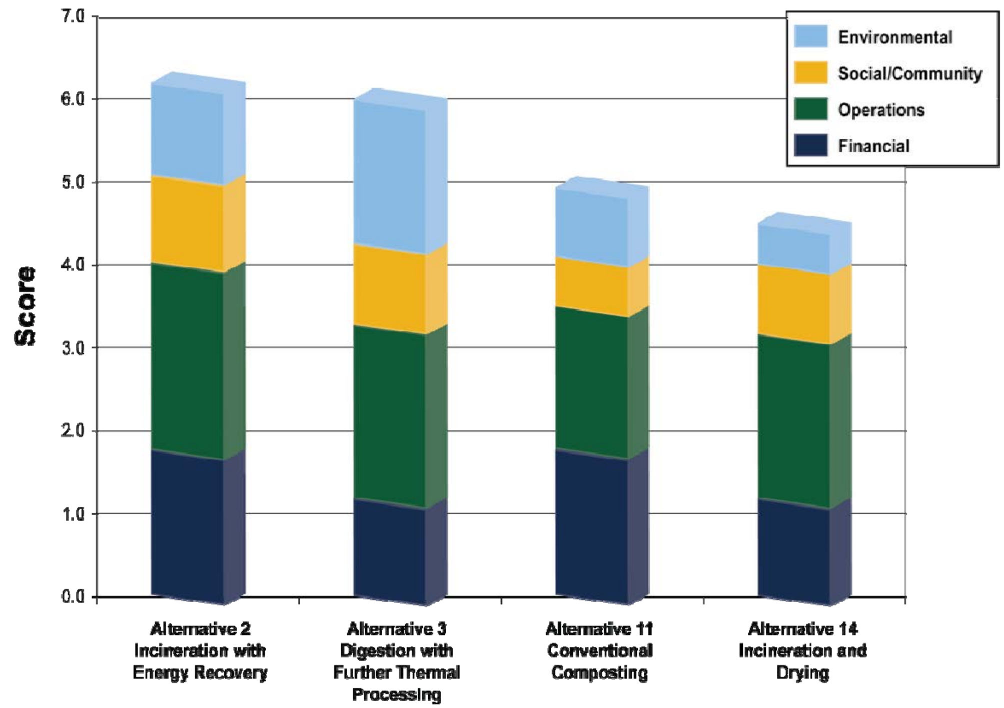
Alternative 3 – Digestion with Further Thermal Processing

- Main processes – digestion, incineration, and drying (waste heat from incinerator is used in dryer).
- Products – biogas, electricity, heat, dried pellets, phosphorus fertilizer, and ash.



Recommended Alternative

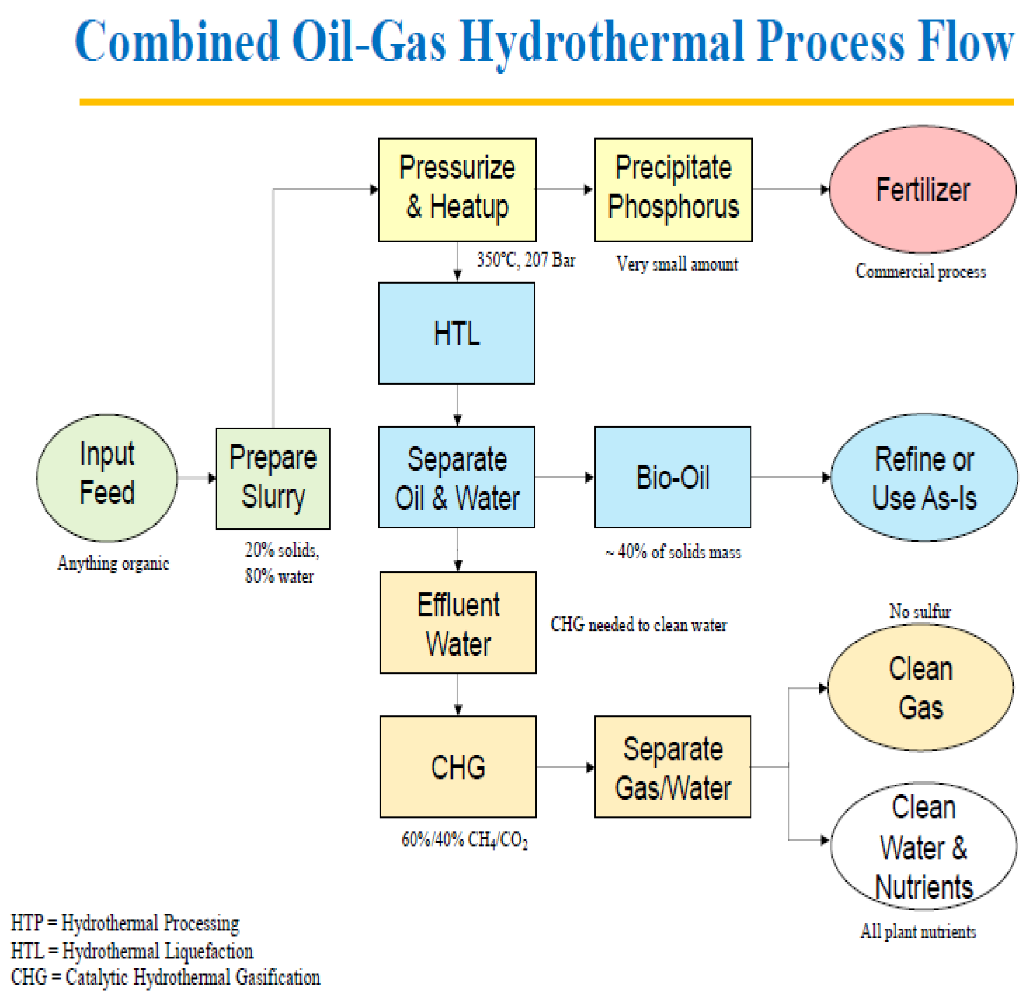
- Alternatives 2 and 3 essentially equal
- Alternative 3 selected: better alignment with GBMSD's strategic plan goals:
  - Supports economic development
  - Promotes environmental stewardship
  - Provides diverse quality services
  - Provides opportunities for staff career development



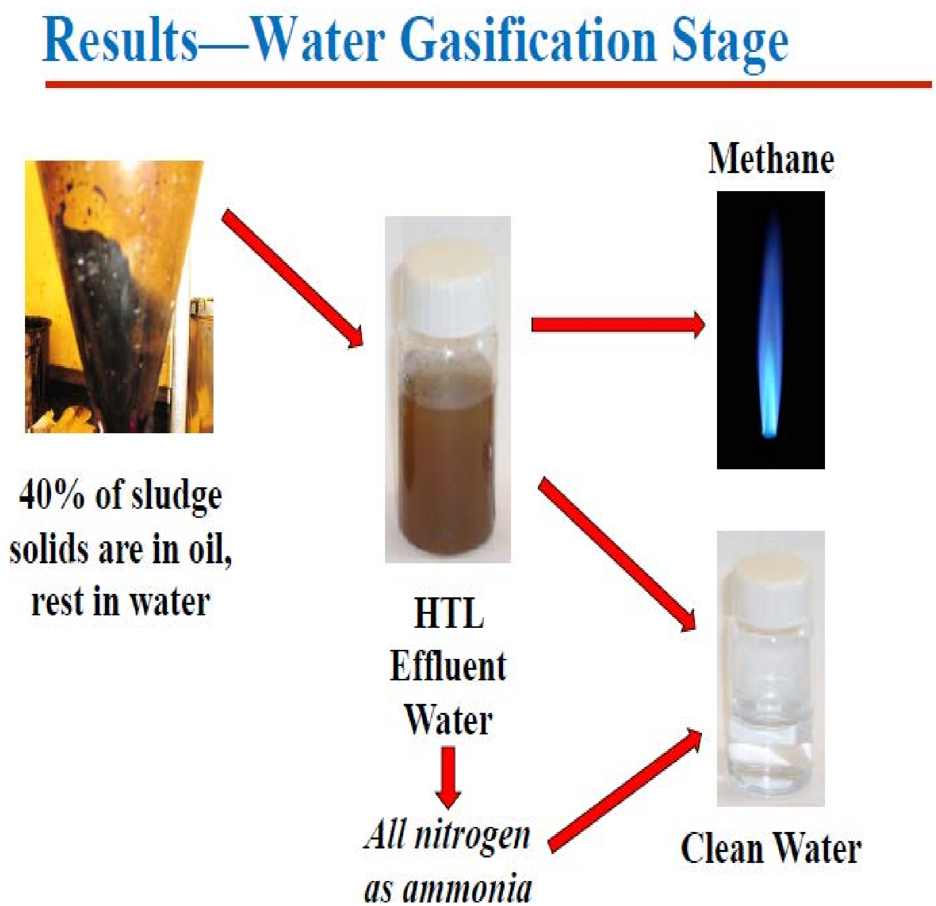
Conceptual Design of R2E2 under Construction

Genifuel

Embryonic
Genifuel - Hydrothermal Liquefaction



Genifuel Status



- Proof of Concept Bench testing at Pacific Northwest National Laboratory
- Bench Tested Primary, Waste Activated and Digested Sludges
- Yield of 25-37% crude oil on mass basis, 39-59% on carbon basis
- High methane content (>75%) in gas
- Metro Vancouver is participating
- Looking for full scale demonstration

Genifuel System

Genifuel System and Biocrude

Summary of Results

Test No.	Sludge Feed	Feed Conc. (wt% solids)	Feed Flow Rate (L/hr)	Reaction Temperature (°C)[a]	Avg. System Pressure (psig)	Liquid Hourly Space Velocity (hr^{-1})[b]	Test Duration			No. of Steady State Liquid Samples (Set-asides)
							Total Feed (hrs)	Baseline steady state (hrs)[c]	RLD steady state (hrs)[c]	
2	Primary	11.9	1.5	318-353	2948	2.1	7.4	2.0	1.5	3
3	Secondary	9.7	1.5	276-358	2919	2.1	7.5	2.0	1.0	3
4[d]	Post-digester	16.0	1.5	332-358	2906	1.2	7.2	2.7	1.5	4

	Primary Sludge	Secondary Sludge	Post-digester Sludge
HTL Biocrude Yield:			
Total mass basis	37.3%	24.8%	34.4%
Carbon basis	59.3%	38.8%	48.7%
CHG Methane Yield (carbon basis)	31.6%	60.3%	56.3%
Total Mass Balance:			
HTL	101%	103%	107%
CHG	93%	95%	88%
Carbon Balance:			
HTL	94%	97%	111%
CHG	67%	99%	88%
Chemical Oxygen Demand (mgO_2/L):			
Sludge Feed	187,000	153,000	203,000
CHG Aqueous Product	54	25	19

- The HTL process is capable of generating separable biocrude from primary and post-digester sludge at yields (34-37%) that are significant with respect to potential revenue to a project, even with feed concentrations that have not been optimized with respect to solids concentration.
- Based on PNNL tests with other feeds, higher solids concentrations in the feed would be expected to generate higher yields
- Wet biomass dewatered between 15%-20% solids.

Defining boundary conditions – Rules to make decisions by

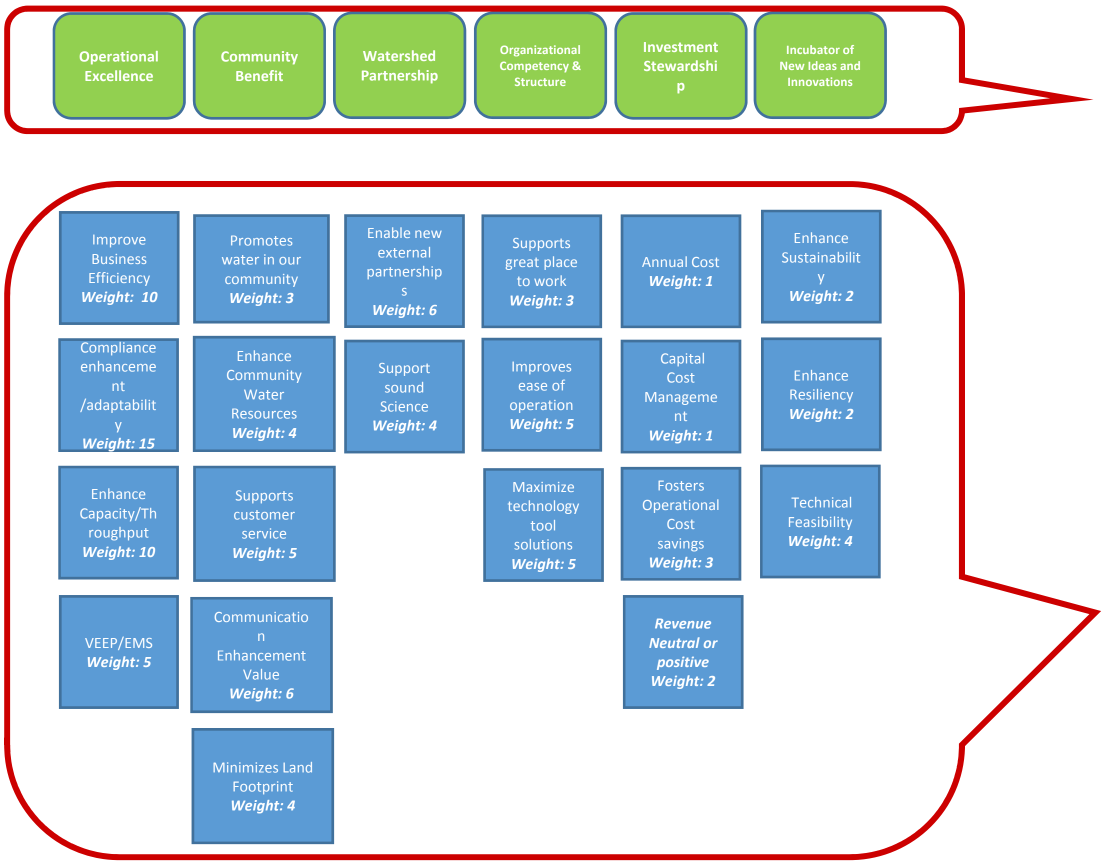
Presentation by Julian Sandino

Decision Model Provides Boundaries for the Strategic Alignment of Planning Effort

Operational Excellence	Community Benefit	Watershed Partnership	Organizational Competency & Structure	Investment Stewardship	Incubator of New Ideas and Innovations
Improve Business Efficiency ***Weight: 10***	Promotes water in our community ***Weight: 3***	Enable new external partnerships ***Weight: 6***	Supports great place to work ***Weight: 3***	Annual Cost ***Weight: 1***	Enhance Sustainability ***Weight: 2***
Compliance enhancement /adaptability ***Weight: 15***	Enhance Community Water Resources ***Weight: 4***	Support sound Science ***Weight: 4***	Improves ease of operation ***Weight: 5***	Capital Cost Management ***Weight: 1***	Enhance Resiliency ***Weight: 2***
Enhance Capacity/Throughput ***Weight: 10***	Supports customer service ***Weight: 5***		Maximize technology tool solutions ***Weight: 5***	Fosters Operational Cost savings ***Weight: 3***	Technical Feasibility ***Weight: 4***
VEEP/EMS ***Weight: 5***	Communication Enhancement Value ***Weight: 6***			***Revenue Neutral or positive Weight: 2***	
	Minimizes Land Footprint ***Weight: 4***				

ALEXANDRIA renew ENTERPRISES

Strategic Elements Help Screen Out and Select Amongst Alternatives



Develop Short Lists: Screening out from "universe" of alternatives (Qualitative basis)

Differentiate between viable options: Comparative evaluation of selected alternatives (Quantitative basis)

Identifying alternative technology pathways towards the envisioned future

Group Exercise Facilitated by
Glen Daigger and Julian Sandino

Identifying alt
technology pa
the envisione

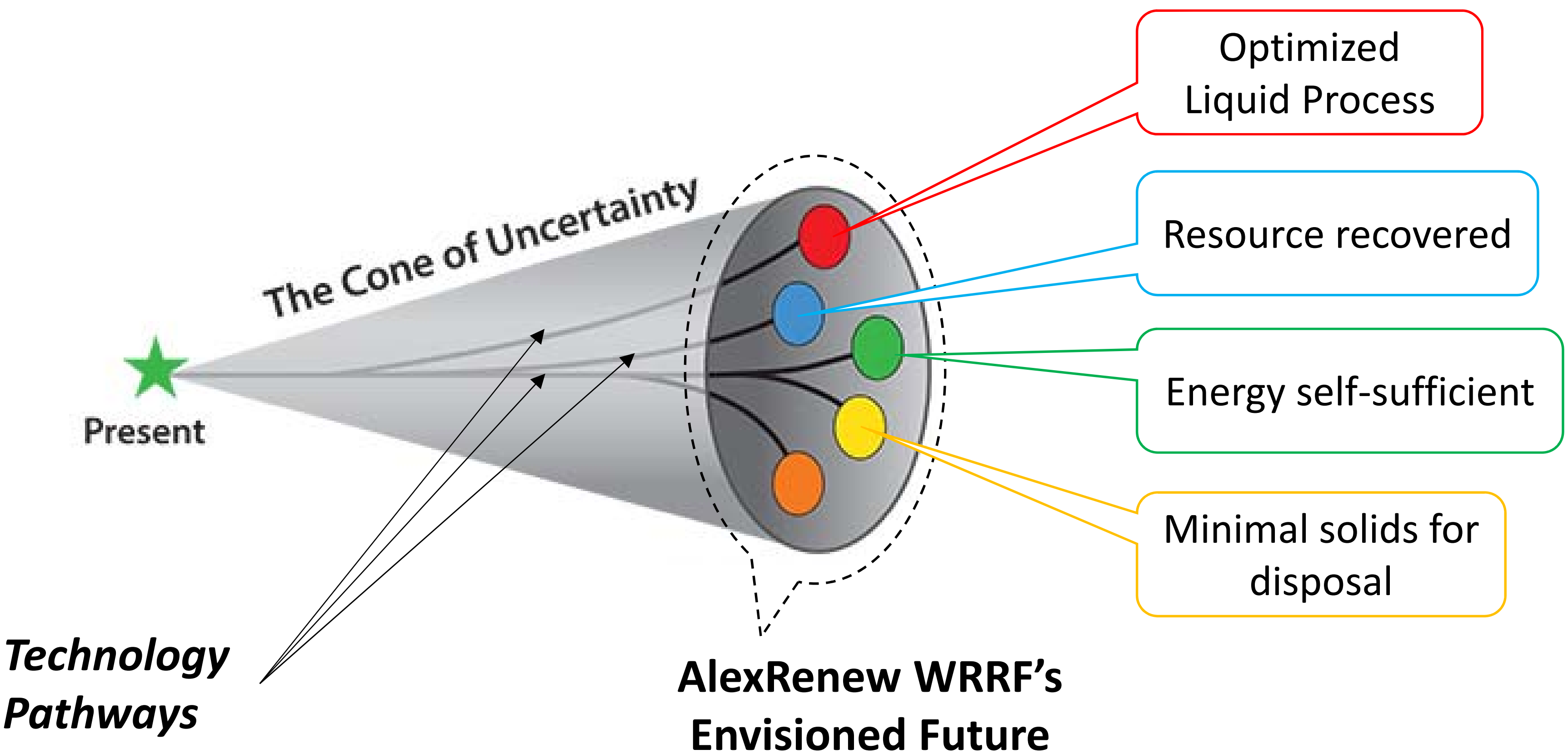
Group Exercise Facilitated by
Glen Daigger and Julian Sandino

Technical Attributes of an Envisioned 2040 AlexRenew WRRF

- **Liquid processes have been optimized**
  - Mainstream deammonification being fully leveraged
  - Carbon redirection (enhanced primary treatment)
  - Bio P conversion (allows P recovery as struvite)
  - Other (Embryonic):
    - MAMBR (Zeelung) for reducing energy consumption
    - RAS Screening to remove inert fibers
    - Other?
- **Residuals leaving plant have been minimized**
  - Minimize land disposal as outlet
  - Minimize transportation requirements
  - Minimize odors
  - Minimize handling needs
- **Resources are being recovered**
  - Water (reclaimed effluent for reuse - a portion)
  - Energy
  - Phosphorus
  - Other (Embryonic)
    - Sludge to oil
    - Bioplastics from biogas
    - Other?

Scenario planning: How do we get from *Now* to an uncertain *Then*

Technology Attributes



A. Restrictive Regulations
B. Sustainability Embraced
C. Engaged Stakeholders

Technology Pathways: alternatives routes to get us from here (today) to there (2040)

- Example: Anaerobic digestion
  - Builds upon existing facilities
  - Reduces solids for disposal
  - Allows energy recovery
  - Facilitates P recovery from sidestream
  - Several ways to enhance it (sub-alternatives)
- What others ????? (Group exercise)

Configuring viable alternative process configurations: selection of unit process building blocks for identified technology pathways

Presentation by Todd Williams followed by Breakout Group Exercise

Breakout groups:

A. Nematodes
B. Filaments
C. Mites

Identifying viable technology unit process “building blocks”

Biosolids Stabilization Technologies

- Pre-Digestion Conditioning or Hydrolysis
  - Pre- pasteurization
  - Aerobic Thermophilic Pretreatment (ATP)
  - Pulsed Electric Hydrolysis
  - Thermal Hydrolysis (Steam)
  - Thermal Hydrolysis (No Steam)
  - Chemical/Thermal Hydrolysis
  - Biological (Acid) Hydrolysis
  - Intermediate Thermal Hydrolysis
  - Solid Stream Thermal Hydrolysis
- Anaerobic Digestion
  - Conventional (Mesophilic) Anaerobic Digestion (MAD)
  - Temperature Phased Anaerobic Digestion (TPAD)
  - Thermophilic Anaerobic Digestion
  - MAD with Post Aerobic Digestion
  - Recuperative Thickening
  - High Solids Digestion
  - Multi-Stage Digestion
- Aerobic Digestion
  - Conventional Aerobic Digestion
  - Auto-Thermophilic Aerobic Digestion (ATAD)
  - Aerobic/Anoxic Digestion
- Composting
  - Windrow
  - Enclosed/ In-vessel
  - Aerated Static Pile
  - Vermi-Composting (mix with earthworms)
  - Membrane Covered Pile
  - Hybrid Compost Systems
- Drying
  - Direct Thermal Drying (Drum, Belt)
  - Indirect Thermal Drying (Paddle, Auger. Disc.)
  - Vertical Tray Dryers
  - Flash Dryer
  - Solar Drying (greenhouse or open air)
  - Fluidized Bed Drying
- Chemical Stabilization
  - Alkaline Stabilization
  - Lime & Heat Stabilization (EnVessel Pasteurization By RDP)
  - Lime & Acid Stabilization (Schwing Bioset)
  - Low temp Chemical-Mechanical Hydrolysis (Lystek)
  - Chemical Stabilization (NuTerra)
  - Chemical Treatment and Drying (VitAg/Anuvia)
- High Temperature Combustion/ Oxidation
  - Fluidized Bed Reactor Incinerator
  - Multiple Hearth Furnace Incineration
  - Super-Critical Wet Oxidation
  - Pyrolysis
  - Gasification
  - Hydrothermal Liquefaction
  - Dryer/Furnace

Emerging Technologies for Biosolids Management as Defined by the USEPA

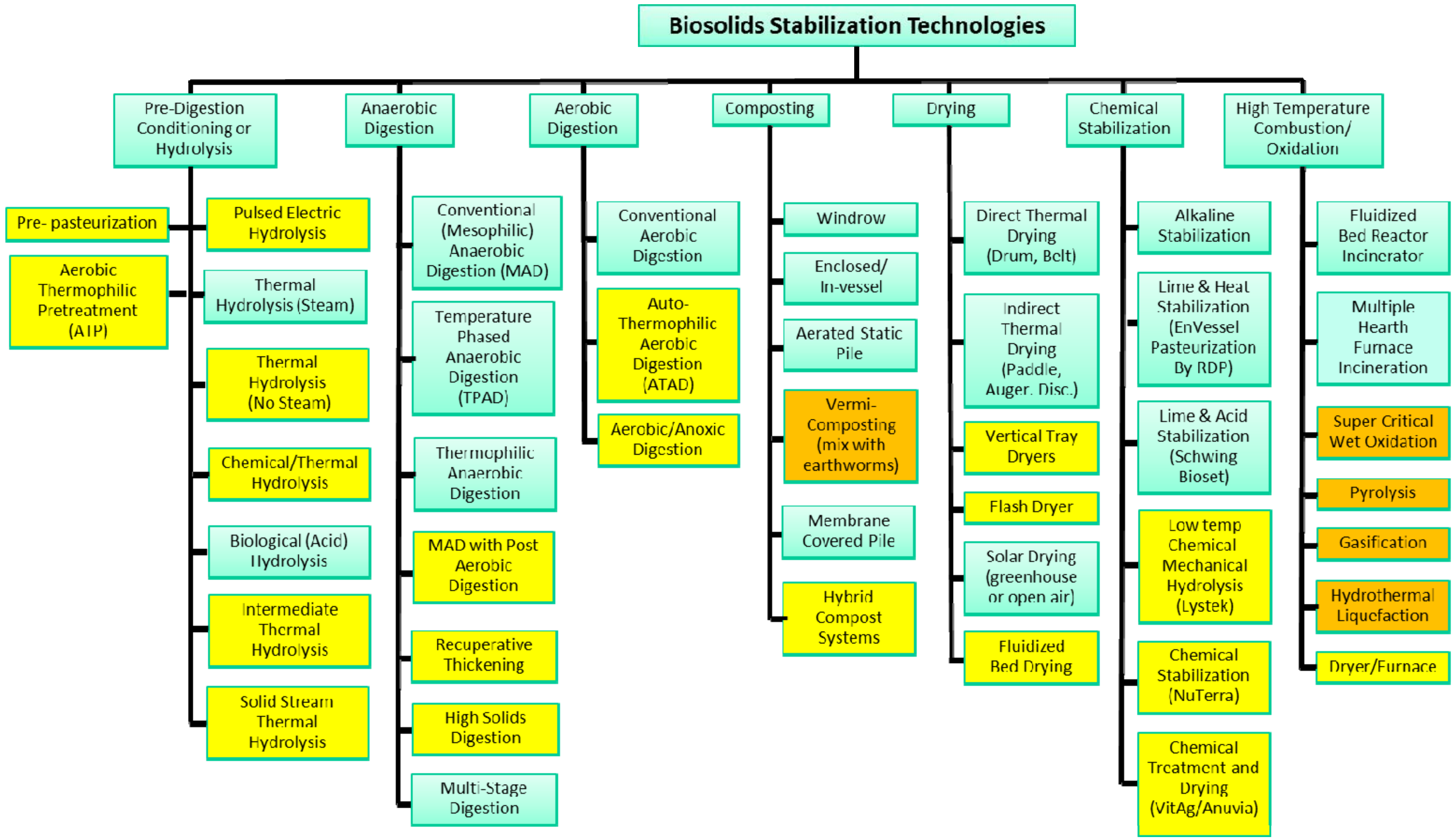
- **Established** – *Technologies widely used (i.e. generally more than 25 facilities) are considered well established.*
- **Innovative** – *Technologies meeting one of the following qualifications: (1) have been tested at a full-scale demonstration site; (2) have been available and implemented for less than 5 years; (3) have some degree of initial use i.e. implemented in less than twenty-five utilities.*
- **Embryonic** – *Technologies in the development stage and/or tested at laboratory or bench scale. New technologies that have reached the demonstration stage overseas, but cannot yet be considered to be established there, are also considered to be embryonic with respect to North American applications*

Status of Biosolids Management Technologies

Established

Innovative

Embryonic



Short listing technologies by applying “fatal flaw” analysis

- Large footprint
- High energy consumption
- High residuals production
- Unproven at scale considered
- Others?

Breakout Groups: Configure Technology Pathways Using Biosolids Unit processes

- One breakout group per "Technology Pathway" identified
- Use biosolids management options and supporting unit processes to configure each pathway. Include liquid treatment train components if warranted
  - Rely primarily on "established/innovative" technologies
  - Identify where "embryonic" technologies would fit if eventually proven viable (potential R&D target)
- Example: let's do one before we split into groups
  - Anaerobic digestion
- Breakout groups to report back

Action Items and Next Steps

Summary by Rich Voigt

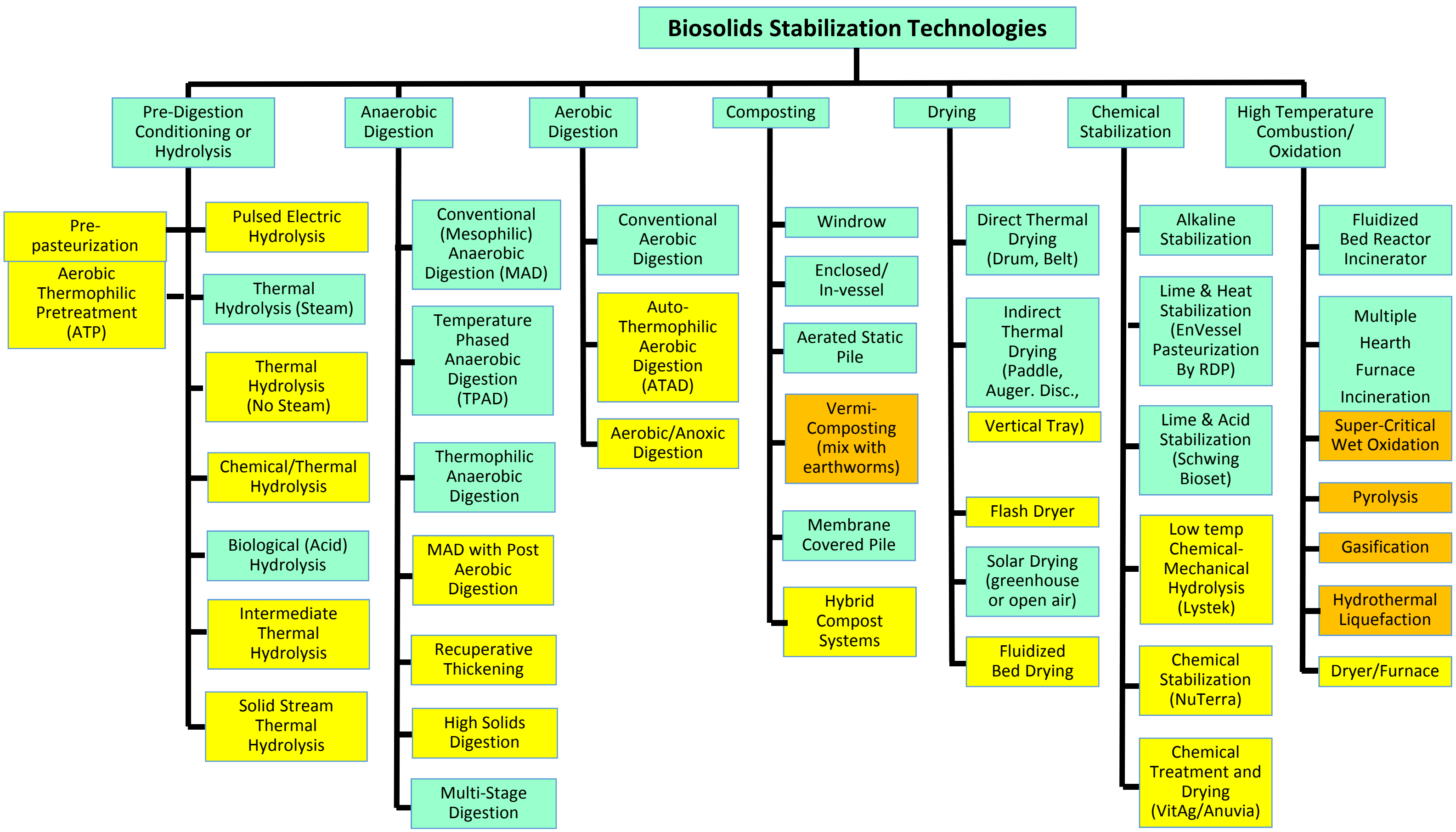
Defining Viable Technology Pathways Towards an Envisioned Future – Group Exercise Summary

Status of Biosolids Management Technologies

Established

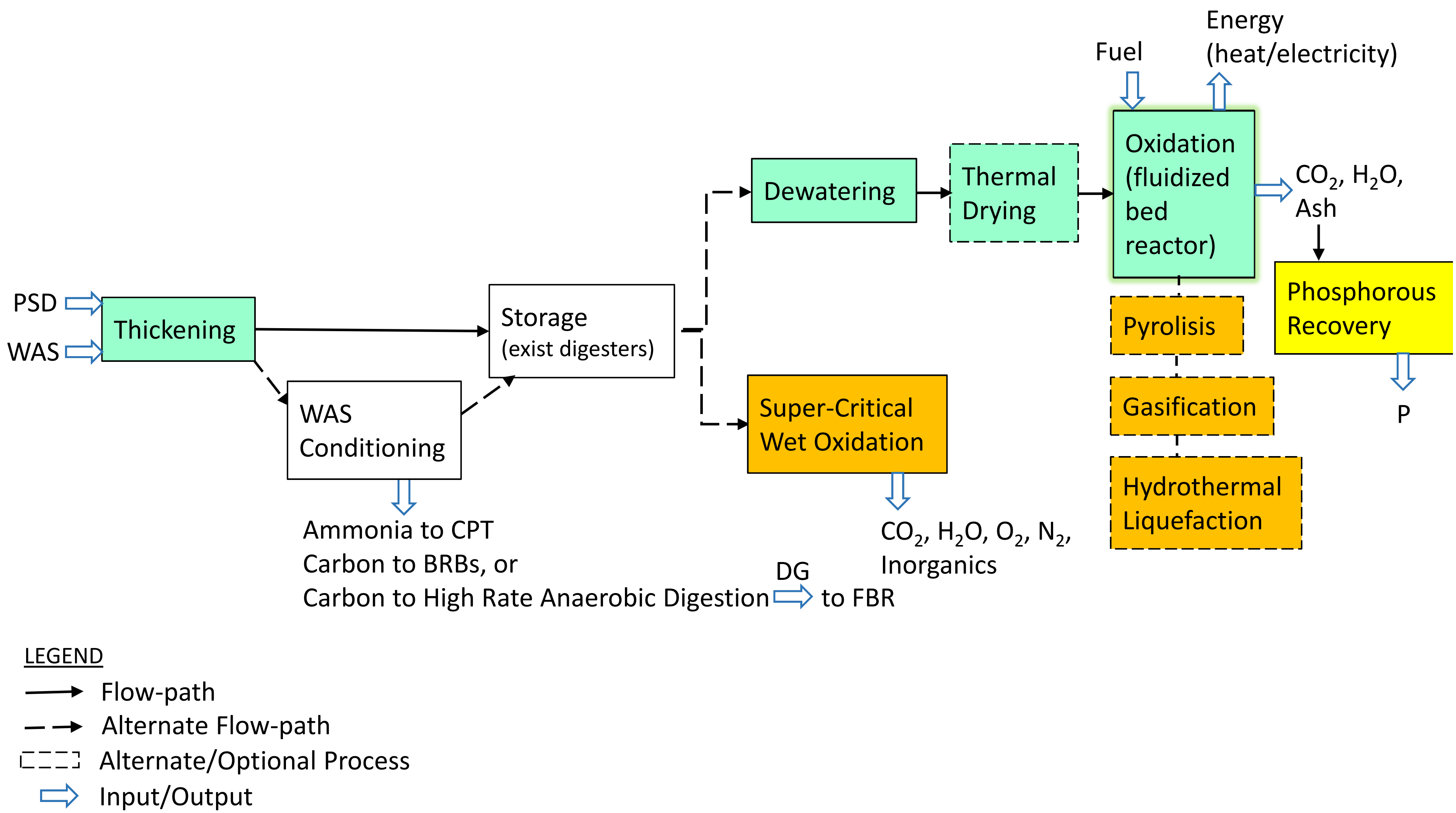
Innovative

Embryonic



Nematodes – Thermal Oxidation

Established
Innovative
Embryonic

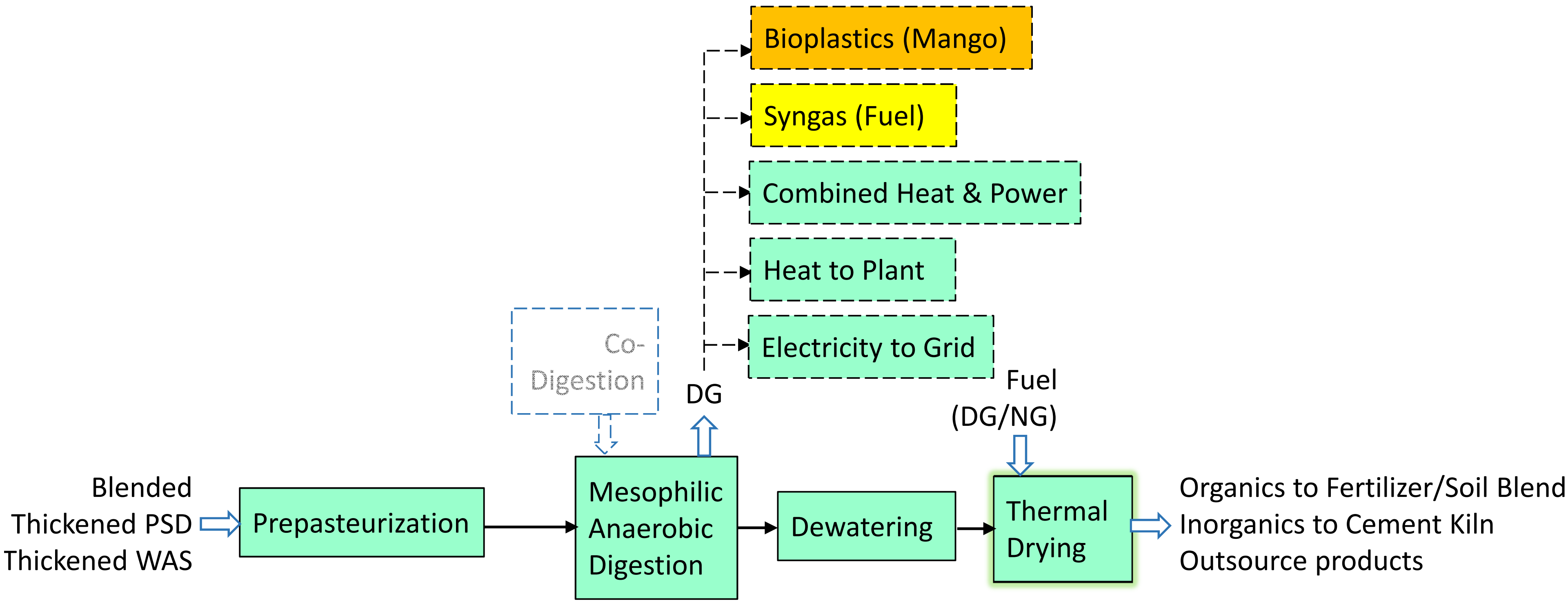


Filaments – Drying

Established

Innovative

Embryonic



LEGEND

Flow-path

Alternate Flow-path

Alternate/Optional Process

Input/Output

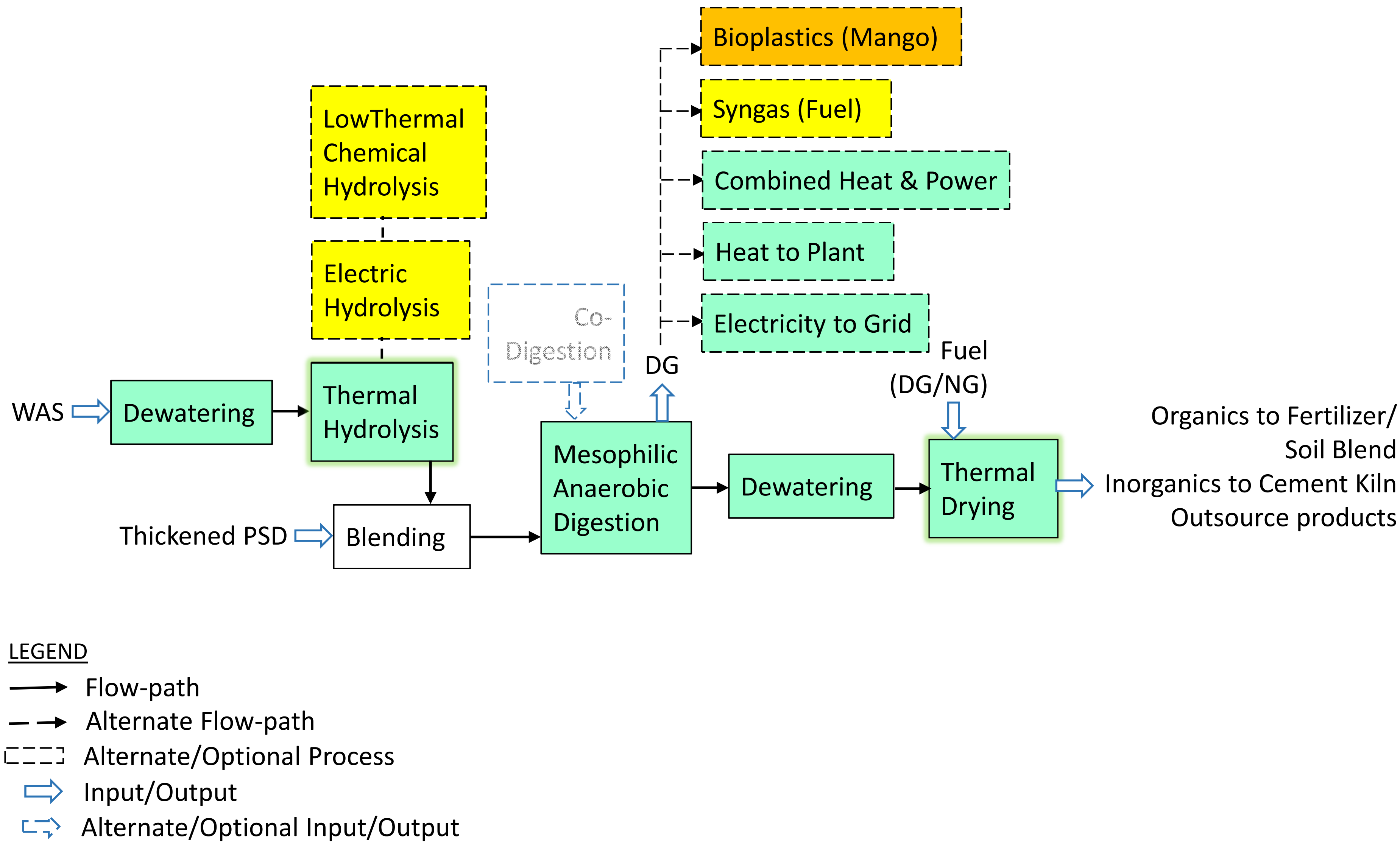
Alternate/Optional Input/Output

Filaments – Drying (WAS pre-conditioning)

Established

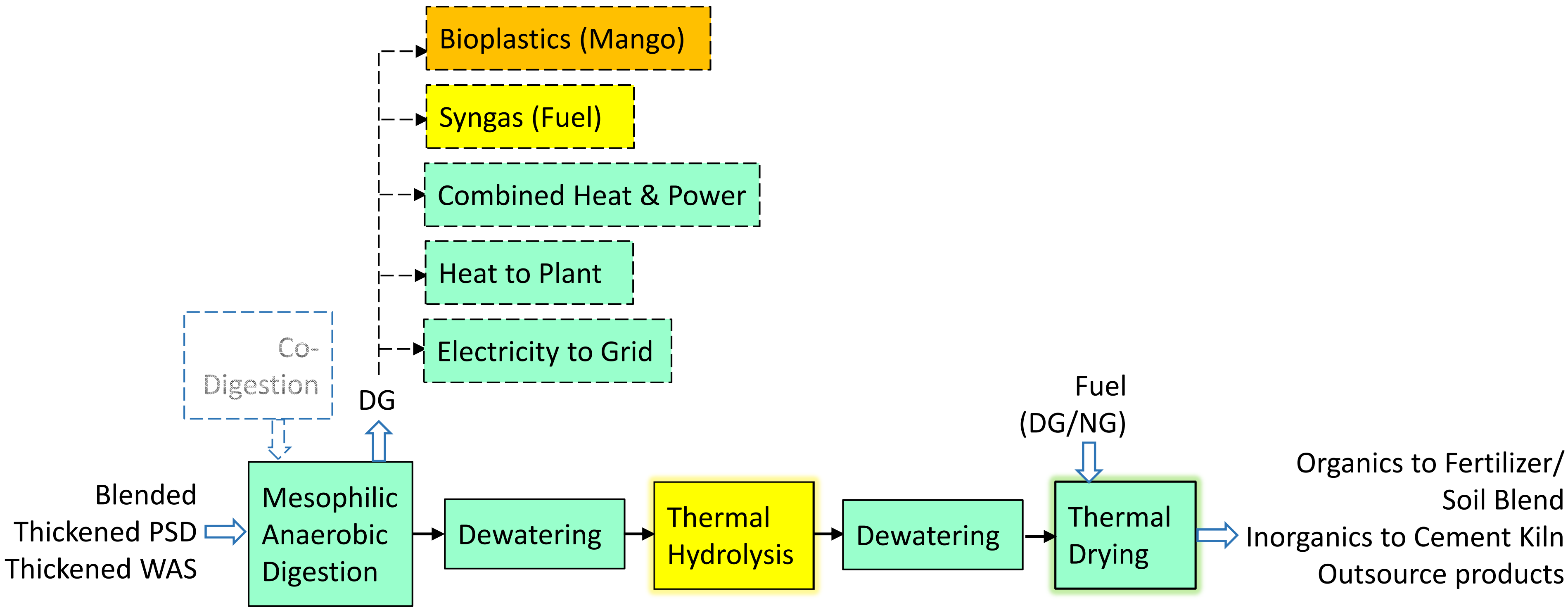
Innovative

Embryonic



Filaments – Drying (post-hydrolysis)

Established
Innovative
Embryonic



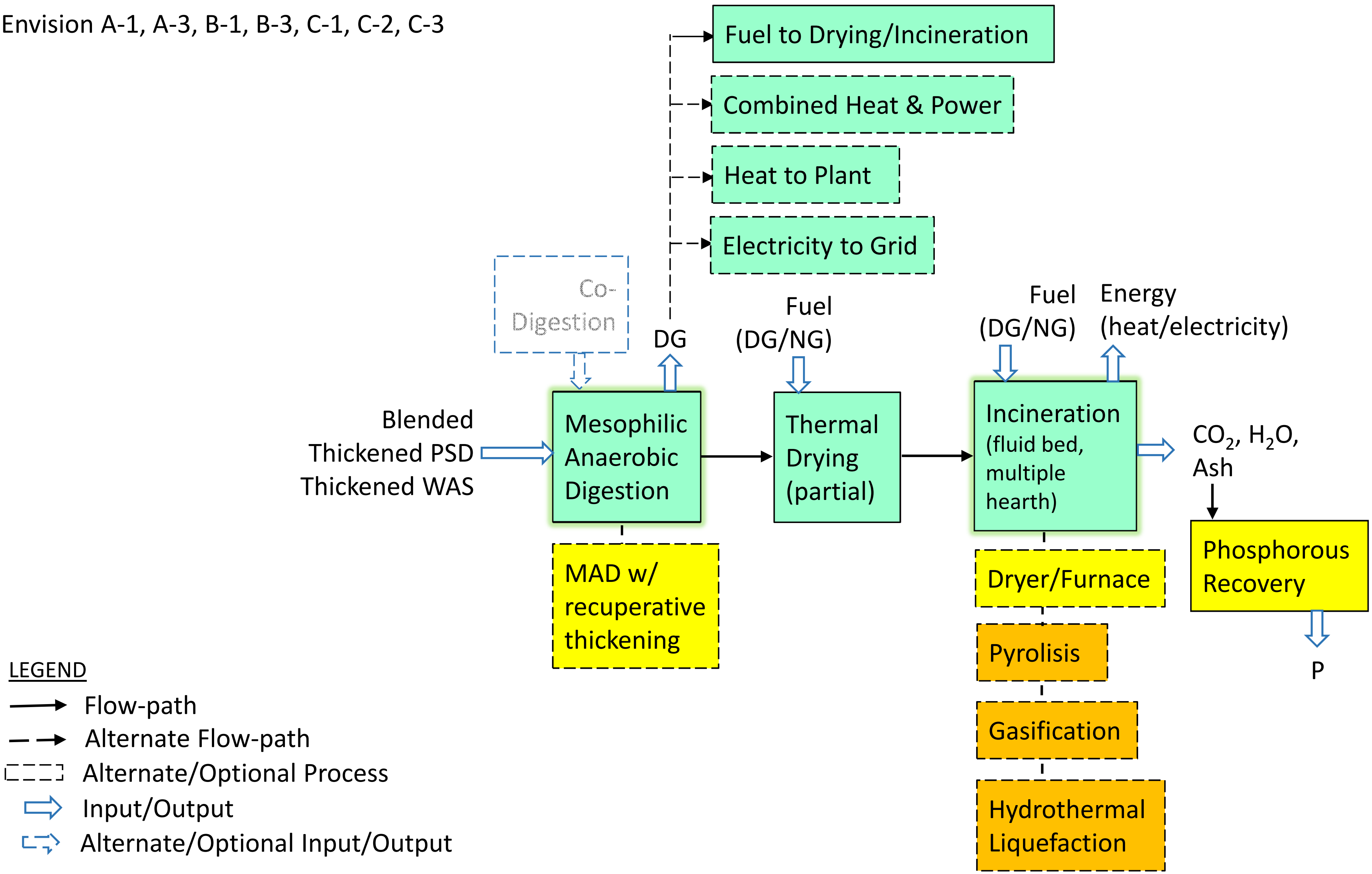
LEGEND

- Flow-path
- Alternate Flow-path
- Alternate/Optional Process
- Input/Output
- Alternate/Optional Input/Output

Mites – Combo Anaerobic Digestion & Thermal Oxidation

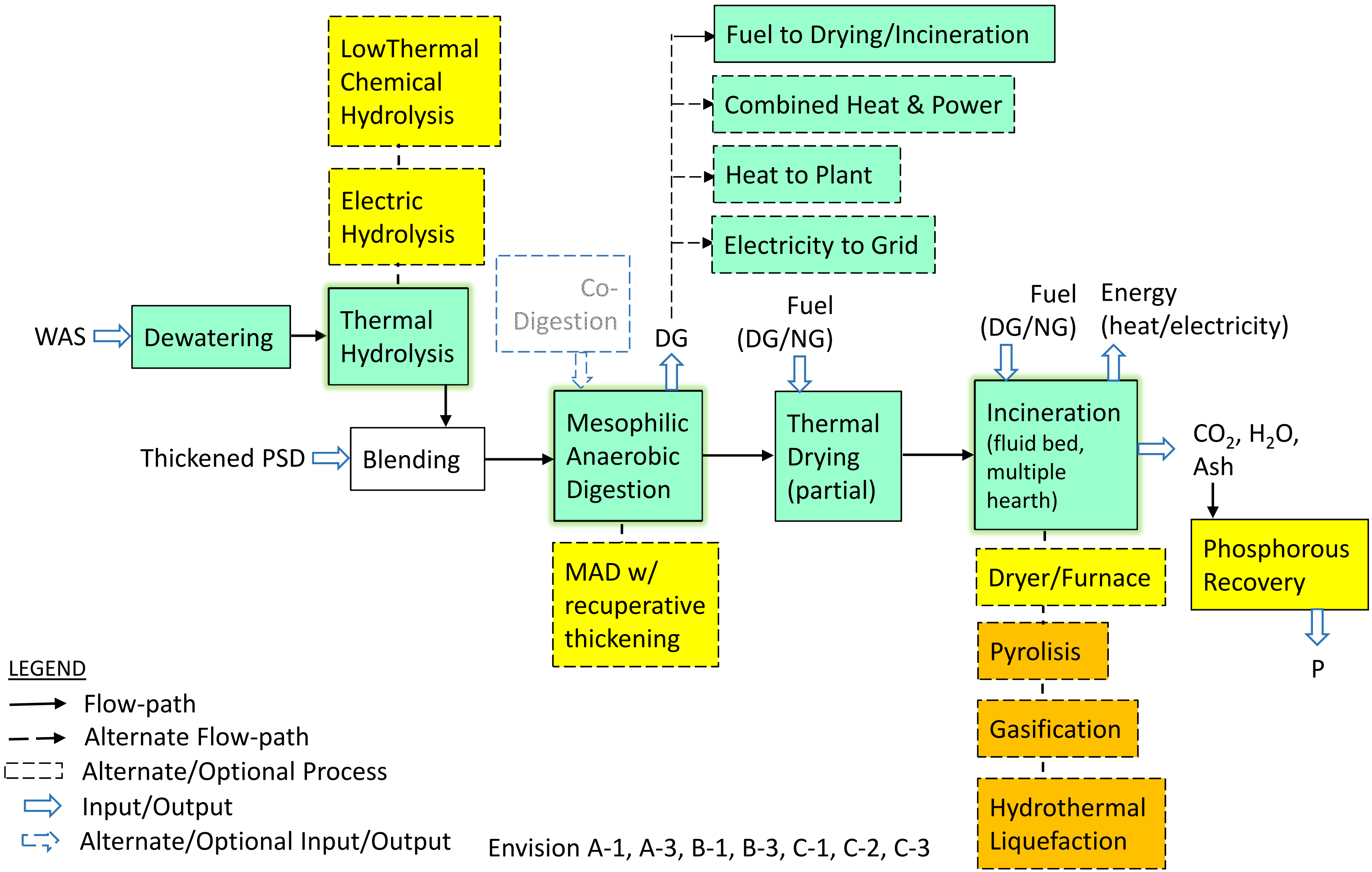
Established
Innovative
Embryonic

Envision A-1, A-3, B-1, B-3, C-1, C-2, C-3



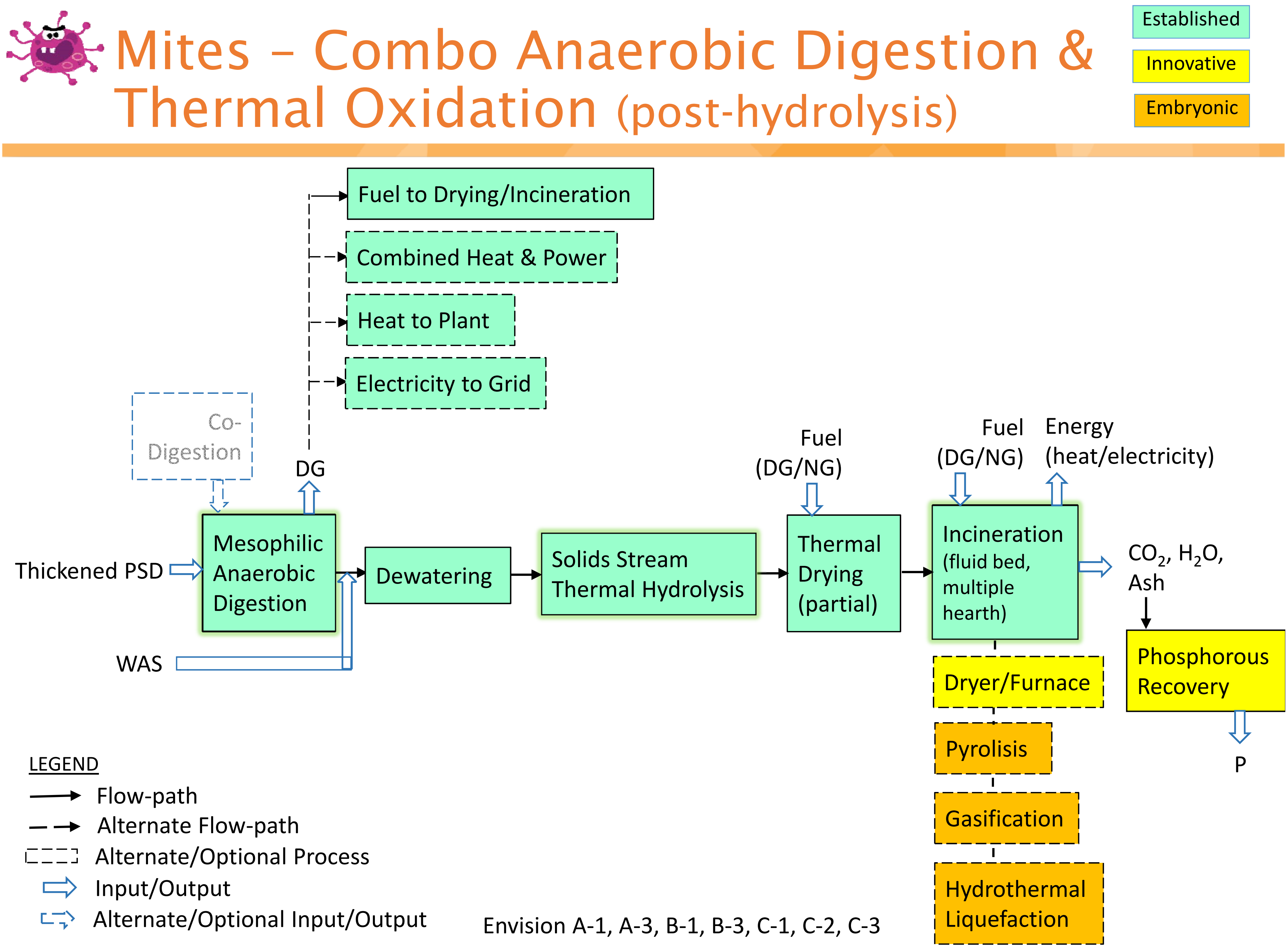
Mites – Combo Anaerobic Digestion & Thermal Oxidation (WAS pre-conditioning)

Established
Innovative
Embryonic



Envision A-1, A-3, B-1, B-3, C-1, C-2, C-3

Mites – Combo Anaerobic Digestion & Thermal Oxidation (post-hydrolysis)



Envision A-1, A-3, B-1, B-3, C-1, C-2, C-3

Alexandria Renew Enterprises Meeting Agenda

Facilitator: Julian Sandino/CH2M	**Meeting topic**: ***Solids Handling & Energy Optimization Technology Pathways Workshop (BOA WA2-2016-7)***
Meeting date: March 29, 2016	**Meeting start time**: 8:30 am
Minutes taken by: Rich Voigt	**Meeting end time**: 3:30 pm

I. Meeting Objectives:

1.	Envisioning Plausible Future Scenarios
2.	Identifying Viable Pathways Toward an Envisioned Future
3.	Screening of Potential Alternative Process Configurations and Corresponding Unit Processes

II. Attendance:

Karen Pallansch	AlexRenew	Mike McGrath	Fairfax County
Sean Stephan	AlexRenew	Sara Motsch	Fairfax County
Janelle Okorie	AlexRenew	Chuck Longerbeam	Fairfax County
Grace Richardson	AlexRenew	Ivan Vølund	VCS Denmark
Johnnie Wallace	AlexRenew	Ib Pedersen	VCS Denmark
Steve Hill	AlexRenew	Dan Lynch	CH2M
Darel Stevens	AlexRenew	Glen Daigger	CH2M
Lisa Reynolds	AlexRenew	Tim Constantine	CH2M
Rickie Everette	AlexRenew	Julian Sandino	CH2M
Andre Yates	AlexRenew	Rich Voigt	CH2M
James Atkinson	AlexRenew	Todd Williams	CH2M
James Cummins	AlexRenew	Marialena Hatzigeorgiou	CH2M
Eugene Singleton	AlexRenew	Savita Schlesinger	CH2M
Charlie Logue	AlexRenew		

III. Discussion/Decision Items:

Start Time		Topics	Notes
	8:30 am	***Breakfast/refreshments***	
1.0	9:00 am	Welcome & Introductions (Karen)	
2.0	9:15 am	Defining Success (Rich)	• Outcomes from Chartering Workshop • Draft boundary conditions • Review of parking lot items
3.0	9:45 am	Confirmation of Planning Basis (Savita)	• Updated population and flows/loads used for planning
4.0	10:00 am	Envisioning a Plausible Future (Julian)	• Group discussion to define Plausible Future Scenarios and boundary conditions associated with each (plus global boundary conditions)

Alexandria Renew Enterprises Meeting Agenda

Start Time		Topics	Notes
5.0	11:00 am	How others are Positioning for the Future (Various)	• VCS Presentation • Fairfax County Biosolids Plan • Green Bay MSD Case Study • Overview of Genifuel technology (Sean)
	Noon	***Lunch***	
6.0	12:30 pm	Defining Boundary Conditions – “Rules to Plan by” (Julian)	• Using the decision model to set boundaries • Review of boundaries outlined in the morning session
7.0	1:00 pm	Identifying Technology Pathways Towards an Envisioned Future (Glen)	• Identify specific approaches required in order to meet the envisioned future scenarios
8.0	1:30 pm	Unit Process Building Blocks (Todd)	• Technology “tree” • Breakout Group Exercise: Screening of Potential Alternative Process Configurations and Corresponding Unit Processes
		BREAK before report-out	
9.0	3:00 pm	Wrap-up (Rich)	• Action Items • Next Steps
	3:30 pm	***Adjourn***	

<u>Break-out Group Exercise</u>

Screen the Unit Process Building Blocks for each of the Technology Pathways (developed in Item 7.0)

Break out groups:

Team Nematodes	Team Filaments	Team Mites
Mike McGrath	Sara Motsch	Chuck Longerbeam
Ivan Volund	Ib Pederson	Savita Schlesinger
Charlie Logue	Darel Stevens	Steve Hill
Grace Richardson	Johnnie Wallace (PTO)	Sean Stephans
Lisa Reynolds	Andre Yates	Rickie Everette
James Atkinson	Eugene Singleton	James Cummins
Julian Sandino	Tim Constantine	Marialena Hatzigeorgiou
Glen Daigger	Todd Williams	Rich Voigt

MEETING SUMMARY

BOA WA2-2016-7

AlexRenew Solids Handling & Energy Optimization – Technology Pathways Screening Workshop – May 11, 2016

ATTENDEES:	Karen Pallansch/AlexRenew Grace Richardson/AlexRenew Steve Hill/AlexRenew Lisa Reynolds/AlexRenew Rickie Everette/AlexRenew Andre Yates/AlexRenew James Atkinson/AlexRenew James Cummins/AlexRenew Eugene Singleton/AlexRenew Charlie Logue/AlexRenew Hong Yin/AlexRenew	Dan Lynch/CH2M Glen Daigger/CH2M Tim Constantine/CH2M Julian Sandino/CH2M Rich Voigt/CH2M Todd Williams/CH2M Peter Burrowes/CH2M Marialena Hatzigeorgiou/CH2M Savita Schlesinger/CH2M Paula Sanjines/CH2M Michael Shuler/CH2M
COPY TO:	Sean Stephan/AlexRenew Aster Tekle/AlexRenew Johnnie Wallace/AlexRenew Darel Stevens/AlexRenew Chuck Phillips/AlexRenew File	
PREPARED BY:	Rich Voigt/CH2M Marialena Hatzigeorgiou/CH2M	
DATE:	May 20, 2016	

Objectives

A workshop for the Alexandria Renew Enterprises (AlexRenew) Solids Handling & Energy Optimization Project was held on May 11, 2016 at the AlexRenew Administration Building. Objectives were as follows:

- Review Viable Pathways Toward an Envisioned Future
- Screen Potential Alternative Process Configurations and Corresponding Unit Processes

Summary

A summary, based on agenda topics, is provided below.

Defining Success

A brief recap of the prior workshop, including initial screening efforts, was conducted. In addition, goals for the current workshop were stated – to reduce the pathway alternative configurations from 8 to 2 or 3 (ideally). Those alternatives will then be defined in greater detail for evaluations at the next workshop.

Confirmation of Planning Basis (Flows and Loads)

Briefly reviewed the planning basis (flows and loads), including the latest population projection information from Fairfax County.

The City of Alexandria provided population projections through 2040 and out to 2060. The City of Alexandria projects the population growth from 2040 to 2060 to occur at a rate of 1% per year.

Fairfax County provided population projections only through 2040. The projected population growth rate in the portion of Fairfax County that is served by AlexRenew between 2015 and 2040 is 0.7% per year.

For the purposes of this evaluation, it was decided to project out the total population served by AlexRenew (in both jurisdictions, City of Alexandria and Fairfax County) through 2060 using a growth rate of 1%. This is considered a more conservative rate and results in a total population of 480,000 in 2060.

The evaluation will also do a sensitivity analysis using the 0.7% rate of growth (applied only to the Fairfax County portion of AlexRenew's service area) which results in a total population of 460,000 in 2060. The difference between the two 2060 population projections is only about 4%.

Plausible Future Scenarios and Pathways

It was reiterated that a flexible approach is needed, because the future is uncertain and subject to change.

Reviewed the planning guidelines, including enhancements from the prior workshop:

- A – Restrictive Regulatory Framework
- B – Embraced Sustainability Principles
- C – Engaged Stakeholders – Board and Community

Reviewed work from last workshop, identifying technology pathways in 3 breakout group teams:

- Thermal Oxidation pathway was developed by Team Nematodes
- Anaerobic Digestion pathway was developed by Team Filaments
- Combination Anaerobic Digestion + Thermal Oxidation pathway was developed by Team Mites

CH2M took the work developed by the teams and further refined the pathways, including performing a mass and energy balance to determine technically feasible configurations. The purpose of this workshop is to review these configurations, discuss their attributes, compare them against the decision model criteria and select the ones that will be evaluated further and scored using quantitative and qualitative data.

Technology Building Blocks

In order to assemble technically feasible pathways, the team had to use reference technologies to serve as "stand ins" for the various unit processes. These technologies provided a base to perform mass balance and energy calculations. Where AlexRenew already has a specific technology (for example centrifuge thickening, anaerobic digestion, centrifuge dewatering), the same technology was maintained. The technologies that would be newly introduced to AlexRenew were conceptually reviewed in order for the group to have a common understanding.

It was noted that the use of these technologies at this point in the evaluation does not mean that these technologies have been "selected". They are only being used for now to assess the feasibility of each pathway. Each unit process can probably use other technologies/vendors/systems and that determination can be made later in the planning process.

Global terminology change: Thermal Conversion of Organics (TCO) replaced Thermal Oxidation (TO), as it is more descriptive.

The following reference technologies were conceptually reviewed, as they are not currently onsite:

- Sludge Thermal Drying (Belt Dryer): Used for full drying (90% solids) to generate an end product
- Sludge Thermal Drying (Disc Dryer): Used for partial drying (30-35% solids) to reduce water content in order to have autogenous thermal oxidation
- Thermal Oxidation (Fluidized Bed Reactor):
    - Size: Buildings are typically 50-60 foot tall to enclose an incinerator unit, which is nominally 40 ft high.
    - Air emissions: Very clean emissions are produced due to high heat/contact.
    - Stacks can be designed to comply with aesthetic requirements – they are typically 1.5-2 times the building height. Various methods are available to reduce the stack height if needed.
    - Redundancy: Due to the cost of units, most users use a single train and then employ an alternate disposal method when the train is down for annual maintenance (approximately a month or so). If excess digester capacity is available, you can also potentially store the solids during a maintenance period.
    - Energy recovery is possible in the form of hot water, steam and/or electricity
- WAS/Digested Sludge Pre-Conditioning (Thermal Hydrolysis) – CAMBI was used as the reference technology/vendor. The system operates using medium pressure steam (175 psi), and would require a steam engine operating engineer licensed in Virginia.
- Thermal Conversion of Organics Recovery (Organic Rankine Cycle or ORC Turbine) – This system is used to recover energy from Thermal Oxidation and convert it to electricity. The system does not operate at high temperature or pressure and does not need specialized staff to operate and maintain. CH2M is currently designing this system for Fairfax County.
- Combined Heat and Power (Internal Combustion Engine or ICE Generator)

** New emerging EPA regulations are moving forward to reduce ammonia discharge concentration, potentially by a factor of ten (0.025 mg/l). Addressing this may require another biological process and/or breakpoint chlorination (controls are critical). Need to research and consider adding to Boundary Conditions and/or how to incorporate? Note that UOSA ran a pilot on breakpoint chlorination (Tim Gallagher). AlexRenew's ability to utilize Mainstream Anammox and equalize/manage nutrient loads are an advantage.

Evaluation Criteria

Reviewed AlexRenew custom decision model, as well as strategic elements and questions to be used by the team for screening of technology pathways/alternatives.

Pathway Configuration Alternatives (Discussion)

Major categories:

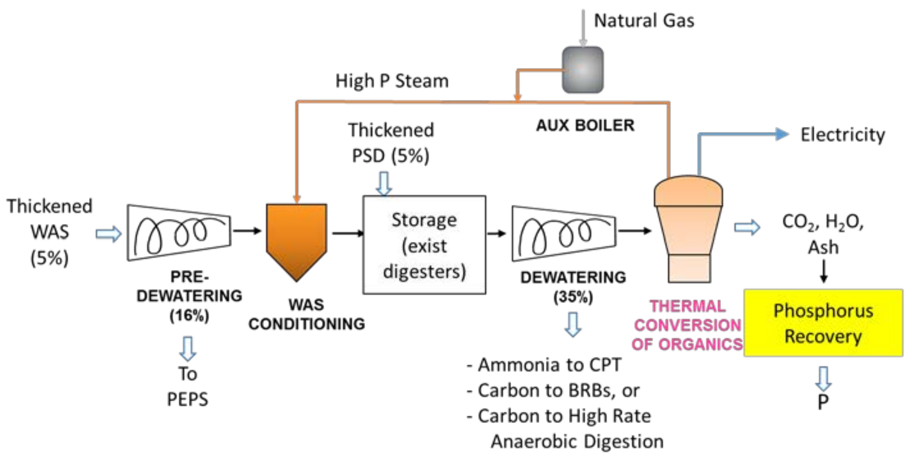
- Thermal Conversion of Organics (TCO)
- Anaerobic Digestion - Drying (AD - Drying)
- Anaerobic Digestion and Thermal Conversion of Organics (AD-TCO)

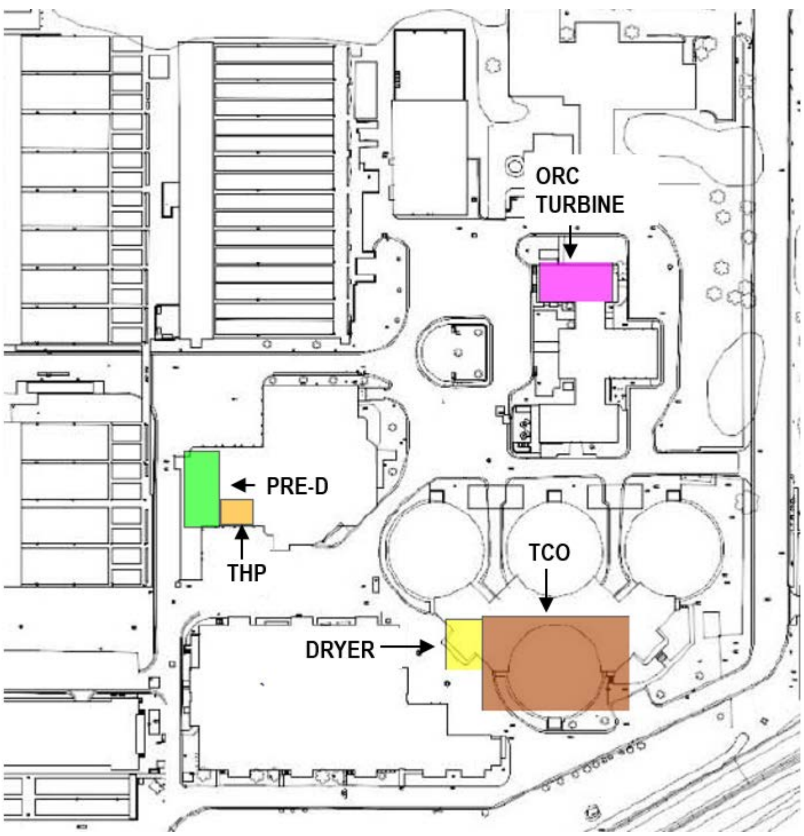
Can we economize on number of steps to dewater and dry solids – or otherwise be more efficient? Starting with low % solids (5%), requires considerable effort to dry solids. Bucher presses are a possibility. May want to research further/investigate feasibility.

Drying and thermal conversion of organics may be surrogates for Genifuel and other embryonic technologies.

Site Utilization/Potential Footprint Use Discussion:

1a/1b – Thermal Conversion of Organics (TCO):





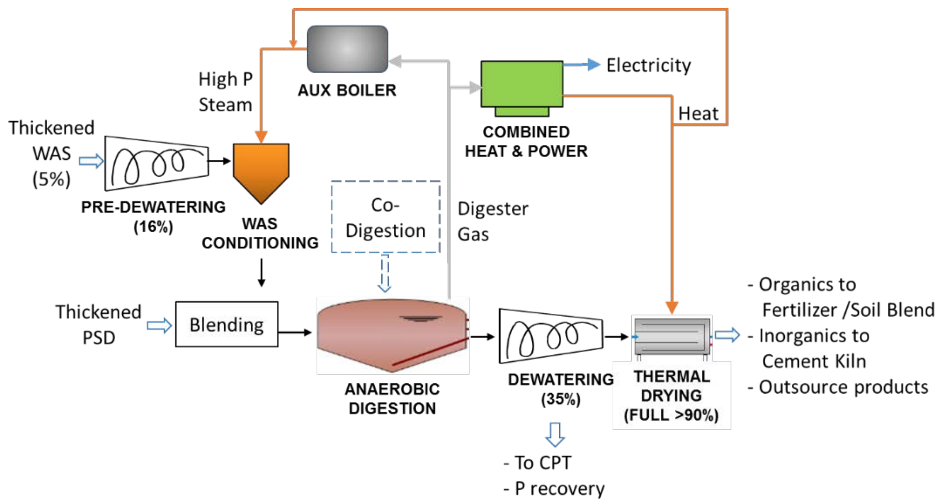
TCO and a Partial Dryer should be close together, as the dried product (33%) needs to be conveyed to the TCO unit.

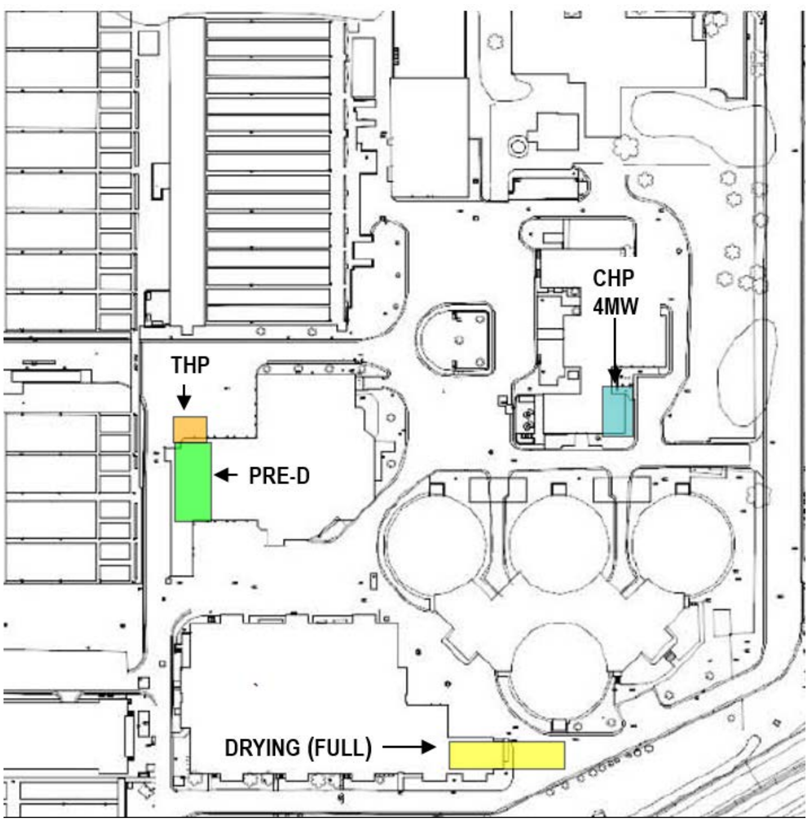
Interim use of lime (during construction) was not viewed favorably. If interim use of lime is not acceptable, then sludge conditioning can be located at the west side of Building L.

This pathway offers flexibility, as the existing digesters will be used for storage. Therefore, not all volume/footprint is needed and pre-dewatering and thermal hydrolysis can be located in place of one of the existing digesters.

The energy recovery from the TOC (turbine) can be located at Building A for both options (1a and 1b).

2a/2b/2c – Anaerobic Digestion - Drying (AD-Drying):





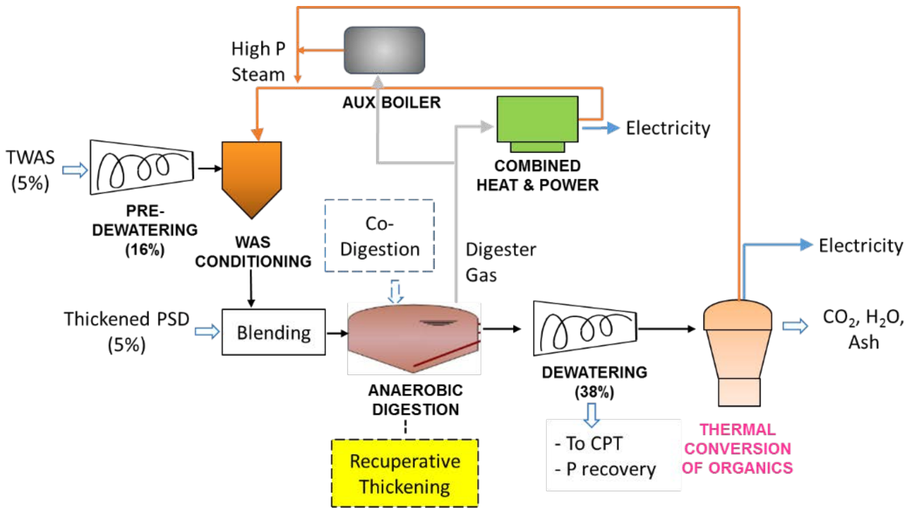
This pathway (AD-Drying) requires all 4 digesters for option 2a (and also recuperative thickening) in order to maintain the minimum SRT of 12 days. Options 2b & 2c can utilize recuperative thickening and reduce the number of anaerobic digesters needed from 4 to 3.

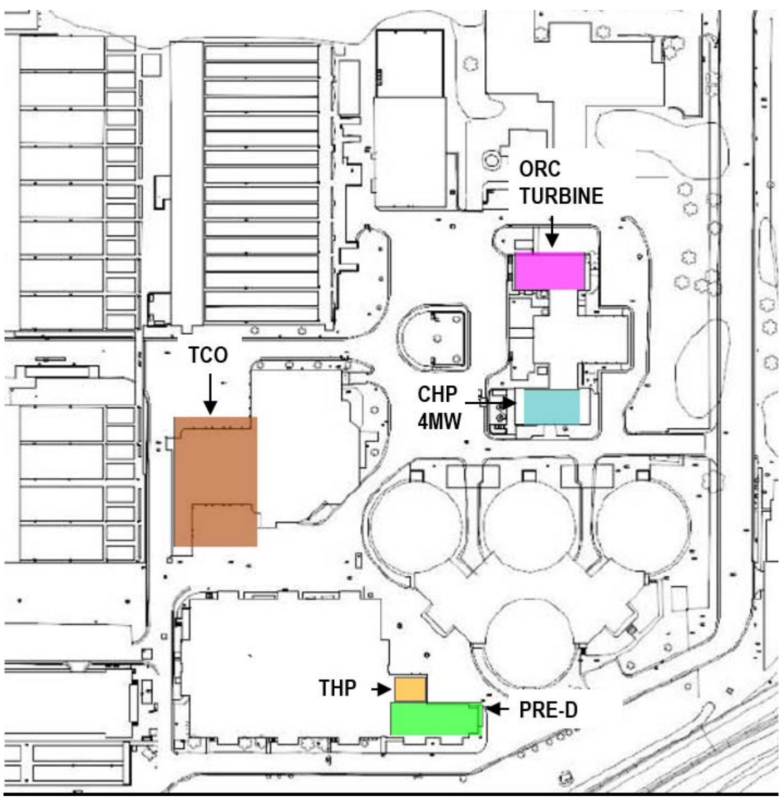
Drying (full) can be located at the current location of Building 55 (Prepasteurization).

For the options with sludge conditioning (2b & 2c), pre-dewatering and thermal hydrolysis can be located on the west side of Building L. However, doing this prohibits the interim use of lime and makes construction sequencing more complicated. Alternatively, with recuperative thickening one digester footprint can be freed up and pre-dewatering and thermal hydrolysis can be located in the space.

Combined heat and power (CHP) can be located in Building A for all three options.

3a/3b/3c – Anaerobic Digestion – Thermal Conversion of Organics (AD-TCO):





This pathway (AD-TO) requires all 4 digesters for option 3a (and recuperative thickening). Options 3b & 3c can use recuperative thickening and reduce the number of anaerobic digesters needed from 4 to 3.

For Option 3a, thermal conversion of organics can be located on the west side of Building L (restricts interim use of lime) or where Building 55 currently sits.

For the options with sludge conditioning (3b & 3c), pre-dewatering and thermal hydrolysis can be located where Building 55 currently sits. Also, with recuperative thickening one digester footprint can be freed up and thermal conversion of organics can be located in the space.

CHP and an ORC turbine can be located at Building A for all three options.

Group Discussion and Voting

Discussed Fatal Flaw Analysis Criteria:

- Doesn't fit (space steward)
- High product yield (site headache – number of trucks onsite)
- Inflexible (doesn't allow phased implementation /reassessment) – avoid putting all eggs in one basket
- Low energy recovery (sustainability)
- "socially" unacceptable

Note: Amount of energy that can be captured from biosolids is finite and the same for all technologies. The difference is how much of it is actually captured.

Is incineration an acceptable process in Virginia and on the AlexRenew site? Note that incineration is a reference technology/surrogate for thermal conversion of organics (TCO) - taking organics and converting them into something else (ex. Biochar). Other processes could include pyrolysis or gasification, which are currently in the embryonic stage.

<u>Scoring</u>

AlexRenew staff each used 3 green/blue dots to define preferred alternatives (votes), then CH2M staff each used 3 orange dots to do the same. Data for each alternative and vote tallies are provided below.

	Alternative	Final Product dry ton/day	Available Electricity (MW)	Available Hot Water (MBTU/day)	Total Available Energy (MBTU/day)	AlexRenew votes	CH2M Votes	Total
1a	TCO w/drying	20	1.5	n/a	5.0	1	0	1
1b	TCO w/WAS cond	19	1.6	n/a	5.4	0	0	0
2a	AD w/drying	55	n/a	38	38	5	0	5
2b	AD w/WAS conditioning and drying	50	4.4	>>(2a)		7	5	12
2c	AD w/post hydrolysis and drying	63	4.4	>>(2a)		3	2	5
3a	AD-TCO	20	3.7	120	133	5	3	8
3b	AD-TCO w/WAS conditioning	19	5.0	>>(3a)		9	10	19
3c	AD-TCO w/post hydrolysis	26	5.0	>>(3a)		3	13	16

- 1a/1b – Requires abandoning existing system and moving everything to incineration, which may be difficult to implement.
- 2a/2b/2c – Utilizes existing AD and builds options. Questions about incineration acceptability – postpone or phase TCO?
- 3a/3b/3c – Provides two options with adaptability

Based on the scoring results/votes, the following options were selected to be evaluated further – 2a (baseline from past Long Range Plan), 2b, 3b, 3c

General Strategy – Abort pre-past/lime, retain AD, reduce volume or biosolids end product (conditioning or drying), future TCO

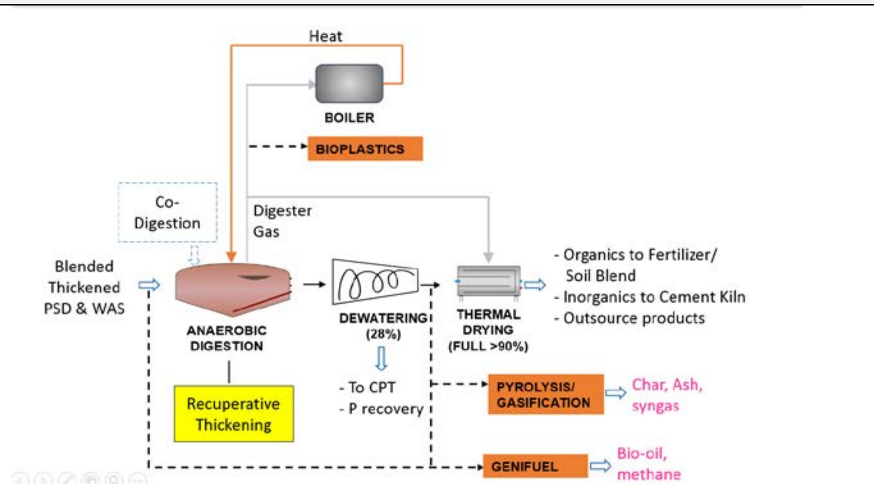
Embryonic Technologies

- Sludge to oil
- Pyrolysis
- Gasification
- Bioplastics from biogas

These technologies are possible modifications/options that can piggyback on top of the technology pathways that are being evaluated. Posterboards were revised to reflect which options are applicable and how/where they would fit.

Could combine pyrolysis and gasification, but gasification is likely to become economically viable well before pyrolysis.

<table>
<tr><th>Alternative</th><th>Summary</th><th>Process Diagram</th></tr>
<tr><td>2a. Anaerobic Digestion (AD) with Thermal Drying</td><td>Genifuel after dewatering

Pyrolysis/Gasification following Thermal Drying</td><td>
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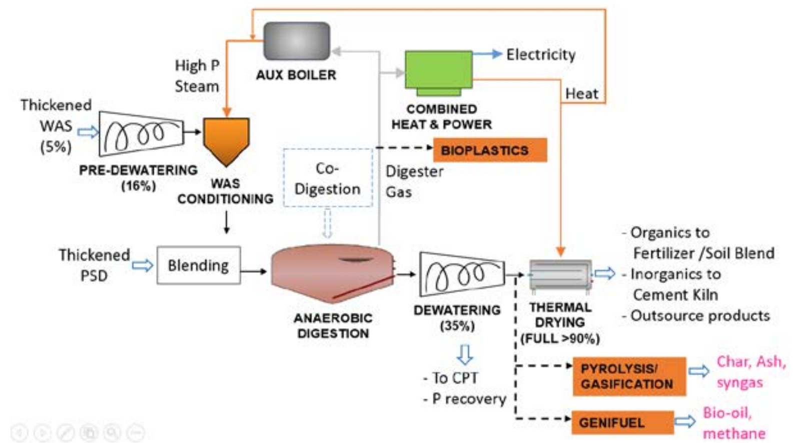
<td>2b. Anaerobic Digestion (AD) with WAS Conditioning and Drying</td>
<td>Genifuel after dewatering

Pyrolysis/Gasification following Thermal Drying</td>
<td>
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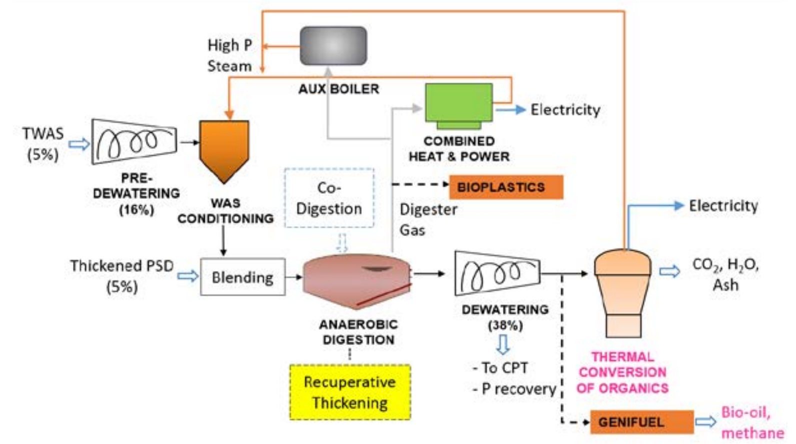
<tr>
<td>3b. Anaerobic Digestion and Thermal Conversion of Organics (AD – TCO) with WAS Conditioning</td>
<td>Genifuel after dewatering, before Thermal Conversion of organics</td>
<td>
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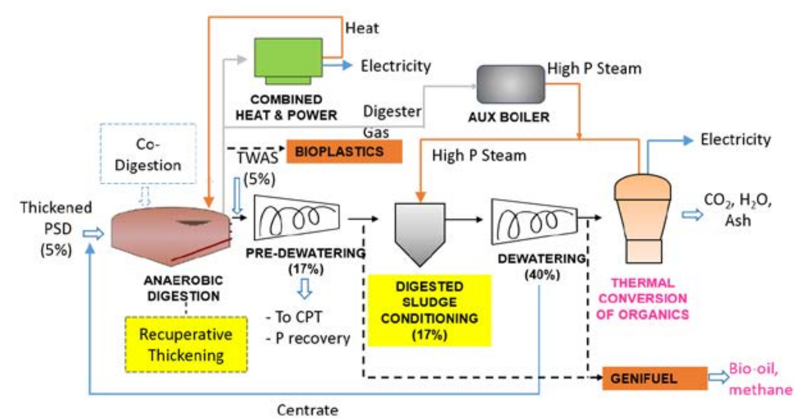
<tr>
<td>3c. Anaerobic Digestion and Thermal Conversion of Organics (AD - TCO) with</td>
<td>Genifuel before Digested Sludge Conditioning, and or after Dewatering</td>
<td>
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Parking Lot Issues

Covanta has an established relationship to receive area food wastes. Might be more of an opportunity to receive fats, oils, and greases (FOG) and screened/cleaned up food waste.

Action Items

Table 1. Action Items List

Item	Responsible Party	Target Due Date
Research/Assess Emerging EPA Regulations for Ammonia Discharge	CH2M	TBD
Consider/Assess possibilities of receiving FOG at AlexRenew	CH2M	TBD
Next workshop date – late June or early July – CH2M to propose dates for AlexRenew approval	All parties	TBD

Attachments

1. Revised Presentation Slides
2. Meeting Agenda




Solids Handling and Energy Optimization Evaluation

Workshop 3: Technology Pathway Alternatives Screening Workshop

May 11, 2016

Revised per comments received at the Workshop

Workshop #3 Objective –
Screening of Technology Pathway Alternatives

- Welcome and Introductions
- Defining Success
- Confirmation of Planning Basis
- Plausible Future Scenarios and Pathways
- Technologies: Brief overview
- Evaluation Criteria
- Discuss and Evaluate Pathway Configuration Alternatives (8)

LUNCH!!!!

- Group Discussion and Voting
- Applicable Embryonic Technologies
- Action Items and Next Steps

2016 Solids Handling and Energy Optimization Planning

Step 1
Develop Leadership
Chartering Workshop #1 Feb 10

Step 2
Frame the Problem
Technology Alternatives Workshop #2 March 29

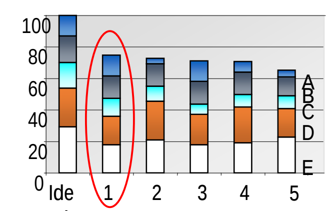
Step 3
Develop Model
Alternative Screening Workshop #3 May 11

Step 4
Collect Data

Step 5
Evaluate & Decide
Workshop #4
Score
Compare
Decide

Step 6
Implement Plan
Long Range Plan Update

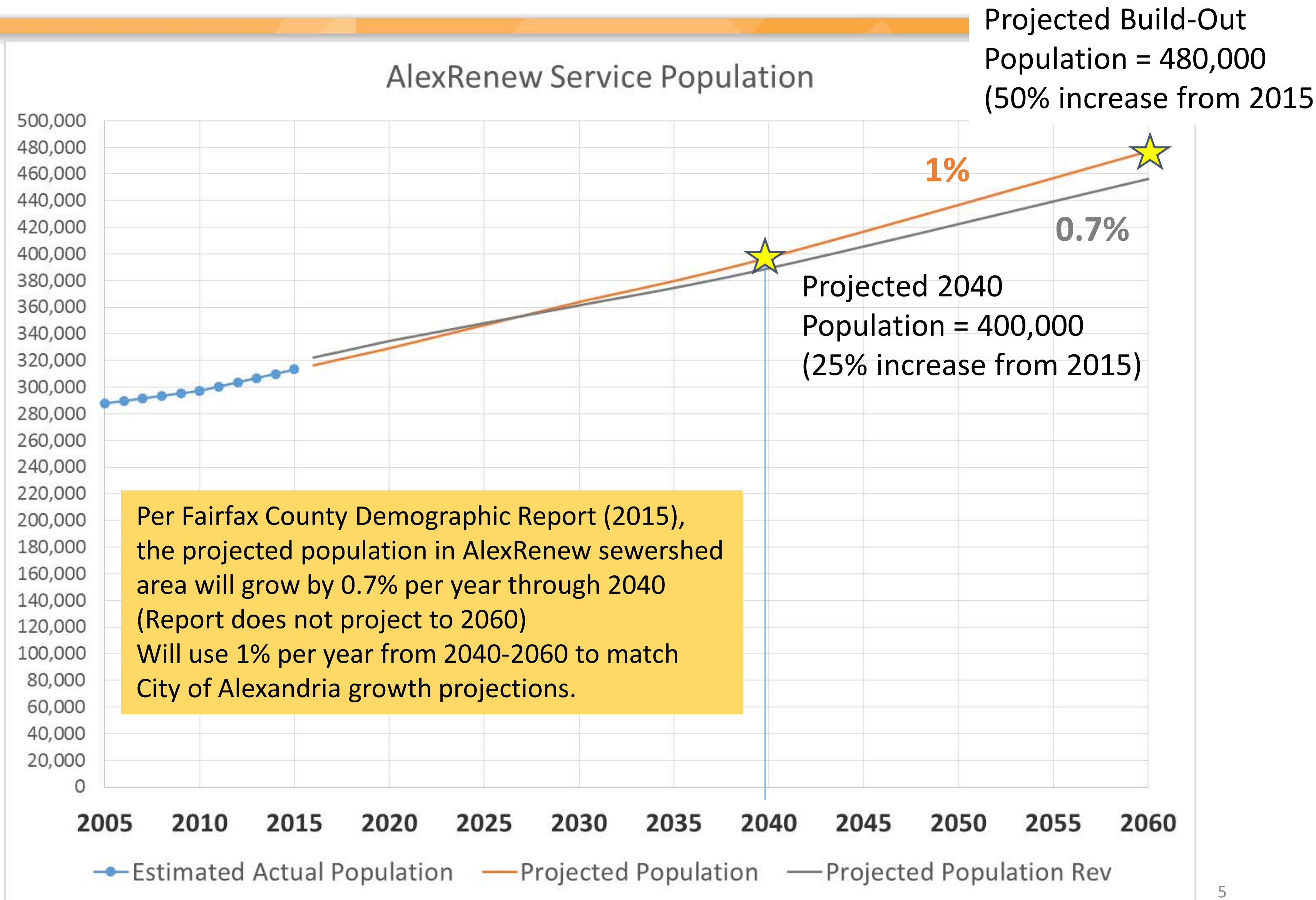
	1	2	3
A	4	8	6
B	6	10	2
C	8	4	0
Cost	$	$	$



Confirmation of Planning Basis

Presentation by Paula Sanjines

AlexRenew Projected Population



Proposed Loading Projections for 2016 Planning Effort

- Used 2007-2015 Data Set to determine historical Per-Capita Loadings and project out to 2040 and Build-Out Condition (~ 2060)

	Population	Flow (MGD)	Loadings (lbs/day)					
			TSS	BOD5	TKN	NH3	TP	OP
2007-2015 Avg. Loadings	~300,000	35	88,000	65,000	12,000	6,400	1,900	700
Per Capita Loading *		120 gpc	0.29	0.22	0.040	0.021	0.006	0.002
2040 Loadings	400,000	48	117,593	86,524	15,954	8,445	2,493	935
Build-Out Loadings (~2060)	480,000	58	141,000	104,000	19,100	10,100	3,000	1,100
Max Month PF *			1.32	1.21	1.20	1.11	1.28	1.17
Max Month Design Loadings			186,000	125,000	22,900	11,200	3,800	1,300

* per-capita loading and peaking factors based on 2007-2015 historical data

Plausible Future Scenarios and Pathways

Presentation and Group Discussion
Facilitated by Julian Sandino

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

A - Restrictive Regulatory Framework

- A-1: Ban on land application of biosolids and/or potentially all land-based uses of biosolids
- A-2: Limits on nutrient effluent discharge concentrations down to Limit-of-Technology (LOT) levels: TN = 1 mg/L; TP = 0.01 mg/L
- A-3: Monitoring and limits on micro-constituents in the biosolids and in the liquids
- A-4: Greenhouse gas (GHG) caps
- **A-5: Air Emission Requirements**
- **A-6: “Integrated” Regulatory Frameworks (air, water, solids)**

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

B – Embraced Sustainability Principles

- B-1: Trend towards energy neutrality and beyond
- B-2: No net increase in air emissions onsite
- B-3: Manage risk associated with biosolids use/disposal
- B-4: Reclaimed water – develop partnerships to utilize 5 mgd capacity
- B-5: Limited footprint at WRRF for future development
- B-6: Resource Recovery
- B-7: Climate change resiliency and adaptation
- **B-8: Supply Chain Considerations (life cycle assessments – where do chemicals come from, what's in them, etc)**
- **B-9: Envision**

Envisioning Plausible Future Scenarios (2040 Planning Horizon)

C - Engaged Stakeholders – Board and Community

- C-1: Support Board 2040 vision and outcomes
- C-2: Supportive development partner in Carlyle Partners
- C-3: Focus on local community stewardship – solutions to enable City to grow
- C-4: No net increase in odor/air emissions/light/noise/traffic
- C-5: Remain neutral on visual impacts of future additional facilities compared with existing
- **C-6: Legislator Advocacy**
- **C-7: "Sector" Organizations (WEF, WERF, NACWA) Influence**
- **C-8: New (revised) interaction between district and clients**

Scenario planning: How do we get from *Now* to an uncertain *Then*

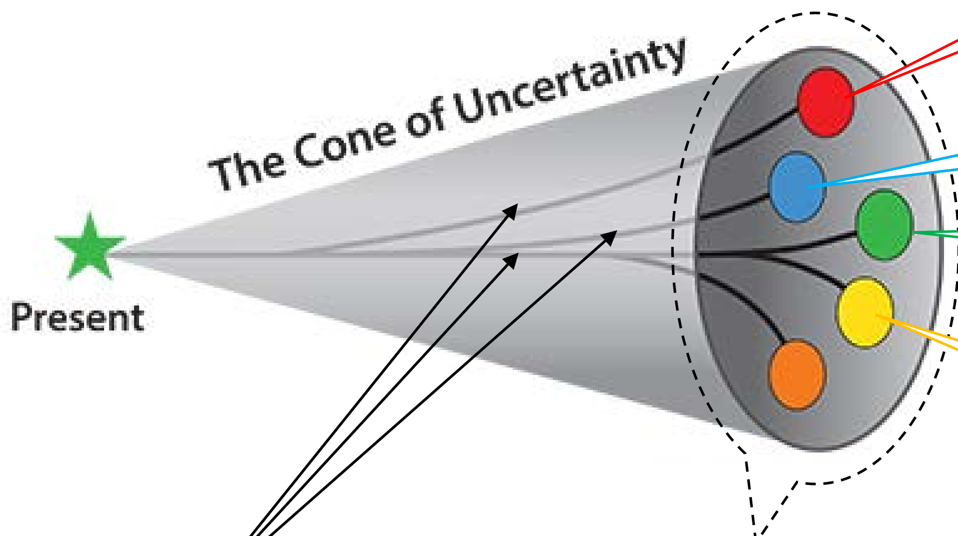
Technology Attributes

Optimized Liquid Process

Resource recovered

Energy self-sufficient

Minimal solids for disposal

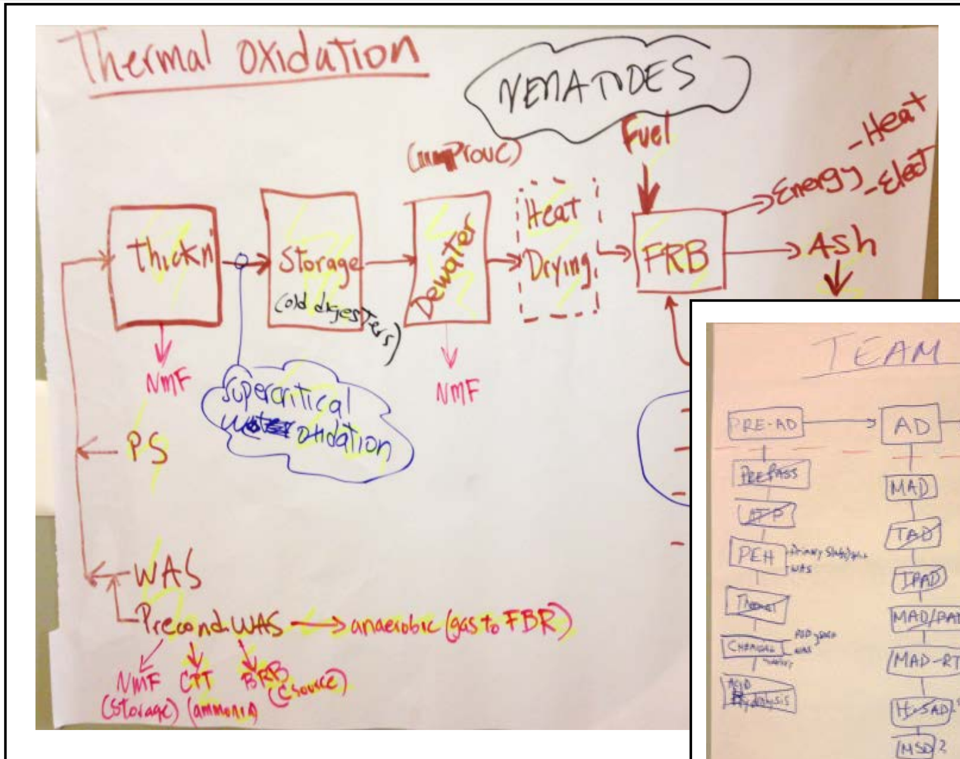


Technology Pathways

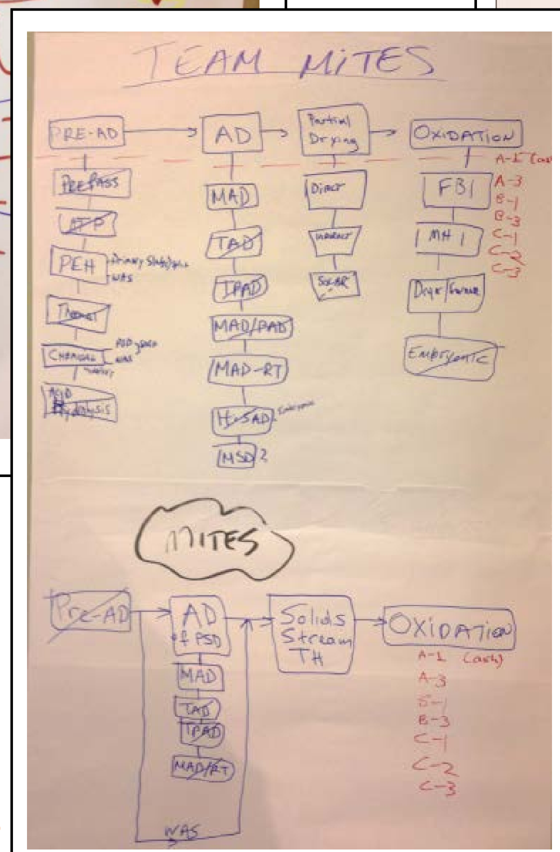
AlexRenew WRRF's Envisioned Future

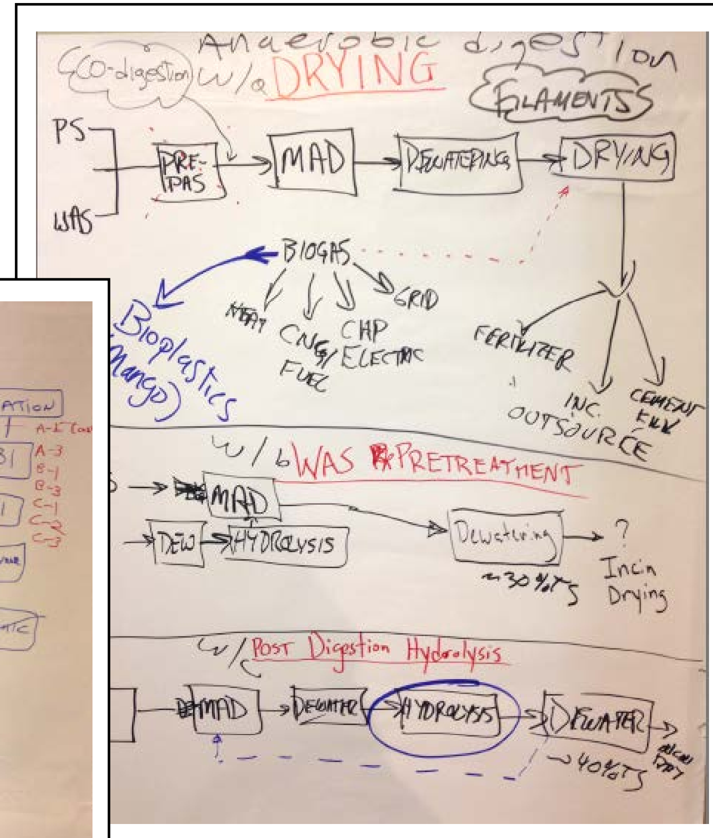
A. Restrictive Regulations
B. Sustainability Embraced
C. Engaged Stakeholders

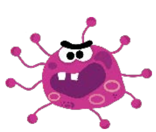
Identification of Pathways and Corresponding Technology Alternatives



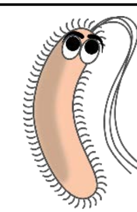
Team Nematodes







Team Mites



Team Filaments

Technology Building Blocks

Presentation by Peter Burrowes

Established

Innovative

Embryonic

Biosolids Management Technologies

Biosolids Stabilization Technologies

- Pre-Digestion Conditioning or Hydrolysis
  - Pre- pasteurization
  - Aerobic Thermophilic Pretreatment (ATP)
  - Pulsed Electric Hydrolysis
  - Thermal Hydrolysis (Steam)
  - Thermal Hydrolysis (No Steam)
  - Chemical/Thermal Hydrolysis
  - Biological (Acid) Hydrolysis
  - Intermediate Thermal Hydrolysis
  - Solid Stream Thermal Hydrolysis
- Anaerobic Digestion
  - Conventional (Mesophilic) Anaerobic Digestion (MAD)
  - Temperature Phased Anaerobic Digestion (TPAD)
  - Thermophilic Anaerobic Digestion
  - MAD with Post Aerobic Digestion
  - Recuperative Thickening
  - High Solids Digestion
  - Multi-Stage Digestion
- Aerobic Digestion
  - Conventional Aerobic Digestion
  - Auto-Thermophilic Aerobic Digestion (ATAD)
  - Aerobic/Anoxic Digestion
- Composting
  - Windrow
  - Enclosed/ In-vessel
  - Aerated Static Pile
  - Vermi-Composting (mix with earthworms)
  - Membrane Covered Pile
  - Hybrid Compost Systems
- Drying
  - Direct Thermal Drying (Drum, Belt)
  - Indirect Thermal Drying (Paddle, Auger. Disc. Vertical Tray)
  - Flash Dryer
  - Solar Drying (greenhouse or open air)
  - Fluidized Bed Drying
- Chemical Stabilization
  - Alkaline Stabilization
  - Lime & Heat Stabilization (EnVessel Pasteurization By RDP)
  - Lime & Acid Stabilization (Schwing Bioset)
  - Low temp Chemical-Mechanical Hydrolysis (Lystek)
  - Chemical Stabilization (NuTerra)
  - Chemical Treatment and Drying (VitAg/Anuvia)
- High Temperature Combustion/ Oxidation
  - Fluidized Bed Reactor Incinerator
  - Multiple Hearth Furnace Incineration
  - Super-Critical Wet Oxidation
  - Pyrolysis
  - Gasification
  - Hydrothermal Liquefaction
  - Dryer/Furnace

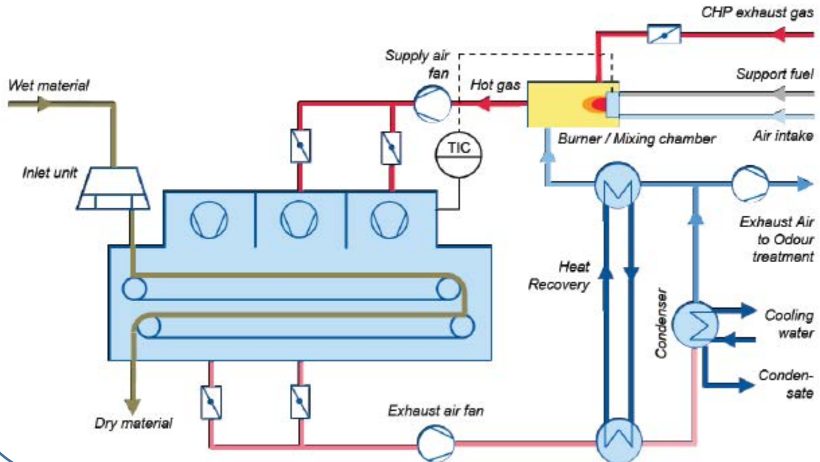
Reference Technologies for Conceptual Definition (Modeling/Sizing/Layout)

- PSD Thickening → Gravity Thickener
- WAS Thickening → Centrifuge
- Anaerobic Digestion → Mesophilic AD
- Recuperative Thickening → Rotary Drum Thickener
- Sludge (PSD, WAS, DS) Conditioning → Thermal Hydrolysis (Cambi)
- Sludge Dewatering → Centrifuge
- Sludge Thermal Drying → Disc (partial); Belt (full)
- Sludge Thermal Conversion of Organics → Fluidized Bed Reactor
- P Recovery → Intentional struvite precipitation (Ostara)
- Combine heat power (CHP) → Internal combustion engine

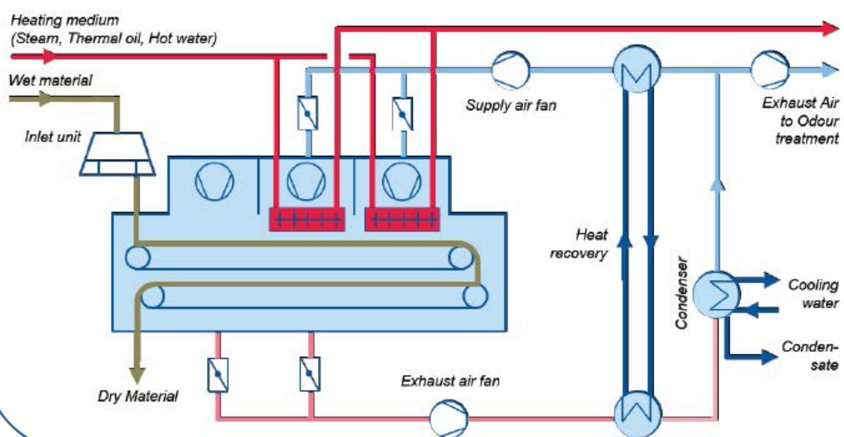
Thermal Drying
Belt Dryer

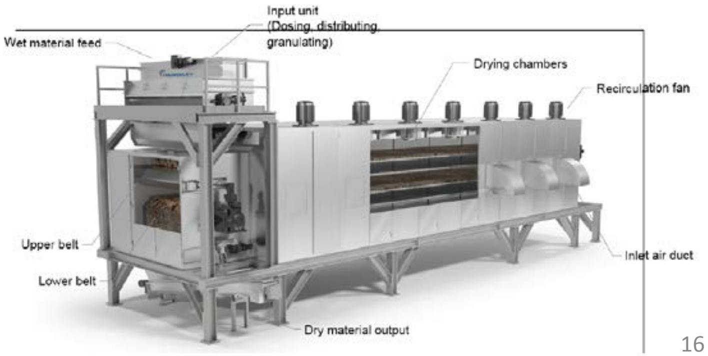
- Full drying (>90% solids) using direct or indirect heat
- Suitable for final drying step

Direct Heat (Digester Gas)



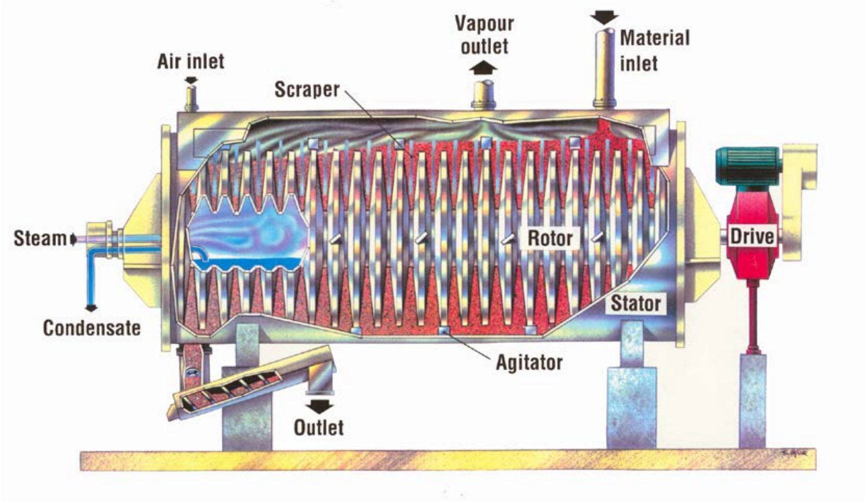
Indirect Heat (Steam/Oil/Water)





Thermal Drying
Disc Dryer

- Partial (~30-35%) drying using indirect heat
- Suitable in Conjunction with Thermal Conversion of Organics



Thermal Conversion of Organics

Fluidized Bed Reactor

- Organic solids are converted to CO_2, H_2O and ash based on "3-T's" concept

Temperature
Complete combustion at 1500 °F

Time
Combustion gas, evaporated water, disengaged material travel upwards (~6.5 sec)

Turbulence
Air blown to sand bed from below

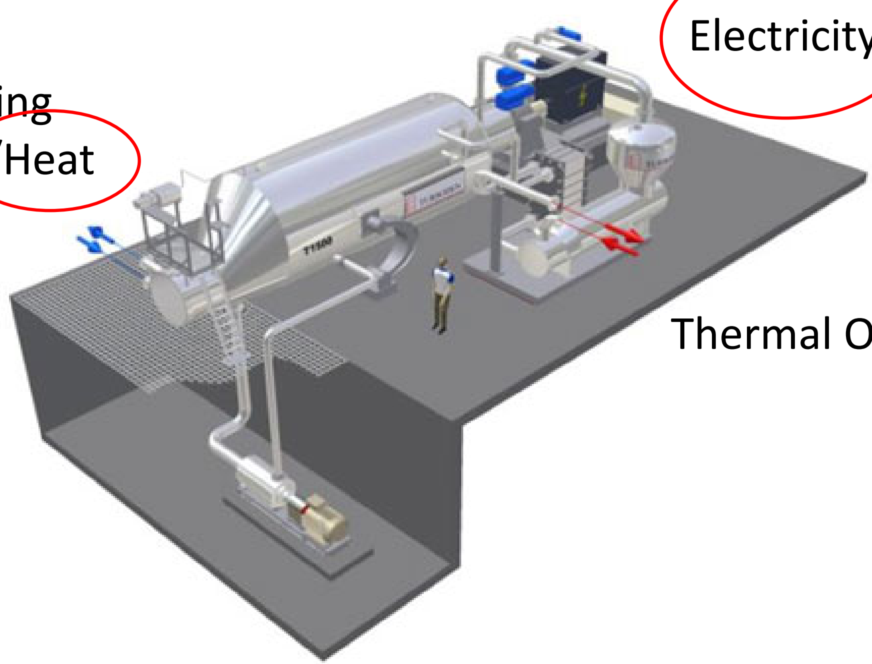
WAS/DS Pre-Conditioning
Thermal Hydrolysis

- High pressure steam pre-treatment disintegrates organic cell structure
  - reduces viscosity, increases volatile solids reduction, improves dewaterability, Process to Further Reduce Pathogens

329 ^{o}F for 20 minutes

Thermal Conversion of Organics (Heat Recovery) - *Organic Rankine Cycle (ORC) Turbine*

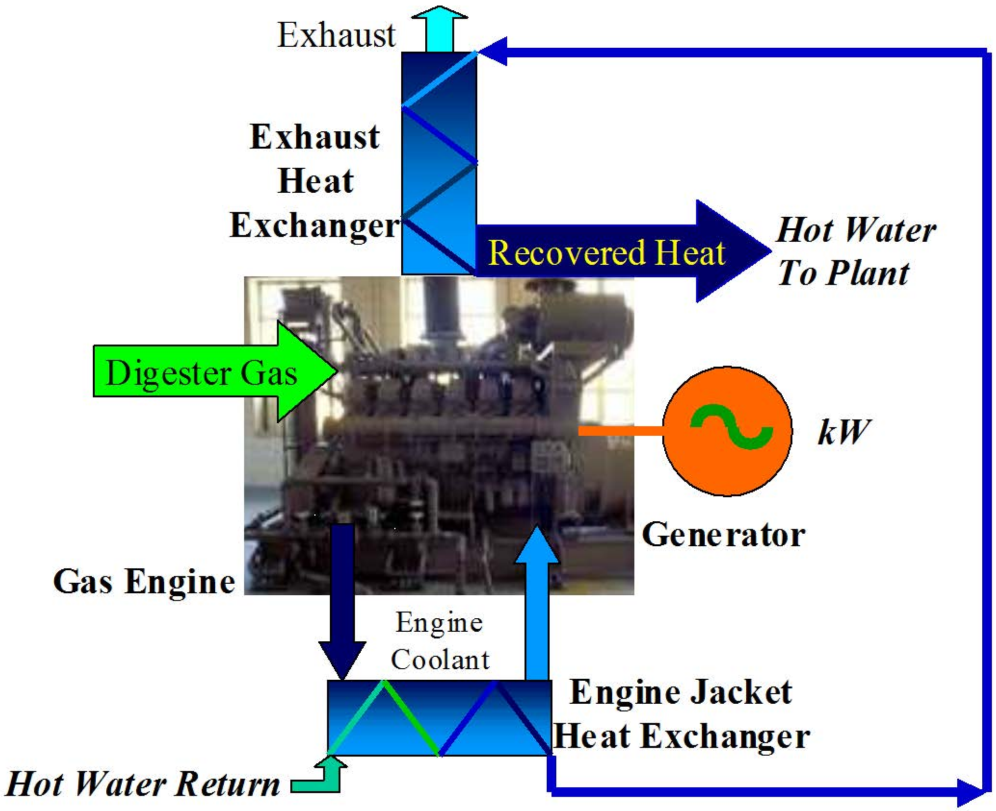
- Recovered heat is used to heat thermal oil → expand the organic working fluid → move the turbine



Thermal Oil Temperature 390 °F

Combined Heat and Power
Internal Combustion Engine (ICE) Generator

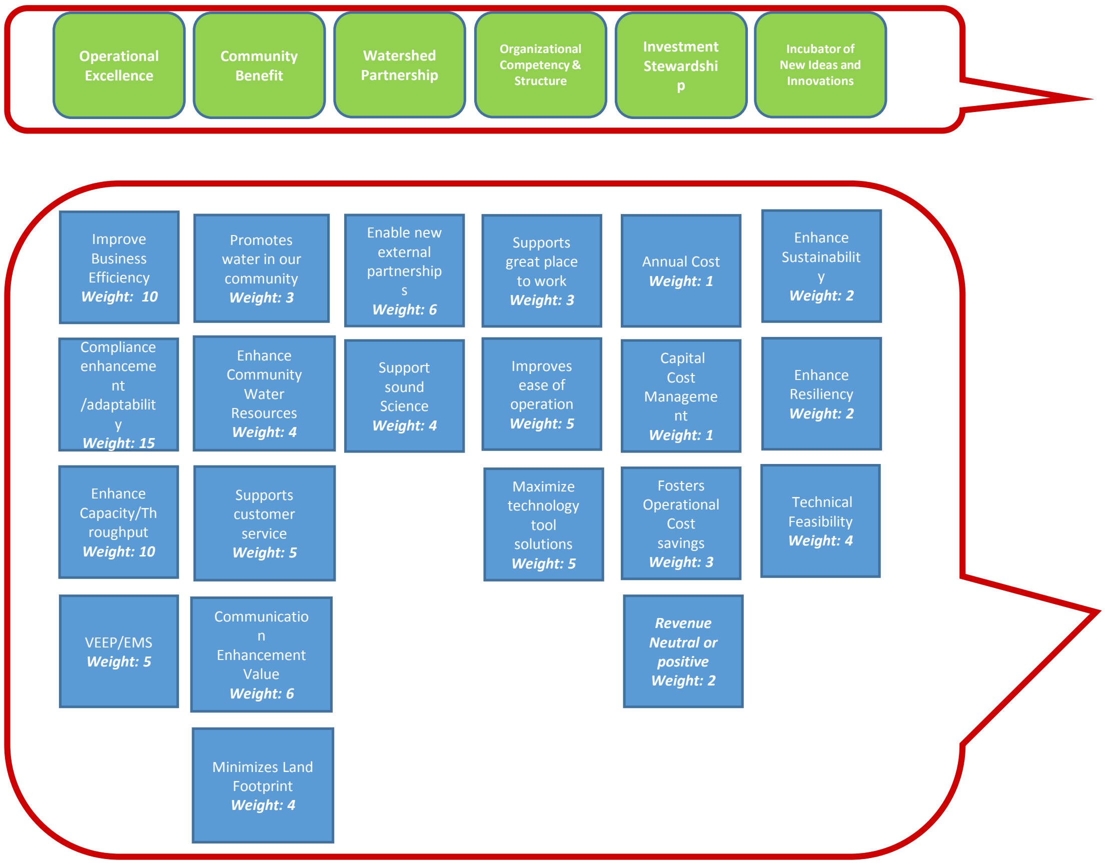
- Digester gas is used to fuel ICE→ electricity generated → waste heat used to heat hot water or generate steam



Evaluation Criteria

Presentation by Sean and Savita

Strategic Elements Help Screen Out and Select Amongst Alternatives



Develop Short Lists: Screening out from "universe" of alternatives (Qualitative basis)

Differentiate between viable options: Comparative evaluation of selected alternatives (Quantitative basis)

Strategic Elements for Screening

Operational Excellence

- Can the alternative accommodate 2040 loads? Can it be adapted for 2060 loads?
- Does is create or increase products?
- Does it minimize waste?

Community Benefits

- How does the Community benefit from the alternative?
- Are there negative impacts to the Community? Can the impacts be mitigated? *Impacts to consider include truck traffic, odor, noise, air emissions, light pollution, etc.*
- Does the alternative require footprint outside the existing fence line?
- Can we create footprint within the fence line by demolition or building up?

Strategic Elements for Screening

Watershed Partnerships

- Can we create a product that leverages an existing partnership?
- Can the alternative create the opportunity to develop new partnerships?

Organizational Competency and Structures

- Is the alternative cutting edge or does it enable cutting edge technologies?
- Are the technologies innovative relative to the baseline (current process)?

Investment Stewardship

- Does it maximize the use of existing assets?

Incubator of New Ideas and Innovations

- Does the alternative provide flexibility to incorporate embryonic technologies?
- What are the risks associated with the alternative?
- Is the alternative “green”?

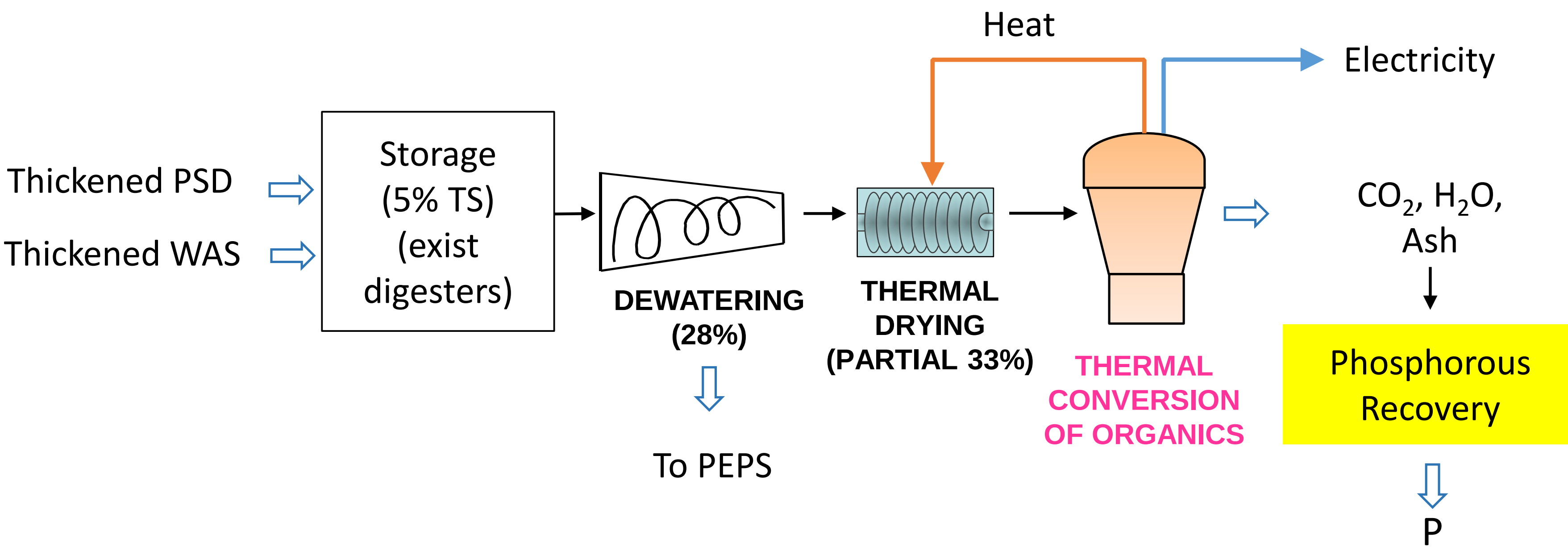
Discuss and Evaluate Pathway Configuration Alternatives

Group Exercise Facilitated by Julian Sandino

Identified Solids Process Pathways
(from Workshop 2, 03-29-2016)

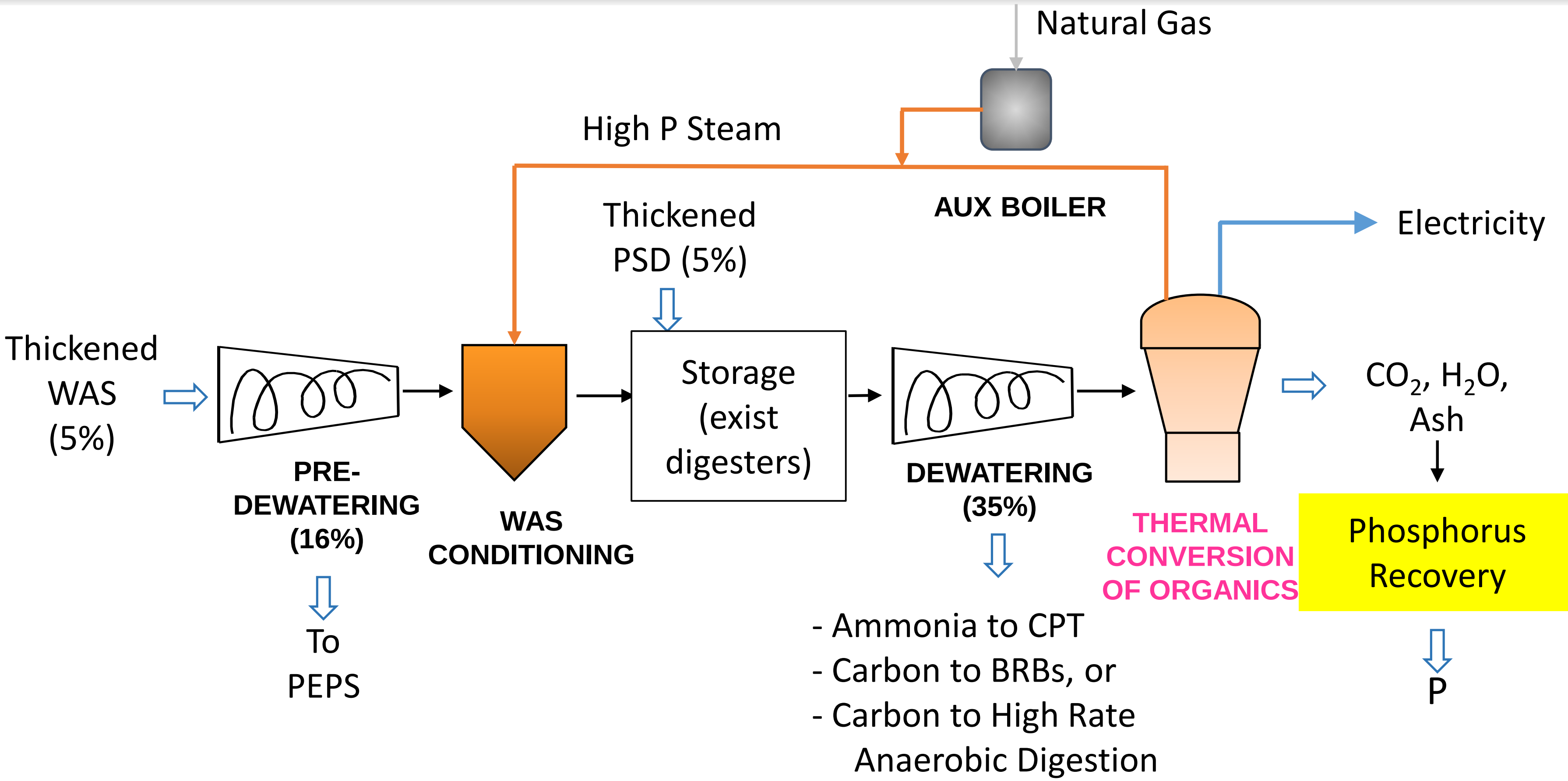
1. Thermal Conversion of Organics (TCO)
2. Anaerobic Digestion (AD)
3. Anaerobic Digestion & Thermal Conversion of Orgnaics (AD-TCO)

1a. Thermal Conversion of Organics (TCO) with Partial Thermal Drying



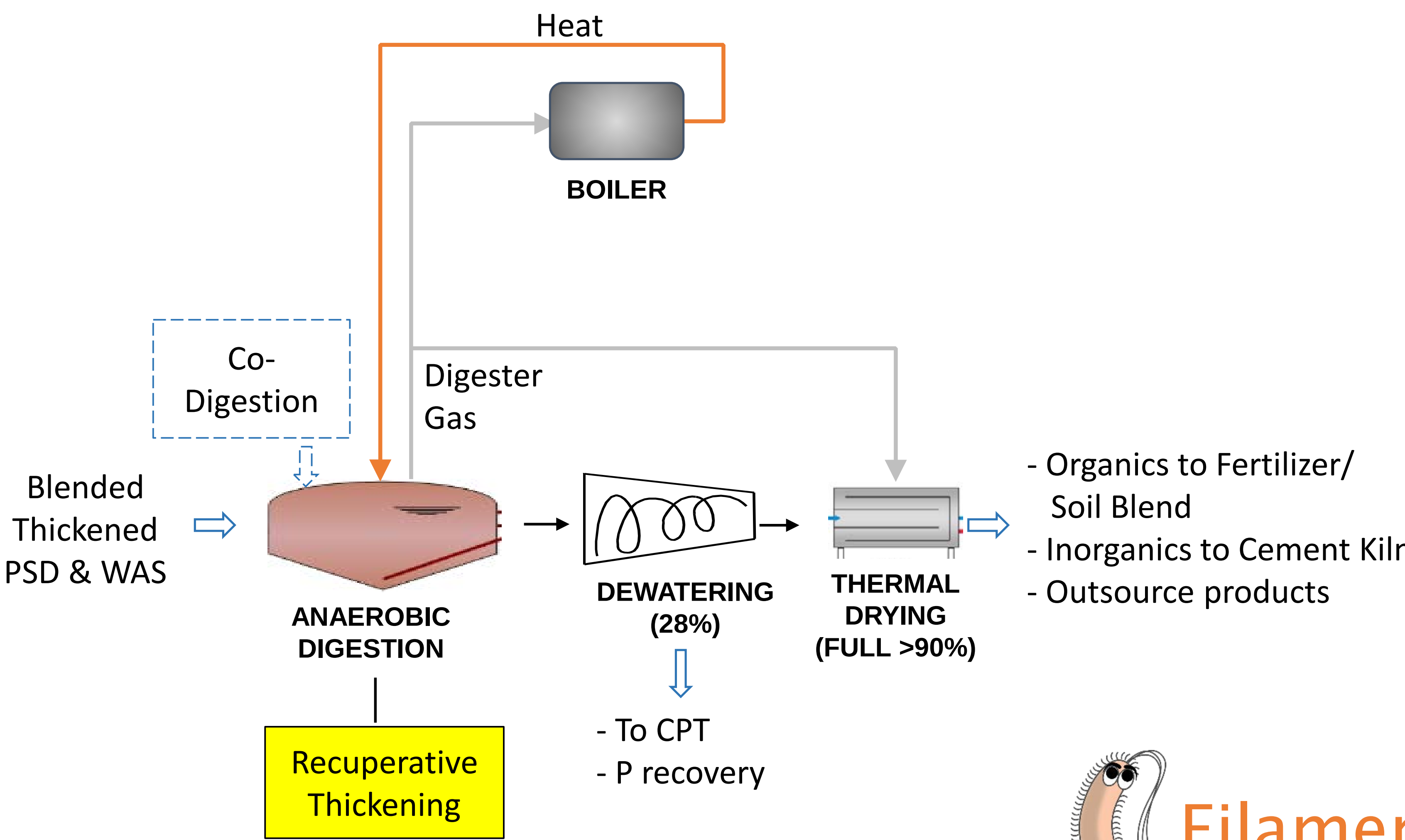
Nematodes

1b. Thermal Conversion of Organics (TCO) with WAS Conditioning



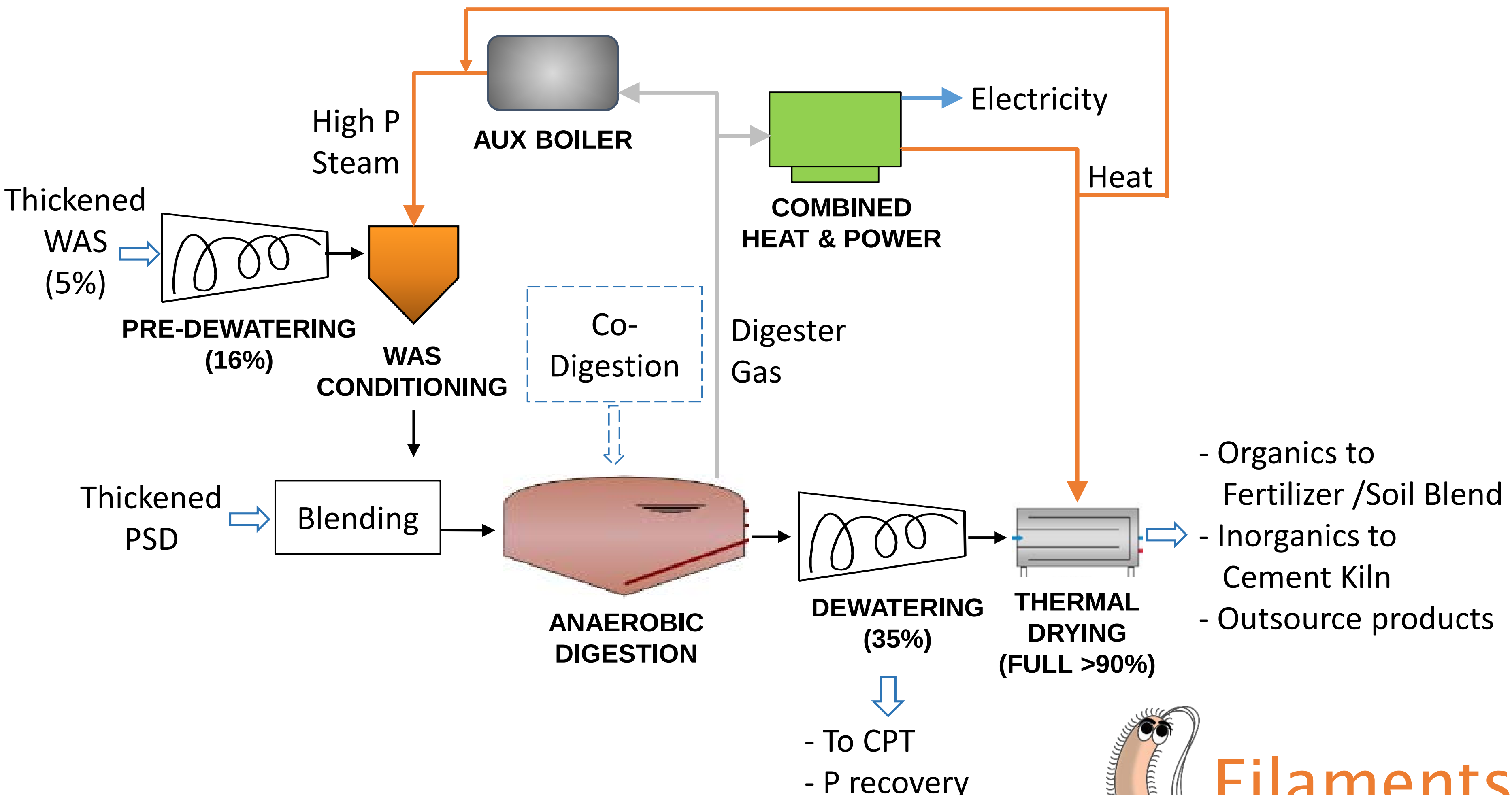
Nematodes

2a. Anaerobic Digestion (AD) with Thermal Drying



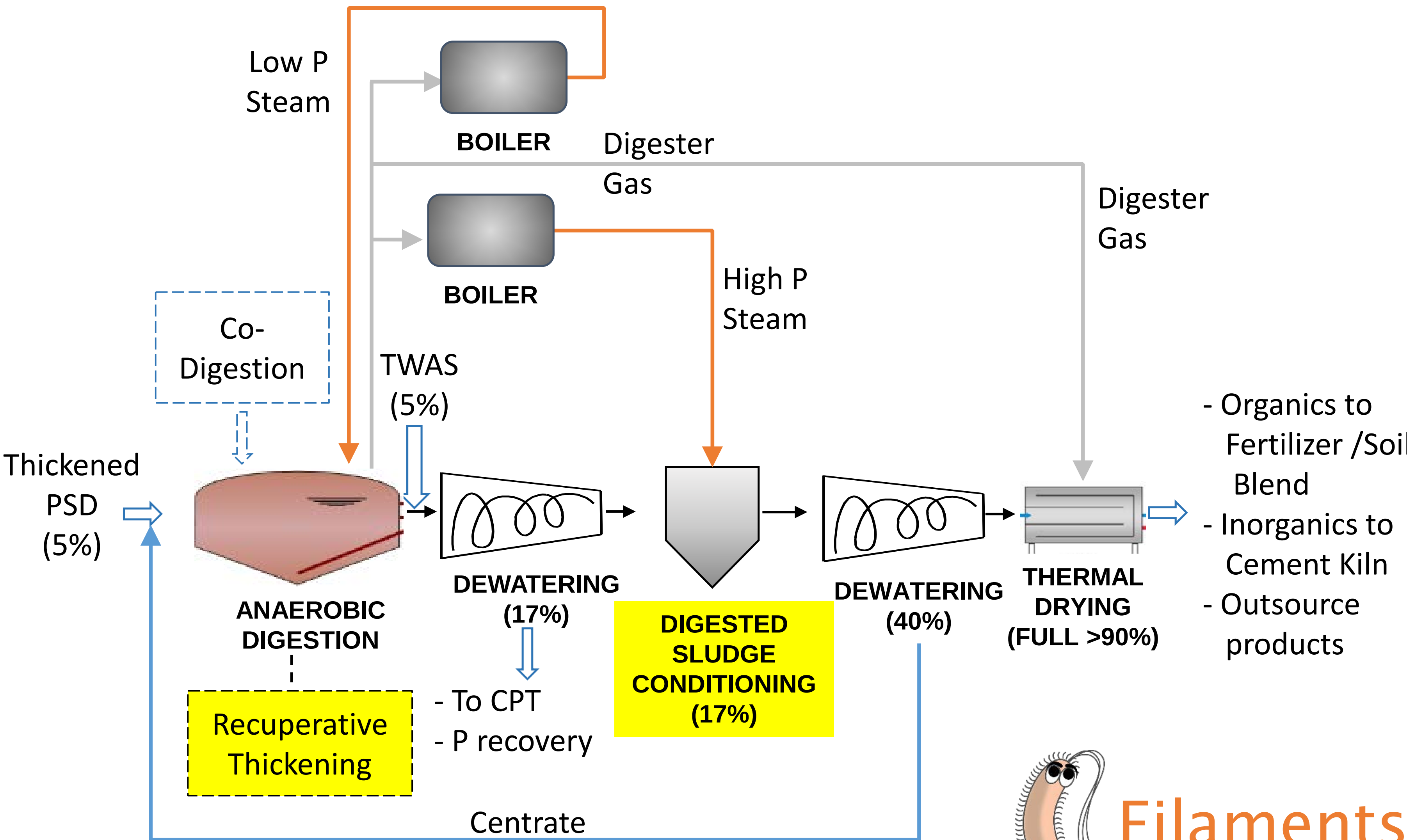
Filaments

2b. Anaerobic Digestion (AD) with WAS Conditioning and Drying



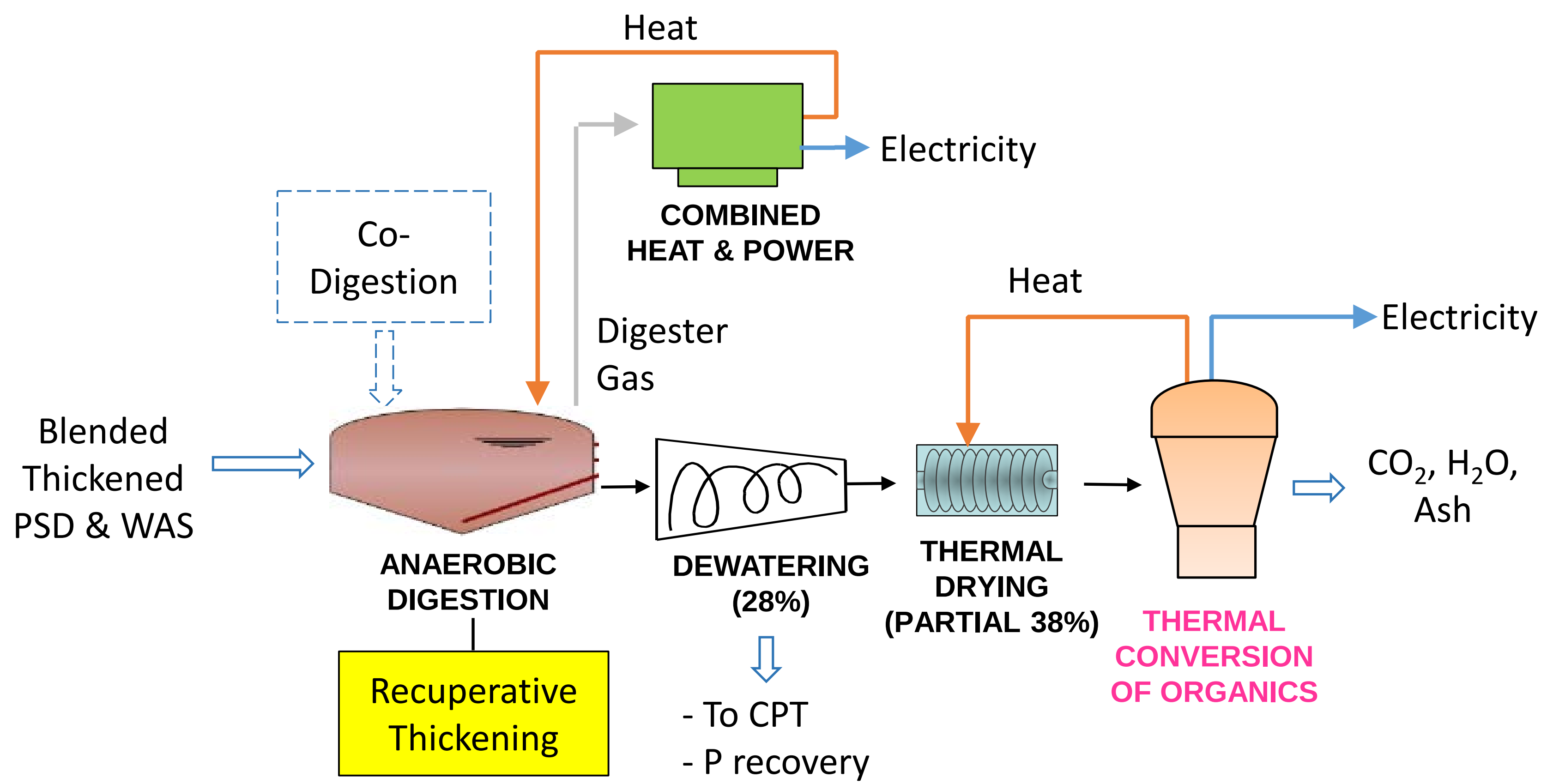
Filaments

2c. Anaerobic Digestion (AD) with DS conditioning and Drying



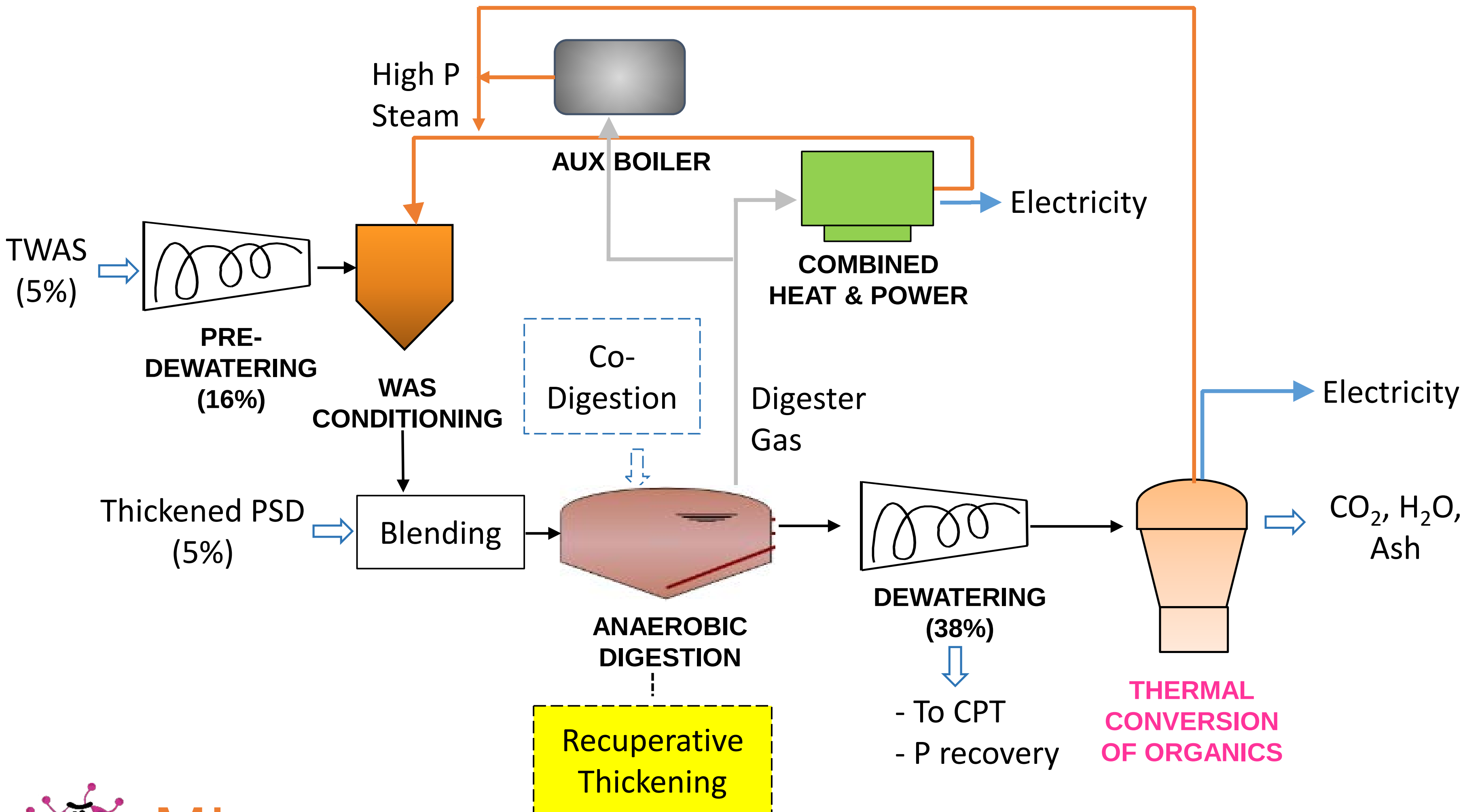
Filaments

3a. Anaerobic Digestion & Thermal Conversion of Organics (AD-TCO) w/o Sludge Conditioning



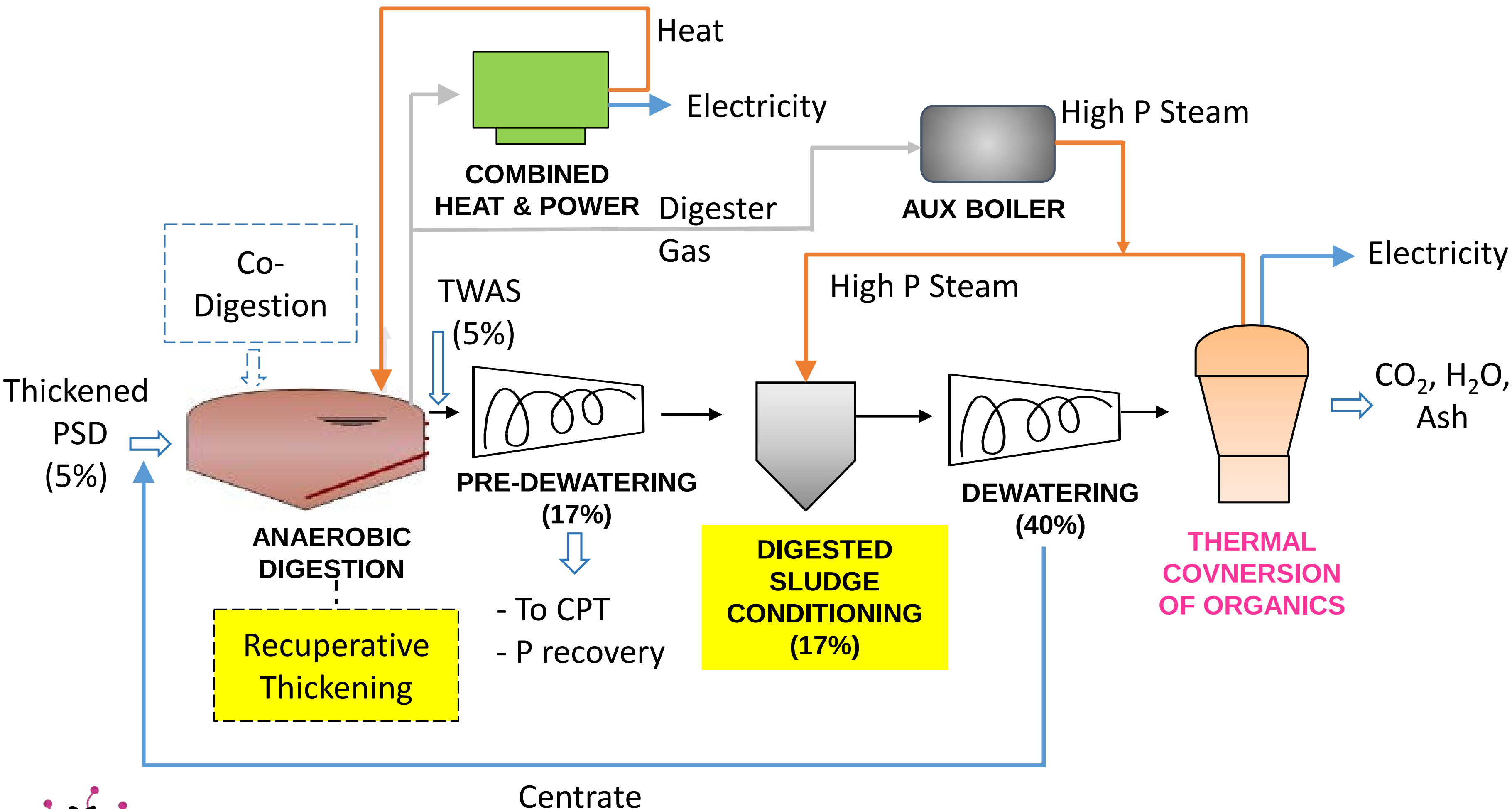
Mites

3b. Anaerobic Digestion & Thermal Conversion of Organics (AD-TCO) with WAS conditioning



Mites

3c. Anaerobic Digestion & Thermal Conversion of Organics (AD-TCO) with post-Conditioning



Mites

Alternatives Summary: Final Product and Available Energy

	Alternative	Final Product dry ton/day	Available Electricity (MW)	Available Hot Water (MBTU/day)	Total Available Energy (MBTU/day)
1a	TCO w/drying (partial)	20	1.5	n/a	5.0
1b	TCO w/WAS conditioning	19	1.6	n/a	5.4
2a	AD w/drying	55	n/a	38	38
2b	AD w/WAS conditioning and drying	50	4.4	>>(2a)	
2c	AD w/post hydrolysis and drying	63	4.4	>>(2a)	
3a	AD-TCO	20	3.7	120	133
3b	AD-TCO w/WAS conditioning	19	5.0	>>(3a)	
3c	AD-TCO w/post hydrolysis	26	5.0	>>(3a)	

Voting Results

	Alternative	Final Product dry ton/day	Available Electricity (MW)	Available Hot Water (MBTU/day)	Total Available Energy (MBTU/day)	AlexRene w votes	CH2M Votes	Total
1a	TCO w/drying	**20**	**1.5**	**n/a**	**5.0**	**1**	**0**	**1**
1b	TCO w/WAS cond	**19**	**1.6**	**n/a**	**5.4**	**0**	**0**	**0**
2a	AD w/drying	**55**	**n/a**	**38**	**38**	**5**	**0**	**5**
2b	AD w/WAS conditioning and drying	**50**	**4.4**	**>>(2a)**		**7**	**5**	**12**
2c	AD w/post hydrolysis and drying	**63**	**4.4**	**>>(2a)**		**3**	**2**	**5**
3a	AD-TCO	**20**	**3.7**	**120**	**133**	**5**	**3**	**8**
3b	AD-TCO w/WAS conditioning	**19**	**5.0**	**>>(3a)**		**9**	**10**	**19**
3c	AD-TCO w/post hydrolysis	**26**	**5.0**	**>>(3a)**		**3**	**13**	**16**

Alternatives Technologies Footprints

- PSD Thickening: Gravity Thickening
  - No change
  - Gravity Thickening Tanks footprint: 220’ x 160’
- WAS Thickening: Centrifuge Thickening
  - Can remove 1 TCEN; available space: 32’ x 40’ (1,280 ft^2)
  - Thickening Centrifuge space footprint: 64’ x 40’
- Dewatering
  - No change, Bldg L 6th floor
  - Dewatering Centrifuge room footprint: 38’ x 60’

Alternatives Technologies Footprints (continue…)

- Anaerobic Digestion
  - Exist footprint: triangle 380’ x 260’ h (49,400 ft^2)
  - Available space per freed digester: 112’ x 104’ (11,650 ft^2)
  - Recuperative thickening at the exist digesters basement

Alternative		No Change	3 Digesters	No Digesters	Notes
1a	TCO w/drying (partial)				Flexible (used for storage)
1b	TCO w/WAS conditioning				Flexible (used for storage)
2a	AD w/drying	X			Rec thickening needed
2b	AD w/WAS conditioning and drying		X		Rec thickening optional
2c	AD w/post hydrolysis and drying		X		Rec thickening optional
3a	AD-TCO w/drying (partial)	X			Rec thickening needed
3b	AD-TCO w/WAS conditioning		X		Rec thickening optional
3c	AD-TCO w/post hydrolysis		X		Rec thickening optional

Alternatives Technologies Footprints (continue…)

- WAS/DS Conditioning: Thermal Hydrolysis
  - 1 train, w/ 2 reactors each, footprint: 44’ x 41’ x 30’
  - 1 train, w/ 4 reactors each, footprint: 44’ x 41’ x 30’

Alternative		1 Train w/ 2 RXs each	1 Train w/ 4 RXs each	Pre-Dewatering, Cake bins, THP feed pumps
1a	TCO w/drying (partial)			-
1b	TCO w/WAS conditioning	X		Bld L, 6th floor & down (lime section)
2a	AD w/drying			-
2b	AD w/WAS conditioning and drying	X		Bld L, 6th floor & down (lime section)
2c	AD w/post hydrolysis and drying		X	Bld L, 6th floor & down (lime section)
3a	AD-TCO			-
3b	AD-TCO w/WAS conditioning	X		Bld L, 6th floor & down (lime section)
3c	AD-TCO w/post hydrolysis		X	Bld L, 6th floor & down (lime section)

Existing sludge screens currently in Bldg 55 needed. Not accounted for sludge screens elsewhere.

Alternatives Technologies Footprints (continue…)

- Drying: Disc Dryer for partial, Belt Dryer for full
  - Partial drying footprint: 50’ x 40’
  - Full drying footprint: 155’ x 46’

Alternative		Partial Drying	Full Drying	Notes
1a	TCO w/drying (partial)	X		
1b	TCO w/WAS conditioning	-		
2a	AD w/drying		X	
2b	AD w/WAS conditioning and drying		X	
2c	AD w/post hydrolysis and drying		X	
3a	AD-TCO w/drying (partial)	X		
3b	AD-TCO w/WAS conditioning	-		
3c	AD-TCO w/post hydrolysis	-		

Alternatives Technologies Footprints (continue…)

- Thermal Conversion of Organics: Fluidized Bed Reactor w/ ORC Turbine
  - FBR w/ 0.6 MW Turbine footprint: 112’ x 80’ + 55’ x 35’
  - FBR w/ 1.6 MW Turbine footprint: 112’ x 88’ x 50’ + 65’ x 35’ x 35’

Alternative		0.6 MW Turbine	1.5 MW Turbine	Notes
1a	TCO w/drying (partial)		X	
1b	TCO w/WAS conditioning		X	
2a	AD w/drying	-		
2b	AD w/WAS conditioning and drying	-		
2c	AD w/post hydrolysis and drying	-		
3a	AD-TCO w/drying (partial)	X		
3b	AD-TCO w/WAS conditioning	X		
3c	AD-TCO w/post hydrolysis	X		

Alternatives Technologies Footprints (continue…)

- CHP: Internal Combustion Engine
  - 2 MW IEC footprint: 50’ x17’
  - 4 MW IEC footprint: 50’ x 34’

	Alternative	CHP	BOILER	Notes
1a	TCO w/drying (partial)	-		
1b	TCO w/WAS conditioning		Auxiliary	Bldg A
2a	AD w/drying		X	Exist in Bldg A
2b	AD w/WAS conditioning and drying	4 MW	Auxiliary	
2c	AD w/post hydrolysis and drying		X	Exist+New high P, in Bldg A
3a	AD-TCO	3 MW		
3b	AD-TCO w/WAS conditioning	4.3 MW	Auxiliary	
3c	AD-TCO w/post hydrolysis	2.1 MW	Auxiliary	

Group Discussion and Voting

Embryonic Technologies

Presentation by Peter Burrowes

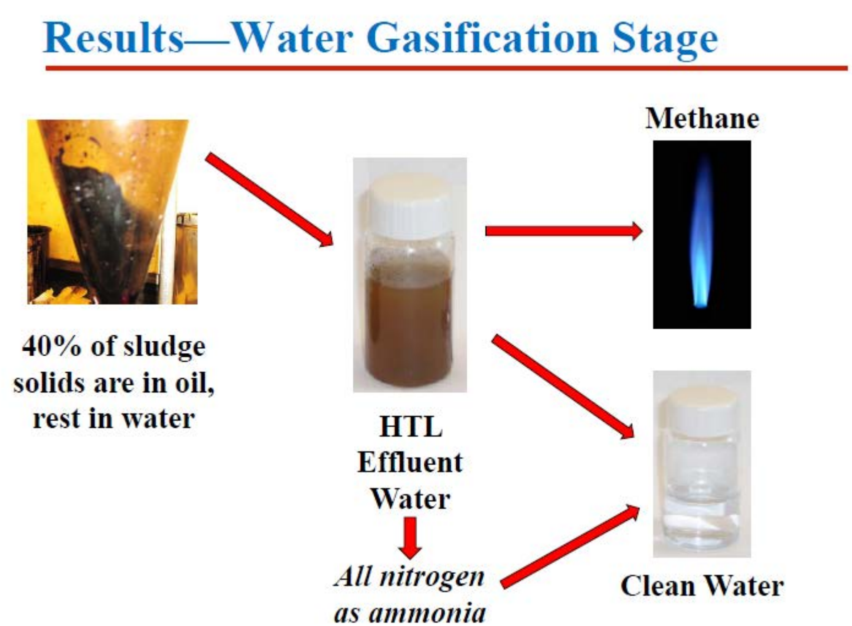
Embryonic Technologies Considered

- Sludge to oil
- Pyrolysis
- Gasification
- Bioplastics from biogas

Sludge to Oil

- Hydrothermal Liquefaction System converts wet biomass into crude-like-oil (biocrude) under high temperature and pressure (350 °C, 275 bar)
- Genifuel system also includes a water gasification stage that separates water and gas

- Proof of Concept Bench testing with municipal sludge at Pacific Northwest National Laboratory
- Yield of 25-37% crude oil on mass basis, 39-59% on carbon basis
- High methane content (>75%) in gas
- Looking for full scale demonstration



Pyrolysis

- Thermal decomposition of dry volatile organics (solid waste, yard waste, wood chips, biosolids, etc)
- High temperature (200-760°C) in the absence of oxygen
- End products:
  - Syngas (contains hydrogen, carbon monoxide, methane) can be used to generate electricity or biofuel
  - Mixture of un-reacted carbon char (non-volatile components) and ash
- KORE Encore Pyrolysis ran pilot at LA San Districts for 5 years. Full scale demonstration project is under construction, on line late 2016

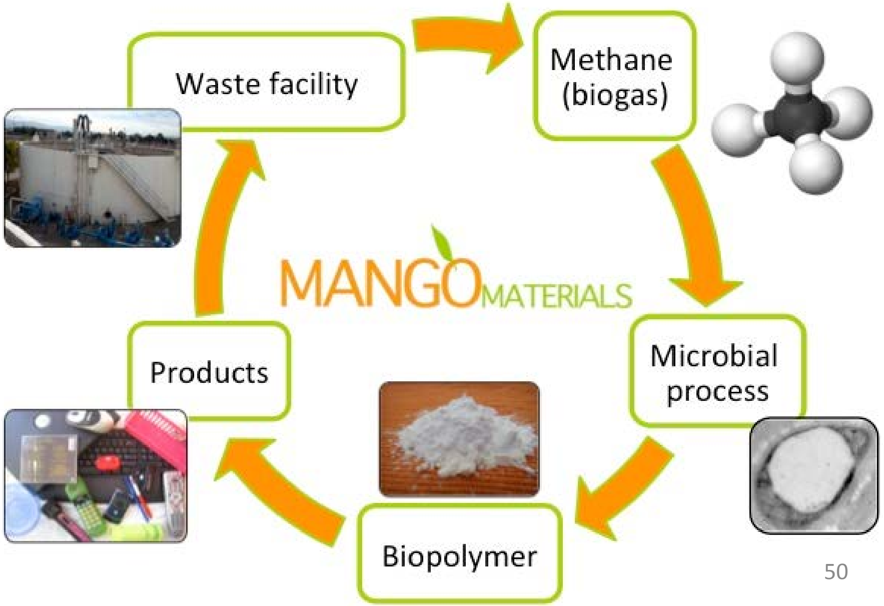
Gasification

- Similar to pyrolysis, uses dry organic material as feed stock and thermally decomposes volatiles to syngas.
- In addition, the non-volatile carbon char that would remain from pyrolysis is converted to additional syngas.
- Operates at higher temperatures (480-1,650°C) using minimum air
- Ash remains as a residual
- A few pilots and full scale installations in North America, Europe and Japan but none economically viable yet

Gasifer in Sanford, FL

Bioplastics

- Methane gas can be converted to a biopolymer with properties similar to polypropylene
- Process uses micro-organisms that metabolize the substrate (methane) to biopolymer. The biopolymer is then extracted from the microbes.
- Resulting biopolymer is biodegradable and generates methane gas
- Mango Technologies currently has a pilot facility in Silicon Valley, CA



Action Items and Next Steps

Summary by Rich Voigt

Alexandria Renew Enterprises Meeting Agenda

Facilitator: Julian Sandino/CH2M	**Meeting topic**: ***Solids Handling & Energy Optimization Technology Pathways Screening Workshop (BOA WA2-2016-7)***
Meeting date: May 11, 2016	**Meeting start time**: 8:00 am
Minutes taken by: Rich Voigt	**Meeting end time**: 3:00 pm

I. Meeting Objectives:

1.	Reviewing the Viable Pathways Toward an Envisioned Future
2.	Screening of Potential Alternative Process Configurations and Corresponding Unit Processes

II. Attendance:

Karen Pallansch	AlexRenew	Dan Lynch	CH2M
Sean Stephan	AlexRenew	Glen Daigger	CH2M
Janelle Okorie	AlexRenew	Tim Constantine	CH2M
Grace Richardson	AlexRenew	Julian Sandino	CH2M
Johnnie Wallace	AlexRenew	Rich Voigt	CH2M
Steve Hill	AlexRenew	Todd Williams	CH2M
Darel Stevens	AlexRenew	Peter Burrowes	CH2M
Lisa Reynolds	AlexRenew	Marialena Hatzigeorgiou	CH2M
Rickie Everette	AlexRenew	Savita Schlesinger	CH2M
Andre Yates	AlexRenew	Paula Sanjines	CH2M
James Atkinson	AlexRenew	Michael Shuler	CH2M
James Cummins	AlexRenew		
Eugene Singleton	AlexRenew		
Charlie Logue	AlexRenew		

III. Discussion/Decision Items:

Start Time		Topics	Notes
	8:00 am	***Breakfast/Refreshments***	
1.0	8:30 am	Welcome & Introductions (Karen)	
2.0	8:45 am	Defining Success (Rich)	• Planning Path • Workshop #3 Goals
3.0	9:00 am	Confirmation of Planning Basis (Paula)	• Updated population and flows/loads used for planning (includes new Fairfax County projections)
4.0	9:15 am	Plausible Future Scenarios and Pathways (Julian)	• Recap of the plausible future scenarios and technology pathways developed in Workshop #2 • Describe work that has been done since WS#2
5.0	9:30 am	Technologies: Brief overview	• Review of Reference Technologies

Alexandria Renew Enterprises Meeting Agenda

Start Time		Topics	Notes
			➢ Dryers (Partial and Full) ➢ Thermal Oxidation ➢ WAS Pre-Conditioning ➢ Digested Sludge Conditioning ➢ Combined Heat and Power
	10:00 am	***Break***	
6.0	10:15 am	Evaluation Criteria (Sean/Savita)	• Identification and definition of criteria to be used for screening purposes
7.0	10:45 am	Discuss and Evaluate Pathway Configuration Alternatives (8)	• Review the 3 pathways and sub-alternatives • Each pathway (and sub-alternatives) will be presented by the group that generated it (Nematodes/Mites/ Filaments) • Discussion will consider how evaluation criteria applies
	Noon	***Lunch***	
8.0	12:30 pm	Group Discussion and Voting (Julian)	• After lunch, ask participants to assign votes to preferred alternatives based on selection criteria (eg each AlexRenew attendee gets 3 votes) • Review the voting results • Select the recommended alternatives for further evaluation (shortlist)
	1:45 pm	***BREAK (if needed)***	
9.0	2:00 pm	Discussion of Embryonic Technologies (Tim)	• Identify where embryonic technologies could be implemented for each shortlisted alternative
10.0	2:30 pm	Wrap-up (Rich)	• Action Items • Next Steps
	3:00 pm	***Adjourn***	

AlexRenew Decision Model-Based Questions

Operational Excellence

1. Can the alternative accommodate 2040 loads? Can it be adapted for 2060 loads?
2. Does is create or increase products?
3. Does it minimize waste?

Community Benefits

1. How does the Community benefit from the alternative?
2. Are there negative impacts to the Community? Can the impacts be mitigated? *Impacts to consider include truck traffic, odor, noise, air emissions, light pollution, etc.*
3. What is the footprint needed? Does the alternative require footprint outside the existing fence line?
4. Can we create footprint within the fence line by demolition or building up?

Watershed Partnerships

1. Can we create a product that leverages an existing partnership?
2. Can the alternative create the opportunity to develop new partnerships?

Organizational Competency and Structures

1. Is the alternative cutting edge or does it enable cutting edge technologies?
2. Are the technologies innovative relative to the baseline (current process)?

Investment Stewardship

Does it maximize the use of existing assets?

Incubator of New Ideas and Innovations

1. Does the alternative provide flexibility to incorporate embryonic technologies?
2. What are the risks associated with the alternative?
3. Is the alternative “green”?

AlexRenew Decision Model

Weights:	40	22	10	13	7	8
Strategic Alignment:	Operational Excellence	Community Benefit	Watershed Partnership	Organizational Competency & Structure	Investment Stewardship	Incubator of New Ideas and Innovations
	Improve Business Efficiency ***Weight: 10***	Promotes water in our community ***Weight: 3***	Enable new external partnerships ***Weight: 6***	Supports great place to work ***Weight: 3***	Annual Cost ***Weight: 1***	Enhance Sustainability ***Weight: 2***
	Compliance enhancement /adaptability ***Weight: 15***	Enhance Community Water Resources ***Weight: 4***	Support sound Science ***Weight: 4***	Improves ease of operation ***Weight: 5***	Capital Cost Management ***Weight: 1***	Enhance Resiliency ***Weight: 2***
	Enhance Capacity/Throughput ***Weight: 10***	Supports customer service ***Weight: 5***		Maximize technology tool solutions ***Weight: 5***	Fosters Operational Cost savings ***Weight: 3***	Technical Feasibility ***Weight: 4***
	VEEP/EMS ***Weight: 5***	Communication Enhancement Value ***Weight: 6***			***Revenue Neutral or positive Weight: 2***	
		Minimizes Land Footprint ***Weight: 4***				

MEETING SUMMARY

BOA WA2-2016-7

AlexRenew Solids Handling & Energy Optimization – Technology Pathways Scoring Workshop – July 13, 2016

ATTENDEES:	Sean Stephan/AlexRenew Charlie Logue/AlexRenew Grace Richardson/AlexRenew Steve Hill/AlexRenew Eugene Singleton/AlexRenew Hong Yin/AlexRenew Johnnie Wallace/AlexRenew Darel Stevens/AlexRenew Andy Ayala/AlexRenew	Anthony Patrick/AlexRenew Kacey King-McRae/AlexRenew Rich Voigt/CH2M Todd Williams/CH2M Marialena Hatzigeorgiou/CH2M Savita Schlesinger/CH2M Paula Sanjines/CH2M Michael Shuler/CH2M
COPY TO:	Karen Pallansch/AlexRenew Lisa Reynolds/AlexRenew Rickie Everette/AlexRenew Andre Yates/AlexRenew James Atkinson/AlexRenew James Cummins/AlexRenew Aster Tekle/AlexRenew	Chuck Phillips/AlexRenew Dan Lynch/CH2M Glen Daigger/CH2M Tim Constantine/CH2M Julian Sandino/CH2M Peter Burrowes/CH2M File
PREPARED BY:	Rich Voigt/CH2M	
DATE:	July 15, 2016	

Objectives

A workshop for the Alexandria Renew Enterprises (AlexRenew) Solids Handling & Energy Optimization Project was held on July 13, 2016 at the AlexRenew Administration Building. Objectives were as follows:

- Review the previously screened alternatives/technology pathways
- Score each alternative and select an approach to recommend for implementation

Summary

A summary of the workshop is provided below.

Defining Success

A brief recap of past work was provided, including initial screening efforts that have brought us to the four alternatives/technology pathways to be evaluated. In addition, goals for the current workshop were stated – to review screened alternatives/technology pathways, and to score each alternative and select an approach to be recommended to the Senior Leadership Team for review and approval.

Decision Model Recap

The team went over the decision model and recent updates/enhancements to the tool. The decision model that was used is attached to these meeting notes.

Alternative Overview

A refresher overview of the four alternatives was provided (and an introduction for those attendees that had not participated in previous workshops.) The overview included a summary of the parameters/assumptions and the resulting impact on biosolids produced, truck traffic, GHG emissions, energy produced (electricity and heat) and costs (operational and capital). A discussion of site layout and construction sequencing was also included. The materials presented are attached to these meeting notes.

A brief review of the impact of Chemically Enhanced Primary Treatment or CEPT (vs. no CEPT) was presented. In addition, a discussion of Phosphorus Recovery (with Ostara as representative of the technology) was conducted by the team. CEPT produces more biogas (and therefore more energy can be generated than without CEPT), but does not allow P recovery as the phosphorus is bound in the chemical sludge. The analysis used for scoring was based on sludge production with CEPT as this scenario generates the most biosolids and therefore presents a more conservative sizing evaluation.

Discussion Notes:

- Existing flares and boilers can only accommodate today's biogas generation. If gas generation goes up, may need to expand flare/boiler capacity to handle excess biogas whenever unit processes like CHP, dryer or high P boilers are out of service for maintenance.
- Recuperative Thickening: Discussed that the existing digester recirculation pumps may not be able to handle thicker sludge and may need replacement.
- Truck routes through Solids Processing Building will need to be considered during construction, particularly for options 2a and 2b that would build a new dryer in the space between Bldg L and Bldg C.
- Discussed the possibility of using Building C for THP Boilers in lieu of Building A as proposed. The reason is that Building C boilers are 40 years old, whereas Building A boilers are only 15 years old – they have serviceable life left and are dual gas boilers. However it was pointed out that the digester gas is already routed to Building A and there may be some advantages to keeping all the biogas uses in one facility. This can be further refined later.
- Need to add microturbine to the process diagram for 3b and 3c
- Truck traffic routing for Thermal Conversion of Organics (TCO) has not been determined, but ash storage space is provided within TCO facility. Trucks will need to load up the ash there.
- For 3b and 3c, existing dewatering centrifuges would have to stay as redundant units for the new dewatering equipment located in the new dewatering building. The existing units can remain or be replaced (some additional cost). AlexRenew pointed out that the existing units are becoming obsolete and it is getting harder to find parts and get vendor service.

Scoring Discussion

- Scoring (all alternatives were evaluated together for each category)
    - Improve Business Efficiency
        - All alternatives that include stationary combustion sources will require an air permit. The TCO alternatives will require a Title V operating permit which will be more involved.

    - Truck traffic is reduced for all options, particularly 3b and 3c
    - Assumed energy efficiency covered in other categories.
    - All four alternatives were viewed as about the same but alternatives 3b and 3c were awarded slightly higher scores due to decreased solids production (ash) and truck traffic
  - Compliance Enhancement/Adaptability
    - 2a and 2b can adapt in the future. Thermal hydrolysis is state of the art today.
    - 3b and 3c are state of the art with flexibility to adapt as TCO can be replaced by other technologies such as pyrolysis and/or gasification. 3c less proven than 3b to date, but piloting and research are ongoing, and one full-scale installation in Germany.
  - Enhance Capacity/Throughput
    - Evaluated based primarily on digester SRT for each alternative
  - VEEP/EMS
    - Only item 4 is applicable (aligning with sustainability goals). Relative to baseline (2a), alternatives 3b and 3c significantly increase energy production, reduce production of solids, and reduce truck traffic. Therefore these alternatives were given a higher score.
  - Promotes Water in our Community
    - Team discussed whether the Title V Air permit requirement would be viewed as a negative by the community, considering the fact that a new stack would be added with the TCO alternatives. However the team decided that AlexRenew already has several odor stacks on site and there are others in surrounding area (Covanta), so the TCO alternatives were not penalized.
    - All alternatives have green elements (energy production, reduced truck traffic, etc) so it was decided to score them the same as "moderate improvement".
  - Enhance Community Water Resources
    - 2a and 2b products could still be used in the soil (either through a land application program and/or through distribution as a fertilizer or soil amendment) and result in runoff to the receiving water bodies (similar to what AlexRenew does now). Therefore these were scored as "no impact"
    - 3b and 3c capture nutrients in ash where they are inert (not bioavailable and therefore eliminate potential nutrient runoff to bodies of water These were scored as "positive impact"
  - Supports Customer Service
    - Strictly evaluated in terms of customer service. The team decided that the alternatives are equal when it comes to serving customer base and they have no impact. Truck traffic was discussed but the conclusion was that this only affects a small portion of the customers (those who live close-by).
  - Communication Enhancement Value
    - No real net impact

- Minimizes Land Footprint
  - Dryer options increase footprint
  - TCO uses footprint of one of the existing digesters, so it was scored as "no impact/neutral"
- Enable New External Partnerships
  - Co-digestion (food waste, FOG, etc.) opportunities to work with City restaurants, others which is applicable to all the alternatives.
  - All options produce energy, freeing up more capacity for local energy utility/users.
  - All options were scored the same: Moderate improvement.
- Support Sound Science
  - 3c is less proven (few installations)
  - 2a uses the most established technology (dryer and no THP)
  - 2b and 3b are about the same (THP is newer technology in both. Dryer and incinerator both proven technology)
- Supports Great Place to Work
  - New technologies, cutting-edge, increased energy efficiency. All alternatives have about the same impact (positive).
- Improves Ease of Operation
  - Team discussed that the alternatives require more processes/technologies, more oversight and new skills needed. High pressure boilers require certified operator
  - Alt. 2a swaps Pre-pasteurization for a Dryer and therefore was considered neutral. Other options add more new technologies and more unit processes (they also replace Pre-pasteurization)
- Maximize Technology Tool Solutions
  - All alternatives improve efficiencies
  - Daily work increased for 2b, 3b, and 3c (relative to baseline – 2a)
- Annual Cost
  - Compared costs to baseline (2a)
- The difference in annual costs is within the margin of error of the estimate (+/- 20% for this level of project definition). Capital Cost Management
  - Estimated capital costs evaluated relative to baseline (2a)
- Fosters Operational Cost Savings
  - All alternatives will result in higher operational costs so none offers operational cost savings. Did discuss that energy savings occur.
- Revenue Neutral or Positive
  - Scores based on energy production only (not enough information to assess other potential revenue sources)

- Enhance Sustainability
    - 3b and 3c reduce GHG
    - 2a does not reduce KWH, but others produce surplus that can be used throughout the plant
    - All alternatives reduce amount of solids for disposal
- Enhance Resiliency
    - Incinerator failure may require notification of regulators – affects alternatives 3b and 3c. Backup is to land apply or landfill Class B biosolids.
    - Existing silos can hold approximately 1 week of biosolids? Need to confirm.
- Technical Feasibility
    - 2a and 2b utilize more space for dryer
    - 3b and 3c utilize existing digester space

Scoring Results

See attached

Analysis of scoring:

- Operational excellence category was driving force for the scoring (also highest weighting)
- Sensitivity Analyses: scores with and without cost were similar – no change in recommended option
- Cost difference between alternatives is significant. Team discussed possible phased implementation. One option discussed would be to start with 2A then expand/enhance later and leverage new technology advances.

Parking Lot Issues

- Implementation/Phasing
- Constructability
- Truck traffic/routing for selected alternative
- Resource recovery add-ons (including impact of bioP and P Recovery)
- Redundancy of major unit processes (dryer or TCO): Analysis was based on a single unit operating and land application/landfill as a backup during periods when equipment is down for maintenance/repairs. Is this adequate/appropriate for AlexRenew?
- Capacity of existing silos

Action Items

Table 1. Action Items List

Item	Responsible Party	Target Due Date
Meeting Minutes	CH2M	7/15/16
Scoring Summary (Draft) for Sean's review	CH2M	7/20/16
Scoring Summary Materials Submitted to Senior Leadership Team for review	AlexRenew	7/26/16
Senior Leadership Team Meeting	All parties	8/2/16
Final Analysis Workshop	All parties	TBD (mid to late August)

Attachments

1. Scoring Summary
2. Meeting Agenda
3. Revised Presentation Slides (with Construction Cost Estimates)
4. Discussion of CEPT and Biological Phosphorus Removal
5. Updated Decision Model
6. Layouts for Technology Pathways/Alternatives

		Alternative 2a		Alternative 2b		Alternative 3b		Alternative 3c	
Operational Excellence	**40**	**Grade**	**Score**	**Grade**	**Score**	**Grade**	**Score**	**Grade**	**Score**
Improve Business Efficiency	10	3	3	3	3	5	5	5	5
Compliance Enhancement/adaptability	15	5	7.5	7	10.5	9	13.5	9	13.5
Enhance Capacity/Throughput	10	3	3	7	7	7	7	5	5
VEEP/EMS	5	3	1.5	3	1.5	7	3.5	7	3.5
Total			15		22		29		27
Community Engagement	**22**								
Promote Water in our Community	3	7	2.1	7	2.1	7	2.1	7	2.1
Enhance Community Water Resources	4	5	2	5	2	7	2.8	7	2.8
Supports Customer Service	5	5	2.5	5	2.5	5	2.5	5	2.5
Communication Enhancement Value	6	5	3	5	3	5	3	5	3
Minimizes Land Footprint	4	3	1.2	3	1.2	5	2	5	2
Total			10.8		10.8		12.4		12.4
Watershed Partnership to Enhance Collective Management	**10**								
Enable New External Partnerships	6	7	4.2	7	4.2	7	4.2	7	4.2
Support Sound Science	4	9	3.6	7	2.8	7	2.8	5	2
Total			7.8		7		7		6.2
Organizational Competency & Structure	**13**								
Supports Great Place to Work	3	7	2.1	7	2.1	7	2.1	7	2.1
Improves Ease of Operations	5	3	1.5	0	0	0	0	0	0
Maximize Technology Tool Solutions	5	3	1.5	0	0	0	0	0	0
Total			5.1		2.1		2.1		2.1
Diversified Revenue	**7**								
Annual Cost	1	5	0.5	0	0	5	0.5	0	0
Capital Cost Management	1	9	0.9	3	0.3	0	0	0	0
Fosters Operational Cost Savings	3	0	0	0	0	0	0	0	0
Revenue Neutral or Positive	2	0	0	3	0.6	9	1.8	9	1.8
Total			1.4		0.9		2.3		1.8
Incubator of New Ideas and Innovations	**8**								
Enhance Sustainability	2	3	0.6	5	1	7	1.4	7	1.4
Enhance Resiliency	2	5	1	5	1	5	1	5	1
Technical Feasibility	4	5	2	5	2	7	2.8	7	2.8
Total			3.6		4		5.2		5.2
Total Score w/out Cost			**42.3**		**46.5**		**57.5**		**54.7**

	Alternative 2a			Alternative 2b			Alternative 3b			Alternative 3c	
Total Score		**43.7**			**46.8**			**58**			**54.7**
Capital Cost ($millions)	$ 39,230,000			$ 49,280,000			$ 121,280,000			$ 130,180,000	
Annual Cost ($Millions)	$ 3,186,000			$ 3,674,000			$ 3,326,000			$ 3,968,000	
O&M Cost ($Million)	$ 1,489,000			$ 2,324,000			$ 2,769,000			$ 3,033,000	
GHG (tonnes CO2e/year)	3,784			1,062			-2,343			-2,308	

Facilitator: Rich Voigt/CH2M	**Meeting topic**: ***Solids Handling & Energy Optimization Scoring Workshop (WS #4) (BOA WA2-2016-7)***
Meeting date: July 13, 2016	**Meeting start time**: 8:00 am
Minutes taken by: Rich Voigt/CH2M	**Meeting end time**: 1:00 pm

I. Meeting Objectives:

1.	Reviewing Screened Alternatives/Technology Pathways
2.	Score Each Alternative and Select an Approach to Implement

II. Attendance:

Sean Stephan	AlexRenew	Kacey King-McRae	AlexRenew
Charlie Logue	AlexRenew	Anthony Patrick	AlexRenew
Hong Yin	AlexRenew	Jessica Jones	AlexRenew
Grace Richardson	AlexRenew	Andy Ayala	AlexRenew
Steve Hill	AlexRenew	Paula Sanjines	CH2M
Darel Stevens	AlexRenew	Savita Schlesinger	CH2M
Johnnie Wallace	AlexRenew	Marialena Hatzigeorgiou	CH2M
James Atkinson	AlexRenew	Rich Voigt	CH2M
Eugene Singleton	AlexRenew	Michael Shuler	CH2M
		Todd Williams	CH2M

III. Discussion/Decision Items:

Start Time		Topics	Notes
	8:00 am	***Breakfast/Refreshments***	
1.0	8:15 am	Welcome & Introductions (Sean)	
2.0	8:30 am	Defining Success (Rich)	• Recap of how we got here • Goals for today
3.0	8:45 am	Decision Model Recap (Sean)	• Quick update of recent edits to tool • How to use the tool
4.0	9:00 am	Review and Scoring of Selected Technology Pathways/Alternatives (All)	• Review and scoring of the technology pathway alternatives selected at Workshop #3
	Noon	***Lunch***	***Working lunch, if needed***
5.0	12:30 pm	Summary of Scoring Analysis/Path Forward (Rich)	• Confirm selected alternative • Discuss why selected alternative was chosen/justification • Discuss Path Forward (Senior Management Leadership Team Review)
	1:00 pm	***Adjourn***	

ALEXANDRIA renew ENTERPRISES

Solids Handling & Energy Optimization Technology Pathways

Alternatives Summary

July 13, 2016

ch2m

Abbreviations

- AD: Anaerobic Digestion
- BTCS: Blended, Thickened Combined Solids
- BTS: Blended Thickened Sludge
- CHP: Combined Heat and Power
- CPT: Centrate Pretreatment
- DBS: Dewatered Blended Sludge
- DS: Digested Sludge
- DSC: Dewatered Digested Solids
- DWAS: Dewatered WAS
- GT: Gravity Thickener
- ORC: Organic-Rankine Cycle
- P Recovery: Struvite precipitation (Ostara)
- PSD: Primary Sludge
- TCO: Thermal Conversion of Organics
- THP: Thermal Hydrolysis Process
- TSD: Tertiary Sludge
- TS: Total Solids
- T (PSD + TSD): Thickened Primary and Tertiary Sludge
- TWAS: Thickened WAS
- WAS: Waste Activated Sludge

Design Condition

- 2060 Planning Horizon
- 480,000 service population
- 58 MGD Annual Average Daily Flow
  - Annual Average condition is the basis for O&M Costs and Greenhouse Gas emissions
- 70 MGD Max Month (30-day) Daily Flow
  - Maximum Month condition is the basis of design for equipment and facility sizing
- Assumes solids generated with Chemically Enhanced Primary Treatment

Summary of Alternatives Process Train

Elements	Alternative 2a (Baseline)	Alternative 2b	Alternative 3b	Alternative 3c
Primary + Tertiary Thickening	✓	✓	✓	✓
WAS Thickening	✓	✓	✓	✓
WAS Pre-Dewatering	✗	✓	✓	✗
WAS Conditioning	✗	✓	✓	✗
Digestion	✓	✓	✓	✓
Recuperative Thickening	✓	✓	✓	✓
Post-Digestion Sludge Conditioning	✗	✗	✗	✓
Dewatering	✓	✓	✓	✓
Drying	✓	✓	✗	✗
Thermal Conversion of Organics	✗	✗	✓	✓

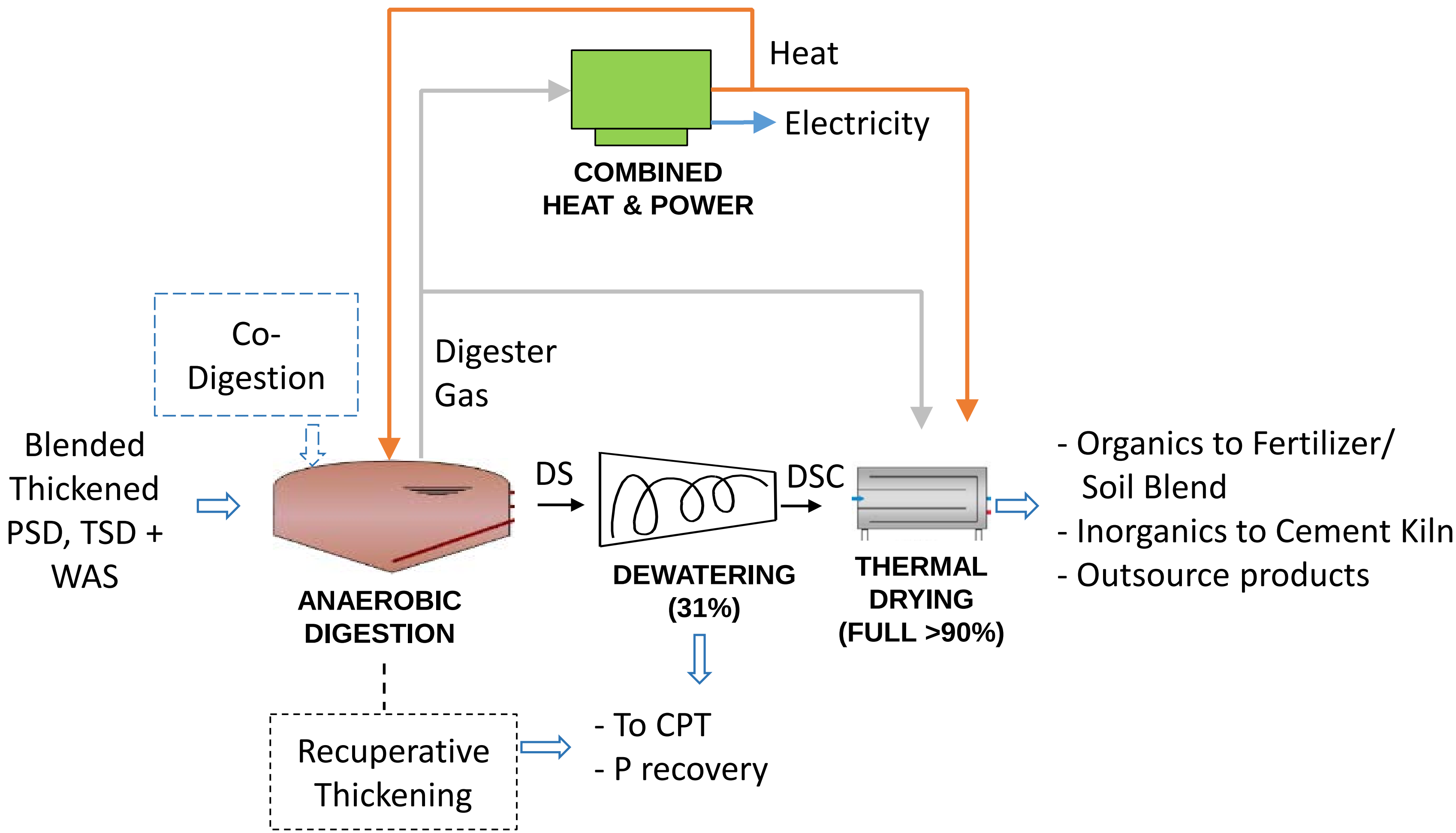
Reference Technologies for Conceptual Definition (Modeling/Sizing/Layout)

- PSD Thickening → Gravity Thickener
- WAS Thickening → Centrifuge
- Anaerobic Digestion → Mesophilic AD
- Recuperative Thickening → Rotary Drum Thickener
- Sludge (PSD, WAS, DS) Conditioning → Thermal Hydrolysis (Cambi)
- Sludge Dewatering → Centrifuge
- Sludge Thermal Drying → Belt
- Thermal Conversion of Organics → Fluidized Bed Reactor
- P Recovery → Intentional struvite precipitation (Ostara)
- Combine heat power (CHP) → Internal combustion engine
- Heat Recovery from TCO → Organic-Rankine Cycle (ORC) Turbines

Baseline Alternative 2a:

Anaerobic Digestion with Thermal Drying

2a. Anaerobic Digestion (AD) - Drying



2a. Process Assumptions

2a. AD-Drying	Solids Capture	Product	Chemical/Gas Usage	Energy Consumption
Thickening PSD+TSD	87% capture	5% TS underflow	-	-
Thickening WAS	95% capture	5% TS out	8 lb polymer/ dry ton feed	33 kWhr/wet ton out
Anaerobic Digestion *	80% VS in 61% VSR	61% VS out	14 ft^3 DG/ lb VS reduced	-
Recuperative Thickening	95% capture	9% TS out	8 lb polymer/ dry ton feed	50 kWhr/wet ton out
Dewatering	95% capture	31% TS out	21 lb polymer/ dry ton feed	55 kWhr/wet ton out
Drying	100% capture	90% TS out	1,500 BTU/lb H_2O evaporated	-
CHP	-	-	49.9% thermal efficiency	40% electrical efficiency

* See next slide for anaerobic digester SRT with and without recuperative thickening

2a. Anaerobic Digestion Process

Design Criteria	SRT with 4 Total Units	SRT with 3 Total Units	SRT with 3 Total Units + Recuperative Thickening
Minimum 12-day SRT at Max Month Condition with All Units in Service	12 days ✓	8.9 days ✗	12 days (44 gpm)
Minimum 15-day SRT at Annual Average Condition with All Units in Service	14.3 days ✗	10.7 days ✗	15 days (132 gpm)
Minimum 12-day SRT at Annual Average Condition with One Unit out of Service	10.7 days ✗	7.1 days ✗	12 days (212 gpm)

SRT Design Criteria with 4 Total Units is close to being met and could work by increasing % TS of thickened sludge by 1 or 2 %

Adding recuperative thickening frees up a digester and ensures adequate SRT.

2a. Process Flow & Mass Balance
(Max Month Conditions)

2a. AD-Drying (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
PSD	5,000,000	164,529	0.39%
WAS	970,000	48,647	0.60%
TSD	1,100,000	19,400	0.21%
T(PSD+TSD)	383,737	160,018	5.0%
TWAS	110,826	46,215	5.0%
BTS	494,563	206,233	5.0%
DS	367,814	105,591	3.4%
DSC	38,799	100,312	31%
Dry Product		**100,312**	90.0%

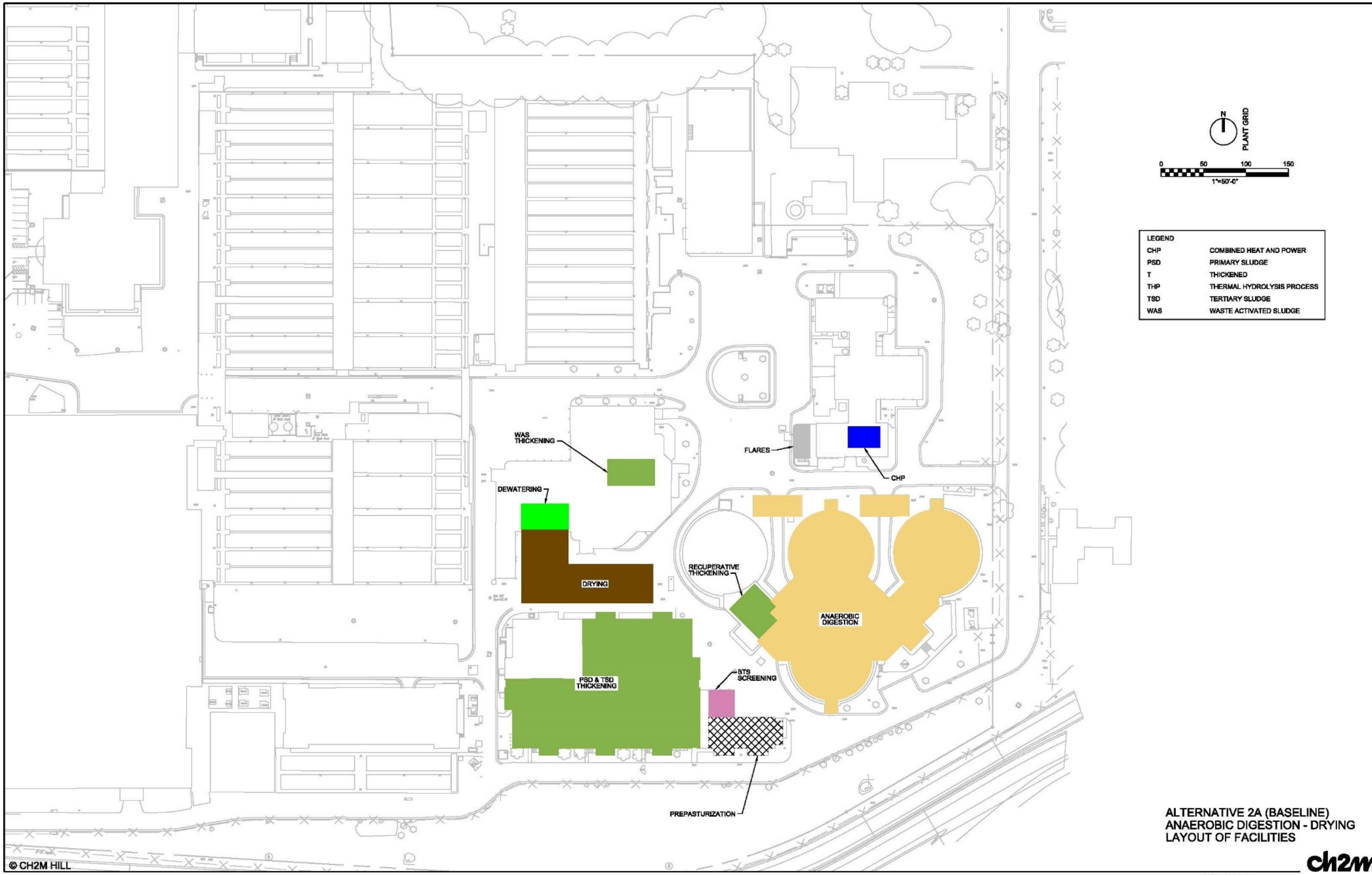
2a. Process Flow & Mass Balance
(Max Month Conditions)

2a. AD-Drying (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
GT Overflow	5,716,263	23,911	0.05%
WAS Thickening Centrate	859,174	2,432	0.03%
Dewatering Centrate	329,015	5,280	0.19%
Rec. Thickening Centrate	126,749	2,858	0.27%
Centrate to CPT	455,764	8,137	0.21%

2a. Equipment & Footprint

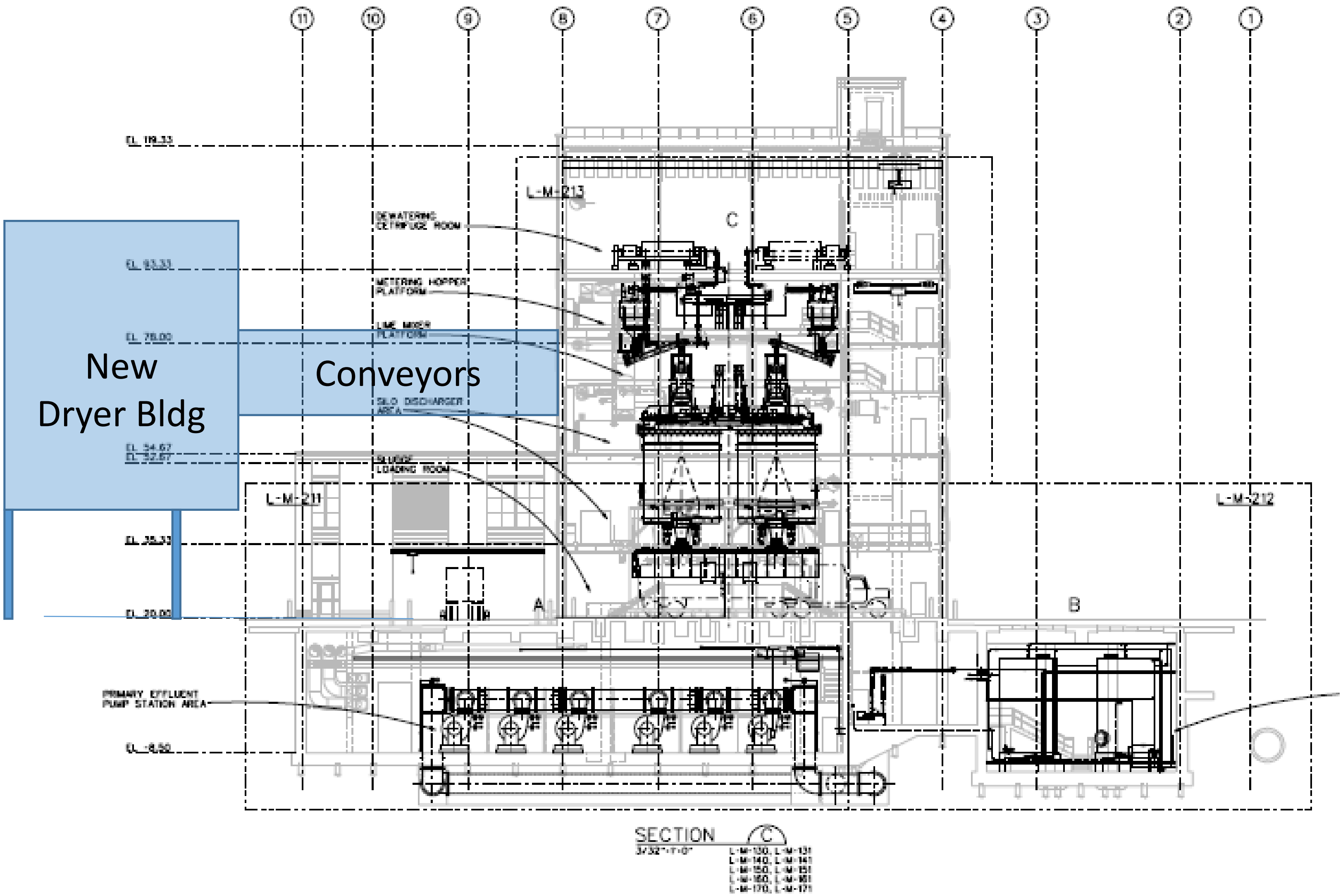
2a. AD-Drying	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w' x l' x h')	Location/Notes
Thickening PSD+TSD	n/a	5	170' x 230'	Gravity Thickeners (existing)
Thickening WAS	AlfaLaval, ALDEC G3 115	2+1	30' x 55'	Bldg L, ground floor
Screening BTS	Huber, StrainPress 5mm	2+1	28' x 30' (3 levels)	Bldg 55 (existing)
Anaerobic Digestion	n/a	3	210' x 230'	Digesters (existing)
Recuperative Thickening	Andritz, RST 8x3	2+1	42' x 50'	Digester basement
Dewatering	AlfaLaval, ALDEC G3 105	2+1	30' x 55'	Bldg L, 6th floor
Drying	Harsleev, SBD3000/8	1	46' x 155'	New Dryer Bldg
CHP	Caterpillar, CG260-12	1	25' x 38'	Bldg A, south
Flares	Bigelow-Liptak	+2 (if needed)	18' x 38'	Complex 52 (existing)

2a. Layout

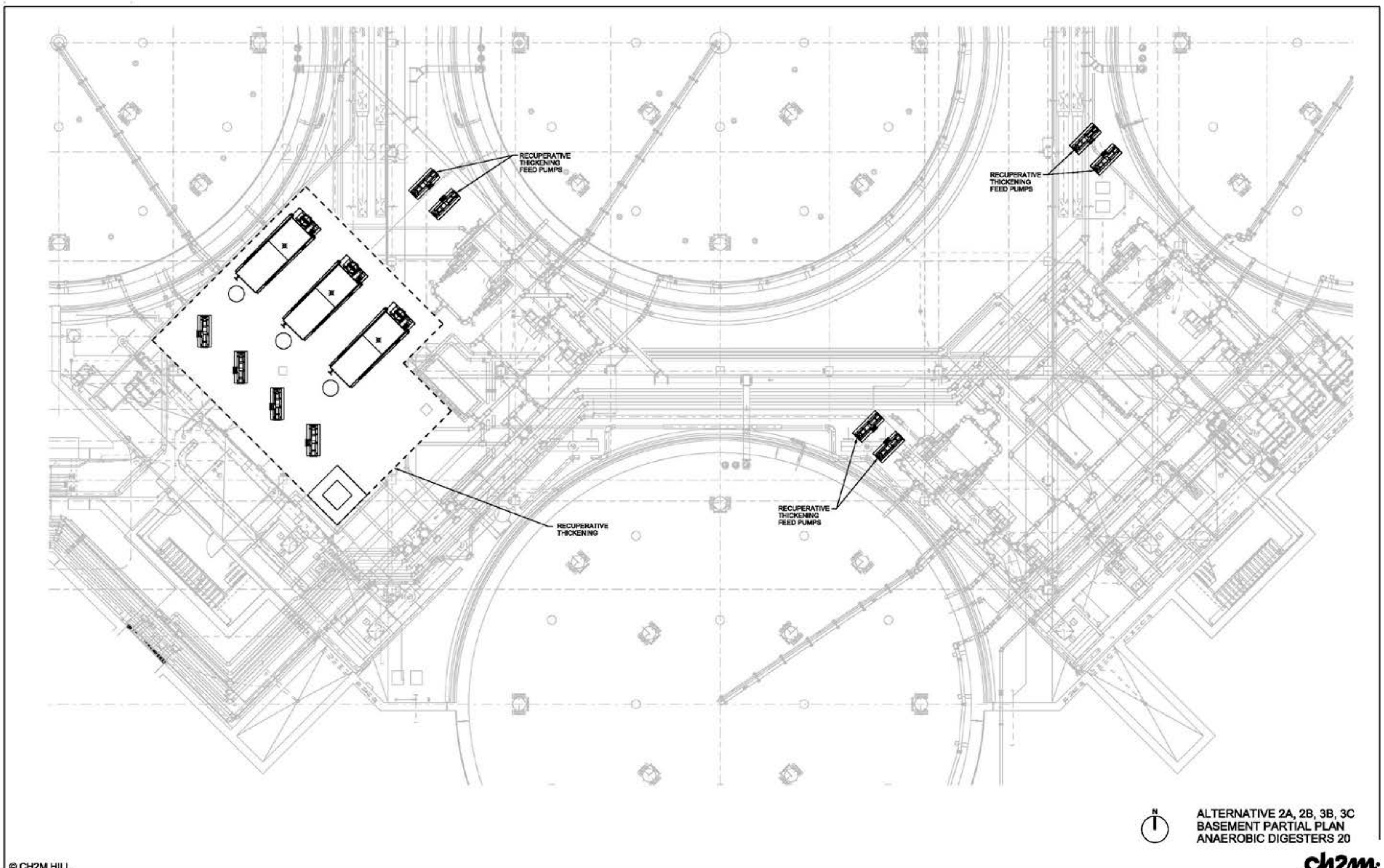


WAS THICKENING
DEWATERING
DRYING
FLARES
CHP
RECUPERATIVE THICKENING
ANAEROBIC DIGESTION
PSD & TSD THICKENING
BTS SCREENING
PREPASTURIZATION
N
PLANT GRID
0 50 100 150
1"=50'-0"
LEGEND
CHP COMBINED HEAT AND POWER
PSD PRIMARY SLUDGE
T THICKENED
THP THERMAL HYDROLYSIS PROCESS
TSD TERTIARY SLUDGE
WAS WASTE ACTIVATED SLUDGE
ALTERNATIVE 2A (BASELINE)
ANAEROBIC DIGESTION - DRYING
LAYOUT OF FACILITIES
© CH2M HILL
ch2m:
OVERALL1.DGN

2a. Dryer Facility Section



2a. Recuperative Thickening Layout



2a. Construction Sequencing and Site Layout Notes

- Dryer facility will be constructed first
- Dewatered cake will be routed to the dryer via conveyors
- Existing dewatered cake silos will be repurposed:
  - Silos for storage of dried product (equipped with dust/odor control)
  - Silos for storage of dewatered cake (for disposal when dryer is out of service)
- Bldg 55:
  - Pre-pasteurization will be decommissioned once dryer is up and running. Equipment will be removed
  - Sludge screens will continue to be used prior to introducing sludge to digesters
- Flares will remain to handle excess digester gas if CHP or Dryer is out of service

2a. Greenhouse Gas Impact at Design Annual Average Conditions

Scope	Emissions Source	GHG Impact (tonnes CO2e/yr)
Scope 1 - Direct	Stationary Combustion – CHP	6.66
	Stationary Combustion - Dryer	2.42
Scope 2 - Indirect	Purchased Electricity (for new systems)	6,947
	Generated Electricity (CHP)	(6,747)
Scope 3 - Optional	Contracted Solids Hauling	316
	Land Application of Biosolids (N2O Release)	3,642
	Inorganic Fertilizer Avoidance	(385)
	Total	3,784

Greenhouse Gas impact based on AlexRenew’s current GHG inventory methodology

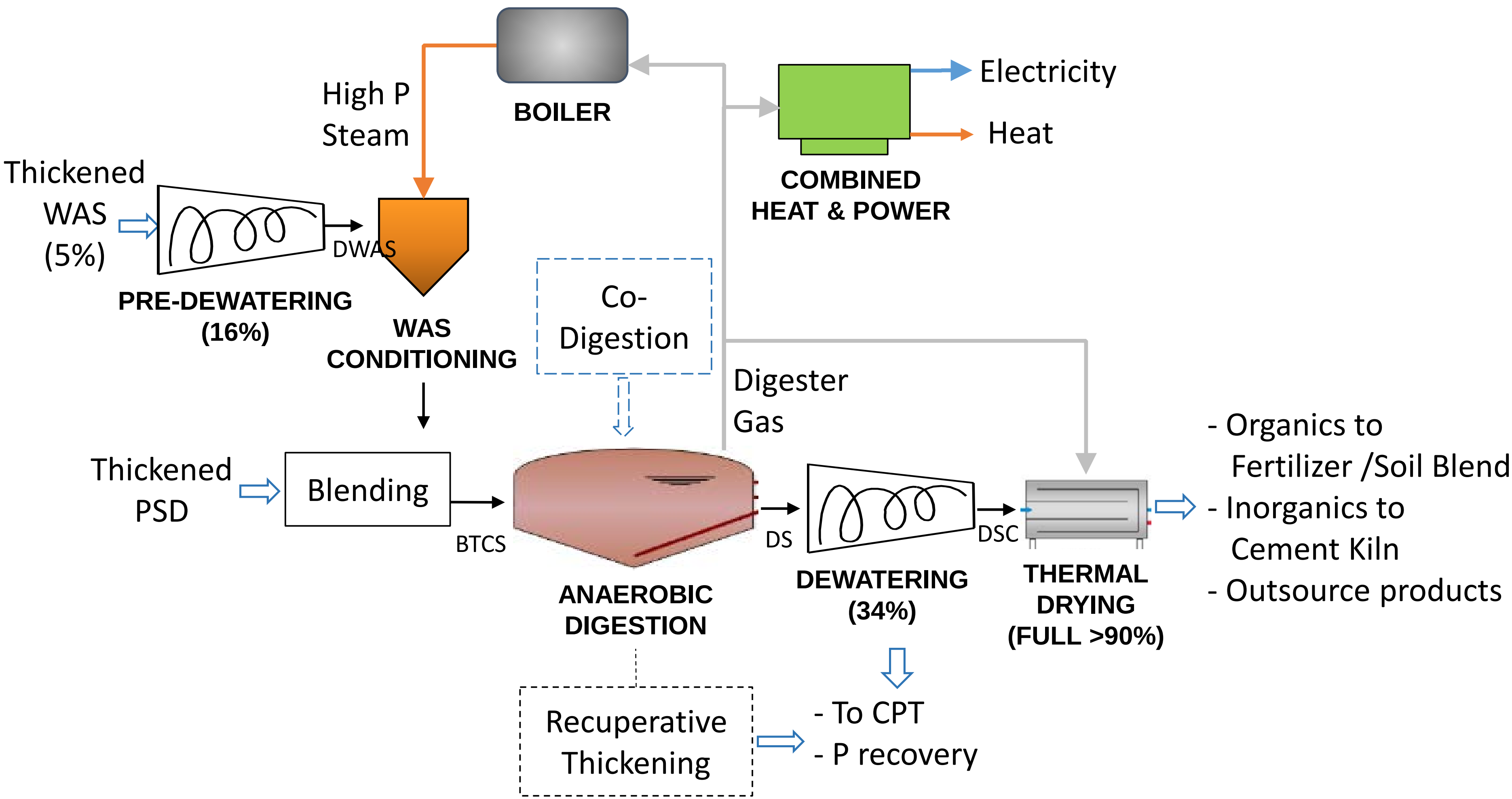
2a. Construction Cost

See Slides 63-64

Alternative 2b:

Anaerobic Digestion with WAS Conditioning and Thermal Drying

2b. Anaerobic Digestion (AD) with WAS conditioning and drying



2b. Process Assumptions

Unit Process	Solids Capture	Product	Chemical/Gas Usage	Energy Consumption
Thickening PSD+TSD	87% capture	5% TS underflow	-	-
Thickening WAS	95% capture	5% TS out	8 lb polymer/ dry ton feed	33 kWhr/wet ton out
Pre-Dewatering TWAS	95% capture	16% TS out	20 lb polymer/ dry ton feed	22 kWhr/wet ton out
Anaerobic Digestion	80% VSS In 66% VSR	58% VS out	14 ft^3 DG/ lb VS reduced	-
Recuperative Thickening	95% capture	9% TS out	8 lb polymer/ dry ton feed	50 kWhr/wet ton out
Dewatering	95% capture	34% TS out	22 lb polymer/ dry ton feed	60 kWhr/wet ton out
Drying	100% capture	90% TS out	1,500 BTU/lb H_2O evaporated	-
Boiler (hi P steam)	-	-	73 ft^3 DG per hp	900 BTU/lb THP feed
CHP	-	-	49.9% thermal efficiency	40% electrical efficiency

2b. Anaerobic Digestion Process

Design Criteria	SRT with 4 Total Units	SRT with 3 Total Units	SRT with 3 Total Units + Recuperative Thickening
Minimum 12-day SRT at Max Month Condition with All Units in Service	14 days ✓	11 days ✗	12 days (51 gpm)
Minimum 15-day SRT at Annual Average Condition with All Units in Service	17 days ✓	13 days ✗	15 days (132 gpm)
Minimum 12-day SRT at Annual Average Condition with One Unit out of Service	13 days ✓	8 days ✗	12 days (129 gpm)

SRT Design Criteria with 4 Total Units is met

WAS Conditioning improves dewaterability of sludge and therefore a lower digester SRT may be adequate. This would free up a digester without adding recuperative thickening.

Adding recuperative thickening frees up a digester and provides flexibility to add SRT if needed

2b. Recuperative Thickening Notes

- Analysis looked at the benefits of adding recuperative thickening to free up the footprint associated with one of the digesters and provide adequate SRT
  - Note that use of dryer or thermal conversion of organics removes the SRT requirements to meet Class A
  - Main purpose of SRT is to ensure good biosolids dewatering
- Using WAS Conditioning improves the dewaterability of biosolids and therefore a lower digester SRT may be adequate. This would free up a digester without adding recuperative thickening.
- For the purposes of this evaluation it was assumed that recuperative thickening would be implemented for all alternatives as the more conservative approach
  - For alternatives with WAS Conditioning, it may not be needed
  - However, the relative cost (capital and O&M) of recuperative thickening is small compared to the rest of the project and it provides additional flexibility and redundancy
  - In the future we can also explore using unused thickening centrifuge capacity for this purpose

2b. Process Flow & Mass Balance
(Max Month Conditions)

Flow Stream	Flowrate (gal/day)	Solids Production (lb/day)	% TS
PSD	5,000,000	164,529	0.39%
WAS	970,000	48,647	0.60%
TSD	1,100,000	19,400	0.21%
T(PSD+TSD)	383,737	160,018	5.0%
TWAS	110,826	46,215	5.0%
DWAS	32,902	43,904	16.0%
BTCS	416,638	203,922	5.9%
DS	367,814	96,447	3.1%
DSC	32,312	91,625	34%
Dried Product		**91,625**	90.0%

2b. Process Flow & Mass Balance
(Max Month Conditions)

2b. AD-Drying w/ WAS THP (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
GT Overflow	5,716,263	23,911	0.05%
WAS Thickening + Pre-Dewatering Centrate	937,098	4,743	0.06%
Dewatering Centrate	335,502	4,822	0.17%
Rec. Thickening Centrate	48,824	1,095	0.27%
Centrate to CPT	384,326	5,780	0.18%

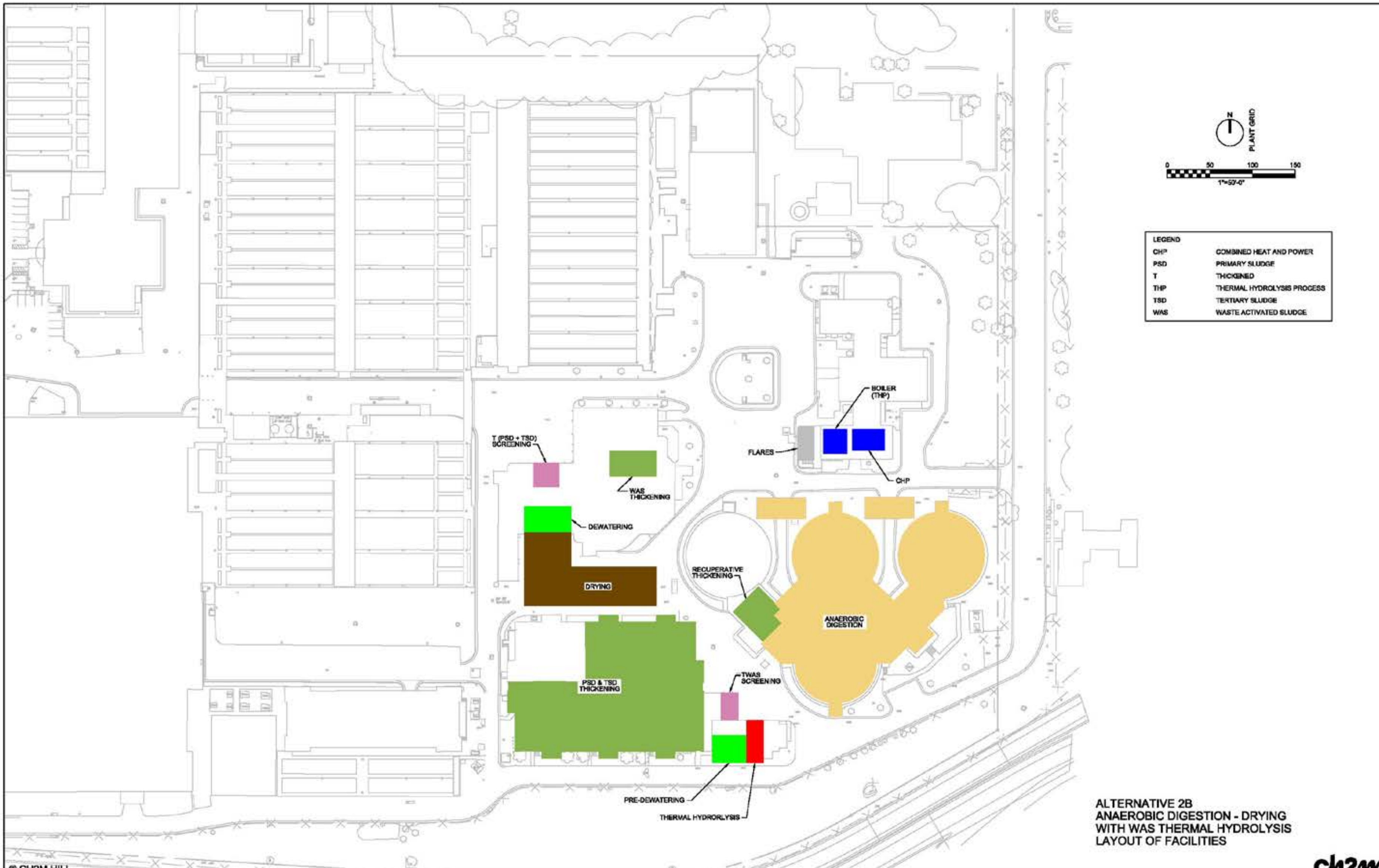
2b. Equipment & Footprint

2b. AD-Drying w/ WAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w' x l' x h')	Location/Notes
Thickening PSD+TSD	n/a	5	170' x 230'	Gravity Thickeners (existing)
Screening T(PSD+TSD)	Huber, StrainPress 5mm	2+1	28' x 30' (3 levels)	Bldg L, north of silos
Thickening WAS	AlfaLaval, ALDEC G3 115	2+1	30' x 55'	Bldg L, ground floor
Screening TWAS	Huber, StrainPress 5mm	1+1	20' x 28' (3 levels)	Bldg 55 (existing)
Pre-Dewatering TWAS	AlfaLaval, ALDEC G3 105	1+1	32' x 40' (3 levels)	New Pre-Dewatering Bldg
Thermal Hydrolysis WAS	Cambi, B2	1	20' x 50'	Outdoors, in place of Bldg 55
Anaerobic Digestion	n/a	3	210' x 230'	Digesters (existing)
Recuperative Thickening	Andritz, RST 8x3	2+1	42' x 50'	Digester basement

2b. Equipment & Footprint (continued)

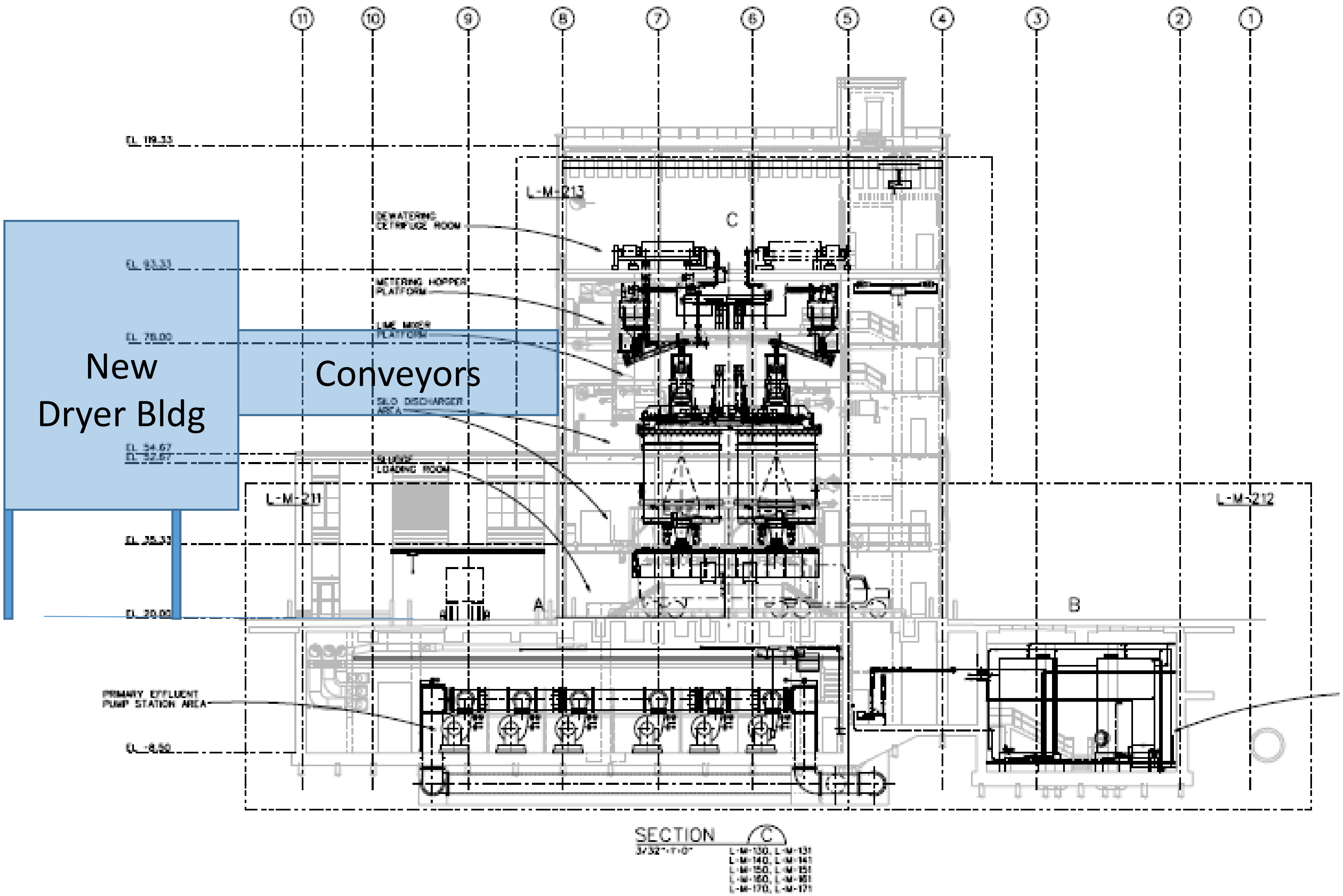
2b. AD-Drying w/ WAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w' x l' x h')	Location/Notes
Dewatering	AlfaLaval, ALDEC G3 105	2+1	30' x 55'	Bldg L, 6th floor
Drying	Harsleev, SBD3000/8	1	155' x 46'	New Dryer Bldg
Boiler (high P steam)	Cleaver-Brooks, 100 CB-LE	1	28' x 29'	Exist Bldg A, south
CHP	Caterpillar, CG260-12	1	25' x 38'	Exist Bldg A, south
Flares	Bigelow-Liptak	+2 (if needed)	38' x 18'	Exist complex 52

2b. Layout

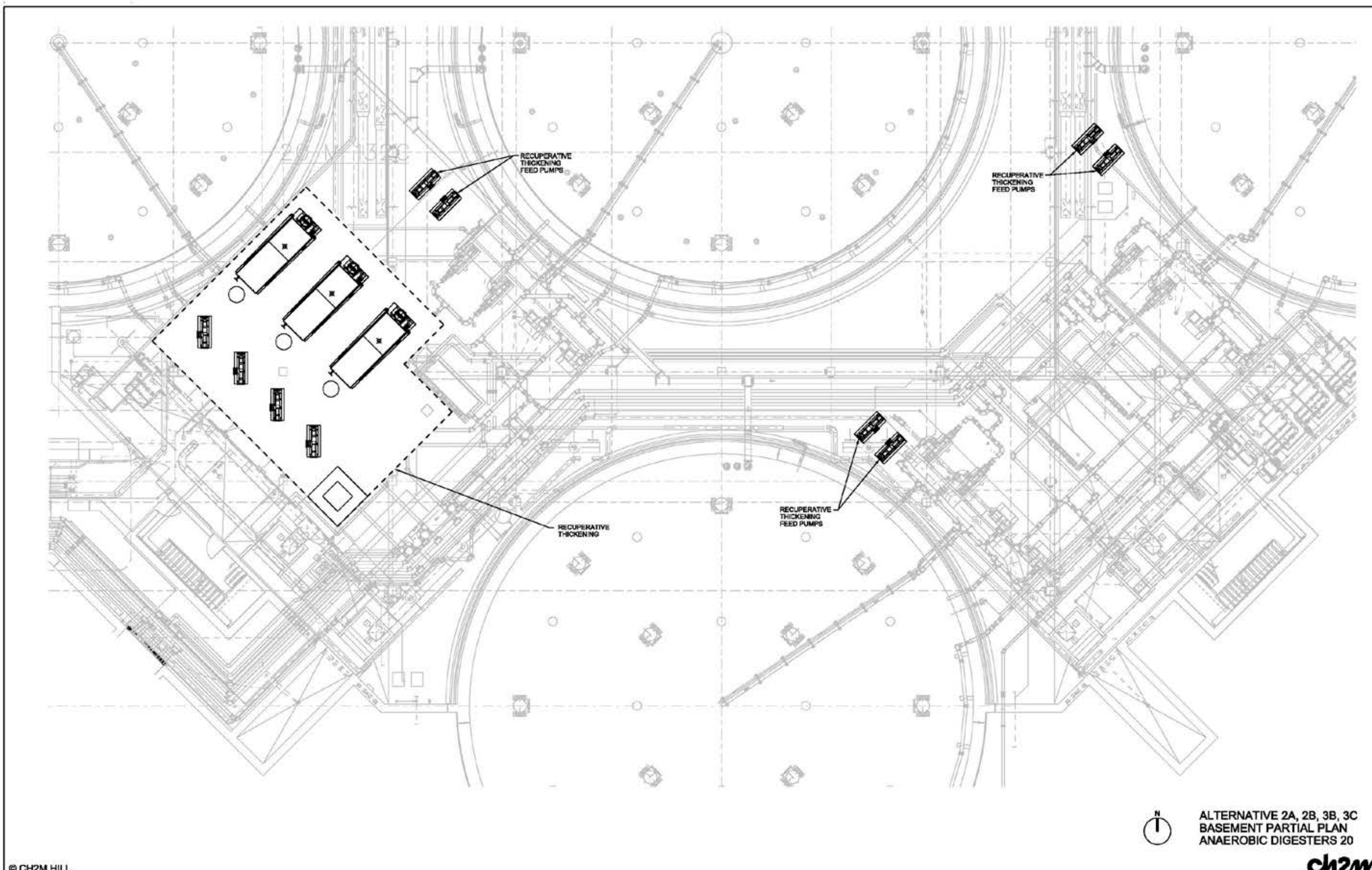


ch2m:

2b. Dryer Facility Section



2b. Recuperative Thickening Layout



2b. Construction Sequencing and Site Layout Notes

- Sequence:
  - Construct Dryer and CHP (Bldg. A, SE) first and operate as in alternative 2a
  - Install Sludge Screens for PSD + TSD in Bldg L
  - Demo pre-pasteurization (Bldg 55) and exist boilers (Bldg. A)
    - Boilers not needed to heat up pasteurization
  - Construct WAS Conditioning (WAS screens, pre-dewatering, cake bins, THP) at Bldg. 55 location, and THP boiler (Bldg. A), and transition to 2b operation

2b. Greenhouse Gas Impact at Design Annual Average Conditions

Scope	Emissions Source	GHG Impact (tonnes CO_2e/yr)
Scope 1 - Direct	Stationary Combustion – CHP	7.8
	Stationary Combustion - Dryer	1.4
	Stationary Combustion – High P Boiler	0.5
Scope 2 - Indirect	Purchased Electricity (for new systems)	5,721
	Generated Electricity (CHP)	(7,933)
Scope 3 - Optional	Contracted Solids Hauling	289
	Land Application of Biosolids (N_2O Release)	3,327
	Inorganic Fertilizer Avoidance	(351)
	Total	1,062

Greenhouse Gas impact based on AlexRenew's current GHG inventory methodology

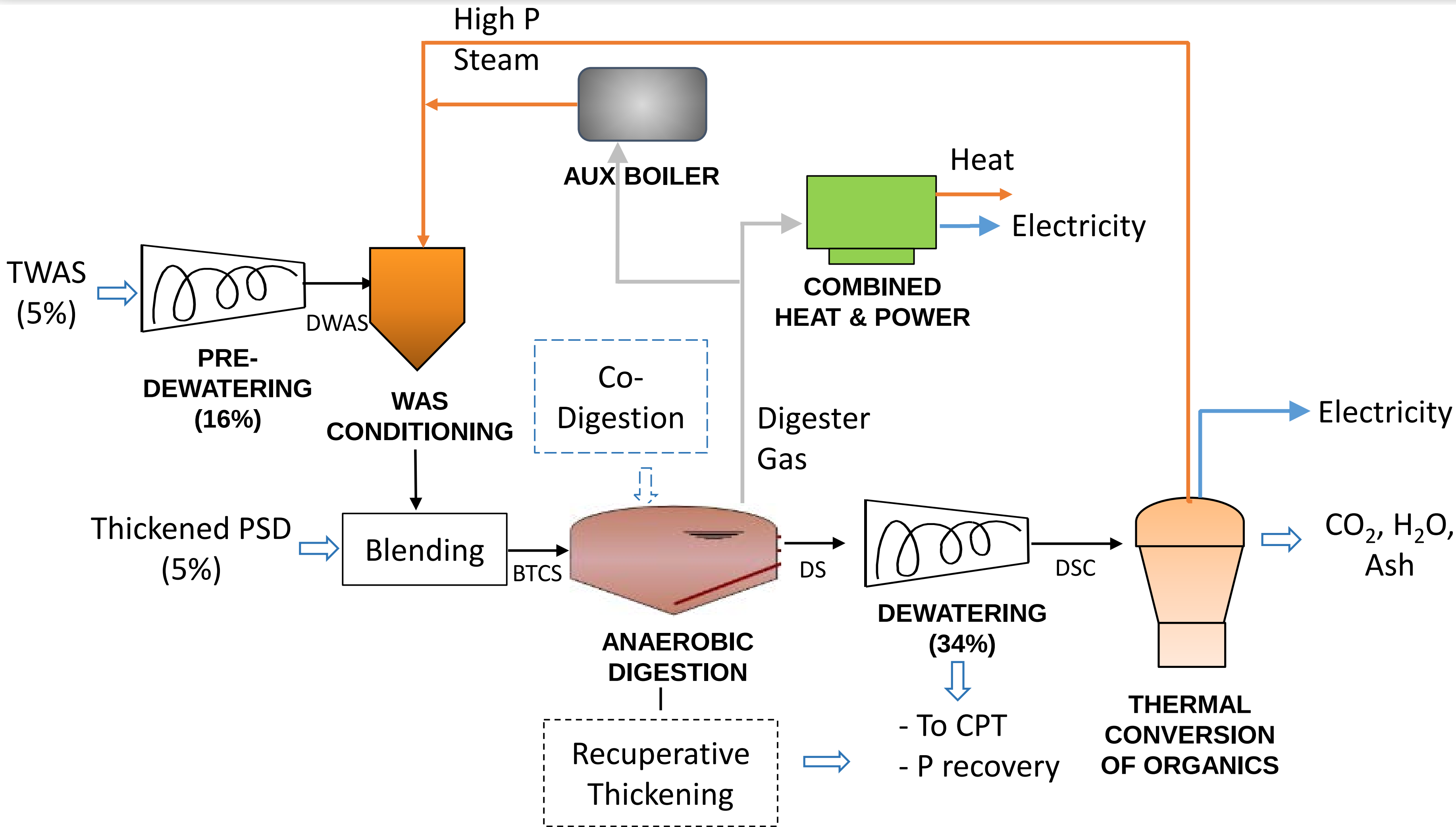
2b. Construction Cost

See Slides 63-64

Alternative 3b:

Anaerobic Digestion & Thermal Conversion of Organics with WAS conditioning

3b. Anaerobic Digestion & Thermal Conversion of Organics (AD–TCO) with WAS conditioning



3b. Process Assumptions

Unit Process	Solids Capture	Product	Chemical/Gas Usage	Energy Consumption
Thickening PSD+TSD	87% capture	5% TS underflow	-	-
Thickening WAS	95% capture	5% TS out	8 lb polymer/ dry ton feed	33 kWhr/wet ton out
Pre-Dewatering TWAS	95% capture	16% TS out	20 lb polymer/ dry ton feed	22 kWhr/wet ton out
Anaerobic Digestion	80% VSS In 66% VSR	58% VS out	14 ft^3 DG/ lb VS reduced	-
Recuperative Thickening	95% capture	9% TS out	8 lb polymer/ dry ton feed	50 kWhr/wet ton out
Dewatering	95% capture	34% TS out	22 lb polymer/ dry ton feed	60 kWhr/wet ton out
Thermal Conversion of Organics	100% capture	100% TS out	-	-
TCO Microturbines	-	-	-	16% electrical efficiency
Boiler (hi P steam)	-	-	900 BTU/lb THP feed	73 ft3 DG per hp
CHP	-	-	49.9% thermal efficiency	40% electrical efficiency

3b. Anaerobic Digestion Process

Design Criteria	SRT with 4 Total Units	SRT with 3 Total Units	SRT with 3 Total Units + Recuperative Thickening
Minimum 12-day SRT at Max Month Condition with All Units in Service	14 days ✓	11 days ✗	12 days (51 gpm)
Minimum 15-day SRT at Annual Average Condition with All Units in Service	17 days ✓	13 days ✗	15 days (132 gpm)
Minimum 12-day SRT at Annual Average Condition with One Unit out of Service	13 days ✓	8 days ✗	12 days (129 gpm)

SRT Design Criteria with 4 Total Units is met

WAS Conditioning improves dewaterability of sludge and therefore a lower digester SRT may be adequate. This would free up a digester without adding recuperative thickening.

Adding recuperative thickening frees up a digester and ensures adequate SRT.

3b. Process Flow & Mass Balance
(Max Month Conditions)

3b. AD-TCO w/WAS THP (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
PSD	5,000,000	164,529	0.39%
WAS	970,000	48,647	0.60%
TSD	1,100,000	19,400	0.21%
T(PSD+TSD)	383,737	160,018	5.0%
TWAS	110,826	46,215	5.0%
DWAS	32,902	43,904	16.0%
BTCS	416,638	203,922	5.9%
DS	367,814	96,447	3.1%
DSC	32,312	91,625	34.0%
TO Out		**38,745**	100.0%

3b. Process Flow & Mass Balance
(Max Month Conditions)

3b. AD-TCO w/WAS THP (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
GT Overflow	5,716,263	23,911	0.05%
WAS Thickening + Pre-Dewatering Centrate	937,098	4,743	0.06%
Dewatering Centrate	335,502	4,822	0.17%
Rec. Thickening Centrate	48,824	958	0.24%
Centrate to CPT	384,326	5,780	0.18%

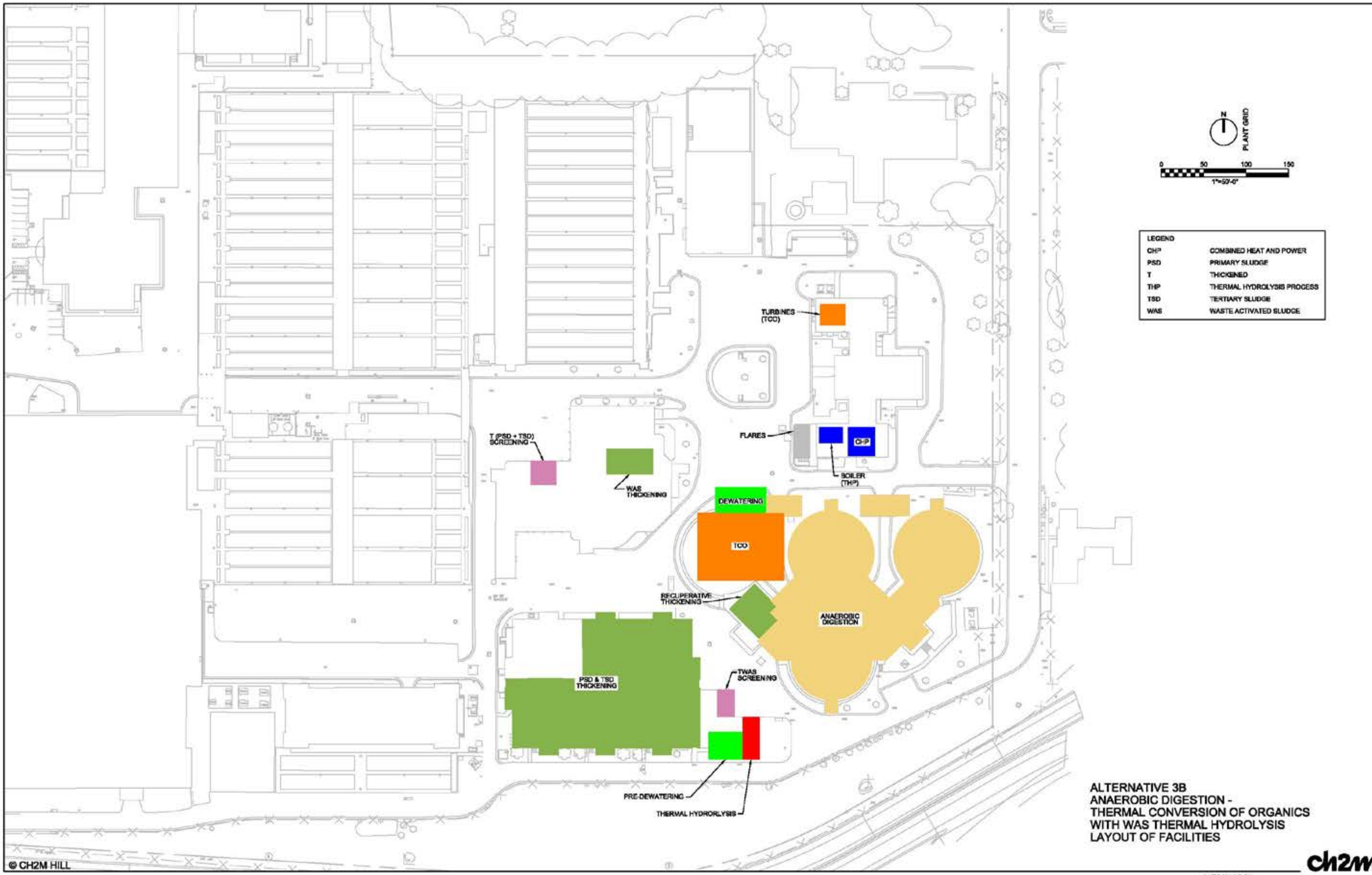
3b. Equipment & Footprint

3b. AD-TCO w/WAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w' x l' x h')	Location/Notes
Thickening PSD+TSD	n/a	5	170' x 230'	Gravity Thickeners (existing)
Screening T(PSD+TSD)	Huber, StrainPress 5 mm	2+1	28' x 30' (3 levels)	Bldg L, north of silos
Thickening WAS	AlfaLaval, ALDEC G3 115	2+1	30' x 55'	Bldg L, ground floor
Screening TWAS	Huber, StrainPress 5mm	1+1	20' x 28' (3 levels)	Bldg 55 (existing)
Pre-Dewatering TWAS	AlfaLaval, ALDEC G3 105	1+1	32' x 40' (3 levels)	New Pre-Dewatering Bldg
Thermal Hydrolysis WAS	Cambi, B2	1	20' x 50'	Outdoors, in place of Bldg 55
Anaerobic Digestion	n/a	3	210' x 230'	Digesters (existing)
Recuperative Thickening	Andritz, RST 8x3	2+1	42' x 50'	Digester basement

3b. Equipment & Footprint (continued)

3b. AD-TCO w/ WAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w’ x l’ x h’)	Location/Notes
Dewatering	AlfaLaval, ALDEC G3 105	2+1	30’ x 60’ (3 levels)	New Dewatering Bldg
Thermal Conversion of Organics	SUEZ, Thermylis	1	80’ x 102’ x 50’	New TCO Bldg
TCO Turbines	Heat Recovery Solutions, CC2	2	25’ x 30’ x 30’	Exist Bldg A, north (needs excavation)
Boiler (hi P steam)	Cleaver-Brooks, 100 CB-LE	1	28’ x 29’	Exist Bldg A, south
CHP	Caterpillar, G3520-C	2	32’ x 34’	Exist Bldg A, south
Flares	Bigelow-Liptak	+2 (as needed)	38’ x 18’	Exist complex 52

3b. Layout



PLANT GRID
N
0 50 100 150
1"=50'-0"
LEGEND
CHP COMBINED HEAT AND POWER
PSD PRIMARY SLUDGE
T THICKENED
THP THERMAL HYDROLYSIS PROCESS
TSD TERTIARY SLUDGE
WAS WASTE ACTIVATED SLUDGE
TURBINES (TCO)
FLARES
CHP
BOILER (THP)
T (PSD + TSD) SCREENING
WAS THICKENING
DEWATERING
TCO
RECUPERATIVE THICKENING
ANAEROBIC DIGESTION
PSD & TSD THICKENING
TWAS SCREENING
PRE-DEWATERING
THERMAL HYDRORLYSIS
ALTERNATIVE 3B
ANAEROBIC DIGESTION -
THERMAL CONVERSION OF ORGANICS
WITH WAS THERMAL HYDROLYSIS
LAYOUT OF FACILITIES
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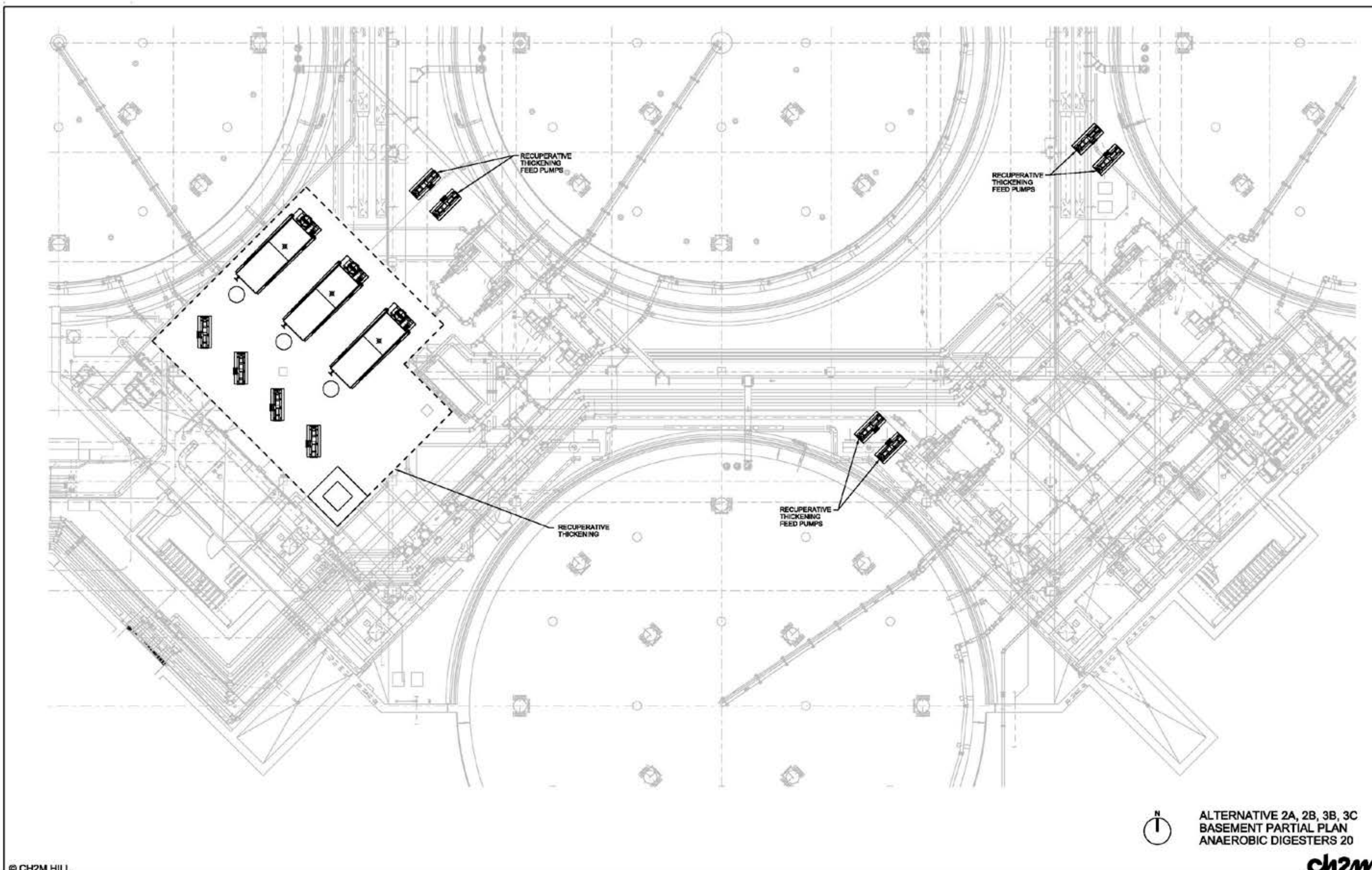
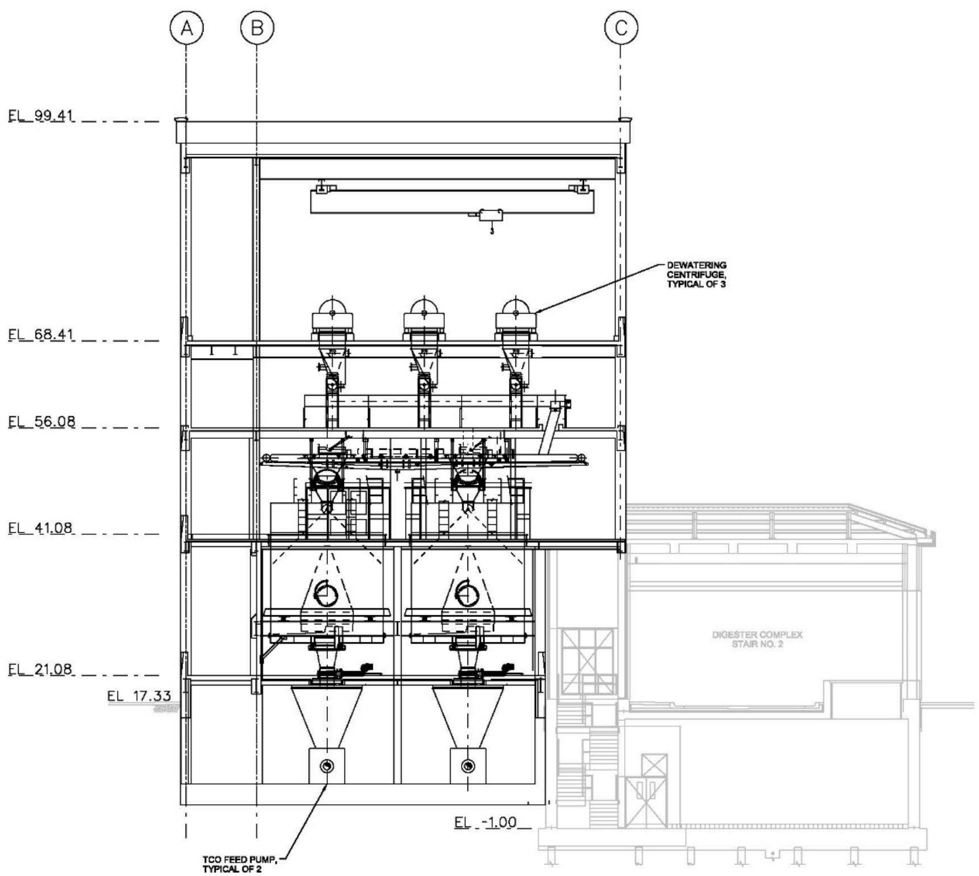
ch2m:
OVERALL3.DGN

3b. Recuperative Thickening Layout



3b. Dewatering Facility Layout



SECTION LOOKING NORTH
NTS

ALTERNATIVE 3B,3C
SECTION
DEWATERING BUILDING

DLV.DGN

3b. Construction Sequencing and Site Layout Notes

- New TCO facility located in Digester #1 footprint
- New dewatering bldg. adjacent to TCO facility
- CHP and TCO energy recovery turbines in Bldg A.
- Sequence:
  - Construct recuperative thickening and demo Digester #1
  - Construct TCO, CHP and TCO turbines and operate
  - Demo pre-pasteurization (Bldg 55) and exist boilers (Bldg. A, SW)
  - Construct THP (screens, pre-dewatering, cake bins, THP) at Bldg. 55 location, and THP boiler (in Bldg. A) and transition to operation with THP.

3b. Greenhouse Gas Impact

Scope	Emissions Source	GHG Impact (tonnes CO_2e/yr)
Scope 1 - Direct	Stationary Combustion – CHP	6.14
	Stationary Combustion – High P Boiler	0.39
	Stationary Combustion - TCO	4,288
Scope 2 - Indirect	Purchased Electricity (for new systems)	6,063
	Generated Electricity (CHP)	(12,807)
Scope 3 - Optional	Contracted Solids Hauling	110
	Land Application of Biosolids (N_2O Release)	--
	Inorganic Fertilizer Avoidance	--
	Total	(2,340)

Greenhouse Gas impact based on AlexRenew's current GHG inventory methodology

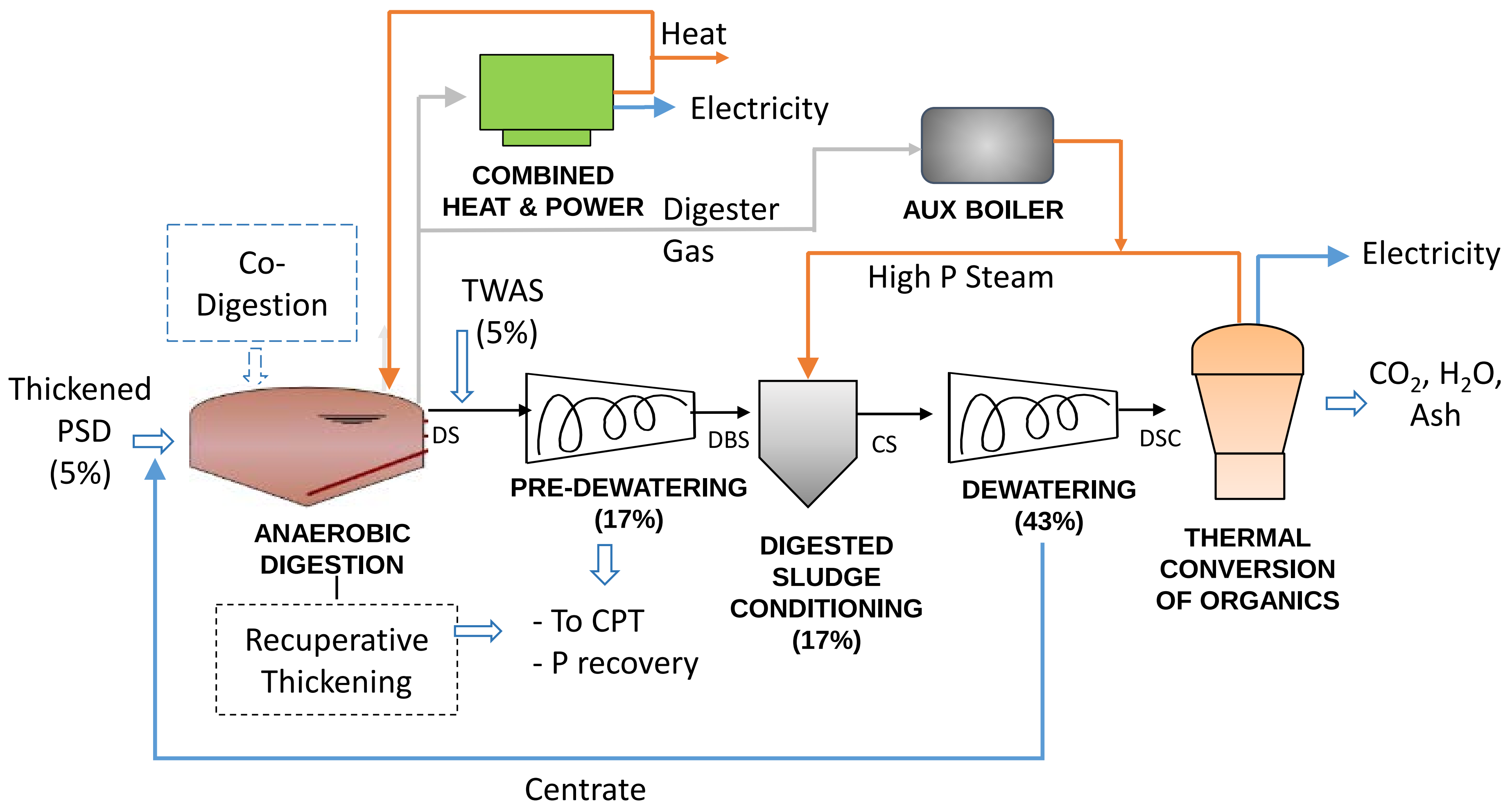
3b. Construction Costs

See Slides 63-64

Alternative 3c:

Anaerobic Digestion & Thermal Conversion of Organics with Post-conditioning

3c. Anaerobic Digestion & Thermal Conversion of Organics (AD-TCO) with post-conditioning



3c. Process Assumptions

Unit Process	Solids Capture	Product	Chemical/Gas Usage	Energy Consumption
Thickening PSD+TSD	87% capture	5% TS underflow	-	-
Thickening WAS	95% capture	5% TS out	8 lb polymer/ dry ton feed	33 kWhr/wet ton out
Anaerobic Digestion	80% VSS In 70% VSR	54% VS out	14 ft^3 DG/ lb VS reduced	-
Recuperative Thickening	95% capture	9% TS out	8 lb polymer/ dry ton feed	50 kWhr/wet ton out
Pre-Dewatering DS+TWAS	95% capture	17% TS out	20 lb polymer/ dry ton feed	23 kWhr/wet ton out
Dewatering	95% capture	43% TS out	22 lb polymer/ dry ton feed	42 kWhr/wet ton out
Thermal Conversion of Organics	100% capture	100% TS out	-	-
TCO Turbines	-	-	-	16% electrical efficiency
Boilers (high P steam)	-	-	739 BTU/lb THP feed	73 ft^3 DG per hp
CHP	-	-	49.9% thermal efficiency	40% electrical efficiency

3c. Anaerobic Digestion Process

Design Criteria	SRT with 4 Total Units	SRT with 3 Total Units	SRT with 3 Total Units + Recuperative Thickening
Minimum 12-day SRT at Max Month Condition with All Units in Service	14 days ✓	10 days ✗	12 days (68 gpm)
Minimum 15-day SRT at Annual Average Condition with All Units in Service	16 days ✓	12 days ✗	15 days (132 gpm)
Minimum 12-day SRT at Annual Average Condition with One Unit out of Service	12 days ✓	8 days ✗	12 days (129 gpm)

SRT Design Criteria with 4 Total Units is met

WAS Conditioning improves dewaterability of sludge and therefore a lower digester SRT may be adequate. This would free up a digester without adding recuperative thickening.

Adding recuperative thickening frees up a digester and ensures adequate SRT.

3c. Process Flow & Mass Balance
(Max Month Conditions)

3c. AD-TCO w/DS+TWAS THP (max month)	Flowrate (gal/day)	Solids Production (lb/day)	% TS
PSD	5,000,000	164,529	0.39%
WAS	970,000	48,647	0.60%
TSD	1,100,000	19,400	0.21%
T(PSD+TSD)	383,737	160,018	5.0%
TWAS	110,826	46,215	5.0%
DSC	24,527	87,957	43.0%
TO Out		**38,709**	100.0%

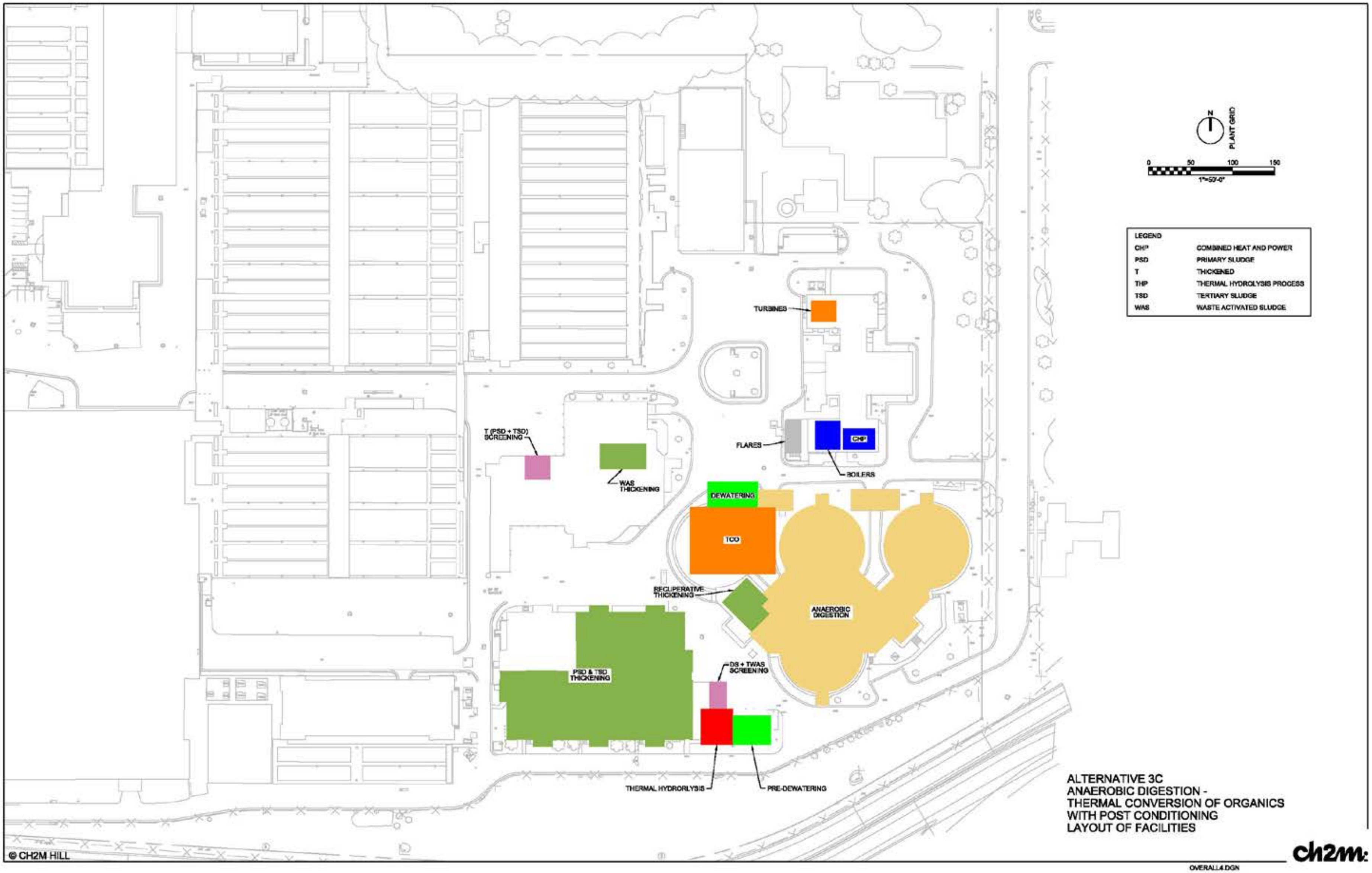
3c. Equipment & Footprint

3c. AD-TCO w/ DS+TWAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w’ x l’ x h’)	Location/Notes
Thickening PSD+TSD	n/a	5	170’ x 230’	Gravity Thickeners (existing)
Screening T(PSD+TSD)	Huber, StrainPress 5mm	2+1	28’ x 30’ (3 levels)	Bldg L, north of silos
Thickening WAS	AlfaLaval, ALDEC G3 115	2+1	30’ x 55’	Bldg L, ground floor
Screening DS+TWAS	Huber, StrainPress 5mm	2+1	28’ x 30’ (3 levels)	Bldg 55 (existing)
Pre-Dewatering DS+TWAS	AlfaLaval, ALDEC G3 125	1+1	35’ x 45’ (3 levels)	New Pre-Dewatering Bldg
Thermal Hydrolysis DS+TWAS	Cambi, B6	1	38’ x 43’	Outdoors, in place of Bldg 55
Anaerobic Digestion	n/a	3	210’ x 230’	Digesters (existing)
Recuperative Thickening	Andritz, RST 8x3	2+1	42’ x 50’	Digester basement

3c. Equipment & Footprint (continued)

3c. AD-TCO w/ DS+TWAS THP Process	Manufacturer, Model	Quantity (Duty + Standby)	Footprint (w’ x l’ x h’)	Location/Notes
Dewatering	AlfaLaval, ALDEC G3 105	1+1	30’ x 40’	New Dewatering Bldg
Thermal Conversion of Organics	SUEZ, Thermylis	1	80’ x 102’ x 50’	New TCO Bldg
TCO Turbines	Heat Recovery Solutions, CC2	2	25’ x 30’ x 30’	Exist Bldg A, north (needs excavation)
Boilers (high P steam)	Cleaver-Brooks, 100 CB-LE	1	28’ x 29’	Exist Bldg A, south
CHP	Caterpillar, G3520-C	2	25’ x 38’	Exist Bldg A, south
Flares	Bigelow-Liptak	+2 (if needed)	38’ x 18’	Exist complex 52

3c. Layout



TURBINES
FLARES
CHP
BOILERS
T (PSD + TSD) SCREENING
WAS THICKENING
DEWATERING
TCO
RECUPERATIVE THICKENING
ANAEROBIC DIGESTION
PSD & TSD THICKENING
DS + TWAS SCREENING
THERMAL HYDRORLYSIS
PRE-DEWATERING
N
PLANT GRID
0 50 100 150
1"=50'-0"
LEGEND
CHP COMBINED HEAT AND POWER
PSD PRIMARY SLUDGE
T THICKENED
THP THERMAL HYDROLYSIS PROCESS
TSD TERTIARY SLUDGE
WAS WASTE ACTIVATED SLUDGE
ALTERNATIVE 3C
ANAEROBIC DIGESTION -
THERMAL CONVERSION OF ORGANICS
WITH POST CONDITIONING
LAYOUT OF FACILITIES
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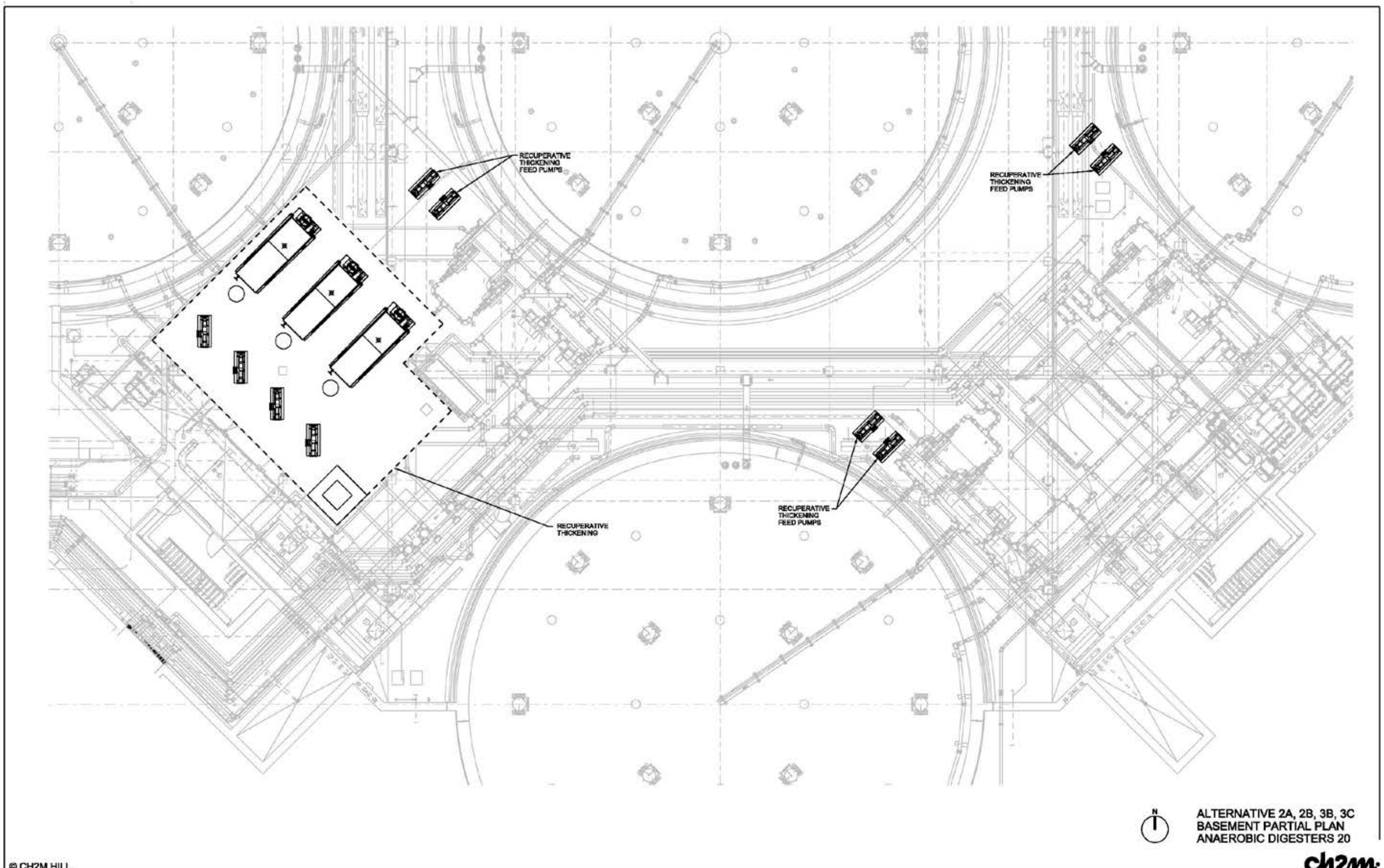
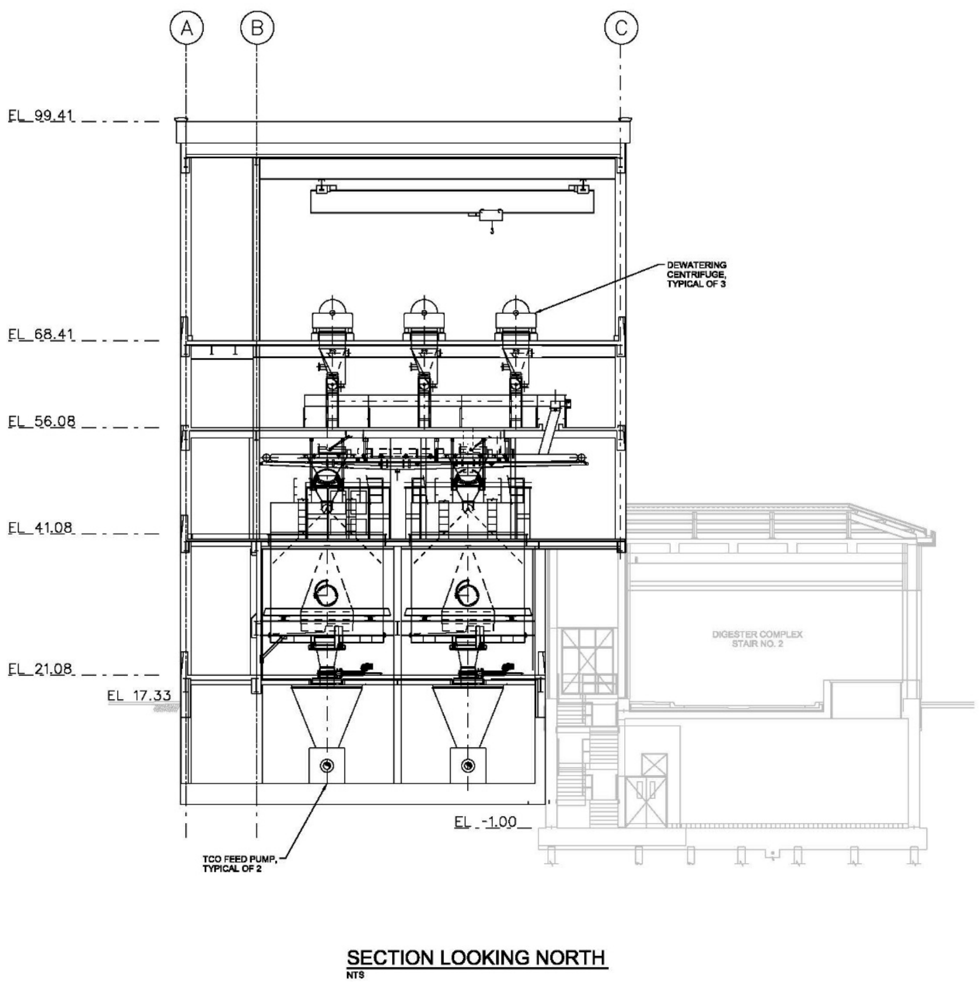
OVERALL4.DGN

3c. Recuperative Thickening Layout



3c. Dewatering Facility Layout



3c. Construction Sequencing and Site Layout Notes

- New TCO facility located in Digester #1 footprint
- New dewatering bldg. adjacent to TCO facility
- CHP and TCO energy recovery turbines in Bldg A.
- Sequence:
  - Construct recuperative thickening and demo Digester #1
  - Construct TCO, CHP and TCO turbines and operate
  - Demo pre-pasteurization (Bldg 55) and exist boilers (Bldg. A)
  - Construct THP (screens, pre-dewatering, cake bins, THP) at Bldg. 55 location, and THP boiler (in Bldg. A) and transition to operation with THP.

3c. Greenhouse Gas Impact

Scope	Emissions Source	GHG Impact (tonnes CO_2e/yr)
Scope 1 - Direct	Stationary Combustion – CHP	6.28
	Stationary Combustion – High P Boiler	0.84
	Stationary Combustion - TCO	4,112
Scope 2 - Indirect	Purchased Electricity (for new systems)	6,416
	Generated Electricity (CHP)	(12,952)
Scope 3 - Optional	Contracted Solids Hauling	110
	Land Application of Biosolids (N_2O Release)	--
	Inorganic Fertilizer Avoidance	--
	Total	(2,308)

Greenhouse Gas impact based on AlexRenew's current GHG inventory methodology

3c. Construction Costs

See Slides 63-64

Additional Information for All Alternatives

Final Product & Energy
(at Design Annual Average Conditions)

	2a. AD-Drying	2b. AD-Drying w/ WAS THP	3b. AD-TCO w/WAS THP	3c. AD-TCO w/ DS+TWAS THP
Final Product (dry tons per day)	42	38	16	16
Final Product (% TS)	90	90	100	100
Estimated Trucks/day	1.9	1.7	0.6	0.6
Electricity Generated (MW)	1.8	2.2	3.5	3.5
% of Total Plant MW *	20%	25%	40%	40%
Available Hot Water (MBTU/day)	62	221	326	332
Total Available Energy (MBTU/day)	68	228	338	345

* This is a rough estimate for comparison purposes. The total plant MW was calculated by escalating current plant annual average MW (~4.8) to design condition (~7.5 MW) in proportion to population growth and adding the energy consumption of the new processes for each alternative. Analysis does not take into account other energy efficiency / green energy projects on the liquids treatment or facilities.

Capital Cost

Elements	Alternative 2a (Baseline)	Alternative 2b	Alternative 3b	Alternative 3c
Primary + Tertiary Thickening	$ 97,800	$97,800	$97,800	$97,800
Screening Primary + Tertiary	-	$784,800	$784,800	$784,800
WAS Thickening	$ 4,350,400	$4,350,400	$4,350,400	$4,350,400
Screening Blended Sludge/WAS	$ 471,300	$384,700	$384,700	$384,700
Pre-Dewatering	-	$10,175,700	$10,175,700	$12,013,400
WAS Conditioning	-	$4,487,500	$4,487,500	-
Digestion	$ 97,800	$97,800	$97,800	$97,800
Recuperative Thickening	$ 2,788,000	$2,788,000	$2,788,000	$2,788,000
Post-Digestion Sludge Conditioning	-	-	-	$9,065,100
Dewatering	$ 3,526,900	$2,382,200	$15,152,600	$17,631,000

Capital Cost

Elements	Alternative 2a (Baseline)	Alternative 2b	Alternative 3b	Alternative 3c
Drying	$ 20,059,600	$15,892,500	-	
Thermal Conversion of Organics	-	-	$69,888,000	$69,888,000
TCO Turbines	-	-	$3,416,400	$3,416,400
Boiler (hi P steam)	-	$395,900	$395,900	$395,900
Combined Heat & Power	$ 7,411,700	$7,411,700	$9,244,200	$9,244,200
Flares	$ 19,600	$ 19,600	$19,600	$19,600
Prepasteurization (demo)	$ 90,900	n/a	n/a	n/a
TOTAL	**$ 39,228,000**	**$49,276,000**	**$121,283,000**	**$130,177,100**

Greenhouse Gas Emissions Summary
(at Design Annual Average Conditions)

	2a. AD-Drying	2b. AD-Drying w/ WAS THP	3b. AD-TCO w/WAS THP	3c. AD-TCO w/ DS+TWAS THP
Estimated GHG Impact (tonnes CO2e)	3,784	1,062	(2,343)	(2,308)
% of Total Entity-Wide Emissions*	8%	2%	-5%	-5%

* This is a rough estimate for comparison purposes. The Total Entity-Wide Emissions at the design condition was calculated by escalating current annual total emissions (~28,000 tonnes CO2e) to design condition (~45,000 tonnes CO2e) in proportion to population growth. Analysis does not take into account other GHG-reducing projects or initiatives.

Operation & Maintenance Annual Cost
(at Design Annual Average Conditions)

	2a. AD-Drying	2b. AD-Drying w/ WAS THP	3b. AD-TCO w/WAS THP	3c. AD-TCO w/ DS+TWAS THP
Polymer	$1,037,000	$1,181,000	$1,181,000	$1,319,000
Solids Handling	$635,000	$443,000	$213,000	$213,000
Labor	$563,000	$1,048,000	$1,324,000	$1,365,000
Maintenance	$926,000	$1,276,000	$1,445,000	$1,668,000
Power	$25,000	$(274,000)	$(837,000)	$(812,000)
Total	**$3,186,000**	**$3,674,000**	**$3,326,000**	**$3,729,000**

Operation & Maintenance Cost Assumptions

- All costs are based on current unit costs (2016)
- Labor
  - $55/hr incl. benefits for operators and mechanics of all grade levels
  - $65 for certified steam boiler operators, if needed
  - $67 for supervisors (1 supervisor per 6 FTE added)
  - 24/7 operations
- Maintenance
  - All new equipment installed in 2016
  - Life expectancy of equipment per standard equipment class
  - Repair and replacement costs for 20 year analysis period, then averaged into annual maintenance cost
  - Includes preventive and corrective maintenance
  - Asset replacement values per vendor estimates
  - CHP maintenance uses $0.02/kwh for third party service contract

Operation & Maintenance Cost Assumptions (continued)

- Power
  - $0.065/kwh all in average power rate
  - CHP electricity assumed to be usable on site
  - CHP electricity generated assumes conservative 80% available runtime to cover maintenance needs
- Chemicals
  - Polymer Cost: $1.52 per lb
- Hauling
  - Haul distance used is average of 2014 and 2015 hauling to various sites
  - $3.50/gal for truck fuel
  - 20% overhead and profit for contract hauler (ie Synagro or other)
  - Driver hours includes loading, unloading, etc.
  - Truck loading at 25 WT limit
  - No revenue generated by pellets or ash - but no tipping fees either

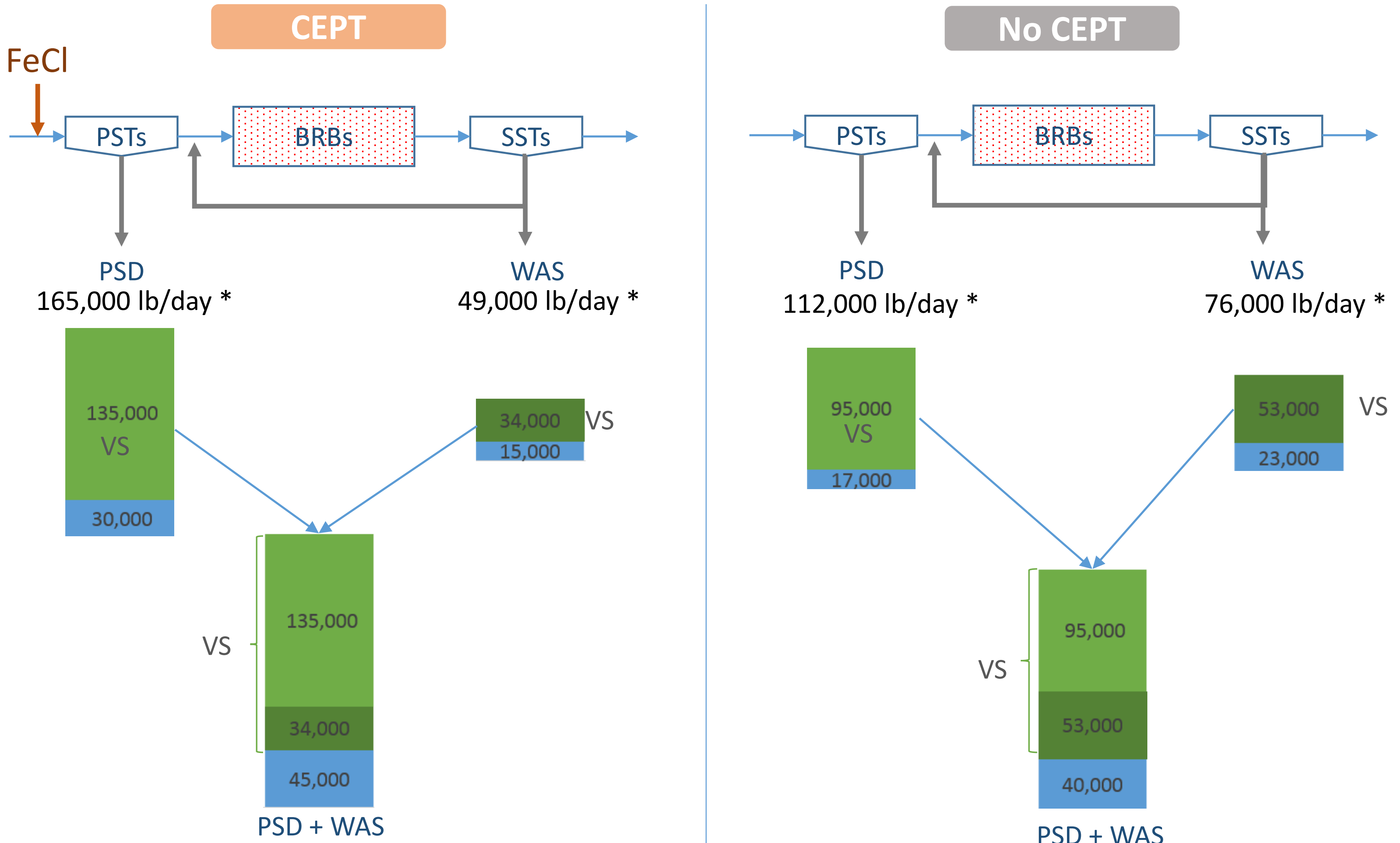
Operation & Maintenance Cost Assumptions (continued)

- Other
  - Miscellaneous expenses ignored for this analysis (insurance, sampling fees, employee training, computers, etc)
  - +/- 20% level of estimating, so O&M costs within this band could be considered essentially equal
  - All costs in 2016 dollars

Liquids Treatment Scenarios CEPT vs. BioP

July 13, 2016

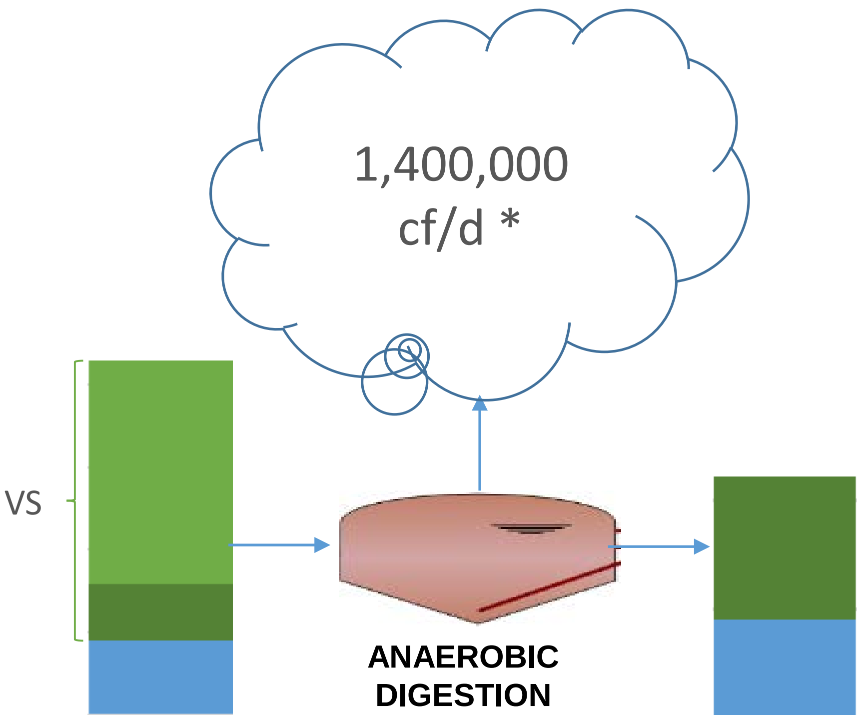
Impact of Chemically Enhanced Primary Treatment (CEPT) on Carbon Removal



* Design Max Month Conditions (70 MGD)

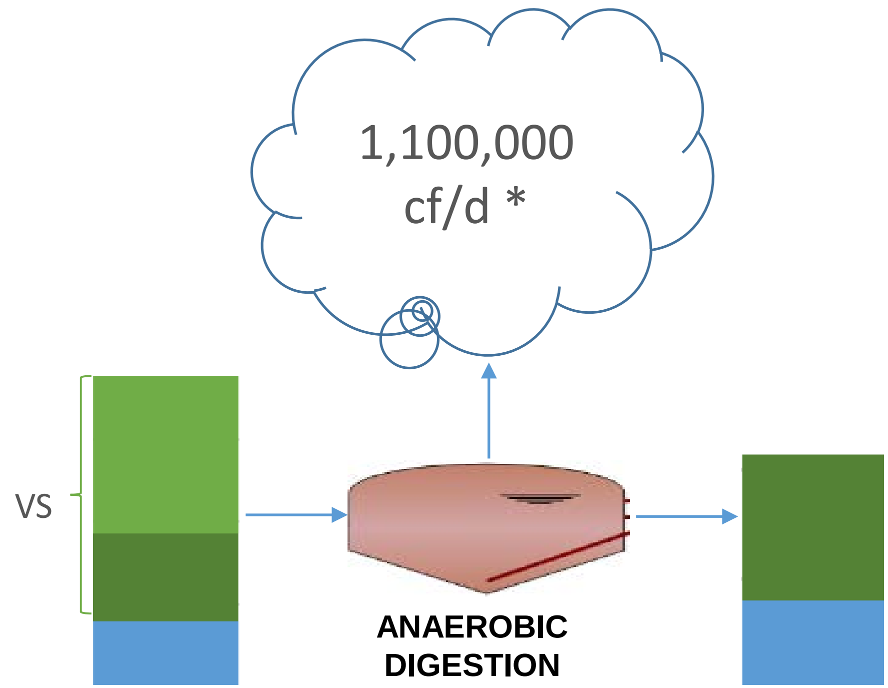
Impact of Chemically Enhanced Primary Treatment (CEPT) on Digester Gas Generation

CEPT



61% Volatile Solids Reduction

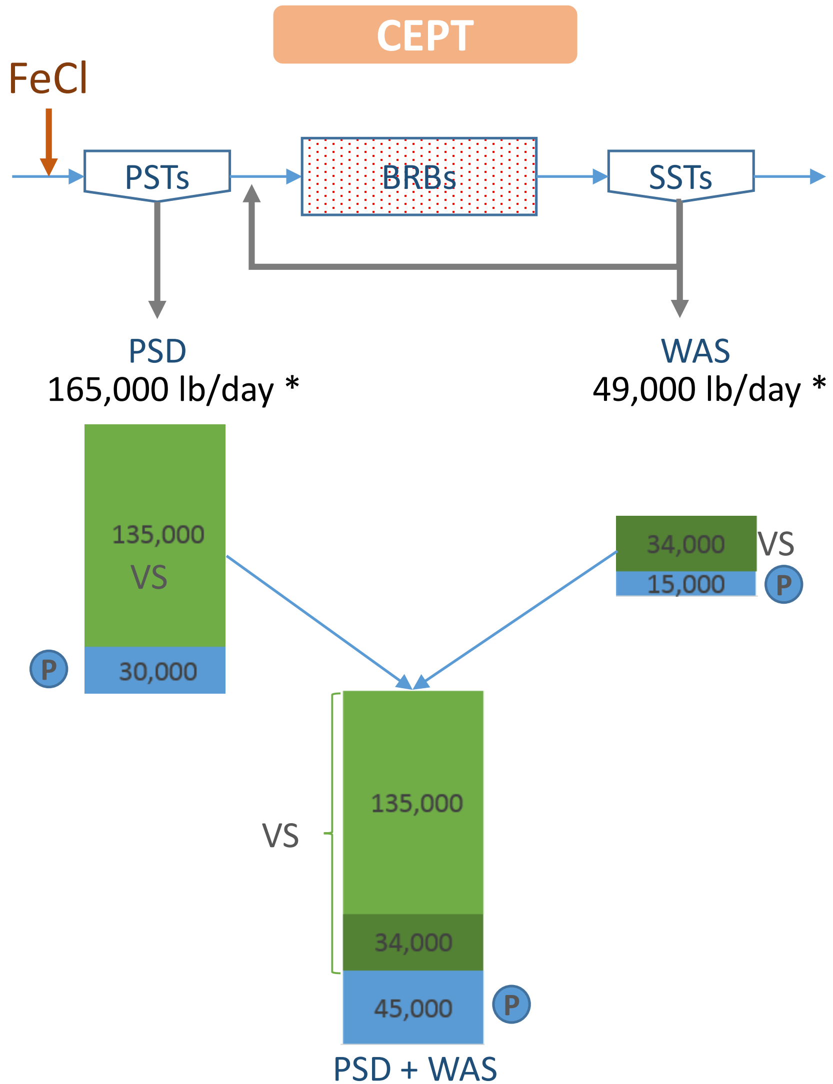
No CEPT

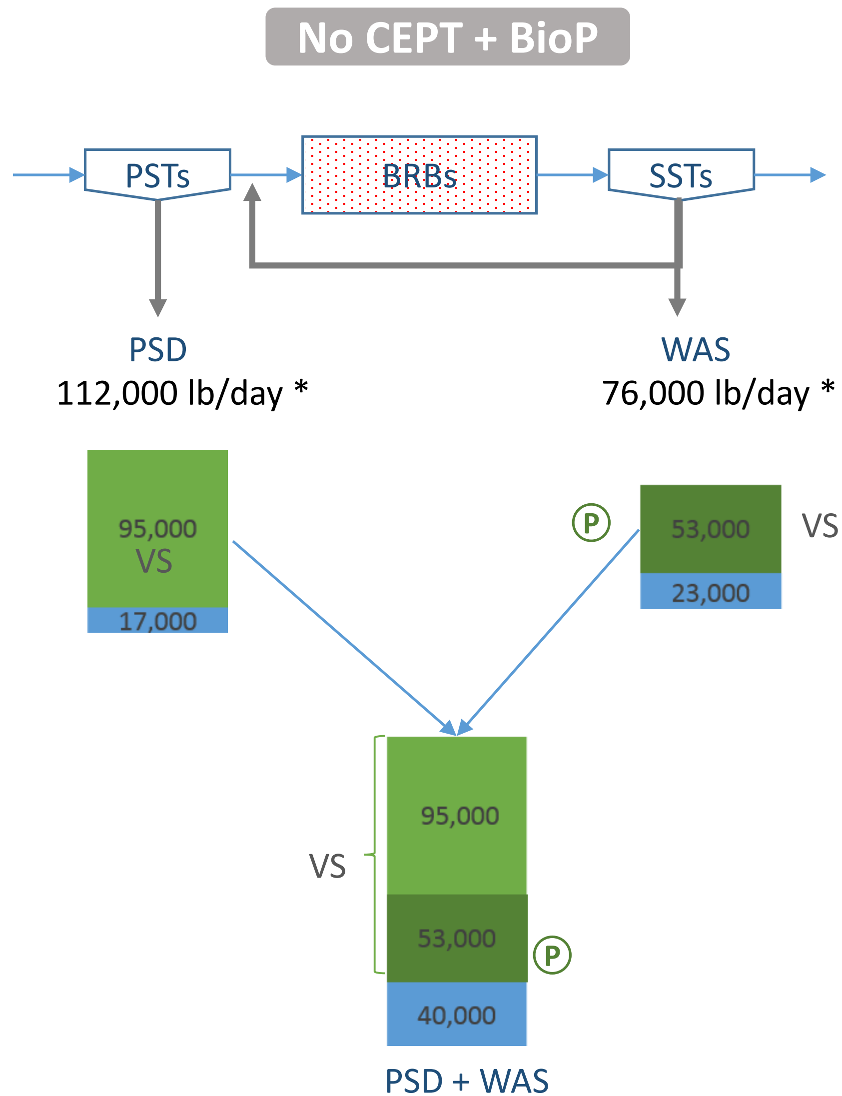


55% Volatile Solids Reduction

* Design Max Month Conditions (70 MGD)

Impact of Chemically Enhanced Primary Treatment (CEPT) on Phosphorus Removal

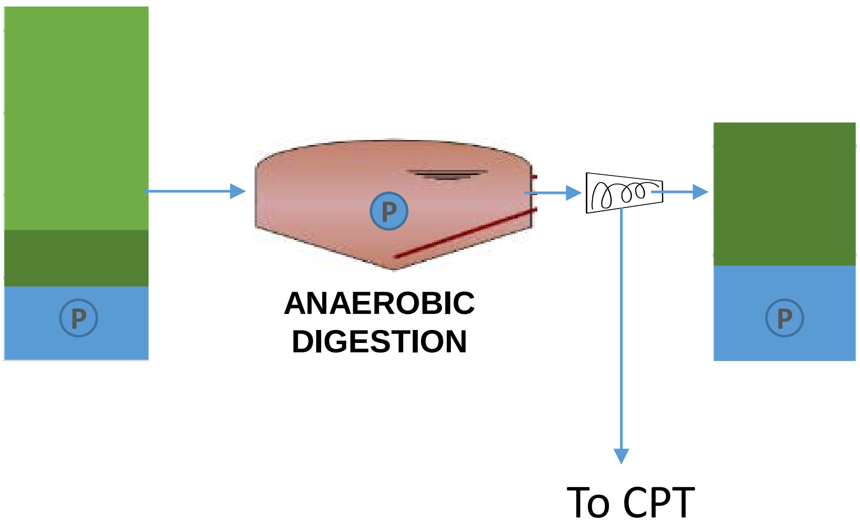




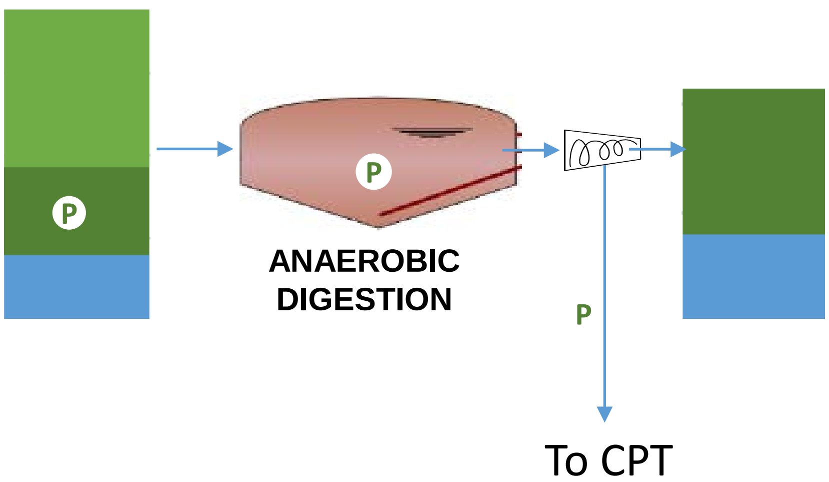
* Design Max Month Conditions (70 MGD)

Impact of Chemically Enhanced Primary Treatment (CEPT) on Phosphorus Removal

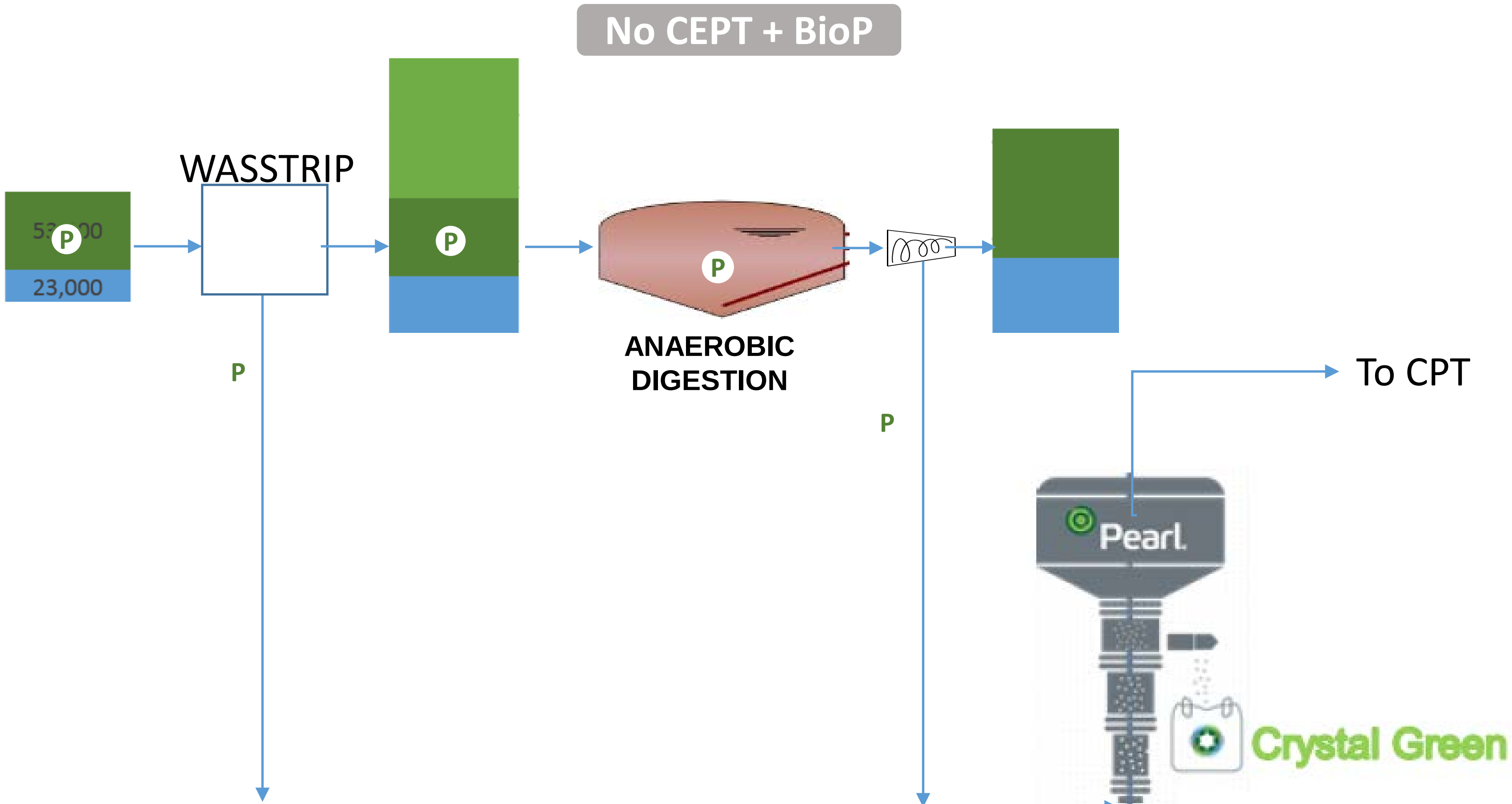
CEPT



No CEPT + BioP



Ostara: WASSTRIP + Pearl



Summary

	CEPT	No CEPT + BioP
Carbon Removal	• More carbon removal in the PSTs • More inerts created in the PSTs • More PSD generated • Higher VSS Reduction (61%) in dig. • More digester gas production	• Less carbon removal in the PSTs • Less PSD generated • More WAS generated • Lower VSS Reduction (55%) in dig. • Less digester gas production
Phosphorus Removal	• Chemical addition binds P in the inert phase • P released in the digesters is absorbed by chemical sludge • P ends in the biosolids (can limit land application) • Higher chemical use	• BioP selects for specific organisms that use carbon to fix P in the biomass • P can be released in the digesters leading to struvite • Ostara system intentionally forms struvite in their reactor and produces a fertilizer that is sold commercially - Estimated ~$500,000 yr at design AADF

Ostara Footprint Requirements

- WAS Holding Tank: 1 to 1.5 MG
- New facility: 4,000 to 4,500 sf (50' x 80')

AlexRenew Decision Model

Weights:	40	22	10	13	7	8
Strategic Alignment:	**Operational Excellence**	**Community Engagement**	**Watershed Partnership that Enhance Collective Mgmt**	**Organizational Competency & Structure**	**Diversified Revenue**	**Incubator of New Ideas and Innovations**
	Improve Business Efficiency ***Weight: 10***	Promotes water in our community ***Weight: 3***	Enable new external partnerships ***Weight: 6***	Supports great place to work ***Weight: 3***	Annual Cost ***Weight: 1***	Enhance Sustainability ***Weight: 2***
	Compliance enhancement /adaptability ***Weight: 15***	Enhance Community Water Resources ***Weight: 4***	Support sound Science ***Weight: 4***	Improves ease of operation ***Weight: 5***	Capital Cost Management ***Weight: 1***	Enhance Resiliency ***Weight: 2***
	Enhance Capacity/Throughput ***Weight: 10***	Supports customer service ***Weight: 5***		Maximize technology tool solutions ***Weight: 5***	Fosters Operational Cost savings ***Weight: 3***	Technical Feasibility ***Weight: 4***
	VEEP/EMS ***Weight: 5***	Communication Enhancement Value ***Weight: 6***			***Revenue Neutral or positive Weight: 2***	
		Minimizes Land Footprint ***Weight: 4***				

Operational Excellence

Improve Business Efficiency– Weight 10

1. Reduce Time & Costs
2. Meets or exceeds our permit requirements
3. Benefit our customer
4. Reduces/Eliminates redundancy in the business process
5. Promote safe environment

A. Has a negative impact on business efficiency or non-applicable (0)

B. Has a neutral impact on business efficiency (3)

C. Has a positive impact on business efficiency (5)

D. Has a significant positive impact on business efficiency and meets or exceeds compliance in 1 or more category (7)

E. Has a significant positive impact on business efficiency and meets or exceeds compliance in 2 or more categories (9)

Compliance Enhancement/Adaptability– Weight 15

1. Awareness and attainment of balance between multi product regulations (Biosolids, Effluent Quality, Air Quality)
2. Processes that provide flexibility to incorporate technological advances and meet future regulations.

A. Will not help comply with future regulations or non- applicable (0)
B. Can adapt, but it is complex (3)
C. Can easily adapt (5)
D. State of the art technology today (7)
E. State of the art technology today with flexibility to adapt (9)

Enhance Capacity/Throughput – Weight 10

1. Increase or offset in hydraulic loading
2. Increase or offset in organic loading (liquids and solids)

A. Current capacity will be reduced or is non-applicable(0)
B. Meets current capacity requirements (3)
C. Capacity will be slightly increased (5)
D. Capacity will be moderately increased (7)
E. Capacity will be significantly increased (9)

VEEP/EMS- Weight 5

1. Support our VEEP and EMS programs
2. Aligns with the Environmental Policy and the EMS
3. Enhances our VEEP requirements
4. Aligns with our overall sustainability goals

A. Does not support our VEEP/EMS program or non-applicable (0)
B. Supports our VEEP/EMS program in 1 category above (3)
C. Supports our VEEP/EMS program in 2 categories above (5)
D. Supports our VEEP/EMS program in 3 categories above(7)
E. Supports out VEEP/EMS program in all 4 categories above (9)

VEEP = Virginia Environmental Excellence Program
EMS = Environmental Management System

Community Engagement

Promotes Water In Our Community – Weight 3

1. Recognize water as truly valuable natural resource
2. Provides opportunity to create partnerships to support the environment, our causes and our products
3. Overall City Improvements (stream restoration, water reuse at parks, help City meet its environmental action plan, Sustainability Plan objectives and Cool Cities)
4. Recognized as efficient/effective public business
5. Includes the desires of ‘greener’ citizens

A. Negative impact on public image or non-applicable (0)
B. Potential negative impact on public image (3)
C. No impact on public image (5)
D. Moderate improvement in public image (7)
E. Significant improvement in public image (9)

Enhance Community Water Resources – Weight 4

1. Provides reduced nutrient loads into the local watersheds
2. Minimizes odor impact to the local watersheds
3. Enhances the quality of the watersheds for fishing and swimming
4. Creates an increase awareness in the community of cleaner watersheds (Potomac/Chesapeake)

A. Negative impact on Community or non-applicable(0)

B. Slight negative impact on Community (3)

C. No impact on Community- neutral (5)

D. Positive impact on Community (7)

E. Significant positive impact on Community (9)

Supports Customer Service-Weight 5

1. Respond to customer/community issues in an expedient manner
2. Educate customers on water resource stewardship
3. Seamless customer payment options
4. Overall customer satisfaction

A. Significantly reduce the ability to provide customer service or non-applicable (0)
B. Reduces the ability to provide customer service (3)
C. No impact on the ability to provide customer service – Neutral (5)
D. Increases the ability to provide customer service (7)
E. Exceptional customer service (9)

Communication Enhancement Value-Weight 6

1. Respond to customer/community issues in an expedient manner
2. Educate customers on water resource stewardship

A. Significantly reduce the ability to communicate our value or non-applicable (0)
B. Reduces the ability to communicate our value (3)
C. No impact on the ability to communicate our value – Neutral (5)
D. Increases the ability to communicate our value (7)
E. Exceptional ability to communicate our value (9)

Minimizes Land Footprint-Weight 4

1. Reduces or maintains community space required to operate
2. Aligns with development plans of the City

A. Significantly increase the land footprint or non-applicable (0)
B. Increases the land footprint (3)
C. No impact on the land footprint Neutral (5)
D. Reduces the land footprint (7)
E. Significantly reduces the land footprint (9)

Watershed Partnership that Enhance Collective Management

Enable New External Partnerships – Weight 6

1. Provides opportunity to create partnerships to support the environment, our causes and our products
2. Overall City Improvements (stream restoration, water reuse at parks, help City meet its environmental action plan, Sustainability Plan objectives and Cool Cities)
3. Recognized as efficient/effective public business
4. Includes the desires of ‘greener’ citizens

A. Negative impact on external partnerships or non-applicable(0)
B. Potential negative impact on external partnerships (3)
C. No impact on external partnerships (5)
D. Moderate improvement in external partnerships (7)
E. Significant improvement in external partnerships (9)

Support Sound Science – Weight 4

1. Impactful Watershed Research
2. Independently 3rd party verified technologies/processes
3. Adaptive lab practices to support watershed management changes
4. Align/Support Industry credited test methods
5. Aligned with new regulations

A. Severe negative impact to the treatment process or non-applicable (0)
B. Negative impact on the treatment process (3)
C. No impact on the treatment process - neutral (5)
D. Positive impact to the treatment process (7)
E. Significant positive impact to the treatment process (9)

Organizational Competency & Structure

Support Great Place to Work – Weight 3

1. Creates safe environment
2. Utilizes technology to increase efficiency
3. Develop new learning opportunities
4. Increases employee engagement

A. Severe impact to the workplace environment or non-applicable (0)
B. Negative impact on the workplace environment (3)
C. No impact on the workplace environment - neutral (5)
D. Positive impact to the workplace environment (7)
E. Significant positive impact to the workplace environment (9)

Improves Ease of Operation – Weight 5

1. Improves the employees workflow
2. Reduces the number of units that need maintenance, required skill/knowledge level, training needed to learn/maintain skills, waste products/streams to monitor –
3. Accessibility of process controls, data and parameters for operation and automation
4. Adequate physical access for O&M activities -

A. Negative impact on employee workflow or non-applicable (0)
B. Neutral impact on employee workflow (3)
C. Improves employee workflow (5)
D. Significantly improves employee workflow (7)
E. Automates employee workflow(9)

Maximize Technology Tool Solutions – Weight 5

1. Technology that increase operational efficiency
2. Communications enhancement/increase speed of data-decisions
3. Reduce daily work

A. Negative impact on employee workflow or non-applicable (0)
B. Neutral impact on employee workflow (3)
C. Improves employee workflow (5)
D. Significantly improves employee workflow (7)
E. Automates employee workflow(9)

Diversified Revenue

Annual Cost – Weight 1

1. Operations Cost
2. Maintenance Cost
3. Improvement, replacement and renewal cost
4. Revenue generated
5. Other costs

A. Annual cost increase greater or equal to 5% from current annual cost or non-applicable (0)
B. Annual cost increase 0 to 5% from current annual cost (3)
C. No rate change-neutral (5)
D. Annual cost decrease 0 to 5% from current annual cost (7)
E. Annual cost decrease equal or greater to 5% from current annual cost (9)

Capital Cost Management – Weight 1

1. Magnitude of Capital Investment needed
2. Ability to finance
3. Reuse of resources available
4. Avoidance of stranded assets

A. Greater than 30% higher than the least cost scenario or non-applicable (0)
B. Less than 30% higher than the least cost scenario (3)
C. Less than 20% higher than the least cost scenario (5)
D. Less than 10% higher than the least cost scenario (7)
E. Least cost scenario that is technically acceptable (i.e. meets boundary condition requirements) (9)

Fosters Cost Savings – Weight 3

1. Reduces Operations Cost
2. Reduces Maintenance Cost
3. Improvement, replacement and renewal cost
4. Revenue generation
5. Other costs

A. Does not deliver cost savings or non-applicable (0)
B. Delivers cost savings up to 5% (3)
C. Delivers cost savings up to 10% (5)
D. Delivers cost savings up to 15% (7)
E. Delivers cost savings over 15% (9)

Revenue Neutral or Positive- Weight 2

1. Create diversified revenue with resources
2. Delivers a positive impact to the local watershed
3. Maintains stable rates for our customers

A. Does not impact revenue or non-applicable (0)
B. Adds up to 5% additional revenue (3)
C. Adds up to 10% additional revenue (5)
D. Adds up to 15% additional revenue (7)
E. Adds revenue over 15% (9)

Incubator of new Ideas & Innovation

Enhance Sustainability – Weight 2

1. Meets LEED requirements where applicable
2. Meets Green Infrastructure requirements where applicable
3. Allows for flexibility to use environmental friendly chemicals in the future
4. Does no harm to the environment
5. Does not require additional human resources to manage process
6. Minimizes internal waste streams
7. Minimizes hazardous waste streams or uses
8. Reduce GHG emissions
9. Reduce KWh and natural gas usage

A. Meets none of the sustainable practices or non-applicable (0)
B. Meets one sustainable practices (3)
C. Meets two sustainable practices (5)
D. Meets four sustainable practices (7)
E. Meets six or more sustainable practices (9)

Enhance Resiliency – Weight 2

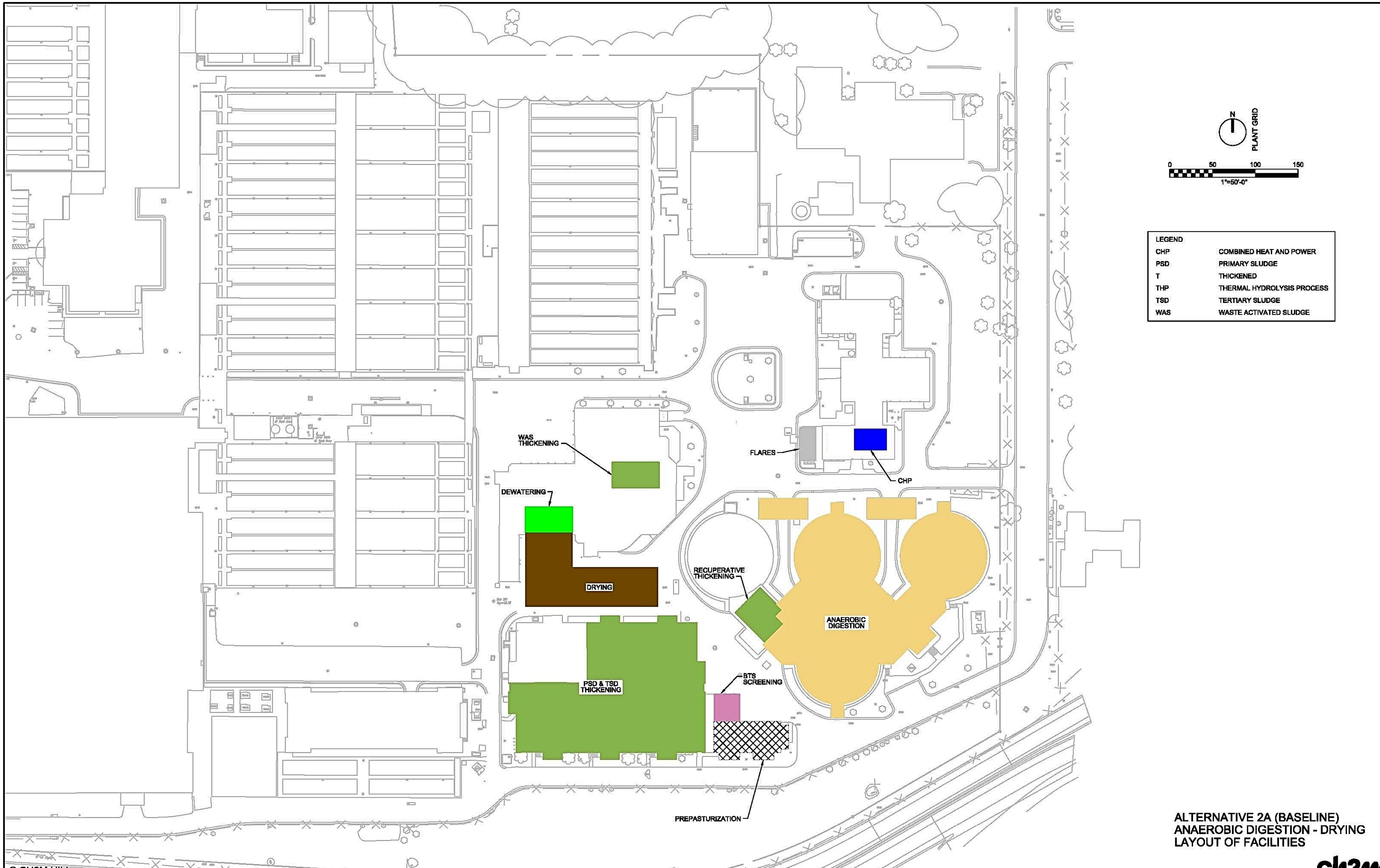
1. Robustness of the system – likelihood of failure and ability to handle variable loads and conditions
2. Redundancy – meets SCAT/regulatory requirements
3. Equipment meets life cycle expectations – minimize premature failures
4. Energy sources will be changing – process flexibility to absorb
5. Integration and risk assessment of new and emerging technologies
6. Secure and safe – continuously provides clean and safe products
7. Negative impact definition:
    a. High: Notification of regulators, permit compliance issues, health and safety, odor complaint, etc.
    b. Low: labor intensive cleanup/repair, spill within the plant, costly repair, etc.

A. High probability of system failure and high negative impact or non-applicable (0)
B. Moderate probability of system failure and high negative impact (3)
C. Low probability of system failure and high negative impact (5)
D. Moderate probability of system failure and low negative impact (7)
E. Low probability of system failure and low negative impact (9)

Technical Feasibility– Weight 4

1. Amount of physical facility footprint required (including access roadways, truck bays, buffer zones, etc)
2. Impact of new process on site
3. Design maximizes site open space available for future

A. Large footprint required, lots of additional land needed or non-applicable (0)
B. Moderate footprint required, some additional land needed (3)
C. Footprint required, fits in existing site (5)
D. No impact on existing site (7)
E. Reduces current site footprint (9)



LEGEND	
CHP	COMBINED HEAT AND POWER
PSD	PRIMARY SLUDGE
T	THICKENED
THP	THERMAL HYDROLYSIS PROCESS
TSD	TERTIARY SLUDGE
WAS	WASTE ACTIVATED SLUDGE

ALTERNATIVE 2A (BASELINE)
ANAEROBIC DIGESTION - DRYING
LAYOUT OF FACILITIES

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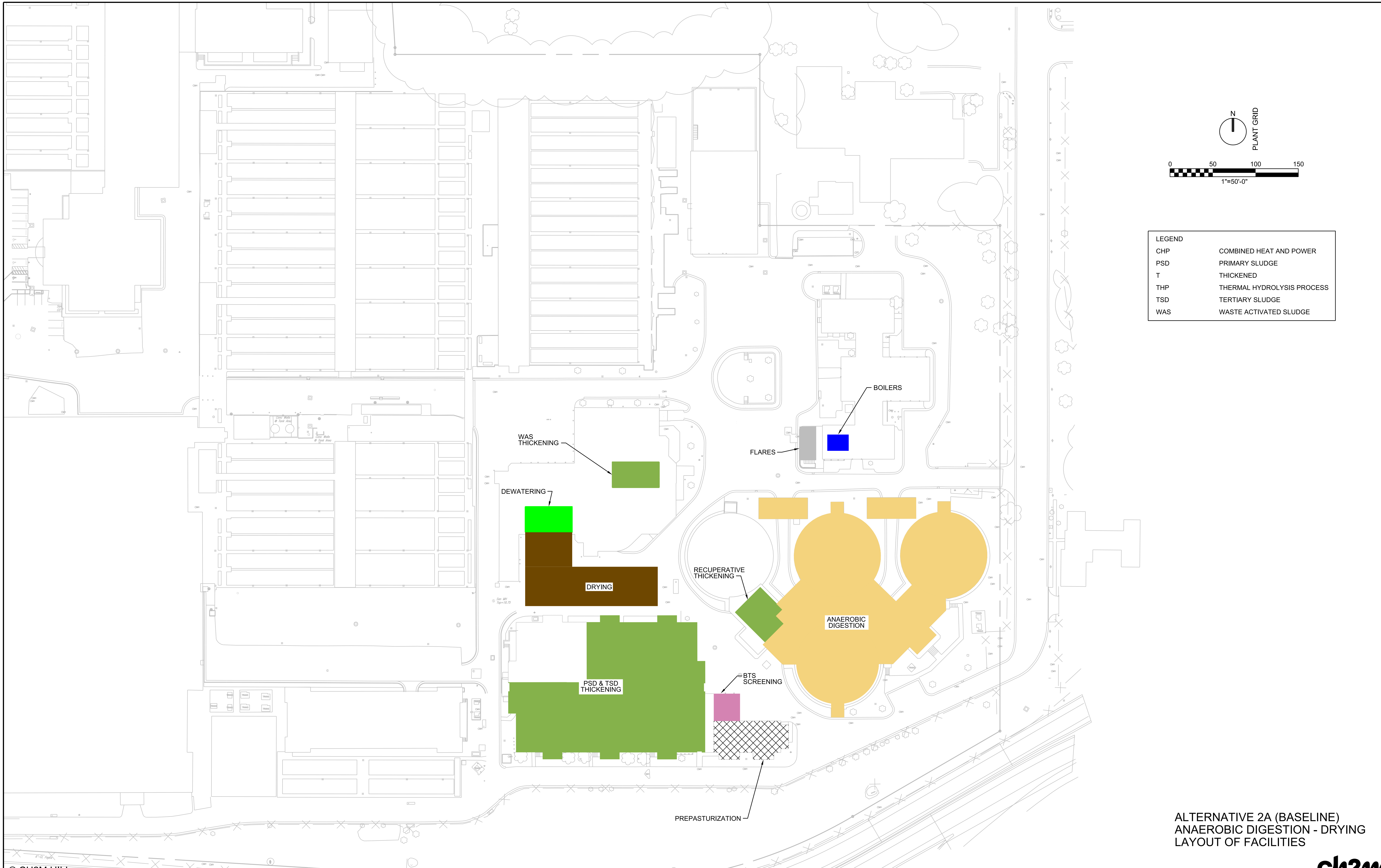
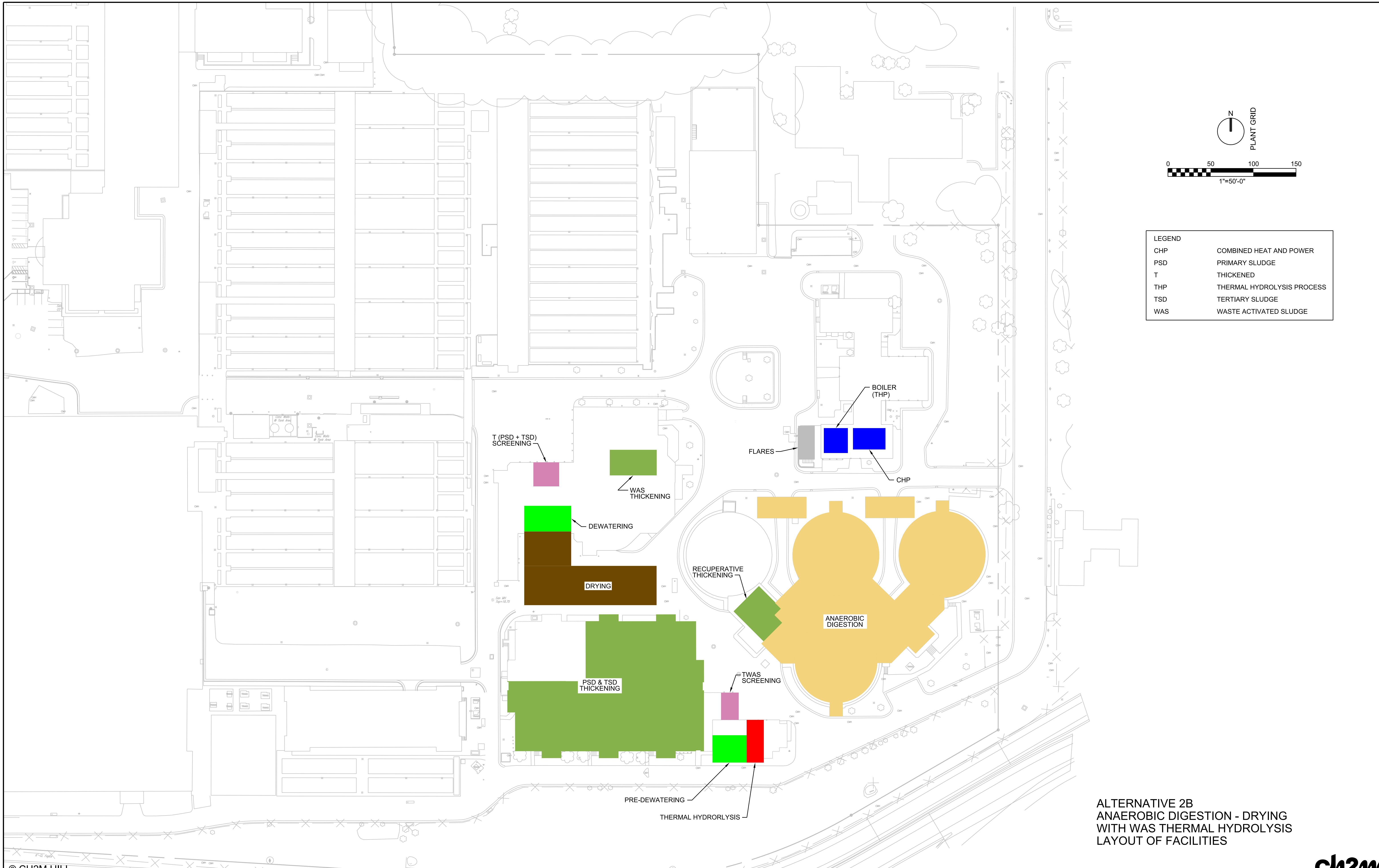
OVERALL1.DGN

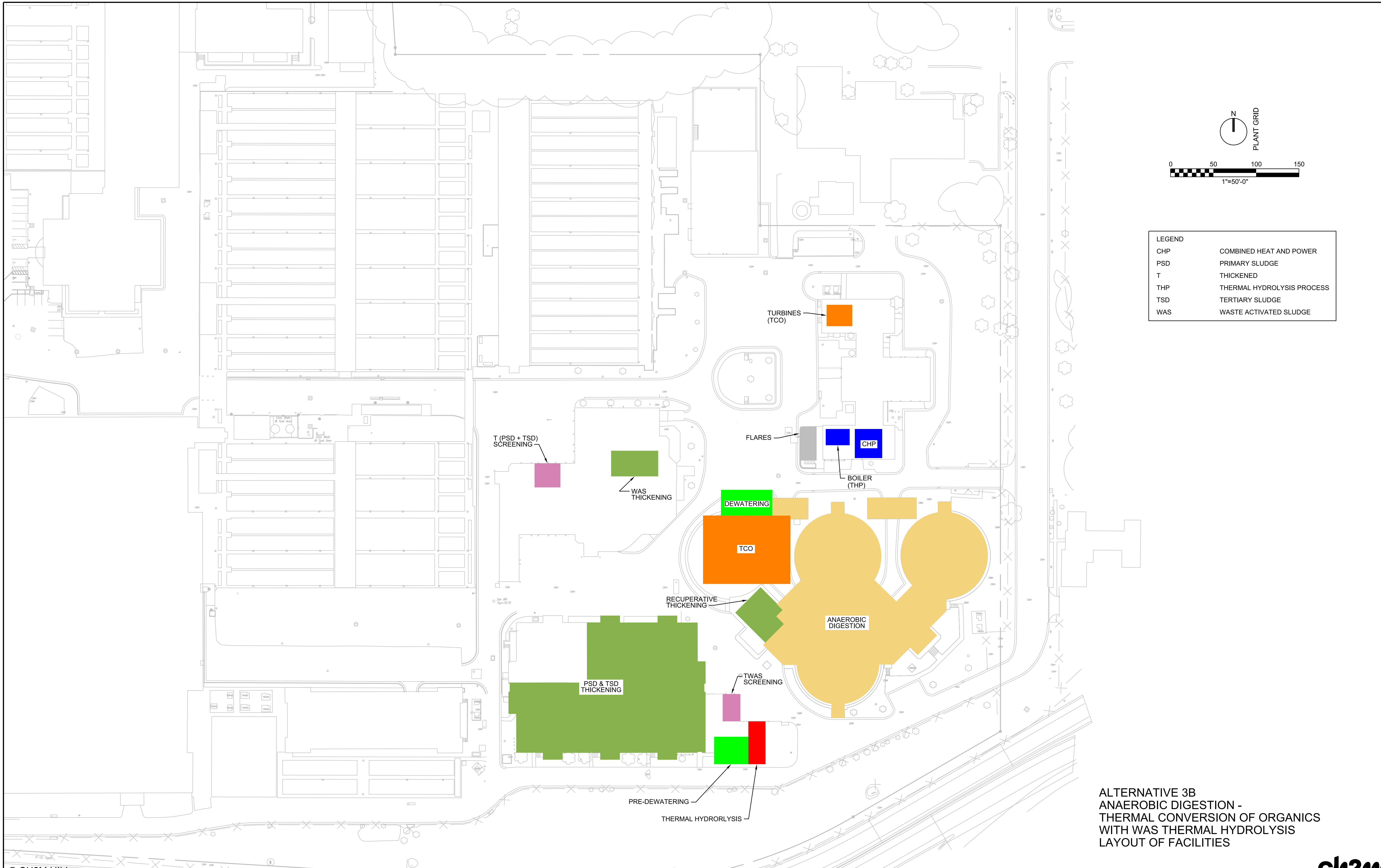


ALTERNATIVE 2A (BASELINE)
ANAEROBIC DIGESTION - DRYING
LAYOUT OF FACILITIES



ALTERNATIVE 2B
ANAEROBIC DIGESTION - DRYING
WITH WAS THERMAL HYDROLYSIS
LAYOUT OF FACILITIES

OVERALL2.DGN

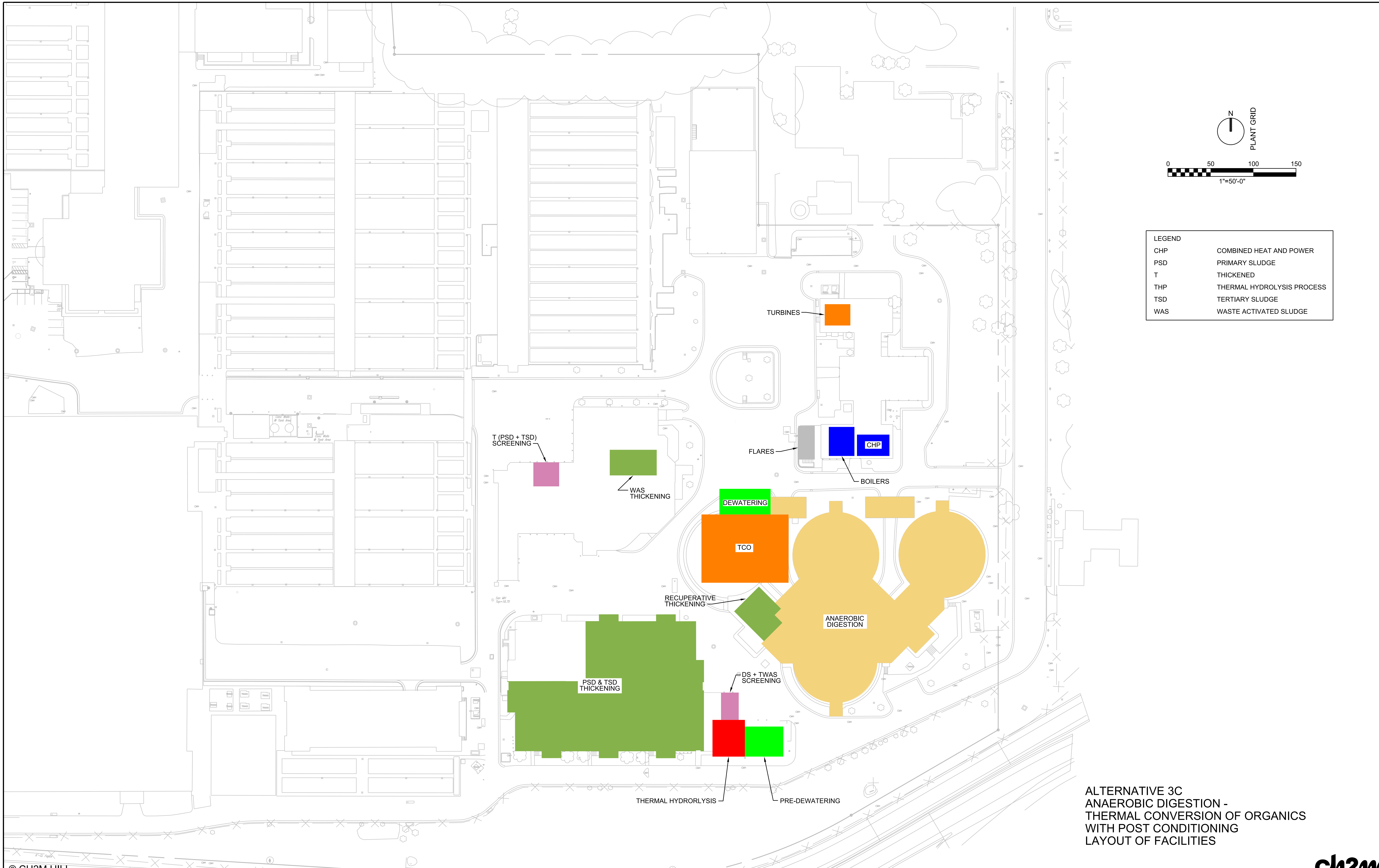


LEGEND	
CHP	COMBINED HEAT AND POWER
PSD	PRIMARY SLUDGE
T	THICKENED
THP	THERMAL HYDROLYSIS PROCESS
TSD	TERTIARY SLUDGE
WAS	WASTE ACTIVATED SLUDGE

ALTERNATIVE 3B
ANAEROBIC DIGESTION -
THERMAL CONVERSION OF ORGANICS
WITH WAS THERMAL HYDROLYSIS
LAYOUT OF FACILITIES

ch2m:

OVERALL3.DGN



ALTERNATIVE 3C
ANAEROBIC DIGESTION -
THERMAL CONVERSION OF ORGANICS
WITH POST CONDITIONING
LAYOUT OF FACILITIES

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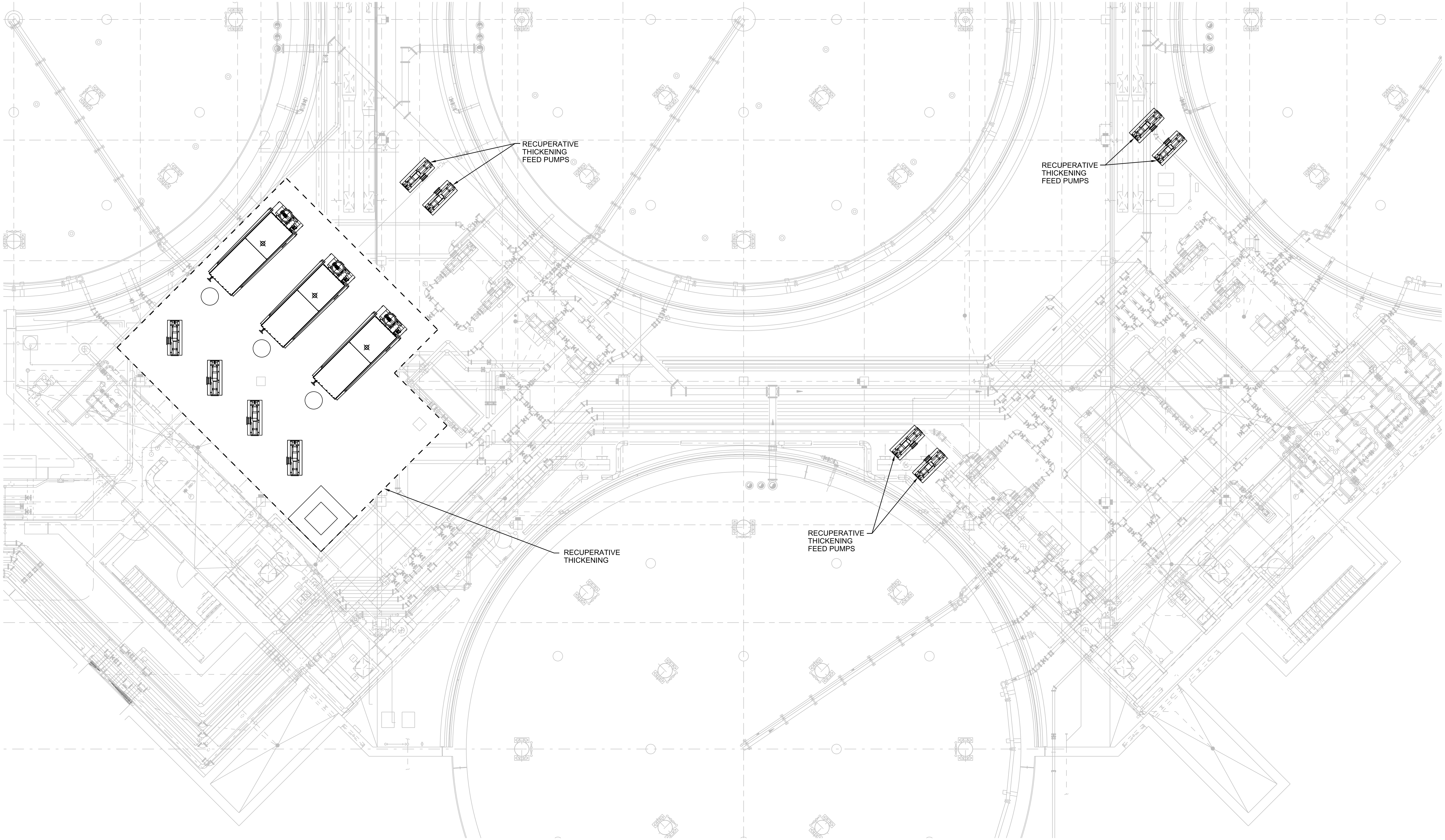
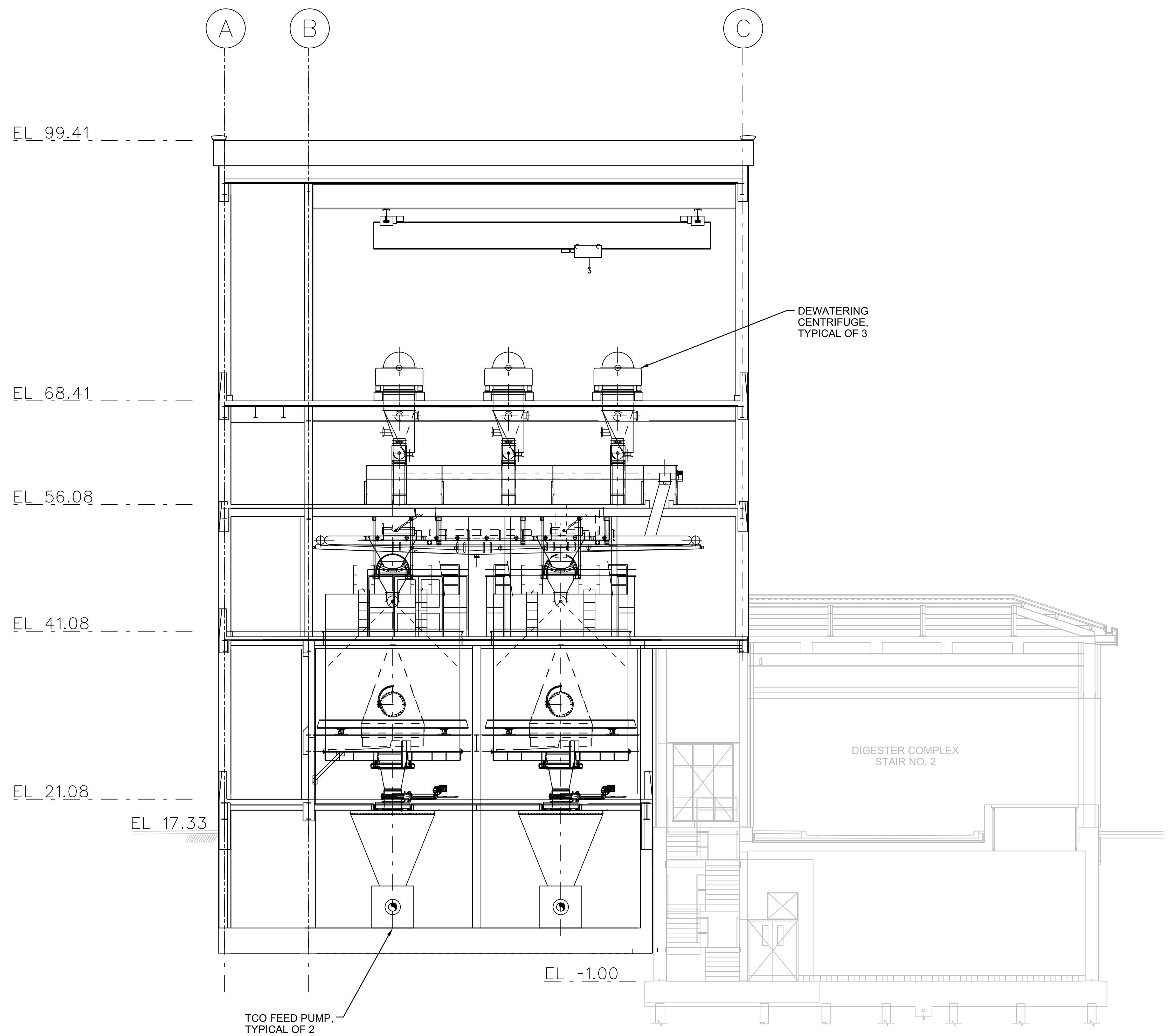
OVERALL4.DGN



ALTERNATIVE 2A, 2B, 3B, 3C
BASEMENT PARTIAL PLAN
ANAEROBIC DIGESTERS 20

ch2m

THICKENER.DGN



SECTION LOOKING NORTH

NTS

ALTERNATIVE 3B,3C
SECTION
DEWATERING BUILDING

ch2m

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MEETING SUMMARY

BOA WA2-2016-7

AlexRenew Solids Handling & Energy Optimization – Alternatives Evaluation Review and Implementation Plan– August 2, 2016

ATTENDEES:	Karen Pallansch/AlexRenew Sean Stephan/AlexRenew Charlie Logue/AlexRenew Lisa Reynolds/AlexRenew	Dan Lynch/CH2M Julian Sandino/CH2M Glen Daigger/CH2M Paula Sanjines/CH2M
PREPARED BY:	Paula Sanjines/CH2M	
DATE:	August 5, 2016	

Objectives

A meeting was held on August 2, 2016 at the AlexRenew Administration Building with the following objectives:

- Reviewing the Alternative Scoring Results and Major Differentiation
- Discussing the Implementation Plan and Next Steps

Summary

A summary, based on agenda topics, is provided below. Agenda is included in Attachment 1.

Scoring Results

Reviewed the results of the scoring exercise on July 13, 2016. See Attachment 2 for the slides that summarize the results and Attachment 3 for background information handed out. Key discussion points:

- The alternatives were scored by representatives of AlexRenew operations, maintenance and engineering with CH2M available to answer questions as needed. The alternatives were discussed and then scored. Scores were assigned to all alternatives in the same category before moving to the next category, which allowed comparison between alternatives.
- The “3” alternatives (thermal conversion) received higher scores than the “2” alternatives (dryer). The main differentiator was production/offset of more electricity, considerable reduction in the final product (and therefore less truck traffic) and reduction of the greenhouse gases at the facility.
- Alternative 3b (conventional Thermal Hydrolysis) received a higher score than 3c (post-digestion Thermal Hydrolysis) mainly because post-digestion thermal hydrolysis is a new technology without the proven track record of the conventional application.
- The estimated annual average costs for all alternatives are roughly the same (within the margin of error of the estimate)
- The capital costs of the “3” alternatives is roughly 3 x the “2” alternatives. The bulk of this cost is the thermal conversion unit (a fluidized bed incinerator was used as reference technology),

which costs about $70M. However, without the thermal conversion cost, the capital cost of the alternatives is very similar.

Facilitated Discussion

A discussion followed regarding the implementation/phasing of improvements to the biosolids treatment train, including short- and medium- and long-term goals for the facility. Key discussion points:

- The evaluation performed to date has taken a very long view (40+ years, to 2060), but we also need to look at the next 5-10 years, which is when changes in regulatory drivers (such as bans or restrictions on land applications) are likely to become a reality and will require utilities to take action. At that point, AlexRenew needs to be well positioned to be as independent as possible when it comes to biosolids reuse.
- The evaluation up to this point has validated anaerobic digestion as a valuable component of AlexRenew's process train that brings benefits now and aligns with future goals (reduction in biosolids produced and biogas production).
- In the short-term, one key decision AlexRenew needs to take is with respect to Pre-Pasteurization.
    - Pre-Pasteurization was selected during the previous upgrade in order to produce Class A Biosolids.
    - Production of Class A biosolids is a mandate of the AlexRenew Board to be good neighbors, not just in the immediate vicinity of the plant, but also in the rural areas where the biosolids are land-applied.
    - The system has operated well for 10 years but recently it has needed repairs, acid cleaning of the heat exchangers, and may require more investment to keep it operational and prevent it from becoming a bottleneck in the process.
- Discussed the options available today (based on proven technologies) in order to address the issue of Class A biosolids and potentially also to produce more biogas, which in turn can be converted to electricity. These are:
    - Continue with pre-pasteurization. This option produces Class A but does not leave enough biogas to generate electricity. This was the option selected in the Long Range Plan in 2008. This option left space for a dryer to be implemented in the future when/if land application of biosolids was banned/restricted.
    - Thermal hydrolysis:
        - Pre-digestion (similar to DC Water), produces Class A, improves VSS destruction and dewaterability (and therefore biosolids produced) and increases gas production
        - Post-Digestion (new application of the THP process), produces Class A, improves VSS destruction and dewaterability to 40% (Glen Daigger brought a sample product, it looks like dirt) and increases gas production
- The benefits of these processes (reduced biosolids and increased biogas production) have to be balanced with other imperatives and drivers at AlexRenew, which include:
    - Land availability: AlexRenew has a very small and tight site. Land is very valuable. Need to maximize the available space and take into account the cost of the land when the life-cycle cost of alternatives is analyzed (for example, gravity thickeners consume less electricity but they take up a lot of space)

    - Financial stability: take into account capital improvements, future O&M costs, staffing costs and ensure that AlexRenew has the ability to run a good business now and in the future.
    - Risks: Air permitting, including environmental social justice issues due to the location of the biosolids treatment infrastructure within the plant (on the East side).
    - Staffing: Challenge in hiring specialized workforce to operate and maintain technologies like thermal hydrolysis (in particular the high pressure steam system) and competing with other large utilities for that workforce. Labor costs may go up as salaries have to become more competitive. Or alternatively, the operation of those processes will have to be subcontracted out (as DC Water is doing) which will also increase annual costs.
- AlexRenew would like to see a baseline that compares today's operations with the conditions in 2008 when decisions were made. Some items discussed include:
    - Sludge production today compared to 2008
    - Projected impact of Mainstream Anammox and Biological Phosphorus (Bio-P) removal. The Bio-P analysis was not clearly shown in the documents produced to date for AlexRenew. Need to better show/explain the impact of Bio-P and how it would affect operations (including chemical use, impact to biosolids, and truck traffic to transport pelletized fertilizer product). Also include the footprint required to implement a phosphorus recovery system like Ostara
    - Assess impact of wet weather flows
    - Assess the condition of the current processes and equipment
    - Assess the quantity and quality of the biosolids produced
- Discussed beneficial use of biogas in a Combined Heat and Power (CHP) system to generate heat and electricity
    - Gas storage is not a requirement for CHP. In some installations it improves operations but at AlexRenew it may not be needed.
    - Discussed that implementing CHP in the near future would not preclude future innovations
- Site Plan/Space:
    - Discussed that a more simplified site plan needs to be generated to show the different pieces and how they fit
    - Make sure there is space onsite for a technological solution to a ban/restriction on land application.
    - Look at Building L and how space can be re-used there

Next Steps

Before the next workshop, a higher level analysis will be performed along the following lines:

- Long Term (The Future): The long-term approach at AlexRenew needs to accomplish: product that is not land applied (ash or dried product) and optimized energy generation.
- Implementation Plan: Look at potential steps along the path to the long-term goal and assess what makes sense to do now and what are steps that have risks/uncertainty attached to them

and therefore may want to defer. However, also look at the risks of doing nothing. Evaluate the following:

- Status of the Facility Today – Baseline Condition:
  - Biosolids Management
    - Land application – Class A product (current quality and quantity)
  - Liquids Treatment
    - Mainstream Anammox (impact to baseline condition)
  - Solids Process unit processes and equipment assessment (gravity thickening, centrifuges, pre-pasteurization, sludge screening, etc.)
  - Assessment of Building L, including available space
- Possible first phase implementation alternatives (towards long-term goals):
  - Baseline: Keep pre-pasteurization and current process as-is
  - Liquids Treatment: implement Bio-P and Phosphorus Recovery
  - Abandon Pre-Pasteurization and produce Class B solids
    - Noman Cole option? Use for a portion of AlexRenew biosolids
  - Implement Combined Heat and Power
  - Post-Digestion Thermal Hydrolysis (evaluate and compare to baseline)
  - Drying (we didn't discuss this at the meeting but could be an interim step that produces Class A and minimizes end product)
- At the workshop, we will evaluate these implementation alternatives, and develop a list of projects/tasks that make sense for AlexRenew to move forward with

Action Items

- CH2M to generate an outline/rough draft of the analysis and present to Karen in order to make sure we are headed in the right direction. Target date: August 26, 2016.
- Next workshop will be in the early October time-frame.

Attachments

1. Agenda
2. Presentation Slides
3. Handouts: Background Information

Facilitator: Julian Sandino /CH2M	**Meeting topic**: ***Solids Handling & Energy Optimization Alternatives Evaluation (BOA WA2-2016-7)***
Meeting date: August 2, 2016	**Meeting start time**: 1:00 pm
Notes taken by: Paula Sanjines/CH2M	**Meeting end time**: 3:00 pm

I. Meeting Objectives:

1.	Reviewing the Alternative Scoring Results and Major Differentiation
2.	Discuss the Implementation Plan and Next Steps

II. Attendance:

Karen Pallansch	AlexRenew	Dan Lynch	CH2M
Lisa Reynolds	AlexRenew	Glen Daigger	CH2M
Sean Stephan	AlexRenew	Julian Sandino	CH2M
Charlie Logue	AlexRenew	Paula Sanjines	CH2M

III. Discussion/Decision Items:

Start Time		Topics	Notes
1.0	1:00 pm	Scoring Results	• Recap of the scoring exercise • Major differences between alternatives
2.0	1:30 pm	Facilitated Discussion	• Short term and long term goals • Possible implementation steps
3.0	2:30 pm	Summary and Next Steps	• List out the information and action items to be completed before the next workshop
	3:00 pm	***Adjourn***	




Solids Handling & Energy Optimization Technology Pathways

Scoring Results and Path Forward

August 2, 2016

Objectives

- Present Decision Model and Scoring Results
- Discuss Major Differentiators in Scoring
- Discuss Implementation Considerations
- Next Steps

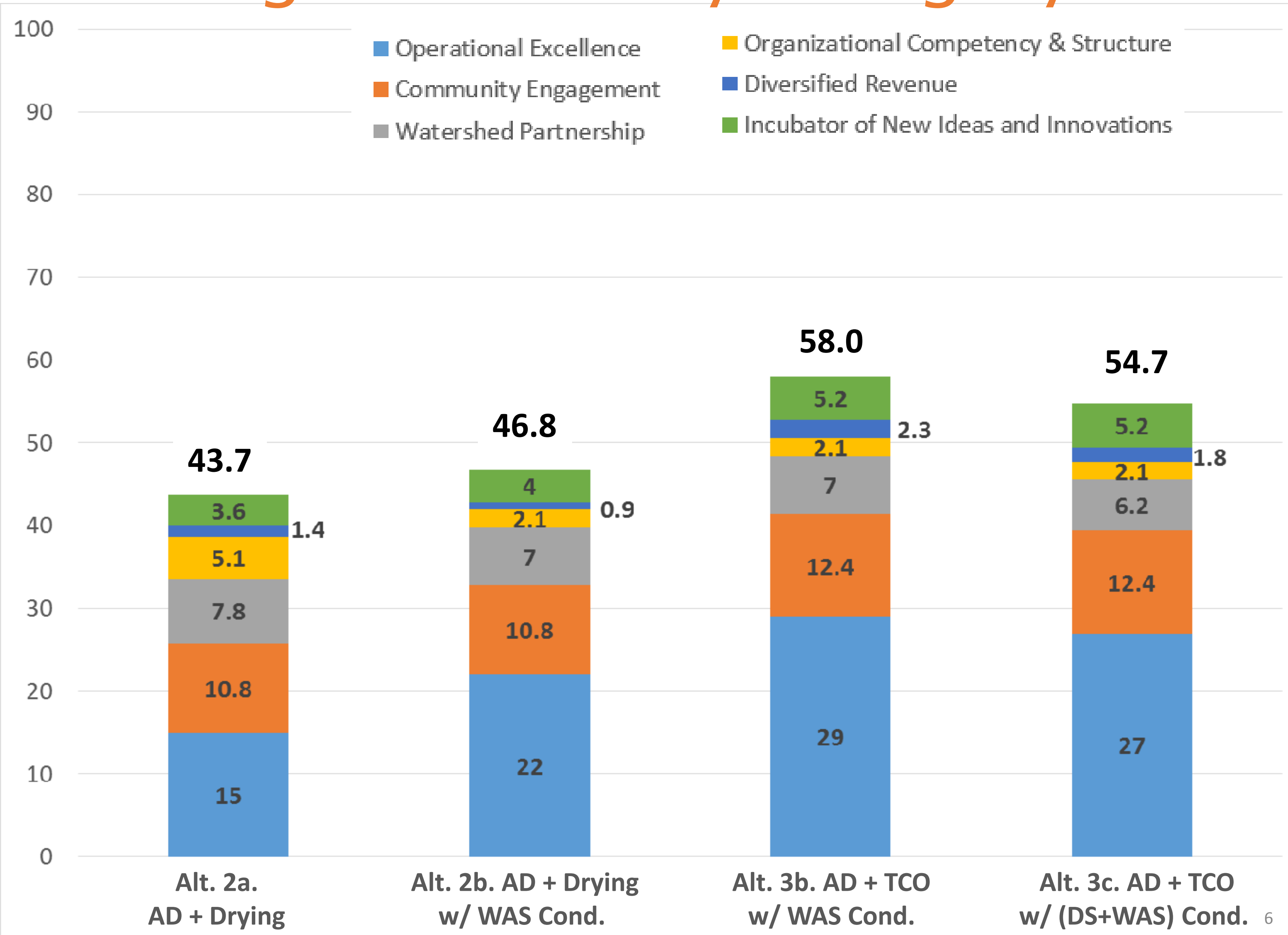
Technology Pathway Alternatives

Decision Model and Scoring Results

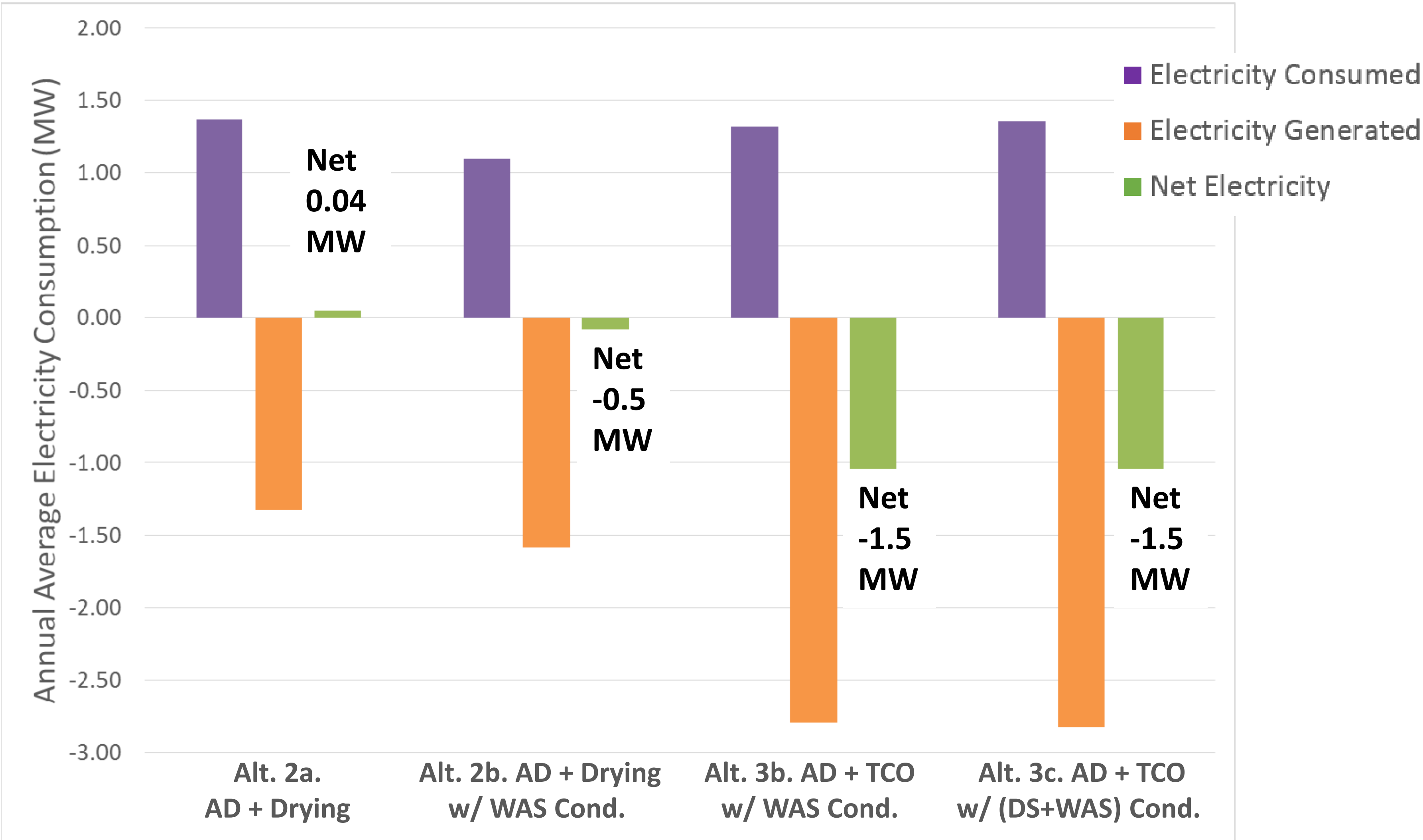
AlexRenew Decision Model

Weights:	40	22	10	13	7	8
Strategic Alignment:	**Operational Excellence**	**Community Engagement**	**Watershed Partnership that Enhance Collective Mgmt**	**Organizational Competency & Structure**	**Diversified Revenue**	**Incubator of New Ideas and Innovations**
	Improve Business Efficiency ***Weight: 10***	Promotes water in our community ***Weight: 3***	Enable new external partnerships ***Weight: 6***	Supports great place to work ***Weight: 3***	Annual Cost ***Weight: 1***	Enhance Sustainability ***Weight: 2***
	Compliance enhancement /adaptability ***Weight: 15***	Enhance Community Water Resources ***Weight: 4***	Support sound Science ***Weight: 4***	Improves ease of operation ***Weight: 5***	Capital Cost Management ***Weight: 1***	Enhance Resiliency ***Weight: 2***
	Enhance Capacity/Throughput ***Weight: 10***	Supports customer service ***Weight: 5***		Maximize technology tool solutions ***Weight: 5***	Fosters Operational Cost savings ***Weight: 3***	Technical Feasibility ***Weight: 4***
	VEEP/EMS ***Weight: 5***	Communication Enhancement Value ***Weight: 6***			***Revenue Neutral or positive Weight: 2***	
		Minimizes Land Footprint ***Weight: 4***				

Scoring Results – By Category

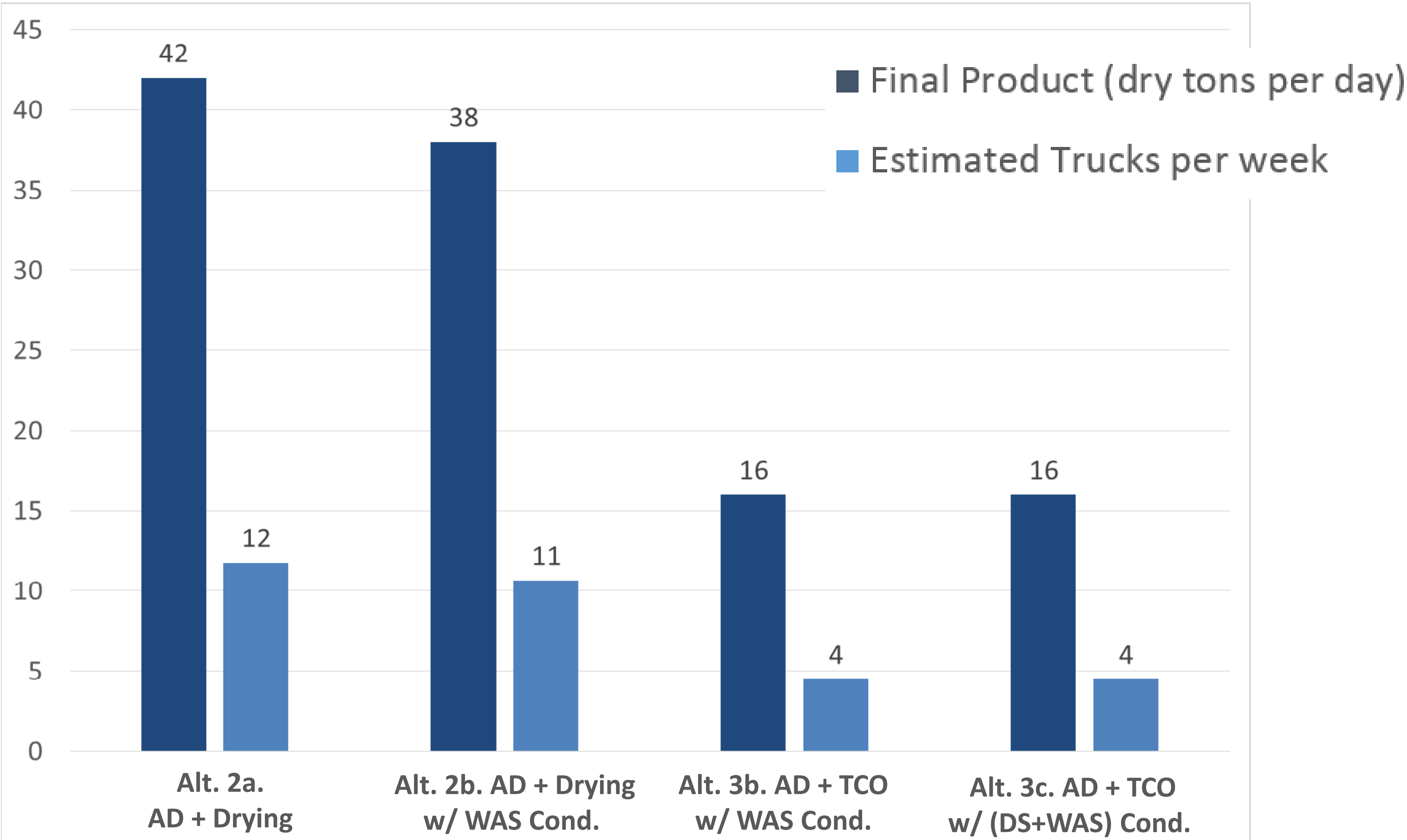


Major Differentiators in Scoring –
3's Alternatives Generate more Electricity than 2's



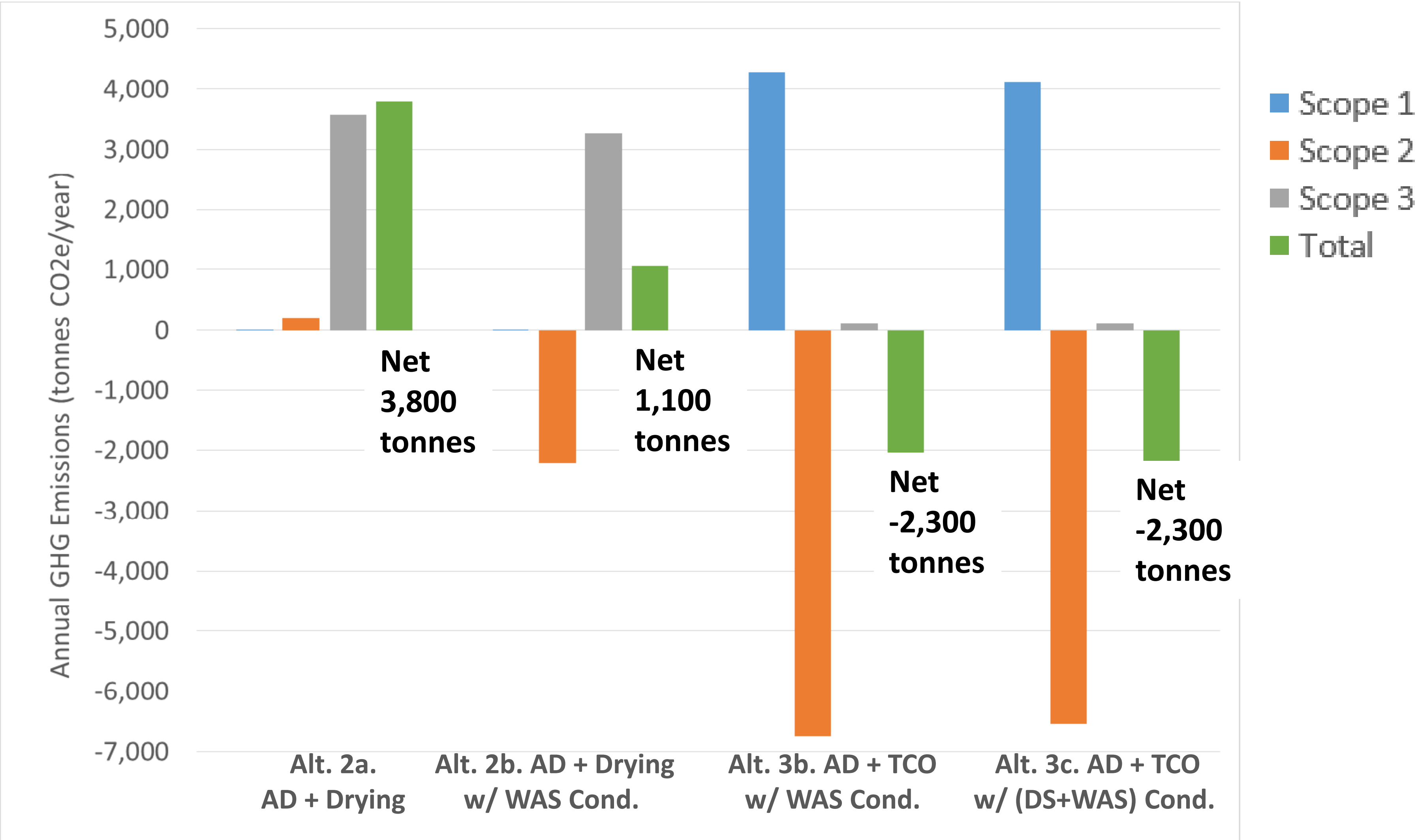
Note: values are at Design Annual Average Condition (58 MGD AADF)

Major Differentiators in Scoring –
3's Result in Less Product and Truck Traffic than 2's



Note: values are at Design Annual Average Condition (58 MGD AADF)

Major Differentiators in Scoring – 3's Result in Less GHG Emissions than 2's

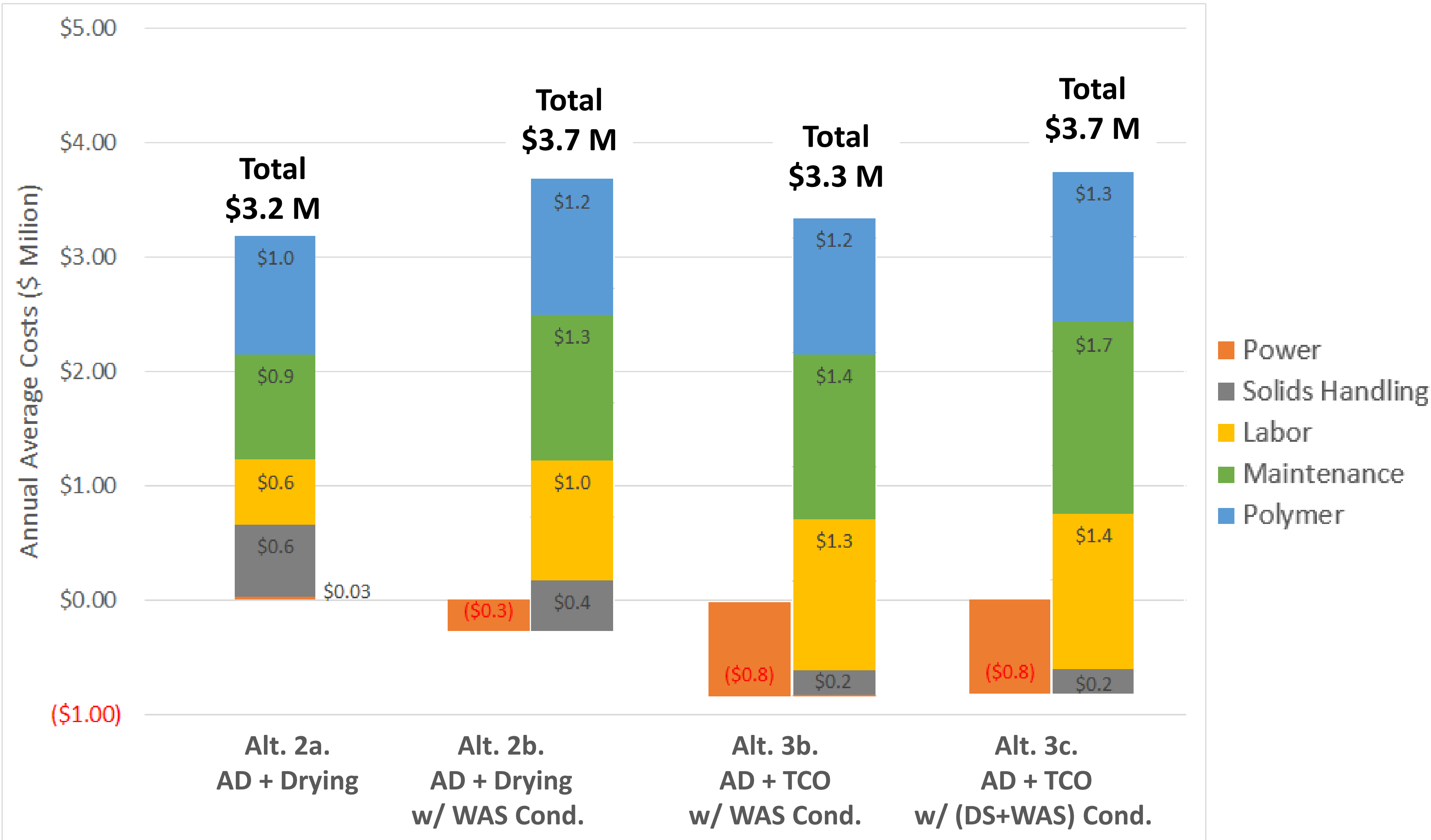


Note: values are at Design Annual Average Condition (58 MGD AADF)

Major Differentiators in Scoring

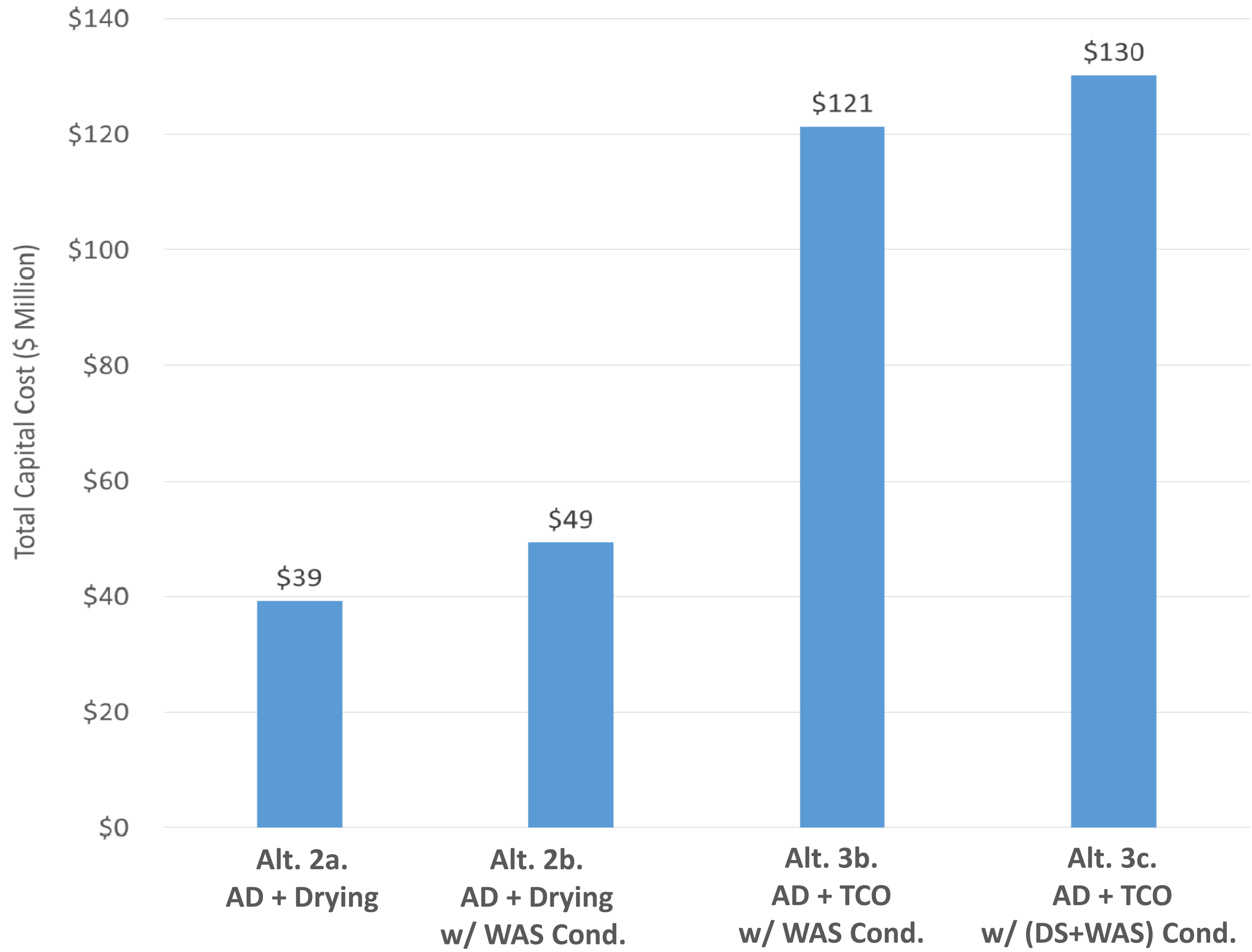
- TCO Alternatives (3’s) scored higher than Dryer Alternatives (2’s)
  - More energy, less product, less truck traffic
  - Lower footprint impact if TCO is constructed on digester footprint.
- Small difference between 3b and 3c.
  - 3b scored higher than 3c because more established technology and less annual cost.

Annual Average Operational Costs



Note: values are at Design Annual Average Condition (58 MGD AADF)

Capital Costs



Implementation Considerations

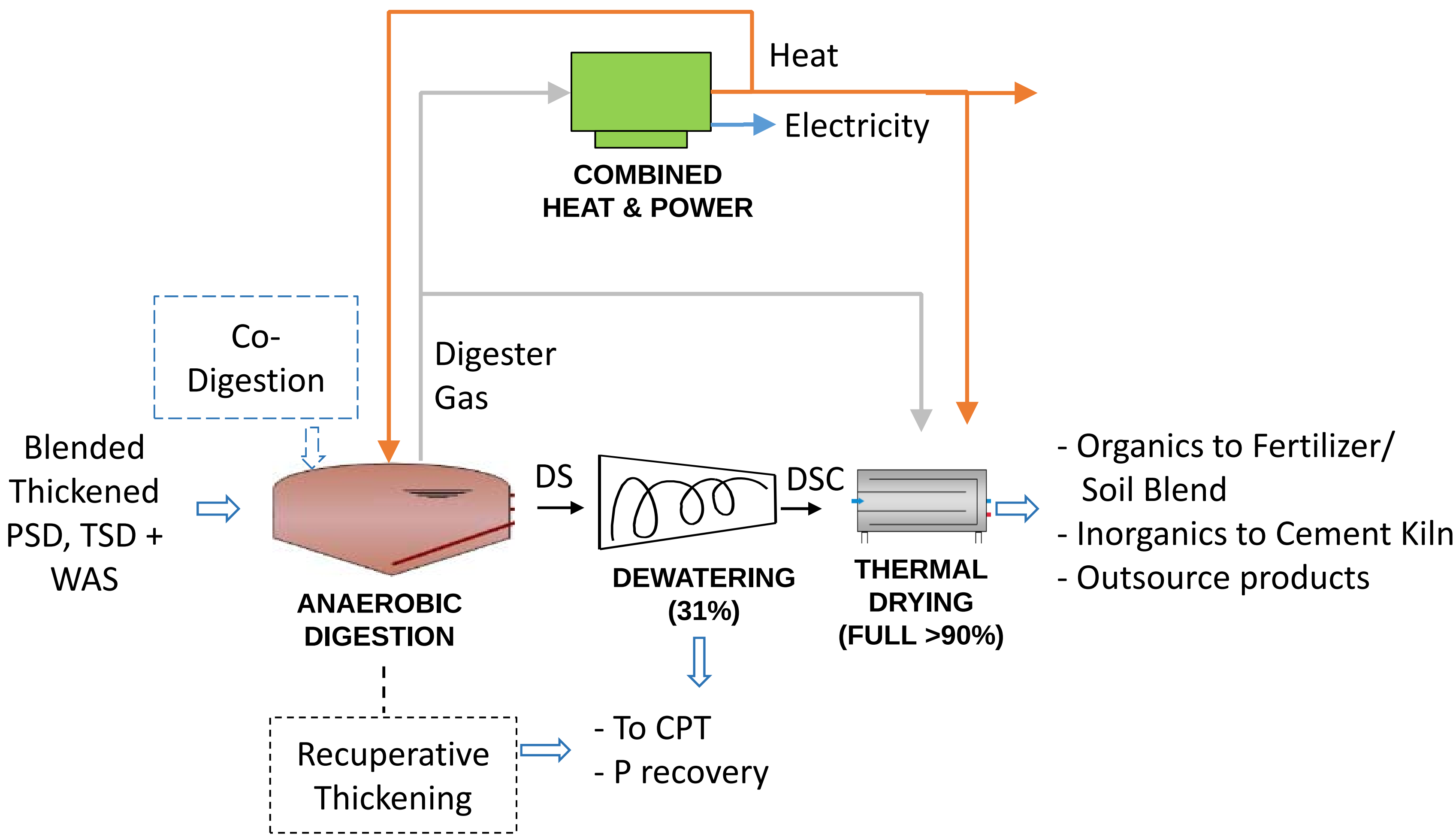
Considerations for Discussion

- Phasing
- Initial Conditions
- End Use Solutions

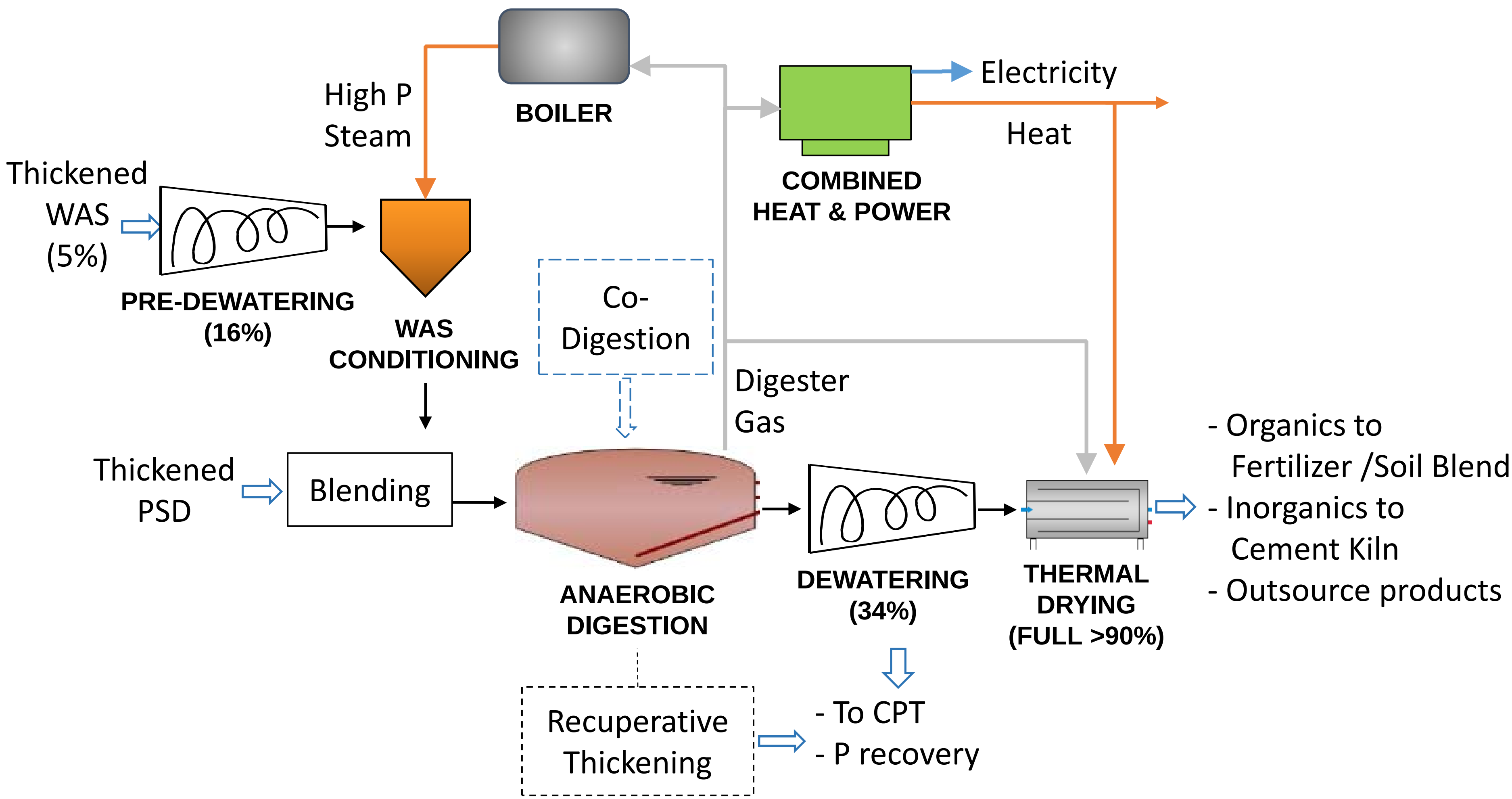
Technology Pathway Alternatives

2a. Anaerobic Digestion (AD) + Drying

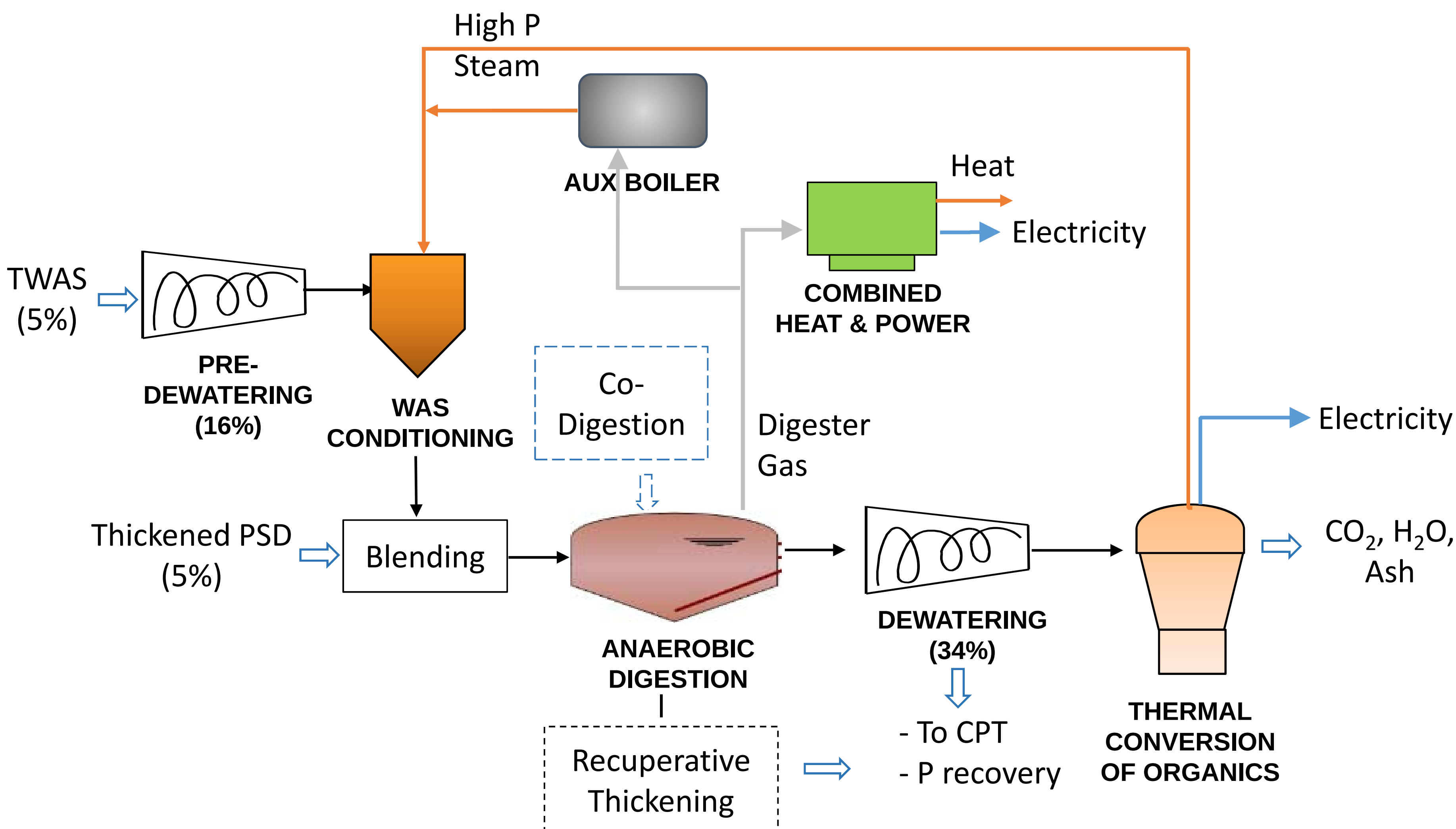
(from 2008 Long Range Plan)



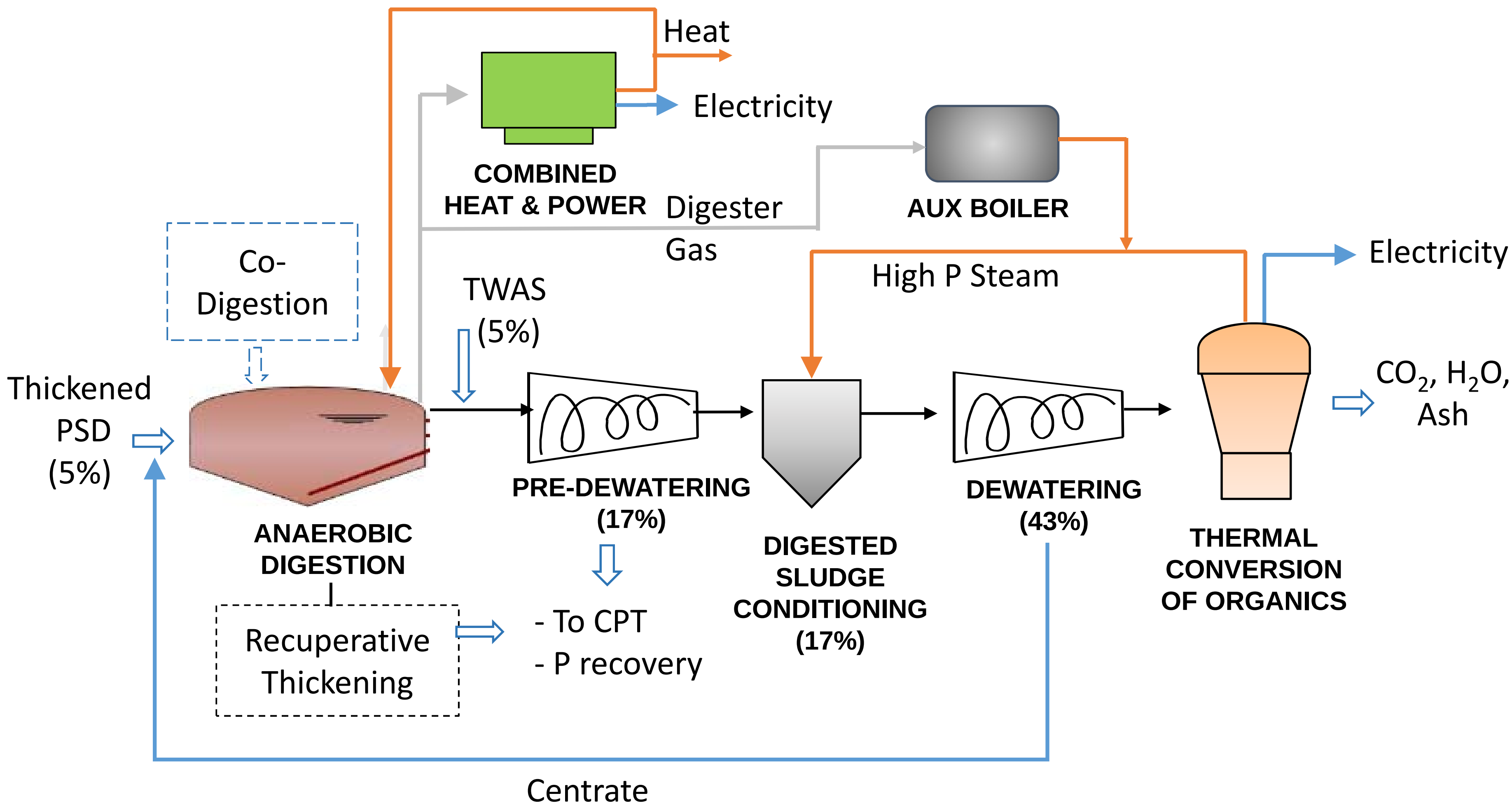
2b. Anaerobic Digestion (AD) with WAS conditioning + Drying



3b. Anaerobic Digestion + Thermal Conversion of Organics (AD + TCO) with WAS conditioning



3c. Anaerobic Digestion + Thermal Conversion of Organics (AD + TCO) with post-conditioning



Planning Basis

- 2060 Planning Horizon
- 480,000 service population
- 58 MGD Annual Average Daily Flow
  - Basis for O&M Costs and Greenhouse Gas emissions
- 70 MGD Max Month (30-day) Daily Flow
  - Basis of design for equipment and facility sizing
- Carbon Re-Direction vs. P-Recovery
  - Evaluation based on CEPT (Chemically Enhanced Primary Treatment)
  - Verified results against bio-P solids projections

Reference Technologies for Conceptual Definition (Modeling/Sizing/Layout)

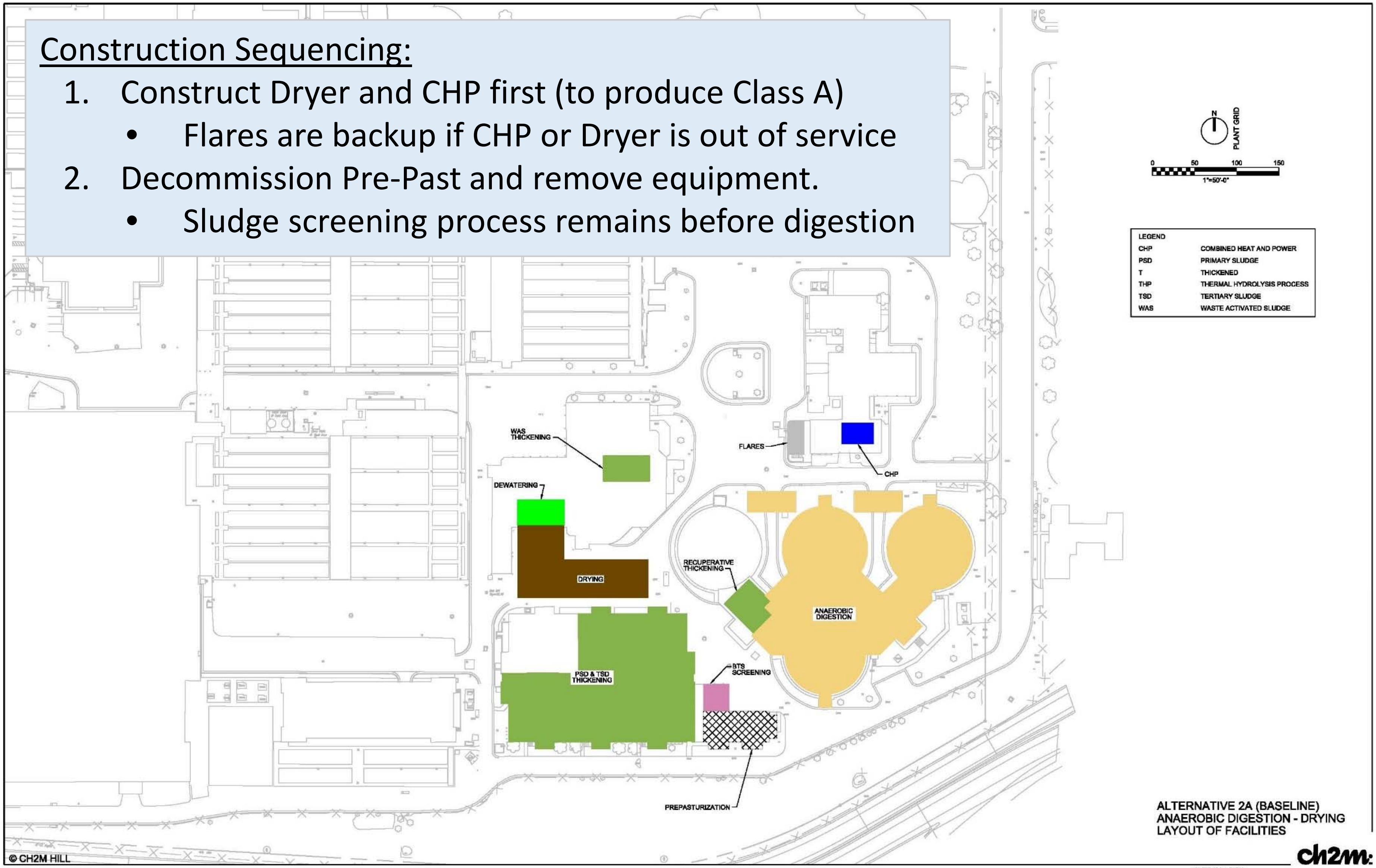
- PSD Thickening → Gravity Thickener
- WAS Thickening → Centrifuge
- Anaerobic Digestion → Mesophilic AD
- Recuperative Thickening → Rotary Drum Thickener
- Sludge (PSD, WAS, DS) Conditioning → Thermal Hydrolysis (Cambi)
- Sludge Dewatering → Centrifuge
- Sludge Thermal Drying → Belt
- Thermal Conversion of Organics → Fluidized Bed Reactor
- P Recovery → Intentional struvite precipitation (Ostara)
- Combine heat power (CHP) → Internal combustion engine
- Energy Recovery from TCO → Organic-Rankine Cycle (ORC) Turbo Generators

Site Plan Layouts

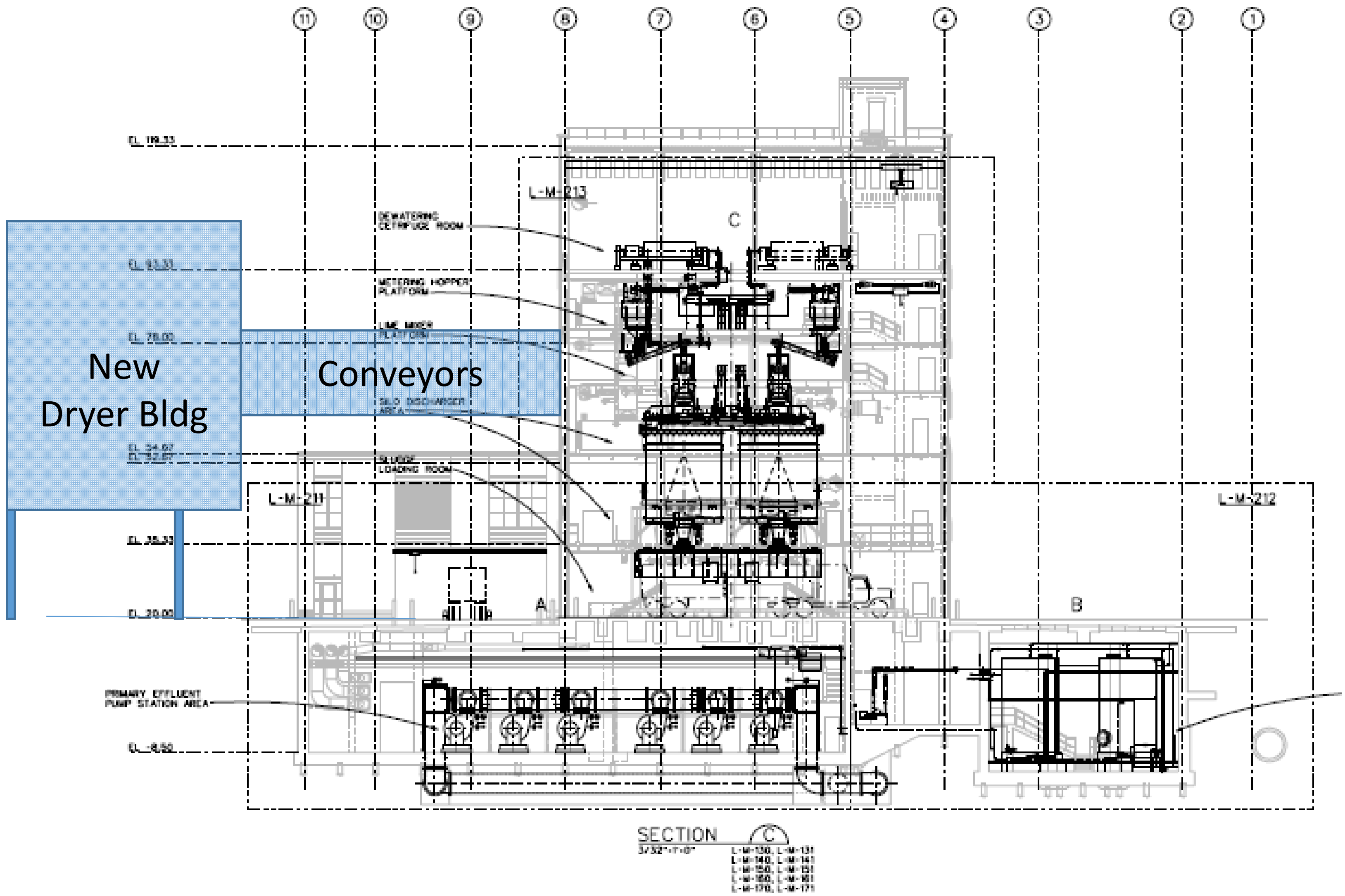
2a. Anaerobic Digestion (AD) + Drying Layout

<u>Construction Sequencing:</u>

1. Construct Dryer and CHP first (to produce Class A)
   - Flares are backup if CHP or Dryer is out of service
2. Decommission Pre-Past and remove equipment.
   - Sludge screening process remains before digestion



2a. Anaerobic Digestion (AD) + Drying
Dryer Facility Section



2b. Anaerobic Digestion (AD) with WAS conditioning + Drying Layout

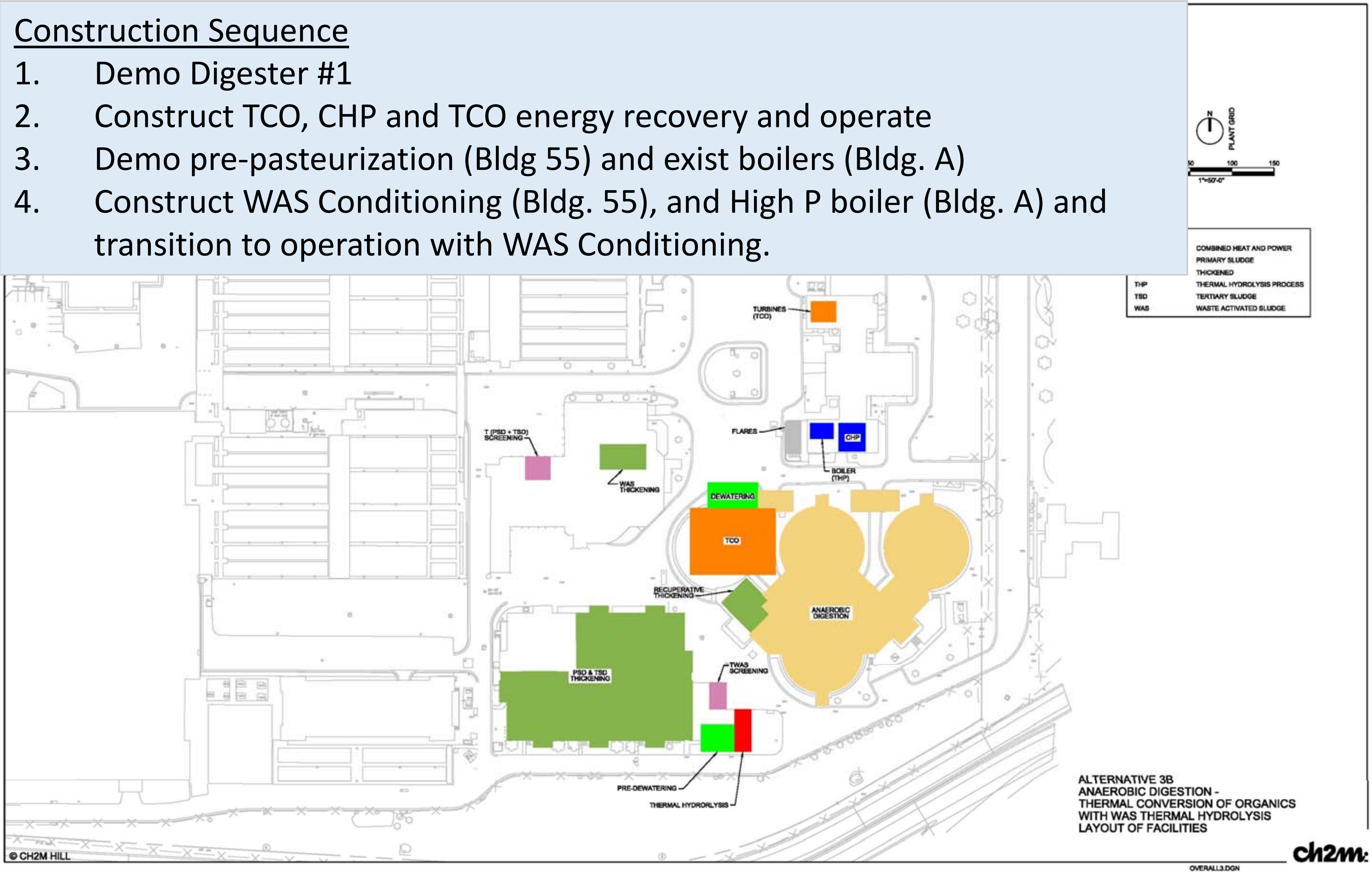
Construction Sequence

1. Construct Dryer and CHP and operate to achieve Class A (same as Alt 2a)
2. Install Sludge Screens for PSD + TSD in Bldg L
3. Demo pre-pasteurization and exist boilers (Bldg. A)
   - Boilers not needed for pasteurization
4. Construct WAS Conditioning (Bldg. 55), and High P boiler (Bldg. A). Transition to operation with WAS Conditioning

3b. AD + TCO + WAS Conditioning Layout

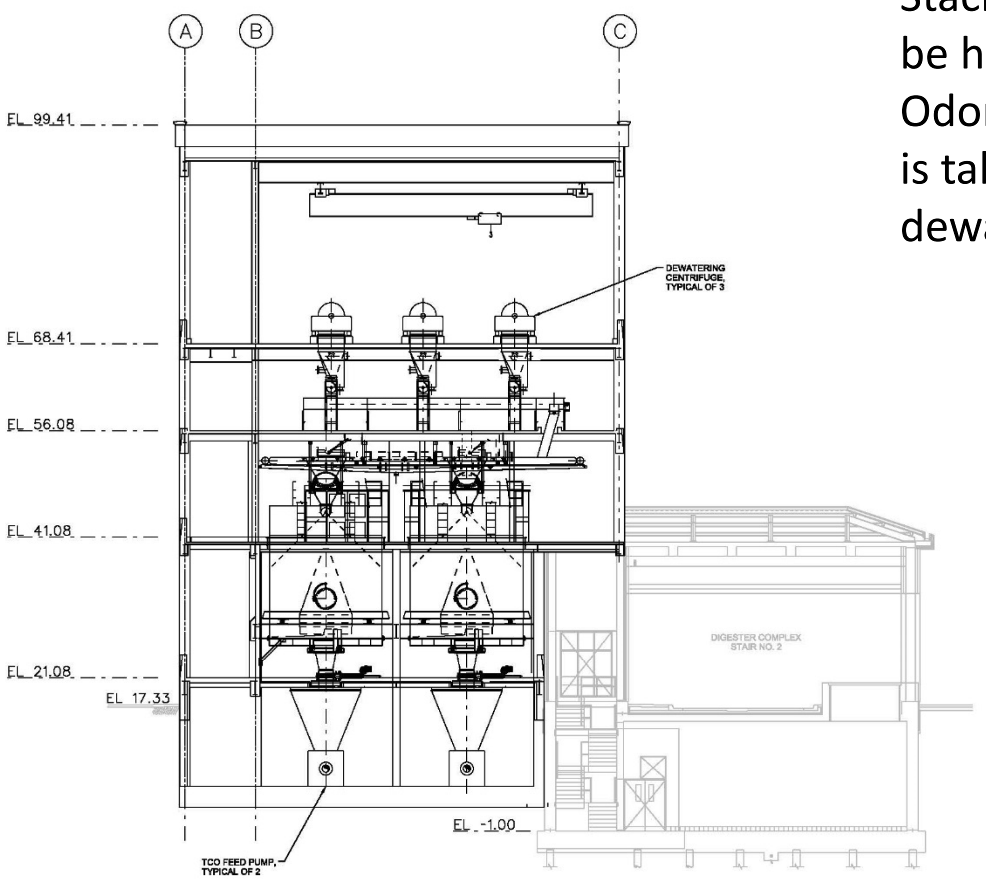
<u>Construction Sequence</u>

1. Demo Digester #1
2. Construct TCO, CHP and TCO energy recovery and operate
3. Demo pre-pasteurization (Bldg 55) and exist boilers (Bldg. A)
4. Construct WAS Conditioning (Bldg. 55), and High P boiler (Bldg. A) and transition to operation with WAS Conditioning.



3b. AD + TCO + WAS Conditioning Dewatering Facility Layout

Stacks from TCO will not be higher than those from Odor Control in Bldg. L, which is taller than the proposed dewatering facility



SECTION LOOKING NORTH
NTS

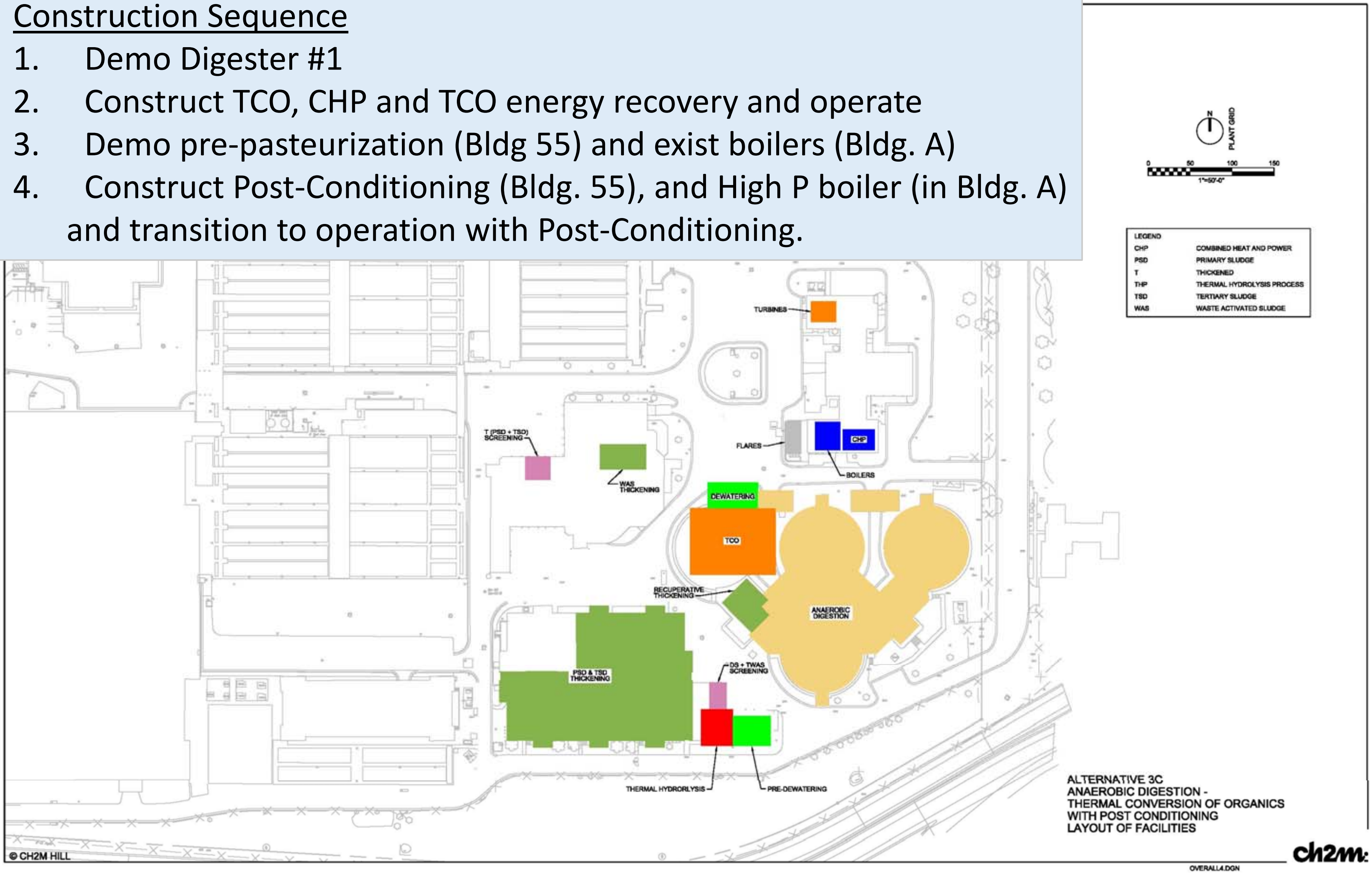
ALTERNATIVE 3B,3C
SECTION
DEWATERING BUILDING

DLV.DGN

3c. AD + TCO + Post-Conditioning Layout

Construction Sequence

1. Demo Digester #1
2. Construct TCO, CHP and TCO energy recovery and operate
3. Demo pre-pasteurization (Bldg 55) and exist boilers (Bldg. A)
4. Construct Post-Conditioning (Bldg. 55), and High P boiler (in Bldg. A) and transition to operation with Post-Conditioning.



Comparison of Alternatives

Final Product & Energy
(at Design Annual Average Conditions)

	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Final Product (dry tons per day)	42	38	16	16
Estimated Trucks/week	12	11	4	4
Electricity Generated (MW)	1.8	2.2	3.5	3.5
% of Total Plant MW *	20%	25%	40%	40%
Available Hot Water (MBTU/day)	62	221	326	332
Total Available Energy (MBTU/day)	68	228	338	345

* This is a rough estimate for comparison purposes. The total plant MW was calculated by escalating current plant annual average MW (~4.8) to design condition (~7.5 MW) in proportion to population growth and adding the energy consumption of the new processes for each alternative. Analysis does not take into account other energy efficiency / green energy projects on the liquids treatment or facilities.

Greenhouse Gas Emissions Summary
(at Design Annual Average Conditions)

	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Estimated GHG Impact (tonnes CO2e)	3,784	1,062	(2,343)	(2,308)
% of Total Entity-Wide Emissions*	8%	2%	-5%	-5%

* This is a rough estimate for comparison purposes. The Total Entity-Wide Emissions at the design condition was calculated by escalating current annual total emissions (~28,000 tonnes CO2e) to design condition (~45,000 tonnes CO2e) in proportion to population growth. Analysis does not take into account other GHG-reducing projects or initiatives.

Operation & Maintenance Annual Cost
(at Design Annual Average Conditions)

	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/ WAS Cond.	3c. AD + TCO w/ (DS+TWAS) Cond.
Polymer	$1,037,000	$1,181,000	$1,181,000	$1,319,000
Solids Handling	$635,000	$443,000	$213,000	$213,000
Labor	$563,000	$1,048,000	$1,324,000	$1,365,000
Maintenance	$926,000	$1,276,000	$1,445,000	$1,668,000
Power	$25,000	$(274,000)	$(837,000)	$(812,000)
Total	**$3,186,000**	**$3,674,000**	**$3,326,000**	**$3,729,000**

Capital Cost

Elements	2a. AD + Drying	2b. AD + Drying w/ WAS Cond.	3b. AD + TCO w/WAS Cond.	3c. AD + TCO w/ (DS+WAS) Cond.
Thickening (GTs & TCENs)	$4,400,000	$4,400,000	$4,400,000	$4,400,000
Screening PSD + TSD	-	$800,000	$800,000	$800,000
Screening WAS	$500,000	$400,000	$400,000	$400,000
WAS Conditioning *	-	$14,700,000	$14,700,000	-
Digestion & Rec. Thick.	$2,900,000	$2,900,000	$2,900,000	$2,900,000
Post-Digestion Sludge Cond. *	-	-	-	$21,100,000
Dewatering	$3,500,000	$2,400,000	$15,200,000	$17,600,000
Drying	$20,100,000	$15,900,000	-	-
TCO	-	-	$69,900,000	$69,900,000
TCO Energy Recovery	-	-	$3,400,000	$3,400,000
Boiler (High P steam)	-	$400,000	$400,000	$400,000
Combined Heat & Power	$7,400,000	$7,400,000	$9,300,000	$9,300,000
Prepasteurization (demo)	$100,000	-	-	-
TOTAL	**$39,200,000**	**$49,300,000**	**$121,300,000**	**$130,200,000**

* Includes Pre-Dewatering

Appendix B
Biological Phosphorus Removal TM

TECHNICAL MEMORANDUM

Appendix B - Evaluation of Biological Phosphorus Removal at AlexRenew WRRF

PREPARED FOR:	Alex Renew
PREPARED BY:	Heather Stewart/CH2M Paula Sanjines/CH2M
REVIEWED BY:	Tim Constantine/CH2M
DATE:	December 20, 2016

The purpose of this TM is to document the evaluation performed on the feasibility of implementing Biological Phosphorus Removal (BioP) at the AlexRenew WRRF and to discuss the implications of BioP for energy recovery, biosolids quality, plant operations, site impact, and cost.

Background

AlexRenew has a goal of significantly increasing resource recovery from its wastewater treatment operations, and this includes energy. This focus on energy is one of the reasons why AlexRenew are interested in implementing mainstream deammonification (Anammox) as this process frees up more carbon to be redirected to digesters, thereby substantially increasing biogas yields, which can in turn be used to produce electricity and/or heat via combustion engines or similar technologies. While energy recovery is a key goal for the future of the AlexRenew WRRF, there are other resource recovery alternatives that could be considered, including the recovery of phosphorus (P), as well as some ammonia, in the form of a fertilizer (struvite) that has a high commercial value. Newer technological developments are now making it possible to recover P from the solids stream of the WRRF; however, to make these technologies viable, there is a need to convert the existing biological treatment process to operate in a BioP mode. Currently, AlexRenew WRRF removes P using dual point chemical addition. Ferric chloride is added in the secondary settling process followed by alum dosing in the tertiary settling process.

The purpose of this study was to evaluate various proven treatment configurations to determine the feasibility and impact of implementing BioP with and without mainstream Anammox. The treatment configurations were modeled using the CH2M in-house process simulator Pro2D.

Methodology

For this study the 2025 projected flows and loads were used which are 10% higher than the current values. The influent characterization was based on a previous calibration of the facility (August 2013). The figure below shows the process diagram used in the Pro2D program. Six scenarios were simulated:

1. A baseline using current process configuration (with no sidestream DEMON)
2. Chemically enhanced primary treatment (CEPT) which removes carbon and P in the primaries
3. Simulated mainstream Anammox with Fe to secondary settling tanks
4. Simulated mainstream Anammox with CEPT
5. Simulated Anammox with struvite recovery via an Ostara's Pearl + WASSTRIP side stream process and no Fe addition

6. Simulated Anammox with struvite recovery via an Ostara's Pearl + WASSTRIP side stream process with CEPT

The operational conditions are given in Table 1. All scenarios had the same influent conditions.

Table 1. Simulated operational conditions

Scenario	Fe to PST *(lb/d)*	MeOH addition *(gal/d)*	Fe to SST *(lb/d)*
1 - Baseline (0)	0	1,500	6,895
2 - B (0) - increased MeOH, no Fe to secondary, CEPT	7,010	1,750	0.00
3 - B (0) - reduced MeOH, simulated Anammox	0	750	6,895
4 - B (0) - reduced MeOH, no Fe to secondary, CEPT, simulated Anammox	7,010	750	0.00
5 - B (0) - reduced MeOH, no Fe, simulated Anammox, struvite recovery	0	750	0.00
6 - B (0) - reduced MeOH, no Fe to secondary, CEPT, simulated Anammox, Struvite recovery	7,010	750	0.00

Note: This table shows the chemical dosing for different nutrient recovery scenario. All scenarios had the same influent, an SRT of 14 d and an Alum dose to tertiary of 1.4 mg Al/L. Aeration in the last pass of the reactor was used in scenarios 3 & 4 to facilitate BioP uptake (0.2 and 1.0 mg O_2/L respectively).

BioP is driven by Phosphorus Accumulating Organisms (PAOs) that store volatile fatty acids and release some phosphate under anaerobic conditions. In a subsequent aerobic zone, PAOs take up more phosphorus than was released in the previous stage and oxidize their stored carbon, which gives PAOs a competitive advantage in the mainstream bioreactor system compared to ordinary heterotrophic organisms that oxidize carbon. PAOs can accumulate up to 5 times as much phosphorus than typical mixed liquor suspended solids which is removed from the system via wasting. These organisms are modeled in Pro2D for each of the scenarios. Struvite precipitation in the dewatered centrate is only included in scenarios 5 and 6.

Mainstream Anammox was simulated by artificially removing a portion of the nitrate produced by full nitrification that would not occur in a well-maintained Anammox process. A pure Anammox culture would produce roughly only 0.11 g of nitrate per 1 g of ammonium removed as opposed to approximately one-to-one production of nitrate via conventional removal. For this study of a mixed culture, we assumed some full nitrification, 0.4 g nitrate produced per g ammonium. This simulation did not incorporate the reduced DO requirement with anoxic ammonium removal nor the reduced sludge production due to the smaller yield of Anammox, both of which would therefore save energy. Figure 1 shows the process design used to simulate AlexRenew WRRF. Secondary treatment and SST are simulated within the PBNR Main unit. The Pearl struvite recovery unit was only used for scenarios 5 & 6.

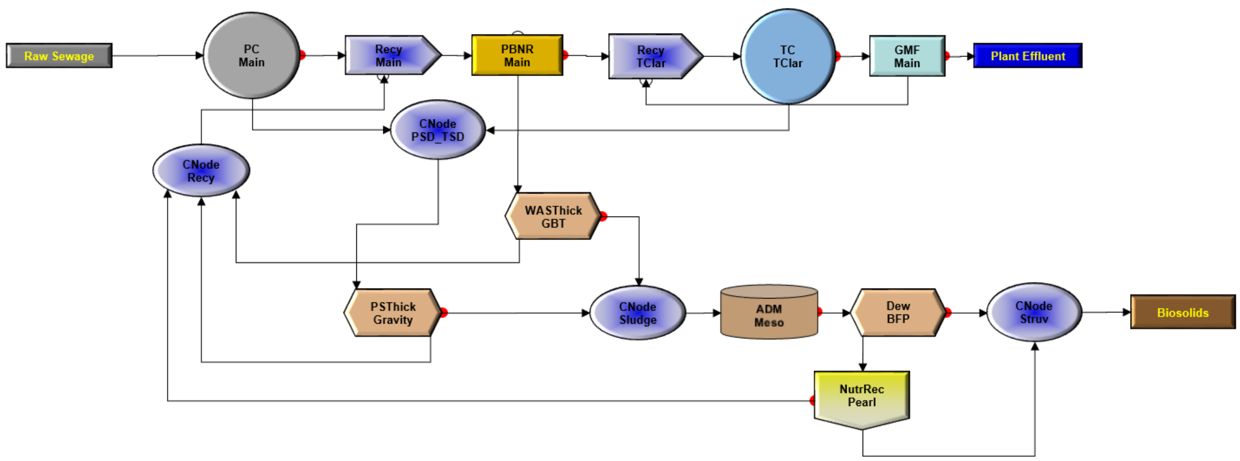


Figure 1. Pro2D Process Flow Diagram

Modeling Results

Table 2 lists the modeling results which show that all scenarios meet the effluent limits of 3 mg/L TN and 0.18 mg/L TP. Replacing the secondary Fe dosing with CEPT (scenario 2) increases biogas production by 16%. However, this is accompanied by a 7% net increase in sludge production. There was no significant difference between the scenarios' tertiary sludge production. The Mainstream Anammox scenarios (3 and 4) require ferric addition in the secondary or primary settling tanks to meet the TP effluent limit, while Scenario 5 does not use any ferric chloride addition and produces a significant amount of struvite. Scenarios without CEPT (3 & 5) produce at least 3% less sludge than the baseline and have the lowest P:N ratio in the biosolids; these are the only scenarios that exhibit BioP (see Figure 2). The inclusion of struvite harvesting in scenario 6 has little effect and the results are essentially the same as scenario 4.

Table 2. Simulation results
Effluent quality, biosolids quality and production, and biogas production

Scenario	**Eff TN** ***(mg N/L)***	**Eff TP** ***(mg P/L)***	**Harvested Struvite** ***(lb/d)***	**P:N of biosolids** ***(lb TP : lb TN)***	**Biogas production** ***Relative difference***	***PS + WAS Relative difference***
1 – Baseline	2.50	0.04	**0**	**0.86**	**-**	**-**
2 – CEPT	2.72	0.08	**0**	**0.82**	**16%**	**7%**
3 – AMX	2.15	0.07	**0**	**0.52**	**15%**	**-3%**
4 – AMX + CEPT	2.44	0.07	**0**	**0.82**	**15%**	**6%**
5 – AMX + P-Recovery	2.15	0.12	**1,054**	**0.49**	**1%**	**-4%**
6 – AMX + P-Recovery + CEPT	2.26	0.05	**2**	**0.83**	**15%**	**6%**

Figure 2 illustrates the phosphorus release and uptake along the biological reactor basin (BRB) zones for each scenario. The model results indicate that with CEPT, the phosphate is precipitated in the primary settling tanks therefore there is not enough remaining for bioP. The scenarios without CEPT show phosphate being released in the anaerobic zones. The baseline scenario doesn't have phosphate release because there is high nitrate concentration in the anoxic zones.

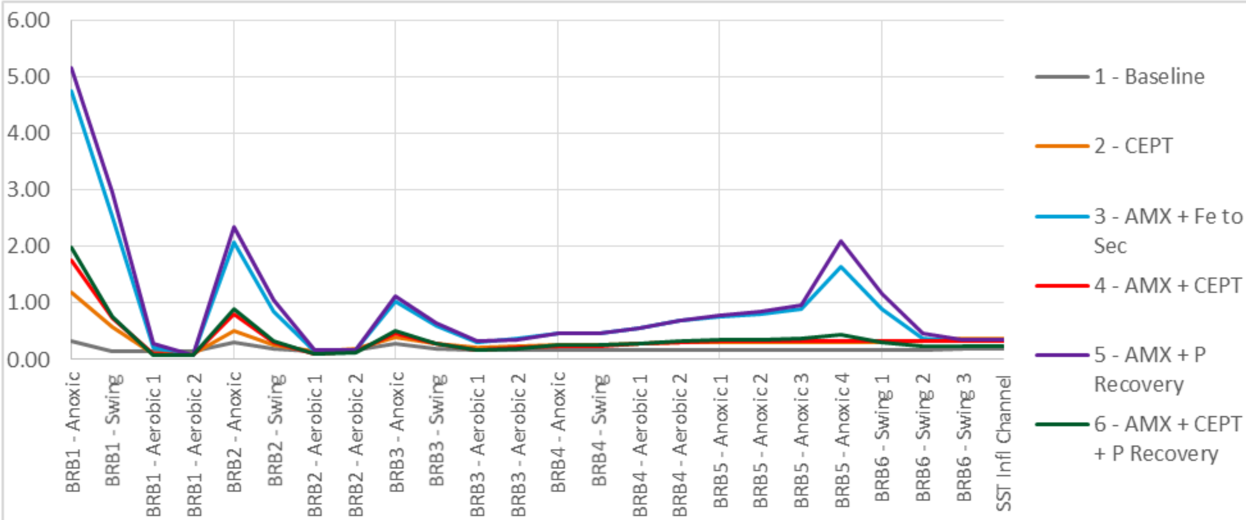


Figure 2. OrthoPhosphate Profile in the BRBs

Discussion

Energy Recovery

Scenario 2, CEPT, increases the biogas production over the baseline by 16%, which can then be used to produce more energy, closely followed by scenarios 3, 4, and 6. However, the increased biosolids production in scenarios with CEPT may require more energy for treatment and increase loading to the gravity thickeners. Mainstream Anammox with Fe addition to the secondary settling tanks (Scenario 3) produces more biogas and less biosolids, due to the reduced need for denitrification sludge. The BioP and struvite harvesting scenario (5) still produces slightly more biogas than the baseline which can be used for electricity or heat. Therefore it seems feasible to do both BioP and collect biogas but the biogas production will not be increased significantly over the baseline.

Biosolids Quality

The application of biosolids as fertilizer is currently being restricted in Maryland based on the phosphorus content of the biosolids. Thus, a lower P:N ratio in AlexRenew's biosolids could be beneficial to increase the number of sites that would receive the material. The mainstream Anammox scenarios without CEPT (3 & 5) have the lowest ratios due to effective BioP and can be more advantageous in terms of biosolids quality.

Intentional Struvite Recovery

There are several commercial struvite recovery technologies in the industry: AIRPREX, PHOSTRIP, Procorp, Multiform Harvest, PhoRedox, NuReSys, PHOSPAQ, Rem-Nut, and OSTARA's Pearl. OSTARA is the most developed and has the most installations in North America and will be used for basic footprint and cost estimates. The proposed WASSTRIP addition to ensure phosphate release before the anaerobic digester would require a tank to hold 1 to 1.5 MG. The Pearl system footprint is estimated at 4,000 to 4,500 square feet and would require Magnesium dosing.

Operational impacts

As seen in Table 3 below, there are potential scaling issues (unintentional buildup of phosphorus precipitates) that cause reduced flow and pump malfunctions, when ferric dosing is stopped. The releasable phosphorus is harvested by intentional struvite precipitation in scenario 5, but the mainstream Anammox scenario with BioP (Scenario 3) does have considerable ortho-phosphate remaining in the liquid stream after dewatering.

Table 3. Scaling Risk

Centrate quality as an indicator of unintentional struvite precipitation in pipes and pumps.

Scenario	Centrate TN *(mg N/L)*	Centrate TP *(mg P/L)*	Centrate OP *(lb PO_4/d)*	Releasable P in WAS *(lb PO_4/d)*
1 – Baseline	224.10	14.63	4.85	1.31
2 – CEPT	243.84	14.01	5.46	2.53
3 – AMX	232.95	26.30	160.81	2.26
4 – AMX + CEPT	240.71	14.04	5.11	2.17
5 – AMX + P Recovery	225.83	13.46	12.89	2.37
6 – AMX + P Recovery + CEPT	240.58	14.06	4.30	1.65

Chemical Use

The purpose of the simulations was to evaluate the feasibility of bioP combined with Anammox. However none of the simulations was optimized for chemical use. With this in mind, the various scenarios do provide a relative comparison of chemical use but without enough precision to develop actual cost estimates.

Scenario 2 (CEPT) uses 17% more Methanol and roughly the same amount of Ferric Chloride as the baseline. This is because adding ferric chloride in the primary settling tanks removes influent carbon and therefore external carbon (i.e. methanol) is needed for denitrification.

Implementation of mainstream Anammox in scenarios 3-6 reduce Methanol demand by 50%. Mainstream Anammox plus P Recovery (Scenario 5) uses no Ferric Chloride.

P Recovery Costs

Per the March 2014 proposal from Ostara (included in Attachment 1), construction of the WASSTRIP and Pearl is estimated at $6.5 – 8 million and the annual O&M costs (for electricity and chemicals) is about $350,000 at current plant flows and loads. The Pearl process produces sellable product: crystal green struvite which OSTARA guarantees to purchase. Ostara's estimate of the value of the fertilizer produced at AlexRenew is $370,000 per year at current plant flows and loads.

Conclusion

The simulations performed in study indicate that BioP is a promising technology with many benefits that appears to be feasible at AlexRenew WRRP. We recommend that further investigation be pursued that will take into account the following:

- Modeling using BioWin in order to assess the impact of intentional struvite precipitation on sidestream DEMON
- Developing better estimates for chemical savings (ferric chloride and methanol)
- Developing better estimates for biogas production

Attachment 1 – Ostara Pearl Proposal, March 2014

Nutrient Recovery Proposal

Alexandria Renew Enterprises

Cost Savings and Process Reliability
Through Sustainable Phosphorus Management

Pearl® at the Rock Creek AWWTP in Hillsboro, OR
One of six Ostara facilities currently serving municipalities in North America

March 14, 2014

Prepared for:

Executive Summary

Alexandria Renewable Enterprises (AlexRenew) has some difficult nutrient management challenges: it must produce effluent with less than 0.18 mg/l total phosphorus and 3 mg/L total nitrogen. These limits are amongst the most restrictive in the country. AlexRenew meets these limits using a combination of enhanced nutrient removal (ENR), supported by chemical removal using ferric and alum. Sludge produced at the plant is anaerobically digested to produce Class A Exceptional Quality biosolids, which are land applied in Virginia.

While ENR and chemical addition produce an effluent that consistently meets tight permit limits, the chemical costs are significant. AlexRenew could save substantial cost by removing more phosphorus with the ENR process, relying less on chemical addition. However, ENR combined with anaerobic digestion creates operational challenges:

1. When WAS from an ENR process is anaerobically digested, the phosphorus that was biologically removed is released back into solution. When the digested WAS is dewatered, the liquids that are separated from the solids have a very high concentration of dissolved phosphorus (orthophosphate.) The recycled phosphorus gets trapped in a vicious cycle, becoming more concentrated and eventually overwhelming the ENR process.
2. The recycled orthophosphate in the dewatering liquor can combine with magnesium and ammonia, both typically present in sufficient concentrations to form the mineral **struvite.** Struvite precipitates as scale and grit in sludge treatment infrastructure, impacting reliability and increasing costs.
3. The ENR process produces digested **biosolids that can be difficult to dewater,** increasing polymer consumption and decreasing cake solids, both of which increase biosolids disposal costs.

To avoid these challenges, AlexRenew adds over 1,100 gallons of ferric chloride and 1,000 gallons of alum everyday. The total cost of this chemical addition, including additional sludge production and alkalinity consumption, is $1.4 million per year.

There is another solution: Nutrient Recovery. Replacing chemical addition with nutrient recovery eliminates chemical costs while recovering struvite as a slow-release fertilizer. Nutrient recovery provides a third exit for phosphorus from the plant, providing operators with improved nutrient management.

This proposal demonstrates how AlexRenew can minimize chemical phosphorus removal by maximizing ENR while avoiding the three operational challenges identified above. Our proposal combines the Pearl® nutrient recovery process with the Waste Activated Sludge Stripping to Recover Internal Phosphate (WASSTRIP®) process to provide you with a complete nutrient management solution.

Implementing Pearl and WASSTRIP significantly reduces AlexRenew's nutrient management costs by:

1. Eliminating ferric and alum addition
2. Reducing biosolids production
3. Decreasing side stream ammonia, carbon free
4. Enhancing ENR performance
5. Boosting anaerobic digester performance
6. Preventing unintentional nuisance struvite formation
7. Producing fertilizer that generates guaranteed revenue

These benefits produce annual savings that can recover the capital investment in a nutrient recovery facility within 2 years! Once your capital investment is retired, you will continue to save nearly $3.5 million per year, every year.

There are currently seven Ostara Nutrient Recovery systems operating in North America and Europe. Two more facilities are under construction and four are in design - including the Metropolitan Water Reclamation District of Greater Chicago's Stickney Water Reclamation Plant, one of the largest secondary treatment plants in the world.

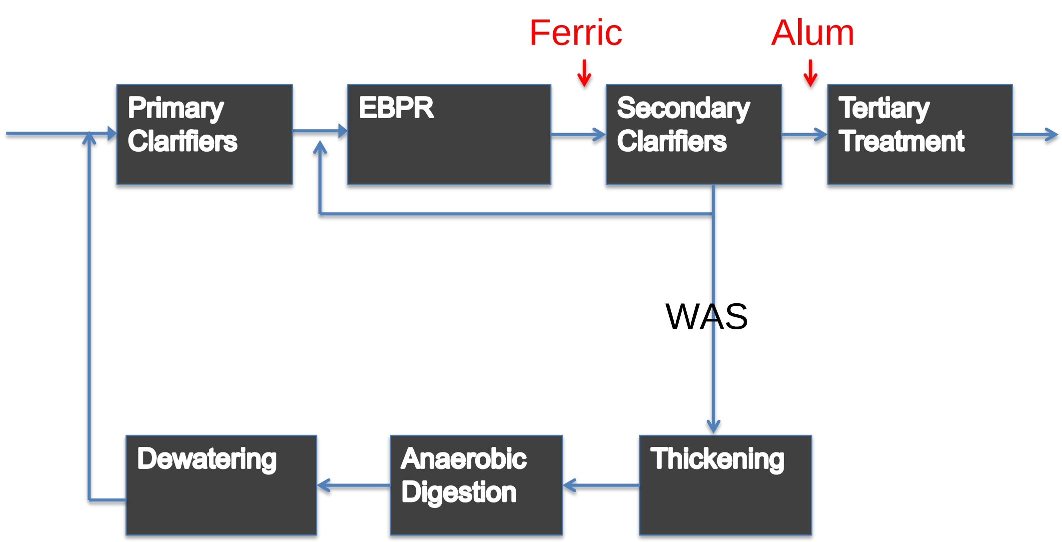
We look forward to delivering to you the many benefits of nutrient recovery that our existing clients enjoy.

CONTENTS

Phosphorus Increases Treatment Costs

AlexRenew must meet stringent effluent nutrient standards to preserve the sensitive Chesapeake Bay Watershed. AlexRenew achieves phosphorus removal using enhanced biological phosphorus removal (ENR), and chemical phosphorus removal using ferric and alum. ENR harnesses natural biological processes to provide economic and environmentally sustainable treatment. Conversely, chemical phosphorus removal imposes significant ongoing treatment costs on AlexRenew, including:

1. Purchase costs for ferric and alum
2. Dosing system O&M costs
3. Chemical sludge disposal costs
4. Chemical sludge "dead weight" impacts on sludge treatment performance (e.g. reduced digestion efficiency due to inert material load)
5. Alkalinity consumption leading to the need to add sodium hydroxide
6. Ferric and alum "side effect" costs (e.g. corrosion, UV lamp fouling, etc.)



AlexRenew Incurs Significant Chemical Phosphorus Removal Costs to Meet Stringent Phosphorus Discharge Permit Limits

Chemical phosphorus removal destroys nutrient resource value, eliminating the potential for phosphorus reuse. Phosphorus is a finite natural resource that underpins modern agriculture.

Offsetting resource depletion through conservation and recycling is therefore critical to long-term sustainable development.

ENR has many advantages over chemical phosphorus removal. Unfortunately, when WAS from an ENR process is anaerobically digested the phosphorus accumulating organisms (PAOs) that remove phosphorus release it back into solution. This phosphorus release creates three key challenges:

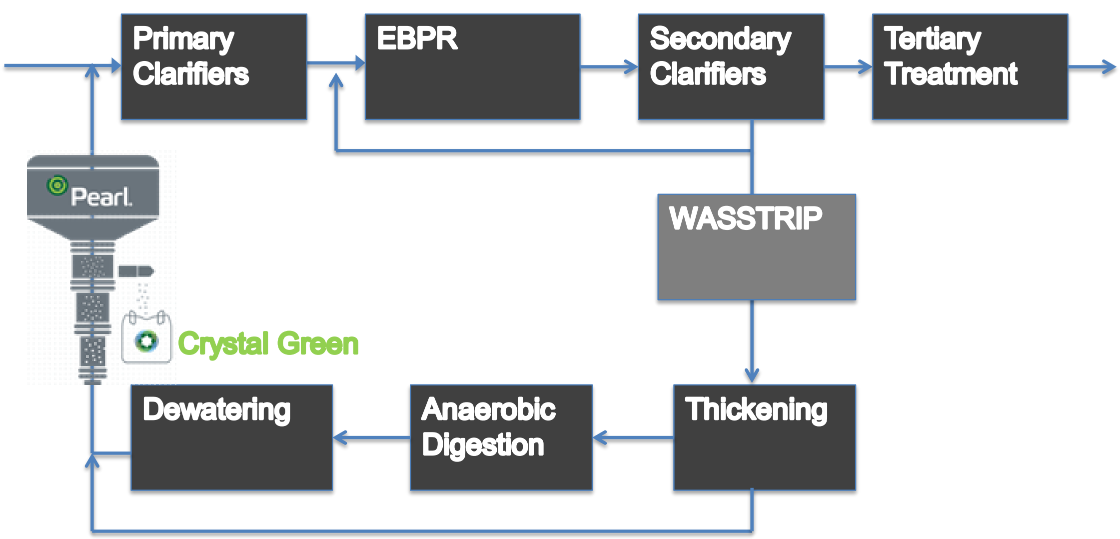
1. **Struvite scale forms in the sludge treatment stream, decreasing plant reliability and increasing costs -** When soluble phosphorus is present with ammonia and magnesium, a precipitate called struvite (magnesium-ammonium-phosphate) forms as a scale on surfaces and as particulate grit. This challenges operational reliability and reduces process efficiency in the sludge treatment stream, whichimpacts digesters, dewatering, and associated biosolids infrastructure.
2. **A significant nutrient load returns to the plant, trapping phosphorus in a vicious circle and challenging effluent permit compliance -** Dewatering digested ENR sludge produces centrate rich in dissolved phosphorus, which returns to the wastewater treatment process. The result is that phosphorus moves in an internal circle: from ENR removal, to digester release, then back to the ENR process. This vicious phosphorus circle creates a concentration loop that overwhelms ENR process capacity andrequires the use of chemical phosphorus removal.
3. **Digested ENR biosolids have high potassium concentrations, reducing dewaterability –** Phosphorus accumulating organisms (PAOs) store potassium (K^+) as a counter ion when storing phosphate (PO_4^{3-}). PAOs release potassium together with phosphate in anaerobic digesters. Dissolved potassium can impede flocculation, causing deterioration in digested sludge dewaterability at ENR plants. Reduced dewaterability reduces cake dry solids content and increases polymer consumption, increasing sludge treatment and disposal costs.

Fortunately, Ostara's nutrient recovery technology solves these challenges. Our proposal enables AlexRenew to minimize chemical phosphorus removal, maximize ENR, tackle its inherent challenges, and up-cycle phosphorus for long term sustainability.

Ostara's Nutrient Recovery Solution Helps You Manage Nutrients

The Pearl® process is the core of our proposed solution for AlexRenew. Pearl is operating at six municipal Water Resource Recovery Facilities (WRRFs) in North America and one in Europe. Please see the projects described as case studies in Appendix A. The Pearl process extracts phosphorus and ammonia from concentrated waste streams, such as dewatering centrate, as high-purity struvite pellets. Ostara takes full responsibility for managing this recovered material, and sells it as premium quality, slow release fertilizer branded Crystal Green®. We commit to purchase every ton of Crystal Green produced by AlexRenew for a guaranteed price.

The WASSTRIP® process complements Pearl by releasing phosphate, magnesium, and potassium from WAS prior to thickening. Thickening separates these released components, preventing them from entering the digester, where they can impact performance. Pearl then treats thickening centrate together with dewatering centrate, avoiding nutrient return to the plant and increasing Crystal Green production.



Ostara's Solution Minimizes Chemical Addition by Maximizing EBPR, and Produces Revenue-Generating Fertilizer

By implementing this proposal, AlexRenew will reduce reliance on chemical phosphorus removal. Pearl provides a new exit for phosphorus (as fertilizer) from your treatment system.

This means the load you have to remove reduces, allowing your ENR process to play a much greater role in meeting your permit limit. The combination of Pearl and WASSTRIP tackles the three key challenges of ENR (uncontrolled struvite formation, phosphate return load, and sludge dewaterability). This means you obtain greater benefit from your investment in EBPR, as well as more operational flexibility to ensure permit limit compliance. The outcome is that AlexRenew's triple bottom line improves considerably.

The Pearl Process enhances AlexRenew's Triple Bottom Line

1. **Society's** non-renewable phosphate reserves are conserved by creating fertilizer for community use, promoting sustainable economic development

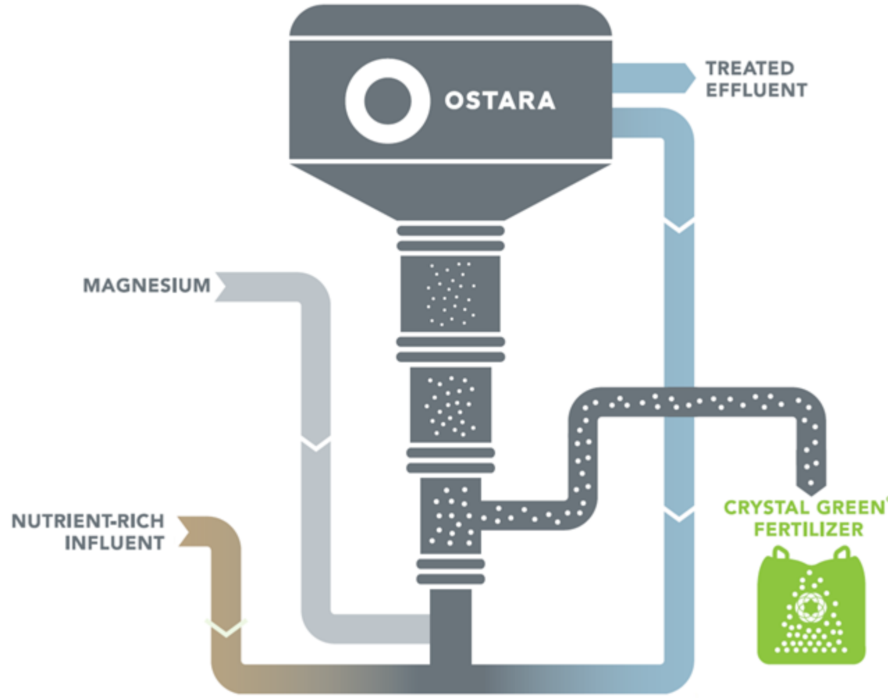
2. **Environment** friendly Crystal Green reduces non-point source nutrient pollution and offsets significant greenhouse gas emissions

3. **Economic** benefits from treatment cost savings and fertilizer sales revenues deliver short payback periods

The Pearl® Process

The Pearl process is a controlled struvite precipitation chemical reaction within an up-flow fluidized bed reactor. Two principles are fundamental in the process – maximizing efficient nutrient removal and consistently recovering high quality, commercial fertilizer. The resulting proprietary design incorporates features that support these objectives, such as reactor geometry and process control methodology. We commit to provide ongoing support of your operations under a long-term agreement, which means you don't have to become nutrient recovery process experts to maximize the value you obtain from your investment in Pearl. Our combined solution of advanced technology and dedicated process support provides you with a valuable tool to meet long term needs of your stakeholders.

"The Pearl process is a ***simple, proven technology*** *that recovers phosphorus and ammonia from concentrated waste streams, producing premium-quality commercial fertilizer."*



The Pearl process operated at full scale beginning May 2007 and consistently demonstrated its reliability and performance. Our complete nutrient management solution combines industry-leading technology with comprehensive fertilizer management. As our success ties to your success, we provide ongoing technical support under a long-term partnership agreement, which provides optimal process performance and nutrient recovery efficiency.

Our proposed Pearl system includes three sub systems:

1. Chemical storage and dosing
2. Pearl reactor (with associated recycle and product harvesting system)
3. Product drying, handling and bagging

We recommend installing Pearl within a building. Our proposed system occupies a footprint of roughly 4,000 to 4,500 square feet, and needs a ceiling height of up to 40 feet. Appendix B provides an indicative general arrangement drawing. System layout is flexible, allowing Pearl process installation into existing buildings or constrained sites.

The WASSTRIP® Process

The waste activated sludge stripping to recover internal phosphate (WASSTRIP) process releases phosphate from ENR WAS. WASSTRIP consists of a mixed tank maintained in an anaerobic condition. Phosphorus accumulating organisms (PAOs) in ENR sludge readily release stored phosphate (together with magnesium and potassium counter ions) in WASSTRIP's anaerobic conditions. Subsequent sludge thickening diverts released nutrients into thickening centrate, which the Pearl process recovers.

Without WASSTRIP, Struvite Scale Impacts Equipment (e.g. Dewatering Centrifuges)

WASSTRIP controls struvite precipitation throughout the sludge treatment stream by removing phosphate and magnesium from the sludge stream before anaerobic digestion (where ammonia forms). This improves sludge treatment performance, tackles struvite related maintenance, and significantly reduces the amount of sludge produced. WASSTRIP also removes potassium prior to digestion, improving digested sludge dewaterability.

The WASSTRIP process hydraulic retention time (HRT) is influenced by WAS phosphorus content and volatile fatty acid (VFA) availability. When PAOs release phosphate, they simultaneously absorb VFAs. VFAs are created when WAS ferments, hence WASSTRIP can operate endogenously on WAS only. Alternatively VFAs can be added to the WASSTRIP process (e.g. from primary sludge fermentate, acid phase digestate, etc.) to accelerate phosphate release and reduce HRT.

We recommend site-specific process configuration to meet AlexRenew's needs and circumstances by considering factors such as WAS wasting point, WASSTRIP HRT, and potential VFA sources. We understand an existing tank might be available for re-purposing to WASSTRIP. We can help you evaluate the suitability of this tank as the project progresses.

Crystal Green®

Our unique nutrient recovery solution ensures you maximize the value of your nutrient resources, while minimizing the risk of realizing this value. We commit to purchase every ton of Crystal Green you produce for an agreed price. We will collect bagged product from your facility and take full responsibility for it from that point on, managing everything from product testing, through certification, to sales and marketing. We have made a major investment to establish Crystal Green as a brand recognized for excellence, and to build a business that delivers on this promise.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PERMIT TO DISTRIBUTE COMMERICAL FERTILIZER

Permit No. 702796 - 3

In accordance with the provisions of Chapter 63 of the Texas Agriculture Code (1981), permission is hereby granted to

OSTARA NUTRIENTS USA, INC.
UNIT 690 - 1199 WEST PENDER STREET
VANCOUVER, BRITISH COLUMBIA V6E 2R1
CANADA

to sell and distribute all classes of commercial fertilizer.

Crystal Green is a **certified commercial fertilizer** in North America and Europe

One ton of Crystal Green eliminates **10 tons** of CO_2 emmisions.

Ostara has sold Crystal Green in bulk since 2007. Extensive testing continuously proves the product to be inorganic, high-purity, and pathogen-free. Its consistently high quality has enabled Ostara to secure fertilizer certification, allowing us to sell it commercially. Growers' experience with Crystal Green confirmed its superior performance and created strong market demand. Our professional fertilizer team has extensive industry experience, and competencies ranging from agronomy, through distribution to product marketing. We have built the supply chains needed to reach target markets, and secured product acceptance in these markets. Our investments mean we are able to manage the agricultural chemical industry's risks, so you don't have to.

Crystal Green is fundamental to our business model, and to **maximizing AlexRenew's triple bottom line benefits.**

Economy

- **Wastewater Treatment Cost Savings**
- **Maximized Value of Recovered Resources**

Environment

- **Reduced Nutrient Runoff**
- **Reduced Carbon Footprint**

Society

- **Sustainable Economic Development**
- **Conservation of Essential Resources**

Nutrient Recovery Design and Performance

Historical operating data from September 2012 to September 2013 forms the process design basis of this proposal. Historical centrate orthophosphate concentration is low (averaging 9 mg/L) because ferric and alum forms chemical bonds that are not broken down in the digester. If you choose to implement this proposal, centrate orthophosphate concentrations will increase, because you will be able to improve ENR.

To estimate Pearl process load, we conducted a high-level phosphorus mass balance and predicted future conditions. We based our mass balance on historical influent TP mass, and Ostara experience of WRRFs operating ENR, anaerobic digestion, WASSTRIP and Pearl. In our experience of such WRRFs, up to approximately 50% of influent total phosphorus is present as orthophosphate in the combined dewatering and thickening centrate feed to Pearl.

Phosphorus mass removal governs Pearl process sizing. The Pearl process uses standard reactor vessel designs to minimize system specific re-engineering. We recommend the Pearl 2000 reactor model for AlexRenew. Each Pearl 2000 reactor provides the nominal capacity to remove 555 lbs/day of PO_4-P. We assessed Pearl process performance for AlexRenew using our numerical model. Table 1 presents model results, together with feed stream characteristics.

Table 1. Process Design Basis and Performance

Parameter	Value	Units
Plant influent flow	35.5	MGD
Plant influent TP	6.45	mg/L
Orthophosphate mass in Pearl feed	953	Lbs/day
Ammonia mass in Pearl feed	1467	Lbs/day
Orthophosphate Removal	92%	%
Orthophosphate Removal	874	Lbs/day
Ammonia Removal	27%	%
Ammonia Removal	395	Lbs/day
# Pearl 2000 reactors needed	1.6	
Potential Crystal Green® Production Rate	1,100	Tons/yr

We propose a system employing two Pearl 2000 reactors for AlexRenew to provide capacity for future growth and (combined with process flexibility) the ability to treat peak loads. Nutrient concentrations (magnesium, ammonia and phosphate) and pH are key factors that affect phosphorus removal performance. Increasing pH increases removal/recovery performance, achieving lower effluent nutrient concentrations. Adjusting pH using sodium hydroxide allows you to obtain the optimum balance between chemical input cost and nutrient removal performance.

The Pearl process also removes ammonia. Struvite formation removes one mole of nitrogen for each mole of phosphorus removed. Expressed in terms of mass, this equates to 45 lbs of NH_3-N recovered for every 100 lbs of PO_4-P recovered.

System Operation and Maintenance

Because both AlexRenew and Ostara benefit from nutrient recovery, Pearl process operation and maintenance is a partnership.

- Ostara focuses on optimizing process performance and fertilizer production
- AlexRenew focuses on equipment oversight and facility operation within the wider plant context

Ostara is fully responsible for Crystal Green following collection

We provide continuous process support to AlexRenew under an ongoing agreement governing O&M and fertilizer responsibilities. Our support includes:

Ostara provides free support and continuous monitoring under a long-term agreement

- 24/7 process monitoring
- on call support
- guidance on fertilizer production set points (“manufacturing recipes”)
- control system improvements

Ostara’s systems are highly automated, limiting operator’s routine duties to material handling (chemical receiving and fertilizer bagging), and plant oversight (equipment inspection and liquids sampling/analysis).

We collect bagged Crystal Green from site and take ownership when it is loaded onto our truck. Ostara is fully responsible for the product from this point on, including testing in accordance with our rigorous Quality Control process, distribution, sales etc. We will pay AlexRenew a contractually agreed amount for every ton collected.

Table 2 summarizes estimated system O&M quantities, and includes cost estimates based on our experience from existing sites.

Table 2 – Estimated O&M Costs

Item	Amount	Cost per year
Maintenance		$30,000
Power	1070 kWh/day[1]	$31,300
Magnesium Chloride liquid	263,400 gal/yr	$224,000
Sodium Hydroxide	45 dry tons/yr	$24,000
Labor	0.5 FTEs	$40,000
Total cost		**349,300**
Technical Support		Free of charge
Crystal Green management		Free of charge

[1] Assumes heat is available for product drying

Nutrient Recovery Provides Attractive Benefits

The Pearl Process Provides Economic and Environmental Sustainability

Implementing this proposal enables you to reduce your reliance on chemical phosphorus removal. Pearl provides a new exit for phosphorus from your treatment system (as fertilizer). This means the load you have to remove reduces, allowing your ENR process to play a much greater role in meeting your permit limit. The combination of Pearl and WASSTRIP tackles the three key challenges of ENR (uncontrolled struvite formation, phosphate return load, and poor sludge dewaterability). This means you obtain greater benefit from your investment in ENR, as well as more operational flexibility to ensure permit limits compliance. The outcome is the lowest cost and most progressive phosphorus management strategy, and an improved triple bottom line.

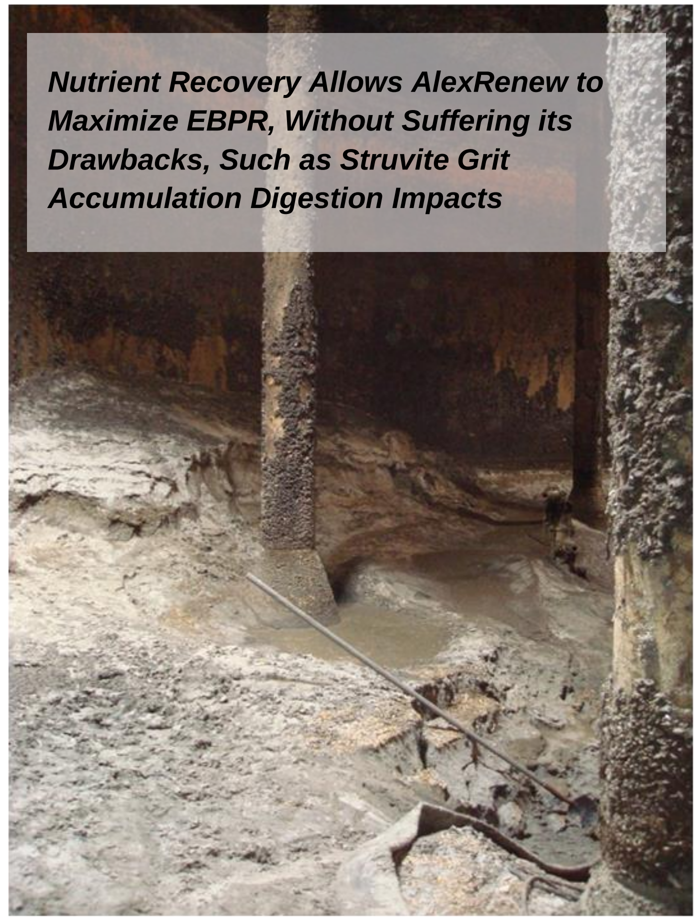
Our preliminary analysis establishes our system will remove 874 lbs/day of phosphorus (see Table 1 above). We compared this removal to your historical phosphorus removal using ferric and alum. We estimate on average you remove approximately 620 lbs/day of phosphorus using ferric and an additional 330 lbs/day of phosphorus using alum (a total of 950 lbs/day). We expect implementing this proposal will enable you to avoid ferric addition and reduce tertiary alum addition. Reducing chemical phosphorus removal provides significant financial benefits to AlexRenew, including:

1. Purchase costs for the chemicals
2. O&M costs of the dosing system
3. Disposal costs for the chemical sludge produced
4. Impacts of chemical sludge "dead weight" on sludge treatment process performance (e.g. reduced digestion efficiency due to inert material load)
5. Reduced alkalinity consumption (hence reduced NaOH addition)
6. Costs to mitigate the drawbacks of ferric and alum (e.g. corrosion, UV lamp fouling, etc.)

Our preliminary analysis establishes our system will remove 395 lbs/day of ammonia. You currently remove this ammonia biologically (primarily in the centrate pre-treatment reactors). This proposal's carbon-free removal of ammonia load provides benefits to AlexRenew that include:

1. Reduced supplemental carbon addition
2. Reduced alkalinity consumption (hence reduced NaOH addition)
3. Liberated process capacity (providing operational flexibility and offsetting future capital investment)
4. Reduced energy consumption

Plants that maximize ENR and anaerobically digest and dewater sludge typically suffer from poor sludge dewaterability and uncontrolled struvite precipitation. Reductions in sludge dewaterability of approximately 4% cake dry solids content are typical relative to plants that do not operate ENR. This increases processing and disposal costs (e.g. polymer demand, transportation costs etc.).



Struvite precipitation occurs as particulate “grit”, and as scale in anaerobic digesters and downstream. Grit accumulates in digesters, reducing active volume. This reduces digester performance, resulting in reduced biogas production/energy recovery, and increased biosolids volumes. Struvite scale coats sensitive equipment, impacting performance and reliability. Struvite scale also reduces equipment life, increasing capital replacement costs.

Ostara’s proposal provides AlexRenew with value. By extracting phosphorus and ammonia from the sludge stream and transforming these nutrients into premium quality fertilizer, AlexRenew reduces treatment costs and profits from fertilizer sales revenue. It also reinforces your commitment to the wider environment by:

1. Reducing CO_2 equivalent emissions by displacing phosphate rock based fertilizers and by offsetting alternative phosphorus and ammonia treatment methods
2. Recovering nutrients as a low-runoff, slow-release fertilizer product, enhancing crop productivity while reducing environmental impacts
3. Promoting environmentally sustainable economic development by recycling and conserving finite phosphate resources

Table 3 presents a preliminary analysis of the financial benefits of nutrient recovery for you. Our analysis quantifies the value of the benefits outlined above, based largely on our experience from other sites. We will be happy to work with you to revise this analysis to reflect AlexRenew’s specific circumstances.

Table 3 –Nutrient Recovery Delivers Significant Cost Savings for AlexRenew

Item	Value	Units	Notes
Chemical P removal			
Current chemical phosphorus removal	950	lbs/day	Assumes a 1.5 to 1 metal to P molar ratio
Annual spend on chemical P removal	$1,200,995	$/yr	AlexRenew data
Proposed P removal with Pearl	$874	lbs/day	Ostara process model
Saving in chemical procurement cost	$1,104,916	$/yr	
Dosing system O&M	$20,000	$/yr	From Ostara's experience
Ferric drawback mitigation costs	$235,000	$/yr	From Ostara's experience
Value of chemical avoidance	***$1,359,916***	***$/yr***	
Sludge disposal			
Sludge reduction of Pearl and WASSTRIP	1761	tons/yr	From Ostara's experience
Cost of sludge processing and disposal	350	$/ton	Lifecycle cost
Value of sludge reduction	***$616,471***	***$/yr***	
Polymer	***$140,908***	***$/yr***	Assumes $100/dry ton of sludge produced
Biogas/Energy Recovery	***$104,999***	***$/yr***	From Ostara's experience, assumes CHP
Ammonia			
Cost of ammonia removal	5.42	$/lb	CT DEEP, 2011. LCC analysis
Quantity of ammonia removed	$133,098	lbs/yr	Ostara process model
Value of ammonia removal	***$721,390***	***$/yr***	
Struvite maintenance/replacements	***$211,034***	***$/yr***	From Ostara's experience
Crystal Green fertilizer			
Potential annual production	1055	tons/yr	Process model
Indicative purchase price from Ostara	350	$/ton	
Value of Fertilizer to the City	***$369,130***	***$/yr***	
Total Value of Financial Benefits	**$3,524,000**	**$/yr**	

Our preliminary analysis indicates that **nutrient recovery will deliver over $3.5M each year** in financial benefits to AlexRenew.

Implementation Costs Will Pay Back Rapidly

To facilitate planning we have provided a cost estimate based on Ostara delivering a full Design-Build scope of supply. Our scope of supply is flexible. For example, we can provide an equipment based scope under a Design-Bid-Build model if AlexRenew prefers. Our Design-Build cost estimate includes the Pearl process, a new pre-engineered building to house Pearl, and the WASSTRIP process (retrofitted into an existing tank). Our estimate provides a budget cost for the complete system, excluding infrastructure tie-ins. We recommend you budget $6.5M to $8M for the proposed nutrient recovery system. We estimate the system will **payback in approximately two years.**

Conclusions

Incorporating the Pearl and WASSTRIP processes at AlexRenew provides significant triple bottom line benefits.

Nutrient recovery's many economic benefits will pay back AlexRenew's capital investment in approximately two years.

The environmental and social benefits of this proposal are also significant. These include reduced greenhouse gas emissions, resource conservation, and sustainable economic development.

Nutrient recovery provides AlexRenew with a unique partnership opportunity to transform potentially polluting nutrients into premium quality, revenue generating commercial fertilizer.

We look forward to continuing to work with you on this exciting opportunity.

Appendix A. Case Studies

Gold Bar WWTP and Clover Bar Solids Handling Facility

City: EPCOR Water Services

Location: Edmonton, AB

Operating Since: May 2007

Treatment Plant Capacity: 82 MGD

Ostara Nutrient Recovery System: 1 x Pearl® 500 system

Contact name: Vince Corkery

Contact Phone: (780) 969-8429

Contact e-mail: vince.corkery@edmonton.ca

Project description:

EPCOR Water Services operates the 82 MGD Gold Bar WWTP which is designed to meet an effluent limit of 1 mg/l phosphorus. The secondary process is designed for biological nutrient removal to meet the effluent phosphorus limit. The plant anaerobically digests the biosolids produced, then stores the digested biosolids in lagoons prior to land disposal. The supernatant from the lagoons is returned back to the wastewater treatment plant for re-processing.

The supernatant from the lagoons contains high concentrations of phosphorus and ammonia. These high nutrient concentrations caused massive problems with struvite formation in the supernatant return pipe. After studying all available options to manage their nutrient recycle, EPCOR implemented the first Pearl® nutrient recovery process to demonstrate its ability to meet the following objectives:

- Eliminate struvite formation in supernatant recycle pipes and appurtenances
- Reduce the costly and inefficient nutrient recycle to the wastewater treatment plant
- Produce a valuable fertilizer product

Vince Corkery, Director of Wastewater Treatment at the Gold Bar Wastewater Treatment Plant has this to say about their Pearl® nutrient recovery system:

"We have supported this technology because it creates a valuable product from phosphorus and other polluting nutrients, which would otherwise clog our pipes and reduce our plant's treatment capacity."

As a result of the success of the original Pearl® installation, EPCOR is now undertaking a detailed design for an expansion of this system, and anticipates construction in 2014.

Durham WWTP

City: Clean Water Services

Location: Tigard, OR

Operating Since: May 2009

Treatment Plant Capacity: 20 MGD

Ostara Nutrient Recovery System: 3 x Pearl® 500 with WASSTRIP®

Contact name: Nate Cullen

Contact Phone: (503) 547-8176

Contact e-mail: cullenn@cleanwaterservices.org

Project Description:

Clean Water Services operates the 20 MGD Durham WWTP which discharges treated effluent to the Tualatin River. Because the Tualatin River is ecologically sensitive, the Durham WWTP has some of the lowest effluent limits in the country. The plant must meet a 0.1 mg/l phosphorus limit during the summer season of May through October. The plant combines biological nutrient removal with tertiary filters to meet this limit. However, because the plant also operates anaerobic digesters, the centrate from the dewatering centrifuges created nutrient recycle and struvite formation problems.

To address these challenges, Clean Water Services pilot tested the Pearl® nutrient recovery process in 2008. Based on the success of this pilot, Clean Water Services procured a nutrient recovery system consisting of three Pearl® 500 reactors and all appurtenant equipment. The system began operating in May 2009, since which time Clean Water Services has realized the following benefits:

- Decreasing the centrate nutrient load returned for treatment (reducing the biological phosphorus removal requirement by about 25% and avoiding alkalinity addition for nitrification.)
- Minimizing metal salts used for chemical phosphorus removal (lessening the cost of chemicals and sludge disposal) by over 50%
- Reducing the phosphorus content of the biosolids (providing a new avenue to remove phosphorus from the system.)
- Producing roughly 350 tons per year of Crystal Green® – conserving mineral phosphate rock reserves and eliminating approximately 4,000 tons CO_2e per year of greenhouse gas emissions.

Clean Water Services was also concerned about struvite formation in their digesters and dewatering equipment. To address this concern, they installed WASSTRIP®, a process that releases phosphorus from BNR activated sludge before the sludge is digested. WASSTRIP®

not only protects the digesters and solids processes from struvite formation, it nearly doubles the amount of phosphorus recoverable from the treatment plant.

Rob Baur, Operations Analyst for Clean Water Services says this about their system:

“Ostara’s Pearl® process integrates directly into our treatment system, processes the sludge liquids, and then converts them into a high-quality environmentally friendly commercial fertilizer. We recover more than 90% of the phosphorus and 20% of the ammonia that would normally be recycled back to the plant from the solids processing.”

Because of the success of the Pearl® process at the Durham WWTP, Clean Water Services installed a second system at their Rock Creek Advanced WWTP (description below) and has recently expanded the capacity at the Durham WWTP by installing a Pearl® 2000 reactor.

Nansemond WWTP

City: Hampton Roads Sanitation City

Location: Suffolk, VA

Operating Since: May 2010

Treatment Plant Capacity: 30 MGD

Ostara Nutrient Recovery System: 3 x Pearl® 500 system

Contact name: Bill Balzer

Contact Phone: (757) 638-7361

Contact e-mail: bbalzer@hrsd.com

Project Description:

Hampton Roads Sanitation City operates the 30 MGD Nansemond WWTP which discharges treated effluent to the environmentally sensitive Chesapeake Bay. To meet HRSD's objective of reducing nutrient loads to the Chesapeake Bay, the Nansemond WWTP is designed to produce effluent with less than 8 mg/l total nitrogen and 1 mg/l phosphorus. The plant uses biological nutrient removal to meet these limits. Because the plant also operates anaerobic digesters, ammonia and phosphorus are concentrated in the centrate from the dewatering centrifuges and recycled to the treatment plant. This also led to problematic struvite formation in the solids processes.

To address these challenges, HRSD explored traditional side stream treatment processes such as adding ferric chloride to precipitate phosphorus. They discovered that Ostara's Pearl® process was not only more economical, but produced other benefits including:

- Carbon free nitrogen removal and reduced aeration energy and alkalinity addition for nitrification.
- Reduced sludge production, handling, and disposal costs.
- Reduced biosolids phosphorus content allowing for higher land application rates
- Producing over 300 tons per year of Crystal Green® – conserving mineral phosphate rock reserves and eliminating approximately 3000 tons CO_2e per year of greenhouse gas emissions.

After completing a successful pilot test in March 2007, HRSD hired Hazen & Sawyer to design a nutrient recovery system consisting of three Pearl® 500 reactors and appurtenant systems. The system began operation in May 2010 and has been operating successfully ever since.

Bill Balzer, P.E., Manager of Nansemond Treatment Plant says this about their system:

"The exciting thing about this partnership is we are implementing a green, sustainable technology that is recovering a reusable resource – phosphorus – and creating a marketable

product. It's a cost-neutral project that helps us solve our nutrient challenges with an environmental benefit."

York WWTP

City: City of York, PA

Location: York, PA

Operating Since: June 2010

Treatment Plant Capacity: 26 MGD

Ostara Nutrient Recovery System: 2 x Pearl® 500 system

Contact name: Steve Douglas

Contact Phone: (717) 845-2794

Contact e-mail: sdouglas@yorkcity.org

Project Description:

The York Sanitation Authority operates a 26 MGD WWTP which discharges treated effluent to Codorus Creek which drains into the Chesapeake Bay. In October 2011, new regulations went into effect in Pennsylvania to protect waterways like Codorus Creek and the environmentally sensitive Chesapeake Bay. The City of York was faced with a new 0.8 mg/l effluent phosphorus limit.

To meet the new limits, the City of York converted their secondary process to biological nutrient removal (BNR) to reduce effluent phosphorus. This solved the effluent limit, but transferred the problem to other parts of the plant. The anaerobic digesters cause biosolids from the BNR process to release phosphorus. The phosphorus becomes concentrated in the dewatering centrate and must be managed, or it will combine with ammonia and magnesium to form struvite. Struvite scales pipes, pumps, and valves creating a significant maintenance challenge.

The City of York initiated a study to evaluate Ostara's nutrient recovery technology to:

- Reduce side stream nutrient loads
- Reduced potential for struvite scale
- Enhance beneficial reuse of wastewater treatment for plant nutrients
- Meet 0.8 mg/l phosphorus effluent limit cost effectively.

Pilot testing in March 2008 confirmed that Ostara's Pearl® process could reduce the phosphorus and nitrogen recycled to the WWTP by 93% and 15% respectively. The City then entered into a unique public/private partnership with Ostara whereby Ostara designed, built, financed and operates the facility, charging the City a monthly fee which is lower than the cost the City was previously spending on nutrient treatment. The fee will remain fixed over the full term of the agreement, delivering immediate savings in the operational budget that will grow even larger over time. The process began operation in June 2010.

Recently, the City had to shut down the feed to the Pearl® system to perform maintenance on the centrate feed system. Steve Douglas, General Manager of the York Wastewater Treatment Plant said this about their experience:

"I never realized how important the Pearl® process was to the rest of the treatment plant until it wasn't available. When we took the system down we immediately began to have difficulty controlling our secondary treatment process. The Pearl® process gives us a way to manage nutrients so the secondary process runs smoothly. Since it became operational we have not had to undertake any chemical phosphorus removal."

Rock Creek WWTP

City: Clean Water Services

Location: Hillsboro, OR

Operating Since: January 2012

Treatment Plant Capacity: 30 MGD

Ostara Nutrient Recovery System: 2 x Pearl® 2000 system

Contact name: Nate Cullen

Contact Phone: (503) 547-8176

Contact e-mail: cullenn@cleanwaterservices.org

Project Description:

With the success of the Pearl® system at the Durham WWTP, Clean Water Services studied the process for its Rock Creek WWTP. Rock Creek was operated as a chemical phosphorus removal plant. Clean Water Services wanted to move away from chemical addition but was familiar with the struvite issues that they experienced at the Durham WWTP. Once the Pearl® nutrient recovery system demonstrated that it was able to overcome these challenges at Durham, Clean Water Services had an option at Rock Creek.

Clean Water Services decided to convert Rock Creek from chemical phosphorus removal to biological phosphorus removal. The Pearl® process was central to this conversion to prevent struvite issues, enhance secondary treatment performance, and recover nitrogen and phosphorus.

Clean Water Systems procured a nutrient recovery system consisting of two Pearl® 2000 reactors and all appurtenant equipment. The system began operation in January 2012 and was inaugurated in May 2012.


Clean Water Services
OSTARA
Nutrient Recovery Facility
MAGNESIUM CHLORIDE
MAGNESIUM CHLORIDE

H.M. Weir WWTP

City: City of Saskatoon

Location: Saskatoon, SK

Operating Since: November 2012

Treatment Plant Capacity: 20 MGD

Ostara Nutrient Recovery System: 1 x Pearl® 2000 with WASSTRIP®

Contact name: Joe Zimmer

Contact: (360) 975-2330 or joe.zimmer@saskatoon.ca

Project Description:

Like many wastewater utilities today, the City of Saskatoon was obliged to meet new, restrictive phosphorus discharge limits. And like many utilities, they met their phosphorus limits by converting their secondary treatment process to biological nutrient removal. But soon after the BNR process began, the plant started experiencing serious struvite problems.

Saskatoon uses lagoons to store digested biosolids until they can be disposed of by land application. Supernatant from the lagoons is returned to the treatment plant. Shortly after the BNR process was started, struvite began forming in the supernatant line from the lagoons to the treatment plant. The problem became so critical that the City was forced to construct a temporary supernatant return line because the original line was plugged with struvite.

In addition, the anaerobic digester performance began to decline. The City discovered that “grit” was accumulating in their digesters. When they tested the content of this “grit”, they discovered that it was ~80% struvite crystals. Digester cleaning was very expensive. Furthermore, without intervention, the digesters would continue to fill with struvite. The City began adding ferric chloride to control their struvite problem, but at substantial cost. Chemical addition also did not fit the City’s vision of a sustainable wastewater treatment plant. To meet their needs and their goals, the City installed a Pearl® nutrient recovery system with WASSTRIP®, which became operational at the end of 2012.


Nutrient Recovery Facility
City of
Saskatoon
OSTARA


Pearl

Nine Springs WWTP

City: Madison Metropolitan Sewerage City

Location: Madison, WI

Anticipated Start-up: Fall 2013

Treatment Plant Capacity: 40 MGD

Ostara Nutrient Recovery System: 2 Pearl® 2000 with WASSTRIP®

Contact name: Steve Reusser

Contact: (608) 222-1201 ext. 263 or stever@madsewer.org

Project Description:

Madison Metropolitan Sewerage City intends to operate an innovative multistage digestion process to maximize gas production and energy production, but biological uptake of phosphorus in their secondary process, needed to meet their effluent limits, created problems in their digestion process. They were seeing struvite formation problems so severe that they had to resort to ferric dosing to try to remain in operation. Unfortunately, this resulted in formations of vivianite (an iron phosphate mineral) leaving the City with no choice but to temporarily revert to conventional single stage digestion while they sought a solution.

Through extensive testing and research the City identified controlled struvite precipitation as the most economical and environmentally sustainable solution. Madison Metropolitan Sewerage was planning an expansion of their entire solids management system, so they incorporated nutrient recovery into the planning process. After thoroughly considering their options, they determined that a Pearl® System with WASSTRIP® was the best way to meet their solids and nutrient management needs and objectives.

Applied Technologies Inc. designed the entire solids project. Ostara's Pearl® System started up in October 2013.

Slough WWTP

City: Thames Water Utilities Limited

Location: Slough, UK

Operating Since: Summer 2013

Treatment Plant Capacity: 15 MGD

Nutrient Recovery System: 1 x Pearl® 500 system

Contact name: Pete Pearce

Contact: (+44) 7747 640814 or pete.pearce@thameswater.co.uk

Project Description:

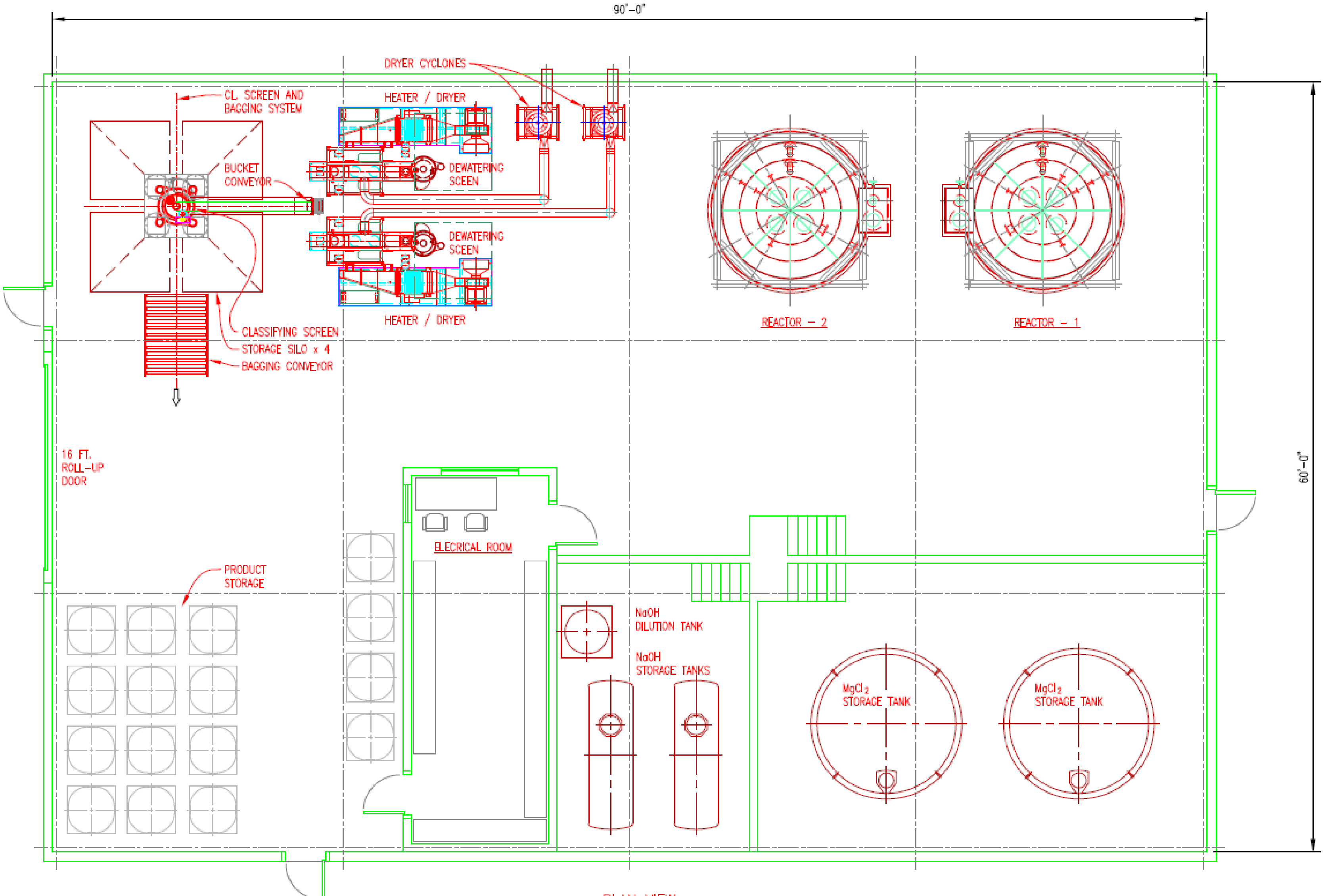
Thames Water is the largest water company in the United Kingdom (by number of customers served), providing both water and wastewater services to all of London. Thames Water operates numerous wastewater treatment plants that are required to meet nutrient limits and is continuously researching and developing improvements that enhance economic and environmental sustainability. The Slough Sewage Treatment Works is one such plant, located just to the west of London's Heathrow Airport.

The Slough STW uses biological nutrient removal to meet both nitrogen and phosphorus limits, and anaerobically digests the sludge produced prior to land application. As is typical for this process configuration, struvite scale and nutrient load recycle challenges are present. Elevated biosolids phosphorus concentrations also present challenges to meeting the UK's best practices for biosolids land application, which seek to balance spreading rates with the nutrient demands of the crop. Thames Water sought to address these challenges using controlled struvite formation.

The Pearl® process was pilot tested in March 2010 and demonstrated that the process could both produce a very high purity product suitable for commercial sale and also consistently produce effluent phosphorus concentrations below 15mg/L. From this success an agreement was entered for Ostara to deliver a single Pearl® 500 reactor based system, which was started up in summer 2013. Crystal Green® has also been certified as a commercial product for sale in the UK, and was used at the London Olympics.


ODOUR CONTROL VENT
Pearl
RECYCLE
HARVEST DRAIN

Appendix B. Indicative Plant Layout



PLAN VIEW
1/8"=1'-0"

Appendix C. Installations and Reference List

Site Name	Location	Plant Owner	Treatment Plant Capacity	Number of Installed Ostara Reactors	Ostara Reactor Model	Includes WASSTRIP	Operational Date	Contact Name
Gold Bar/Clover Bar (demonstration)	Edmonton, AB	EPCOR Water Services	80 MGD	1	Pearl 500	No	May-07	Vince Corkery
Durham AWWTP	Tigard, OR	Clean Water Services	20 MGD	3	Pearl 500/2000	Yes	May-09	Nate Cullen
Nansemond WWTP	Suffolk, VA	Hampton Roads Sanitation District	20 MGD	3	Pearl 500	Planned	May-10	Bill Balzer
York WWTP	York, PA	City of York	20 MGD	2	Pearl 500	No	Jun-10	Jim Gross
Rock Creek AWWTP	Hillsboro, OR	Clean Water Services	30 MGD	2	Pearl 2000	Planned	Mar-12	Nate Cullen
Slough STW	United Kingdom	Thames Water	15 MGD	1	Pearl 500	No	Dec-12	Pete Pearce
H.M. Weir WWTP	Saskatoon, SK	City of Saskatoon	20 MGD	1	Pearl 2000	Yes	Jan-13	Joe Zimmer
Nine Springs WWTP	Madison, WI	Madison Metropolitan Sewerage District	40 MGD	2	Pearl 2000	Yes	Jan-14	Steve Reusser
F. Wayne Hill WRC	Gwinnett County, GA	Gwinnett County Department of Water Resources	50 MGD	2 (under construction)	Pearl 2000	Yes	Jan-15	Richard Porter
Amersfoort	Amersfoort, Netherlands	Waterboard Vallei & Veluwe	15 MGD	1 (in design)	Pearl 2000	Yes	Mar-16	Rick Langeris
Gold Bar/Clover Bar	Edmonton, AB	EPCOR Water Services	80 MGD	1 (in design)	Pearl 10,000	No	Mar-15	Gavin Post
Stickney Water Reclamation Plant	Stickney, IL	Metropolitan Water Reclamation District of Greater Chicago	1,200 MGD	3 (In design)	Pearl 10,000	Yes	Oct-15	Glenn Rohloff
Bonnybrook WWTP	Calgary, AB	City of Calgary	110 MGD	3 (In design)	Pearl 2000	Yes	Mar-16	Lal Amatya
Truckee Meadows Water Reclamation Facility	Reno, NV	Cities of Reno and Sparks	40 MGD	1 (in design)	Pearl 2000	No	Dec-14	Steve Frost

Appendix C
Process Modelling Results

TECHNICAL MEMORANDUM

Appendix C – Results of Process Modeling to Estimate Solids Production at AlexRenew WRRF

PREPARED FOR: Alex Renew

PREPARED BY: Heather Stewart/CH2M
Paula Sanjines/CH2M

REVIEWED BY: Tim Constantine/CH2M

DATE: January 11, 2017

The purpose of this TM is to document the process modelling conducted in order to estimate the future solids production at AlexRenew WRRF. The projected future solids production was used to evaluate the capacity of the existing systems and perform preliminary sizing of the treatment technology alternatives.

Background

AlexRenew is currently in the process of implementing Mainstream Anammox and optimizing the biological treatment process to reduce the air and chemical addition required to meet permit limits. As part of the design phase of the Mainstream Anammox project, a process model was developed (using BioWin) in order to assess the impact of the proposed new process on the solids handling facilities at AlexRenew. The model was thoroughly calibrated using plant data. The details on how the model was developed, including the influent characterization (using August 2013 data) and the model calibration effort can be found in the document titled “AlexRenew WRRF Whole Plant Model” dated Sept. 2014.

Methodology

For this study, the 2060 projected maximum month flows and loads were used in a steady-state simulation run. Table 1 lists the influent parameters used. The model configuration is illustrated in Figure 1.

Table 1. Influent Flows and Loads
Parameters Used for Simulation of Solids Production

Condition	Flow (MGD)	TSS (lb/day)	$CBOD_5$ (lb/day)	TKN (lb/day)	NH3 (lb/day)	TP (lb/day)	OP (lb/da)
Design Max Month	75	186,000	113,400	20,700	10,200	3,800	1,300

The model included the following elements:

- The impact of chemically-enhanced primary treatment (CEPT) on primary sludge production was simulated by assuming a ferric chloride dose of 20 mg/L and total suspended solids (TSS) removal of 88%.
- The centrate pre-treatment system (DEMON) was simulated as a “black box” that reduced the nitrogen content in the centrate by 90%.
- Methanol was added to the biological reactor basins to meet the target effluent TN concentration of < 3 mg/L. The main purpose was to determine the associated waste activated sludge (WAS) production.

- Alum addition was not included for total phosphorus (TP) removal in the tertiary treatment process and therefore the model results show the final effluent TP concentration above the permit limit. Tertiary sludge production at the design condition was estimated simply by escalating the actual tertiary sludge production in 2014-2015 (8,000 lb/day) proportionally to the flow.

Modeling Results

Table 2 lists the resulting mass balance for the simulation.

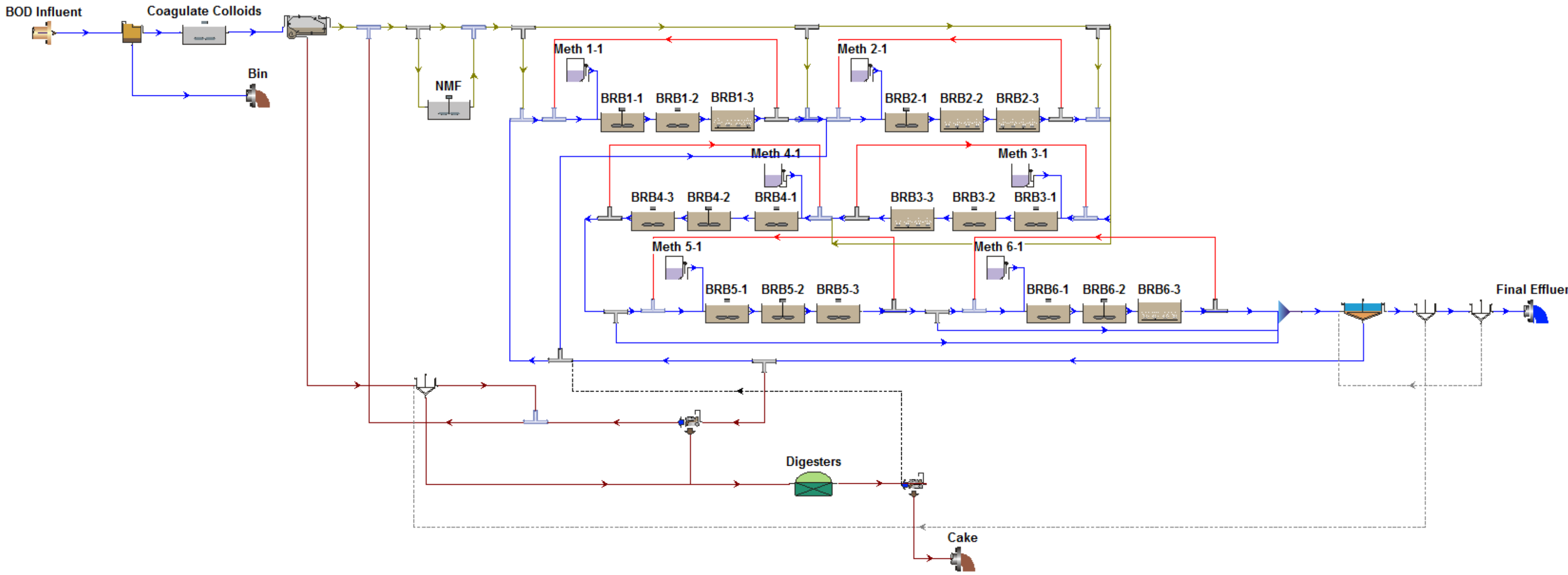


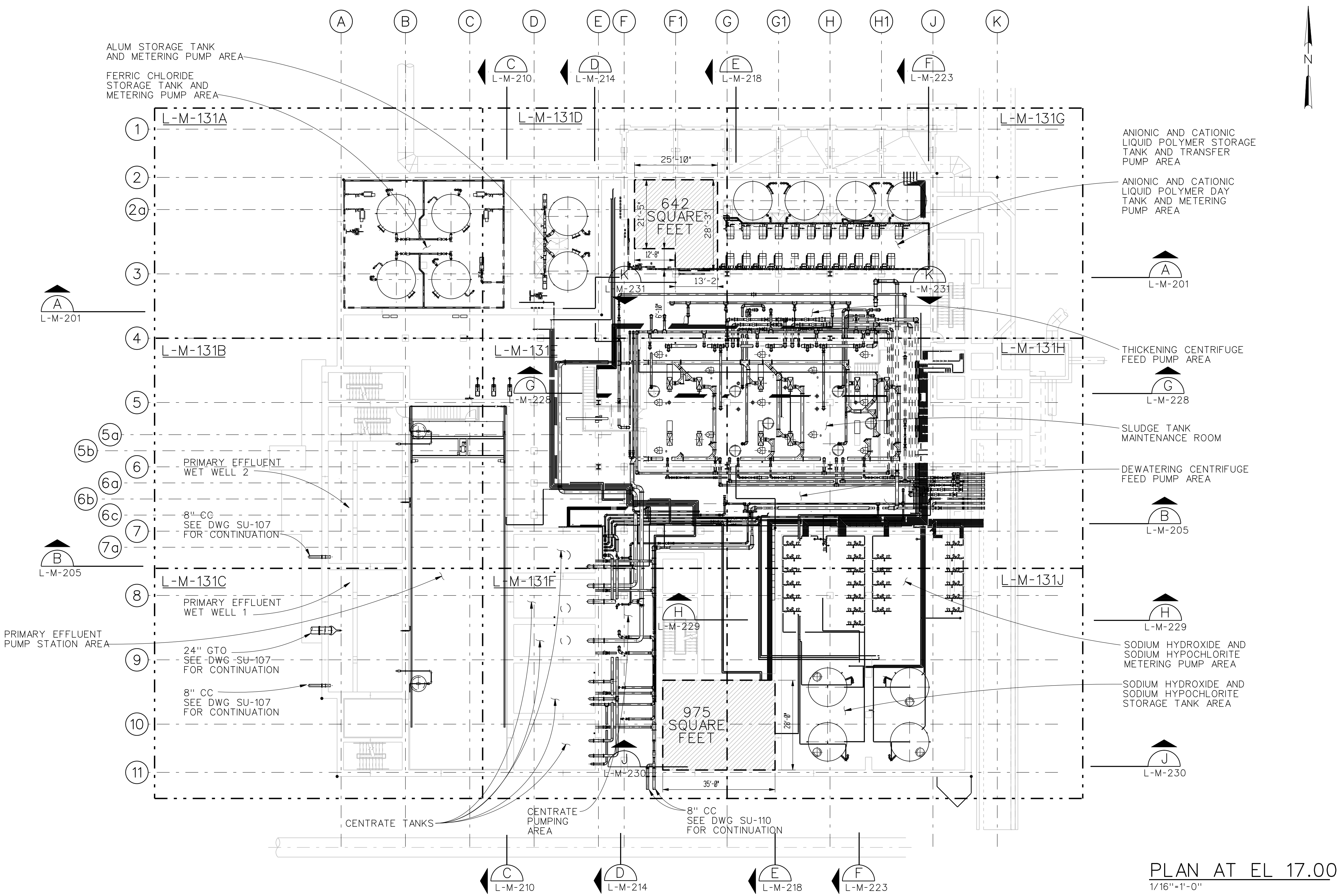
Figure 1. BioWin Process Flow Diagram

Table 2. Simulation Results

Maximum Month Design Condition with Chemically-Enhanced Primary Treatment (CEPT)

Flow Stream	Flow (MGD)	$CBOD_5$ (lb/day)	TSS (lb/day)	VSS (lb/day)	Total N (lb/day)	TKN (lb/day)	NH3 (lb/day)	TP (lb/day)	OP (lb/day)
Plant Influent	75.0	113,480	185,884	100,276	20,717	20,717	10,213	3,803	1,301
Grit Tank	75.0	113,469	176,585	100,266	20,715	20,715	10,212	3,803	1,301
PSTs	71.8	40,519	46,158	28,605	15,081	15,081	9,745	1,817	1,241
Primary Sludge	***3.2***	***65,324***	***164,529***	***95,764***	***5,633***	***5,633***	***467***	***1,986***	***59***
NMF	0.0	0	0	0	0	0	0	0	0
BRB1-3	120.1	1,060,951	5,800,305	3,125,081	277,803	269,458	827	89,343	5,159
BRB2-3	118.5	817,979	4,463,642	2,405,463	216,668	207,271	243	69,210	4,413
BRB3-3	134.9	821,386	4,476,311	2,412,898	217,331	208,052	298	69,689	4,684
BRB4-3	134.9	819,777	4,475,767	2,412,351	214,645	208,072	764	69,689	4,680
BRB5-3	134.9	819,061	4,475,551	2,412,117	211,748	208,087	837	69,689	4,671
BRB6-3	134.9	816,613	4,473,312	2,409,866	209,660	207,423	75	69,689	4,732
SSTs	82.6	2,113	8,947	4,820	2,208	872	45	2,956	2,826
SSTs (U)	61.0	814,526	4,464,384	2,405,056	207,538	206,574	32	66,868	2,040
WAS Splitter	60.4	805,304	4,415,647	2,377,826	205,188	204,235	32	66,111	2,017
WAS	***0.6***	***9,222***	***48,737***	***27,231***	***2,350***	***2,339***	***0***	***757***	***23***
TPS	78.68	460	18	10	1,706	437	43	2,685	2,684
Tertiary Sludge	3.88	1,652	8,929	4,810	502	435	2	271	141
GMF	75.00	434	0	0	1,620	414	41	2,550	2,550
GMF (U)	3.68	26	18	10	86	23	2	134	134
Final Effluent	75.00	434	0	0	1,620	414	41	2,550	2,550

Appendix D
Building L Utilization Plans



PLAN AT EL 17.00

1/16"=1'-0"

DSGN	M EVEGES / E TING					
DR	L DEMARTE / R FREIER					
CHK	CF SHOTTS					
APVD	JL HAWLEY	NO.	DATE	REVISION	BY	APVD

VERIFY SCALE

BAR IS ONE INCH ON ORIGINAL DRAWING.

0 1"

IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

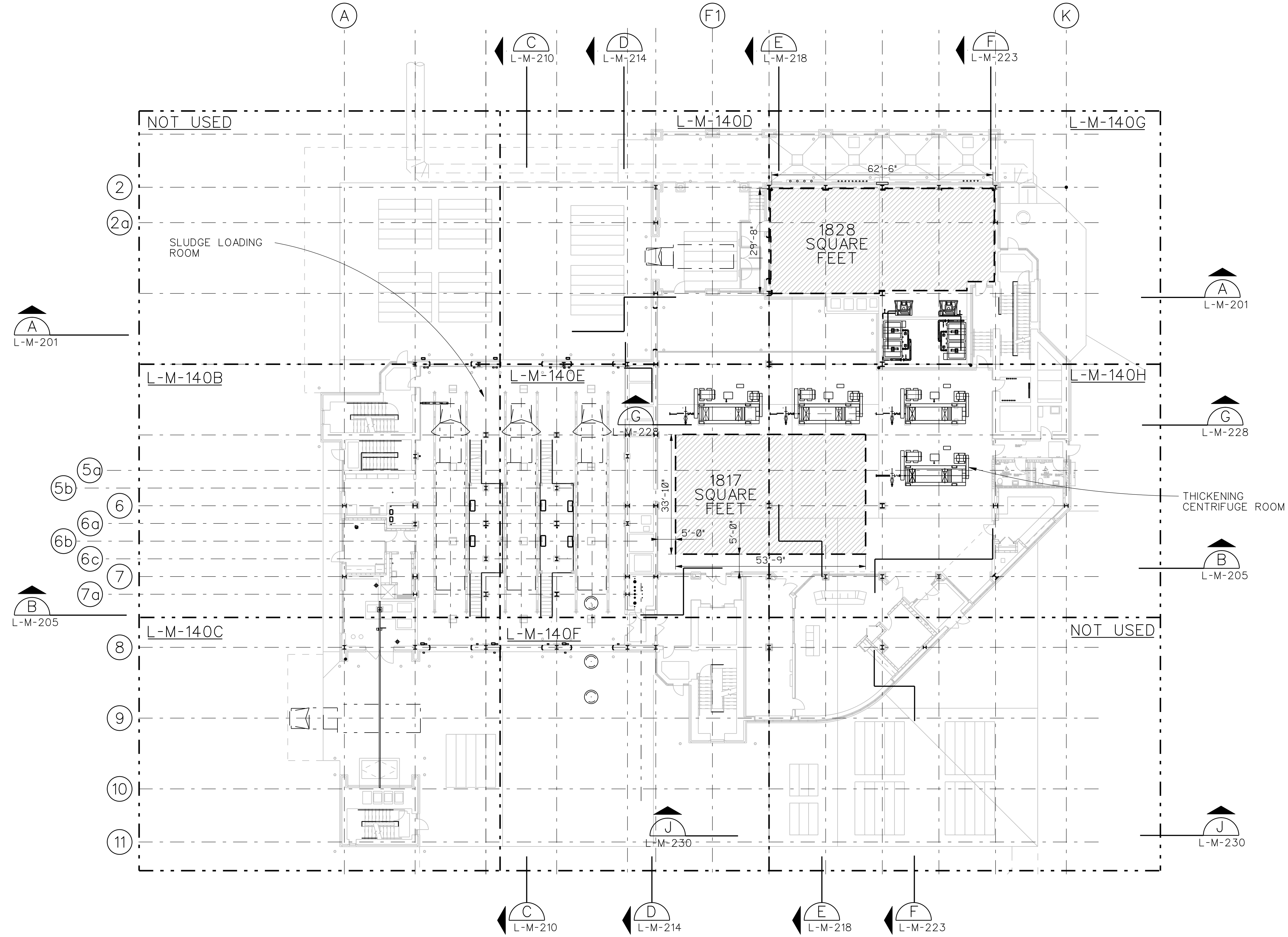
CH2MHILL

ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
BASEMENT - PLAN AT EL 17.00

SHEET	1120
DWG NO.	L-M-131
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1120.dgn



PLAN AT EL 33.00

1/16"=1'-0"

DSGN	M EVEGES E TING				
DR	L DEMARTE R FREIER				
CHK	CF SHOTTS				
APVD	JL HAWLEY	NO.	DATE	REVISION	BY / APVD

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
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CH2MHILL

ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
GROUND FLOOR-PLAN AT EL 33.00

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DATE	APR 1999
PROJ NO.	144125-B

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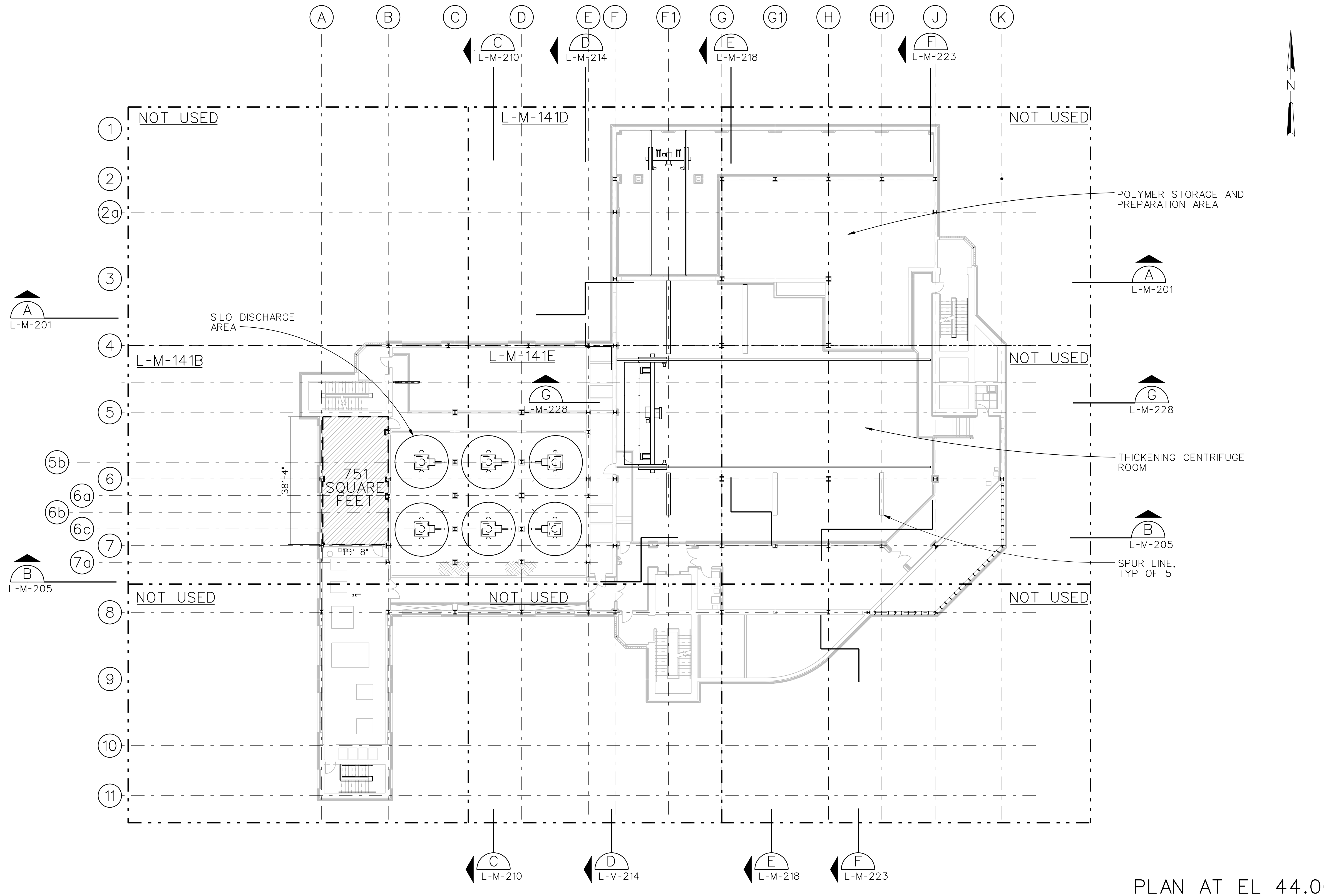

PLAN AT EL 44.00

1/16"=1'-0"

DSGN	E TING		
DR	L DEMARTE		
CHK	CF SHOTTS		
APVD	JL HAWLEY		
NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 — 1"
IF NOT ONE INCH ON THIS SHEET, ADJUST SCALES ACCORDINGLY.

CH2MHILL

ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
GROUND FLOOR-PLAN AT EL 44.00

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DWG NO.	L-M-141
DATE	APR 1999
PROJ NO.	144125-B

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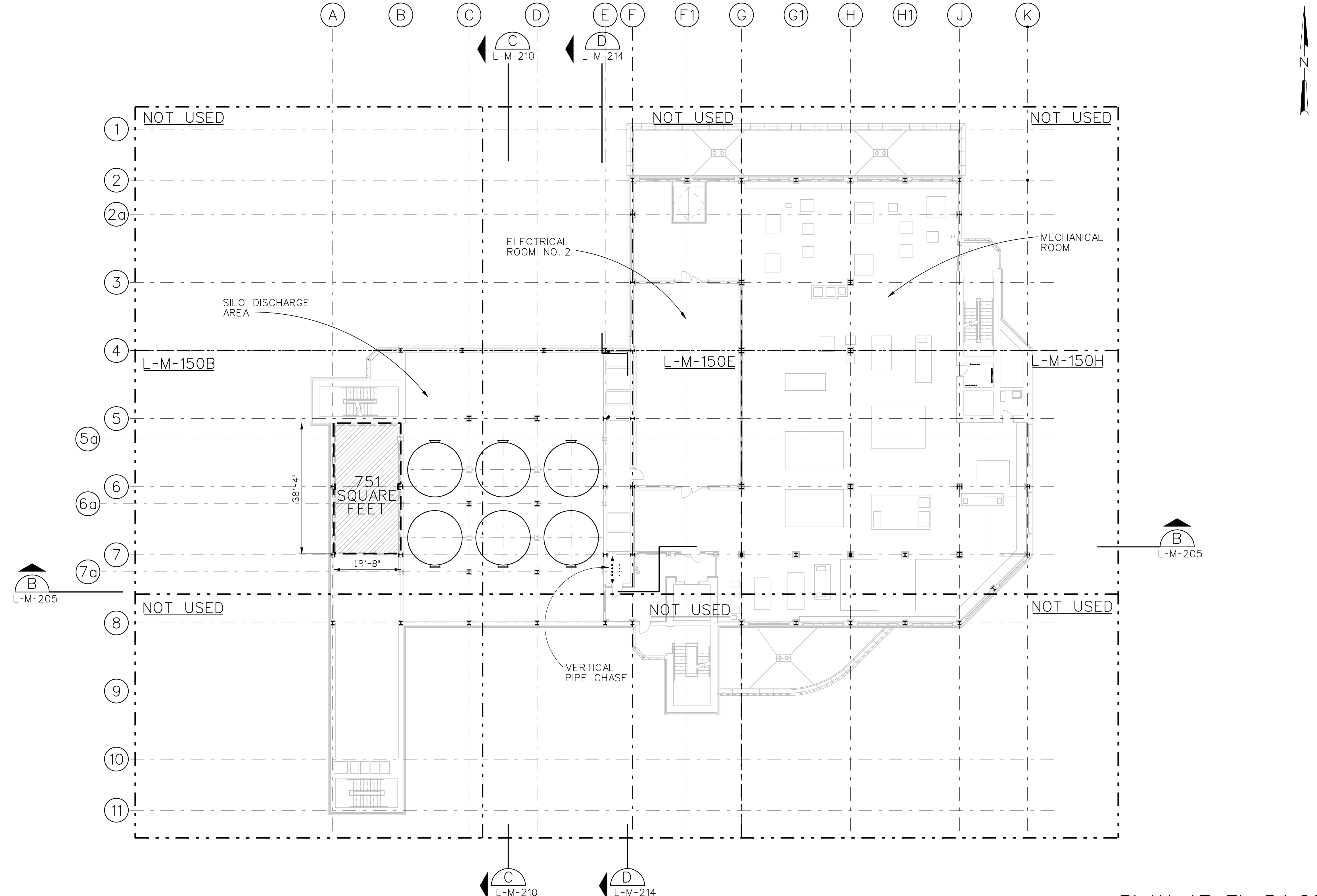

PLAN AT EL 54.00

1/16"=1'-0"

DSGN E TING						
DR L DEMARTE						
CHK CF SHOTTS						
APVD JL HAWLEY	NO.	DATE	REVISION	BY	APVD	

VERIFY SCALE
BAR IS ONE INCH ON ORIGINAL DRAWING.
0 1"
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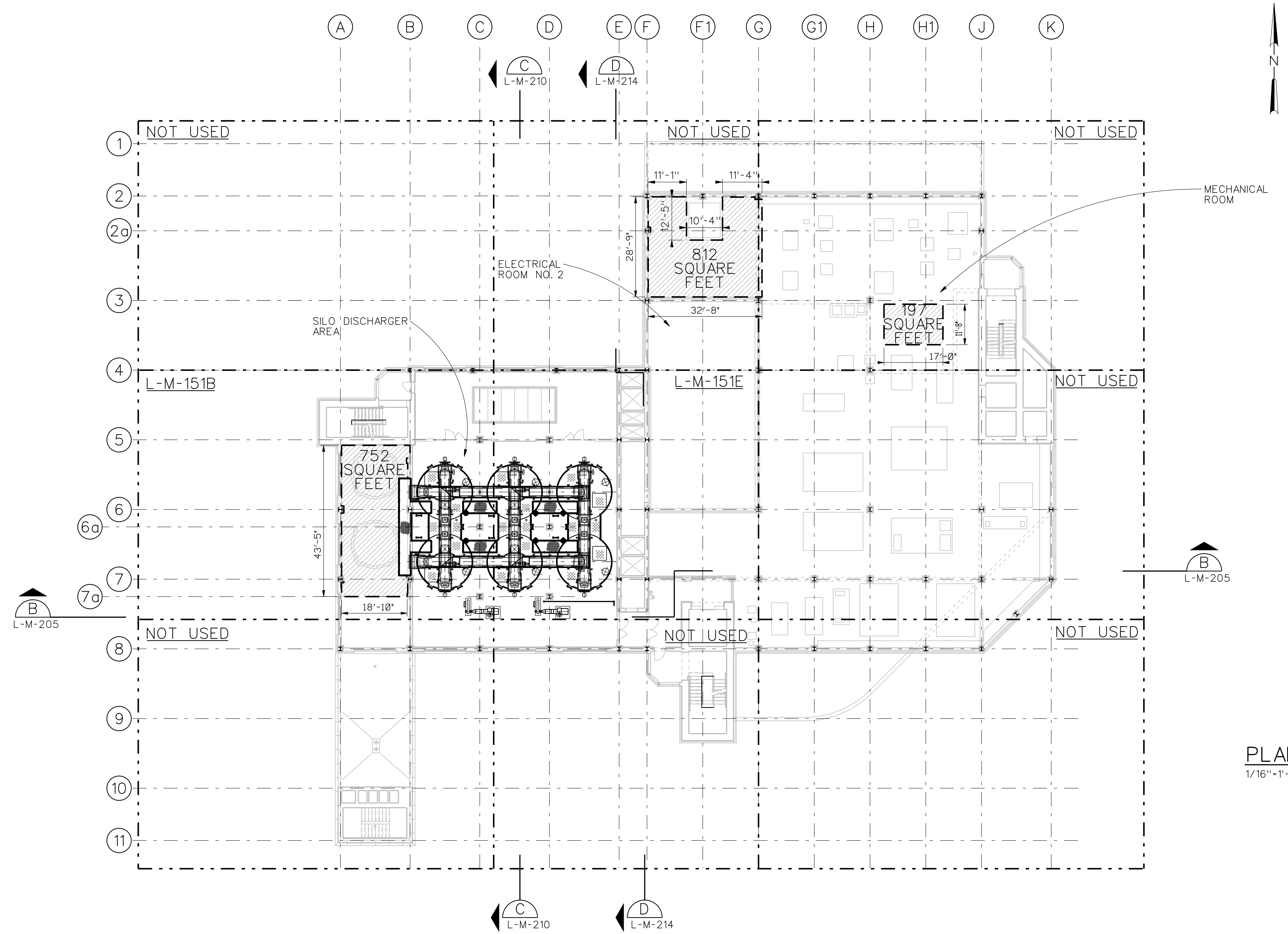
ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER
TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
SECOND FLOOR - PLAN AT EL 54.00

SHEET	1143
DWG NO.	L-M-150
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1143.dgn



PLAN AT EL 67.00

1/16"=1'-0"

DSGN	E TING	NO.	DATE	REVISION	BY	APVD
DR	L DEMARTE					
CHK	CF SHOTTS					
APVD	JL HAWLEY					

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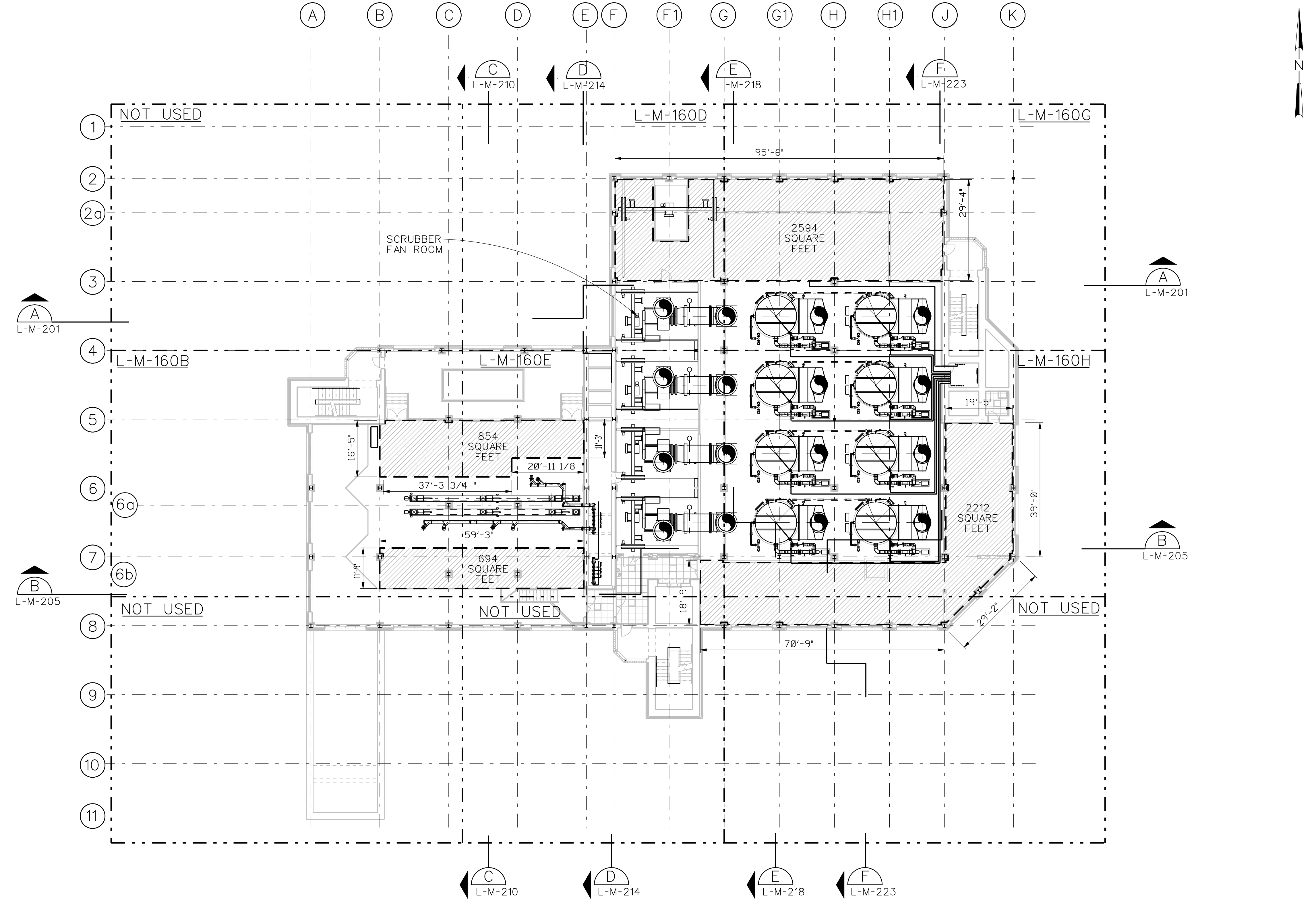
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
SECOND FLOOR - PLAN AT EL 67.00

SHEET	1147
DWG NO.	L-M-151
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1147.dgn



PLAN AT EL 77.00

1/16"=1'-0"

DSGN	E TING RA VOIGT	NO.	DATE	REVISION	BY	APVD
DR	L DEMARTE JR HARGIS					
CHK	E TING CF SHOTTS					
APVD	JL HAWLEY					

VERIFY SCALE
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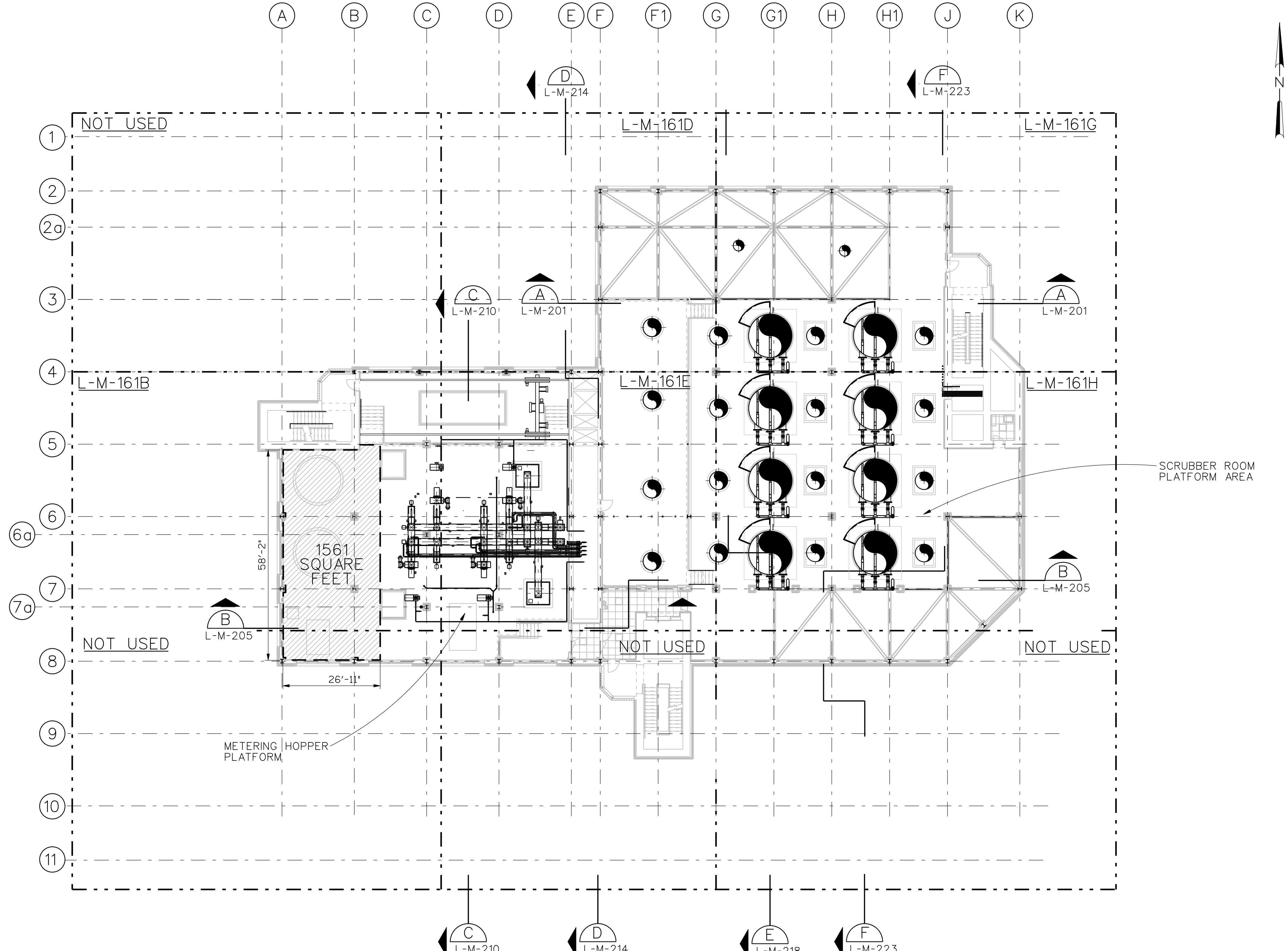
ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
THIRD FLOOR - PLAN AT EL 77.00

SHEET	1150
DWG NO.	L-M-160
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1150.dgn



PLAN AT EL 89.00

1/16"=1'-0"

DSGN E TING RA VOIGT						
DR L DEMARTE JR HARGIS						
CHK E TING CF SHOTTS						
APVD JL HAWLEY	NO.	DATE	REVISION	BY	APVD	

VERIFY SCALE
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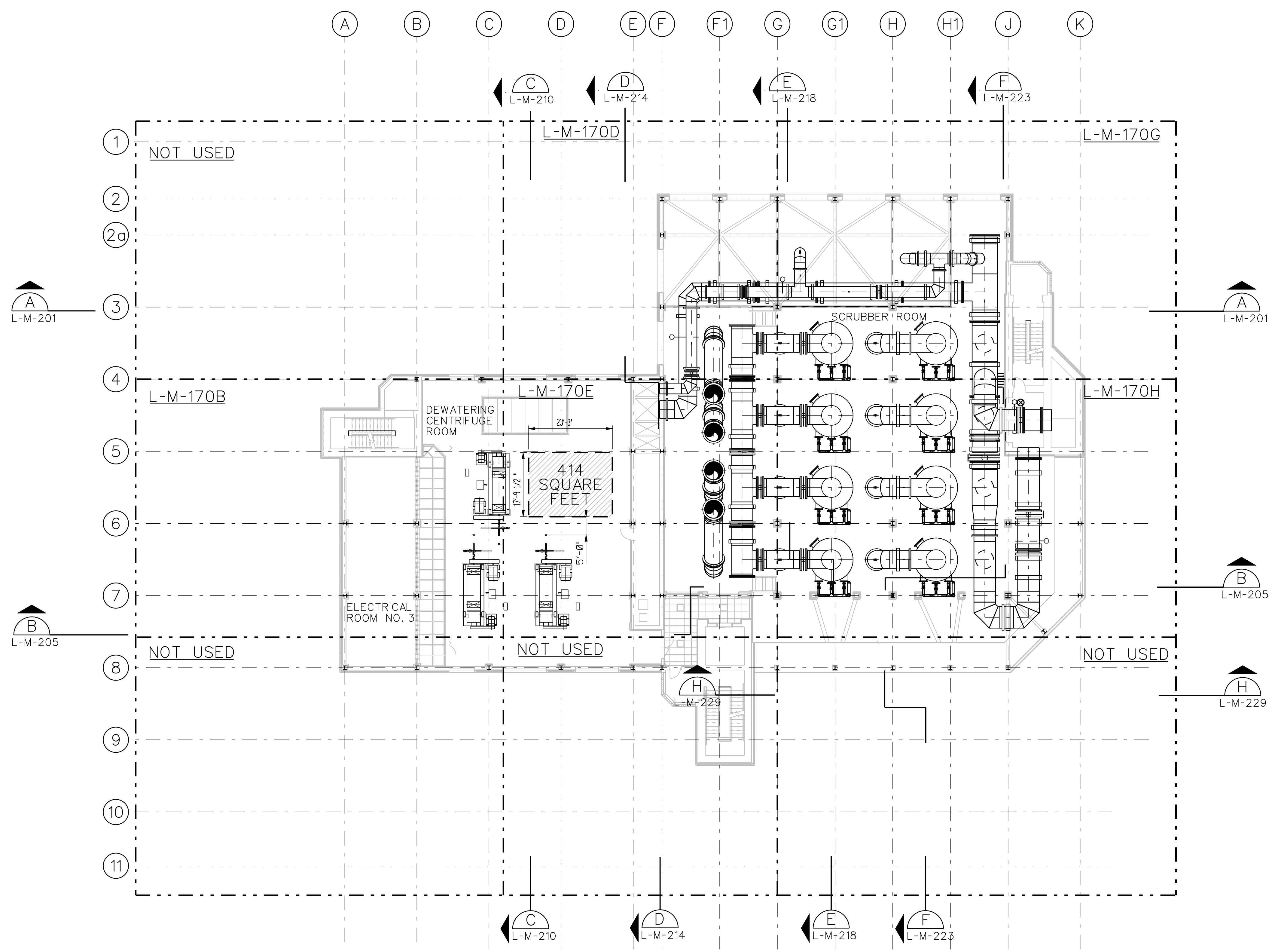
ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
THIRD FLOOR SERVICE PLATFORM - PLAN AT EL 89.00

SHEET	1156
DWG NO.	L-M-161
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1156.dgn



PLAN AT EL 103.33

1/16"=1'-0"

DSGN M EVEGES RA VOIGT						
DR L DEMARTE JR HARGIS						
CHK E TING CF SHOTTS						
APVD JL HAWLEY	NO.	DATE	REVISION	BY	APVD	

VERIFY SCALE
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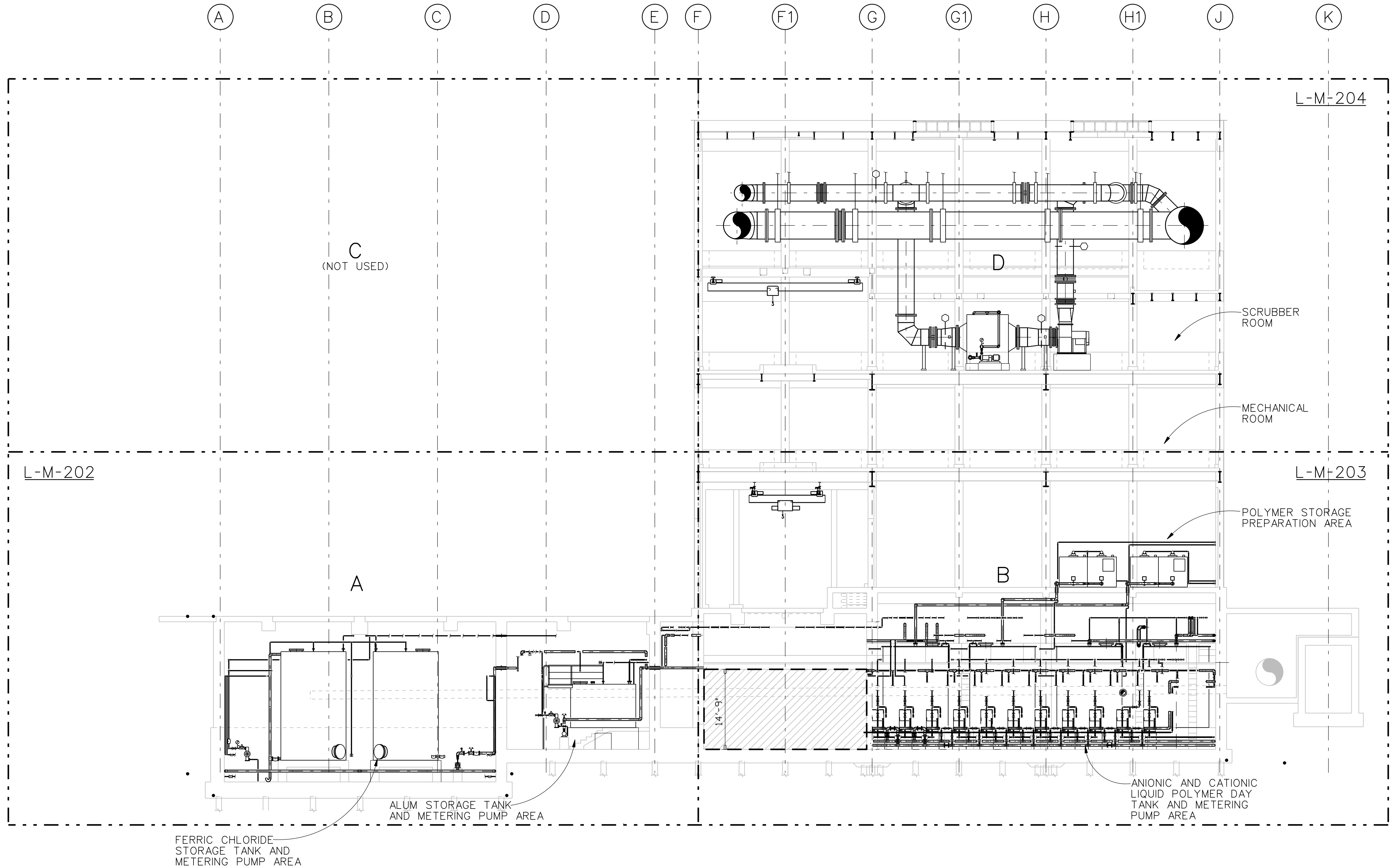
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
FOURTH FLOOR - PLAN AT EL 103.33

SHEET	1162
DWG NO.	L-M-170
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1162.dgn



SECTION A

3/32"=1'-0"

L-M-130, L-M-131
L-M-140, L-M-141
L-M-150, L-M-151
L-M-160, L-M-161
L-M-170, L-M-171

DSGN M. EVEGES R. VOIGT						
DR L. DEMARTE J. HARGIS						
CHK E. TING CF SHOTTS						
APVD JL HAWLEY	NO.	DATE	REVISION	BY	APVD	

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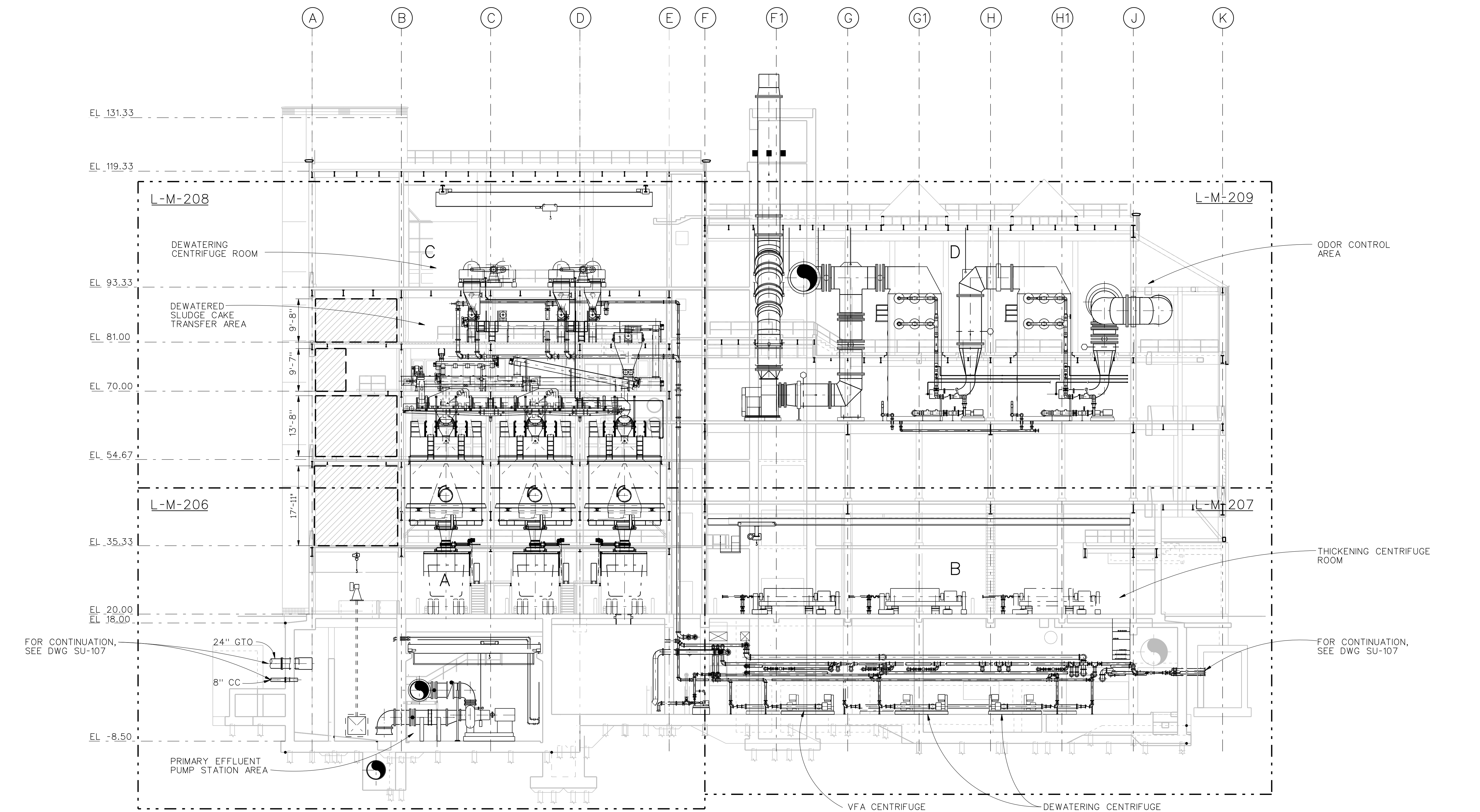
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
SECTION A

SHEET	1171
DWG NO.	L-M-201
DATE	APR 1999
PROJ NO.	144125-B



SECTION B

3/32"=1'-0" L-M-130, L-M-131, L-M-140, L-M-141
L-M-150, L-M-151, L-M-160, L-M-161
L-M-170, L-M-171

DSGN	E. TING M. EVEGES				
DR	X L. DEMARTE				
CHK	E. TING CF SHOTTS				
APVD	JL HAWLEY	NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
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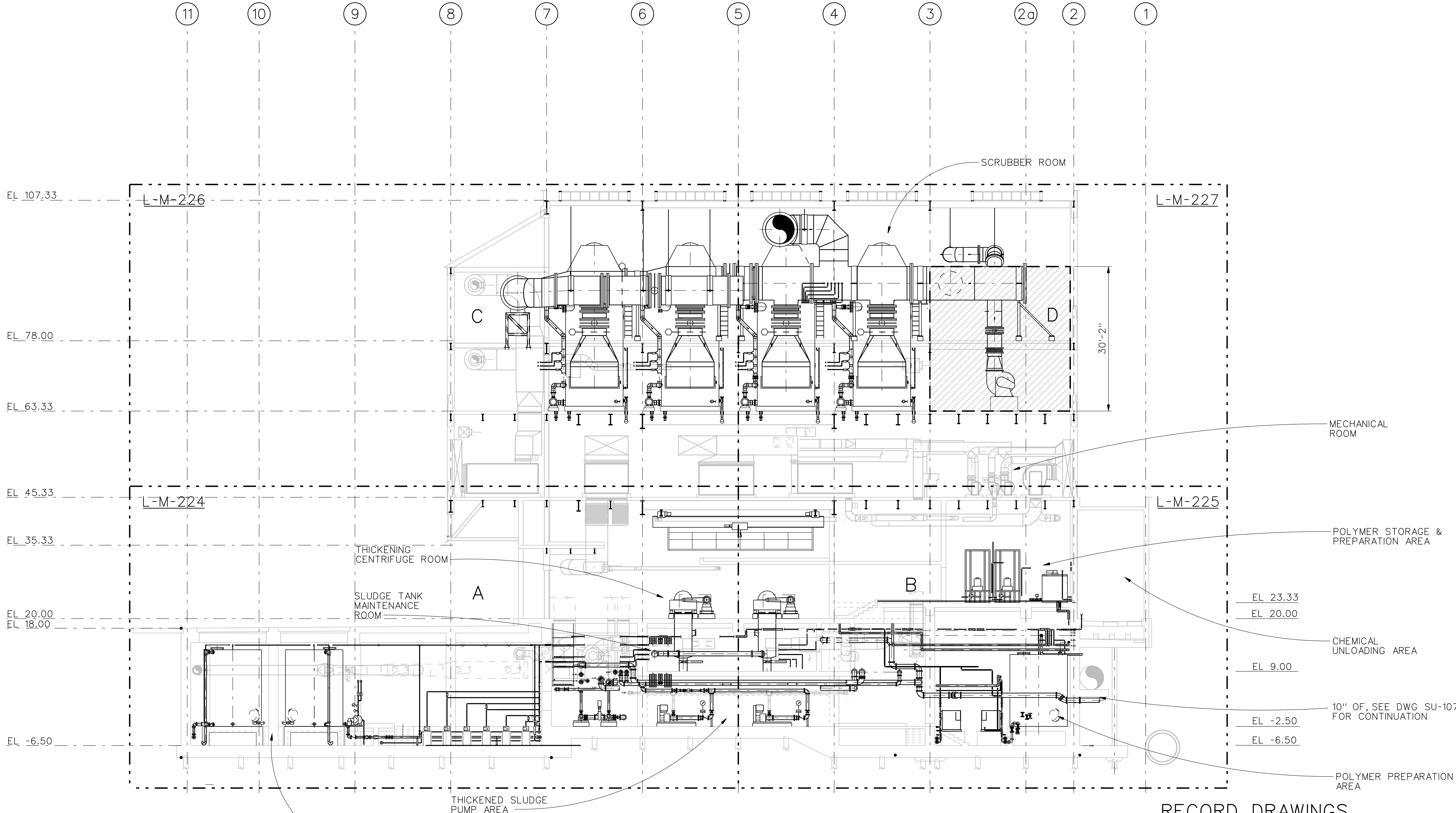
ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
SECTION B

SHEET	1175
DWG NO.	L-M-205
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1175.dgn



SECTION F
3/32"=1'-0"
L-M-130, L-M-131, L-M-140, L-M-141, L-M-150, L-M-151, L-M-160, L-M-161, L-M-170

RECORD DRAWINGS

Revisions Drawn By H. LATTIMER Date DEC. 04

THESE RECORD DRAWINGS HAVE BEEN PREPARED, IN PART, ON THE BASIS OF INFORMATION COMPILED BY OTHERS. THEY ARE NOT INTENDED TO REPRESENT IN DETAIL THE EXACT LOCATION, TYPE OF COMPONENT NOR MANNER OF CONSTRUCTION. THE ENGINEER WILL NOT BE RESPONSIBLE FOR ANY ERRORS OR OMISSIONS WHICH HAVE BEEN INCORPORATED INTO THE RECORD DRAWINGS.

DSGN	EVEGES/TING RA VOIGT
DR	L DEMARTE JR HARGIS
CHK	E TING CF SHOTTS
APVD	JL HAWLEY

NO.	DATE	REVISION	BY	APVD

VERIFY SCALE
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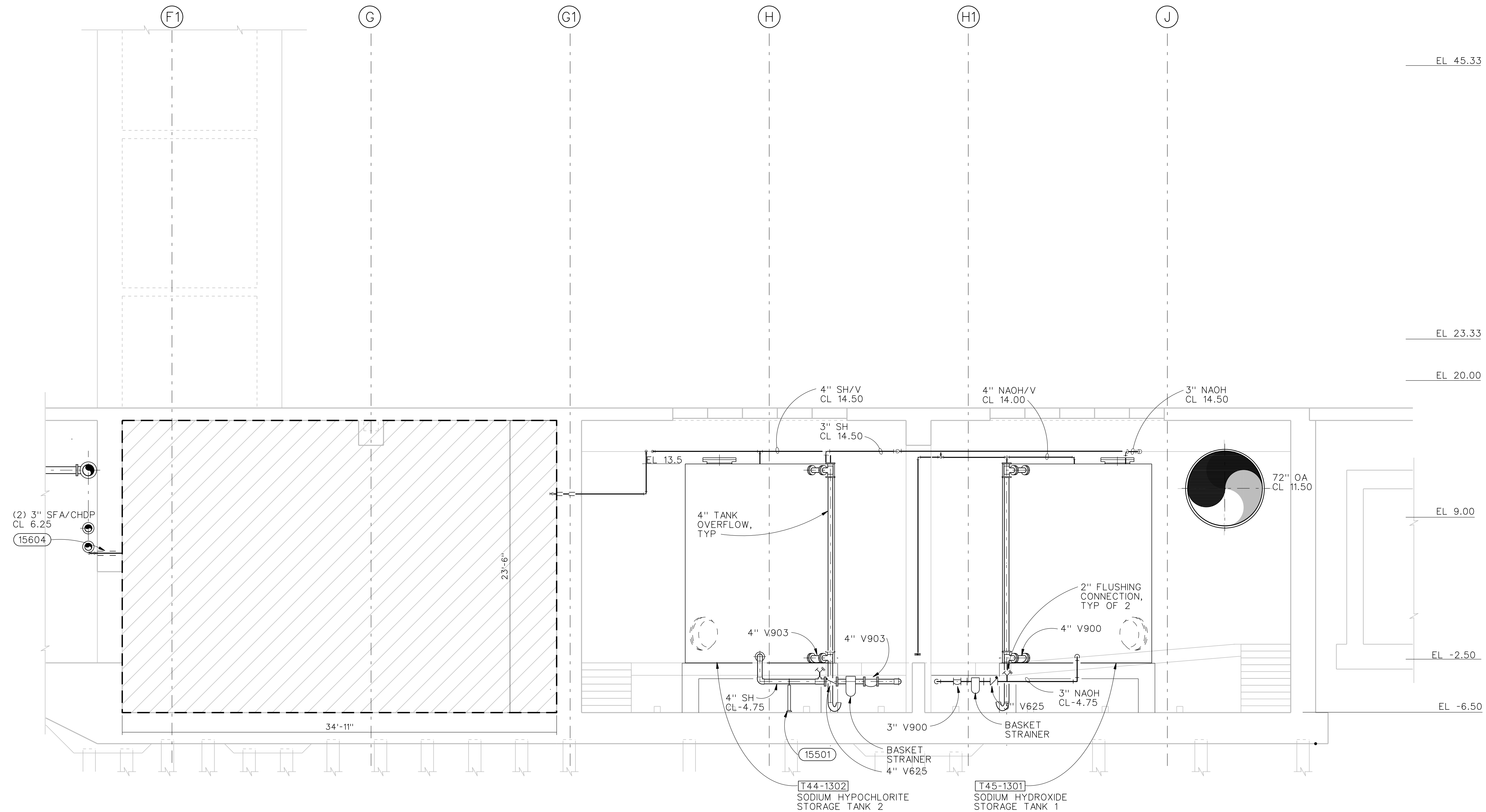
ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL
GENERAL ARRANGEMENT
SECTION F

SHEET	1193
DWG NO.	L-M-223
DATE	APR 1999
PROJ NO.	144125-B



SECTION J
1/4"=1'-0"
L-M-130
L-M-131

DSGN	E TING	NO.	DATE	REVISION	BY	APVD
DR	R FREIER					
CHK	CF SHOTTS					
APVD	JL HAWLEY					

VERIFY SCALE
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ALEXANDRIA SANITATION AUTHORITY
ADVANCED WASTEWATER TREATMENT FACILITY UPGRADE
PACKAGE B

SOLIDS PROCESSING BUILDING L
MECHANICAL

SECTION J

SHEET	1200
DWG NO.	L-M-230
DATE	APR 1999
PROJ NO.	144125-B

pkgb-sheet1200.dgn

Appendix E
Cost Estimates

Alexandria Renew Enterprises
Primary Effluent Pump Station Modifications Design (PEPS)
Construction Cost Estimate for 60% Design

Project name	AlexRenew PEPS Mods
Estimator	Tweneboa-Kodua, A/WDC
Project Number	66053
Market Segment	Water
Business Group	WBG
Estimate Class 1-5	3
Design Stage	60%
Project Manager	S. Schlesinger/WDC
Rev No. / Date	R01/9-June-2016

The construction cost estimate (s) shown herein have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, competitive market conditions, final project costs, implementation schedule and other variable factors. As a result, the final costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evauluation and adequate funding. Our estimate is based on material, equipment, and labor pricing as of the estimate revision date. The owner should be cautioned that such prices are highly subject to variation as a result of shortages resulting from recent natural disasters and current escalation trends.

Facility Summary

Project:	AlexRenew PEPS Mods	Estimator:	Tweneboa-Kodua, A/WDC
Project No.:	66053	Revision / Date:	R01/9-June-2016
Design Stage:	60%	Estimate Class:	3

Job Size: 1 LS
Duration: 1 LS

Facility	Description	Direct Amount	Grand Total w/Markups	Percent of Total
010	**AlexRenew PEPS Modifications**			
	Existing Conditions	76,725	144,382	2.343
	Concrete Work	7,002	13,177	0.214
	Masonry	11,002	20,704	0.336
	Metals	19,197	36,126	0.586
	Thermal and Moisture Protection	11,188	21,054	0.342
	Openings	27,541	51,826	0.841
	Finishes	507,927	955,821	15.514
	Specialties	8,763	16,490	0.268
	Conveying Equipment	20,595	38,756	0.629
	Plumbing	11,813	22,820	0.370
	HVAC	256,319	495,158	8.037
	Electrical Work	1,115,965	2,211,628	35.897
	Process Pipe	59,169	113,121	1.836
	Instrumentation & Controls	245,660	486,851	7.902
	Process Equipment - Industrial	814,719	1,533,145	24.884
	010 AlexRenew PEPS Modifications	**3,193,586**	**6,161,059**	**100.000**

Estimate Totals

Construction Costs	Amount	Totals	Rate	% of Total
Labor	777,669			12.62%
Material	3,787,574			61.48%
Subcontract	1,553,119			25.21%
Equipment	41,895			0.68%
Other	802			0.01%
Total Construction Costs	**6,161,059**	**6,161,059**		**100.00**

Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew PEPS Mods
Project No.: 66053
Design Stage: 60%

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/9-June-2016
Estimate Class: 3

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
010			**AlexRenew PEPS Modifications**											
	02.0		**Existing Conditions**											
		02.40	**Demolition**											
			General Demolition											
			Selective Demolition, Cut-out, Masonry Walls											
			Selective demolition, masonry, concrete block walls, reinforced alternate courses, 12" thick	1,140.00 sf	100.3	3,878	-	-	-	-	3.40 /sf	3,878	6.40 /sf	7,297
			Selective Demolition, Cut-out, Masonry Walls	**1,140.00 SF**	**100.3**	**3,878**					**3.40 /SF**	**3,878**	**6.40 /SF**	**7,297**
			Selective Demolition, Cut-out, Partitions											
			Walls and partitions demolition, drywall, nailed or screwed	100.00 sf	8.0	309	-	-	-	-	3.09 /sf	309	5.82 /sf	582
			Selective Demolition, Cut-out, Partitions	**100.00 SF**	**8.0**	**309**					**3.09 /SF**	**309**	**5.82 /SF**	**582**
			Selective Demolition, Cut-out, Ceilings											
			Ceiling demolition, suspended ceiling system including mineral fiber, 2 x 2 or 2 x 4, remove	308.00 sf	18.5	714	-	-	-	-	2.32 /sf	714	4.37 /sf	1,345
			Selective Demolition, Cut-out, Ceilings	**308.00 SF**	**18.5**	**714**					**2.32 /SF**	**714**	**4.37 /SF**	**1,345**
			Selective Demolition, Cut-out, Flooring											
			Flooring demolition, tile, ceramic, mud set	363.00 sf	29.0	1,123	-	-	-	-	3.09 /sf	1,123	5.82 /sf	2,113
			Selective Demolition, Cut-out, Flooring	**363.00 SF**	**29.0**	**1,123**					**3.09 /SF**	**1,123**	**5.82 /SF**	**2,113**
			Selective Demolition, Cut-out, Millwork & Trim											
			Selective demolition, millwork and trim, casework, selective area, remove	30.00 lf	6.0	232	-	-	-	-	7.73 /lf	232	14.55 /lf	437
			Selective Demolition, Cut-out, Millwork & Trim	**30.00 LF**	**6.0**	**232**					**7.73 /LF**	**232**	**14.55 /LF**	**437**
			Selective Demolition, Cut-out, Doors											
			Door demolition, exterior door, single, 3' x 7' high, 1-3/4" thick, remove	5.00 ea	5.0	193	-	-	-	-	38.66 /ea	193	72.76 /ea	364
			Door demolition, exterior door, double, 6' x 7' high, 1-3/4" thick, remove	1.00 ea	2.0	77	-	-	-	-	77.32 /ea	77	145.51 /ea	146
			Selective Demolition, Cut-out, Doors	**6.00 EA**	**7.0**	**271**					**45.11 /EA**	**271**	**84.88 /EA**	**509**
			Selective Demolition, Cut-out, Windows											
			Window demolition, glass, maximum	15.00 sf	3.9	150	-	-	-	-	10.00 /sf	150	18.82 /sf	282
			Selective demolition, remove portion of existing store front	30.00 sf	7.8	300	-	-	-	-	10.00 /sf	300	18.82 /sf	565
			Selective Demolition, Cut-out, Windows	**45.00 SF**	**11.6**	**450**					**10.00 /SF**	**450**	**18.82 /SF**	**847**
			Selective Demolition, Cut-out, Roofing											
			Roofing demolition, sawcut and remove portion of roof deck	88.00 sf	17.6	735	-	-	1,918	-	30.15 /sf	2,653	56.73 /sf	4,992
			Roofing and siding demolition, roofing, built-up, gravel removal, maximum	88.00 sf	8.8	345	-	-	-	-	3.92 /sf	345	7.38 /sf	649
			Selective Demolition, Cut-out, Roofing	**80.00 SF**	**26.4**	**1,080**			**1,918**		**37.47 /SF**	**2,998**	**70.52 /SF**	**5,641**
			General Demolition	**1.00 LS**	**206.9**	**8,057**			**1,918**		**9,974.48 /LS**	**9,974**	**18,770.05 /LS**	**18,770**
			Plumbing Demolition											
			Plumbing Demolition											
			Fixture, shower pan, disconnect and remove, maximum	1.00 ea	0.5	27	-	-	-	-	27.35 /ea	27	51.47 /ea	51
			Fixture, sink, single compartment, selective demolition	1.00 ea	1.0	55	-	-	-	-	54.71 /ea	55	102.95 /ea	103
			Fixture, water closet, wall mounted, selective demolition	1.00 ea	1.1	63	-	-	-	-	62.52 /ea	63	117.65 /ea	118
			Plumbing demolition, remove floor drain and cap in place, selective demolition	4.00 ea	8.0	438	400	-	-	-	209.41 /ea	838	394.08 /ea	1,576
			Plumbing demolition, remove hub drain and cap in place, selective demolition	1.00 ea	2.0	109	100	-	-	-	209.41 /ea	209	394.05 /ea	394
			Fixture, utility sink, selective demolition	1.00 ea	4.0	219	-	-	-	-	218.82 /ea	219	411.78 /ea	412
			Miscellaneous piping, metal pipe, to 1"-4" diam., selective demolition	300.00 lf	47.4	2,593	-	-	-	-	8.64 /lf	2,593	16.27 /lf	4,880
			Water heater, 1650 thru 4000 GPH, selective demolition. Store for reuse	1.00 ea	48.0	2,566	-	-	-	-	2,565.94 /ea	2,566	4,828.62 /ea	4,829
			Miscellaneous plumbing demo	1.00 ls	60.0	3,207		-	-	-	3,207.42 /ls	3,207	6,035.74 /ls	6,036
			Plumbing Demolition	**1.00 LS**	**172.0**	**9,277**	**500**				**9,776.88 /LS**	**9,777**	**18,398.20 /LS**	**18,398**
			Plumbing Demolition	**1.00 LS**	**172.0**	**9,277**	**500**				**9,776.88 /LS**	**9,777**	**18,398.20 /LS**	**18,398**
			HVAC Demolition											
			HVAC Demolition											
			Demo Exhaust Fans, EF-L-4301, selective demolition	1.00 ea	4.5	233	-	-	-	-	233.09 /ea	233	438.65 /ea	439
			Demo Exhaust Fans, EF-L-2101, selective demolition	1.00 ea	4.5	233	-	-	-	-	233.09 /ea	233	438.63 /ea	439
			HVAC demo, remove supply, return & exhaust ductwork/insulation and cap	250.00 lf	80.0	4,195	-	-	-	-	16.78 /lf	4,195	31.57 /lf	7,893
			Relocate existing thermostat including conduit and wire	1.00 ea	4.0	210	350	-	-	-	559.73 /ea	560	1,053.32 /ea	1,053
			Miscellaneous HVAC demo	1.00 ls	80.0	4,195		-	-	-	4,194.56 /ls	4,195	7,893.34 /ls	7,893
			HVAC Demolition	**1.00 LS**	**173.0**	**9,065**	**350**				**9,415.03 /LS**	**9,415**	**17,717.29 /LS**	**17,717**
			HVAC Demolition	**1.00 LS**	**173.0**	**9,065**	**350**				**9,415.03 /LS**	**9,415**	**17,717.29 /LS**	**17,717**
			Process Equipment Demolition											
			Process Equipment Demolition											
			Demo existing effluent pumps	6.00 ea	240.0	11,803		-	3,523	-	2,554.42 /ea	15,327	4,806.92 /ea	28,842
			Process Equipment Demolition	**6.00 EA**	**240.0**	**11,803**			**3,523**		**2,554.42 /EA**	**15,327**	**4,806.92 /EA**	**28,842**
			Process Equipment Demolition	**1.00 LS**	**240.0**	**11,803**			**3,523**		**15,326.50 /LS**	**15,327**	**28,841.50 /LS**	**28,842**
			Electrical Demolition											
			Electrical Facility Demolition											
			Remove existing conduit and conductors from each drive as stated on the drawings	1.00 ea	300.0	16,334		-	-	-	16,333.80 /ea	16,334	30,737.09 /ea	30,737

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Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew PEPS Mods
Project No.: 66053
Design Stage: 60%

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/9-June-2016
Estimate Class: 3

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Electrical Facility Demolition											
			Disconnect and remove existing vfds , electrical demolition,	6.00 ea	240.0	13,067	-	-	-	-	2,177.84 /ea	13,067	4,098.27 /ea	24,590
			Miscellaneous electrical demolition	1.00 ea	40.0	2,178	-	-	-	-	2,177.84 /ea	2,178	4,098.26 /ea	4,098
			Electrical Facility Demolition	**1.00 LS**	**580.0**	**31,579**					**31,578.68 /LS**	**31,579**	**59,424.99 /LS**	**59,425**
			Electrical Selective Demolition, Lights											
			Demo existing light fixtures	6.00 ea	12.0	653	-	-	-	-	108.89 /ea	653	204.92 /ea	1,230
			Electrical Selective Demolition, Lights	**6.00 EA**	**12.0**	**653**					**108.89 /EA**	**653**	**204.92 /EA**	**1,230**
			Electrical Demolition	**1.00 LS**	**592.0**	**32,232**					**32,232.03 /LS**	**32,232**	**60,654.49 /LS**	**60,654**
			02.40 Demolition	**1.00 LS**	**1,383.9**	**70,434**	**850**		**5,441**		**76,724.92 /LS**	**76,725**	**144,381.53 /LS**	**144,382**
			02.0 Existing Conditions	**1.00 AC**	**1,383.9**	**70,434**	**850**		**5,441**		**76,724.92 /AC**	**76,725**	**144,381.53 /AC**	**144,382**
	03.0		**Concrete Work**											
		03.10	**Cast-In-Place Concrete Work**											
			Concrete Equipment Pad - Electrical Room											
			Cast-In-Place Concrete, Equipment Pads, 12" thick											
			Concrete pumping, subcontract, all inclusive price	4.52 cy		-	-	68	-	-	15.00 /cy	68	28.23 /cy	128
			Equipment pad forms, large	122.00 sf	30.5	1,489	183	-	-	-	13.71 /sf	1,672	25.80 /sf	3,147
			Speed Dowels, #5	20.00 ea		-	280	-	-	-	14.00 /ea	280	26.34 /ea	527
			Reinforcing in place, A615 Gr 60, priced per lbs.	451.85 lb		-	226	181	-	-	0.90 /lb	407	1.69 /lb	765
			Concrete, ready mix, 4000 psi	4.52 CY		-	511	-	-	-	113.00 /CY	511	212.65 /CY	961
			Add for concrete waste, 4000 psi	0.23 cy		-	26	-	-	-	113.00 /cy	26	212.65 /cy	48
			Placing concrete, concrete pump	4.52 cy	3.4	128	-	-	-	-	28.33 /cy	128	53.32 /cy	241
			Finishing floors, monolithic, broom finish	122.00 sf	3.7	165	2	-	-	-	1.37 /sf	167	2.58 /sf	315
			Patch & plug tieholes	122.00 sf	1.8	69	2	-	-	-	0.59 /sf	72	1.10 /sf	135
			Sack rub	122.00 sf	4.9	184	4	-	-	-	1.54 /sf	188	2.90 /sf	354
			Curing, water	122.00 sf	0.4	15	6	-	-	-	0.18 /sf	21	0.33 /sf	40
			Cast-In-Place Concrete, Equipment Pads, 12" thick	**4.52 CY**	**44.7**	**2,051**	**1,240**	**249**			**783.08 /CY**	**3,540**	**1,473.60 /CY**	**6,661**
			Concrete Equipment Pad - Electrical Room	**4.52 CY**	**44.7**	**2,051**	**1,240**	**249**			**783.08 /CY**	**3,540**	**1,473.60 /CY**	**6,661**
			03.10 Cast-In-Place Concrete Work	**4.52 CY**	**44.7**	**2,051**	**1,240**	**249**			**783.08 /CY**	**3,540**	**1,473.60 /CY**	**6,661**
		03.35	**Concrete Miscellaneous**											
			Concrete Repairs											
			Concrete Restoration, Surface Repair											
			Patching concrete, floors due to demolition, epoxy grout, 1/4" thick	200.00 sf	40.0	1,813	1,650	-	-	-	17.31 /sf	3,463	32.58 /sf	6,516
			Concrete Restoration, Surface Repair	**200.00 SF**	**40.0**	**1,813**	**1,650**				**17.31 /SF**	**3,463**	**32.58 /SF**	**6,516**
			Concrete Repairs	**200.00 SF**	**40.0**	**1,813**	**1,650**				**17.31 /SF**	**3,463**	**32.58 /SF**	**6,516**
			03.35 Concrete Miscellaneous	**1.00 LS**	**40.0**	**1,813**	**1,650**				**3,462.76 /LS**	**3,463**	**6,516.25 /LS**	**6,516**
			03.0 Concrete Work	**4.52 CY**	**84.7**	**3,864**	**2,890**	**249**			**1,549.18 /CY**	**7,002**	**2,915.25 /CY**	**13,177**
	04.0		**Masonry**											
		04.20	**Concrete Unit Masonry**											
			Glazed CMU Wall 8" Thick											
			Masonry Concrete Masonry Units, 8"											
			Grout block cores, solid, 8" thick	408.00 sf		-	-	979	-	-	2.40 /sf	979	4.52 /sf	1,843
			Grout door frames, single opening	1.00 ea		-	-	25	-	-	25.00 /ea	25	47.05 /ea	47
			Grout door frames, double opening	2.00 ea		-	-	90	-	-	45.00 /ea	90	84.68 /ea	169
			Masonry reinforcing per square foot	408.00 sf		-	-	612	-	-	1.50 /sf	612	2.82 /sf	1,152
			Lintel, 8" wide	16.00 lf		-	-	320	-	-	20.00 /lf	320	37.64 /lf	602
			Glazed, double face, 8" thick	408.00 sf		-	-	8,976	-	-	22.00 /sf	8,976	41.40 /sf	16,891
			Masonry Concrete Masonry Units, 8"	**408.00 SF**				**11,002**			**26.97 /SF**	**11,002**	**50.75 /SF**	**20,704**
			Glazed CMU Wall 8" Thick	**408.00 SF**				**11,002**			**26.97 /SF**	**11,002**	**50.75 /SF**	**20,704**
			04.20 Concrete Unit Masonry	**408.00 SF**				**11,002**			**26.97 /SF**	**11,002**	**50.75 /SF**	**20,704**
			04.0 Masonry	**408.00 SF**				**11,002**			**26.97 /SF**	**11,002**	**50.75 /SF**	**20,704**
	05.0		**Metals**											
		05.10	**Structural Steel**											
			Structural Steel Modification at Roof Opening											
			Metals, Structural Steel											
			Beam, structural, W12x19, A992 steel, incl shop primer, splice plates, bolts	270.00 lb	15.7	876	540	-	339	-	6.50 /lb	1,755	12.23 /lb	3,303
			Channel framing, structural steel, field fabricated, C8x11.5, incl cutting & welding	713.00 lb	35.7	2,116	1,426	-	489	-	5.65 /lb	4,031	10.64 /lb	7,585
			Steel plate, structural, for connections & stiffeners, 1/4" T, shop fabricated, incl shop primer	75.00 sf	30.0	1,669	1,013	-	-	-	35.75 /sf	2,681	67.27 /sf	5,045
			Metals, Structural Steel	**1.00 TN**	**81.4**	**4,661**	**2,979**		**828**		**8,467.28 /TN**	**8,467**	**15,933.80 /TN**	**15,934**
			Structural Steel Modification at Roof Opening	**1.00 LS**	**81.4**	**4,661**	**2,979**		**828**		**8,467.28 /LS**	**8,467**	**15,933.80 /LS**	**15,934**
			05.10 Structural Steel	**1.00 LS**	**81.4**	**4,661**	**2,979**		**828**		**8,467.28 /LS**	**8,467**	**15,933.80 /LS**	**15,934**
		05.50	**Metal Fabrications**											
			Metals, Aluminum Ladder											
			Metal Ladders, Aluminum w/o Cage											
			Ladder, aluminum, bolted to concrete, without cage	12.00 lf	4.8	282	780	-	-	-	88.50 /lf	1,062	166.53 /lf	1,998

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Metal Ladders, Aluminum w/o Cage	12.00 LF	4.8	282	780				88.50 /LF	1,062	166.53 /LF	1,998
			Metals, Aluminum Ladder	12.00 VLF	4.8	282	780				88.50 /VLF	1,062	166.53 /VLF	1,998
			Guardrails											
			Metals, Handrailing, 3-Rail											
			Handrail, aluminum, 3 rail, 1 1/2" dia., clear anodized	130.00 lf	65.0	3,818	5,850	-	-	-	74.37 /lf	9,668	139.95 /lf	18,194
			Metals, Handrailing, 3-Rail	130.00 LF	65.0	3,818	5,850				74.37 /LF	9,668	139.95 /LF	18,194
			Guardrails	130.00 LF	65.0	3,818	5,850				74.37 /LF	9,668	139.95 /LF	18,194
			05.50 Metal Fabrications	1.00 LS	69.8	4,100	6,630				10,730.19 /LS	10,730	20,192.14 /LS	20,192
			05.0 Metals	1.00 LS	151.2	8,761	9,609		828		19,197.47 /LS	19,197	36,125.94 /LS	36,126
	07.0		Thermal and Moisture Protection											
		07.70	Roof & Wall Specialties and Accessories											
			Roof Repairs											
			Thermal & Moisture Protection, Built Up Roofing											
			Miscellaneous roofing repairs, Built up roof, asphalt base sheet, 3-plies #15 felt, mopped w/ gravel	2.00 ea	48.0	2,261	800	-	-	-	1,530.47 /ea	3,061	2,880.05 /ea	5,760
			Thermal & Moisture Protection, Built Up Roofing	50.00 SF	48.0	2,261	800				61.22 /SF	3,061	115.20 /SF	5,760
			Roof Repairs	2.00 EA	48.0	2,261	800				1,530.47 /EA	3,061	2,880.05 /EA	5,760
			Roof Hatch											
			Thermal & Moisture Protection, Other											
			Roof hatches, 2'-6" x 3', w/curb, 1" fbgls insul, alum curb & cover	1.00 ea	3.2	148	985	-	-	-	1,132.78 /ea	1,133	2,131.68 /ea	2,132
			Thermal & Moisture Protection, Other	1.00 EA	3.2	148	985				1,132.78 /EA	1,133	2,131.68 /EA	2,132
			Roof Hatch	1.00 EA	3.2	148	985				1,132.78 /EA	1,133	2,131.68 /EA	2,132
			07.70 Roof & Wall Specialties and Accessories	1.00 LS	51.2	2,409	1,785				4,193.72 /LS	4,194	7,891.78 /LS	7,892
		07.90	Joint Protection											
			Joint Sealant											
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	500.00 lf	76.7	2,964	-	-	-	-	5.93 /lf	2,964	11.16 /lf	5,578
			Caulking and sealants, backer rod, polyethylene, 1" dia	5.00 clf	15.0	713	250	-	-	-	192.63 /clf	963	362.50 /clf	1,812
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	500.00 lf	50.0	2,377	690	-	-	-	6.13 /lf	3,067	11.54 /lf	5,772
			Thermal & Moisture Protection, Caulking and Sealants	50.00 LF	141.7	6,054	940				139.89 /LF	6,994	263.24 /LF	13,162
			Joint Sealant	1.00 LS	141.7	6,054	940				6,994.31 /LS	6,994	13,161.93 /LS	13,162
			07.90 Joint Protection	1.00 LS	141.7	6,054	940				6,994.31 /LS	6,994	13,161.93 /LS	13,162
			07.0 Thermal and Moisture Protection	1.00 LS	192.9	8,463	2,725				11,188.03 /LS	11,188	21,053.71 /LS	21,054
	08.0		Openings											
		08.10	Doors and Frames											
			Stainless Steel Doors											
			Doors and Frames, Hollow Metal											
			Stainless Steel w/v ision light, 3' x 7'	4.00 ea	16.0	771	10,000	-	-	-	2,692.69 /ea	10,771	5,067.12 /ea	20,268
			Stainless Steel door frame, 7" single	2.00 ea	8.0	385	1,700	-	-	-	1,042.69 /ea	2,085	1,962.13 /ea	3,924
			Stainless steel door frame, 7" double	1.00 ea	6.0	289	1,200	-	-	-	1,489.03 /ea	1,489	2,802.08 /ea	2,802
			Doors and Frames, Hollow Metal	4.00 EA	30.0	1,445	12,900				3,586.29 /EA	14,345	6,748.70 /EA	26,995
			Door Hardware											
			Door hardware, average - H.M., wood, or aluminum	4.00 set	16.0	771	3,000	-	-	-	942.69 /set	3,771	1,773.95 /set	7,096
			Door Hardware	4.00 EA	16.0	771	3,000				942.69 /EA	3,771	1,773.95 /EA	7,096
			Stainless Steel Doors	4.00 EA	46.0	2,216	15,900				4,528.97 /EA	18,116	8,522.65 /EA	34,091
			Aluminum Storefront Doors											
			Doors and Frames, Aluminum											
			Doors,aluminum,commercial entrance,narrow stile,standard hardware,pair of,3'-0"x7'-0",incl hinges,push/pull,deadlock,cylinder,threshold,excl glazing	1.00 pr	16.0	801	3,300	-	-	-	4,100.75 /pr	4,101	7,716.82 /pr	7,717
			Doors and Frames, Aluminum	1.00 EA	16.0	801	3,300				4,100.75 /EA	4,101	7,716.82 /EA	7,717
			Aluminum Storefront Doors	1.00 EA	16.0	801	3,300				4,100.75 /EA	4,101	7,716.82 /EA	7,717
			08.10 Doors and Frames	5.00 EA	62.0	3,017	19,200				4,443.33 /EA	22,217	8,361.49 /EA	41,807
		08.40	Entrances, Storefronts and Curtain Walls											
			Aluminum Store Front - Filler Panel											
			Entrances, Storefronts and Curtain Walls											
			Aluminum filler panel, store front entrance unit, w/ hdwre, glass,	1.00 ea	8.0	464	1,860	-	-	-	2,324.12 /ea	2,324	4,373.55 /ea	4,374
			Entrances, Storefronts and Curtain Walls	1.00 EA	8.0	464	1,860				2,324.12 /EA	2,324	4,373.55 /EA	4,374
			Aluminum Store Front - Filler Panel	1.00 EA	8.0	464	1,860				2,324.12 /EA	2,324	4,373.55 /EA	4,374
			Window Film Tint											
			Window Film TInt											
			Window Film Tint	1.00 ea				3,000	-	-	3,000.00 /ea	3,000	5,645.42 /ea	5,645
			Window Film TInt	1.00 EA				3,000			3,000.00 /EA	3,000	5,645.42 /EA	5,645

Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew PEPS Mods
Project No.: 66053
Design Stage: 60%

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/9-June-2016
Estimate Class: 3

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Window Film Tint	**1.00 EA**				**3,000**			**3,000.00 /EA**	**3,000**	**5,645.42 /EA**	**5,645**
			08.40 Entrances, Storefronts and Curtain Walls	**1.00 EA**	**8.0**	**464**	**1,860**	**3,000**			**5,324.12 /EA**	**5,324**	**10,018.97 /EA**	**10,019**
			08.0 Openings	**1.00 LS**	**70.0**	**3,481**	**21,060**	**3,000**			**27,540.75 /LS**	**27,541**	**51,826.40 /LS**	**51,826**
	09.0		**Finishes**											
		09.10	**Finishes, Special Coatings**											
			Floor and Wall Repairs: Ferric Chloride Tank Room											
			Cast-In-Place Concrete, Fill/Topping/Grouting											
			Fiber reinforced grout topping; self-level/dry 6100 psi, pumped, to 1-1/2"	2,000.00 sf	7.5	318	28,500	-	74	-	14.45 /sf	28,892	27.18 /sf	54,368
			Cast-In-Place Concrete, Fill/Topping/Grouting	**2,000.00 SF**	**7.5**	**318**	**28,500**		**74**		**14.45 /SF**	**28,892**	**27.18 /SF**	**54,368**
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	500.00 lf	41.7	1,611	-	-	-	-	3.22 /lf	1,611	6.06 /lf	3,031
			Caulking and sealants, backer rod, polyethylene, 1" dia	5.00 clf	15.0	713	250	-	-	-	192.63 /clf	963	362.50 /clf	1,812
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	500.00 lf	50.0	2,377	690	-	-	-	6.13 /lf	3,067	11.54 /lf	5,772
			Thermal & Moisture Protection, Caulking and Sealants	**500.00 LF**	**106.7**	**4,701**	**940**				**11.28 /LF**	**5,641**	**21.23 /LF**	**10,616**
			Finishes, Surface Preparation											
			Surface Preparation, pressure wash floor slab surfaces to remove existing coating, based on 2500 lb operating pressure, and haul for disposal	2,000.00 sf	104.0	4,021	-	-	854	-	2.44 /sf	4,875	4.59 /sf	9,173
			Surface Preparation, pressure wash pads, walls, col, stair & landings to remove ex coating, based on 2500 lb operating pressure, and haul for disposal	3,198.00 sf	166.3	6,429	-	-	1,365	-	2.44 /sf	7,794	4.59 /sf	14,668
			Surface Preparation, remove all deterioated concrete and prep surface for new coating/topping	5,198.00 sf	96.7	4,000	-	-	-	-	0.77 /sf	4,000	1.45 /sf	7,528
			Finishes, Surface Preparation	**5,198.00 SF**	**367.0**	**14,450**			**2,219**		**3.21 /SF**	**16,669**	**6.03 /SF**	**31,368**
			Finishes, Topical Vapor Barrier											
			Apply epoxy resin based vapor barrier sytem 2 coats, to floor slab	2,000.00 sf	36.5	1,509	4,000	-	-	-	2.76 /sf	5,509	5.18 /sf	10,367
			Apply epoxy resin based vapor barrier sytem 2 coats, to walls,pads, stairs, and landings, surfaces	3,198.00 sf	58.3	2,413	6,396	-	-	-	2.76 /sf	8,809	5.18 /sf	16,578
			Finishes, Topical Vapor Barrier	**5,198.00 SF**	**94.8**	**3,923**	**10,396**				**2.76 /SF**	**14,319**	**5.18 /SF**	**26,945**
			Finishes, Chemical Resistant Coating											
			Chemical resistant coatings, Tnemec coating to floor, resin base, max	2,000.00 sf	200.0	8,275	24,000	-	-	-	16.14 /sf	32,275	30.37 /sf	60,735
			Chemical resistant coatings, Tnemec coating to walls, pads, stairs & landings, resin base, max	3,198.00 sf	319.8	13,231	38,376	-	-	-	16.14 /sf	51,607	30.37 /sf	97,115
			Finishes, Chemical Resistant Coating	**5,198.00 SF**	**519.8**	**21,506**	**62,376**				**16.14 /SF**	**83,882**	**30.37 /SF**	**157,850**
			Floor and Wall Repairs: Ferric Chloride Tank Room	**5,038.00 SF**	**1,095.7**	**44,898**	**102,212**		**2,293**		**29.66 /SF**	**149,403**	**55.81 /SF**	**281,147**
			Floor and Wall Repairs: Alum Tank Room											
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	40.00 lf	3.3	129	-	-	-	-	3.22 /lf	129	6.06 /lf	242
			Caulking and sealants, backer rod, polyethylene, 1" dia	0.40 clf	1.2	57	20	-	-	-	192.63 /clf	77	362.48 /clf	145
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	40.00 lf	4.0	190	55	-	-	-	6.14 /lf	245	11.54 /lf	462
			Thermal & Moisture Protection, Caulking and Sealants	**40.00 LF**	**8.5**	**376**	**75**				**11.28 /LF**	**451**	**21.23 /LF**	**849**
			Finishes, Surface Preparation											
			Surface Preparation, pressure wash floor slab surfaces to remove existing coating, based on 2500 lb operating pressure, and haul for disposal	1,060.00 sf	55.1	2,131	-	-	453	-	2.44 /sf	2,584	4.59 /sf	4,862
			Surface Preparation, pressure wash pads, walls, col, stair & landings to remove ex coating, based on 2500 lb operating pressure, and haul for disposal	999.00 sf	51.9	2,008	-	-	426	-	2.44 /sf	2,435	4.59 /sf	4,582
			Surface Preparation, remove all deterioated concrete and prep surface for new coating/topping	999.00 sf	18.6	769	-	-	-	-	0.77 /sf	769	1.45 /sf	1,447
			Finishes, Surface Preparation	**2,059.00 SF**	**125.6**	**4,908**			**879**		**2.81 /SF**	**5,787**	**5.29 /SF**	**10,890**
			Finishes, Topical Vapor Barrier											
			Apply epoxy resin based vapor barrier sytem 2 coats, to floor slab	1,060.00 sf	19.3	800	2,120	-	-	-	2.76 /sf	2,920	5.18 /sf	5,495
			Apply epoxy resin based vapor barrier sytem 2 coats, to walls,pads, stairs, and landings, surfaces	999.00 sf	18.2	754	1,998	-	-	-	2.76 /sf	2,752	5.18 /sf	5,179
			Finishes, Topical Vapor Barrier	**2,059.00 SF**	**37.6**	**1,554**	**4,118**				**2.76 /SF**	**5,672**	**5.18 /SF**	**10,673**
			Finishes, Chemical Resistant Coating											
			Chemical resistant coatings, Tnemec coating to floor, resin base, max	1,060.00 sf	106.0	4,386	12,720	-	-	-	16.14 /sf	17,106	30.37 /sf	32,190
			Chemical resistant coatings, Tnemec coating to walls, pads, stairs & landings, resin base, max	999.00 sf	99.9	4,133	11,988	-	-	-	16.14 /sf	16,121	30.37 /sf	30,337
			Finishes, Chemical Resistant Coating	**2,059.00 SF**	**205.9**	**8,519**	**24,708**				**16.14 /SF**	**33,227**	**30.37 /SF**	**62,527**
			Floor and Wall Repairs: Alum Tank Room	**2,059.00 SF**	**377.6**	**15,357**	**28,901**		**879**		**21.92 /SF**	**45,137**	**41.25 /SF**	**84,940**
			Floor and Wal Repairs: Polymer Prep Area											
			Thermal & Moisture Protection, Caulking and Sealants											

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	122.50 lf	10.2	395	-	-	-	-	3.22 /lf	395	6.06 /lf	743
			Caulking and sealants, backer rod, polyethylene, 1" dia	1.25 clf	3.8	178	63	-	-	-	192.63 /clf	241	362.50 /clf	453
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	122.50 lf	12.3	582	169	-	-	-	6.13 /lf	751	11.54 /lf	1,414
			Thermal & Moisture Protection, Caulking and Sealants	**122.50 LF**	**26.2**	**1,155**	**232**				**11.32 /LF**	**1,387**	**21.31 /LF**	**2,610**
			Finishes, Surface Preparation											
			Surface Preparation, pressure wash floor slab surfaces to remove existing coating, based on 2500 lb operating pressure, and haul for disposal	1,675.00 sf	87.1	3,367	-	-	715	-	2.44 /sf	4,082	4.59 /sf	7,682
			Surface Preparation, pressure wash pads, walls, col, stair & landings to remove ex coating, based on 2500 lb operating pressure, and haul for disposal	1,976.44 sf	102.8	3,973	-	-	844	-	2.44 /sf	4,817	4.59 /sf	9,065
			Surface Preparation, remove all deterioated concrete and prep surface for new coating/topping	3,651.44 sf	67.9	2,810	-	-	-	-	0.77 /sf	2,810	1.45 /sf	5,288
			Finishes, Surface Preparation	**3,651.44 SF**	**257.8**	**10,151**			**1,559**		**3.21 /SF**	**11,710**	**6.03 /SF**	**22,035**
			Finishes, Topical Vapor Barrier											
			Apply epoxy resin based vapor barrier sytem 2 coats, to floor slab	1,675.00 sf	30.6	1,264	3,350	-	-	-	2.76 /sf	4,614	5.18 /sf	8,683
			Apply epoxy resin based vapor barrier sytem 2 coats, to walls,pads, stairs, and landings, surfaces	1,976.44 sf	36.1	1,492	3,953	-	-	-	2.76 /sf	5,444	5.18 /sf	10,245
			Finishes, Topical Vapor Barrier	**3,651.44 SF**	**66.6**	**2,756**	**7,303**				**2.76 /SF**	**10,058**	**5.18 /SF**	**18,928**
			Finishes, Chemical Resistant Coating											
			Chemical resistant coatings, Tnemec coating to floor, resin base, max	1,675.00 sf	167.5	6,930	20,100	-	-	-	16.14 /sf	27,030	30.37 /sf	50,866
			Chemical resistant coatings, Tnemec coating to walls, pads, stairs & landings, resin base, max	1,976.44 sf	197.6	8,177	23,717	-	-	-	16.14 /sf	31,895	30.37 /sf	60,019
			Finishes, Chemical Resistant Coating	**3,651.44 SF**	**365.1**	**15,107**	**43,817**				**16.14 /SF**	**58,925**	**30.37 /SF**	**110,885**
			Floor and Wal Repairs: Polymer Prep Area	**3,651.44 SF**	**715.7**	**29,169**	**51,352**		**1,559**		**22.48 /SF**	**82,080**	**42.30 /SF**	**154,458**
			Floor and Wall Repairs: Sulfuric Acid Room											
			Cast-In-Place Concrete, Fill/Topping/Grouting											
			Fiber reinforced grout topping; self-level/dry 6100 psi, pumped, to 1-1/2"	918.00 sf	3.4	146	13,082	-	34	-	14.45 /sf	13,261	27.18 /sf	24,955
			Cast-In-Place Concrete, Fill/Topping/Grouting	**918.00 SF**	**3.4**	**146**	**13,082**		**34**		**14.45 /SF**	**13,261**	**27.18 /SF**	**24,955**
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	127.00 lf	10.6	409	-	-	-	-	3.22 /lf	409	6.06 /lf	770
			Caulking and sealants, backer rod, polyethylene, 1" dia	1.27 clf	3.8	181	64	-	-	-	192.63 /clf	245	362.48 /clf	460
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	127.00 lf	12.7	604	175	-	-	-	6.13 /lf	779	11.54 /lf	1,466
			Thermal & Moisture Protection, Caulking and Sealants	**127.00 LF**	**27.1**	**1,194**	**239**				**11.28 /LF**	**1,433**	**21.23 /LF**	**2,696**
			Finishes, Surface Preparation											
			Surface Preparation, pressure wash floor slab surfaces to remove existing coating, based on 2500 lb operating pressure, and haul for disposal	918.00 sf	47.7	1,846	-	-	392	-	2.44 /sf	2,237	4.59 /sf	4,210
			Surface Preparation, pressure wash pads, walls, col, stair & landings to remove ex coating, based on 2500 lb operating pressure, and haul for disposal	848.00 sf	44.1	1,705	-	-	362	-	2.44 /sf	2,067	4.59 /sf	3,889
			Surface Preparation, remove all deterioated concrete and prep surface for new coating/topping	1,766.00 sf	32.8	1,359	-	-	-	-	0.77 /sf	1,359	1.45 /sf	2,557
			Finishes, Surface Preparation	**1,766.00 SF**	**124.7**	**4,909**			**754**		**3.21 /SF**	**5,663**	**6.03 /SF**	**10,657**
			Finishes, Topical Vapor Barrier											
			Apply epoxy resin based vapor barrier sytem 2 coats, to floor slab	918.00 sf	16.7	693	1,836	-	-	-	2.76 /sf	2,529	5.18 /sf	4,759
			Apply epoxy resin based vapor barrier sytem 2 coats, to walls,pads, stairs, and landings, surfaces	848.00 sf	15.5	640	1,696	-	-	-	2.76 /sf	2,336	5.18 /sf	4,396
			Finishes, Topical Vapor Barrier	**1,766.00 SF**	**32.2**	**1,333**	**3,532**				**2.76 /SF**	**4,865**	**5.18 /SF**	**9,154**
			Finishes, Chemical Resistant Coating											
			Chemical resistant coatings, Tnemec coating to floor, resin base, max	918.00 sf	91.8	3,798	11,016	-	-	-	16.14 /sf	14,814	30.37 /sf	27,877
			Chemical resistant coatings, Tnemec coating to walls, pads, stairs & landings, resin base, max	848.00 sf	84.8	3,509	10,176	-	-	-	16.14 /sf	13,685	30.37 /sf	25,752
			Finishes, Chemical Resistant Coating	**1,766.00 SF**	**176.6**	**7,307**	**21,192**				**16.14 /SF**	**28,499**	**30.37 /SF**	**53,629**
			Floor and Wall Repairs: Sulfuric Acid Room	**1,766.00 SF**	**364.0**	**14,889**	**38,044**		**788**		**30.42 /SF**	**53,721**	**57.24 /SF**	**101,092**
			Floor and Wall Repairs: Sodium Hypochlorite/Sodium Hydroxide Room											
			Thermal & Moisture Protection, Caulking and Sealants											
			Selective demolition, remove caulking/sealant, to 1" x 1" joint and clean area for new install	615.00 lf	51.2	1,981	-	-	-	-	3.22 /lf	1,981	6.06 /lf	3,728
			Caulking and sealants, backer rod, polyethylene, 1" dia	6.15 clf	18.5	877	308	-	-	-	192.63 /clf	1,185	362.49 /clf	2,229
			Caulking and sealants, polyurethane, bulk, in place, 1 or 2 component, 1" x 1/2"	615.00 lf	61.5	2,924	849	-	-	-	6.13 /lf	3,773	11.54 /lf	7,099
			Thermal & Moisture Protection, Caulking and Sealants	**615.00 LF**	**131.2**	**5,782**	**1,156**				**11.28 /LF**	**6,939**	**21.23 /LF**	**13,057**
			Finishes, Surface Preparation											

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Finishes, Surface Preparation											
			Surface Preparation, pressure wash floor slab surfaces to remove existing coating, based on 2500 lb operating pressure, and haul for disposal	4,139.00 sf	215.2	8,321	-	-	1,767	-	2.44 /sf	10,088	4.59 /sf	18,984
			Surface Preparation, pressure wash pads, walls, col, stair & landings to remove ex coating, based on 2500 lb operating pressure, and haul for disposal	3,583.00 sf	186.3	7,203	-	-	1,530	-	2.44 /sf	8,733	4.59 /sf	16,433
			Surface Preparation, remove all deterioated concrete and prep surface for new coating/topping	7,722.00 sf	143.6	5,943	-	-	-	-	0.77 /sf	5,943	1.45 /sf	11,183
			Finishes, Surface Preparation	**7,722.00 SF**	**545.2**	**21,467**			**3,297**		**3.21 /SF**	**24,763**	**6.03 /SF**	**46,600**
			Finishes, Topical Vapor Barrier											
			Apply epoxy resin based vapor barrier sytem 2 coats, to floor slab	4,139.00 sf	75.5	3,124	8,278	-	-	-	2.76 /sf	11,402	5.18 /sf	21,456
			Apply epoxy resin based vapor barrier sytem 2 coats, to walls,pads, stairs, and landings, surfaces	3,583.00 sf	65.4	2,704	7,166	-	-	-	2.76 /sf	9,870	5.18 /sf	18,573
			Finishes, Topical Vapor Barrier	**7,722.00 SF**	**140.8**	**5,828**	**15,444**				**2.76 /SF**	**21,272**	**5.18 /SF**	**40,029**
			Finishes, Chemical Resistant Coating											
			Chemical resistant coatings, Tnemec coating to floor, resin base, max	4,139.00 sf	413.9	17,125	49,668	-	-	-	16.14 /sf	66,793	30.37 /sf	125,691
			Chemical resistant coatings, Tnemec coating to walls, pads, stairs & landings, resin base, max	3,583.00 sf	358.3	14,824	42,996	-	-	-	16.14 /sf	57,820	30.37 /sf	108,807
			Finishes, Chemical Resistant Coating	**7,722.00 SF**	**772.2**	**31,949**	**92,664**				**16.14 /SF**	**124,613**	**30.37 /SF**	**234,498**
			Floor and Wall Repairs: Sodium Hypochlorite/Sodium Hydroxide Room	**7,722.00 SF**	**1,589.4**	**65,026**	**109,264**		**3,297**		**23.00 /SF**	**177,586**	**43.28 /SF**	**334,183**
			09.10 Finishes, Special Coatings	**1.00 LS**	**4,142.5**	**169,338**	**329,773**		**8,816**		**507,927.02 /LS**	**507,927**	**955,820.80 /LS**	**955,821**
			09.0 Finishes	**1.00 LS**	**4,142.5**	**169,338**	**329,773**		**8,816**		**507,927.02 /LS**	**507,927**	**955,820.80 /LS**	**955,821**
	10.0		**Specialties**											
		10.00	**Specialties**											
			Fire Extinguisher											
			Specialties Fire Protection Specialties											
			Fire equipment cabinets,portable extinguisher,single,steel box,recessed,ds glass door,stainless steel door&frame,8"x12"x27",excludes equipment	3.00 ea	6.0	310	648	-	-	-	319.37 /ea	958	600.99 /ea	1,803
			Fire extinguishers, dry chemical, pressurized, standard type, portable, painted, 30 lb	3.00 ea		-	1,305	-	-	-	435.00 /ea	1,305	818.59 /ea	2,456
			Specialties Fire Protection Specialties	**3.00 EA**	**6.0**	**310**	**1,953**				**754.37 /EA**	**2,263**	**1,419.58 /EA**	**4,259**
			Fire Extinguisher	**1.00 LS**	**6.0**	**310**	**1,953**				**2,263.10 /LS**	**2,263**	**4,258.74 /LS**	**4,259**
			Signage											
			Specialties, Other											
			Miscellaneous signage allowance	1.00 ea			0	6,500	-	-	6,500.00 /ea	6,500	12,231.74 /ea	12,232
			Specialties, Other	**1.00 LS**				**6,500**			**6,500.00 /LS**	**6,500**	**12,231.74 /LS**	**12,232**
			Signage	**1.00 LS**				**6,500**			**6,500.00 /LS**	**6,500**	**12,231.74 /LS**	**12,232**
			10.00 Specialties	**1.00 LS**	**6.0**	**310**	**1,953**	**6,500**			**8,763.10 /LS**	**8,763**	**16,490.48 /LS**	**16,490**
			10.0 Specialties	**1.00 LS**	**6.0**	**310**	**1,953**	**6,500**			**8,763.10 /LS**	**8,763**	**16,490.48 /LS**	**16,490**
	14.0		**Conveying Equipment**											
		14.00	**Conveying Equipment**											
			Monorail Hoist											
			Material Handling, Other											
			Material Handling Hoists, electric overhead, chain, hook hung, 15' lift, 7.5 ton capacity	1.00 ea	36.0	2,095	18,500	-	-	-	20,595.20 /ea	20,595	38,756.19 /ea	38,756
			Material Handling, Other	**1.00 EA**	**36.0**	**2,095**	**18,500**				**20,595.20 /EA**	**20,595**	**38,756.19 /EA**	**38,756**
			Monorail Hoist	**1.00 EA**	**36.0**	**2,095**	**18,500**				**20,595.20 /EA**	**20,595**	**38,756.19 /EA**	**38,756**
			14.00 Conveying Equipment	**1.00 LS**	**36.0**	**2,095**	**18,500**				**20,595.20 /LS**	**20,595**	**38,756.19 /LS**	**38,756**
			14.0 Conveying Equipment	**1.00 LS**	**36.0**	**2,095**	**18,500**				**20,595.20 /LS**	**20,595**	**38,756.19 /LS**	**38,756**
	22.0		**Plumbing**											
		22.00	**Plumbing**											
			Miscellaneous Plumbing											
			Mechanical, Plumbing											
			Miscellaneous plumbing allowance	1.00 ea				10,000	-	-	10,000.00 /ea	10,000	19,318.08 /ea	19,318
			Re-install existing Water heater and recirulation pump	1.00 ea	24.0	1,313	500	-	-	-	1,812.94 /ea	1,813	3,502.25 /ea	3,502
			Mechanical, Plumbing	**1.00 LS**	**24.0**	**1,313**	**500**	**10,000**			**11,812.94 /LS**	**11,813**	**22,820.33 /LS**	**22,820**
			Miscellaneous Plumbing	**1.00 LS**	**24.0**	**1,313**	**500**	**10,000**			**11,812.94 /LS**	**11,813**	**22,820.33 /LS**	**22,820**
			22.00 Plumbing	**1.00 LS**	**24.0**	**1,313**	**500**	**10,000**			**11,812.94 /LS**	**11,813**	**22,820.33 /LS**	**22,820**
			22.0 Plumbing	**1.00 LS**	**24.0**	**1,313**	**500**	**10,000**			**11,812.94 /LS**	**11,813**	**22,820.33 /LS**	**22,820**
	23.0		**HVAC**											
		23.00	**HVAC**											
			HVAC Equipment											
			Mechanical, HVAC											

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			Mechanical, HVAC											
			Rooftop air conditioner, multizone, electric cool, gas heat, 16.5 ton cooling, 360 MBH heating, includes, standard controls, curb and economizer	2.00 ea	105.1	5,818	132,000	-	4,656	-	71,237.01 /ea	142,474	137,616.17 /ea	275,232
			Mechanical, HVAC	**1.00 LS**	**105.1**	**5,818**	**132,000**		**4,656**		**142,474.01 /LS**	**142,474**	**275,232.35 /LS**	**275,232**
			Electrical Equipment, VFDs - 1 to 5 HP											
			Variable frequency drives, enclosed, 460 volt, 5 HP motor size, NEMA 1	4.00 ea	40.0	2,178	14,000	-	-	-	4,044.46 /ea	16,178	7,813.12 /ea	31,252
			Electrical Equipment, VFDs - 1 to 5 HP	**4.00 EA**	**40.0**	**2,178**	**14,000**				**4,044.46 /EA**	**16,178**	**7,813.12 /EA**	**31,252**
			HVAC Equipment	**1.00 LS**	**145.1**	**7,996**	**146,000**		**4,656**		**158,651.85 /LS**	**158,652**	**306,484.83 /LS**	**306,485**
			HVAC Duct Work and Accessories											
			Mechanical, HVAC											
			Unit Heater 3 kw 1Ph	2.00 E	8.0	427	1,500	-	-	-	963.67 /E	1,927	1,861.61 /E	3,723
			Balancing, air, heating and ventilating unit, (Subcontractor's quote including material & labor)	1.00 ea	40.0	6,000	-	-	-		6,000.00 /ea	6,000	11,590.84 /ea	11,591
			HVAC Controls Allowance	1.00 ea		-	-	10,000	-	415	10,415.00 /ea	10,415	20,119.78 /ea	20,120
			Metal ductwrk,fabrctd rctnglr,1000 2000lb, aluminm alloy 3003-h14,includs fittngs,joints,supprts and allownc for a flexibl connctn,excludes insulation	3,113.00 lb	933.9	48,966	7,783	-	-	-	18.23 /lb	56,749	35.22 /lb	109,628
			Duct accessories, fire damper, curtain type, vertical, 36" x 36", U.L. label, 1-1/2 hour rated	4.00 ea	6.4	332	544	-	-	-	218.88 /ea	876	422.83 /ea	1,691
			Duct accessories, motorized damper, 48" x 24"	2.00 ea	4.0	215	690	-	-	-	452.40 /ea	905	873.95 /ea	1,748
			Duct accessories, motorized damper, 38" x 32"	2.00 ea	5.3	286	760	-	-	-	523.20 /ea	1,046	1,010.73 /ea	2,021
			Allowance for miscellaneous grilles, registers and diffusers	1.00 ea				6,500	-	-	6,500.00 /ea	6,500	12,556.73 /ea	12,557
			Fans,,supply fan,aluminum wheel/hub,7000 cfm	2.00 ea	32.0	1,675	5,500	-	-	-	3,587.25 /ea	7,175	6,929.88 /ea	13,860
			Exhaust, centrifugal, 7000 CFM,	2.00 ea	32.0	1,675	4,400	-	-	-	3,037.25 /ea	6,075	5,867.38 /ea	11,735
			Mechanical, HVAC	**1.00 LS**	**1,061.6**	**59,575**	**21,177**	**16,500**		**415**	**97,666.78 /LS**	**97,667**	**188,673.39 /LS**	**188,673**
			HVAC Duct Work and Accessories	**1.00 LS**	**1,061.6**	**59,575**	**21,177**	**16,500**		**415**	**97,666.78 /LS**	**97,667**	**188,673.39 /LS**	**188,673**
			23.00 HVAC	**1.00 LS**	**1,206.7**	**67,571**	**167,177**	**16,500**	**4,656**	**415**	**256,318.63 /LS**	**256,319**	**495,158.22 /LS**	**495,158**
			23.0 HVAC	**1.00 LS**	**1,206.7**	**67,571**	**167,177**	**16,500**	**4,656**	**415**	**256,318.63 /LS**	**256,319**	**495,158.22 /LS**	**495,158**
	26.0		**Electrical Work**											
		26.20	**Facility Electrical**											
			Electrical Allowance											
			Electrical, Other											
			Electrical Allowance - 20% of total direct cost	1.00 ls		-	-	491,321	-	-	491,321.00 /ls	491,321	973,703.58 /ls	973,704
			Electrical, Other	**1.00 LS**				**491,321**			**491,321.00 /LS**	**491,321**	**973,703.58 /LS**	**973,704**
			Electrical Allowance	**1.00 LS**				**491,321**			**491,321.00 /LS**	**491,321**	**973,703.58 /LS**	**973,704**
			26.20 Facility Electrical	**1.00 LS**				**491,321**			**491,321.00 /LS**	**491,321**	**973,703.58 /LS**	**973,704**
		26.25	**Electrical Equipment**											
			Variable Frequency Drive											
			Electrical Equipment, VFDs - 300 HP											
			Variable frequency drives, custom-engineered, 460 volt, 200 HP motor size	6.00 ea	413.8	22,366	600,000	-	2,278	-	104,107.37 /ea	624,644	206,320.75 /ea	1,237,925
			Electrical Equipment, VFDs - 300 HP	**6.00 EA**	**413.8**	**22,366**	**600,000**		**2,278**		**104,107.37 /EA**	**624,644**	**206,320.75 /EA**	**1,237,925**
			Variable Frequency Drive	**6.00 EA**	**413.8**	**22,366**	**600,000**		**2,278**		**104,107.37 /EA**	**624,644**	**206,320.75 /EA**	**1,237,925**
			26.25 Electrical Equipment	**1.00 LS**	**413.8**	**22,366**	**600,000**		**2,278**		**624,644.20 /LS**	**624,644**	**1,237,924.50 /LS**	**1,237,925**
			26.0 Electrical Work	**1.00 LS**	**413.8**	**22,366**	**600,000**	**491,321**	**2,278**		**1,115,965.20 /LS**	**1,115,965**	**2,211,628.08 /LS**	**2,211,628**
	40.0		**Process Pipe**											
		40.00	**Exposed Process Pipe**											
			Miscellaneous Piping											
			Finishes, Painting Pipe											
			Paint process pipe and fittings, subcontracted, priced per LF, 36" dia.	27.00 lf		-	-	1,215	-	-	45.00 /lf	1,215	86.03 /lf	2,323
			Finishes, Painting Pipe	**27.00 LNF**				**1,215**			**45.00 /LNF**	**1,215**	**86.03 /LNF**	**2,323**
			Process Pipe, Ductile Iron, 36"											
			36" Fabricated DI Spool, FxF, 1' 6" - FURNISH	6.00 ea		-	27,030	-	-	-	4,505.00 /ea	27,030	8,612.69 /ea	51,676
			36" Fabricated DI Spool, FxF, 1' 6" - INSTALL	6.00 ea	116.4	6,250	-	-	-	-	1,041.65 /ea	6,250	1,991.43 /ea	11,949
			36" DI, FL, Ell, 90, reuse existing, install only	6.00 ea	108.5	5,829	0	-	-	-	971.56 /ea	5,829	1,857.44 /ea	11,145
			36" DI, Flex coupling	6.00 ea	101.3	5,443	4,500	-	-	-	1,657.11 /ea	9,943	3,168.08 /ea	19,008
			36" Bolt & Gasket Kits, CS, 150#	12.00 ea	103.2	5,543	3,360	-	-	-	741.88 /ea	8,903	1,418.33 /ea	17,020
			Process Pipe, Ductile Iron, 36"	**9.00 LF**	**429.5**	**23,064**	**34,890**				**6,439.39 /LF**	**57,954**	**12,310.86 /LF**	**110,798**
			Miscellaneous Piping	**9.00 LF**	**429.5**	**23,064**	**34,890**	**1,215**			**6,574.39 /LF**	**59,169**	**12,568.96 /LF**	**113,121**
			40.00 Exposed Process Pipe	**9.00 LF**	**429.5**	**23,064**	**34,890**	**1,215**			**6,574.39 /LF**	**59,169**	**12,568.96 /LF**	**113,121**
			40.0 Process Pipe	**9.00 LF**	**429.5**	**23,064**	**34,890**	**1,215**			**6,574.39 /LF**	**59,169**	**12,568.96 /LF**	**113,121**
	40.9		**Instrumentation & Controls**											
		40.90	**Instrumentation & Controls**											
			Instrumentation & Controls Allowance											
			I&C, Other											
			I&C Allowance - 10% ot total direct cost	1.00 ls		-	-	245,660	-	-	245,660.00 /ls	245,660	486,850.80 /ls	486,851

Fac	Work Pkg	Trade Pkg	Description	Takeoff Quantity	Labor Man Hrs	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Direct Cost/Unit	Direct Amount	Grand Total Unit Price	Grand Total w/Markups
			I&C, Other	**1.00 LS**				**245,660**			**245,660.00 /LS**	**245,660**	**486,850.80 /LS**	**486,851**
			Instrumentation & Controls Allowance	**1.00 LS**				**245,660**			**245,660.00 /LS**	**245,660**	**486,850.80 /LS**	**486,851**
			40.90 Instrumentation & Controls	**1.00 LS**				**245,660**			**245,660.00 /LS**	**245,660**	**486,850.80 /LS**	**486,851**
			40.9 Instrumentation & Controls	**1.00 LS**				**245,660**			**245,660.00 /LS**	**245,660**	**486,850.80 /LS**	**486,851**
	43.0		**Process Equipment - Industrial**											
		43.05	**Furnish and Install Process Equipment**											
			Equipment Primary Effluent Pump											
			Non-Clog Horizontal End Suction Centrifugal Pump: 300hp											
			Functional Testing, Pumps, 101-500 hp	6.00 ea	24.0	1,171	600	-	-	-	295.18 /ea	1,771	555.48 /ea	3,333
			Sleeved anchor bolts - Medium	48.00 ea	16.8	820	1,008	-	-	-	38.08 /ea	1,828	71.66 /ea	3,440
			Non-Shrink Machine Grout	48.00 cuft	45.6	2,225	3,552	-	-	-	120.36 /cuft	5,777	226.49 /cuft	10,871
			Grease, Oil, and Lube Pumps, 101-500 hp	6.00 ea	24.0	1,171	450	-	-	-	270.18 /ea	1,621	508.43 /ea	3,051
			FURNISH Non-Clog Horizontal End Suction Centrifugal Pump, 300 hp	6.00 EA		-	780,000	-	-	-	130,000.00 /EA	780,000	244,634.96 /EA	1,467,810
			Set pump assembly, 300 hp	6.00 ea	480.0	23,422	300	-	-	-	3,953.68 /ea	23,722	7,440.07 /ea	44,640
			Non-Clog Horizontal End Suction Centrifugal Pump: 300hp	**6.00 EA**	**590.4**	**28,809**	**785,910**				**135,786.52 /EA**	**814,719**	**255,524.09 /EA**	**1,533,145**
			Equipment Primary Effluent Pump	**6.00 EA**	**590.4**	**28,809**	**785,910**				**135,786.52 /EA**	**814,719**	**255,524.09 /EA**	**1,533,145**
			43.05 Furnish and Install Process Equipment	**1.00 LS**	**590.4**	**28,809**	**785,910**				**814,719.15 /LS**	**814,719**	**1,533,144.51 /LS**	**1,533,145**
			43.0 Process Equipment - Industrial	**1.00 LS**	**590.4**	**28,809**	**785,910**				**814,719.15 /LS**	**814,719**	**1,533,144.51 /LS**	**1,533,145**
			010 AlexRenew PEPS Modifications	**1.00 LS**	**8,731.5**	**409,870**	**1,975,836**	**785,447**	**22,019**	**415**	**3,193,586.36 /LS**	**3,193,586**	**6,161,058.55 /LS**	**6,161,059**

Job Size:	1 LS
Duration:	1 LS

Detail Report

Project:	AlexRenew PEPS Mods	Estimator:	Tweneboa-Kodua, A/WDC
Project No.:	66053	Revision / Date:	R01/9-June-2016
Design Stage:	60%	Estimate Class:	3

Estimate Totals

Construction Costs	Amount	Totals	Rate	% of Total
Labor	409,870			6.65%
Material	1,975,836			32.07%
Subcontract	785,447			12.75%
Equipment	22,019			0.36%
Other	415			0.01%
Subtotal Raw Costs	**3,193,587**	**3,193,587**		**51.84**
Material Sales & Use Tax - %				
Construction Equip Tax - %				
Total Taxes		**3,193,587**		
Existing Conditions I,OH&P	11,509		15.000 %	0.19%
Concrete Work I,OH&P	1,050		15.000 %	0.02%
Masonry Work I,OH&P	1,650		15.000 %	0.03%
Metals Work I,OH&P	2,880		15.000 %	0.05%
Architectural (Div 6-12)I,OH&P	83,313		15.000 %	1.35%
Conveying Equipment I,OH&P	3,089		15.000 %	0.05%
Mechanical Work I,OH&P	53,626		20.000 %	0.87%
Electrical Work I,OH&P	278,991		25.000 %	4.53%
Process Piping I,OH&P	10,651		18.000 %	0.17%
Instruments & Controls I,OH&P	61,415		25.000 %	1.00%
Process Equipment I,OH&P	122,208		15.000 %	1.98%
Subtotal Subcontractor I,OH&P	**630,382**	**3,823,969**		**10.23**
Contractor Contingency				
Subtotal Contingency		**3,823,969**		
General Conditions	382,397		10.000 %	6.21%
Mobilization/Demobilization	114,719		3.000 %	1.86%
Subtotal Indirect Costs	**497,116**	**4,321,085**		**8.07**
Prime Contractor Home OfficeOH	432,108		10.000 %	7.01%
Prime Contractor Profit	216,054		5.000 %	3.51%
Blder's Risk & Gen Liab Ins -%	61,611		1.000 %	1.00%
Payment & Performance Bonds	71,468		1.160 %	1.16%
Subtotal OH&P	**781,241**	**5,102,326**		**12.68**
Contractor MU on Mech OFCI				
Contractor MU on Elec OFCI				
Total MU on OFCI Equip		**5,102,326**		
Design Contingency	765,349		15.000 %	12.42%
Subtotal Contingency	**765,349**	**5,867,675**		12.42
Escalation	293,384		5.000 %	4.76%
Subtotal Escalation	**293,384**	**6,161,059**		**4.76**
Total Construction Costs		**6,161,059**		

Cover Report by Facility (Allocated)

Alexandria Renew Enterprises
Biosolids to Engergy Alternates
Construction Cost Estimate for Concetual Design

Project name	AlexRenew Solids - Energy
Estimator	Tweneboa-Kodua, A/WDC
Project Number	66053
Market Segment	Water
Business Group	WBG
Estimate Class 1-5	4
Design Stage	Concept
Project Manager	Savita Schlinsinger
Rev No. / Date	R01/12-July-2016

The construction cost estimate (s) shown herein have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. The final costs of the project will depend on actual labor and material costs, competitive market conditions, final project costs, implementation schedule and other variable factors. As a result, the final costs will vary from the estimates presented herein. Because of this, project feasibility and funding needs must be carefully reviewed prior to making specific financial decisions to help ensure proper project evauluation and adequate funding. Our estimate is based on material, equipment, and labor pricing as of the estimate revision date. The owner should be cautioned that such prices are highly subject to variation as a result of shortages resulting from recent natural disasters and current escalation trends.

Facility Summary

Project:	AlexRenew Solids - Energy	Estimator:	Tweneboa-Kodua, A/WDC
Project No.:	66053	Revision / Date:	R01/12-July-2016
Design Stage:	Concept	Estimate Class:	4

Job Size: 1 LS
Duration: 1 LS

Facility	Bid Item	Description	Total Amount
2A		**ALTERNATE 2A**	
	0001	Thickening PSD + TSD	97,819
	0002	Thickening WAS	4,350,364
	0003	Screening BTS	785,337
	0004	Anaerobic Digestion	97,819
	0005	Recuperative Thickening	2,788,044
	0006	Dewatering	3,526,914
	0007	Drying	20,059,616
	0008	Combine Heat Power (CHP)	7,411,748
	0009	Flares	19,564
	0010	Pre-Pasteurization Building	90,878
		2A ALTERNATE 2A	**39,228,102**

Facility Summary

		Project:	AlexRenew Solids - Energy
		Estimator:	Tweneboa-Kodua, A/WDC
Job Size:	1 LS	Project No.:	66053
		Revision / Date:	R01/12-July-2016
Duration:	1 LS	Design Stage:	Concept
		Estimate Class:	4

Facility	Bid Item	Description	Total Amount
2B		**ALTERNATE 2B**	
	0021	Thickening PSD + TSD	97,819
	0022	Thickening WAS	4,350,364
	0023	Screening T(PSD+TSD)	791,813
	0024	Screening TWAS	384,748
	0025	Pre-Dewatering	10,175,699
	0026	Thermal Hydrolysis WAS	4,487,461
	0027	Anaerobic Digestion	97,819
	0028	Recuperative Thickening	2,788,044
	0029	Dewatering	2,382,233
	0030	Drying	15,892,523
	0031	Boiler (High P Steam)	395,919
	0032	Combine Heat Power (CHP)	7,411,748
	0033	Flares	19,564
		2B ALTERNATE 2B	**49,275,754**

Facility Summary

CH2MHILL

Job Size: 1 LS	Project: AlexRenew Solids - Energy	Estimator: Tweneboa-Kodua, A/WDC
Duration: 1 LS	Project No.: 66053	Revision / Date: R01/12-July-2016
	Design Stage: Concept	Estimate Class: 4

Facility	Bid Item	Description	Total Amount
3B		**ALTERNATE 3B**	
	0021	Thickening PSD + TSD	97,819
	0022	Thickening WAS	4,350,364
	0023	Screening T(PSD+TSD)	784,799
	0024	Screening TWAS	384,748
	0025	Pre-Dewatering	10,175,699
	0026	Thermal Hydrolysis WAS	4,487,461
	0027	Anaerobic Digestion	97,819
	0028	Recuperative Thickening	2,788,044
	0029	Dewatering	15,152,632
	0031	Boiler (High P Steam)	395,919
	0032	Combine Heat Power (CHP)	9,244,189
	0033	Flares	19,564
	0034	Thermal Conversion of Organics	69,887,957
	0035	TCO Turbines	3,416,351
		3B ALTERNATE 3B	**121,283,365**

Facility Summary

		Project: AlexRenew Solids - Energy	Estimator: Tweneboa-Kodua, A/WDC
Job Size:	1 LS	Project No.: 66053	Revision / Date: R01/12-July-2016
Duration:	1 LS	Design Stage: Concept	Estimate Class: 4

Facility	Bid Item	Description	Total Amount
3C		**ALTERNATE 3C**	
	0021	Thickening PSD + TSD	97,819
	0022	Thickening WAS	4,350,364
	0023	Screening T(PSD+TSD)	784,799
	0024	Screening TWAS	384,748
	0025	Pre-Dewatering	12,013,405
	0026	Thermal Hydrolysis WAS	9,065,103
	0027	Anaerobic Digestion	97,819
	0028	Recuperative Thickening	2,788,044
	0029	Dewatering	17,630,970
	0031	Boiler (High P Steam)	395,919
	0032	Combine Heat Power (CHP)	9,244,189
	0033	Flares	19,564
	0034	Thermal Conversion of Organics	69,887,957
	0035	TCO Turbines	3,416,351
		3C ALTERNATE 3C	**130,177,050**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
2A						**ALTERNATE 2A**								
	0001					**Thickening PSD + TSD**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.05 /ls	97,819
						09.00.99.00 Finishes, Other	*1.00 LS*			*97,819*			*97,819.05 /LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement	**1.00 LS**			**97,819**			**97,819.05 /LS**	**97,819**
						09.00 Finishes	**1.00 LS**			**97,819**			**97,819.05 /LS**	**97,819**
						09.0 Finishes	**1.00 LS**			**97,819**			**97,819.05 /LS**	**97,819**
						0001 Thickening PSD + TSD	**1.00 LS**			**97,819**			**97,819.05 /LS**	**97,819**
	0002					**Thickening WAS**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing centrifuges and all associated works	4.00 ea	46,184		-	22,975	-	17,289.73 /ea	69,159
						02.01.05.00 Process Equipment Demolition	*4.00 EA*	*46,184*			*22,975*		*17,289.73 /EA*	*69,159*
						02.40.01.0001 Demolition	**1.00 LS**	**46,184**			**22,975**		**69,158.92 /LS**	**69,159**
						02.40 Demolition	**1.00 LS**	**46,184**			**22,975**		**69,158.92 /LS**	**69,159**
						02.0 Existing Conditions	**1.00 LS**	**46,184**			**22,975**		**69,158.92 /LS**	**69,159**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		198,638	-	-	198,638.14 /ls	198,638
						40.10.99.99 Process Pipe, Other	*1.00 LS*			*198,638*			*198,638.14 /LS*	*198,638*
						40.00.01.0001 Miscellaneous Piping and Valves	**1.00 LS**			**198,638**			**198,638.14 /LS**	**198,638**
						40.00 Exposed Process Pipe	**1.00 LF**			**198,638**			**198,638.14 /LF**	**198,638**
						40.0 Process Pipe	**1.00 LS**			**198,638**			**198,638.14 /LS**	**198,638**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	7.00 ea	1,278	685	-	-	-	280.46 /ea	1,963
						Sleeved anchor bolts - Small	28.00 ea	767	657	-	-	-	50.87 /ea	1,424
						Non-Shrink Machine Grout	14.00 cuft	1,215	2,027	-	-	-	231.53 /cuft	3,241
						Grease, Oil, and Lube Pumps, 5-20 hp	7.00 ea	1,278	1,027	-	-	-	329.36 /ea	2,306
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	7.00 EA	-	547,787	-	-	-	78,255.27 /EA	547,787
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.16 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*7.00 EA*	*13,305*	*552,330*				*80,804.99 /EA*	*565,635*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**7.00 EA**	**13,305**	**552,330**				**80,804.99 /EA**	**565,635**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.36 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.34 /EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	3,404,104	-	-	-	1,134,701.32 /ea	3,404,104
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.39 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*3.00 EA*	*77,278*	*3,411,906*		*10,564*		*1,166,582.75 /EA*	*3,499,748*
						44.05.01.0001 Equipment Centrifuges	**3.00 EA**	**81,643**	**3,411,906**		**23,383**		**1,172,310.53 /EA**	**3,516,932**
						44.05 Furnish and Install Process Equipment		**94,948**	**3,964,236**		**23,383**		**/EA**	**4,082,566**
						43.0 Process Equipment - Industrial	**1.00 LS**	**94,948**	**3,964,236**		**23,383**		**4,082,566.50 /LS**	**4,082,566**
						0002 Thickening WAS	**1.00 LS**	**141,133**	**3,964,236**	**198,638**	**46,357**		**4,350,363.56 /LS**	**4,350,364**
	0003					**Screening BTS**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.25 /ea	78,255

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.01.99.00 Special Construction, Other	*1.00 SF*			*78,255*			*78,255.25 /SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin	**1.00 LS**			**78,255**			**78,255.25 /LS**	**78,255**
						13.00 Special Construction	**1.00 LS**			**78,255**			**78,255.25 /LS**	**78,255**
						13.0 Special Construction	**1.00 SF**			**78,255**			**78,255.25 /SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.37 /EA*	*17,183*
					44.05.34.00	*New Screens*								
						Furnish Strain Press SLudge Cleaner Screen	1.00 ea		322,803	-	-	-	322,802.94 /ea	322,803
						Install Strain Press SLudge Cleaner Screen	1.00 ea	19,224		-	-	-	19,223.81 /ea	19,224
						44.05.34.00 New Screens	*1.00 EA*	*19,224*	*322,803*				*342,026.75 /EA*	*342,027*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.17 /ea	173,598
						44.05.34.01 Refurbish Existing Screens	*2.00 EA*	*17,088*		*156,511*			*86,799.17 /EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner	**1.00 EA**	**40,677**	**322,803**	**156,511**	**12,818**		**532,808.46 /EA**	**532,808**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	573	293	-	-	-	288.75 /ea	866
						Local panel	3.00 ea	1,718	8,804	-	-	-	3,507.36 /ea	10,522
						Pressure indicators	6.00 ea	859	2,935	-	-	-	632.29 /ea	3,794
						Sleeved anchor bolts - Small	12.00 ea	344	282	-	-	-	52.12 /ea	625
						Non-Shrink Machine Grout	6.00 cuft	544	869	-	-	-	235.47 /cuft	1,413
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	573	440	-	-	-	337.65 /ea	1,013
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	146,729	-	-	-	48,909.53 /EA	146,729
						Set pump assembly, 5 - 20 hp	3.00 ea	9,165	147	-	-	-	3,103.75 /ea	9,311
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*3.00 EA*	*13,775*	*160,498*				*58,091.03 /EA*	*174,273*
						44.05.01.0003 Equipment Centrifugal Pumps	**3.00 EA**	**13,775**	**160,498**				**58,091.03 /EA**	**174,273**
						44.05 Furnish and Install Process Equipment	**1.00 EA**	**54,452**	**483,301**	**156,511**	**12,818**		**707,081.54 /EA**	**707,082**
						43.0 Process Equipment - Industrial	**1.00 LS**	**54,452**	**483,301**	**156,511**	**12,818**		**707,081.54 /LS**	**707,082**
						0003 Screening BTS	**1.00 LS**	**54,452**	**483,301**	**234,766**	**12,818**		**785,336.79 /LS**	**785,337**
	0004					**Anaerobic Digestion**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.07 /ls	97,819
						09.00.99.00 Finishes, Other	*1.00 LS*			*97,819*			*97,819.07 /LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement	**1.00 LS**			**97,819**			**97,819.07 /LS**	**97,819**
						09.00 Finishes	**1.00 LS**			**97,819**			**97,819.07 /LS**	**97,819**
						09.0 Finishes	**1.00 LS**			**97,819**			**97,819.07 /LS**	**97,819**
						0004 Anaerobic Digestion	**1.00 LS**			**97,819**			**97,819.07 /LS**	**97,819**
	0005					**Recuperative Thickening**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.01.07	*General Site Demolition, Saw Cutting Concrete*								
						Sawcutting, concrete slabs, mesh or bar reinforcing, up to 12" deep	36.00 lf	828	156	-	461	-	40.11 /lf	1,444
						02.01.01.07 General Site Demolition, Saw Cutting Concrete	*36.00 LF*	*828*	*156*		*461*		*40.11 /LF*	*1,444*
					02.01.02.02	*Selective Demolition, Cut-out, Concrete, Slabs*								
						Selective demolition, cutout, slab on grade, non-reinforced, to 12" thick, 8-16 S.F., excludes loading and disposal	80.00 cf	4,834	-	-	644	-	68.47 /cf	5,478
						02.01.02.02 Selective Demolition, Cut-out, Concrete, Slabs	*80.00 CF*	*4,834*			*644*		*68.47 /CF*	*5,478*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing pumps and all associated works	4.00 ea	15,395	-		-	-	3,848.68 /ea	15,395
						Miscellaneous demolition	1.00 ls	5,773		-	-	-	5,772.89 /ls	5,773
						02.01.05.00 Process Equipment Demolition	*4.00 EA*	*21,168*					*5,291.90 /EA*	*21,168*
						02.40.01.0001 Demolition	**1.00 LS**	**26,830**	**156**		**1,104**		**28,089.35 /LS**	**28,089**
						02.40 Demolition	**1.00 LS**	**26,830**	**156**		**1,104**		**28,089.35 /LS**	**28,089**
						02.0 Existing Conditions	**1.00 LS**	**26,830**	**156**		**1,104**		**28,089.35 /LS**	**28,089**
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				03.10.01.0001		**New Sump Structure**								
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Concrete pumping, subcontract, all inclusive price	4.89 cy	-	-	241	-	-	49.22 /cy	241
						Forms in place, structural walls, to 8' high, hand set	264.00 sf	6,345	866	-	-	-	27.31 /sf	7,211
						Waterstop, PVC, center bulb, 6" wide	22.00 lf	282	144	-	-	-	19.38 /lf	426
						Speed Dowels, #7	22.00 ea	-	1,949	-	-	-	88.59 /ea	1,949
						Reinforcing in place, A615 Gr 60, priced per lbs.	880.00 lb	-	1,444	1,155	-	-	2.95 /lb	2,599
						Concrete, ready mix, 4000 psi	4.89 CY	-	1,813	-	-	-	370.76 /CY	1,813
						Add for concrete waste, 4000 psi	0.24 cy	-	90	-	-	-	370.62 /cy	90
						Placing concrete, concrete pump, for structural wall to 12" thick	4.89 cy	515	-	-	-	-	105.35 /cy	515
						Patch & plug tieholes	264.00 sf	491	17	-	-	-	1.93 /sf	508
						Sack rub	264.00 sf	1,309	26	-	-	-	5.06 /sf	1,335
						Curing, membrane spray	264.00 sf	65	35	-	-	-	0.38 /sf	100
						Below grade dampproofing, Bituminous Asphalt	132.00 sf	-	433	-	-	-	3.28 /sf	433
						03.10.00.12 Concrete, Cast-in-Place, Grade Walls, 12" Wide	*4.89 CY*	*9,007*	*6,817*	*1,396*			*3,521.46 /CY*	*17,220*
					03.10.05.12	*Cast-In-Place Concrete, Slabs on Grade, 12" thick*								
						Fine grade, for slab on grade, by hand	100.00 sf	104	12	-	-	-	1.16 /sf	116
						Concrete pumping, subcontract, all inclusive price	3.70 cy	-	-	219	-	-	59.02 /cy	219
						Slab on grade edge forms, 7" to 12"	40.00 sf	1,384	157	-	-	-	38.52 /sf	1,541
						Speed Dowels, #7	40.00 ea	-	4,250	-	-	-	106.25 /ea	4,250
						Reinforcing in place, A615 Gr 60, priced per lbs.	592.59 lb	-	1,166	933	-	-	3.54 /lb	2,099
						Concrete, ready mix, 4000 psi	3.70 CY	-	1,647	-	-	-	444.67 /CY	1,647
						Add for concrete waste, 4000 psi	0.19 cy	-	82	-	-	-	444.60 /cy	82
						Placing concrete, concrete pump	3.70 cy	413	-	-	-	-	111.50 /cy	413
						Finishing floors, monolithic, trowel finish (machine)	100.00 sf	355	8	-	-	-	3.63 /sf	363
						Curing, membrane spray	100.00 sf	30	16	-	-	-	0.46 /sf	46
						Polyethelene vapor barrier, 10 mil thick	1.00 sq	42	42	-	-	-	83.45 /sq	83
						03.10.05.12 Cast-In-Place Concrete, Slabs on Grade, 12" thick	*3.70 CY*	*2,327*	*7,380*	*1,151*			*2,934.58 /CY*	*10,858*
						03.10.01.0001 New Sump Structure	**8.59 CY**	**11,334**	**14,197**	**2,547**			**3,268.67 /CY**	**28,078**
						03.10 Cast-In-Place Concrete Work	**8.59 CY**	**11,334**	**14,197**	**2,547**			**3,268.67 /CY**	**28,078**
						03.0 Concrete Work	**8.59 CY**	**11,334**	**14,197**	**2,547**			**3,268.67 /CY**	**28,078**
		31.0				**Earthwork**								
			31.25			**Earthworks, Structural**								
				31.25.01.0001		**Structural Excavation**								
					31.25.01.00	*Earthworks, Structural, Excavation*								
						Shoring, soldier beams & lagging with tie-backs and walers, subcontracted	320.00 sf		-	24,402	-	-	76.26 /sf	24,402
						Structural Excavation, Excavator and Trucks, Small Crew, 6' depth	29.60 cy	382	-	-	465	-	28.59 /cy	846
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	11.11 sy	111	-	-	101	-	19.03 /sy	211
						Import Aggregate Base - under slab, Dozer and Traxcavator or Loader, Small Crew	5.50 tn	45	231	-	40	-	57.46 /tn	316
						Structural Backfill, Dozer and Traxcavator or Loader, Small Crew	22.93 cy	142	874	-	125	-	49.77 /cy	1,141
						Load Excess for Hauling, Rubber Tire Loader, Cat 930	29.60 cy	814	-	-	879	-	57.19 /cy	1,693
						Haul / Remove Excess, 12 yd capacity, 15 miles RT	29.60 cy	306	-	-	540	-	28.60 /cy	846
						Dump Charges for For Excess, 12 yd tandem, per cy	29.60 cy	-	2,539	-	-	-	85.79 /cy	2,539
						31.25.01.00 Earthworks, Structural, Excavation	*29.60 CY*	*1,800*	*3,644*	*24,402*	*2,149*		*1,080.92 /CY*	*31,995*
						31.25.01.0001 Structural Excavation	**29.60 CY**	**1,800**	**3,644**	**24,402**	**2,149**		**1,080.92 /CY**	**31,995**
						31.25 Earthworks, Structural	**29.60 CY**	**1,800**	**3,644**	**24,402**	**2,149**		**1,080.92 /CY**	**31,995**
						31.0 Earthwork	**1.00 LS**	**1,800**	**3,644**	**24,402**	**2,149**		**31,995.26 /LS**	**31,995**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.05 /ls	99,319
						40.10.99.99 Process Pipe, Other	*1.00 LS*			*99,319*			*99,319.05 /LS*	*99,319*
						40.00.01.0001 Miscellaneous Piping and Valves	**1.00 LS**			**99,319**			**99,319.05 /LS**	**99,319**
						40.00 Exposed Process Pipe	**1.00 LF**			**99,319**			**99,319.05 /LF**	**99,319**
						40.0 Process Pipe	**1.00 LS**			**99,319**			**99,319.05 /LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0004		**Equipment Rotary Drum Thickener**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.56 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.39 /EA*	*17,183*
					44.05.71.32	*Rotary Drum Thickener, 3 meter*								
						FURNISH Rotary Drum Thickener	3.00 ea	-	1,584,669	-	-	-	528,223.02 /ea	1,584,669

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					44.05.71.32	Rotary Drum Thickener, 3 meter								
						Install Rotary Drum Thickener	3.00 ea	88,037	-	-	-	-	29,345.73 /ea	88,037
						44.05.71.32 Rotary Drum Thickener, 3 meter	3.00 EA	88,037	1,584,669				557,568.75 /EA	1,672,706
						43.05.01.0004 Equipment Rotary Drum Thickener	**3.00 EA**	**92,403**	**1,584,669**		**12,818**		**563,296.55 /EA**	**1,689,890**
				43.05.01.0005		**Equipment Recuperative Thickening Feed Pumps**								
					44.05.40.11	Horizontal End Suction Centrifugal Pump: 5hp-20hp								
						Functional Testing, Pumps, 5-20 hp	10.00 ea	1,826	978	-	-	-	280.46 /ea	2,805
						Sleeved anchor bolts - Small	40.00 ea	1,096	939	-	-	-	50.87 /ea	2,035
						Non-Shrink Machine Grout	20.00 cuft	1,735	2,895	-	-	-	231.53 /cuft	4,631
						Grease, Oil, and Lube Pumps, 5-20 hp	10.00 ea	1,826	1,467	-	-	-	329.37 /ea	3,294
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	10.00 EA	-	782,553	-	-	-	78,255.26 /EA	782,553
						Set pump assembly, 5 - 20 hp	10.00 ea	29,222	489	-	-	-	2,971.15 /ea	29,711
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	10.00 EA	35,706	789,322				82,502.78 /EA	825,028
						43.05.01.0005 Equipment Recuperative Thickening Feed Pumps	**10.00 EA**	**35,706**	**789,322**				**82,502.78 /EA**	**825,028**
				44.05.01.0004		**Equipment Submersible Pumps**								
					44.05.49.01	Submersible Pump: 6hp-20hp								
						Functional Testing, Submersible Pumps, 6 - 20 hp	2.00 ea	764	196	-	-	-	479.69 /ea	959
						FURNISH Submersible Pump, 6 - 20 hp	2.00 EA	-	78,255	-	-	-	39,127.63 /EA	78,255
						Set base elbow / pump assembly, 6 - 20 hp	2.00 ea	4,582	196	-	-	-	2,388.95 /ea	4,778
						Stainless steel guide rails, 2"	32.00 lf	764	563	-	-	-	41.47 /lf	1,327
						Install upper guide rail bracket	2.00 ea	286	39	-	-	-	162.77 /ea	326
						44.05.49.01 Submersible Pump: 6hp-20hp	2.00 EA	6,396	79,249				42,822.60 /EA	85,645
						44.05.01.0004 Equipment Submersible Pumps	**2.00 EA**	**6,396**	**79,249**				**42,822.60 /EA**	**85,645**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**134,505**	**2,453,240**		**12,818**		**2,600,562.66 /LS**	**2,600,563**
						43.0 Process Equipment - Industrial	**1.00 LS**	**134,505**	**2,453,240**		**12,818**		**2,600,562.66 /LS**	**2,600,563**
						0005 Recuperative Thickening	**1.00 LS**	**174,468**	**2,471,237**	**126,268**	**16,071**		**2,788,044.22 /LS**	**2,788,044**
	0006					**Dewatering**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	Process Equipment Demolition								
						Demo existing centrifuges and all associated works	3.00 ea	34,638		-	17,231	-	17,289.72 /ea	51,869
						Miscellaneous demolition	1.00 .	3,849		-	-	-	3,848.60 /.	3,849
						02.01.05.00 Process Equipment Demolition	3.00 EA	38,487			17,231		18,572.59 /EA	55,718
						02.40.01.0001 Demolition	**1.00 LS**	**38,487**			**17,231**		**55,717.76 /LS**	**55,718**
						02.40 Demolition	**1.00 LS**	**38,487**			**17,231**		**55,717.76 /LS**	**55,718**
						02.0 Existing Conditions	**1.00 LS**	**38,487**			**17,231**		**55,717.76 /LS**	**55,718**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	Process Pipe, Other								
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.05 /ls	99,319
						40.10.99.99 Process Pipe, Other	1.00 LS			99,319			99,319.05 /LS	99,319
						40.00.01.0001 Miscellaneous Piping and Valves	**1.00 LS**			**99,319**			**99,319.05 /LS**	**99,319**
						40.00 Exposed Process Pipe	**1.00 LF**			**99,319**			**99,319.05 /LF**	**99,319**
						40.0 Process Pipe	**1.00 LS**			**99,319**			**99,319.05 /LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	Horizontal End Suction Centrifugal Pump: 5hp-20hp								
						Functional Testing, Pumps, 5-20 hp	5.00 ea	913	489	-	-	-	280.46 /ea	1,402
						Sleeved anchor bolts - Small	20.00 ea	548	470	-	-	-	50.88 /ea	1,017
						Non-Shrink Machine Grout	10.00 cuft	868	1,448	-	-	-	231.52 /cuft	2,315
						Grease, Oil, and Lube Pumps, 5-20 hp	5.00 ea	913	734	-	-	-	329.37 /ea	1,647
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	5.00 EA	-	391,276	-	-	-	78,255.26 /EA	391,276
						Set pump assembly, 5 - 20 hp	5.00 ea	14,611	245	-	-	-	2,971.15 /ea	14,856
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	5.00 EA	17,853	394,661				82,502.79 /EA	412,514
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**5.00 EA**	**17,853**	**394,661**				**82,502.79 /EA**	**412,514**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	Process Equipment, General Conditions								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	3.00 EA	4,365			12,818		5,727.79 /EA	17,183
					43.05.10.01	Liquid Centrifuge: 150-249 gpm								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	2,846,535	-	-	-	948,845.07 /ea	2,846,535
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.39 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*3.00 EA*	*77,278*	*2,854,337*		*10,564*		*980,726.49 /EA*	*2,942,179*
						44.05.01.0001 Equipment Centrifuges	**3.00 EA**	**81,643**	**2,854,337**		**23,383**		**986,454.28 /EA**	**2,959,363**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**99,496**	**3,248,998**		**23,383**		**3,371,876.78 /LS**	**3,371,877**
						43.0 Process Equipment - Industrial	**1.00 LS**	**99,496**	**3,248,998**		**23,383**		**3,371,876.78 /LS**	**3,371,877**
						0006 Dewatering	**1.00 LS**	**137,983**	**3,248,998**	**99,319**	**40,614**		**3,526,913.59 /LS**	**3,526,914**
	0007					**Drying**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0001		**Dryer Building**								
					13.01.99.00	*Special Construction, Other*								
						Dryer Building 46' x 155', including foundation, superstructure and finishes	7,130.00 sf	-	-	7,671,950	-	-	1,076.01 /sf	7,671,950
						13.01.99.00 Special Construction, Other	*7,130.00 SF*			*7,671,950*			*1,076.01 /SF*	*7,671,950*
						13.10.01.0001 Dryer Building	**7,130.00 SF**			**7,671,950**			**1,076.01 /SF**	**7,671,950**
						13.00 Special Construction	**1.00 LS**			**7,671,950**			**7,671,950.34 /LS**	**7,671,950**
						13.0 Special Construction	**7,130.00 SF**			**7,671,950**			**1,076.01 /SF**	**7,671,950**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (10% of total direct cost)	1.00 ls	-	-	372,799	-	-	372,799.36 /ls	372,799
						26.00.99.00 Electrical, Other				*372,799*			*/LS*	*372,799*
						26.15.01.0007 Miscellaneous Electrical				**372,799**			**/LS**	**372,799**
						26.00 Electrical				**372,799**			**/LS**	**372,799**
						26.0 Electrical Work				**372,799**			**/LS**	**372,799**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (6% of total direct cost)	1.00 ls	-	-	224,146	-	-	224,145.60 /ls	224,146
						40.90.99.01 I&C, Other				*224,146*			*/LS*	*224,146*
						40.90.01.0002 Miscellaneous I&C				**224,146**			**/LS**	**224,146**
						40.90 Instrumentation and Controls				**224,146**			**/LS**	**224,146**
						40.9 Instrumentation & Controls				**224,146**			**/LS**	**224,146**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0006		**Equipment Dryer Package**								
					41.00.01.04	*Material Handling, Other Conveyors*								
						Equipment, conveyors	120.00 lf			586,914	-	-	4,890.95 /lf	586,914
						41.00.01.04 Material Handling, Other Conveyors	*120.00 LF*			*586,914*			*4,890.95 /LF*	*586,914*
					44.05.82.30	*Sludge Dryer*								
						Furnish Dryer Package	1.00 ls		11,002,690	-		-	11,002,689.99 /ls	11,002,690
						Install Dryer Package	1.00 ls	139,686	-	-	61,430	-	201,116.01 /ls	201,116
						44.05.82.30 Sludge Dryer	*1.00 EA*	*139,686*	*11,002,690*		*61,430*		*11,203,806.00 /EA*	*11,203,806*
						43.05.01.0006 Equipment Dryer Package	**1.00 LS**	**139,686**	**11,002,690**	**586,914**	**61,430**		**11,790,720.48 /LS**	**11,790,720**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**139,686**	**11,002,690**	**586,914**	**61,430**		**11,790,720.48 /LS**	**11,790,720**
						43.0 Process Equipment - Industrial	**1.00 LS**	**139,686**	**11,002,690**	**586,914**	**61,430**		**11,790,720.48 /LS**	**11,790,720**
						0007 Drying	**7,130.00 SF**	**139,686**	**11,002,690**	**8,855,810**	**61,430**		**2,813.41 /SF**	**20,059,616**
	0008					**Combine Heat Power (CHP)**								
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		397,276	-	-	397,276.33 /ls	397,276
						40.10.99.99 Process Pipe, Other	*1.00 LS*			*397,276*			*397,276.33 /LS*	*397,276*
						40.00.01.0001 Miscellaneous Piping and Valves	**1.00 LS**			**397,276**			**397,276.33 /LS**	**397,276**
						40.00 Exposed Process Pipe	**1.00 LF**			**397,276**			**397,276.33 /LF**	**397,276**
						40.0 Process Pipe	**1.00 LS**			**397,276**			**397,276.33 /LS**	**397,276**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0009		**Combine Heat Power**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183

CH2MHILL

Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.36 /EA*	*17,183*
					43.05.28.00	*Energy Recovery*								
						Furnish Combine Heat Power Package	1.00 ea		6,847,336	-		-	6,847,335.51 /ea	6,847,336
						Install Combine Heat Power Package	1.00 ea	132,183		-	17,770	-	149,952.59 /ea	149,953
						43.05.28.00 Energy Recovery	*1.00 EA*	*132,183*	*6,847,336*		*17,770*		*6,997,288.10 /EA*	*6,997,288*
						43.05.01.0009 Combine Heat Power	**1.00 EA**	**136,548**	**6,847,336**		**30,588**		**7,014,471.46 /EA**	**7,014,471**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**136,548**	**6,847,336**		**30,588**		**7,014,471.46 /LS**	**7,014,471**
						43.0 Process Equipment - Industrial	**1.00 LS**	**136,548**	**6,847,336**		**30,588**		**7,014,471.46 /LS**	**7,014,471**
						0008 Combine Heat Power (CHP)	**1.00 LS**	**136,548**	**6,847,336**	**397,276**	**30,588**		**7,411,747.79 /LS**	**7,411,748**
	0009					**Flares**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	19,564	-	-	19,563.82 /ls	19,564
						09.00.99.00 Finishes, Other				*19,564*			*/LS*	*19,564*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**19,564**			**/LS**	**19,564**
						09.00 Finishes				**19,564**			**/LS**	**19,564**
						09.0 Finishes				**19,564**			**/LS**	**19,564**
						0009 Flares	**1.00 LS**			**19,564**			**19,563.82 /LS**	**19,564**
	0010					**Pre-Pasteurization Building**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	17,124		-	-	-	17,124.13 /ls	17,124
						02.01.04.20 Piping Demolition	*1.00 LS*	*17,124*					*17,124.13 /LS*	*17,124*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing tanks 12K gallon	3.00 ea	28,865		-	10,339	-	13,067.90 /ea	39,204
						Demo existing Hex	3.00 ea	17,319		-	17,231	-	11,516.71 /ea	34,550
						02.01.05.00 Process Equipment Demolition	*6.00 EA*	*46,184*			*27,570*		*12,292.30 /EA*	*73,754*
						02.40.01.0001 Demolition	**1.00 LS**	**63,308**			**27,570**		**90,877.95 /LS**	**90,878**
						02.40 Demolition	**1.00 LS**	**63,308**			**27,570**		**90,877.95 /LS**	**90,878**
						02.0 Existing Conditions	**1.00 LS**	**63,308**			**27,570**		**90,877.95 /LS**	**90,878**
						0010 Pre-Pasteurization Building	**1.00 LS**	**63,308**			**27,570**		**90,877.95 /LS**	**90,878**
						2A ALTERNATE 2A	**1.00 LS**	**847,578**	**28,017,797**	**10,127,279**	**235,448**		**39,228,101.62 /LS**	**39,228,102**

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Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
2B						**ALTERNATE 2B**								
	0021					**Thickening PSD + TSD**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.09 /ls	97,819
						09.00.99.00 Finishes, Other				*97,819*			*/LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**97,819**			**/LS**	**97,819**
						09.00 Finishes				**97,819**			**/LS**	**97,819**
						09.0 Finishes				**97,819**			**/LS**	**97,819**
						0021 Thickening PSD + TSD	**1.00 LS**			**97,819**			**97,819.09 /LS**	**97,819**
	0022					**Thickening WAS**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing centrifuges and all associated works	4.00 ea	46,184		-	22,975	-	17,289.72 /ea	69,159
						02.01.05.00 Process Equipment Demolition		*46,184*			*22,975*		*/EA*	*69,159*
						02.40.01.0001 Demolition		**46,184**			**22,975**		**/LS**	**69,159**
						02.40 Demolition		**46,184**			**22,975**		**/LS**	**69,159**
						02.0 Existing Conditions		**46,184**			**22,975**		**/LS**	**69,159**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		198,638	-	-	198,638.15 /ls	198,638
						40.10.99.99 Process Pipe, Other				*198,638*			*/LS*	*198,638*
						40.00.01.0001 Miscellaneous Piping and Valves				**198,638**			**/LS**	**198,638**
						40.00 Exposed Process Pipe				**198,638**			**/LF**	**198,638**
						40.0 Process Pipe				**198,638**			**/LS**	**198,638**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	7.00 ea	1,278	685	-	-	-	280.46 /ea	1,963
						Sleeved anchor bolts - Small	28.00 ea	767	657	-	-	-	50.87 /ea	1,424
						Non-Shrink Machine Grout	14.00 cuft	1,215	2,027	-	-	-	231.53 /cuft	3,241
						Grease, Oil, and Lube Pumps, 5-20 hp	7.00 ea	1,278	1,027	-	-	-	329.37 /ea	2,306
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	7.00 EA	-	547,787	-	-	-	78,255.26 /EA	547,787
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.14 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*13,305*	*552,330*				*/EA*	*565,635*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**13,305**	**552,330**				**/EA**	**565,635**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.60 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	3,404,104	-	-	-	1,134,701.31 /ea	3,404,104
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.39 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm		*77,278*	*3,411,906*		*10,564*		*/EA*	*3,499,748*
						44.05.01.0001 Equipment Centrifuges		**81,643**	**3,411,906**		**23,383**		**/EA**	**3,516,932**
						44.05 Furnish and Install Process Equipment		**94,948**	**3,964,236**		**23,383**		**/EA**	**4,082,566**
						43.0 Process Equipment - Industrial		**94,948**	**3,964,236**		**23,383**		**/LS**	**4,082,566**
						0022 Thickening WAS	**1.00 LS**	**141,133**	**3,964,236**	**198,638**	**46,357**		**4,350,363.51 /LS**	**4,350,364**
	0023					**Screening T(PSD+TSD)**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.25 /ea	78,255

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction	**1.00 SF**			**78,255**			**78,255.25 /SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.52 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.38 /EA*	*17,183*
					44.05.34.00	*New Screens*								
						Furnish Strain Press SLudge Cleaner Screen	1.00 ea		322,803	-	-	-	322,802.97 /ea	322,803
						Install Strain Press SLudge Cleaner Screen	1.00 ea	19,224		-	-	-	19,223.79 /ea	19,224
						44.05.34.00 New Screens	*1.00 EA*	*19,224*	*322,803*				*342,026.76 /EA*	*342,027*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.18 /ea	173,598
						44.05.34.01 Refurbish Existing Screens	*2.00 EA*	*17,088*		*156,511*			*86,799.18 /EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner	**3.00 EA**	**40,677**	**322,803**	**156,511**	**12,818**		**177,602.83 /EA**	**532,808**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	573	293	-	-	-	288.75 /ea	866
						Local panel	5.00 ea	2,864	14,673	-	-	-	3,507.35 /ea	17,537
						Pressure indicators	3.00 ea	430	1,467	-	-	-	632.29 /ea	1,897
						Sleeved anchor bolts - Small	20.00 ea	573	470	-	-	-	52.12 /ea	1,042
						Non-Shrink Machine Grout	10.00 cuft	907	1,448	-	-	-	235.46 /cuft	2,355
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	573	440	-	-	-	337.66 /ea	1,013
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	146,729	-	-	-	48,909.54 /EA	146,729
						Set pump assembly, 5 - 20 hp	3.00 ea	9,165	147	-	-	-	3,103.75 /ea	9,311
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*3.00 EA*	*15,083*	*165,666*				*60,249.89 /EA*	*180,750*
						44.05.01.0003 Equipment Centrifugal Pumps	**3.00 EA**	**15,083**	**165,666**				**60,249.89 /EA**	**180,750**
						44.05 Furnish and Install Process Equipment		**55,760**	**488,469**	**156,511**	**12,818**		**/EA**	**713,558**
						43.0 Process Equipment - Industrial	**1.00 LS**	**55,760**	**488,469**	**156,511**	**12,818**		**713,558.15 /LS**	**713,558**
						0023 Screening T(PSD+TSD)	**1.00 LS**	**55,760**	**488,469**	**234,766**	**12,818**		**791,813.40 /LS**	**791,813**
	0024					**Screening TWAS**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.26 /ea	78,255
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction				**78,255**			**/SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.37 /EA*	*17,183*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.17 /ea	173,598
						44.05.34.01 Refurbish Existing Screens	*2.00 EA*	*17,088*		*156,511*			*86,799.17 /EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner	**2.00 EA**	**21,453**		**156,511**	**12,818**		**95,390.85 /EA**	**190,782**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	2.00 ea	382	196	-	-	-	288.74 /ea	577
						Local panel	2.00 ea	1,146	5,869	-	-	-	3,507.35 /ea	7,015
						Pressure indicators	4.00 ea	573	1,956	-	-	-	632.30 /ea	2,529
						Sleeved anchor bolts - Small	8.00 ea	229	188	-	-	-	52.11 /ea	417
						Non-Shrink Machine Grout	2.00 cuft	181	290	-	-	-	235.48 /cuft	471
						Grease, Oil, and Lube Pumps, 5-20 hp	2.00 ea	382	293	-	-	-	337.64 /ea	675
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	2.00 EA	-	97,819	-	-	-	48,909.54 /EA	97,819
						Set pump assembly, 5 - 20 hp	2.00 ea	6,110	98	-	-	-	3,103.74 /ea	6,207

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Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*2.00 EA*	*9,002*	*106,709*				*57,855.53 /EA*	*115,711*
						44.05.01.0003 Equipment Centrifugal Pumps	**2.00 EA**	**9,002**	**106,709**				**57,855.53 /EA**	**115,711**
						44.05 Furnish and Install Process Equipment		**30,455**	**106,709**	**156,511**	**12,818**		**/EA**	**306,493**
						43.0 Process Equipment - Industrial		**30,455**	**106,709**	**156,511**	**12,818**		**/LS**	**306,493**
						0024 Screening TWAS	**1.00 LS**	**30,455**	**106,709**	**234,766**	**12,818**		**384,748.03 /LS**	**384,748**
	0025					**Pre-Dewatering**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.02.00	*Structure/Building Demolition*								
						Demo Building, 88' x 38'x 30' high Concrete, per cubic foot and haul debris away for disposal	100,320.00 cf		-	166,825	-	-	1.66 /cf	166,825
						02.01.02.00 Structure/Building Demolition	*3,344.00 SF*			*166,825*			*49.89 /SF*	*166,825*
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	17,124		-	-	-	17,124.12 /ls	17,124
						02.01.04.20 Piping Demolition		*17,124*					*/LS*	*17,124*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing tanks 12K gallon	3.00 ea	28,865		-	10,339	-	13,067.90 /ea	39,204
						Demo existing Hex	3.00 ea	17,319		-	17,231	-	11,516.71 /ea	34,550
						Miscellaneous demolition	1.00 .	19,243		-	-	-	19,242.95 /.	19,243
						02.01.05.00 Process Equipment Demolition	*6.00 EA*	*65,427*			*27,570*		*15,499.46 /EA*	*92,997*
						02.40.01.0001 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
						02.40 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
						02.0 Existing Conditions		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 32' x 40' - 3 Story Building, including foundation, superstructure and finishes	3,840.00 sf	-	-	4,131,878	-	-	1,076.01 /sf	4,131,878
						13.01.99.00 Special Construction, Other	*3,840.00 SF*			*4,131,878*			*1,076.01 /SF*	*4,131,878*
						13.10.01.0003 Dewatering Building	**3,840.00 SF**			**4,131,878**			**1,076.01 /SF**	**4,131,878**
						13.00 Special Construction	**1.00 LS**			**4,131,878**			**4,131,877.90 /LS**	**4,131,878**
						13.0 Special Construction				**4,131,878**			**/SF**	**4,131,878**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (12% of total direct cost)	1.00 ls	-	-	1,143,735	-	-	1,143,735.38 /ls	1,143,735
						26.00.99.00 Electrical, Other				*1,143,735*			*/LS*	*1,143,735*
						26.15.01.0007 Miscellaneous Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.00 Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.0 Electrical Work				**1,143,735**			**/LS**	**1,143,735**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, erosion control and all associated works	1.00 ls	123,623	-	-	352,972	-	476,595.52 /ls	476,596
						31.15.01.05 Site Preparation,		*123,623*			*352,972*		*/AC*	*476,596*
						31.15.01.0001 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.15 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.0 Earthwork		**123,623**			**352,972**		**/LS**	**476,596**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 10% of total direct cost	1.00 ls	-	0	898,142	-	-	898,142.43 /ls	898,142
						40.10.99.99 Process Pipe, Other				*898,142*			*/LS*	*898,142*
						40.00.01.0001 Miscellaneous Piping and Valves				**898,142**			**/LS**	**898,142**
						40.00 Exposed Process Pipe				**898,142**			**/LF**	**898,142**
						40.0 Process Pipe				**898,142**			**/LS**	**898,142**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (6% of total direct cost)	1.00 ls	-	-	774,828	-	-	774,828.13 /ls	774,828
						40.90.99.01 I&C, Other				*774,828*			*/LS*	*774,828*
						40.90.01.0002 Miscellaneous I&C				**774,828**			**/LS**	**774,828**
						40.90 Instrumentation and Controls				**774,828**			**/LS**	**774,828**
						40.9 Instrumentation & Controls				**774,828**			**/LS**	**774,828**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	6.00 ea	1,096	587	-	-	-	280.46 /ea	1,683
						Sleeved anchor bolts - Small	24.00 ea	658	563	-	-	-	50.87 /ea	1,221
						Non-Shrink Machine Grout	12.00 cuft	1,041	1,737	-	-	-	231.53 /cuft	2,778
						Grease, Oil, and Lube Pumps, 5-20 hp	6.00 ea	1,096	880	-	-	-	329.37 /ea	1,976
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	6.00 EA	-	469,532	-	-	-	78,255.26 /EA	469,532
						Set pump assembly, 5 - 20 hp	6.00 ea	17,533	293	-	-	-	2,971.15 /ea	17,827
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*6.00 EA*	*21,424*	*473,593*				*82,502.79 /EA*	*495,017*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**6.00 EA**	**21,424**	**473,593**				**82,502.79 /EA**	**495,017**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.37 /EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	16.00 ea	764	376	-	-	-	71.21 /ea	1,139
						Non-Shrink Machine Grout	33.00 cuft	2,993	4,777	-	-	-	235.46 /cuft	7,770
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	-	1,897,690	-	-	-	948,845.06 /ea	1,897,690
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	47,732	-	-	7,043	-	27,387.38 /ea	54,775
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*2.00 EA*	*51,488*	*1,902,843*		*7,043*		*980,687.25 /EA*	*1,961,374*
						44.05.01.0001 Equipment Centrifuges	**2.00 EA**	**55,854**	**1,902,843**		**19,861**		**989,278.93 /EA**	**1,978,558**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**77,277**	**2,376,436**		**19,861**		**2,473,574.58 /LS**	**2,473,575**
						43.0 Process Equipment - Industrial	**1.00 LS**	**77,277**	**2,376,436**		**19,861**		**2,473,574.58 /LS**	**2,473,575**
						0025 Pre-Dewatering	**1.00 LS**	**283,452**	**2,376,436**	**7,115,408**	**400,403**		**10,175,699.43 /LS**	**10,175,699**
	0026					**Thermal Hydrolysis WAS**								
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0002		**Concrete Pad 20' x 50' x 24" Thick**								
					03.10.13.24	*Cast-In-Place Concrete, Equipment Pads, 24" thick*								
						Fine grade, for slab on grade, by hand	1,000.00 sf	1,256	59	-	-	-	1.32 /sf	1,315
						Structural Excavation, Excavator and Trucks, Medium Crew, 15' depth	96.60 cy	477	-	-	661	-	11.78 /cy	1,138
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	111.11 sy	527	-	-	477	-	9.04 /sy	1,004
						Structural Backfill, Dozer and Traxcavator or Loader, Medium Crew	25.00 cy	162	-	-	161	-	12.94 /cy	324
						Load Excess for Hauling, Rubber Tire Loader, Cat 950	71.60 cy	35	-	-	49	-	1.17 /cy	84
						Dump Charges for For Excess, 17 yd tandem, per cy	71.60 cy	-	1,443	-	-	-	20.15 /cy	1,443
						Fill, gravel subbase, under building slab on grade	37.04 cy	1,369	2,138	-	-	-	94.67 /cy	3,506
						Concrete pumping, subcontract, all inclusive price	74.07 cy	-	-	2,174	-	-	29.35 /cy	2,174
						Slab on grade edge forms, 12" to 24"	280.00 sf	5,885	548	-	-	-	22.97 /sf	6,433
						Reinforcing in place, A615 Gr 60, priced per lbs.	11,851.85 lb	-	11,593	9,275	-	-	1.76 /lb	20,868
						Concrete, ready mix, 4000 psi	74.07 CY	-	16,376	-	-	-	221.07 /CY	16,376
						Add for concrete waste, 4000 psi	3.70 cy	-	819	-	-	-	221.07 /cy	819
						Placing concrete, concrete pump	74.07 cy	4,106	-	-	-	-	55.43 /cy	4,106
						Finishing floors, monolithic, trowel finish (machine)	1,000.00 sf	1,763	39	-	-	-	1.80 /sf	1,802
						Curing, membrane spray	1,000.00 sf	148	78	-	-	-	0.23 /sf	226
						Polyethelene vapor barrier, 10 mil thick	10.00 sq	207	207	-	-	-	41.47 /sq	415
						03.10.13.24 Cast-In-Place Concrete, Equipment Pads, 24" thick	*74.07 CY*	*15,936*	*33,299*	*11,448*	*1,348*		*837.47 /CY*	*62,031*
						03.10.01.0002 Concrete Pad 20' x 50' x 24" Thick	**74.07 CY**	**15,936**	**33,299**	**11,448**	**1,348**		**837.47 /CY**	**62,031**
						03.10 Cast-In-Place Concrete Work	**74.07 CY**	**15,936**	**33,299**	**11,448**	**1,348**		**837.47 /CY**	**62,031**
						03.0 Concrete Work	**74.07 CY**	**15,936**	**33,299**	**11,448**	**1,348**		**837.47 /CY**	**62,031**
		33.0				**Utilities**								
			33.05			**Buried Process Piping**								
				33.10.01.0001		**Allowance for Buried Piping**								
					33.00.50.00	*Buried Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		97,819	-	-	97,819.08 /ls	97,819
						33.00.50.00 Buried Pipe, Other	*1.00 LS*			*97,819*			*97,819.08 /LS*	*97,819*

Detail Report

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Job Size: 1 LS
Duration: 1 LS

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						33.10.01.0001 Allowance for Buried Piping	**1.00 LS**			**97,819**			**97,819.08 /LS**	**97,819**
						33.05 Buried Process Piping	**1.00 LS**			**97,819**			**97,819.08 /LS**	**97,819**
						33.0 Utilities	**1.00 LS**			**97,819**			**97,819.08 /LS**	**97,819**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	548	293	-	-	-	280.46 /ea	841
						Sleeved anchor bolts - Small	16.00 ea	438	376	-	-	-	50.87 /ea	814
						Non-Shrink Machine Grout	6.00 cuft	521	869	-	-	-	231.53 /cuft	1,389
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	548	440	-	-	-	329.37 /ea	988
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	234,766	-	-	-	78,255.27 /EA	234,766
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.15 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*3.00 EA*	*10,821*	*236,890*				*82,570.61 /EA*	*247,712*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**3.00 EA**	**10,821**	**236,890**				**82,570.61 /EA**	**247,712**
				43.05.01.0010		**Thermal Hydrolysis Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.40 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.35 /EA*	*17,183*
					43.05.28.01	*Thermal Hydrolysis Package*								
						Furnish Thermal Hydrolysis Package	1.00 ea		3,912,763	-		-	3,912,763.17 /ea	3,912,763
						Install Thermal Hydrolysis Package	1.00 ea	132,183		-	17,770	-	149,952.60 /ea	149,953
						43.05.28.01 Thermal Hydrolysis Package	*1.00 LS*	*132,183*	*3,912,763*		*17,770*		*4,062,715.77 /LS*	*4,062,716*
						43.05.01.0010 Thermal Hydrolysis Package	**1.00 LS**	**136,548**	**3,912,763**		**30,588**		**4,079,899.12 /LS**	**4,079,899**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**147,370**	**4,149,654**		**30,588**		**4,327,610.95 /LS**	**4,327,611**
						43.0 Process Equipment - Industrial	**1.00 LS**	**147,370**	**4,149,654**		**30,588**		**4,327,610.95 /LS**	**4,327,611**
						0026 Thermal Hydrolysis WAS	**1.00 LS**	**163,305**	**4,182,953**	**109,268**	**31,935**		**4,487,461.22 /LS**	**4,487,461**
	0027					**Anaerobic Digestion**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.06 /ls	97,819
						09.00.99.00 Finishes, Other				*97,819*			*/LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**97,819**			**/LS**	**97,819**
						09.00 Finishes				**97,819**			**/LS**	**97,819**
						09.0 Finishes				**97,819**			**/LS**	**97,819**
						0027 Anaerobic Digestion	**1.00 LS**			**97,819**			**97,819.06 /LS**	**97,819**
	0028					**Recuperative Thickening**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.01.07	*General Site Demolition, Saw Cutting Concrete*								
						Sawcutting, concrete slabs, mesh or bar reinforcing, up to 12" deep	36.00 lf	828	156	-	461	-	40.11 /lf	1,444
						02.01.01.07 General Site Demolition, Saw Cutting Concrete		*828*	*156*		*461*		*/LF*	*1,444*
					02.01.02.02	*Selective Demolition, Cut-out, Concrete, Slabs*								
						Selective demolition, cutout, slab on grade, non-reinforced, to 12" thick, 8-16 S.F., excludes loading and disposal	80.00 cf	4,834	-	-	644	-	68.47 /cf	5,478
						02.01.02.02 Selective Demolition, Cut-out, Concrete, Slabs		*4,834*			*644*		*/CF*	*5,478*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing pumps and all associated works	4.00 ea	15,395	-		-	-	3,848.67 /ea	15,395
						Miscellaneous demolition	1.00 ls	5,773		-	-	-	5,772.88 /ls	5,773
						02.01.05.00 Process Equipment Demolition		*21,168*					*/EA*	*21,168*
						02.40.01.0001 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.40 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.0 Existing Conditions		**26,830**	**156**		**1,104**		**/LS**	**28,089**
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0001		**New Sump Structure**								
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Concrete pumping, subcontract, all inclusive price	4.89 cy	-	-	241	-	-	49.23 /cy	241
						Forms in place, structural walls, to 8' high, hand set	264.00 sf	6,345	866	-	-	-	27.31 /sf	7,211
						Waterstop, PVC, center bulb, 6" wide	22.00 lf	282	144	-	-	-	19.38 /lf	426
						Speed Dowels, #7	22.00 ea	-	1,949	-	-	-	88.59 /ea	1,949

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Detail Report

Job Size: 1 LS
Duration: 1 LS

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Reinforcing in place, A615 Gr 60, priced per lbs.	880.00 lb	-	1,444	1,155	-	-	2.95 /lb	2,599
						Concrete, ready mix, 4000 psi	4.89 CY	-	1,813	-	-	-	370.76 /CY	1,813
						Add for concrete waste, 4000 psi	0.24 cy	-	90	-	-	-	370.66 /cy	90
						Placing concrete, concrete pump, for structural wall to 12" thick	4.89 cy	515	-	-	-	-	105.35 /cy	515
						Patch & plug tieholes	264.00 sf	491	17	-	-	-	1.93 /sf	508
						Sack rub	264.00 sf	1,309	26	-	-	-	5.06 /sf	1,335
						Curing, membrane spray	264.00 sf	65	35	-	-	-	0.38 /sf	100
						Below grade dampproofing, Bituminous Asphalt	132.00 sf	-	433	-	-	-	3.28 /sf	433
						03.10.00.12 Concrete, Cast-in-Place, Grade Walls, 12" Wide		*9,007*	*6,817*	*1,396*			*/CY*	*17,220*
					03.10.05.12	*Cast-In-Place Concrete, Slabs on Grade, 12" thick*								
						Fine grade, for slab on grade, by hand	100.00 sf	104	12	-	-	-	1.16 /sf	116
						Concrete pumping, subcontract, all inclusive price	3.70 cy	-	-	219	-	-	59.03 /cy	219
						Slab on grade edge forms, 7" to 12"	40.00 sf	1,384	157	-	-	-	38.52 /sf	1,541
						Speed Dowels, #7	40.00 ea	-	4,250	-	-	-	106.25 /ea	4,250
						Reinforcing in place, A615 Gr 60, priced per lbs.	592.59 lb	-	1,166	933	-	-	3.54 /lb	2,099
						Concrete, ready mix, 4000 psi	3.70 CY	-	1,647	-	-	-	444.67 /CY	1,647
						Add for concrete waste, 4000 psi	0.19 cy	-	82	-	-	-	444.70 /cy	82
						Placing concrete, concrete pump	3.70 cy	413	-	-	-	-	111.50 /cy	413
						Finishing floors, monolithic, trowel finish (machine)	100.00 sf	355	8	-	-	-	3.63 /sf	363
						Curing, membrane spray	100.00 sf	30	16	-	-	-	0.46 /sf	46
						Polyethelene vapor barrier, 10 mil thick	1.00 sq	42	42	-	-	-	83.46 /sq	83
						03.10.05.12 Cast-In-Place Concrete, Slabs on Grade, 12" thick		*2,327*	*7,380*	*1,151*			*/CY*	*10,858*
						03.10.01.0001 New Sump Structure		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.10 Cast-In-Place Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.0 Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
		31.0				**Earthwork**								
			31.25			**Earthworks, Structural**								
				31.25.01.0001		**Structural Excavation**								
					31.25.01.00	*Earthworks, Structural, Excavation*								
						Shoring, soldier beams & lagging with tie-backs and walers, subcontracted	320.00 sf		-	24,402	-	-	76.26 /sf	24,402
						Structural Excavation, Excavator and Trucks, Small Crew, 6' depth	29.60 cy	382	-	-	465	-	28.59 /cy	846
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	11.11 sy	111	-	-	101	-	19.03 /sy	211
						Import Aggregate Base - under slab, Dozer and Traxcavator or Loader, Small Crew	5.50 tn	45	231	-	40	-	57.47 /tn	316
						Structural Backfill, Dozer and Traxcavator or Loader, Small Crew	22.93 cy	142	874	-	125	-	49.77 /cy	1,141
						Load Excess for Hauling, Rubber Tire Loader, Cat 930	29.60 cy	814	-	-	879	-	57.19 /cy	1,693
						Haul / Remove Excess, 12 yd capacity, 15 miles RT	29.60 cy	306	-	-	540	-	28.60 /cy	846
						Dump Charges for For Excess, 12 yd tandem, per cy	29.60 cy	-	2,539	-	-	-	85.79 /cy	2,539
						31.25.01.00 Earthworks, Structural, Excavation		*1,800*	*3,644*	*24,402*	*2,149*		*/CY*	*31,995*
						31.25.01.0001 Structural Excavation		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.25 Earthworks, Structural		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.0 Earthwork		**1,800**	**3,644**	**24,402**	**2,149**		**/LS**	**31,995**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.08 /ls	99,319
						40.10.99.99 Process Pipe, Other				*99,319*			*/LS*	*99,319*
						40.00.01.0001 Miscellaneous Piping and Valves				**99,319**			**/LS**	**99,319**
						40.00 Exposed Process Pipe				**99,319**			**/LF**	**99,319**
						40.0 Process Pipe				**99,319**			**/LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0004		**Equipment Rotary Drum Thickener**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.50 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.71.32	*Rotary Drum Thickener, 3 meter*								
						FURNISH Rotary Drum Thickener	3.00 ea	-	1,584,669	-	-	-	528,223.02 /ea	1,584,669
						Install Rotary Drum Thickener	3.00 ea	88,037	-	-	-	-	29,345.73 /ea	88,037
						44.05.71.32 Rotary Drum Thickener, 3 meter		*88,037*	*1,584,669*				*/EA*	*1,672,706*
						43.05.01.0004 Equipment Rotary Drum Thickener		**92,403**	**1,584,669**		**12,818**		**/EA**	**1,689,890**
				43.05.01.0005		**Equipment Recuperative Thickening Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								

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Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	10.00 ea	1,826	978	-	-	-	280.46 /ea	2,805
						Sleeved anchor bolts - Small	40.00 ea	1,096	939	-	-	-	50.87 /ea	2,035
						Non-Shrink Machine Grout	20.00 cuft	1,735	2,895	-	-	-	231.53 /cuft	4,631
						Grease, Oil, and Lube Pumps, 5-20 hp	10.00 ea	1,826	1,467	-	-	-	329.37 /ea	3,294
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	10.00 EA	-	782,553	-	-	-	78,255.26 /EA	782,553
						Set pump assembly, 5 - 20 hp	10.00 ea	29,222	489	-	-	-	2,971.15 /ea	29,711
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*35,706*	*789,322*				*/EA*	*825,028*
						43.05.01.0005 Equipment Recuperative Thickening Feed Pumps		**35,706**	**789,322**				**/EA**	**825,028**
				44.05.01.0004		**Equipment Submersible Pumps**								
					44.05.49.01	*Submersible Pump: 6hp-20hp*								
						Functional Testing, Submersible Pumps, 6 - 20 hp	2.00 ea	764	196	-	-	-	479.68 /ea	959
						FURNISH Submersible Pump, 6 - 20 hp	2.00 EA	-	78,255	-	-	-	39,127.63 /EA	78,255
						Set base elbow / pump assembly, 6 - 20 hp	2.00 ea	4,582	196	-	-	-	2,388.95 /ea	4,778
						Stainless steel guide rails, 2"	32.00 lf	764	563	-	-	-	41.47 /lf	1,327
						Install upper guide rail bracket	2.00 ea	286	39	-	-	-	162.75 /ea	325
						44.05.49.01 Submersible Pump: 6hp-20hp		*6,396*	*79,249*				*/EA*	*85,645*
						44.05.01.0004 Equipment Submersible Pumps		**6,396**	**79,249**				**/EA**	**85,645**
						43.05 Furnish and Install Process Equipment		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						43.0 Process Equipment - Industrial		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						0028 Recuperative Thickening	**1.00 LS**	**174,468**	**2,471,237**	**126,268**	**16,071**		**2,788,044.20 /LS**	**2,788,044**
	0029					**Dewatering**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					** multiple*									
						Demo existing centrifuges and all associated works	3.00 ea	34,638		-	17,231	-	17,289.72 /ea	51,869
						Miscellaneous demolition	1.00 .	3,849		-	-	-	3,848.61 /.	3,849
						** multiple*		*38,487*			*17,231*			*55,718*
						02.40.01.0001 Demolition		**38,487**			**17,231**		**/LS**	**55,718**
						02.40 Demolition		**38,487**			**17,231**		**/LS**	**55,718**
						02.0 Existing Conditions		**38,487**			**17,231**		**/LS**	**55,718**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					** multiple*									
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.07 /ls	99,319
						** multiple*				*99,319*				*99,319*
						40.00.01.0001 Miscellaneous Piping and Valves				**99,319**			**/LS**	**99,319**
						40.00 Exposed Process Pipe				**99,319**			**/LF**	**99,319**
						40.0 Process Pipe				**99,319**			**/LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					** multiple*									
						Functional Testing, Pumps, 5-20 hp	3.00 ea	548	293	-	-	-	280.46 /ea	841
						Sleeved anchor bolts - Small	16.00 ea	438	376	-	-	-	50.87 /ea	814
						Non-Shrink Machine Grout	10.00 cuft	868	1,448	-	-	-	231.53 /cuft	2,315
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	548	440	-	-	-	329.37 /ea	988
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	234,766	-	-	-	78,255.26 /EA	234,766
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.15 /ea	8,913
						** multiple*		*11,168*	*237,470*					*248,638*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**3.00 EA**	**11,168**	**237,470**				**82,879.32 /EA**	**248,638**
				44.05.01.0001		**Equipment Centrifuges**								
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						Sleeved anchor bolts, SS - Small	16.00 ea	764	376	-	-	-	71.21 /ea	1,139
						Non-Shrink Machine Grout	33.00 cuft	2,993	4,777	-	-	-	235.46 /cuft	7,770
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	-	1,897,690	-	-	-	948,845.07 /ea	1,897,690
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	47,732	-	-	7,043	-	27,387.38 /ea	54,775
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*2.00 EA*	*55,854*	*1,902,843*		*19,861*		*989,278.94 /EA*	*1,978,558*
						44.05.01.0001 Equipment Centrifuges		**55,854**	**1,902,843**		**19,861**		**/EA**	**1,978,558**
						43.05 Furnish and Install Process Equipment		**67,022**	**2,140,313**		**19,861**		**/LS**	**2,227,196**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						43.0 Process Equipment - Industrial		67,022	2,140,313		19,861		/LS	2,227,196
						0029 Dewatering	1.00 LS	105,509	2,140,313	99,319	37,092		2,382,232.66 /LS	2,382,233
	0030					Drying								
		13.0				Special Construction								
			13.00			Special Construction								
				13.10.01.0001		Dryer Building								
					13.01.99.00	*Special Construction, Other*								
						Dryer Building 46' x 155', including foundation, superstructure and finishes	7,130.00 sf	-	-	7,671,950	-	-	1,076.01 /sf	7,671,950
						13.01.99.00 Special Construction, Other				*7,671,950*			*/SF*	*7,671,950*
						13.10.01.0001 Dryer Building				7,671,950			/SF	7,671,950
						13.00 Special Construction				7,671,950			/LS	7,671,950
						13.0 Special Construction				7,671,950			/SF	7,671,950
		26.0				Electrical Work								
			26.00			Electrical								
				26.15.01.0007		Miscellaneous Electrical								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (10% of total direct cost)	1.00 ls	-	-	372,799	-	-	372,799.35 /ls	372,799
						26.00.99.00 Electrical, Other				*372,799*			*/LS*	*372,799*
						26.15.01.0007 Miscellaneous Electrical				372,799			/LS	372,799
						26.00 Electrical				372,799			/LS	372,799
						26.0 Electrical Work				372,799			/LS	372,799
		40.9				Instrumentation & Controls								
			40.90			Instrumentation and Controls								
				40.90.01.0002		Miscellaneous I&C								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (6% of total direct cost)	1.00 ls	-	-	224,146	-	-	224,145.60 /ls	224,146
						40.90.99.01 I&C, Other				*224,146*			*/LS*	*224,146*
						40.90.01.0002 Miscellaneous I&C				224,146			/LS	224,146
						40.90 Instrumentation and Controls				224,146			/LS	224,146
						40.9 Instrumentation & Controls				224,146			/LS	224,146
		43.0				Process Equipment - Industrial								
			43.05			Furnish and Install Process Equipment								
				43.05.01.0006		Equipment Dryer Package								
					41.00.01.04	*Material Handling, Other Conveyors*								
						Equipment, conveyors	120.00 lf			586,914	-	-	4,890.95 /lf	586,914
						41.00.01.04 Material Handling, Other Conveyors				*586,914*			*/LF*	*586,914*
					44.05.82.30	*Sludge Dryer*								
						Furnish Dryer Package	1.00 ls		6,835,597	-		-	6,835,597.25 /ls	6,835,597
						Install Dryer Package	1.00 ls	139,686	-	-	61,430	-	201,116.01 /ls	201,116
						44.05.82.30 Sludge Dryer	*1.00 EA*	*139,686*	*6,835,597*		*61,430*		*7,036,713.26 /EA*	*7,036,713*
						43.05.01.0006 Equipment Dryer Package		139,686	6,835,597	586,914	61,430		/LS	7,623,628
						43.05 Furnish and Install Process Equipment		139,686	6,835,597	586,914	61,430		/LS	7,623,628
						43.0 Process Equipment - Industrial		139,686	6,835,597	586,914	61,430		/LS	7,623,628
						0030 Drying	1.00 LS	139,686	6,835,597	8,855,810	61,430		15,892,523.03 /LS	15,892,523
	0031					Boiler (High P Steam)								
		02.0				Existing Conditions								
			02.40			Demolition								
				02.40.01.0001		Demolition								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing boilers and all associated works	2.00 ea	11,546		-	5,744	-	8,644.85 /ea	17,290
						02.01.05.00 Process Equipment Demolition		*11,546*			*5,744*		*/EA*	*17,290*
						02.40.01.0001 Demolition		11,546			5,744		/LS	17,290
						02.40 Demolition		11,546			5,744		/LS	17,290
						02.0 Existing Conditions		11,546			5,744		/LS	17,290
		40.0				Process Pipe								
			40.00			Exposed Process Pipe								
				40.00.01.0001		Miscellaneous Piping and Valves								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		49,660	-	-	49,659.56 /ls	49,660
						40.10.99.99 Process Pipe, Other				*49,660*			*/LS*	*49,660*
						40.00.01.0001 Miscellaneous Piping and Valves				49,660			/LS	49,660
						40.00 Exposed Process Pipe				49,660			/LF	49,660
						40.0 Process Pipe				49,660			/LS	49,660
		43.0				Process Equipment - Industrial								

CH2MHILL

Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0011		**Equipment Boilers**								
					43.00.02.00	*Process Equipment, General Conditions*								
						Furnish Boiler	1.00 ea		316,934	-		-	316,933.83 /ea	316,934
						Install new Boiler	1.00 ea	8,592	-	-	3,443	-	12,035.64 /ea	12,036
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*8,592*	*316,934*		*3,443*		*328,969.47 /EA*	*328,969*
						43.05.01.0011 Equipment Boilers	**1.00 LS**	**8,592**	**316,934**		**3,443**		**328,969.47 /LS**	**328,969**
						43.05 Furnish and Install Process Equipment	**1.00 LS**	**8,592**	**316,934**		**3,443**		**328,969.47 /LS**	**328,969**
						43.0 Process Equipment - Industrial	**11.00 LS**	**8,592**	**316,934**		**3,443**		**29,906.31 /LS**	**328,969**
						0031 Boiler (High P Steam)	**1.00 LS**	**20,138**	**316,934**	**49,660**	**9,187**		**395,918.73 /LS**	**395,919**
	0032					**Combine Heat Power (CHP)**								
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		397,276	-	-	397,276.32 /ls	397,276
						40.10.99.99 Process Pipe, Other				*397,276*			*/LS*	*397,276*
						40.00.01.0001 Miscellaneous Piping and Valves				**397,276**			**/LS**	**397,276**
						40.00 Exposed Process Pipe				**397,276**			**/LF**	**397,276**
						40.0 Process Pipe				**397,276**			**/LS**	**397,276**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0009		**Combine Heat Power**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.28.00	*Energy Recovery*								
						Furnish Combine Heat Power Package	1.00 ea		6,847,336	-		-	6,847,335.52 /ea	6,847,336
						Install Combine Heat Power Package	1.00 ea	132,183		-	17,770	-	149,952.58 /ea	149,953
						43.05.28.00 Energy Recovery		*132,183*	*6,847,336*		*17,770*		*/EA*	*6,997,288*
						43.05.01.0009 Combine Heat Power		**136,548**	**6,847,336**		**30,588**		**/EA**	**7,014,471**
						43.05 Furnish and Install Process Equipment		**136,548**	**6,847,336**		**30,588**		**/LS**	**7,014,471**
						43.0 Process Equipment - Industrial		**136,548**	**6,847,336**		**30,588**		**/LS**	**7,014,471**
						0032 Combine Heat Power (CHP)	**1.00 LS**	**136,548**	**6,847,336**	**397,276**	**30,588**		**7,411,747.78 /LS**	**7,411,748**
	0033					**Flares**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	19,564	-	-	19,563.80 /ls	19,564
						09.00.99.00 Finishes, Other				*19,564*			*/LS*	*19,564*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**19,564**			**/LS**	**19,564**
						09.00 Finishes				**19,564**			**/LS**	**19,564**
						09.0 Finishes				**19,564**			**/LS**	**19,564**
						0033 Flares	**1.00 LS**			**19,564**			**19,563.80 /LS**	**19,564**
						2B ALTERNATE 2B	**1.00 LS**	**1,250,454**	**29,730,219**	**17,636,380**	**658,700**		**49,275,753.94 /LS**	**49,275,754**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
3B						**ALTERNATE 3B**								
	0021					**Thickening PSD + TSD**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.11 /ls	97,819
						09.00.99.00 Finishes, Other				*97,819*			*/LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**97,819**			**/LS**	**97,819**
						09.00 Finishes				**97,819**			**/LS**	**97,819**
						09.0 Finishes				**97,819**			**/LS**	**97,819**
						0021 Thickening PSD + TSD	**1.00 LS**			**97,819**			**97,819.11 /LS**	**97,819**
	0022					**Thickening WAS**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing centrifuges and all associated works	4.00 ea	46,184		-	22,975	-	17,289.71 /ea	69,159
						02.01.05.00 Process Equipment Demolition		*46,184*			*22,975*		*/EA*	*69,159*
						02.40.01.0001 Demolition		**46,184**			**22,975**		**/LS**	**69,159**
						02.40 Demolition		**46,184**			**22,975**		**/LS**	**69,159**
						02.0 Existing Conditions		**46,184**			**22,975**		**/LS**	**69,159**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		198,638	-	-	198,638.17 /ls	198,638
						40.10.99.99 Process Pipe, Other				*198,638*			*/LS*	*198,638*
						40.00.01.0001 Miscellaneous Piping and Valves				**198,638**			**/LS**	**198,638**
						40.00 Exposed Process Pipe				**198,638**			**/LF**	**198,638**
						40.0 Process Pipe				**198,638**			**/LS**	**198,638**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	7.00 ea	1,278	685	-	-	-	280.46 /ea	1,963
						Sleeved anchor bolts - Small	28.00 ea	767	657	-	-	-	50.87 /ea	1,424
						Non-Shrink Machine Grout	14.00 cuft	1,215	2,027	-	-	-	231.53 /cuft	3,241
						Grease, Oil, and Lube Pumps, 5-20 hp	7.00 ea	1,278	1,027	-	-	-	329.37 /ea	2,306
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	7.00 EA	-	547,787	-	-	-	78,255.26 /EA	547,787
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.15 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*13,305*	*552,330*				*/EA*	*565,635*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**13,305**	**552,330**				**/EA**	**565,635**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.56 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	3,404,104	-	-	-	1,134,701.31 /ea	3,404,104
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.39 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm		*77,278*	*3,411,906*		*10,564*		*/EA*	*3,499,748*
						44.05.01.0001 Equipment Centrifuges		**81,643**	**3,411,906**		**23,383**		**/EA**	**3,516,932**
						44.05 Furnish and Install Process Equipment		**94,948**	**3,964,236**		**23,383**		**/EA**	**4,082,566**
						43.0 Process Equipment - Industrial		**94,948**	**3,964,236**		**23,383**		**/LS**	**4,082,566**
						0022 Thickening WAS	**1.00 LS**	**141,132**	**3,964,236**	**198,638**	**46,357**		**4,350,363.51 /LS**	**4,350,364**
	0023					**Screening T(PSD+TSD)**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.27 /ea	78,255

Detail Report

CH2MHILL

Job Size: 1 LS
Duration: 1 LS

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction				**78,255**			**/SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.40 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.34.00	*New Screens*								
						Furnish Strain Press SLudge Cleaner Screen	1.00 ea		322,803	-	-	-	322,802.97 /ea	322,803
						Install Strain Press SLudge Cleaner Screen	1.00 ea	19,224		-	-	-	19,223.79 /ea	19,224
						44.05.34.00 New Screens		*19,224*	*322,803*				*/EA*	*342,027*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.17 /ea	173,598
						44.05.34.01 Refurbish Existing Screens		*17,088*		*156,511*			*/EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner		**40,677**	**322,803**	**156,511**	**12,818**		**/EA**	**532,808**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	573	293	-	-	-	288.76 /ea	866
						Local panel	3.00 ea	1,718	8,804	-	-	-	3,507.35 /ea	10,522
						Pressure indicators	3.00 ea	430	1,467	-	-	-	632.29 /ea	1,897
						Sleeved anchor bolts - Small	20.00 ea	573	470	-	-	-	52.12 /ea	1,042
						Non-Shrink Machine Grout	10.00 cuft	907	1,448	-	-	-	235.46 /cuft	2,355
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	573	440	-	-	-	337.66 /ea	1,013
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	146,729	-	-	-	48,909.54 /EA	146,729
						Set pump assembly, 5 - 20 hp	3.00 ea	9,165	147	-	-	-	3,103.75 /ea	9,311
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*3.00 EA*	*13,938*	*159,797*				*57,911.66 /EA*	*173,735*
						44.05.01.0003 Equipment Centrifugal Pumps		**13,938**	**159,797**				**/EA**	**173,735**
						44.05 Furnish and Install Process Equipment		**54,615**	**482,600**	**156,511**	**12,818**		**/EA**	**706,543**
						43.0 Process Equipment - Industrial		**54,615**	**482,600**	**156,511**	**12,818**		**/LS**	**706,543**
						0023 Screening T(PSD+TSD)	**1.00 LS**	**54,615**	**482,600**	**234,766**	**12,818**		**784,798.69 /LS**	**784,799**
	0024					**Screening TWAS**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.25 /ea	78,255
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction				**78,255**			**/SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.52 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.17 /ea	173,598
						44.05.34.01 Refurbish Existing Screens		*17,088*		*156,511*			*/EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner		**21,453**		**156,511**	**12,818**		**/EA**	**190,782**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	2.00 ea	382	196	-	-	-	288.75 /ea	578
						Local panel	2.00 ea	1,146	5,869	-	-	-	3,507.34 /ea	7,015
						Pressure indicators	4.00 ea	573	1,956	-	-	-	632.30 /ea	2,529
						Sleeved anchor bolts - Small	8.00 ea	229	188	-	-	-	52.12 /ea	417
						Non-Shrink Machine Grout	2.00 cuft	181	290	-	-	-	235.46 /cuft	471
						Grease, Oil, and Lube Pumps, 5-20 hp	2.00 ea	382	293	-	-	-	337.65 /ea	675
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	2.00 EA	-	97,819	-	-	-	48,909.53 /EA	97,819
						Set pump assembly, 5 - 20 hp	2.00 ea	6,110	98	-	-	-	3,103.76 /ea	6,208

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*9,002*	*106,709*				*/EA*	*115,711*
						44.05.01.0003 Equipment Centrifugal Pumps		**9,002**	**106,709**				**/EA**	**115,711**
						44.05 Furnish and Install Process Equipment		**30,455**	**106,709**	**156,511**	**12,818**		**/EA**	**306,493**
						43.0 Process Equipment - Industrial		**30,455**	**106,709**	**156,511**	**12,818**		**/LS**	**306,493**
						0024 Screening TWAS	**1.00 LS**	**30,455**	**106,709**	**234,766**	**12,818**		**384,748.05 /LS**	**384,748**
	0025					**Pre-Dewatering**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.02.00	*Structure/Building Demolition*								
						Demo Building, 88' x 38'x 30' high Concrete, per cubic foot and haul debris away for disposal	100,320.00 cf		-	166,825	-	-	1.66 /cf	166,825
						02.01.02.00 Structure/Building Demolition				*166,825*			*/SF*	*166,825*
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	17,124		-	-	-	17,124.14 /ls	17,124
						02.01.04.20 Piping Demolition		*17,124*					*/LS*	*17,124*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing tanks 12K gallon	3.00 ea	28,865		-	10,339	-	13,067.90 /ea	39,204
						Demo existing Hex	3.00 ea	17,319		-	17,231	-	11,516.71 /ea	34,550
						Miscellaneous demolition	1.00 .	19,243		-	-	-	19,242.96 /.	19,243
						02.01.05.00 Process Equipment Demolition		*65,427*			*27,570*		*/EA*	*92,997*
						02.40.01.0001 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
						02.40 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
						02.0 Existing Conditions		**82,551**		**166,825**	**27,570**		**/LS**	**276,945**
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 32' x 40' - 3 Story Building, including foundation, superstructure and finishes	3,840.00 sf	-	-	4,131,878	-	-	1,076.01 /sf	4,131,878
						13.01.99.00 Special Construction, Other				*4,131,878*			*/SF*	*4,131,878*
						13.10.01.0003 Dewatering Building				**4,131,878**			**/SF**	**4,131,878**
						13.00 Special Construction				**4,131,878**			**/LS**	**4,131,878**
						13.0 Special Construction				**4,131,878**			**/SF**	**4,131,878**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (15% of total direct cost)	1.00 ls	-	-	1,143,735	-	-	1,143,735.36 /ls	1,143,735
						26.00.99.00 Electrical, Other				*1,143,735*			*/LS*	*1,143,735*
						26.15.01.0007 Miscellaneous Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.00 Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.0 Electrical Work				**1,143,735**			**/LS**	**1,143,735**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, erosion control and all associated works	1.00 ls	123,623	-	-	352,972	-	476,595.51 /ls	476,596
						31.15.01.05 Site Preparation,		*123,623*			*352,972*		*/AC*	*476,596*
						31.15.01.0001 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.15 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.0 Earthwork		**123,623**			**352,972**		**/LS**	**476,596**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 12% of total direct cost	1.00 ls	-		898,142	-	-	898,142.42 /ls	898,142
						40.10.99.99 Process Pipe, Other				*898,142*			*/LS*	*898,142*
						40.00.01.0001 Miscellaneous Piping and Valves				**898,142**			**/LS**	**898,142**
						40.00 Exposed Process Pipe				**898,142**			**/LF**	**898,142**
						40.0 Process Pipe				**898,142**			**/LS**	**898,142**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				40.90.01.0002		Miscellaneous I&C								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (10% of total direct cost)	1.00 ls	-	-	774,828	-	-	774,828.15 /ls	774,828
						40.90.99.01 I&C, Other				*774,828*			*/LS*	*774,828*
						40.90.01.0002 Miscellaneous I&C				**774,828**			**/LS**	**774,828**
						40.90 Instrumentation and Controls				**774,828**			**/LS**	**774,828**
						40.9 Instrumentation & Controls				**774,828**			**/LS**	**774,828**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	6.00 ea	1,096	587	-	-	-	280.46 /ea	1,683
						Sleeved anchor bolts - Small	24.00 ea	658	563	-	-	-	50.87 /ea	1,221
						Non-Shrink Machine Grout	12.00 cuft	1,041	1,737	-	-	-	231.53 /cuft	2,778
						Grease, Oil, and Lube Pumps, 5-20 hp	6.00 ea	1,096	880	-	-	-	329.37 /ea	1,976
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	6.00 EA	-	469,532	-	-	-	78,255.26 /EA	469,532
						Set pump assembly, 5 - 20 hp	6.00 ea	17,533	293	-	-	-	2,971.15 /ea	17,827
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*21,424*	*473,593*				*/EA*	*495,017*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**21,424**	**473,593**				**/EA**	**495,017**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	16.00 ea	764	376	-	-	-	71.21 /ea	1,139
						Non-Shrink Machine Grout	33.00 cuft	2,993	4,777	-	-	-	235.46 /cuft	7,770
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	-	1,897,690	-	-	-	948,845.07 /ea	1,897,690
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	47,732	-	-	7,043	-	27,387.38 /ea	54,775
						43.05.10.01 Liquid Centrifuge: 150-249 gpm		*51,488*	*1,902,843*		*7,043*		*/EA*	*1,961,375*
						44.05.01.0001 Equipment Centrifuges		**55,854**	**1,902,843**		**19,861**		**/EA**	**1,978,558**
						43.05 Furnish and Install Process Equipment		**77,277**	**2,376,436**		**19,861**		**/LS**	**2,473,575**
						43.0 Process Equipment - Industrial		**77,277**	**2,376,436**		**19,861**		**/LS**	**2,473,575**
						0025 Pre-Dewatering	**1.00 LS**	**283,452**	**2,376,436**	**7,115,408**	**400,403**		**10,175,699.40 /LS**	**10,175,699**
	0026					**Thermal Hydrolysis WAS**								
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0002		**Concrete Pad 20' x 50' x 24" Thick**								
					03.10.13.24	*Cast-In-Place Concrete, Equipment Pads, 24" thick*								
						Fine grade, for slab on grade, by hand	1,000.00 sf	1,256	59	-	-	-	1.32 /sf	1,315
						Structural Excavation, Excavator and Trucks, Medium Crew, 15' depth	96.60 cy	477	-	-	661	-	11.78 /cy	1,138
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	111.11 sy	527	-	-	477	-	9.04 /sy	1,004
						Structural Backfill, Dozer and Traxcavator or Loader, Medium Crew	25.00 cy	162	-	-	161	-	12.94 /cy	324
						Load Excess for Hauling, Rubber Tire Loader, Cat 950	71.60 cy	35	-	-	49	-	1.17 /cy	84
						Dump Charges for For Excess, 17 yd tandem, per cy	71.60 cy	-	1,443	-	-	-	20.15 /cy	1,443
						Fill, gravel subbase, under building slab on grade	37.04 cy	1,369	2,138	-	-	-	94.67 /cy	3,506
						Concrete pumping, subcontract, all inclusive price	74.07 cy	-	-	2,174	-	-	29.35 /cy	2,174
						Slab on grade edge forms, 12" to 24"	280.00 sf	5,885	548	-	-	-	22.97 /sf	6,433
						Reinforcing in place, A615 Gr 60, priced per lbs.	11,851.85 lb	-	11,593	9,275	-	-	1.76 /lb	20,868
						Concrete, ready mix, 4000 psi	74.07 CY	-	16,376	-	-	-	221.07 /CY	16,376
						Add for concrete waste, 4000 psi	3.70 cy	-	819	-	-	-	221.07 /cy	819
						Placing concrete, concrete pump	74.07 cy	4,106	-	-	-	-	55.43 /cy	4,106
						Finishing floors, monolithic, trowel finish (machine)	1,000.00 sf	1,763	39	-	-	-	1.80 /sf	1,802
						Curing, membrane spray	1,000.00 sf	148	78	-	-	-	0.23 /sf	226
						Polyethelene vapor barrier, 10 mil thick	10.00 sq	207	207	-	-	-	41.47 /sq	415
						03.10.13.24 Cast-In-Place Concrete, Equipment Pads, 24" thick		*15,936*	*33,299*	*11,448*	*1,348*		*/CY*	*62,031*
						03.10.01.0002 Concrete Pad 20' x 50' x 24" Thick		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
						03.10 Cast-In-Place Concrete Work		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
						03.0 Concrete Work		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
		33.0				**Utilities**								
			33.05			**Buried Process Piping**								
				33.10.01.0001		**Allowance for Buried Piping**								
					33.00.50.00	*Buried Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		97,819	-	-	97,819.07 /ls	97,819
						33.00.50.00 Buried Pipe, Other				*97,819*			*/LS*	*97,819*

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						33.10.01.0001 Allowance for Buried Piping				**97,819**			**/LS**	**97,819**
						33.05 Buried Process Piping				**97,819**			**/LS**	**97,819**
						33.0 Utilities				**97,819**			**/LS**	**97,819**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	548	293	-	-	-	280.46 /ea	841
						Sleeved anchor bolts - Small	16.00 ea	438	376	-	-	-	50.87 /ea	814
						Non-Shrink Machine Grout	6.00 cuft	521	869	-	-	-	231.53 /cuft	1,389
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	548	440	-	-	-	329.37 /ea	988
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	234,766	-	-	-	78,255.27 /EA	234,766
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.15 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*10,821*	*236,890*				*/EA*	*247,712*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**10,821**	**236,890**				**/EA**	**247,712**
				43.05.01.0010		**Thermal Hydrolysis Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.40 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.28.01	*Thermal Hydrolysis Package*								
						Furnish Thermal Hydrolysis Package	1.00 ea		3,912,763	-		-	3,912,763.16 /ea	3,912,763
						Install Thermal Hydrolysis Package	1.00 ea	132,183		-	17,770	-	149,952.57 /ea	149,953
						43.05.28.01 Thermal Hydrolysis Package		*132,183*	*3,912,763*		*17,770*		*/LS*	*4,062,716*
						43.05.01.0010 Thermal Hydrolysis Package		**136,548**	**3,912,763**		**30,588**		**/LS**	**4,079,899**
						43.05 Furnish and Install Process Equipment		**147,370**	**4,149,654**		**30,588**		**/LS**	**4,327,611**
						43.0 Process Equipment - Industrial		**147,370**	**4,149,654**		**30,588**		**/LS**	**4,327,611**
						0026 Thermal Hydrolysis WAS	**1.00 LS**	**163,305**	**4,182,953**	**109,268**	**31,935**		**4,487,461.19 /LS**	**4,487,461**
	0027					**Anaerobic Digestion**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.09 /ls	97,819
						09.00.99.00 Finishes, Other				*97,819*			*/LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**97,819**			**/LS**	**97,819**
						09.00 Finishes				**97,819**			**/LS**	**97,819**
						09.0 Finishes				**97,819**			**/LS**	**97,819**
						0027 Anaerobic Digestion	**1.00 LS**			**97,819**			**97,819.09 /LS**	**97,819**
	0028					**Recuperative Thickening**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.01.07	*General Site Demolition, Saw Cutting Concrete*								
						Sawcutting, concrete slabs, mesh or bar reinforcing, up to 12" deep	36.00 lf	828	156	-	461	-	40.11 /lf	1,444
						02.01.01.07 General Site Demolition, Saw Cutting Concrete		*828*	*156*		*461*		*/LF*	*1,444*
					02.01.02.02	*Selective Demolition, Cut-out, Concrete, Slabs*								
						Selective demolition, cutout, slab on grade, non-reinforced, to 12" thick, 8-16 S.F., excludes loading and disposal	80.00 cf	4,834	-	-	644	-	68.47 /cf	5,478
						02.01.02.02 Selective Demolition, Cut-out, Concrete, Slabs		*4,834*			*644*		*/CF*	*5,478*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing pumps and all associated works	4.00 ea	15,395	-		-	-	3,848.67 /ea	15,395
						Miscellaneous demolition	1.00 ls	5,773		-	-	-	5,772.91 /ls	5,773
						02.01.05.00 Process Equipment Demolition		*21,168*					*/EA*	*21,168*
						02.40.01.0001 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.40 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.0 Existing Conditions		**26,830**	**156**		**1,104**		**/LS**	**28,089**
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0001		**New Sump Structure**								
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Concrete pumping, subcontract, all inclusive price	4.89 cy	-	-	241	-	-	49.22 /cy	241
						Forms in place, structural walls, to 8' high, hand set	264.00 sf	6,345	866	-	-	-	27.31 /sf	7,211
						Waterstop, PVC, center bulb, 6" wide	22.00 lf	282	144	-	-	-	19.38 /lf	426
						Speed Dowels, #7	22.00 ea	-	1,949	-	-	-	88.59 /ea	1,949

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Reinforcing in place, A615 Gr 60, priced per lbs.	880.00 lb	-	1,444	1,155	-	-	2.95 /lb	2,599
						Concrete, ready mix, 4000 psi	4.89 CY	-	1,813	-	-	-	370.76 /CY	1,813
						Add for concrete waste, 4000 psi	0.24 cy	-	90	-	-	-	370.66 /cy	90
						Placing concrete, concrete pump, for structural wall to 12" thick	4.89 cy	515	-	-	-	-	105.35 /cy	515
						Patch & plug tieholes	264.00 sf	491	17	-	-	-	1.93 /sf	508
						Sack rub	264.00 sf	1,309	26	-	-	-	5.06 /sf	1,335
						Curing, membrane spray	264.00 sf	65	35	-	-	-	0.38 /sf	100
						Below grade dampproofing, Bituminous Asphalt	132.00 sf	-	433	-	-	-	3.28 /sf	433
						03.10.00.12 Concrete, Cast-in-Place, Grade Walls, 12" Wide		*9,007*	*6,817*	*1,396*			*/CY*	*17,220*
					03.10.05.12	*Cast-In-Place Concrete, Slabs on Grade, 12" thick*								
						Fine grade, for slab on grade, by hand	100.00 sf	104	12	-	-	-	1.16 /sf	116
						Concrete pumping, subcontract, all inclusive price	3.70 cy	-	-	219	-	-	59.03 /cy	219
						Slab on grade edge forms, 7" to 12"	40.00 sf	1,384	157	-	-	-	38.52 /sf	1,541
						Speed Dowels, #7	40.00 ea	-	4,250	-	-	-	106.25 /ea	4,250
						Reinforcing in place, A615 Gr 60, priced per lbs.	592.59 lb	-	1,166	933	-	-	3.54 /lb	2,099
						Concrete, ready mix, 4000 psi	3.70 CY	-	1,647	-	-	-	444.67 /CY	1,647
						Add for concrete waste, 4000 psi	0.19 cy	-	82	-	-	-	444.70 /cy	82
						Placing concrete, concrete pump	3.70 cy	413	-	-	-	-	111.50 /cy	413
						Finishing floors, monolithic, trowel finish (machine)	100.00 sf	355	8	-	-	-	3.63 /sf	363
						Curing, membrane spray	100.00 sf	30	16	-	-	-	0.46 /sf	46
						Polyethelene vapor barrier, 10 mil thick	1.00 sq	42	42	-	-	-	83.46 /sq	83
						03.10.05.12 Cast-In-Place Concrete, Slabs on Grade, 12" thick		*2,327*	*7,380*	*1,151*			*/CY*	*10,858*
						03.10.01.0001 New Sump Structure		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.10 Cast-In-Place Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.0 Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
		31.0				**Earthwork**								
			31.25			**Earthworks, Structural**								
				31.25.01.0001		**Structural Excavation**								
					31.25.01.00	*Earthworks, Structural, Excavation*								
						Shoring, soldier beams & lagging with tie-backs and walers, subcontracted	320.00 sf		-	24,402	-	-	76.26 /sf	24,402
						Structural Excavation, Excavator and Trucks, Small Crew, 6' depth	29.60 cy	382	-	-	465	-	28.59 /cy	846
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	11.11 sy	111	-	-	101	-	19.03 /sy	211
						Import Aggregate Base - under slab, Dozer and Traxcavator or Loader, Small Crew	5.50 tn	45	231	-	40	-	57.46 /tn	316
						Structural Backfill, Dozer and Traxcavator or Loader, Small Crew	22.93 cy	142	874	-	125	-	49.77 /cy	1,141
						Load Excess for Hauling, Rubber Tire Loader, Cat 930	29.60 cy	814	-	-	879	-	57.19 /cy	1,693
						Haul / Remove Excess, 12 yd capacity, 15 miles RT	29.60 cy	306	-	-	540	-	28.60 /cy	847
						Dump Charges for For Excess, 12 yd tandem, per cy	29.60 cy	-	2,539	-	-	-	85.79 /cy	2,539
						31.25.01.00 Earthworks, Structural, Excavation		*1,800*	*3,644*	*24,402*	*2,149*		*/CY*	*31,995*
						31.25.01.0001 Structural Excavation		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.25 Earthworks, Structural		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.0 Earthwork		**1,800**	**3,644**	**24,402**	**2,149**		**/LS**	**31,995**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.09 /ls	99,319
						40.10.99.99 Process Pipe, Other				*99,319*			*/LS*	*99,319*
						40.00.01.0001 Miscellaneous Piping and Valves				**99,319**			**/LS**	**99,319**
						40.00 Exposed Process Pipe				**99,319**			**/LF**	**99,319**
						40.0 Process Pipe				**99,319**			**/LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0004		**Equipment Rotary Drum Thickener**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.71.32	*Rotary Drum Thickener, 3 meter*								
						FURNISH Rotary Drum Thickener	3.00 ea	-	1,584,669	-	-	-	528,223.02 /ea	1,584,669
						Install Rotary Drum Thickener	3.00 ea	88,037	-	-	-	-	29,345.74 /ea	88,037
						44.05.71.32 Rotary Drum Thickener, 3 meter		*88,037*	*1,584,669*				*/EA*	*1,672,706*
						43.05.01.0004 Equipment Rotary Drum Thickener		**92,403**	**1,584,669**		**12,818**		**/EA**	**1,689,890**
				43.05.01.0005		**Equipment Recuperative Thickening Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	10.00 ea	1,826	978	-	-	-	280.46 /ea	2,805
						Sleeved anchor bolts - Small	40.00 ea	1,096	939	-	-	-	50.87 /ea	2,035
						Non-Shrink Machine Grout	20.00 cuft	1,735	2,895	-	-	-	231.53 /cuft	4,631
						Grease, Oil, and Lube Pumps, 5-20 hp	10.00 ea	1,826	1,467	-	-	-	329.37 /ea	3,294
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	10.00 EA	-	782,553	-	-	-	78,255.26 /EA	782,553
						Set pump assembly, 5 - 20 hp	10.00 ea	29,222	489	-	-	-	2,971.15 /ea	29,712
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*35,706*	*789,322*				*/EA*	*825,028*
						43.05.01.0005 Equipment Recuperative Thickening Feed Pumps		**35,706**	**789,322**				**/EA**	**825,028**
				44.05.01.0004		**Equipment Submersible Pumps**								
					44.05.49.01	*Submersible Pump: 6hp-20hp*								
						Functional Testing, Submersible Pumps, 6 - 20 hp	2.00 ea	764	196	-	-	-	479.67 /ea	959
						FURNISH Submersible Pump, 6 - 20 hp	2.00 EA	-	78,255	-	-	-	39,127.63 /EA	78,255
						Set base elbow / pump assembly, 6 - 20 hp	2.00 ea	4,582	196	-	-	-	2,388.96 /ea	4,778
						Stainless steel guide rails, 2"	32.00 lf	764	563	-	-	-	41.47 /lf	1,327
						Install upper guide rail bracket	2.00 ea	286	39	-	-	-	162.75 /ea	325
						44.05.49.01 Submersible Pump: 6hp-20hp		*6,396*	*79,249*				*/EA*	*85,645*
						44.05.01.0004 Equipment Submersible Pumps		**6,396**	**79,249**				**/EA**	**85,645**
						43.05 Furnish and Install Process Equipment		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						43.0 Process Equipment - Industrial		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						0028 Recuperative Thickening	**1.00 LS**	**174,468**	**2,471,237**	**126,268**	**16,071**		**2,788,044.21 /LS**	**2,788,044**
	0029					**Dewatering**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 30' x 60' x 100' - 3 Story Building, including foundation, superstructure and finishes	5,400.00 sf	-	-	7,923,345	-	-	1,467.29 /sf	7,923,345
						13.01.99.00 Special Construction, Other				*7,923,345*			*/SF*	*7,923,345*
						13.10.01.0003 Dewatering Building				**7,923,345**			**/SF**	**7,923,345**
						13.00 Special Construction				**7,923,345**			**/LS**	**7,923,345**
						13.0 Special Construction				**7,923,345**			**/SF**	**7,923,345**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (15% of total direct cost)	1.00 ls	-	-	1,143,735	-	-	1,143,735.37 /ls	1,143,735
						26.00.99.00 Electrical, Other				*1,143,735*			*/LS*	*1,143,735*
						26.15.01.0007 Miscellaneous Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.00 Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.0 Electrical Work				**1,143,735**			**/LS**	**1,143,735**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, erosion control and all associated works	1.00 ls	123,623	-	-	352,972	-	476,595.53 /ls	476,596
						31.15.01.05 Site Preparation,		*123,623*			*352,972*		*/AC*	*476,596*
						31.15.01.0001 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.15 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.0 Earthwork		**123,623**			**352,972**		**/LS**	**476,596**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 12% of total direct cost	1.00 ls	-		898,142	-	-	898,142.43 /ls	898,142
						40.10.99.99 Process Pipe, Other				*898,142*			*/LS*	*898,142*
						40.00.01.0001 Miscellaneous Piping and Valves				**898,142**			**/LS**	**898,142**
						40.00 Exposed Process Pipe				**898,142**			**/LF**	**898,142**
						40.0 Process Pipe				**898,142**			**/LS**	**898,142**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								

Detail Report

Job Size: 1 LS
Duration: 1 LS

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (10% of total direct cost)	1.00 ls	-	-	774,828	-	-	774,828.09 /ls	774,828
						40.90.99.01 I&C, Other				*774,828*			*/LS*	*774,828*
						40.90.01.0002 Miscellaneous I&C				**774,828**			**/LS**	**774,828**
						40.90 Instrumentation and Controls				**774,828**			**/LS**	**774,828**
						40.9 Instrumentation & Controls				**774,828**			**/LS**	**774,828**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	5.00 ea	913	489	-	-	-	280.46 /ea	1,402
						Sleeved anchor bolts - Small	24.00 ea	658	563	-	-	-	50.87 /ea	1,221
						Non-Shrink Machine Grout	5.00 cuft	434	724	-	-	-	231.53 /cuft	1,158
						Grease, Oil, and Lube Pumps, 5-20 hp	5.00 ea	913	734	-	-	-	329.37 /ea	1,647
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	5.00 EA	-	391,276	-	-	-	78,255.26 /EA	391,276
						Set pump assembly, 5 - 20 hp	5.00 ea	14,611	245	-	-	-	2,971.15 /ea	14,856
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp	*5.00 EA*	*17,529*	*394,031*				*82,311.96 /EA*	*411,560*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**5.00 EA**	**17,529**	**394,031**				**82,311.96 /EA**	**411,560**
				43.05.01.0012		**Equipment Silos**								
					44.05.76.40	*Equipment Silos*								
						Silos, 14' dia x 45' h, excl. foundations	2.00 ea	116,934	391,276	-	56,852	-	282,531.23 /ea	565,062
						44.05.76.40 Equipment Silos	*2.00 EA*	*116,934*	*391,276*		*56,852*		*282,531.23 /EA*	*565,062*
						43.05.01.0012 Equipment Silos	**2.00 EA**	**116,934**	**391,276**		**56,852**		**282,531.23 /EA**	**565,062**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.37 /EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	2,846,535	-	-	-	948,845.06 /ea	2,846,535
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.39 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*3.00 EA*	*77,278*	*2,854,337*		*10,564*		*980,726.49 /EA*	*2,942,179*
						44.05.01.0001 Equipment Centrifuges	**3.00 EA**	**81,643**	**2,854,337**		**23,383**		**986,454.28 /EA**	**2,959,363**
						43.05 Furnish and Install Process Equipment		**216,106**	**3,639,644**		**80,234**		**/LS**	**3,935,985**
						43.0 Process Equipment - Industrial		**216,106**	**3,639,644**		**80,234**		**/LS**	**3,935,985**
						0029 Dewatering	**1.00 LS**	**339,730**	**3,639,644**	**10,740,051**	**433,207**		**15,152,631.93 /LS**	**15,152,632**
	0031					**Boiler (High P Steam)**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing boilers and all associated works	2.00 ea	11,546		-	5,744	-	8,644.87 /ea	17,290
						02.01.05.00 Process Equipment Demolition		*11,546*			*5,744*		*/EA*	*17,290*
						02.40.01.0001 Demolition		**11,546**			**5,744**		**/LS**	**17,290**
						02.40 Demolition		**11,546**			**5,744**		**/LS**	**17,290**
						02.0 Existing Conditions		**11,546**			**5,744**		**/LS**	**17,290**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		49,660	-	-	49,659.52 /ls	49,660
						40.10.99.99 Process Pipe, Other				*49,660*			*/LS*	*49,660*
						40.00.01.0001 Miscellaneous Piping and Valves				**49,660**			**/LS**	**49,660**
						40.00 Exposed Process Pipe				**49,660**			**/LF**	**49,660**
						40.0 Process Pipe				**49,660**			**/LS**	**49,660**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0011		**Equipment Boilers**								
					43.00.02.00	*Process Equipment, General Conditions*								
						Furnish Boiler	1.00 ea		316,934	-		-	316,933.82 /ea	316,934
						Install new Boiler	1.00 ea	8,592	-	-	3,443	-	12,035.66 /ea	12,036
						43.00.02.00 Process Equipment, General Conditions		*8,592*	*316,934*		*3,443*		*/EA*	*328,969*
						43.05.01.0011 Equipment Boilers		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						43.05 Furnish and Install Process Equipment		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**
						43.0 Process Equipment - Industrial		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**
						0031 Boiler (High P Steam)	**1.00 LS**	**20,138**	**316,934**	**49,660**	**9,187**		**395,918.73 /LS**	**395,919**
	0032					**Combine Heat Power (CHP)**								
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		397,276	-	-	397,276.32 /ls	397,276
						40.10.99.99 Process Pipe, Other				*397,276*			*/LS*	*397,276*
						40.00.01.0001 Miscellaneous Piping and Valves				**397,276**			**/LS**	**397,276**
						40.00 Exposed Process Pipe				**397,276**			**/LF**	**397,276**
						40.0 Process Pipe				**397,276**			**/LS**	**397,276**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0009		**Combine Heat Power**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.28.00	*Energy Recovery*								
						Furnish Combine Heat Power Package	2.00 ea		8,529,824	-		-	4,264,911.84 /ea	8,529,824
						Install Combine Heat Power Package	2.00 ea	264,366		-	35,539	-	149,952.57 /ea	299,905
						43.05.28.00 Energy Recovery		*264,366*	*8,529,824*		*35,539*		*/EA*	*8,829,729*
						43.05.01.0009 Combine Heat Power		**268,731**	**8,529,824**		**48,357**		**/EA**	**8,846,912**
						43.05 Furnish and Install Process Equipment		**268,731**	**8,529,824**		**48,357**		**/LS**	**8,846,912**
						43.0 Process Equipment - Industrial		**268,731**	**8,529,824**		**48,357**		**/LS**	**8,846,912**
						0032 Combine Heat Power (CHP)	**1.00 LS**	**268,731**	**8,529,824**	**397,276**	**48,357**		**9,244,188.52 /LS**	**9,244,189**
	0033					**Flares**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	19,564	-	-	19,563.83 /ls	19,564
						09.00.99.00 Finishes, Other				*19,564*			*/LS*	*19,564*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**19,564**			**/LS**	**19,564**
						09.00 Finishes				**19,564**			**/LS**	**19,564**
						09.0 Finishes				**19,564**			**/LS**	**19,564**
						0033 Flares	**1.00 LS**			**19,564**			**19,563.83 /LS**	**19,564**
	0034					**Thermal Conversion of Organics**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.02.00	*Structure/Building Demolition*								
						Demo digester, 100' dia x 50' high Concrete, per cubic foot and haul debris away for disposal	392,699.00 cf		-	653,029	-	-	1.66 /cf	653,029
						02.01.02.00 Structure/Building Demolition	*7,953.00 SF*			*653,029*			*82.11 /SF*	*653,029*
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	39,128		-	-	-	39,127.68 /ls	39,128
						02.01.04.20 Piping Demolition	*1.00 LS*	*39,128*					*39,127.68 /LS*	*39,128*
					02.01.05.00	*Process Equipment Demolition*								
						Miscellaneous demolition equipment within digester	1.00 ea	21,520		-	-	-	21,520.20 /ea	21,520
						02.01.05.00 Process Equipment Demolition	*1.00 EA*	*21,520*					*21,520.20 /EA*	*21,520*
						02.40.01.0001 Demolition		**60,648**		**653,029**			**/LS**	**713,677**
						02.40 Demolition		**60,648**		**653,029**			**/LS**	**713,677**
						02.0 Existing Conditions		**60,648**		**653,029**			**/LS**	**713,677**
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 80' x 102' x 50' - 3 Story Building, including foundation, superstructure and finishes	23,562.00 sf	-	-	16,133,692	-	-	684.73 /sf	16,133,692
						13.01.99.00 Special Construction, Other				*16,133,692*			*/SF*	*16,133,692*

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.10.01.0003 Dewatering Building				**16,133,692**			**/SF**	**16,133,692**
						13.00 Special Construction				**16,133,692**			**/LS**	**16,133,692**
						13.0 Special Construction				**16,133,692**			**/SF**	**16,133,692**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (8% of total direct cost)	1.00 ls	-	-	4,828,629	-	-	4,828,628.64 /ls	4,828,629
						26.00.99.00 Electrical, Other				*4,828,629*			*/LS*	*4,828,629*
						26.15.01.0007 Miscellaneous Electrical				**4,828,629**			**/LS**	**4,828,629**
						26.00 Electrical				**4,828,629**			**/LS**	**4,828,629**
						26.0 Electrical Work				**4,828,629**			**/LS**	**4,828,629**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, backfill, erosion control and all associated works	1.00 ls	247,246	-	-	705,944	-	953,190.69 /ls	953,191
						31.15.01.05 Site Preparation,		*247,246*			*705,944*		*/AC*	*953,191*
						31.15.01.0001 Site Preparation		**247,246**			**705,944**		**/AC**	**953,191**
						31.15 Site Preparation		**247,246**			**705,944**		**/AC**	**953,191**
						31.0 Earthwork		**247,246**			**705,944**		**/LS**	**953,191**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 9% of total direct cost	1.00 ls	-	0	5,247,293	-	-	5,247,293.10 /ls	5,247,293
						40.10.99.99 Process Pipe, Other				*5,247,293*			*/LS*	*5,247,293*
						40.00.01.0001 Miscellaneous Piping and Valves				**5,247,293**			**/LS**	**5,247,293**
						40.00 Exposed Process Pipe				**5,247,293**			**/LF**	**5,247,293**
						40.0 Process Pipe				**5,247,293**			**/LS**	**5,247,293**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (4% of total direct cost)	1.00 ls	-	-	2,414,313	-	-	2,414,313.29 /ls	2,414,313
						40.90.99.01 I&C, Other				*2,414,313*			*/LS*	*2,414,313*
						40.90.01.0002 Miscellaneous I&C				**2,414,313**			**/LS**	**2,414,313**
						40.90 Instrumentation and Controls				**2,414,313**			**/LS**	**2,414,313**
						40.9 Instrumentation & Controls				**2,414,313**			**/LS**	**2,414,313**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0013		**Thermal Conversion Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						Furnish Thermal Conversion Package	1.00 ls		34,432,316	-		-	34,432,315.77 /ls	34,432,316
						Install Thermal Conversion Package (15% of equipment cost)	1.00 ls	5,164,847	-	-		-	5,164,847.36 /ls	5,164,847
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*5,164,847*	*34,432,316*				*39,597,163.13 /EA*	*39,597,163*
						43.05.01.0013 Thermal Conversion Package	**1.00 LS**	**5,164,847**	**34,432,316**				**39,597,163.13 /LS**	**39,597,163**
						43.05 Furnish and Install Process Equipment		**5,164,847**	**34,432,316**				**/LS**	**39,597,163**
						43.0 Process Equipment - Industrial		**5,164,847**	**34,432,316**				**/LS**	**39,597,163**
						0034 Thermal Conversion of Organics	**1.00 LS**	**5,472,742**	**34,432,316**	**29,276,956**	**705,944**		**69,887,957.36 /LS**	**69,887,957**
	0035					**TCO Turbines**								
		31.0				**Earthwork**								
			31.17			**Piling and Caissons**								
				31.17.01.0001		**Underpinning 12' Deep**								
					31.30.04.00	*Site Specialties, Under-pinning*								
						Underpinning foundations, 5' to 16' below grade, over 500 C.Y., includes excavation, forming, reinforcing, concrete and equipment	333.33 cy	724,457	191,831	-	132,222	-	3,145.53 /cy	1,048,510
						31.30.04.00 Site Specialties, Under-pinning		*724,457*	*191,831*		*132,222*		*/LS*	*1,048,510*
						31.17.01.0001 Underpinning 12' Deep		**724,457**	**191,831**		**132,222**		**/CY**	**1,048,510**
						31.17 Piling and Caissons		**724,457**	**191,831**		**132,222**		**/LS**	**1,048,510**
						31.0 Earthwork	**1.00 LS**	**724,457**	**191,831**		**132,222**		**1,048,509.73 /LS**	**1,048,510**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		198,638	-	-	198,638.17 /ls	198,638
						40.10.99.99 Process Pipe, Other				*198,638*			*/LS*	*198,638*
						40.00.01.0001 Miscellaneous Piping and Valves				**198,638**			**/LS**	**198,638**
						40.00 Exposed Process Pipe				**198,638**			**/LF**	**198,638**
						40.0 Process Pipe	**1.00 LS**			**198,638**			**198,638.17 /LS**	**198,638**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0015		**TCO Turbine Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.37 /EA*	*17,183*
					43.05.28.00	*Energy Recovery*								
						Furnish Combine Heat Power Package	2.00 ea		1,956,382	-		-	978,190.79 /ea	1,956,382
						Install Combine Heat Power Package	2.00 ea	172,455		-	23,183	-	97,819.09 /ea	195,638
						43.05.28.00 Energy Recovery	*1.00 EA*	*172,455*	*1,956,382*		*23,183*		*2,152,019.76 /EA*	*2,152,020*
						43.05.01.0015 TCO Turbine Package	**1.00 LS**	**176,820**	**1,956,382**		**36,002**		**2,169,203.13 /LS**	**2,169,203**
						43.05 Furnish and Install Process Equipment		**176,820**	**1,956,382**		**36,002**		**/LS**	**2,169,203**
						43.0 Process Equipment - Industrial	**1.00 LS**	**176,820**	**1,956,382**		**36,002**		**2,169,203.13 /LS**	**2,169,203**
						0035 TCO Turbines	**1.00 LS**	**901,277**	**2,148,212**	**198,638**	**168,224**		**3,416,351.03 /LS**	**3,416,351**
						3B ALTERNATE 3B	**1.00 LS**	**7,850,046**	**62,651,101**	**48,896,896**	**1,885,322**		**############ /LS**	**121,283,365**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
3C						ALTERNATE 3C								
	0021					Thickening PSD + TSD								
		09.0				Finishes								
			09.00			Finishes								
				09.01.01.0001		Miscellaneous Refurbishment and Improvement								
					09.00.99.00	Finishes, Other								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.08 /ls	97,819
						09.00.99.00 Finishes, Other				97,819			/LS	97,819
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				97,819			/LS	97,819
						09.00 Finishes				97,819			/LS	97,819
						09.0 Finishes				97,819			/LS	97,819
						0021 Thickening PSD + TSD	1.00 LS			97,819			97,819.08 /LS	97,819
	0022					Thickening WAS								
		02.0				Existing Conditions								
			02.40			Demolition								
				02.40.01.0001		Demolition								
					02.01.05.00	Process Equipment Demolition								
						Demo existing centrifuges and all associated works	4.00 ea	46,184		-	22,975	-	17,289.72 /ea	69,159
						02.01.05.00 Process Equipment Demolition		46,184			22,975		/EA	69,159
						02.40.01.0001 Demolition		46,184			22,975		/LS	69,159
						02.40 Demolition		46,184			22,975		/LS	69,159
						02.0 Existing Conditions		46,184			22,975		/LS	69,159
		40.0				Process Pipe								
			40.00			Exposed Process Pipe								
				40.00.01.0001		Miscellaneous Piping and Valves								
					40.10.99.99	Process Pipe, Other								
						Miscellaneous piping and valves	1.00 ls	-		198,638	-	-	198,638.16 /ls	198,638
						40.10.99.99 Process Pipe, Other				198,638			/LS	198,638
						40.00.01.0001 Miscellaneous Piping and Valves				198,638			/LS	198,638
						40.00 Exposed Process Pipe				198,638			/LF	198,638
						40.0 Process Pipe				198,638			/LS	198,638
		43.0				Process Equipment - Industrial								
			44.05			Furnish and Install Process Equipment								
				43.05.01.0008		Equipment Centrifuge Feed Pumps								
					44.05.40.11	Horizontal End Suction Centrifugal Pump: 5hp-20hp								
						Functional Testing, Pumps, 5-20 hp	7.00 ea	1,278	685	-	-	-	280.46 /ea	1,963
						Sleeved anchor bolts - Small	28.00 ea	767	657	-	-	-	50.87 /ea	1,424
						Non-Shrink Machine Grout	14.00 cuft	1,215	2,027	-	-	-	231.53 /cuft	3,241
						Grease, Oil, and Lube Pumps, 5-20 hp	7.00 ea	1,278	1,027	-	-	-	329.37 /ea	2,306
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	7.00 EA	-	547,787	-	-	-	78,255.26 /EA	547,787
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.15 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		13,305	552,330				/EA	565,635
						43.05.01.0008 Equipment Centrifuge Feed Pumps		13,305	552,330				/EA	565,635
				44.05.01.0001		Equipment Centrifuges								
					43.00.02.00	Process Equipment, General Conditions								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		4,365			12,818		/EA	17,183
					43.05.10.01	Liquid Centrifuge: 150-249 gpm								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	3,404,104	-	-	-	1,134,701.32 /ea	3,404,104
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	71,598	-	-	10,564	-	27,387.38 /ea	82,162
						43.05.10.01 Liquid Centrifuge: 150-249 gpm		77,278	3,411,906		10,564		/EA	3,499,748
						44.05.01.0001 Equipment Centrifuges		81,643	3,411,906		23,383		/EA	3,516,932
						44.05 Furnish and Install Process Equipment		94,948	3,964,236		23,383		/EA	4,082,566
						43.0 Process Equipment - Industrial		94,948	3,964,236		23,383		/LS	4,082,566
						0022 Thickening WAS	1.00 LS	141,133	3,964,236	198,638	46,357		4,350,363.52 /LS	4,350,364
	0023					Screening T(PSD+TSD)								
		13.0				Special Construction								
			13.00			Special Construction								
				13.10.01.0002		Modify Existing Building to Accommodate Screening Bin								
					13.01.99.00	Special Construction, Other								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.26 /ea	78,255

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction				**78,255**			**/SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.44 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.34.00	*New Screens*								
						Furnish Strain Press SLudge Cleaner Screen	1.00 ea		322,803	-	-	-	322,802.97 /ea	322,803
						Install Strain Press SLudge Cleaner Screen	1.00 ea	19,224		-	-	-	19,223.81 /ea	19,224
						44.05.34.00 New Screens		*19,224*	*322,803*				*/EA*	*342,027*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.16 /ea	173,598
						44.05.34.01 Refurbish Existing Screens		*17,088*		*156,511*			*/EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner		**40,677**	**322,803**	**156,511**	**12,818**		**/EA**	**532,808**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	573	293	-	-	-	288.75 /ea	866
						Local panel	3.00 ea	1,718	8,804	-	-	-	3,507.36 /ea	10,522
						Pressure indicators	3.00 ea	430	1,467	-	-	-	632.29 /ea	1,897
						Sleeved anchor bolts - Small	20.00 ea	573	470	-	-	-	52.12 /ea	1,042
						Non-Shrink Machine Grout	10.00 cuft	907	1,448	-	-	-	235.46 /cuft	2,355
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	573	440	-	-	-	337.66 /ea	1,013
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	146,729	-	-	-	48,909.54 /EA	146,729
						Set pump assembly, 5 - 20 hp	3.00 ea	9,165	147	-	-	-	3,103.75 /ea	9,311
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*13,938*	*159,797*				*/EA*	*173,735*
						44.05.01.0003 Equipment Centrifugal Pumps		**13,938**	**159,797**				**/EA**	**173,735**
						44.05 Furnish and Install Process Equipment		**54,615**	**482,600**	**156,511**	**12,818**		**/EA**	**706,543**
						43.0 Process Equipment - Industrial		**54,615**	**482,600**	**156,511**	**12,818**		**/LS**	**706,543**
						0023 Screening T(PSD+TSD)	**1.00 LS**	**54,615**	**482,600**	**234,766**	**12,818**		**784,798.70 /LS**	**784,799**
	0024					**Screening TWAS**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0002		**Modify Existing Building to Accommodate Screening Bin**								
					13.01.99.00	*Special Construction, Other*								
						Modify existing building to create opening for new screening bins	1.00 ea			78,255	-	-	78,255.26 /ea	78,255
						13.01.99.00 Special Construction, Other				*78,255*			*/SF*	*78,255*
						13.10.01.0002 Modify Existing Building to Accommodate Screening Bin				**78,255**			**/LS**	**78,255**
						13.00 Special Construction				**78,255**			**/LS**	**78,255**
						13.0 Special Construction				**78,255**			**/SF**	**78,255**
		43.0				**Process Equipment - Industrial**								
			44.05			**Furnish and Install Process Equipment**								
				44.05.01.0002		**Equipment Strain Press Sludge Cleaner**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.56 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.34.01	*Refurbish Existing Screens*								
						Allowance to refurbish existing Screens	2.00 ea	17,088		156,511	-	-	86,799.16 /ea	173,598
						44.05.34.01 Refurbish Existing Screens		*17,088*		*156,511*			*/EA*	*173,598*
						44.05.01.0002 Equipment Strain Press Sludge Cleaner		**21,453**		**156,511**	**12,818**		**/EA**	**190,782**
				44.05.01.0003		**Equipment Centrifugal Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	2.00 ea	382	196	-	-	-	288.74 /ea	577
						Local panel	2.00 ea	1,146	5,869	-	-	-	3,507.35 /ea	7,015
						Pressure indicators	4.00 ea	573	1,956	-	-	-	632.30 /ea	2,529
						Sleeved anchor bolts - Small	8.00 ea	229	188	-	-	-	52.12 /ea	417
						Non-Shrink Machine Grout	2.00 cuft	181	290	-	-	-	235.46 /cuft	471
						Grease, Oil, and Lube Pumps, 5-20 hp	2.00 ea	382	293	-	-	-	337.66 /ea	675
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	2.00 EA	-	97,819	-	-	-	48,909.54 /EA	97,819
						Set pump assembly, 5 - 20 hp	2.00 ea	6,110	98	-	-	-	3,103.74 /ea	6,207

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*9,002*	*106,709*				*/EA*	*115,711*
						44.05.01.0003 Equipment Centrifugal Pumps		**9,002**	**106,709**				**/EA**	**115,711**
						44.05 Furnish and Install Process Equipment		**30,455**	**106,709**	**156,511**	**12,818**		**/EA**	**306,493**
						43.0 Process Equipment - Industrial		**30,455**	**106,709**	**156,511**	**12,818**		**/LS**	**306,493**
						0024 Screening TWAS	**1.00 LS**	**30,455**	**106,709**	**234,766**	**12,818**		**384,748.04 /LS**	**384,748**
	0025					**Pre-Dewatering**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.02.00	*Structure/Building Demolition*								
						Demo Building, 88' x 38'x 30' high Concrete, per cubic foot and haul debris away for disposal	100,320.00 cf		-	166,825	-	-	1.66 /cf	166,825
						02.01.02.00 Structure/Building Demolition				*166,825*			*/SF*	*166,825*
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	17,124		-	-	-	17,124.14 /ls	17,124
						02.01.04.20 Piping Demolition		*17,124*					*/LS*	*17,124*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing tanks 12K gallon	3.00 ea	28,865		-	10,339	-	13,067.90 /ea	39,204
						Demo existing Hex	3.00 ea	17,319		-	17,231	-	11,516.71 /ea	34,550
						Miscellaneous demolition	1.00 .	19,243		-	-	-	19,242.97 /.	19,243
						02.01.05.00 Process Equipment Demolition		*65,427*			*27,570*		*/EA*	*92,997*
						02.40.01.0001 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,946**
						02.40 Demolition		**82,551**		**166,825**	**27,570**		**/LS**	**276,946**
						02.0 Existing Conditions		**82,551**		**166,825**	**27,570**		**/LS**	**276,946**
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 35' x 45' - 3 Story Building, including foundation, superstructure and finishes	3,840.00 sf	-	-	4,131,878	-	-	1,076.01 /sf	4,131,878
						13.01.99.00 Special Construction, Other				*4,131,878*			*/SF*	*4,131,878*
						13.10.01.0003 Dewatering Building				**4,131,878**			**/SF**	**4,131,878**
						13.00 Special Construction				**4,131,878**			**/LS**	**4,131,878**
						13.0 Special Construction				**4,131,878**			**/SF**	**4,131,878**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (15% of total direct cost)	1.00 ls	-	-	1,143,735	-	-	1,143,735.35 /ls	1,143,735
						26.00.99.00 Electrical, Other				*1,143,735*			*/LS*	*1,143,735*
						26.15.01.0007 Miscellaneous Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.00 Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.0 Electrical Work				**1,143,735**			**/LS**	**1,143,735**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, erosion control and all associated works	1.00 ls	123,623	-	-	352,972	-	476,595.52 /ls	476,596
						31.15.01.05 Site Preparation,		*123,623*			*352,972*		*/AC*	*476,596*
						31.15.01.0001 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.15 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.0 Earthwork		**123,623**			**352,972**		**/LS**	**476,596**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 12% of total direct cost	1.00 ls	-		898,142	-	-	898,142.43 /ls	898,142
						40.10.99.99 Process Pipe, Other				*898,142*			*/LS*	*898,142*
						40.00.01.0001 Miscellaneous Piping and Valves				**898,142**			**/LS**	**898,142**
						40.00 Exposed Process Pipe				**898,142**			**/LF**	**898,142**
						40.0 Process Pipe				**898,142**			**/LS**	**898,142**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								

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Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				40.90.01.0002		Miscellaneous I&C								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (10% of total direct cost)	1.00 ls	-	-	774,828	-	-	774,828.13 /ls	774,828
						40.90.99.01 I&C, Other				*774,828*			*/LS*	*774,828*
						40.90.01.0002 Miscellaneous I&C				**774,828**			**/LS**	**774,828**
						40.90 Instrumentation and Controls				**774,828**			**/LS**	**774,828**
						40.9 Instrumentation & Controls				**774,828**			**/LS**	**774,828**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	6.00 ea	1,096	587	-	-	-	280.46 /ea	1,683
						Sleeved anchor bolts - Small	24.00 ea	658	563	-	-	-	50.87 /ea	1,221
						Non-Shrink Machine Grout	12.00 cuft	1,041	1,737	-	-	-	231.53 /cuft	2,778
						Grease, Oil, and Lube Pumps, 5-20 hp	6.00 ea	1,096	880	-	-	-	329.37 /ea	1,976
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	6.00 EA	-	469,532	-	-	-	78,255.26 /EA	469,532
						Set pump assembly, 5 - 20 hp	6.00 ea	17,533	293	-	-	-	2,971.15 /ea	17,827
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*21,424*	*473,593*				*/EA*	*495,017*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**21,424**	**473,593**				**/EA**	**495,017**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.50 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.38 /EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	24.00 ea	1,146	563	-	-	-	71.21 /ea	1,709
						Non-Shrink Machine Grout	50.00 cuft	4,535	7,239	-	-	-	235.46 /cuft	11,773
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	-	3,668,215	-	-	-	1,222,738.49 /ea	3,668,215
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	3.00 ea	99,104	-	-	18,279	-	39,127.63 /ea	117,383
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*2.00 EA*	*104,784*	*3,676,018*		*18,279*		*1,899,540.23 /EA*	*3,799,080*
						44.05.01.0001 Equipment Centrifuges		**109,149**	**3,676,018**		**31,097**		**/EA**	**3,816,264**
						43.05 Furnish and Install Process Equipment		**130,573**	**4,149,611**		**31,097**		**/LS**	**4,311,281**
						43.0 Process Equipment - Industrial		**130,573**	**4,149,611**		**31,097**		**/LS**	**4,311,281**
						0025 Pre-Dewatering	**1.00 LS**	**336,748**	**4,149,611**	**7,115,408**	**411,639**		**12,013,405.36 /LS**	**12,013,405**
	0026					**Thermal Hydrolysis WAS**								
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0002		**Concrete Pad 20' x 50' x 24" Thick**								
					03.10.13.24	*Cast-In-Place Concrete, Equipment Pads, 24" thick*								
						Fine grade, for slab on grade, by hand	1,000.00 sf	1,256	59	-	-	-	1.32 /sf	1,315
						Structural Excavation, Excavator and Trucks, Medium Crew, 15' depth	96.60 cy	477	-	-	661	-	11.78 /cy	1,138
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	111.11 sy	527	-	-	477	-	9.04 /sy	1,004
						Structural Backfill, Dozer and Traxcavator or Loader, Medium Crew	25.00 cy	162	-	-	161	-	12.94 /cy	324
						Load Excess for Hauling, Rubber Tire Loader, Cat 950	71.60 cy	35	-	-	49	-	1.17 /cy	84
						Dump Charges for For Excess, 17 yd tandem, per cy	71.60 cy	-	1,443	-	-	-	20.15 /cy	1,443
						Fill, gravel subbase, under building slab on grade	37.04 cy	1,369	2,138	-	-	-	94.67 /cy	3,506
						Concrete pumping, subcontract, all inclusive price	74.07 cy	-	-	2,174	-	-	29.35 /cy	2,174
						Slab on grade edge forms, 12" to 24"	280.00 sf	5,885	548	-	-	-	22.97 /sf	6,433
						Reinforcing in place, A615 Gr 60, priced per lbs.	11,851.85 lb	-	11,593	9,275	-	-	1.76 /lb	20,868
						Concrete, ready mix, 4000 psi	74.07 CY	-	16,376	-	-	-	221.07 /CY	16,376
						Add for concrete waste, 4000 psi	3.70 cy	-	819	-	-	-	221.07 /cy	819
						Placing concrete, concrete pump	74.07 cy	4,106	-	-	-	-	55.43 /cy	4,106
						Finishing floors, monolithic, trowel finish (machine)	1,000.00 sf	1,763	39	-	-	-	1.80 /sf	1,802
						Curing, membrane spray	1,000.00 sf	148	78	-	-	-	0.23 /sf	226
						Polyethelene vapor barrier, 10 mil thick	10.00 sq	207	207	-	-	-	41.47 /sq	415
						03.10.13.24 Cast-In-Place Concrete, Equipment Pads, 24" thick		*15,936*	*33,299*	*11,448*	*1,348*		*/CY*	*62,031*
						03.10.01.0002 Concrete Pad 20' x 50' x 24" Thick		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
						03.10 Cast-In-Place Concrete Work		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
						03.0 Concrete Work		**15,936**	**33,299**	**11,448**	**1,348**		**/CY**	**62,031**
		33.0				**Utilities**								
			33.05			**Buried Process Piping**								
				33.10.01.0001		**Allowance for Buried Piping**								
					33.00.50.00	*Buried Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		97,819	-	-	97,819.05 /ls	97,819
						33.00.50.00 Buried Pipe, Other				*97,819*			*/LS*	*97,819*

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Detail Report

Job Size: 1 LS
Duration: 1 LS

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						33.10.01.0001 Allowance for Buried Piping				**97,819**			**/LS**	**97,819**
						33.05 Buried Process Piping				**97,819**			**/LS**	**97,819**
						33.0 Utilities				**97,819**			**/LS**	**97,819**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	6.00 ea	1,096	587	-	-	-	280.46 /ea	1,683
						Sleeved anchor bolts - Small	32.00 ea	877	751	-	-	-	50.87 /ea	1,628
						Non-Shrink Machine Grout	11.00 cuft	954	1,592	-	-	-	231.53 /cuft	2,547
						Grease, Oil, and Lube Pumps, 5-20 hp	6.00 ea	1,096	880	-	-	-	329.37 /ea	1,976
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	6.00 EA	-	469,532	-	-	-	78,255.26 /EA	469,532
						Set pump assembly, 5 - 20 hp	6.00 ea	17,533	293	-	-	-	2,971.15 /ea	17,827
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*21,556*	*473,636*				*/EA*	*495,192*
						43.05.01.0008 Equipment Centrifuge Feed Pumps	**3.00 EA**	**21,556**	**473,636**				**165,064.06 /EA**	**495,192**
				43.05.01.0010		**Thermal Hydrolysis Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					43.05.28.01	*Thermal Hydrolysis Package*								
						Furnish Thermal Hydrolysis Package	1.00 ea		7,629,888	-		-	7,629,888.17 /ea	7,629,888
						Install Thermal Hydrolysis Package (10% of equipment cost)	1.00 ea	672,573		-	90,416	-	762,988.80 /ea	762,989
						43.05.28.01 Thermal Hydrolysis Package		*672,573*	*7,629,888*		*90,416*		*/LS*	*8,392,877*
						43.05.01.0010 Thermal Hydrolysis Package	**1.00 LS**	**676,939**	**7,629,888**		**103,234**		**8,410,060.34 /LS**	**8,410,060**
						43.05 Furnish and Install Process Equipment		**698,495**	**8,103,524**		**103,234**		**/LS**	**8,905,253**
						43.0 Process Equipment - Industrial		**698,495**	**8,103,524**		**103,234**		**/LS**	**8,905,253**
						0026 Thermal Hydrolysis WAS	**1.00 LS**	**714,430**	**8,136,824**	**109,267**	**104,581**		**9,065,102.76 /LS**	**9,065,103**
	0027					**Anaerobic Digestion**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	97,819	-	-	97,819.07 /ls	97,819
						09.00.99.00 Finishes, Other				*97,819*			*/LS*	*97,819*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**97,819**			**/LS**	**97,819**
						09.00 Finishes				**97,819**			**/LS**	**97,819**
						09.0 Finishes				**97,819**			**/LS**	**97,819**
						0027 Anaerobic Digestion	**1.00 LS**			**97,819**			**97,819.07 /LS**	**97,819**
	0028					**Recuperative Thickening**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.01.07	*General Site Demolition, Saw Cutting Concrete*								
						Sawcutting, concrete slabs, mesh or bar reinforcing, up to 12" deep	36.00 lf	828	156	-	461	-	40.11 /lf	1,444
						02.01.01.07 General Site Demolition, Saw Cutting Concrete		*828*	*156*		*461*		*/LF*	*1,444*
					02.01.02.02	*Selective Demolition, Cut-out, Concrete, Slabs*								
						Selective demolition, cutout, slab on grade, non-reinforced, to 12" thick, 8-16 S.F., excludes loading and disposal	80.00 cf	4,834	-	-	644	-	68.47 /cf	5,478
						02.01.02.02 Selective Demolition, Cut-out, Concrete, Slabs		*4,834*			*644*		*/CF*	*5,478*
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing pumps and all associated works	4.00 ea	15,395	-		-	-	3,848.67 /ea	15,395
						Miscellaneous demolition	1.00 ls	5,773		-	-	-	5,772.91 /ls	5,773
						02.01.05.00 Process Equipment Demolition		*21,168*					*/EA*	*21,168*
						02.40.01.0001 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.40 Demolition		**26,830**	**156**		**1,104**		**/LS**	**28,089**
						02.0 Existing Conditions		**26,830**	**156**		**1,104**		**/LS**	**28,089**
		03.0				**Concrete Work**								
			03.10			**Cast-In-Place Concrete Work**								
				03.10.01.0001		**New Sump Structure**								
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Concrete pumping, subcontract, all inclusive price	4.89 cy	-	-	241	-	-	49.22 /cy	241
						Forms in place, structural walls, to 8' high, hand set	264.00 sf	6,345	866	-	-	-	27.31 /sf	7,211
						Waterstop, PVC, center bulb, 6" wide	22.00 lf	282	144	-	-	-	19.38 /lf	426
						Speed Dowels, #7	22.00 ea	-	1,949	-	-	-	88.59 /ea	1,949

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					03.10.00.12	*Concrete, Cast-in-Place, Grade Walls, 12" Wide*								
						Reinforcing in place, A615 Gr 60, priced per lbs.	880.00 lb	-	1,444	1,155	-	-	2.95 /lb	2,599
						Concrete, ready mix, 4000 psi	4.89 CY	-	1,813	-	-	-	370.76 /CY	1,813
						Add for concrete waste, 4000 psi	0.24 cy	-	90	-	-	-	370.70 /cy	90
						Placing concrete, concrete pump, for structural wall to 12" thick	4.89 cy	515	-	-	-	-	105.35 /cy	515
						Patch & plug tieholes	264.00 sf	491	17	-	-	-	1.93 /sf	508
						Sack rub	264.00 sf	1,309	26	-	-	-	5.06 /sf	1,335
						Curing, membrane spray	264.00 sf	65	35	-	-	-	0.38 /sf	100
						Below grade dampproofing, Bituminous Asphalt	132.00 sf	-	433	-	-	-	3.28 /sf	433
						03.10.00.12 Concrete, Cast-in-Place, Grade Walls, 12" Wide		*9,007*	*6,817*	*1,396*			*/CY*	*17,220*
					03.10.05.12	*Cast-In-Place Concrete, Slabs on Grade, 12" thick*								
						Fine grade, for slab on grade, by hand	100.00 sf	104	12	-	-	-	1.16 /sf	116
						Concrete pumping, subcontract, all inclusive price	3.70 cy	-	-	219	-	-	59.03 /cy	219
						Slab on grade edge forms, 7" to 12"	40.00 sf	1,384	157	-	-	-	38.53 /sf	1,541
						Speed Dowels, #7	40.00 ea	-	4,250	-	-	-	106.25 /ea	4,250
						Reinforcing in place, A615 Gr 60, priced per lbs.	592.59 lb	-	1,166	933	-	-	3.54 /lb	2,099
						Concrete, ready mix, 4000 psi	3.70 CY	-	1,647	-	-	-	444.67 /CY	1,647
						Add for concrete waste, 4000 psi	0.19 cy	-	82	-	-	-	444.60 /cy	82
						Placing concrete, concrete pump	3.70 cy	413	-	-	-	-	111.50 /cy	413
						Finishing floors, monolithic, trowel finish (machine)	100.00 sf	355	8	-	-	-	3.63 /sf	363
						Curing, membrane spray	100.00 sf	30	16	-	-	-	0.46 /sf	46
						Polyethelene vapor barrier, 10 mil thick	1.00 sq	42	42	-	-	-	83.48 /sq	83
						03.10.05.12 Cast-In-Place Concrete, Slabs on Grade, 12" thick		*2,327*	*7,380*	*1,151*			*/CY*	*10,858*
						03.10.01.0001 New Sump Structure		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.10 Cast-In-Place Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
						03.0 Concrete Work		**11,334**	**14,197**	**2,547**			**/CY**	**28,078**
		31.0				**Earthwork**								
			31.25			**Earthworks, Structural**								
				31.25.01.0001		**Structural Excavation**								
					31.25.01.00	*Earthworks, Structural, Excavation*								
						Shoring, soldier beams & lagging with tie-backs and walers, subcontracted	320.00 sf		-	24,402	-	-	76.26 /sf	24,402
						Structural Excavation, Excavator and Trucks, Small Crew, 6' depth	29.60 cy	382	-	-	465	-	28.59 /cy	846
						Grade for slabs / Scarify and Recompact, Dozer and Traxcavator or Loader, Medium Crew	11.11 sy	111	-	-	101	-	19.03 /sy	211
						Import Aggregate Base - under slab, Dozer and Traxcavator or Loader, Small Crew	5.50 tn	45	231	-	40	-	57.46 /tn	316
						Structural Backfill, Dozer and Traxcavator or Loader, Small Crew	22.93 cy	142	874	-	125	-	49.77 /cy	1,141
						Load Excess for Hauling, Rubber Tire Loader, Cat 930	29.60 cy	814	-	-	879	-	57.19 /cy	1,693
						Haul / Remove Excess, 12 yd capacity, 15 miles RT	29.60 cy	306	-	-	540	-	28.60 /cy	847
						Dump Charges for For Excess, 12 yd tandem, per cy	29.60 cy	-	2,539	-	-	-	85.79 /cy	2,539
						31.25.01.00 Earthworks, Structural, Excavation		*1,800*	*3,644*	*24,402*	*2,149*		*/CY*	*31,995*
						31.25.01.0001 Structural Excavation		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.25 Earthworks, Structural		**1,800**	**3,644**	**24,402**	**2,149**		**/CY**	**31,995**
						31.0 Earthwork		**1,800**	**3,644**	**24,402**	**2,149**		**/LS**	**31,995**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		99,319	-	-	99,319.08 /ls	99,319
						40.10.99.99 Process Pipe, Other				*99,319*			*/LS*	*99,319*
						40.00.01.0001 Miscellaneous Piping and Valves				**99,319**			**/LS**	**99,319**
						40.00 Exposed Process Pipe				**99,319**			**/LF**	**99,319**
						40.0 Process Pipe				**99,319**			**/LS**	**99,319**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0004		**Equipment Rotary Drum Thickener**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		*4,365*			*12,818*		*/EA*	*17,183*
					44.05.71.32	*Rotary Drum Thickener, 3 meter*								
						FURNISH Rotary Drum Thickener	3.00 ea	-	1,584,669	-	-	-	528,223.03 /ea	1,584,669
						Install Rotary Drum Thickener	3.00 ea	88,037	-	-	-	-	29,345.73 /ea	88,037
						44.05.71.32 Rotary Drum Thickener, 3 meter		*88,037*	*1,584,669*				*/EA*	*1,672,706*
						43.05.01.0004 Equipment Rotary Drum Thickener		**92,403**	**1,584,669**		**12,818**		**/EA**	**1,689,890**
				43.05.01.0005		**Equipment Recuperative Thickening Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	10.00 ea	1,826	978	-	-	-	280.46 /ea	2,805
						Sleeved anchor bolts - Small	40.00 ea	1,096	939	-	-	-	50.87 /ea	2,035
						Non-Shrink Machine Grout	20.00 cuft	1,735	2,895	-	-	-	231.53 /cuft	4,631
						Grease, Oil, and Lube Pumps, 5-20 hp	10.00 ea	1,826	1,467	-	-	-	329.37 /ea	3,294
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	10.00 EA	-	782,553	-	-	-	78,255.26 /EA	782,553
						Set pump assembly, 5 - 20 hp	10.00 ea	29,222	489	-	-	-	2,971.15 /ea	29,711
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*35,706*	*789,322*				*/EA*	*825,028*
						43.05.01.0005 Equipment Recuperative Thickening Feed Pumps		**35,706**	**789,322**				**/EA**	**825,028**
				44.05.01.0004		**Equipment Submersible Pumps**								
					44.05.49.01	*Submersible Pump: 6hp-20hp*								
						Functional Testing, Submersible Pumps, 6 - 20 hp	2.00 ea	764	196	-	-	-	479.67 /ea	959
						FURNISH Submersible Pump, 6 - 20 hp	2.00 EA	-	78,255	-	-	-	39,127.64 /EA	78,255
						Set base elbow / pump assembly, 6 - 20 hp	2.00 ea	4,582	196	-	-	-	2,388.95 /ea	4,778
						Stainless steel guide rails, 2"	32.00 lf	764	563	-	-	-	41.47 /lf	1,327
						Install upper guide rail bracket	2.00 ea	286	39	-	-	-	162.76 /ea	326
						44.05.49.01 Submersible Pump: 6hp-20hp		*6,396*	*79,249*				*/EA*	*85,645*
						44.05.01.0004 Equipment Submersible Pumps		**6,396**	**79,249**				**/EA**	**85,645**
						43.05 Furnish and Install Process Equipment		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						43.0 Process Equipment - Industrial		**134,505**	**2,453,240**		**12,818**		**/LS**	**2,600,563**
						0028 Recuperative Thickening	**1.00 LS**	**174,468**	**2,471,237**	**126,268**	**16,071**		**2,788,044.25 /LS**	**2,788,044**
	0029					**Dewatering**								
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 30' x 60' x 100' - 3 Story Building, including foundation, superstructure and finishes	5,400.00 sf	-	-	7,923,345	-	-	1,467.29 /sf	7,923,345
						13.01.99.00 Special Construction, Other				*7,923,345*			*/SF*	*7,923,345*
						13.10.01.0003 Dewatering Building				**7,923,345**			**/SF**	**7,923,345**
						13.00 Special Construction				**7,923,345**			**/LS**	**7,923,345**
						13.0 Special Construction				**7,923,345**			**/SF**	**7,923,345**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (15% of total direct cost)	1.00 ls	-	-	1,143,735	-	-	1,143,735.38 /ls	1,143,735
						26.00.99.00 Electrical, Other				*1,143,735*			*/LS*	*1,143,735*
						26.15.01.0007 Miscellaneous Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.00 Electrical				**1,143,735**			**/LS**	**1,143,735**
						26.0 Electrical Work				**1,143,735**			**/LS**	**1,143,735**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, erosion control and all associated works	1.00 ls	123,623	-	-	352,972	-	476,595.51 /ls	476,596
						31.15.01.05 Site Preparation,		*123,623*			*352,972*		*/AC*	*476,596*
						31.15.01.0001 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.15 Site Preparation		**123,623**			**352,972**		**/AC**	**476,596**
						31.0 Earthwork		**123,623**			**352,972**		**/LS**	**476,596**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 12% of total direct cost	1.00 ls	-		898,142	-	-	898,142.42 /ls	898,142
						40.10.99.99 Process Pipe, Other				*898,142*			*/LS*	*898,142*
						40.00.01.0001 Miscellaneous Piping and Valves				**898,142**			**/LS**	**898,142**
						40.00 Exposed Process Pipe				**898,142**			**/LF**	**898,142**
						40.0 Process Pipe				**898,142**			**/LS**	**898,142**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (10% of total direct cost)	1.00 ls	-	-	774,828	-	-	774,828.15 /ls	774,828
						40.90.99.01 I&C, Other				*774,828*			*/LS*	*774,828*
						40.90.01.0002 Miscellaneous I&C				**774,828**			**/LS**	**774,828**
						40.90 Instrumentation and Controls				**774,828**			**/LS**	**774,828**
						40.9 Instrumentation & Controls				**774,828**			**/LS**	**774,828**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0008		**Equipment Centrifuge Feed Pumps**								
					44.05.40.11	*Horizontal End Suction Centrifugal Pump: 5hp-20hp*								
						Functional Testing, Pumps, 5-20 hp	3.00 ea	548	293	-	-	-	280.46 /ea	841
						Sleeved anchor bolts - Small	16.00 ea	438	376	-	-	-	50.87 /ea	814
						Non-Shrink Machine Grout	5.00 cuft	434	724	-	-	-	231.53 /cuft	1,158
						Grease, Oil, and Lube Pumps, 5-20 hp	3.00 ea	548	440	-	-	-	329.36 /ea	988
						FURNISH Horizontal End-Suction Centrifugal Pump, 5 - 20 hp	3.00 EA	-	234,766	-	-	-	78,255.27 /EA	234,766
						Set pump assembly, 5 - 20 hp	3.00 ea	8,767	147	-	-	-	2,971.14 /ea	8,913
						44.05.40.11 Horizontal End Suction Centrifugal Pump: 5hp-20hp		*10,735*	*236,746*				*/EA*	*247,480*
						43.05.01.0008 Equipment Centrifuge Feed Pumps		**10,735**	**236,746**				**/EA**	**247,480**
				43.05.01.0012		**Equipment Silos**								
					44.05.76.40	*Equipment Silos*								
						Silos, 14' dia x 45' h, excl. foundations	2.00 ea	116,934	391,276	-	56,852	-	282,531.25 /ea	565,062
						44.05.76.40 Equipment Silos		*116,934*	*391,276*		*56,852*		*/EA*	*565,062*
						43.05.01.0012 Equipment Silos	**2.00 EA**	**116,934**	**391,276**		**56,852**		**282,531.25 /EA**	**565,062**
				44.05.01.0001		**Equipment Centrifuges**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*2.00 EA*	*4,365*			*12,818*		*8,591.69 /EA*	*17,183*
					43.05.10.01	*Liquid Centrifuge: 150-249 gpm*								
						Sleeved anchor bolts, SS - Small	16.00 ea	764	376	-	-	-	71.21 /ea	1,139
						Non-Shrink Machine Grout	33.00 cuft	2,993	4,777	-	-	-	235.46 /cuft	7,770
						FURNISH Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	-	5,477,868	-	-	-	2,738,934.21 /ea	5,477,868
						Install Centrifuge w/ DC Backdrive, 150 - 249 GPM	2.00 ea	85,241	-	-	12,578	-	48,909.51 /ea	97,819
						43.05.10.01 Liquid Centrifuge: 150-249 gpm	*2.00 EA*	*88,998*	*5,483,022*		*12,578*		*2,792,298.52 /EA*	*5,584,597*
						44.05.01.0001 Equipment Centrifuges	**2.00 EA**	**93,363**	**5,483,022**		**25,396**		**2,800,890.20 /EA**	**5,601,780**
						43.05 Furnish and Install Process Equipment		**221,032**	**6,111,043**		**82,248**		**/LS**	**6,414,323**
						43.0 Process Equipment - Industrial		**221,032**	**6,111,043**		**82,248**		**/LS**	**6,414,323**
						0029 Dewatering	**1.00 LS**	**344,656**	**6,111,043**	**10,740,051**	**435,220**		**17,630,970.01 /LS**	**17,630,970**
	0031					**Boiler (High P Steam)**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.05.00	*Process Equipment Demolition*								
						Demo existing boilers and all associated works	2.00 ea	11,546		-	5,744	-	8,644.85 /ea	17,290
						02.01.05.00 Process Equipment Demolition		*11,546*			*5,744*		*/EA*	*17,290*
						02.40.01.0001 Demolition		**11,546**			**5,744**		**/LS**	**17,290**
						02.40 Demolition		**11,546**			**5,744**		**/LS**	**17,290**
						02.0 Existing Conditions		**11,546**			**5,744**		**/LS**	**17,290**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves	1.00 ls	-		49,660	-	-	49,659.55 /ls	49,660
						40.10.99.99 Process Pipe, Other				*49,660*			*/LS*	*49,660*
						40.00.01.0001 Miscellaneous Piping and Valves				**49,660**			**/LS**	**49,660**
						40.00 Exposed Process Pipe				**49,660**			**/LF**	**49,660**
						40.0 Process Pipe				**49,660**			**/LS**	**49,660**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0011		**Equipment Boilers**								
					43.00.02.00	*Process Equipment, General Conditions*								
						Furnish Boiler	1.00 ea		316,934	-		-	316,933.82 /ea	316,934
						Install new Boiler	1.00 ea	8,592	-	-	3,443	-	12,035.65 /ea	12,036
						43.00.02.00 Process Equipment, General Conditions		*8,592*	*316,934*		*3,443*		*/EA*	*328,969*
						43.05.01.0011 Equipment Boilers		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						43.05 Furnish and Install Process Equipment		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**
						43.0 Process Equipment - Industrial		**8,592**	**316,934**		**3,443**		**/LS**	**328,969**
						0031 Boiler (High P Steam)	**1.00 LS**	**20,138**	**316,934**	**49,660**	**9,187**		**395,918.72 /LS**	**395,919**
	0032					**Combine Heat Power (CHP)**								
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		397,276	-	-	397,276.33 /ls	397,276
						40.10.99.99 Process Pipe, Other				*397,276*			*/LS*	*397,276*
						40.00.01.0001 Miscellaneous Piping and Valves				**397,276**			**/LS**	**397,276**
						40.00 Exposed Process Pipe				**397,276**			**/LF**	**397,276**
						40.0 Process Pipe				**397,276**			**/LS**	**397,276**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0009		**Combine Heat Power**								
					43.00.02.00	*Process Equipment, General Conditions*								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.40 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions	*1.00 EA*	*4,365*			*12,818*		*17,183.35 /EA*	*17,183*
					43.05.28.00	*Energy Recovery*								
						Furnish Combine Heat Power Package	2.00 ea		8,529,824	-		-	4,264,911.84 /ea	8,529,824
						Install Combine Heat Power Package	2.00 ea	264,366		-	35,539	-	149,952.58 /ea	299,905
						43.05.28.00 Energy Recovery	*2.00 EA*	*264,366*	*8,529,824*		*35,539*		*4,414,864.42 /EA*	*8,829,729*
						43.05.01.0009 Combine Heat Power		**268,731**	**8,529,824**		**48,357**		**/EA**	**8,846,912**
						43.05 Furnish and Install Process Equipment		**268,731**	**8,529,824**		**48,357**		**/LS**	**8,846,912**
						43.0 Process Equipment - Industrial		**268,731**	**8,529,824**		**48,357**		**/LS**	**8,846,912**
						0032 Combine Heat Power (CHP)	**1.00 LS**	**268,731**	**8,529,824**	**397,276**	**48,357**		**9,244,188.51 /LS**	**9,244,189**
	0033					**Flares**								
		09.0				**Finishes**								
			09.00			**Finishes**								
				09.01.01.0001		**Miscellaneous Refurbishment and Improvement**								
					09.00.99.00	*Finishes, Other*								
						Miscellaneous refurbishment and Improvements	1.00 ls	-	-	19,564	-	-	19,563.81 /ls	19,564
						09.00.99.00 Finishes, Other				*19,564*			*/LS*	*19,564*
						09.01.01.0001 Miscellaneous Refurbishment and Improvement				**19,564**			**/LS**	**19,564**
						09.00 Finishes				**19,564**			**/LS**	**19,564**
						09.0 Finishes				**19,564**			**/LS**	**19,564**
						0033 Flares	**1.00 LS**			**19,564**			**19,563.81 /LS**	**19,564**
	0034					**Thermal Conversion of Organics**								
		02.0				**Existing Conditions**								
			02.40			**Demolition**								
				02.40.01.0001		**Demolition**								
					02.01.02.00	*Structure/Building Demolition*								
						Demo digester, 100' dia x 50' high Concrete, per cubic foot and haul debris away for disposal	392,699.00 cf		-	653,029	-	-	1.66 /cf	653,029
						02.01.02.00 Structure/Building Demolition				*653,029*			*/SF*	*653,029*
					02.01.04.20	*Piping Demolition*								
						Demo miscellaneous piping assoicated with tanks and HEX within Pre-Pasteurization bldg	1.00 ls	39,128		-	-	-	39,127.68 /ls	39,128
						02.01.04.20 Piping Demolition		*39,128*					*/LS*	*39,128*
					02.01.05.00	*Process Equipment Demolition*								
						Miscellaneous demolition equipment within digester	1.00 ea	21,520		-	-	-	21,520.20 /ea	21,520
						02.01.05.00 Process Equipment Demolition		*21,520*					*/EA*	*21,520*
						02.40.01.0001 Demolition		**60,648**		**653,029**			**/LS**	**713,677**
						02.40 Demolition		**60,648**		**653,029**			**/LS**	**713,677**
						02.0 Existing Conditions		**60,648**		**653,029**			**/LS**	**713,677**
		13.0				**Special Construction**								
			13.00			**Special Construction**								
				13.10.01.0003		**Dewatering Building**								
					13.01.99.00	*Special Construction, Other*								
						Dewatering Building 80' x 102' x 50' - 3 Story Building, including foundation, superstructure and finishes	23,562.00 sf	-	-	16,133,692	-	-	684.73 /sf	16,133,692
						13.01.99.00 Special Construction, Other				*16,133,692*			*/SF*	*16,133,692*

CH2MHILL

Job Size: 1 LS
Duration: 1 LS

Detail Report

Project: AlexRenew Solids - Energy
Project No.: 66053
Design Stage: Concept

Estimator: Tweneboa-Kodua, A/WDC
Revision / Date: R01/12-July-2016
Estimate Class: 4

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
						13.10.01.0003 Dewatering Building				**16,133,692**			**/SF**	**16,133,692**
						13.00 Special Construction				**16,133,692**			**/LS**	**16,133,692**
						13.0 Special Construction				**16,133,692**			**/SF**	**16,133,692**
		26.0				**Electrical Work**								
			26.00			**Electrical**								
				26.15.01.0007		**Miscellaneous Electrical**								
					26.00.99.00	*Electrical, Other*								
						Allowance for electrical (8% of total direct cost)	1.00 ls	-	-	4,828,629	-	-	4,828,628.63 /ls	4,828,629
						26.00.99.00 Electrical, Other				*4,828,629*			*/LS*	*4,828,629*
						26.15.01.0007 Miscellaneous Electrical				**4,828,629**			**/LS**	**4,828,629**
						26.00 Electrical				**4,828,629**			**/LS**	**4,828,629**
						26.0 Electrical Work				**4,828,629**			**/LS**	**4,828,629**
		31.0				**Earthwork**								
			31.15			**Site Preparation**								
				31.15.01.0001		**Site Preparation**								
					31.15.01.05	*Site Preparation,*								
						Site preparation including, grading, excavation, backfill, erosion control and all associated works	1.00 ls	247,246	-	-	705,944	-	953,190.67 /ls	953,191
						31.15.01.05 Site Preparation,		*247,246*			*705,944*		*/AC*	*953,191*
						31.15.01.0001 Site Preparation		**247,246**			**705,944**		**/AC**	**953,191**
						31.15 Site Preparation		**247,246**			**705,944**		**/AC**	**953,191**
						31.0 Earthwork		**247,246**			**705,944**		**/LS**	**953,191**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								
				40.00.01.0001		**Miscellaneous Piping and Valves**								
					40.10.99.99	*Process Pipe, Other*								
						Miscellaneous piping and valves 9% of total direct cost	1.00 ls	-		5,247,293	-	-	5,247,293.12 /ls	5,247,293
						40.10.99.99 Process Pipe, Other				*5,247,293*			*/LS*	*5,247,293*
						40.00.01.0001 Miscellaneous Piping and Valves				**5,247,293**			**/LS**	**5,247,293**
						40.00 Exposed Process Pipe				**5,247,293**			**/LF**	**5,247,293**
						40.0 Process Pipe				**5,247,293**			**/LS**	**5,247,293**
		40.9				**Instrumentation & Controls**								
			40.90			**Instrumentation and Controls**								
				40.90.01.0002		**Miscellaneous I&C**								
					40.90.99.01	*I&C, Other*								
						Allowance for instrumentation and controls (4% of total direct cost)	1.00 ls	-	-	2,414,313	-	-	2,414,313.30 /ls	2,414,313
						40.90.99.01 I&C, Other				*2,414,313*			*/LS*	*2,414,313*
						40.90.01.0002 Miscellaneous I&C				**2,414,313**			**/LS**	**2,414,313**
						40.90 Instrumentation and Controls				**2,414,313**			**/LS**	**2,414,313**
						40.9 Instrumentation & Controls				**2,414,313**			**/LS**	**2,414,313**
		43.0				**Process Equipment - Industrial**								
			43.05			**Furnish and Install Process Equipment**								
				43.05.01.0013		**Thermal Conversion Package**								
					43.00.02.00	*Process Equipment, General Conditions*								
						Furnish Thermal Conversion Package	1.00 ls		34,432,316	-		-	34,432,315.74 /ls	34,432,316
						Install Thermal Conversion Package (15% of equipment cost)	1.00 ls	5,164,847	-	-		-	5,164,847.37 /ls	5,164,847
						43.00.02.00 Process Equipment, General Conditions		*5,164,847*	*34,432,316*				*/EA*	*39,597,163*
						43.05.01.0013 Thermal Conversion Package		**5,164,847**	**34,432,316**				**/LS**	**39,597,163**
						43.05 Furnish and Install Process Equipment		**5,164,847**	**34,432,316**				**/LS**	**39,597,163**
						43.0 Process Equipment - Industrial		**5,164,847**	**34,432,316**				**/LS**	**39,597,163**
						0034 Thermal Conversion of Organics	**1.00 LS**	**5,472,742**	**34,432,316**	**29,276,956**	**705,944**		**69,887,957.40 /LS**	**69,887,957**
	0035					**TCO Turbines**								
		31.0				**Earthwork**								
			31.17			**Piling and Caissons**								
				31.17.01.0001		**Underpinning 12' Deep**								
					31.30.04.00	*Site Specialties, Under-pinning*								
						Underpinning foundations, 5' to 16' below grade, over 500 C.Y., includes excavation, forming, reinforcing, concrete and equipment	333.33 cy	724,457	191,831	-	132,222	-	3,145.53 /cy	1,048,510
						31.30.04.00 Site Specialties, Under-pinning		*724,457*	*191,831*		*132,222*		*/LS*	*1,048,510*
						31.17.01.0001 Underpinning 12' Deep		**724,457**	**191,831**		**132,222**		**/CY**	**1,048,510**
						31.17 Piling and Caissons		**724,457**	**191,831**		**132,222**		**/LS**	**1,048,510**
						31.0 Earthwork		**724,457**	**191,831**		**132,222**		**/LS**	**1,048,510**
		40.0				**Process Pipe**								
			40.00			**Exposed Process Pipe**								

Facility	Bid Item	Work Pkg	Trade Pkg	WorkActiv	Unit Price	Description	Takeoff Quantity	Labor Amount	Material Amount	Sub Amount	Equip Amount	Other Amount	Total Cost/Unit	Total Amount
				40.00.01.0001		Miscellaneous Piping and Valves								
					40.10.99.99	Process Pipe, Other								
						Allowance for Miscellaneous scope and connections	1.00 ls	-		198,638	-	-	198,638.16 /ls	198,638
						40.10.99.99 Process Pipe, Other				198,638			/LS	198,638
						40.00.01.0001 Miscellaneous Piping and Valves				198,638			/LS	198,638
						40.00 Exposed Process Pipe				198,638			/LF	198,638
						40.0 Process Pipe				198,638			/LS	198,638
		43.0				Process Equipment - Industrial								
			43.05			Furnish and Install Process Equipment								
				43.05.01.0015		TCO Turbine Package								
					43.00.02.00	Process Equipment, General Conditions								
						100 tn Crawler	0.25 mo	4,365	-	-	12,818	-	68,733.48 /mo	17,183
						43.00.02.00 Process Equipment, General Conditions		4,365			12,818		/EA	17,183
					43.05.28.00	Energy Recovery								
						Furnish Combine Heat Power Package	2.00 ea		1,956,382	-		-	978,190.78 /ea	1,956,382
						Install Combine Heat Power Package	2.00 ea	172,455		-	23,183	-	97,819.10 /ea	195,638
						43.05.28.00 Energy Recovery		172,455	1,956,382		23,183		/EA	2,152,020
						43.05.01.0015 TCO Turbine Package		176,820	1,956,382		36,002		/LS	2,169,203
						43.05 Furnish and Install Process Equipment		176,820	1,956,382		36,002		/LS	2,169,203
						43.0 Process Equipment - Industrial		176,820	1,956,382		36,002		/LS	2,169,203
						0035 TCO Turbines	1.00 LS	901,277	2,148,212	198,638	168,224		3,416,351.03 /LS	3,416,351
						3C ALTERNATE 3C	1.00 LS	8,459,393	70,849,545	48,896,896	1,971,217		############ /LS	130,177,050

Appendix F
List of Previous Reports and Studies

APPENDIX F

List of Previous Studies at AlexRenew WRRF

The following table lists all the studies and reports that have been generated for the AlexRenew WRRF and have been referenced in the 2016 Update to the Long Range Plan report.

Title	Author	Issue Date
Pre-pasteurization System Evaluation, Heat Exchangers Recommendations	CH2M	January 2016
Primary Effluent Pump Station Evaluation Report	CH2M	February 2016
Better Plants Program: CHP Analysis Summary Report	Jim Freihaut, Penn State University	May 2016
Alexandria Renew Enterprises Building Energy Analysis, Task Order 20 Final Report	CH2M	June 2016
Primary Effluent Pump Station 60% Design	CH2M	June 2016
AlexRenew BOA 14-017-2 Task Order WA2-2015-4, Pre-pasteurization Tank Exhaust System Replacement, Preliminary Design	AlexRenew	December 2015
Nutrient Recovery Proposal	Ostara	March 2014
Energy Master Plan	Greeley & Hansen	July 2014
Biosolids Update to the Long Range Plan	Black & Veatch	December 2014
City of Alexandria Wastewater Capacity and Wet Weather Management Evaluation – Final Report	CH2M	November 2010
Long Range Planning Report (LRPR)	CH2M	May 2009

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Exhibit E
RFP 21-015 Cover Sheet

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RFP 21-015 Cover Sheet

Issue Date: July 27, 2021

RFP #: 21-015

Proposals submitted to AlexRenew: No later than 4:00 pm (EST) on September 27, 2021

Location of Submission: Alexandria Renew Enterprises
1800 Limerick Street
Alexandria, VA 22314

Contract Administrator: Maryam Zahory
Purchasing Agent
purchasing@alexrenew.com

Proposal Submitted by:

Name: Click or tap here to enter text.

Address: Click or tap here to enter text.

Telephone: Click or tap here to enter text.

Email: Click or tap here to enter text.

TIN or SSN: Click or tap here to enter text.

Alexandria Professional & Occupational License Tax #: Click or tap here to enter text.

License # and Specialty: Click or tap here to enter text.

Business Classification (check all that apply):

☐ Minority Owned ☐ Woman Owned ☐ Veteran Owned ☐ Disability

☐ Individual ☐ Partnership ☐ Corporation ☐ State Incorporated

☐ Small ☐ Large

Attestation:

The undersigned offers and agrees that the terms, conditions and detailed information provided herein, including all appendices attached hereto, will serve as the basis for a professional services contract, if awarded thereto.

Click or tap here to enter text.

Name and Title (respondent 's authorized representative)

Authorized Signature ______________________ Date ______________________

RETURN THIS FORM WITH YOUR PROPOSAL.

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Exhibit F
RFP 21-015 Checklist

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RFP 21-015 Checklist

RESPONDENT. Please provide contact information for respondent 's authorized representative:

NAME: Click or tap here to enter text.

ADDRESS: Click or tap here to enter text.

TELEPHONE: Click or tap here to enter text.

EMAIL: Click or tap here to enter text.

PAY TO ADDRESS:

Click or tap here to enter text.

DOCUMENTATION. The documents listed below, which are included herein, will be incorporated in whole or in part into a final contract for an engagement resulting from this RFP. Your signature below serves as your acknowledgment that these documents will serve as the foundation to a formal contract for professional services.

A. Executed Cover Sheet
B. Table of Contents
C. Introductory Letter
D. Project Understanding and Management Approach
E. Proposed Project Team
F. Related Project Experience
G. RFP Checklist
H. Proposal Form
I. Resumes
J. Sample Solids Master Plan Scope

ADDENDA ACKNOWLEDGEMENT. Your signature below serves as your acknowledgment that all addenda have been received and incorporated into the proposal submission. Check all that apply.

☐ Addendum No. 1 ☐ Addendum No. 2 ☐ Addendum No. 3 ☐ Addendum No. 4

☐ Addendum No. 5 ☐ Addendum No. 6 ☐ Addendum No. 7 ☐ Addendum No. 8

Click or tap here to enter text.
Name and Title (respondent's authorized representative)

____
Authorized Signature

Click or tap here to enter text.
Date

RETURN THIS FORM WITH YOUR PROPOSAL.

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Exhibit G

Proposal Form

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REQUEST FOR PROPOSALS NUMBER 21-015

PROPOSAL FORM

THE FULL LEGAL NAME OF THE FIRM OR ENTITY SUBMITTING THIS PROPOSAL MUST BE WRITTEN IN THE SPACE PROVIDED BELOW. THIS PROPOSAL FORM, AND ALL OTHER DOCUMENT(S) REQUIRED BY THE SOLICITATION TO BE SUBMITTED WITH THIS PROPOSAL FORM, INCLUDING, BUT NOT LIMITED TO ALL ISSUED ADDENDA, MUST BE FULLY AND ACCURATELY COMPLETED AND SIGNED BY A PERSON AUTHORIZED TO LEGALLY AND CONTRACTUALLY BIND THE RESPONDENT, OR THE PROPOSAL MAY BE REJECTED:

SUBMITTED BY: (Legal Name Of Entity)
FORMER NAMES: (Insert all other names that this entity has been known by in the past twenty (20) years)
AGE OF THE ENTITY: How many years has this entity been in business under the current name?
PRINCIPAL PLACE OF BUSINESS:
TELEPHONE NUMBER: FAX NUMBER: CORPORATE WEBSITE:
DUNS NUMBER:
FORM OF ORGANIZATION: _____CORPORATION; ________GENERAL PARTNERSHIP; _________UNINCORPORATED ASSOCIATION; ______LIMITED LIABILITY COMPANY; _______LIMITED PARTNERSHIP; ______SOLE PROPRIETORSHIP WHERE THE ENTITY WAS FORMED: (INSERT NAME OF STATE) ______________________
IDENTIFICATION NO. ISSUED TO THE FIRM BY SCC: If Respondent is exempt from the SCC authorization requirement, then it shall include a statement on the entity's letterhead with its application certifying their exemption from this requirement. ______________________

DEBARMENT, DISQUALIFICATION AND OR SUSPENSION: Is the entity or any of its principals currently debarred, suspended or disqualified from submitting responses to the City, or any other state, local or federal entities?	______YES; _______NO
RESPONDENT'S STATUS PLEASE INITIAL ONE: _____MINORITY OWNED; ______WOMAN OWNED; ________NEITHER	
NOTE: If the answers to any questions below are yes, use additional pages to provide detailed description of the situation and or provide full documentation	
CLAIMS/FINAL RESOLUTION/JUDGMENTS Have any of the following actions occurred on, or in conjunction with, any project(s) performed by the Respondent, any affiliate, or their officers, partners or directors in the last five (5) years? "Legal Actions" shall include civil or criminal litigation, administrative; proceedings, indictments, arbitrations or the like	______YES; _______NO
TERMINATION/FAILURE TO COMPLETE Has the Respondent ever been terminated for work awarded to it? This includes termination for default (or cause) or for the convenience of the owner? Has Respondent for any other reason failed to complete a project?	______YES; _______NO
BREACH, DEFAULT, DEBARRED: Within the last five (5) years, has Respondent been disqualified, removed, or otherwise declared in material breach or default of any contract by a public agency, or debarred from participating in the RFP process for any contract? If yes, please explain the circumstances:	______YES; _______NO
RELEASE FROM CONTRACT APPLICATION, PROPOSAL OR AWARD: Has the Respondent filed a request to be released from an application, proposal, selection or award of any contract within the last five (5) years? If yes, please explain the circumstances.	______YES; _______NO

FAILURE TO EXECUTE A CONTRACT: Has the Respondent ever been selected for award or awarded a contract in which the entity failed to execute the contract? This would include: the entity not signing the contract document(s); an inability of the company to obtain insurance requirements; or failure of the company to submit required forms and attestations. If yes, please explain the circumstances:	______YES; _______NO
BANKRUPTCY: Has the Respondent filed for bankruptcy in the last seven years or currently the debtor in a bankruptcy case? If yes, please explain the circumstances	______YES; _______NO
CONTACT PERSON AND MAILING ADDRESS FOR DELIVERY OF NOTICES Provide the name and address of the person designated by the Respondent to receive notices and other communications (Refer to the Sample Agreement in Exhibit H for further details):	______________________________________

TRADE SECRETS OR PROPRIETARY INFORMATION:

Trade secrets or proprietary information submitted by a Respondent in connection with a procurement transaction shall not be subject to public disclosure under the Virginia Freedom of Information Act. However, the Respondent must identify the data and materials need such protection prior to submission of such data and material, and state the reasons why protection is necessary. Please mark one:

( ) **Yes,** the Proposal I have submitted does contain trade secrets and/or proprietary information.

( ) **No,** the Proposal I have submitted **does** not contain any trade secrets and/or proprietary information.

If Yes, you must clearly identify below the exact data or other materials to be protected and list all applicable page numbers of the Proposal containing such data or materials:

____

____

____

STATE THE SPECIFIC REASON(S) WHY PROTECTION IS NECESSARY:

____

____

NOTE: If the Respondent fails to identify the data or other materials to be protected and state the reasons why such protection is necessary in the space provided above, it has not invoked the protection, and accordingly, the Proposal will be open for public inspection consistent with applicable law.

CERTIFICATION OF NON-COLLUSION:

The undersigned certifies that this Proposal is not the result of, or affected by, any act of collusion with another person (as defined in Code of Virginia Section 59.1-68.6 et seq.), engaged in the same line of business or commerce; or any act of fraud punishable under the Virginia Governmental Frauds Act (Code of Virginia §18.2-498.1 et seq.).

CONFLICTS OF INTEREST:

The undersigned certifies and warrants that to the best of its knowledge and belief and except as otherwise disclosed, it does not have any organizational conflicts of interest, which are defined as a situation in which the nature or work under the contract and the Respondent's organizational, financial, contractual or other interest are such that award of the contract may result in the Respondent receiving an unfair competitive advantage, or the Respondent's objectivity in performing the contract work may be impaired. The Respondent agrees that if after being awarded it discovers an organizational conflict of interest with respect to the being awarded, it shall make an immediate and full disclosure in writing to AlexRenew which shall include a description of the action which the Respondent has taken or intends to take to eliminate or neutralize the conflict.

INDICATE THE NAME AND CONTACT INFORMATION OF THE PERSON WHO CAN RESPOND AUTHORITATIVELY TO ANY QUESTIONS REGARDING THIS PROPOSAL (I.E. PROJECT MANAGER):

NAME (PRINTED): ______________________________ TITLE: __________________________

E-MAIL ADDRESS: __________________________ TEL. NO.: _________________________

The undersigned swears or affirms under the penalty of perjury and upon personal knowledge that the contents of the Proposal are true and correct.

The undersigned swears or affirms under the penalty of perjury that the Respondent, its agents, servants and/or employees, to the best of their knowledge and belief, have not in any way colluded with anyone for and on behalf of the Respondent an unfair advantage over others, nor have they colluded with anyone for and on behalf of the Respondent, or themselves, to gain any favoritism in the award of any contract resulting from this proposal.

____

NAME OF AND TITLE RESPONDENT'S REPRESENTATIVE

____

SIGNATURE OF RESPONDENT'S REPRESENTATIVE

Exhibit H

AlexRenew Standard Professional Services Agreement (Sample)

FOLLOWING THIS PAGE IS A SAMPLE AGREEMENT SIMILAR TO THAT WHICH WILL BE ENTERED INTO BETWEEN ALEXRENEW AND THE CONSULTANT. THE SAMPLE AGREEMENT IS PART OF THIS SOLICITATION. THIS SAMPLE AGREEMENT IS SUBJECT TO REVIEW BY ALEXRENEW ATTORNEY PRIOR TO BEING FINALIZED AND SUBMITTED FOR CONSULTANT'S SIGNATURE.

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STANDARD PROFESSIONAL SERVICES AGREEMENT

AGREEMENT NO. 21-015

FOR

BASIC ORDERING OF PROFESSIONAL ENGINEERING SERVICES

BY AND BETWEEN

ALEXANDRIA RENEW ENTERPRISES
1800 LIMERICK STREET
ALEXANDRIA, VA 22314

AND

[NAME OF BIOSOLIDS MASTER PLAN ENGINEERING CONSULTANT]

[EFFECTIVE DATE ______________________________]

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Table of Contents

EXHIBITS

PROFESSIONAL SERVICES AGREEMENT

THIS PROFESSIONAL SERVICES AGREEMENT (this "Agreement") is entered into as of ________________________________, by and between **ALEXANDRIA RENEW ENTERPRISES ("AlexRenew")**, an authority duly organized and existing under the laws of the Commonwealth of Virginia, having an office and place of business at 1800 Limerick Street, Alexandria, Virginia 22314, hereinafter referred to as "AlexRenew", and ____________________, ("Consultant"), a corporation duly organized and existing under the laws of the State of __________, having an office and place of business at ______________________________________, hereinafter referred to as the "Consultant."

WITNESSETH:

WHEREAS, AlexRenew conducted a lawful procurement process in accordance with § 2.2-4303.1 Code of Virginia which resulted in awards to multiple Consultants. AlexRenew will issue Task Orders and assignments on a rotating basis and/or based on the availability and expertise of the Consultants, whichever is in the best interest of AlexRenew at the time of issuance of Task Orders. However, AlexRenew will not require the selected Consultants to compete for individual Task Orders based on price;

WHEREAS, as a result of this award, AlexRenew may, at its sole discretion, authorize the Consultant to perform Professional Engineering Services ("Services") relative to AlexRenew's capital program and other such services as requested by AlexRenew on an as needed basis, through Task Orders duly executed by the parties;

WHEREAS, AlexRenew from time to time will issue a document describing the deliverables, due dates, assignment duration and payment obligations for a specific project, engagement, or assignment that the Consultant commits to provide (hereinafter referred to as "Task Order"). The parties agree that this Agreement shall represent the general terms and conditions between the parties for all services performed by Consultant on behalf of AlexRenew under any and all Task Orders issued under this Agreement;

WHEREAS, AlexRenew has also engaged, or intends in the future to engage, other entities to provide support to AlexRenew's capital program, and Consultant will be interfacing with such entities during the course of its performance of the Services;

WHEREAS, the Consultant represents that it is duly licensed in Virginia, where necessary, and is qualified and authorized to provide the Services, and that the Services will be performed by experienced and qualified personnel; and

WHEREAS, the parties now desire to set forth the terms and conditions under which the Services shall be performed.

NOW THEREFORE, in consideration of the promises and mutual covenants herein contained, the parties hereto agree as follows:

ARTICLE 1. ENTIRE AGREEMENT

A. The following Exhibits, including all subparts thereof, are attached to this Agreement and are made a part of this Agreement for all purposes:

- Exhibit A – Scope of Services, including its subparts (individual Task Orders issued by AlexRenew)
- Exhibit B – Key Personnel
- Exhibit C – Compensation Schedule
- Exhibit D – List of Hazardous/Regulated Substances and Reportable Quantities
- Exhibit E – Site Security
- Exhibit F – Information Management System
- Exhibit G – Work Breakdown Structure (WBS)

B. This Agreement, its Exhibits and any Task Orders issued by AlexRenew constitute the entire agreement between AlexRenew and the Consultant and supersede any and all previous representations, understandings, discussions or agreements between AlexRenew and the Consultant as to the subject matter hereof. This Agreement may only be amended by an instrument in writing signed by an AlexRenew Authorized Representative and a Consultant Authorized Representative as defined herein in Article 12.M.

C. AlexRenew and the Consultant may enter into one or more Task Orders pursuant to this Agreement. To the extent that such Task Orders include any terms and conditions inconsistent with the terms and conditions of this Agreement, any such inconsistent terms and conditions shall be of no force and effect.

D. AlexRenew and the Consultant agree that Services performed hereunder shall be for the sole benefit of AlexRenew, not for the benefit of any other person or entity, and may not be relied upon by anyone other than AlexRenew.

E. AlexRenew and the Consultant each acknowledge that it has had the opportunity to review this Agreement and to obtain appropriate legal review if it so chose.

ARTICLE 2. TERM, COMPENSATION LIMIT, TERMINATION OF AGREEMENT, AND RELATED MATTERS

A. Agreement Term

This Agreement is effective and legally binding as of the Effective Date and, unless terminated as provided for in the Agreement, shall continue until January 31, 2021 (“Initial Agreement Term”), subject to modifications as provided in the Agreement. Upon satisfactory performance by the Consultant AlexRenew may, through issuance of an amendment executed by the parties, authorize continuation of the Agreement under the same terms and conditions for not more than four (4) additional 12-month periods, from February 1, 2021 to January 31, 2025 (each a “Subsequent Agreement Term”). The Initial Agreement Term and any Subsequent Agreement Term(s) are together the (“Agreement Term”).

It is understood that the Consultant's Work under the Task Orders issued may not be completed during the Agreement Term; however, all terms and conditions of this Agreement, including all rights and obligations, shall survive until the Work is completed, except AlexRenew's right to issue, and the Consultant's right to accept, additional Task Orders.

B. Compensation Limit
The sum of all Fees during each one (1) year term shall not exceed six million dollars ($6,000,000). For the purpose of this subsection, any unused amounts from one contract term shall not be carried forward to any additional term.

C. Termination

1. Termination for Convenience. AlexRenew may terminate the Agreement in whole or in part, or any Task Order issued hereunder, in whole or in part upon not less than thirty (30) days prior written notice at any time for any reason.

2. Termination for Breach or Default. AlexRenew shall have the right to terminate this Agreement, in whole or in part, or any Task Orders issued hereunder, in whole or in part for breach and/or default of the Consultant. The Consultant shall be deemed in breach and/or default in the event that Consultant fails to meet any material obligation set forth in this Agreement or in any Task Order issued hereunder.

   If AlexRenew deems the Consultant to be in breach and/or default, AlexRenew shall provide the Consultant with notice of breach and/or default and allow the Consultant fifteen (15) days to cure the breach and/or default. If the Consultant fails to cure the breach as noted, AlexRenew may immediately terminate this Agreement or any order or Task Order issued hereunder, in whole or in part.

   Any such termination shall be deemed a Termination for Breach or Termination for Default.

3. Termination for Non-Appropriation of Funds.
   All payment obligations from AlexRenew under this Agreement are subject to the availability of appropriations by AlexRenew Board of Directors, for this purpose. In the event of non-appropriation of funds, irrespective of the source of funds, for the items under this Agreement, AlexRenew may terminate this Agreement, in whole or in part, or any Task Order, in whole or in part, for those goods or services for which funds have not been appropriated. Written notice will be provided to the Consultant as soon as possible after such action is completed.

D. Effect of Termination. Upon termination, the Consultant shall cease its Services in accordance with the terms of the termination notice and shall deliver all work completed to date to AlexRenew, unless AlexRenew provides written notification to the Consultant that it declines to receive or accept such work due to failure of the work to comply with the requirements of this Agreement.

1. Upon termination, AlexRenew shall be responsible to pay for any Services performed by the Consultant and accepted by AlexRenew but which have not yet been paid, provided the Consultant submits invoices in accordance with this Agreement for such amounts. Otherwise, AlexRenew shall have no further liability under this Agreement, and reserves to itself all remedies available under law or this Agreement with respect to such termination or any performance by the Consultant prior to termination

2. In the event of a Termination for Breach or Termination for Default, the Consultant shall accept return of any deliverable that was not accepted by AlexRenew and shall

refund any monies paid by AlexRenew for such deliverable, including all costs to return the deliverable(s).

3. Consequential Damages. The Consultant waives claims against AlexRenew for consequential damages arising out of or relating to this Agreement, including but not limited to damages incurred by the Consultant for principal office expenses including the compensation of personnel stationed there, for losses of financing, business and reputation, and for loss of profit. This waiver is applicable, without limitation, to all consequential damages of the Consultant due to termination in accordance with the provisions of this Agreement.

E. Transition of Services
Prior to or upon expiration or termination of this Agreement and at the request of AlexRenew, the Consultant shall provide all assistance as AlexRenew may reasonably require to transition the Consultant's contractual obligations, or any portion thereof, as requested by AlexRenew. This obligation may extend beyond expiration or termination of the Agreement for a period of time (e.g., three (3) months, six (6) months, twelve (12) months) as required and mutually agreed-upon by AlexRenew and the Consultant (herein referred to as "Transition Period”). The Consultant shall provide all reasonable transition assistance requested by AlexRenew to allow for the expired or terminated portion of the Services to continue without interruption or adverse effect, and to facilitate the orderly transfer of such Services to AlexRenew. Such transition assistance will be deemed by the parties to be governed by the terms and conditions of the Agreement, except for those terms or conditions that do not reasonably apply to such transition assistance.

F. Assignment. Neither this Agreement or any Task Orders, or any rights or interests hereunder, nor any part hereof shall be assigned by the Consultant without the prior written consent of an AlexRenew Authorized Representative, which consent may not be unreasonably withheld.

G. Contract Kick-Off/Chartering Meeting
Within thirty (30) days of Effective Date of the Agreement, the Consultant may be required to attend a contract orientation meeting, along with AlexRenew Project Manager and any other significant stakeholders who have a part in the successful performance of this Agreement. The purpose of this meeting will be to review all contractual obligations for both parties, all administrative and reporting requirements, and to discuss any other relationship, responsibility, communication and performance criteria set forth in the Agreement. The time and location of this meeting will be coordinated with the Consultant and other meeting participants by the AlexRenew.

H. Contract Closeout
Prior to or upon expiration or termination of this Agreement, the Consultant shall provide such close out documentation as may be requested by AlexRenew. The Consultant shall submit such closeout documentation within thirty (30) days of receipt of such request from AlexRenew.

ARTICLE 3. CONTRACTING ARRANGEMENT, SCOPE OF SERVICES AND RELATED MATTERS

A. Ordering, Fees, and Payment Procedures
   1. Ordering
      a. It is anticipated that AlexRenew shall, from time-to-time, retain Consultant to provide Services on specific capital projects by issuing Task Orders to

Consultant. Each Task Order shall identify, among other things: (i) Services to be performed and a schedule for performance; (ii) the compensation associated with the Services; and (iii) an identification of personnel who will provide the Services. Consultant for a specific assignment under a Task Order, AlexRenew may request Consultant to prepare, at Consultant's cost, a proposal that will, among other things, identify Consultant's approach to performing the contemplated Services, as well as the information that is described in the preceding sentence.

b. This Agreement is not a commitment by AlexRenew to issue any Task Orders to Consultant. Consultant shall not perform any work under any prospective Task Order until AlexRenew issues a Notice to Proceed and/or Purchase Order for such Task Order.

c. At any time during the performance of a Task Order AlexRenew shall have the right to make changes in, deletions from or additions to the Task Order's scope of services (referred to hereinafter as a "Task Order Amendment"). In the event that such changes require different and/or additional Services by the Consultant, prior to commencement of such Services per a change, the Consultant shall present to AlexRenew, and AlexRenew shall consider, a proposal for an equitable increase in its compensation and/or schedule for Services rendered because of such change. Such proposal shall be supported by such data and information as AlexRenew reasonably may require. Any such proposal by the Consultant for an equitable change in compensation and/or schedule shall be mutually agreed to by Task Order Amendment prior to the commencement of any Services under the proposed change.

d. All Task Orders and Task Order Amendments shall be executed by an AlexRenew's and a Consultant Authorized Representatives.

2. Fees and Charges

a. Compensation maybe based on time and materials, fixed price, or not to exceed price with the type of compensation identified in each Task Order. All fee amounts will be derived from Exhibit C – Compensation Schedule, attached hereto and made a material part hereof.

(i) Alex Renew reserves the right to negotiate lower multipliers for field based positions/services on an individual Task Order basis.

(ii) AlexRenew reserves the right to negotiate the inclusion of additional personnel job classifications on an individual Task Order basis.

The sum of all Task Order Fees during each one (1) year contract term shall not exceed the compensation Limit Set forth in Article 2.B.

b. The Consultant shall utilize only those personnel reasonably necessary to insure proper performance of the Services, including the Key Personnel set forth in Exhibit B, and shall not overstaff any element of Services performed. The Consultant shall use the level or job classification of personnel commensurate with the Services required unless AlexRenew has given prior approval, in writing, for a different level or class of personnel to be used.

c. In emergency situations or for investigations or similar work where an estimate of time required cannot reasonably be determined to establish a lump sum fee, the Task Order may be issued to be paid on an hourly basis per the marked up hourly rates set forth in Exhibit C. Such Task Orders shall usually include a "maximum" or "not-to-exceed" fee amount. The actual Task Order cost shall be based on the actual man-hours expended on the Task Order by the Consultant.

d. The Consultant shall be responsible for all work associated with obtaining necessary permits for the work associated with task orders. The cost of obtaining such permits will be invoiced by the Consultant and paid by AlexRenew unless otherwise negotiated in the individual Task Order.

3. Adjustment in Fees and Charges

a. AlexRenew may, but is not required to, at its sole discretion, renegotiate the fee, cost, and expense schedule set forth in Exhibit C, on an annual basis. Baseline Labor Rates will be established as part of this Agreement in Exhibit C, and may be adjusted annually, starting in February 1 2021 (“Fees and Charges Adjustment Date”). Adjustments are not automatic and must be requested in writing by the Consultant and approved by AlexRenew via a formal amendment to the Agreement. Adjustment requests must be made at least ninety (90) days in advance Fees and Charges Adjustment Date. The Consultant agrees that it shall not request an adjustment in the rates more than once during any twelve (12) month period. No such adjustment shall exceed the percentage of change in the U.S. Department of Labor, Bureau of Labor Statistics Employment Cost Index for wages and salaries, for civilian workers, by Occupational Group and Industry for Service Occupations. The Quarterly Employment Cost Index for the 3-month period ending in September of each year of the Agreement or three percent (3%), whichever is lesser, will serve as a basis for such adjustments. Any adjustment in fee(s) and price(s) that result from this provision will become in effect on February 1st of each year, and will be binding for the next twelve (12) months. If the consultant does not request an adjustment, the prevailing rates shall continue to govern.

b. If the Consultant and AlexRenew have not agreed on a requested adjustment thirty (30) days before the anniversary of Effective Date of Agreement, AlexRenew may terminate the Agreement, whether or not AlexRenew has previously elected to extend the Agreement's term.

4. Reimbursable Travel-Related Expenses

a. No reimbursable travel-related expenses shall be allowed for employees of firms located within the greater Baltimore-Washington Metropolitan Area, as defined by the United States Office of Management and Budget (OMB), gsa.gov. The Consultant shall ensure that all travel on behalf of AlexRenew is necessary and allowable under the Contract and is approved in advance by AlexRenew. A management official of the Consultant shall authorize all travel and travel vouchers reflecting travel expenditures. The following categories of expenses are reimbursable under this Contract at the not to exceed amounts noted:

(i) Airfare is reimbursed at commercial coach class using the lowest logical airfare and advance purchase options not to exceed $1,000 per round trip flight. Airfare should be booked as soon as practical to obtain best pricing options. AlexRenew shall not be responsible for reimbursing any travel expenses incurred, but not used, by the Consultant due to untimely cancellations or the Consultant's lack of adherence to vendor cancellation policies.

(ii) Hotel lodging will be reimbursed at actual cost not to exceed the current GSA per diem rate for lodging for City of Alexandria, VA.

(iii) Meals will be reimbursed at actual cost not to exceed the current GSA per diem rate for lodging for City of Alexandria, VA.

(iv) Mileage for use of personal vehicles is permitted and will be reimbursed based on the current published IRS standard mileage rates for the use of a car.

(v) Rental Cars will be reimbursed at a not to exceed rate of $100 per day.

b. AlexRenew must approve any aggregate travel expense in excess of $2,000, in writing, prior to the incurrence of the expense.

c. Valid original receipts are required for all expenditures regardless of cost. If a receipt is not normally provided for the expense (metro, bus token, etc.), the certification signed by the traveler on the voucher will justify the expense.

d. Receipts submitted with the invoices should be originals indicating the name of the payee, date paid, amount, and the service rendered. This includes the original passenger receipt coupon of the airline ticket. If an electronic ticket is used, the boarding passes for each flight must be submitted with the travel voucher.

5. Non-Reimbursable Travel-Related Expenses

a. Examples of expenses that will not be reimbursed include the following:

- alcoholic beverages and entertainment;
- unused tickets, airport ticket class changes, or seat location upgrades
- Hotel "no show" fees and additional in-room amenities such as movies, mini-bar, and room services
- laundry, dry cleaning and pressing;
- travel insurance;
- tolls and parking fines;
- charges incurred because of indirect travel for personal reasons;
- gratuities and tips paid to porters, bellboys, and hotel maids inside the lodging facility;

- nonproductive time related to official travel to and from one's temporary duty station; and
- any charges, fees, or other associated costs related to the making of reservations or other accommodations for travel.

6. Invoice Procedures

   a. The Consultant shall remit each invoice to invoicing@alexrenew.com, with a copy to the AlexRenew Task Order Project Manager, promptly after all Consultant's performance obligations have been accepted and in accordance with the milestone payment schedule, if any, in the applicable Task Order. Invoices issued by the Consultant shall identify at a minimum:

      (i) This Agreement number and the applicable Task Order number and title as well as the relevant Purchase Order number(s) and Account Code(s);

      (ii) Dates/periods that the invoice covers;

      (iii) Progress Report summarizing services provided for the billed timed period including deliverables, as applicable;

      (iv) Project schedule and status;

      (v) Invoice amount, total budget spent to date, total budget remaining

      (vi) Summary of Professional services performed by each employee including the employee's name, hourly rate, and hours worked in alignment with the AlexRenew-approved Work Breakdown Structure (WBS) for the task order; and

      (vii) Summary and Documentation of expenses.

      (viii) All necessary backup documentation, including additional documentation as requested by AlexRenew.

   b. Any terms included on the Consultant's invoice shall have no force or effect and will in no way bind AlexRenew.

   c. Invoice format shall be coordinated with and approved in advance of submission of the first invoice by AlexRenew.

   d. All supporting Documents attached to the Consultant's invoice shall conform to the requirements herein, as applicable.

7. Payment Terms

   a. AlexRenew shall not be required to make any payment to the Consultant until it has provided AlexRenew with its federal employer identification number.

   b. The Consultant is responsible for the accuracy of its billing information. The Consultant is responsible for preparing complete and timely invoices in accordance with the requirements of this Agreement and any applicable Task Order.

c. Amounts due under this Agreement shall be invoiced to AlexRenew as soon as possible after the end of each calendar month, but no later than the 15th day of the following month.

d. AlexRenew will notify the Consultant of objections to any some or all of any invoice within fifteen (15) days after receipt of such invoice.

e. All payment terms are net 30 days. AlexRenew will pay the Consultant within thirty (30) calendar days after the date of receipt of a correct and complete invoice as approved by the Project Manager, which includes, at minimum all applicable information described in this Agreement.

f. In no event shall payment be made for Services performed by the Consultant if such Services are not authorized under this Agreement and clearly stated in Exhibit A or an Amendment to this Agreement approved, in writing, by mutual agreement of AlexRenew and the Consultant.

g. Amounts charged to AlexRenew for Services purchased by the Consultant for resale without modification, shall not exceed the amount paid by the Consultant for such Services, except as specified below:

- For subcontracted services provided by others, or for purchased material or equipment for use on behalf of AlexRenew in connection with the Services, the Consultant may include a mark-up not to exceed 10% of a subcontracted service or purchased material or equipment.
- Any mark-up is intended to reimburse the Consultant for administration and management of the subcontract, material or equipment. Such mark-up is not intended as profit.
- The Consultant may include a mark-up in lieu of the labor costs associated with subcontracted Services, but may not charge AlexRenew both direct labor and mark-up for the same service.

h. The Consultant shall be liable to AlexRenew for damages caused by its personnel and or subconsultants, including costs required to be expanded by AlexRenew to correct deficiencies in the services. Such costs shall be deducted from any amount due to the Consultant or shall be promptly paid by the Consultant to AlexRenew upon demand by AlexRenew.

i. At any time prior to final payment under this Agreement and within three (3) years thereafter, AlexRenew shall have the right to audit direct charges, to the extent AlexRenew may deem necessary, for the purpose of verifying charges claimed under invoices. The Consultant agrees to maintain and make available records and books of accounts detailing fees, costs and expenses charged against this Agreement or invoiced hereunder.

8. Payment to Subconsultants (see Article 8 Mandatory Provisions)

B. Related Matters

1. Coordination and Delegation of Management

   Consultant acknowledges that it will be one of several other entities, including program managers/advisors and design professionals, providing support to AlexRenew in the performance of AlexRenew's capital program. Consultant agrees to work cooperatively with such other entities. If AlexRenew determines that it is in its best interests to delegate to another such entity certain responsibilities related to the management of Consultant's performance of the Services, it shall notify Consultant and identify the nature and limits of such delegation.

2. Services Review

   The Consultant agrees to allow all Services to be reviewed by designated AlexRenew employees or representatives at reasonable times and places selected by AlexRenew.

   a. The Consultant agrees that any review of Services performed by an AlexRenew employee or representative shall not lessen the obligation of the Consultant to perform such Services in accordance with the standard of care described in Article 5, or be deemed a defense on the part of the Consultant for infraction thereof.

   b. Only the AlexRenew Authorized Representative is authorized to revoke, alter, enlarge, relax, or release any of the requirements of this Agreement.

   c. Any omission or failure on the part of an AlexRenew employee or representative to disapprove or reject any work shall not be construed to be an acceptance of any such defective work.

   d. AlexRenew shall be under no obligation to compensate the Consultant for Services not rendered in conformity with this Agreement.

3. Duty to Proceed

   No failure of the Consultant and AlexRenew to reach agreement on Services to be performed that require a mutually agreed decision shall excuse the Consultant from diligently proceeding with the performance of Services unrelated to the decision, except as otherwise expressly provided in this Agreement or except in the event of a material default by AlexRenew.

4. Access and Right of Entry

   AlexRenew grants to the Consultant, and if AlexRenew does not own a Program Site, it warrants that, permission has been granted for right of entry from time to time by the Consultant, its employees, agents and sub subconsultants, onto AlexRenew property and/or Program Sites for performing the Services. When required by AlexRenew, the Consultant shall provide advance notice to AlexRenew prior to Consultant's entry onto AlexRenew property and/or Program Sites. The Consultant agrees, however, to use best efforts to leave AlexRenew Property and Program Sites, whenever possible, in a condition substantially similar to the condition prior to the performance of the Services. Site security shall comply with the requirements of Exhibit E – Site Security.

5. Subcontracting. The Consultant may use the services of sub subconsultants for Services that, under normal contracting practices, are performed by sub

subconsultants. The Consultant shall obtain AlexRenew's approval of subconsultants, in writing, prior to entering into an agreement with sub subconsultants.

a. The Consultant shall cause appropriate provisions to be inserted in subcontracts relative to any Services to bind sub subconsultants to the Consultant by the terms of this Agreement insofar as applicable to the work of the sub subconsultants and to give the Consultant the same power as regards terminating any subcontract that AlexRenew may exercise over the Consultant under provisions of this Agreement.

6. Information Management System. AlexRenew is in the process of implementing an e-CMIS platform (e-Builder) to manage the life-cycle of project generated documents. Consultant shall utilize this system for specific task orders as directed by the AlexRenew Project Manager. Information on this system can be found in Exhibit F – Information Management System.

7. Project Records. Consultant shall maintain project records in accordance with AlexRenew's Project Management Information System (PMIS) standards and Work Breakdown Structure (WBS). Information on this system can be found in Exhibit G - AlexRenew WBS Requirements.

ARTICLE 4. KEY PERSONNEL

A. All Key Personnel identified in Exhibit B are committed to this Agreement for the duration of the Agreement, for so long as they remain employed by the Consultant. Likewise, if a Key Person is identified in a Task Order, such individual shall be committed to the Task Order for the duration of the Task Order, for so long as they remain employed by the Consultant.

B. If extraordinary circumstances require a proposed change in Key Personnel under either this Agreement or a Task Order, it must be submitted in writing to AlexRenew's Project Manager.

1. In circumstances where the change is based on a Key Personnel leaving the employ of the Consultant, qualifications information shall be provided on one or more proposed substitutes, and the AlexRenew Authorized Representative, at his/her sole discretion, will determine who will become the substitute and remain a Key Personnel going forward, and an Amendment to Exhibit B shall be executed to reflect the approved change.

2. In circumstances where the change concerns a Key Personnel who will remain in the employ of the Consultant, information about the basis for the change request and qualifications information for one or more proposed substitutes will be provided and the AlexRenew Authorized Representative, at his/her sole discretion, will determine whether to authorize the proposed removal and, if approved, who shall become the substitute and remain a Key Personnel going forward and an Amendment to Exhibit B shall be executed to reflect the approved change.

ARTICLE 5. STANDARD OF CARE

A. General

All Services shall be performed in a safe, timely and professional manner, in accordance with the generally accepted standards of professional skill and judgment in the same profession, in effect at the time and in the locale the Services are rendered, in accordance with the specifications set forth in this Agreement, and any Exhibit or Amendment attached thereto.

Services shall also be performed in accordance with the care and skill ordinarily exercised by members of the same profession on projects of similar size and complexity who are experienced and skilled in the appropriate technical fields and licensed if so required at the time services are performed. These Services are to be performed by the Consultant for AlexRenew in consideration of the payments specified herein and with the obligation that, should the Services not satisfy the requirements listed above, in AlexRenew's reasonable judgment, the Consultant shall re-perform Services originally undertaken by the Consultant as necessary to correct such defective Services, at no additional cost to AlexRenew.

B. Design-Not-To-Exceed Budget

Where applicable, and in the best interest of AlexRenew and the Work (as determined by AlexRenew), the Consultant agrees to design the project covered under the issued Task Order(s) so that bids can be expected to fall within a "design-not-to-exceed " project budget developed for the Task Order. If the low bid amount exceeds the "design-not-to-exceed" budget by less than ten (10%) percent, the Consultant agrees to assist AlexRenew in negotiations with the low bidder to arrive at a contract amount acceptable to AlexRenew. If the low bid amount exceeds the "design-not-to-exceed" budget by more than ten (10%) percent, the Consultant agrees, if directed by AlexRenew, to redesign or modify the design of the project as necessary to obtain a bid within the "design-not-to-exceed" project budget. Such negotiation and/or redesign services by the Consultant, if due to causes within the Consultant's reasonable control and not due to events related to force majeure, shall be at no additional cost to AlexRenew.

ARTICLE 6. INSURANCE

A. The Consultant agrees to secure and carry, throughout the term of this Agreement, the following insurance coverage:

1. Commercial General Liability ("CGL") insurance, including premises and operations, completed operations/products liability, personal injury liability, blanket contractual liability and broad-form property damage liability coverage. The types, amounts and limits of CGL insurance required are detailed below:
   - $1 million Each Occurrence (Bodily Injury and Property Damage)
   - $2 million General Aggregate that applies on a per project basis
   - $2 million Products/Completed Operations Aggregate
   - $1 million Per Person or Organization (Personal and Advertising Injury)
2. Automobile bodily injury and property damage liability insurance covering owned, non-owned, rented, and hired cars. The combined single limit for bodily injury and property damage shall be $1,000,000 per accident.

3. Employer's Liability Insurance. The policy limit shall be $1,000,000 bodily injury by accident per accident; $1,000,000 bodily injury by disease per employee; and $1,000,000 bodily injury by disease policy limit.

4. Virginia Statutory Workers Compensation (W/C) coverage including Virginia benefits and employer's liability with limits of $100,000/100,000/500,000. AlexRenew will not accept W/C coverage issued by the Injured Worker's Insurance Fund, Towson, MD.

5. Professional Liability insurance. The policy limit shall be $2,000,000 per claim and $3,000,000 annual policy aggregate. Coverage shall apply at all times from

commencement of work or contract date (whichever is earlier) and shall continue for a period of three years after Completion of the project. Such policy should also include coverage for pollution liability.

B. All insurances required above shall be written with companies authorized to conduct business within the Commonwealth of Virginia, with an A.M. Best Rating of at least A-, VII or better.

C. The Consultant shall provide AlexRenew with a certificate of insurance and endorsements confirming that coverage compliant with the above requirements is procured and maintained throughout the period during which the Consultant provides Services to AlexRenew under this Agreement. Upon AlexRenew's written request, the Consultant shall provide AlexRenew with copies of any or all of such policies of insurance, however, the Consultant shall be entitled to redact any premium or proprietary information from such policies.

D. AlexRenew, its officers, elected and appointed officials, employees, and agents shall be named as "additional insured" with respect to both the Commercial General Liability (for both work in progress {i.e., on-going operations} and completed work {completed operations}) and Automobile Liability policies for the duration of the contract.

E. The Consultant must provide a copy of the Additional Insured endorsement, or an "Accord" certificate with the additional insured endorsement box checked for all policies that include an additional insured endorsement, to AlexRenew prior to the execution of the Agreement and any extension. Failure to provide such documentation shall result in cancellation of the award or of the Agreement.

F. If there is a material change or reduction in coverage, nonrenewal of any insurance coverage or cancellation of any insurance coverage required by the Agreement, the Consultant shall notify the Purchasing Agent immediately.

G. Any policy for which the Consultant has received notification from an insurer that the policy has, or will be, cancelled, materially changed, or reduced, must be immediately replaced with another policy consistent with the terms of the Agreement and in such a manner that there is no lapse in coverage, and Purchasing Agent must be immediately notified of the replacement.

H. Not having the required insurance throughout the applicable term is considered a material breach of the Agreement and grounds for termination.

I. Each certificate of insurance shall also provide for 30 days written notice (10 days for non-payment) to AlexRenew if thee insurance policy is to be cancelled. or non-renewed. A copy of the certificate of insurance shall be provided to the Purchasing Agent prior to the execution of the Agreement or any extension thereafter.

    a. Should evidence of continuous insurance coverage meeting the requirements of this Article not be maintained, AlexRenew may withhold payment on invoices payable to the Consultant until such insurance is restored to the reasonable satisfaction of AlexRenew.

J. Any insurance coverage that is placed as a "claims made" policy must remain valid and in force, or the Consultant must obtain an extended reporting endorsement consistent with the terms of the Agreement, until the applicable statute of limitations has expired, such date as determined to begin running from the date of the Consultant's receipt of final payment.

K. Contract Identification – The certificate of insurance required hereunder shall state the Agreement's number and title.

L. Certificate Holder - The Certificate Holder must be identified as:

   Alexandria Renew Enterprises
   c/o Purchasing Agent
   1800 Limerick Street
   Alexandria, Virginia 22314

   The Consultant must disclose the amount of any deductible or self- insurance component applicable to the General Liability, Automobile Liability, or any other policies required herein, if any. AlexRenew reserves the right to request additional information to determine if the Consultant has the financial capacity to meet its obligations under a deductible.

M. The Consultant shall require all sub subconsultants to maintain during the term of the Agreement, Commercial General Liability insurance, Business Automobile Liability insurance, and Workers' Compensation insurance, including employer liability coverage in the same form and manner as specified for the Consultant. The Consultant shall furnish sub subconsultants' documentation of coverage and endorsements specified herein to the Purchasing Agent immediately upon request by AlexRenew.

N. No acceptance or approval of any insurance by AlexRenew shall be construed as relieving or excusing the Consultant from any liability or obligation imposed upon the Consultant by the provisions of this Agreement.

O. The Consultant shall be responsible for the work performed under this Agreement and every part thereof, and for all materials, tools, equipment, appliances, and property of any description used in connection with the Services.

P. The Consultant shall be as fully responsible to AlexRenew for the acts and omissions of its sub subconsultants and of persons employed by them as it is for acts and omissions of persons directly employed by it.

Q. Notwithstanding any of the above, the Consultant may satisfy its obligations under this section by means of self-insurance for all or any part of the insurance required, provided that the Consultant can demonstrate financial capacity, the alternative coverage(s) is/are submitted to and acceptable to the AlexRenew and the terms and additional endorsements required hereunder are met to the satisfaction of the Purchasing Agent. The Consultant must provide its most recent actuarial report and provide a copy of its self-insurance resolution to determine the adequacy and security of the insurance funding.

ARTICLE 7. CLAIMS

A. Whenever the Consultant believes there has occurred an act or omission of AlexRenew or an event beyond the reasonable control of the Consultant that may affect its performance, it shall promptly notify AlexRenew by telephone and shall follow-up with notice, in writing, within three (3) business days of first identifying the act or omission. The Consultant shall use commercially reasonable efforts to minimize any delay and continue its performance.
B. AlexRenew and Consultant shall be excused for any delays due to causes beyond its reasonable control.

C. If the Consultant suffers any injury or damage due to an act or omission of AlexRenew, its employees, agents or others for whom AlexRenew is legally liable, written notice of such injury or damage, whether or not insured, shall be given by the Consultant to AlexRenew not later than twenty-one (21) days after first observance. The notice shall provide sufficient detail to enable AlexRenew to investigate the matter. If a claim of additional cost or time is asserted, such claim shall be included in the notice required herein. If not resolved by mutual agreement of the parties, any claims made by the Consultant shall be presented to the AlexRenew Chief Financial Officer, in writing, along with any additional information the Consultant wishes to present, who shall consider the claim and issue a written decision to the Consultant within 30 days of receipt of such notice. For the purposes of this provision, the Consultant may appeal the written decision of the AlexRenew Chief Financial Officer by delivering such appeal, in writing, to the AlexRenew Chief Executive Officer within 30 days of receipt of the Chief Financial Officer's written decision. The AlexRenew Chief Executive Officer will review the Consultants appeal and shall render a final written decision within 30 days of receipt of the Consultant's appeal. The AlexRenew Chief Executive Officer is deemed AlexRenew's designated final decision-maker in accordance with the Virginia Public Procurement Act.

ARTICLE 8. MANDATORY PROVISIONS

A. Payment to Subconsultants
   a. The Consultant shall take one of the two following actions within seven (7) days after receipt of amounts paid to the Consultant by AlexRenew for Services performed by subconsultants:

      - Pay the subconsultant for the proportionate share of the total payment received from AlexRenew attributable to the Services performed by the subconsultant; or
      - Notify AlexRenew and the subconsultant, in writing, of the Consultant's intention to withhold all or a part of the sub Consultant's payment with the reason for nonpayment.

   b. The Consultant shall pay interest to the subconsultant on all amounts owed by the Consultant that remain unpaid after seven days following receipt by the Consultant of payment from AlexRenew for Services performed by the subconsultant, except for amounts withheld as allowed herein.

   c. The Consultant shall include in each of its subcontracts a provision requiring each subconsultant to include or otherwise be subject to the same invoicing, payment and interest requirements with respect to each lower-tier subconsultants.

   d. The Consultant's obligation to pay an interest charge to a subconsultant pursuant to this Agreement shall not be construed to be an obligation of AlexRenew. A contract modification shall not be made for providing reimbursement for the interest charge. A cost reimbursement claim shall not include any amount for reimbursement for the interest charge.

e. Nothing contained in this Agreement shall create any contractual relationship between any subconsultants and AlexRenew.

B. Non-Discrimination

1. The Consultant will not discriminate against any employee or applicant for employment because of age, race, color, handicap, religion, sex, national origin or other basis prohibited by state law relating to discrimination in employment, except where there is a bona fide occupational qualification reasonably necessary to the normal operation of the Consultant.

2. The Consultant agrees to post in conspicuous places, available to employees and applicants for employment, notices setting forth the provisions of this nondiscrimination clause.

3. The Consultant, in all solicitations or advertisements for employees placed by or on behalf of the Consultant, will state that it is an equal opportunity employer. Notices, advertisements and solicitations placed in accordance with federal law, rule or regulation shall be deemed sufficient for meeting this requirement.

4. The Consultant will include the substance of this Article in every subcontract or purchase order equal to or greater than $10,000 in value unless exempted by rules, regulations, or orders of the U.S. Secretary of Labor issued pursuant to Section 204 of Executive Order 11246 of September 24, 1965, as amended by Executive Order 11375 of October 13, 1967, so that such provisions will be binding upon each subconsultant or vendor.

C. Non-Discrimination against Faith-Based Organizations

AlexRenew does not discriminate against faith-based organizations and the Consultant agrees not to discriminate against faith-based organizations.

D. Federal Immigration Law

The Consultant, its subconsultants and any others it may employ do not, and will not during the term of this Agreement, knowingly employ an unauthorized alien as defined in the Federal Immigration and Reform and Control Act of 1986.

E. Drug-Free Workplace

Throughout the term of this Agreement, the Consultant agrees to:

i. provide a drug-free workplace for the Consultant's employees;

ii. post in conspicuous places, available to employees and applicants for employment, a statement notifying employees that the unlawful manufacture, sale, distribution, dispensation, possession, or use of a controlled substance or marijuana is prohibited in the Consultant's workplace and specifying the actions that will be taken against employees for violations of such prohibition;

iii. state in all solicitations or advertisements for employees placed by or on behalf of the Consultant that the Consultant maintains a drug-free workplace; and

iv. include the provisions of the foregoing clauses in every subcontract or purchase order equal to or greater than $10,000 in value, so that the provisions will be binding upon each subconsultant or vendor.

For the purposes of this provision, “drug-free workplace” means any site for the performance of Services in connection with this Agreement, where the employees of the Consultant are prohibited from engaging in the unlawful manufacture, sale, distribution, dispensation, possession or use of any controlled substance or marijuana.

F. **Antitrust**

By entering into this Agreement, the Consultant conveys, sells, assigns, and transfers to AlexRenew all rights, title and interest in and to all causes of action it may now have or hereafter acquire under the antitrust laws of the United States and the Commonwealth of Virginia relating to the particular goods or services purchased or acquired by AlexRenew under this Agreement.

G. **Authorization to Conduct Business in the Commonwealth of VA**

The Consultant must pursuant to Code of Virginia §2.2-4311.2, be and remain authorized to transact business in the Commonwealth of Virginia during the entire term of the Agreement, otherwise, the Agreement is voidable at the sole option of and no expense to AlexRenew.

H. **Small and Minority-Owned Businesses**

1. It is the policy of AlexRenew to undertake every effort to increase opportunities for small and minority-owned businesses in all aspects of procurement to the maximum extent practicable. In connection with this Agreement, the Consultant agrees to use commercially reasonable efforts to carry out this policy and to ensure that small and minority-owned businesses have the maximum practicable opportunity to compete for subcontract work under this Agreement consistent with the efficient performance of the Services.

2. As used in this Agreement, the term “small business” means a corporation, partnership, or sole proprietorship, or other legal entity formed for the purpose of making a profit, which is independently owned and operated and has either fewer than 100 employees or less than $1,000,000 in annual revenues.

3. As used in this Agreement, the term “minority business” means a business enterprise that is at least fifty-one (51) percent owned and controlled by a minority person or persons. Such persons include African Americans, Hispanic Americans, Asian Americans, American Indians, Eskimos and Aleuts; women and veterans regardless of race or ethnicity; and persons with a physical impairment that substantially limits one or more of the major life activities of such individuals including a record of such impairment and who are regarded as having such an impairment.

4. If Federal grants fund some or all of the Program, it is the policy of AlexRenew, through its agents and employees, to comply with the requirements set forth in the U.S. Office of Management and Budget Circular No. A-102, uniform administrative requirements for Grants and Cooperative Agreements with State and Local Governments, as they pertain to small and minority businesses.

I. **Health and Safety**

1. The Consultant has full responsibility for the safety of its employees, agents and subconsultants, including providing or requiring the use of appropriate safety equipment for field personnel. The Consultant is responsible for developing, maintaining, and implementing its own health and safety program (the “HASP”), policies, procedures and equipment as necessary to protect its workers and others from their activities. The Consultant shall provide AlexRenew with a copy of the HASP for AlexRenew’s review prior to commencing the covered activities.

2. In development of the HASP and performance of the Services, the Consultant shall (a) comply with all applicable federal, state and local statutes, regulations and ordinances regarding health and safety, including, but not limited to those codified by the Occupational Safety and Health Administration (OSHA) in Title 29 of the Code of Federal Regulations (CFR) Parts 1910 and 1926, particularly 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response; and (b) comply with its HASP as well as any health and safety requirements prepared by AlexRenew, if any, and provided to Consultant for the Services.

3. The Consultant shall indemnify, defend and hold harmless all AlexRenew Indemnitees from all claims, damages, suits, losses, fines, penalties and expenses, including attorneys’ fees, to the extent arising from noncompliance by the Consultant, its employees, agents and subconsultants with all applicable health and safety requirements required herein.

J. Spills

1. In the event the Consultant or any of its employees, agents or subconsultants cause any Regulated Material, as defined in Exhibit D, attached hereto, to be spilled or otherwise spread upon any AlexRenew property or Program Site during the performance of the Services or otherwise (a “Spill”), the Consultant shall immediately initiate action to clean and restore all such AlexRenew Property and/or Program Site to the condition existing before such Spill. To the extent the Spill is caused by the negligence or willful misconduct of the Consultant, the Consultant, at its own expense, shall pursue the cleaning and restoration of the property with due diligence until completed to the satisfaction of AlexRenew and any regulatory agency with jurisdiction. To the extent the Spill is caused by the negligence or willful misconduct of the Consultant, the Consultant shall pay the costs for disposal of materials resulting from the Spill and clean-up activity.

2. In the event of and to the extent a Spill is caused by the negligence or willful misconduct of the Consultant, the Consultant shall indemnify and hold harmless all AlexRenew Indemnitees from liabilities, damages, costs, claims, demands, expenses, reasonable attorney’s fees, fines and penalties of whatever type or nature which may arise from or in any manner be connected with the Spill.

ARTICLE 9. INDEMNIFICATION, INTELLECTUAL PROPERTY, AND SECURITY

A. Indemnification

1. The Consultant hereby agrees to indemnify, defend and hold harmless AlexRenew, including AlexRenew employees, officers, directors, and agents (collectively, "AlexRenew’s Indemnified Parties") from and against any and all losses, damages, claims, demands, proceedings, suits and actions; including any related liabilities, obligations, losses, damages, assessments, fines, penalties (whether criminal or civil),

judgments, settlements, expenses (including reasonable attorneys' and accountants' fees and disbursements) and costs (each, a "Claim" and collectively, "Claims"), incurred by, borne by or asserted against any of AlexRenew's Indemnified Parties to the extent such Claims are caused by:

(i) any intentional or willful misconduct or negligence of any employee, agent, or subconsultant of the Consultant,

(ii) any negligent act or omission of any employee, agent, or subconsultant of the Consultant,

(iii) breach of any representation, or covenant of the Consultant contained herein,

(iv) any defect in the Consultant-provided products or services to the extent such defect is a result of the Consultant's failure to meet the Standard of Care set forth in Article 5 of this Agreement, or

(v) any actual or alleged infringement or misappropriation of any third party's intellectual property rights by any of the Consultant-provided products or services. Approval of any settlement shall be accomplished in accordance with all applicable laws, rules and regulations.

2. In the event that a Claim is commenced against any of AlexRenew's Indemnified Parties alleging that use of the Consultant-provided products or services (including any components thereof), or that the Consultant's performance or delivery of any product or service under this Agreement infringes any third party's intellectual property rights, and the Consultant is of the opinion that the allegations in such Claim (in whole or in part) are not covered by this indemnification provision, the Consultant shall immediately notify AlexRenew in writing, via certified mail, specifying to what extent the Consultant believes it is obligated to defend and indemnify under the terms and conditions of this Agreement. The Consultant shall in such event protect the interests of AlexRenew's Indemnified Parties and secure a continuance to permit AlexRenew to appear and defend their interests in cooperation with the Consultant as is appropriate.

3. In the event of a Claim pursuant to any actual or alleged infringement or misappropriation of any third party's intellectual property rights by any of the Consultant-provided deliverables, products, and services, as applicable, or the Consultant's performance, and in addition to all other obligations of the Consultant in this Section, the Consultant shall at its expense, either:

(i) procure the right to continue use of such infringing deliverables, products, and services, as applicable, or any component thereof; or

(ii) replace or modify such infringing deliverables, products, and services, as applicable, or any component thereof, with non-fringing deliverables, products, or services, as applicable, satisfactory to AlexRenew.

4. In addition, the Consultant shall provide any a comparable temporary replacement products and/or services or reimburse AlexRenew for the reasonable costs incurred by AlexRenew in obtaining an alternative product or service, in the event such affected deliverable, product, and services, cannot be used by AlexRenew. If the Consultant

cannot accomplish any of the foregoing within a reasonable time and at commercially reasonable rates, then the Consultant shall accept the return of the infringing deliverables, products, and services, as applicable, or any component thereof, along with any other components rendered unusable by AlexRenew as a result of the infringing component, and refund the price paid to the Consultant for such components

5. The Consultant's duties under this provision will include the duty to obtain the approval of AlexRenew as to legal counsel selected to defend AlexRenew and to confer with AlexRenew concerning any defense.

6. The provisions of this Article shall survive the completion of the Services hereunder and the expiration, cancellation, or termination of this Agreement.

B. Intellectual Property

1. All documents, papers, reports, forms, materials, creations or inventions prepared for or furnished to AlexRenew by the Consultant ("Documents") in the performance of this Agreement shall, upon payment to the Consultant of all amounts due and owing under this Agreement for such work shall become the sole property of AlexRenew, and all title and property rights, including copyright, patent, intellectual property, and common law rights, in the documents prepared for or furnished to AlexRenew by the Consultant shall transfer to AlexRenew. The Consultant shall have and retain the ownership, title, and property rights, including copyright, patent, intellectual property, and common law rights, in any elements (including but not limited to standard details or computation) used in the documents, but developed by the Consultant independent of this Agreement. The Consultant shall provide appropriate verification of such independent development upon AlexRenew's request. Upon transfer of ownership, title, and property rights to AlexRenew, the Consultant shall receive a limited, nonexclusive license to use the content of any subject document on other projects, provided such use does not conflict with AlexRenew's business, commercial, proprietary, competitive, or security interests.

2. The Consultant represents that all information and resources it uses or relies upon to perform the Services belong to the Consultant or is information or resources the Consultant has the legal right to use. The Consultant further represents and warrants that all Work Product is the original work of the Consultant and that the Work Product does not infringe upon or otherwise violate a third party's copyright, patent, or other proprietary rights.

3. AlexRenew and the Consultant agree that all Documents furnished for AlexRenew by the Consultant shall be used for their intended purpose. Any modification of such Documents or their re-use for purposes other than those intended in the issued Task Order, without written authorization from the Consultant, may be at AlexRenew's sole risk .

C. Cyber Security Compliance

1. The Consultant shall comply with all applicable federal, state and local laws and regulations related to cybersecurity. The Consultant also agrees to comply with all provisions of the then-current AlexRenew's cybersecurity and information technology policies and procedures, as are pertinent to the Consultant's operation. The Consultant may, at any time, be required to execute and complete, for each individual Consultant's employee or agents, additional forms which may include non-disclosure agreements to be signed by the Consultant's employees or agents acknowledging the

confidentiality of AlexRenew' information entrusted with which such employees and agents while working on AlexRenew projects.

2. Any unauthorized release of proprietary or personal information by the Consultant or an employee or agent of the Consultant shall constitute a breach of its obligations under this Section and the Agreement.

3. The Consultant shall immediately notify AlexRenew, if applicable, of any "breach of security of the system" as that term is defined in Virginia Code 18.2-186.6, and other personal identifying information, such as personnel data or date of birth, provided by AlexRenew to the Consultant.

4. The Consultant shall provide AlexRenew the opportunity to participate in the investigation of the breach and to exercise control over reporting the unauthorized disclosure, to the extent permitted by law. The Consultant shall indemnify, defend, and hold AlexRenew's Indemnified Parties harmless from and against any and all fines, penalties (whether criminal or civil), judgments, damages and assessments, including reasonable expenses suffered by, accrued against, or charged to or recoverable from AlexRenew's Indemnified Parties, on account of the failure of the Consultant to perform its obligations pursuant to this Article.

ARTICLE 10. GOVERNING LAW, CONTRACTUAL DISPUTES, AND COMPLIANCE

A. Governing Law

This Agreement shall be governed by and construed in accordance with the laws of the Commonwealth of Virginia without regard to that body of law controlling choice of law. Any and all litigation shall be brought in the circuit courts of City of Alexandria, Virginia. The United Nations Convention on Contracts for the International Sale of Goods and all other laws and international treaties or conventions relating to the sale of goods are expressly disclaimed. Uniform Computer Information Transactions Act (UCITA) shall apply to this Agreement only to the extent required by §59.1-501.15 of the Code of Virginia.

B. Licenses and Permits

1. The Consultant agrees to obtain and maintain, at its own expense, permits, licenses and other forms of documentation required for the Consultant to comply with existing laws, ordinances, and regulations of any state, county, township, or municipal subdivision thereof, or other governmental agency, which may be applicable to the Consultant's performance of the Services, throughout the term of this Agreement.

2. If the Consultant becomes aware of non-compliance with a regulatory, permit or licensing matter, the Consultant must notify AlexRenew, in writing, within five (5) business days of the Consultants awareness of such non-compliance.

C. Ethics in Public Procurement and Conflicts of Interest

1. The ethics in public contracting provisions of Sections 2.2-4367 through 2.2-4377 of the Code of Virginia are applicable to all contracts entered into by AlexRenew, including this Agreement.

2. The Consultant represents and warrants, with regard to this Agreement and any Task Order issued hereunder, that neither the Consultant (including any of its officers, partners, employees or agents) nor any subconsultant or subconsultant employee has (i) provided, attempted to provide, or offered to provide any kickback; (ii) solicited,

accepted or attempted to accept any kickback; (iii) included, directly or indirectly, the amount of any kickback in the price applicable to this Agreement or in the subcontract price charged by any sub subconsultant to a higher tier sub subconsultant; or (iv) committed any violation of the Ethics in Public Contracting provisions of the Virginia Public Procurement Act, Virginia Code Sections 2.2-4367 et seq.

3. In addition to any other remedies that AlexRenew may have, the Consultant shall indemnify In addition to any other remedies that AlexRenew may have, the Consultant shall indemnify and hold harmless all AlexRenew's Indemnified Parties from and against loss or damage, including but not limited to, costs, attorney's fees, or any fines or penalties assessed against the Consultant, resulting from a confirmed violation of the Anti-Kickback Act of 1986 by the Consultant (including any of its directors, officers, partners, employees, or agents).

4. The Consultant, its sub subconsultants s and any others used by the Consultant in the performance of Services shall at all times comply with applicable laws and regulations and shall avoid and refrain from all activities on behalf of AlexRenew which could be interpreted as creating conflicts of interest or the appearance of a conflict for AlexRenew or the Consultant.

5. Throughout the Agreement Term, the Consultant shall have the duty to promptly notify AlexRenew, in writing, of an action, change or development, which would make any representation, covenant or agreement in, under or as a part of this Agreement, untrue, inaccurate or incomplete. The Consultant further agree to disclose to AlexRenew any other facts of which the Consultant becomes aware which might in Consultant's good faith judgement reasonably be expected to involve or give rise to a conflict of interest or appearance of conflict of interest.

6. In accordance with § 2.2-4374 Code of Virginia, the Consultant, its agents or employees shall not solicit to sell building materials, supplies or equipment for any building or structure.

D. Dispute Resolution

1. In accordance with §2.2-4363 of the Code of Virginia, contractual claims, whether for money or other relief, shall be submitted in writing to the public body from whom the relief is sought no later than sixty (60) days after final payment; however, written notice of the Consultant's intention to file such claim must be given to AlexRenew at the time of the occurrence or beginning of the work upon which the claim is based. Pendency of claims shall not delay payment of amounts agreed due in the final payment. AlexRenew shall render a final decision in writing within thirty (30) days after its receipt of the Consultant's written claim.

2. The Consultant may not institute legal action prior to receipt of the decision of AlexRenew on the claim, unless AlexRenew fails to render its decision within thirty (30) days. The decision of AlexRenew shall be final and conclusive unless the Consultant, within six (6) months of the date of the final decision on the claim, invokes appropriate action under §2.2-4364, Code of Virginia.

E. Relationship between AlexRenew and the Consultant

Consultant has no authority to contract for AlexRenew in any way to bind, to commit AlexRenew to any agreement of any kind, or to assume any liabilities of any nature in the name of or on behalf of AlexRenew. Under no circumstances shall the Consultant, or any of its employees, hold itself out as or be considered an agent or an employee of AlexRenew, and neither AlexRenew shall have any duty to provide or maintain any insurance or other employee benefits on behalf of the Consultant or its employees. The Consultant represents and warrants that it is an independent contractor for purposes of federal, state and local employment taxes and agrees that neither AlexRenew is responsible to collect or withhold any federal, state or local employment taxes, including, but not limited to, income tax withholding and social security contributions, for the Consultant. Any and all taxes, interest or penalties, (including, but not limited to, any federal, state or local withholding or employment taxes, and any penalties related to health care or employee benefits laws) that are imposed, assessed or levied as a result of this Agreement or services performed pursuant to this Agreement shall be paid or withheld by the Consultant or, if assessed against and paid by AlexRenew, shall be reimbursed by the Consultant upon demand by AlexRenew.

F. Compliance with Laws

1. The Consultant agrees to comply with all federal, state and local administrative regulations respecting the assumption of liability for the aforesaid taxes or contributions. The Consultant represents that the fees incorporated herein include such taxes or contributions and agrees to indemnify and hold harmless all AlexRenew's Indemnified Parties from and against liability for the delay or failure of the Consultant and its sub subconsultants to pay such taxes or contributions.
2. The Consultant agrees to execute certificates reasonably required by AlexRenew if such certificate is required pursuant to federal, state, or local laws or regulations.

3. The Consultant agrees to comply with applicable federal, state, and local laws pertinent to performance of the Services, and further agrees to include the substance of Article 10 in all subcontracts entered into by the Consultant.

G. Liens

AlexRenew's interest, whether in fee simple or easement, in any site at which the work or services under this Agreement is to be provided, cannot be subjected to a mechanic's lien because mechanics liens cannot be placed on publicly-owned property rights in the Commonwealth of Virginia.

H. Import/Export

In addition to compliance by the Consultant with all export laws and regulations, AlexRenew requires that any data deemed "restricted" or "sensitive" by either federal or state authorities, must only be collected, developed, analyzed, or otherwise used or obtained by persons or entities working within the boundaries of the United States.

I. Bankruptcy

If the Consultant becomes insolvent, takes any step leading to its cessation as a going concern, fails to pay its debts as they become due, or ceases business operations continuously for longer than fifteen (15) business days, then AlexRenew may immediately terminate this Agreement, on notice to the Consultant unless the Consultant immediately gives AlexRenew adequate assurance of the future performance of this Agreement or the applicable Task Order. If bankruptcy proceedings are commenced with respect to the Consultant and if this Agreement has not otherwise terminated, then AlexRenew may suspend all further performance of this Agreement until the Consultant assumes this Agreement and provides adequate assurance of performance thereof or rejects this Agreement pursuant to Section 365 of the Bankruptcy Code or any similar or successor provision, it being agreed by

AlexRenew and the Consultant that this is an executory agreement. Any such suspension of further performance by AlexRenew pending Consultant's assumption or rejection shall not be a breach of this Agreement, and shall not affect the rights of AlexRenew to pursue or enforce any of its rights under this Agreement or otherwise.

ARTICLE 11. CONFIDENTIALITY REQUIREMENTS

A. Treatment and Protection

Each party shall (i) hold in strict confidence all confidential information of the other party, (ii) use the confidential information solely to perform or to exercise its rights under this Agreement, and (iii) not transfer, display, convey or otherwise disclose or make available all or any part of such confidential information to any third-party. However, parties may disclose the confidential information to such individuals that are bound by non-disclosure contracts. Each party shall take the same measures to protect against the disclosure or use of the confidential information as it takes to protect its own proprietary or confidential information (but in no event shall such measures be less than reasonable care).

1. Exclusions

The term "confidential information" shall not include information that is:

(i) in the public domain through no fault of the receiving party or of any other person or entity that is similarly contractually or otherwise obligated;

(ii) obtained independently from a third-party without an obligation of confidentiality to the disclosing party and without breach of this Agreement;

(iii) developed independently by the receiving party without reference to the Confidential Information of the other party; or

(iv) required to be disclosed under the Virginia Freedom of Information Act (§§2.2-3700 et seq. of the Code of Virginia) or similar laws or pursuant to a court order.

2. Return or Destruction

Upon the termination or expiration of this Agreement or upon the earlier request of AlexRenew, the Consultant shall:

(i) at its own expense, (a) promptly return to AlexRenew all tangible confidential information (and all copies thereof except the record required by law), or (b) upon written request from AlexRenew, destroy such confidential information and provide AlexRenew with written certification of such destruction, and

(ii) cease all further use of AlexRenew's confidential information, whether in tangible or intangible form.

Notwithstanding the requirements herein, the Consultant may retain one (1) archival copy of the confidential information for its use in the performance of Services hereunder, provided that such information is kept in strict confidence and the Consultant employs prudent measures to maintain its integrity and nondisclosure.

AlexRenew shall retain and dispose of Consultant's confidential information in accordance with the Commonwealth of Virginia's records retention policies.

B. Advertisement, Communication and Use of AlexRenew Proprietary Mark; Disclosures

a. The Consultant shall not use the name of AlexRenew or refer to AlexRenew, directly or indirectly, in any press release or formal advertisement without receiving prior written consent of AlexRenew. In no event may the Consultant use a proprietary mark of AlexRenew without receiving a prior written consent of AlexRenew.

b. No communications, in any form or at any time, made on behalf of AlexRenew shall take place with federal, state, or local government officials or news media without a prior written approval of an AlexRenew.

c. AlexRenew may present information resulting from the performance of Services pursuant to this Agreement in duly constituted administrative or licensing proceedings, disputes, litigation, or other legal action, including in judicial appeals directly resulting from such proceedings.

d. All work product produced by the Consultant under this Agreement shall be clearly and conspicuously marked "Privileged Work Product-Prepared at the Request of AlexRenew." No communications (including electronic mail) on behalf of AlexRenew or pursuant to a request or demand received from outside of AlexRenew (including demands made by governmental agencies) shall be made without a prior written consent of AlexRenew.

e. All Work-Product produced by the Consultant at the request of AlexRenew's General Counsel shall be clearly and conspicuously marked "Privileged Work Product-Prepared at the Request of the AlexRenew General Counsel." No communications (including electronic mail) on behalf of AlexRenew or pursuant to a request or demand received from outside of AlexRenew (including demands made by governmental agencies) shall be made without the prior written consent of AlexRenew's General Counsel.

ARTICLE 12. MISCELLANEOUS PROVISIONS

A. Attorney's Fees. In the event either party commences legal proceedings against the other, then the prevailing party shall, in addition to any other recovery, be entitled to recover its reasonable attorneys' fees.

B. Remedies. The remedies set forth in this Agreement are intended to be cumulative. In addition to any specified remedy, AlexRenew reserve any and all other remedies that may be available at law or in equity.

C. Captions. The captions are for convenience and in no way define, limit or enlarge the scope of this Agreement or any of its Articles.

D. Force Majeure. Neither party will be held responsible for failure to perform the duties and responsibilities imposed by the Agreement if such failure is due to a fire, riot, rebellion, natural disaster, war, acts of terrorism or acts of God that is beyond the control of the party and that makes performance impossible or illegal, unless otherwise specified in the Agreement.

E. Interpretation. Ambiguities, inconsistencies, or conflicts arising out of or related to this Agreement shall not be strictly construed against AlexRenew; rather, they shall be resolved by applying the most reasonable interpretation under the circumstances, considering the intentions of the parties at the time of contracting.

F. Waiver. Failure by AlexRenew or the Consultant to insist on performance of any or all of the terms, covenants or conditions of this Agreement, or failure to exercise any rights, remedies or privileges hereunder, or AlexRenew's waiver of any breach hereunder, shall not thereafter be construed as a waiver of any such terms, covenants, privileges or breach unless otherwise provided herein.

G. No Waiver of Sovereign Immunity. Notwithstanding any other provision of this Agreement, nothing in this Agreement or any action taken by AlexRenew pursuant to this Agreement shall constitute or to be construed as a waiver of either sovereign or governmental immunity of AlexRenew. The parties intend for this provision to be read as broadly as possible.

H. Arbitration. No claim arising under or related to the Agreement may be subject to arbitration.

I. Survival. All representations, warranties, and covenants contained in the Agreement, or in any instrument, certificate, exhibit, or other writing intended by the parties to be a part of their Agreement, will survive the termination of the Agreement.

J. Amendments. Unless otherwise specified herein, this Agreement shall not be amended except by written amendment executed by persons dully authorized to bind the Consultant and AlexRenew.

K. Severability. In the event any one or more of the provisions contained in this Agreement are, for any reason, held by a court of competent jurisdiction to be unenforceable in any respect, such holding will not affect any other provisions of the Agreement, and the Agreement will then be construed as if such unenforceable provisions are not a part thereof.

L. Notices. All notices required under this Agreement shall be delivered, in writing, by facsimile, personal delivery or mail and shall be addressed to the following persons:

TO THE CONSULTANT:

____
____
____

Attn: __________________
Ph: __________________

TO ALEXRENEW:

Director, Enterprise Utility Asset Management [Felicia Glapion]
Alexandria Renew Enterprises
1800 Limerick Street
Alexandria, VA 22314

AND

Purchasing Agent [Maryam Zahory]
Alexandria Renew Enterprises
1800 Limerick Street
Alexandria, VA 22314

Notice shall be effective upon delivery to the above addresses. Either party may notify the other that a new person has been designated by it to receive notices, or that the address or Fax number for the delivery of such notices has been changed, provided that, until such time as the other party receives such notice in the manner provided for herein, any notice addressed to the previously-designated person and/or delivered to the previously-designated address or Fax number shall be effective.

M. Authority and Validity of Signatures

1. Each party executing the Agreement on behalf of such entity represents that he or she is duly authorized to execute and deliver the Agreement on the entity's behalf, including the entity's Board of Directors or Chief Executive Officer. The Agreement shall not be effective or binding unless countersigned by the AlexRenew's Authorized Representative (i.e., AlexRenew's Chief Executive (CEO) Officer or the CEO's authorized designee), as evidenced by their signature as set forth in the Agreement.

2. The Agreement may be executed in one or more counterparts, each of which will be considered an original, but all of which together will constitute one and the same instrument. The parties agree that the Agreement, its amendments, and ancillary Task Orders to be entered into in connection with the Agreement will be considered signed when the signature of a party is delivered by email transmission. Such emailed signature must be treated in all respects as having the same effect as an original signature.

IN WITNESS WHEREOF, the parties hereto have caused their names to be set as of the day and year written below.

Alexandria Renew Enterprises	Consultant
By:____________________________	By:____________________________
Karen L. Pallansch,	____________________
Chief Executive Officer	____________________
Date:____________________________	Date:____________________________

EXHIBIT A

SCOPE OF SERVICES

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EXHIBIT B

KEY PERSONNEL

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EXHIBIT C

PRICING AND FEES, SCHEDULES, AND LABOR MATRIX

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EXHIBIT D

LIST OF HAZARDOUS/REGULATED SUBSTANCES AND REPORTABLE QUANTITIES

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EXHIBIT E

SITE SECURITY

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EXHIBIT F

INFORMATION MANAGEMENT SYSTEM

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EXHIBIT G

ALEXRENEW WORK BREAKDOWN STRUCTURE (WBS) REQUIREMENTS

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Exhibit I

AlexRenew Standard Task Order Format (Sample)

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Sample Task Order: RFP_21-015

Biosolids Master Planning Sample Scope

1. Reference

This sample Task Order is being submitted as part of the response to RFP21-015.

2. Purpose

The purpose of this high-level sample scope is to help AlexRenew gain a deeper understanding of how [Company Name Here] will approach the Biosolids master planning process.

3. Scope of Services

Use this section to provide a description of potential services (such as potential tasks, subtasks and/or workshops and associated goals) and explain the rationale for inclusion.

Use subsections as needed, such as:

3.1 Scope Item 1 (e.g., Project Management)

3.2 Scope Item 2

Etc.

4. Deliverables

Use this section to list/describe the potential deliverables associated with this sample task order and explain the rationale for inclusion. Use subsections as needed.

5. Schedule

Use this section to discuss the list/describe the potential schedule associated with this sample task order. The sample schedule should identify the sequence in which tasks will be executed, the interrelationship between tasks, their duration, key milestones and deliverables.

Appendix A – Assumptions

1. Use this section to list/describe the task order assumptions.

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