Advanced Study for Regional Biosolids Digestion, Drying, and Thermal Processing

Prepared for

Portland Water District

December 21, 2023

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Portland Water District, Portland, Maine

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FINAL

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%	percent
BACT	Best Available Control Technology
BC	Brown and Caldwell
BCE	Business case evaluation
BMP	Biosolids Master Plan
CFIA	Canadian Food Inspection Agency
dtpd	dry tons per day
FOG	fats, oils, grease
GHG	greenhouse gas
HTC	Hydrothermal carbonization
HTL	hydrothermal liquefaction
MOPO	Maintenance of Plant Operations
NPC	net present cost
O&M	Operations and Maintenance
OMB	Office of Management and Budget
PWD	Portland Water District
PFAS	Per- and polyfluoroalkyl substances
PS MAD	Primary sludge mesophilic anaerobic digestion
RFI	Request for Information
RFP	Request for Proposal
SCWO	Super critical water oxidation
SSI	sewer sludge incineration
TCHP	thermal chemical hydrolysis process
THP	thermal hydrolysis process
TS	Total solids
USEPA	United States Environmental Protection Agency
VS	Volatile solids
WAS	Waste activated sludge
WEF	Water Environment Federation
WM	Waste Management
wtpd	wet tons per day
wtpy	wet tons per year
WWTF	Wastewater Treatment Facility

Executive Summary

Portland Water District (PWD) completed a Biosolids Master Plan (BMP) in April 2023 with Brown and Caldwell (BC) to identify a path forward for addressing wastewater solids management challenges spurred by legislative action requiring wastewater solids managed instate be landfilled due to concerns for per- and polyfluoroalkyl substance (PFAS). The BMP also sought to integrate PWD's programmatic goals of enhancing reliability and regulatory resiliency and support the public's confidence in PWD's environmental stewardship. The BMP recommended PWD engage with regional partners to explore the viability of collaboratively implementing an offsite regional biosolids processing facility using solids processing technologies such as anerobic digestion, drying, and thermal treatment that could meet PWD's goals and objectives. This report describes an advanced study completed following the BMP to evaluate the commercial offerings to deploy these technologies at a regional scale and characterize the scope of the facility to support PWD's engagement with potential regional partners.

To complete this task, BC issued a Request for Information (RFI) to technology suppliers (manufacturers) and service providers (companies with additional offerings to finance, build, and operate a regional facility). The RFI resulted in 29 Responses that provided an overview of commercially available technologies and project delivery models with budgetary capital and operating cost data, information on company standing, and publicly available data on PFAS fate. Responses were evaluated and screened based on predetermined scoring criteria to develop three alternatives for regional solids processing and three alternatives for processing PWD's solids onsite as a basis for comparison.

In the BMP, we introduced the idea of 'no-regret' projects. Upgrading dewatering was recommended as a 'no-regrets' project because it would reduce the mass of solids needing to be managed and address a core, state-of-good-repair need. Given the findings of this advanced study, BC also recommends implementation of onsite primary sludge mesophilic anaerobic digestion (PS MAD) as a 'no regrets' project for the following reasons.

a. PS MAD reduces East End's solids production by approximately 22 percent, saving $1.2M per year at the current disposal cost of $131 per wet ton at the planning horizon midterm solids production projection (10-years out). Digestion also generates a renewable fuel in biogas, further reducing annual costs and onsite greenhouse gas emissions. At these assumptions, the cost to build and operate PS MAD, with resulting cost savings, is roughly equivalent to PWD's current solids management cost of $131 per wet ton. As solids management unit costs continue to increase, PS MAD's mass reduction would further increase cost savings.
b. Onsite digestion is substantially more cost effective than offsite digestion since offsite digestion requires additional facilities to reliquefy hauled solids for digester feed and re-dewatering post-digestion.
c. Without onsite anaerobic digestion, PWD's opportunities for offsite processing are limited. The top-ranking RFI responses process solids through thermal dryers for further mass reduction. Thermal drying with undigested sludge is known to cause a host of operational issues. Undigested primary sludge has poor handling characteristics, increases combustible dust generation, and has objectionable odors. Only two service providers are in operation in the United States with a demonstrated history of managing undigested primary sludge drying

but operation has come at considerable cost given increased operations and maintenance requirements and substantial repairs following thermal events. Examples of undigested sludge drying facilities that have closed or paused operation due to operational issues include Springfield, MA; Schenectady, NY; Linden, NJ; Morrisville, PA; and Livonia, MI.

d. With a digested PS, PWD has a much wider array of downstream thermal drying options available. This includes onsite installation with a wider variety of dryer technologies and offsite regional solutions with a much larger pool of service providers. Additionally, much of the wastewater utilities in southern Maine are secondary treatment only facilities and do not produce a primary sludge so a regional dryer would be compatible with their feedstock as well. The thermal dryer will produce a more uniform and less odorous product that will also be more desirable for beneficial reuse. Several biosolids management companies have expressed interest in transporting dried product out of state for beneficial reuse for substantially less cost than in-state disposal options.

e. Onsite PS MAD provides several synergies with dewatering at East End. PS production follows a diurnal trend and digestion acts as an equalization tank, so PWD will have a more consistent blend of digested PS and secondary sludge to improve polymer dosing. Digested PS does not have the septicity concerns of undigested PS which provides PWD the opportunity to store digested PS ahead of dewatering for schedule control. Digestion also breaks down grease and fiber in PS, reducing maintenance requirements on the dewatering unit and downstream transfer lines.

f. Table ES-1 provides an economic breakdown for implementation of the technologies discussed in this report. PS MAD is recommended for near-term installation for the benefits described above. The PS MAD 20-year net present cost (including amortized capital, operating and product management costs) is roughly equivalent to PWD's current solids management cost and will save PWD money as solids management unit costs continue to increase. With PS MAD, PWD will have the opportunity to evaluate a wider variety of onsite dryer options, or regional drying options under a second project phase. Depending on the dried product management fee, onsite installation of a dryer is projected to result in a $148 - $168 cost per wet ton over the 20-year horizon. Offsite, regional drying is projected to cost partners $169 - $208 per wet ton over the project period. However, the offsite project costs were developed using municipal construction cost assumptions and level of redundancy. Private developers are likely to propose facilities with less redundancy and maintain contingency plans during outages for a lower project cost. If dried product management costs increase, or PWD wishes to generate an alternative biosolids-based product where contaminants have been thermally treated (e.g. biosolids biochar) a pyrolysis facility could be installed to manage the dried product at a conceptual level cost of $117 - $123 per wet ton, depending on the cost for managing the biochar.

Table ES-1. Economic Project Summary and Phasing Recommendations				
Project Phasing	**Location**	**Technology Implementation**	**Total Project Capital**	**20-Year Net Present Cost ($/wet ton-equivalent)1**
Phase 1	**Onsite**	**PS MAD**	**$24 ($12M - $48M)**	**$136**
Phase 2a	**Onsite**	**Belt Drying (Representative)**	**$40M ($20M - $80M)**	**$148 - $168**
Phase 2b	**Offsite**	**Thin Film (Representative)**	**$103 ($52M – ($206M)**	**$169 - $208**
Phase 3	**Offsite**	**Pyrolysis**	**$54M**	**$117 - $123**

Note: 1 the cost includes the annual O&M and a yearly amortized capital cost assuming a 20-year loan with 1.5% interest rate.

Based on the findings from this advanced study, BC recommends PWD advance the following steps.

1. Implement PS MAD and dewatering upgrades at East End ('no-regrets' projects). Advance preliminary design of onsite dryer to refine cost estimates, verify constructability and select preferred dryer technology.
2. Engage regional partners to identify available sites for an offsite regional processing project.
3. Issue a Request for Proposal (RFP) to solids processing service providers with regional partners. If no offsite location has been identified, require proposer to secure the site. Develop RFP based on service provider feedback from this project (e.g. recommendations for delivery method, governance structure, and contracting methods) and use evaluation criteria from this project to score proposals.
4. Implement most cost-effective solids processing option (either onsite thermal drying, highest-scoring offsite service provider, or continued dewatered solids management contract). Continue to monitor final product management costs and development of pyrolysis technology for potential future pyrolysis integration with a dryer project.

Section 1

Introduction

Concerns over per- and polyfluoroalkyl substances (PFAS) in wastewater residuals, or solids, prompted legislative action to prohibit land application of treated wastewater solids (biosolids) and products containing biosolids in Maine (LD 1911 [An Act to Prohibit the Contamination of Clean Soils with So-Called Forever Chemicals]). The Governor signed this bill in April 2022, and it is currently in effect as Public Law 2021 Chapter 641. This law leaves Maine wastewater utilities with landfill as the only option for solids management within the state—and few, costly options outside the state.

Instate wastewater solids landfilling became more challenging with the passing of solid waste bill, LD 1639 (An Act To Protect the Health and Welfare of Maine Communities and Reduce Harmful Solid Waste) in April 2022, and enacted February 1, 2023. This bill restricts the importation of out-of-state solid waste for processing in the state of Maine. Dewatered wastewater solids cake is considered a “wet waste” by landfill operators and is typically mixed with bulking agents at landfills to avoid stability issues. Out-of-state solid waste (e.g., oversized bulky waste and construction and demolition debris) was one of the main sources of bulking agents for stabilizing wastewater solids. When the availability of these bulking agents decreased, the landfill operators handling most of the biosolids disposal in the state reported they needed to consequently reduce the amount of wastewater solids they accept. This left many utilities scrambling for alternatives, including costly long-distance hauling to Canada. Despite a two-year reprieve to LD 1639 (via LD 718, An Act to Facilitate the Management of Wastewater Treatment Plant Sludge at the State-owned Juniper Ridge Landfill), wastewater utilities in Maine, including Portland Water District (PWD), are still restricted to landfilling instate in the short-term, and following the two-year reprieve will face severe challenges in the long-term.

In April 2022, PWD engaged Brown and Caldwell (BC) to develop a Biosolids Master Plan to identify alternatives for solids processing and management to address the regional management challenges and meet PWD’s long-term goals and objectives. These goals were summarized in the following vision statement for the Biosolids Master Plan (BMP) (Brown and Caldwell, 2023):

> *“To create a 20-year sustainable and adaptable biosolids management plan inclusive of near- and long-term improvements that will mitigate emerging contaminants risk, while improving reliability and regulatory resiliency. A successful outcome will increase public confidence in PWD’s environmental stewardship as one of New England’s leading utilities at the forefront of emerging contaminants mitigation and successful management of biosolids for the future.”*

This vision statement was used throughout the BMP to guide development and assessment of alternatives. Alternatives were developed to evaluate adoption of solids treatment technologies such as anaerobic digestion, drying, and high temperature thermal processing. The BMP identified several benefits of adopting these technologies, but also found that PWD’s options for locating these technologies onsite at their wastewater treatment facilities (WWTF) were limited due to footprint constraints. In May 2023, PWD reengaged BC to evaluate adoption of these technologies at an offsite location, potentially with regional partners, to reduce the burden of their installation at the existing WWTFs and realize economies of scale.

The purpose of this report is to summarize and describe the methodology BC employed, as well as the economic and noneconomic findings, from the evaluation of a regional, offsite biosolids processing facility. Ultimately, the goal is to characterize the economic viability and noneconomic attributes to assist PWD in determining a path forward to manage their biosolids in alignment with their vision statement.

1.1 Project Approach

This project was completed to define the technical, economic, and programmatic considerations for implementing a regional anaerobic digestion, drying, and thermal treatment biosolids processing facility. These technologies were selected for consideration for their following attributes:

- **Anaerobic Digestion.** Anaerobic digestion biologically degrades solids, reducing their mass by 40-50 percent and generating energy-rich biogas. Anaerobic digestion can process a wide variety of liquid organic wastes, including food and beverage processing wastes and fats, oils, and grease (FOG) waste. Anaerobic digestion and biogas utilization offer substantial opportunities for greenhouse gas (GHG) reduction at a WWTF and for the region when processing imported organic waste. Anaerobic digestion can also treat solids to United States Environmental Protection Agency (USEPA) requirements for Class B or A stabilization and improves downstream processing by improving and homogenizing solids quantities and quality.
- **Thermal Drying.** Thermal drying removes nearly all the entrained water in dewatered solids, reducing solids mass by 4 to 5 times. This reduces the amount of solids needing to be hauled and can remedy capacity and structural limitations associated with landfilling of dewatered solids. Thermal drying can also meet USEPA Class A stabilization requirements, which provides nearly unrestricted beneficial reuse opportunities in other states.
- **High Temperature Thermal Processing.** Thermal processing submits solids to high temperatures (600° to 900°C) for further mass reduction and treatment of emerging contaminants such as PFAS. This has traditionally been performed by sewage sludge incineration (SSI), which oxidizes all solids to an ash. However, SSI air permitting regulations have become especially onerous and make SSI adoption in New England unlikely today. Pyrolysis and gasification are emerging, non-incineration thermal processes that employ high temperatures at oxygen free or starved conditions to generate a carbon-dense beneficial reuse product called biochar and a gas stream with an appreciable energy value. The technology is still in a developmental stage with one commercial biosolids pyrolysis facility in operation in the US at Silicon Valley, CA. In 2020, the USEPA found the Silicon Valley pyrolysis system removed PFAS from biochar to below reportable levels (Thoma et al., 2021). BC, with Silicon Valley Clean Water and the Water Environment Federation (WEF) are scheduled to perform a PFAS air emissions test early 2024 to evaluate PFAS destruction in the gas phase. The Silicon Valley pyrolysis system uses a thermal oxidizer for emissions control and heat recovery and previous work by the USEPA demonstrated thermal oxidation as suitable for designation as a Best Available Control Technology (BACT) for PFAS and capable of meeting permitted PFAS destruction criteria (Barr, 2022; Beahm, 2019; Focus Environmental Inc., 2020). While pyrolysis and gasification require solids be dewatered and dried for processing, a new class of thermal processes is also emerging called hydrothermal treatment, that treat solids in a liquid, slurry form at high temperatures. Super critical water oxidation (SCWO) is one example where all organics (including organoflourines such as PFAS) are intended for oxidation within a flow-through reactor. Hydrothermal carbonization (HTC) and hydrothermal liquefaction (HTL) use heat without an oxidant to refine the solids into solid and liquid biofuels, respectively.

The BC and PWD team completed the following outreach and assessment tasks to identify and compare current market offerings for the solids processing technologies mentioned above. The investigation included assessment of commercially available equipment and overall project delivery and operation under the following tasks.

- **Request for Information (RFI)**: BC developed and issued an RFI digestion, drying, and thermal processing system suppliers. The goal of issuing this RFI was to identify interested technology and/or solution providers and to compare current commercial offerings based on lifecycle cost and key non-economic criteria.
- **Technology Summit**: Responders to the RFI could participate in a two-day in-person and virtual technology summit, in which each participant had 20 minutes to present information about their technology. These presentations were recorded and are available on the PWD website.
- **RFI Submission Review**: Each submission was evaluated based upon set criteria, established in the RFI document.
- **Alternative Evaluation**: Based on the top three ranked system supplier offerings/technologies, facility concept level designs were developed for a business case evaluation (BCE).
- **Recommendations**: The RFI submissions and BCEs enabled the PWD and BC team to identify a potential phased path forward for PWD.

Section 2

RFI Process and Findings

On June 28, 2023, BC issued the RFI to over fifty companies to solicit information on current market offerings to process PWD solids and address market and regulatory issues and meet PWD's overall goals and objectives. Companies contacted included both technology manufacturers and service providers (companies proving additional services such as facility financing, construction and/or operations). Addenda to clarify information in the RFI and to answer questions submitted to PWD were released on July 31, 2023 and August 4, 2023. Technology and service providers who responded to the RFI (Responders) were encouraged to provide all available information to inform the next phase of this project which may include development of a Request for Proposal (RFP) to procure solids management technology(ies) or services. The detailed information requested if outlined in Appendix A. The 29 submissions to the RFI (Responses) were assessed and are summarized in the following sections.

2.1 Overview of RFI Process and Key Criteria

Responders were invited to submit proposed approaches for solids processing and handling to be assessed as under the evaluation criteria defined in the RFI. In the invitation, Responders were encouraged to submit technical approaches for both solutions treating only PWD solids and/or for an offsite, regional solution to provide a basis for comparison to evaluate potential economics of scale under the regional scenario. The RFI focused on deployment of anaerobic digestion, drying and thermal treatment for the attributes they provide, as discussed in Section 1.

Guidance regarding PWD goals and objectives for these technologies were also included in the RFI. The following information was requested for each technology or service submission:

- Types, cost, and development status of processing technology.
- Available data for PFAS fate and destruction through the proposed technology for solid, liquid, and gaseous phases.
- Types of end products generated to meet landfill requirements or the marketability or commercial viability for beneficial use solutions.
- Recommended project delivery structure or business arrangement to implement technologies.

Following the release of the RFI, Responders were given six weeks to submit a response. During that time, Responders were also given the opportunity to participate in a Technology Summit in which a broad audience was invited (in person and virtually) to learn more about the technologies included.

Once written responses were received, they were reviewed and ranked based on the pre-determined evaluation criteria. The six criteria were as follows:

1. Team structure, business approach, and financial information (20 points) – This criterion included a conceptual overview of a proposed team structure, whether the proposal would be a stand-alone solution or a portion of one, qualifications for the services, financial backing, and coordination and communication plan.
2. Proposed technical approach (20 points) – This criterion included a description of the main processing technology and its compatibility with PWD's overall treatment goals, details on PFAS

destruction mechanisms, and characteristics about the end products resultant from the technology, including market compatibility.

3. Lifecycle costs (20 points) – This criterion requested 10-year lifecycle costs (capital equipment costs, annual costs, and revenue factors) for two separate scenarios: (1) PWD-only facility and (2) a regional solids handling facility.
4. PFAS control (20 points) – This criterion addressed PFAS testing for technologies with purported PFAS destruction, including the ability to collect PFAS data or existing PFAS concentration and destruction data.
5. Availability of service delivery (5 points) – This criterion included details about site acquisition, regulatory permitting, and marketing and distribution plans for end products.
6. Contractual arrangements (5 points) – This criterion requested contract expectations and preferences between a PWD-specific facility or a regional solution.

PWD received 29 Responses to the RFI. Responders were grouped into two primary categories to define which Responses were based on demonstrated, or mature technologies with two or more installations at a WWTF and emerging technologies that proposed technologies still in a developmental stage. Responders were further organized on whether their response was limited to technology sales or included a broader service offering as defined above, or both (hybrid). The Responders and technologies included in their response are presented in the following table.

Table 2-1. Responders, Technologies, and Categorization

	Established Technologies	Emerging Technologies
Technology Supplier	Huber (Dryer) Komline-Sanderson (Dryer) LCI Corp. (Dryer) Ovivo (Digestion) PWTech (Dewatering, Dryer) Schwing Bioset (Cake Receiving, Storage) SEVAR (Dryer)	374Water (Supercritical Water Oxidation) BCR and IQ (Dryer, Gasification) C-Green (Hydrothermal Carbonization) C-Level (Electro-coagulation, Dryer) EcoRemedy (Dryer, Gasification)
Hybrid	Anaergia (Digestion, Dryer, Pyrolysis) Cambi (Digestion) Lystek (Digestion) Veolia (Dryer, Incineration)	Aries Clean Technology (Dryer, Gasification) CTEC (Dryer, Gasification) Griffin Residuals (Dryer) Heartland (Dryer, Gasification)
Service Provider	EQ Renewables (Digestion, Drying) Johnson Controls (Aerobic Digestion) NORESCO (Not Provided) Synagro (Drying, Pyrolysis) Viridi (Digestion, Drying)	Peaks Renewable (Digestion, Drying) Stircor (Drying, Gasification) Maine Biofuels (Digestion, Drying, Pyrolysis) Waste Management (Drying)

2.2 Selection of Response for Further Study

Responses were evaluated based upon their ability to specifically address the information requests detailed in the RFI's six criteria. Responses providing greater levels of detail, demonstrating greater amounts of experience, and illustrating an advanced technology readiness level were given higher scores. Final scores for all Responses are presented in Appendix B. As defined in Section 1, this project was completed to assess three alternatives for solids processing under two scenarios: PWD solids only and regional solids processing. Consequently, the highest scoring responses that made up six total alternatives were selected for more detailed assessment under this project, These Responses and their scoring are presented in Table 2-2. Note that high temperature processes were included in only two of the highest scoring Responses. While high temperature processes stand to offer value in addressing regional solids management challenges, their inclusion was limited in the Responses due to their lack of full-scale operational data to support a detailed lifecycle cost projection, or assessment of their reliability. Consequently, these technologies may be better assessed through future pilots or targeted deployment where their operational parameters and reliability can be monitored to support their maturation.

Table 2-2. Scores for Highest Ranked Responders

Responder	Team Structure, Business Approach, and Financial Information	Technical Approach	Life Cycle Costs[a]	PFAS Data Capabilities	Availability of Service Delivery	Contractual Arrangement	Maximum Potential Score	Score (%)
Max Points Available	20	20	20	20	5	5	90	--
Veolia	20	20	20	20	5	5	90	100%
LCI Corp	15/15[b]	20	20	10	NA[b]	5	70	100%
Cambi	20	20	18	10/10[b]	5	5	80	98%
Synagro	19	18	19	20	5	5	90	96%
Huber	15/15[b]	17	20	8	NA[b]	5	70	93%
Lystek	16	20	20	18	4	5	90	92%

a. *Refer to proposals for life cycle cost breakdowns.*

b. *Point totals were adjusted if responses were from technology suppliers or if the technology was not designed for PFAS destruction. For Technology Suppliers, the "Team Structure" category was worth 15 points, and the "Service Delivery" category was removed. If a particular technology was not intended for PFAS destruction, the "PFAS Data" category was worth 10 points.*

2.3 Considering Additional Technologies and Offerings

As discussed above, this report focuses on documenting the detailed evaluation of six solids processing alternatives developed from a select subset of Responses. However, there were Responses that were not selected for alternatives analysis but were still found to be of value to PWD and could support PWD's solids management strategy. This subsection provides an overview of benefits from several Responses not selected for detailed evaluation.

Regional Service Provider Responses. Three Responses were provided from service providers seeking to lead development of a regional processing facility in Maine. Two responses were highly conceptual in nature: (1) the Viridi Response that described goals for implementing a project at the old Brunswick digester facility and (2) the Peaks Renewable Response that described a potential project in partnership with the Anson-Madison WWTF. These two Responses could offer value in their proximity to PWD but did not provide sufficient details to identify the current level of project definition or timeline. Waste Management (WM) provided a third Response for an offsite regional project at the Norridgewock landfill and has since reported their project has completed 30 percent design and has been submitted for permitting, with commissioning targeted 18 months after receiving the permit.

WM's technical and financial capabilities, progress to date, and asset of the existing landfill site likely represent a workable solution. WM's technical approach for the facility is to use a thermal dryer manufactured by a company with limited successful runtime in the US and without anaerobic digestion. However, WM reports having done a thorough due diligence on the dryer technology, that the manufacturer has addressed historical operating challenges, and that WM would be willing to discuss the technical approach in more detail as necessary,

Solids Drying and Pyrolysis or Gasification Only Responses. Several responders (Anaergia, Aries, CTEC, Ecoremedy and Heartland) and other companies that did not submit a response (e.g., Earthcare and Northeastern Biochar) are currently advancing projects in the United States to dry solids without anaerobic digestion and further process the dried product with pyrolysis or gasification. Forgoing anaerobic digestion reduces capital outlay and increases the carbon content of the solid product, biochar, which may increase its market value. However, undigested solids, especially primary sludge, are difficult to handle and dry and have led to substantial operational issues at several facilities. Additionally, wastewater solids pyrolysis and gasification are operationally complex, generate difficult to handle gaseous products, and have not yet been proven at scale. This solids processing strategy offers the potential to process solids at a reduced cost and provide destruction of contaminants due to high operating temperatures. However, the technology would have to be proven at full scale before it could be considered a demonstrated option. Additionally, utilities that have sought to pilot the technologies to advance their development process have found it difficult because they are large and complex with limited mobile commercial offerings and require an upfront dryer. Consequently, it is unlikely that individual utilities alone would be able to develop their own pyrolysis facility, but an offsite regional processing facility could provide a testing ground with an appropriately configured dryer system. In addition, if PWD is still seeking a solids management solution after the companies offering these technologies have operational reference facilities, these reference facilities could be assessed for potential applicability for a technical approach for regional processing in Maine.

Hydrothermal Treatment Responses. Two responders (374Water and C-Green) and other companies that did not submit a response (e.g., SoMax, Genifuel, Beyond the Dome, and General Atomics) are currently advancing hydrothermal treatment technologies that submit slurried wastewater solids to high temperatures to generate liquid or solid biofuels, or in the case of 374Water, to fully oxidize all organic content to generate useful heat. These technologies, including supercritical water oxidation (SCWO) and HTC, have the potential to generate an alternative product or recoverable energy in a single unit process. This could meet PWD's goals for sustainability and emerging contaminant management while simplifying the scope of the processing system and reducing capital outlay. PWD may wish to investigate opportunities to advance these emerging technologies and evaluate their applicability to PWD's solids management needs. Both 374Water and C-Green identified opportunities for piloting their technologies, 374Water at a demonstration scale (6 wet tons per day) and C-Green at a commercial scale (80 wet tons per day). Since these options are more readily available for piloting and do not require an upfront dryer, they are likely more readily available for piloting as a standalone unit process or as a supplement to the technologies considered here within an offsite regional facility.

2.3.1 Potential Piloting Strategies for Emerging Treatment Technologies

As discussed above, several emerging technologies were identified through the RFI process that, if proven operationally successful, would provide treatment of PFAS-laden solids, and enhance mass reduction and energy recovery in a solids processing facility. Consequently, PWD may wish to further assess these technologies through onsite, demonstration or commercial scale pilots. Piloting with PWD and/or regional solids feedstocks provides an opportunity to demonstrate a technology's operational reliability at a continuous, realistic loading while PWD and potential regional partners gain familiarity with the technology. However, piloting carries additional cost and potentially schedule burdens, as well as project risks if the technology is not proven out. BC recommends considering piloting opportunities under three, high-level strategies to first consider how their value relates to PWD's goals for project schedule and cost.

1. Advance Core Project and Later Consider Pilot. This category advances a core project using demonstrated technologies and later considers adding an emerging technology pilot once the core processing facility is built. This delays the pilot but provides PWD an opportunity to re-assess the solids management market and regulatory environment before implementing the pilot. One example would be building a digestion and drying facility and once commissioned, re-assess whether piloting pyrolysis for treatment of the dried solids is worth pursuing.

2. Advance Pilot and Later Consider Core Project. If PWD has a greater sense of urgency to deploy technologies for PFAS treatment, PWD could prioritize implementation of a thermal processing pilot facility first, and then scale the technology up if successful. One example would be an onsite demonstration of SCWO or HTC at East End with minor infrastructure upgrades to feed the pilot dewatered solids, collect and treat the return stream, and haul the final product. Several hydrothermal pilot units are commercially available or in development (from 6 to 80 wet ton/day capacity) and a larger scale unit, if selected for piloting and proven successful, may be able to transition to a permanent installation to process all PWD's solids.

3. Advance Core Project and Pilot in Parallel, Complementary Path. This category would advance a full-scale, solids processing facility with both demonstrated technologies and pilot deployment of an emerging technology. These two elements would be coordinated so that the technologies selected are complementary. For example, a digestion and drying facility could be installed with a pyrolysis facility configured to process the dried solids and recirculate useful heat to the dryer. Alternatively, a smaller scale dryer facility (in terms of capacity or redundancy) could be provided with a SCWO or HTC system to process a separate stream of dewatered solids in parallel.

Example pilot project timelines and their corresponding decision points for the piloting strategies are provided below in Table 2-3. As discussed above, pyrolysis and gasification pilots would require construction of an upfront drying facility and would require advancement under the first or third strategy for inclusion of the dryer facility.

Table 2-3. Piloting Strategies and Example Timelines

<table>
<tr><th>Strategy</th><th>0-1.5 Years</th><th><u>Decision</u></th><th>1.5-3 Years</th><th><u>Decision</u></th><th>3-4.5 Years</th><th><u>Decision</u></th></tr>
<tr><td>1</td><td colspan="3">Design and Build Core Facility</td><td>Reconsider Pilot</td><td>Deploy Pilot If Warranted</td><td>Assess Pilot Findings if Deployed</td></tr>
<tr><td rowspan="2">2</td><td rowspan="2">Deploy Onsite Pilot</td><td rowspan="2">Assess Pilot Findings</td><td colspan="4">(If Successful) Build New Facility or Transition to Permanent Install</td></tr>
<tr><td>(If Unsuccessful) Pilot New Technology</td><td>Assess Pilot Findings</td><td>(If Successful) Build Permanent
(If Unsuccessful) Pilot New</td><td>Assess Pilot Findings if Deployed</td></tr>
<tr><td>3</td><td colspan="4">Design and Build Core Facility and Pilot Facility</td><td>Operate Pilot</td><td>Assess Pilot Findings</td></tr>
</table>

Section 3

Alternatives Evaluations

This section provides an overview of the alternatives established and compared for this project to provide PWD with an overview of the processing equipment, facility layout and utility consumption needs for biosolids processing at an offsite regional facility, and as compared to onsite processing facilities. Alternatives were developed by incorporating the highest scoring RFI responses into a concept level design and lifecycle costing for solids processing and final disposition. Capital and annual operating costs were developed for the alternatives and the findings were compared to evaluate both economic viability and noneconomic benefits and risks.

3.1 Alternatives Development

Anaerobic digestion and thermal drying were established as the core processing steps for each alternative as described above. Biosolids drying, specifically, reduces the mass of solids needing to be managed, can overcome structural limitations with landfilling dewatered solids, can support beneficial reuse out of state, or feed downstream high temperature processes such as pyrolysis and gasification. Alternatives were developed under the two primary groupings.

Onsite PWD-Only. Three alternatives were developed to evaluate installation of biosolids processing systems at the East End WWTF (East End), which includes solids from the other three PWD WWTFs Cape Elizabeth, Peaks Island, and Westbrook-Gorham (Westbrook), sized to handle PWD's solids only. These alternatives were developed based on the most promising concepts identified in the Biosolids Master Plan and with updated pricing and layout information from the RFI responses. These alternatives assumed continued dewatering at Westbrook and cake transfer to East End for co-processing.

Offsite Regional. Three alternatives were developed for receipt and processing of dewatered solids generated by PWD, other regional WWTFs, and other regional organic wastes such as food production waste and FOG. It was assumed that a suitable location (footprint, utilities, and community support) would be available for the facility. The Offsite Regional Alternatives also included cake reliquification and anaerobic digestion for further mass reduction, generation of a renewable fuel in biogas, and improvement of the solids quality to support beneficial reuse opportunities out of state.

3.1.1 Onsite PWD-Only Alternatives

Primary Sludge Mesophilic Anaerobic Digestion and Belt Drying. This alternative installs a new anaerobic digestion facility to process primary sludge from East End and a belt dryer to dry the combined digested sludge with the undigested waste activated sludge (WAS) from the plant. Undigested primary sludge is problematic in dryers as its parameters can fluctuate widely with changing influent loads and it is generally stickier, more odorous, and has higher levels of grit, fiber, and debris. Primary sludge is also more digestible and can be fed to digestion at relatively high loading rates. Consequently, installation of a primary sludge only digestion facility provides a means to achieve many of the benefits of anaerobic digestion while limiting capital and maintenance costs. A belt dryer was selected for this alternative to generate a dried, Class A product. Belt dryers have a larger footprint requirement compared to other dryer types but require the least amount of operations and maintenance attention and generate a dried granule with relatively low levels of dust. A new dewatering and drying facility was included in this alternative to co-locate dewatering centrifuges and solids drying to optimize solids handling and operations. A cake receiving, holding, and pumping facility is included to receive and co-feed Westbrook solids to the dryer based on the Schwing RFI response. Figure 3-1 is a sketch of the primary sludge mesophilic digestion and belt drying alternative.

- Benefits. Uses widely adopted technologies, belt dryers available at operating temperatures below dust ignition point, relatively low operating and maintenance demands, proven out of state market interest in dried granule, co-locates cake transfer and drying, provides opportunity to generate renewable process heat from biogas with relatively simple hot water boilers.
- Drawbacks. Limited space on site complicates construction and post-commissioning truck traffic.

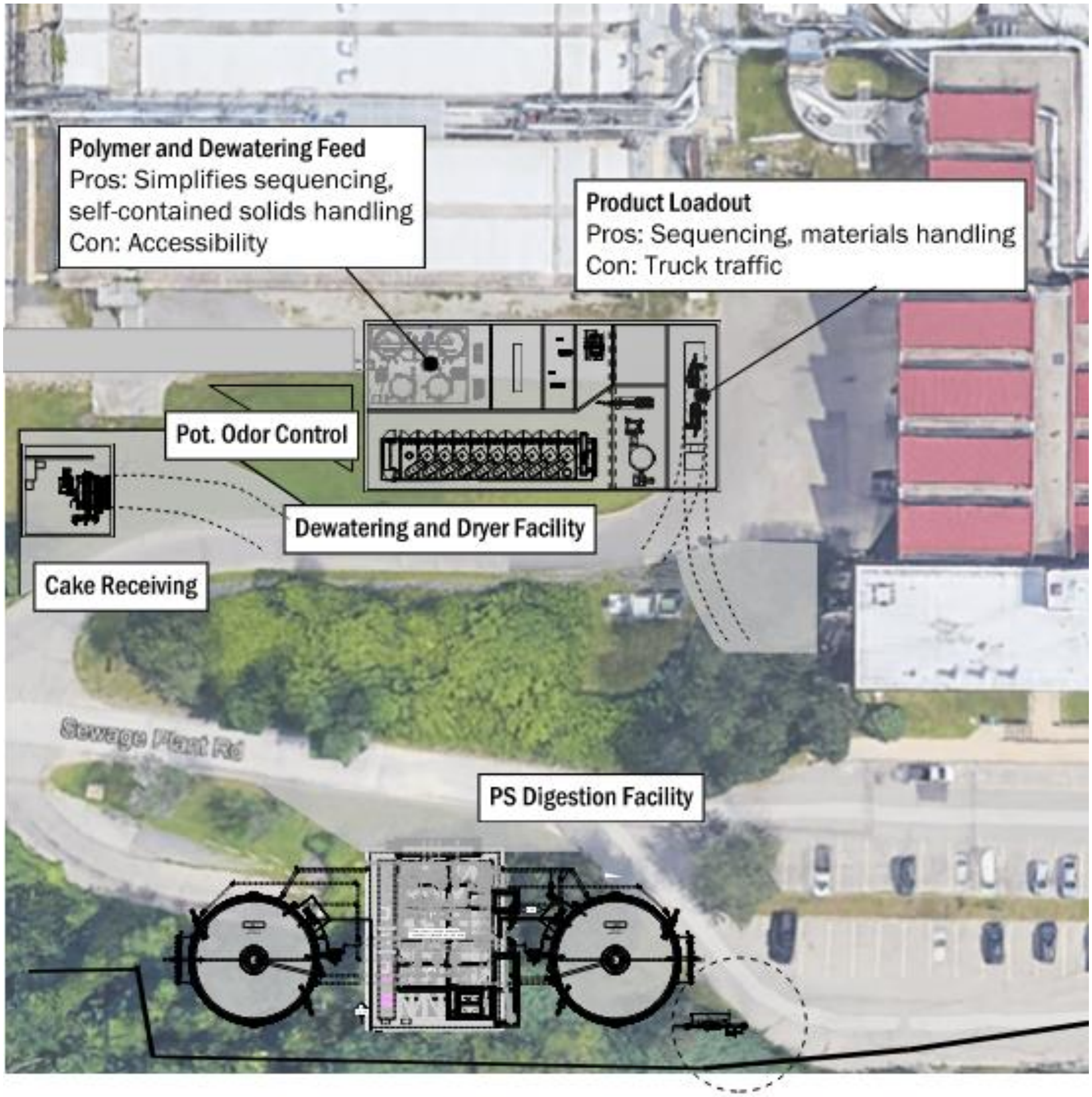

Figure 3-1. Primary sludge mesophilic anaerobic digestion and belt drying at East End concept sketch

Thin Film Drying. This alternative installs a thin film dryer facility and was the one alternative developed without upstream anaerobic digestion. Thin film dryers are commonly used overseas for partial drying of undigested sludges and consequently could provide an appropriate solution to evaluate a drying-only flow scheme. Thin film dryers employ a high-torque rotating shaft to force solids along a heated jacket reactor and the mechanical force makes the system less vulnerable to operating challenges from the undigested primary sludge. However, the high odors and debris from undigested sludge limits the potential market reach of the dried product and it was assumed product generated from this facility would have to be landfilled. A cake receiving, holding, and pumping facility is included to receive and co-feed Westbrook solids to the dryer. A separate cake silo was included to store East End dewatered solids to allow for continued dewatering at a limited operating schedule from the current configuration while feeding to the dryer at a lower, continuous rate. However, the silo could be removed if dewatering was operated on a continuous basis. Figure 3-2 is the potential layout of the thin film drying concept at East End.

- Benefits. Less equipment to operate and maintain, smaller footprint of new facility.
- Drawbacks. Only one other thin film dryer in United States, poor product quality that likely requires landfilling, high odor, limited to no opportunities for energy recovery.

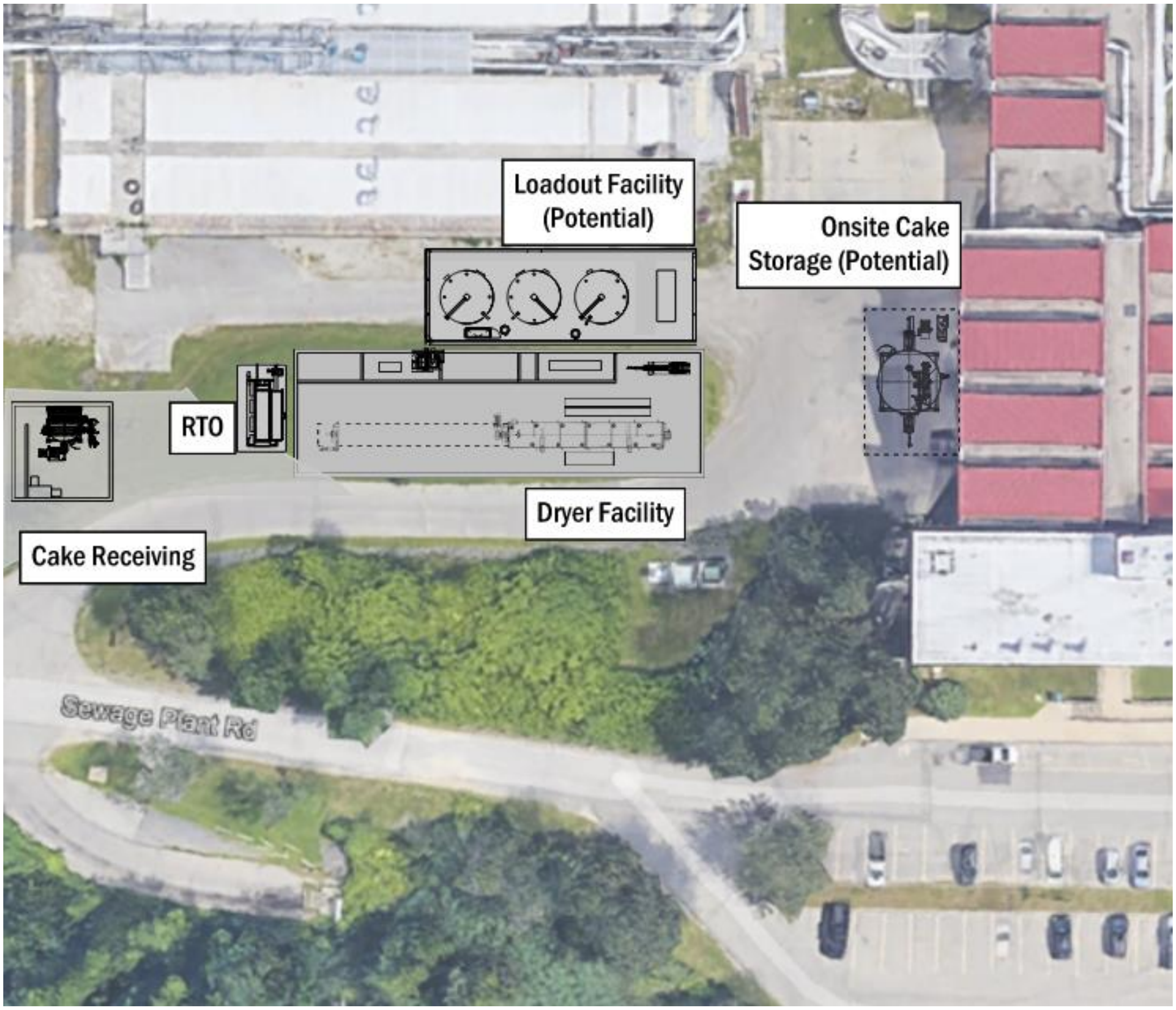

Figure 3-2. Thin film drying at East End concept sketch

Belt Dryer and Furnace. This alternative includes installation of a combined belt dryer and dried product furnace system. This alternative follows Veolia's RFI response and represents an opportunity for further mass reduction from dried product to ash. The dried pellet furnace operates similar to an incinerator in that it combusts all organic content via application of heat and excess oxygen. The product furnace employs similar air pollution control equipment to an incinerator to meet SSI air regulations and includes a heat recovery economizer to transfer heat to the belt dryer via thermal oil. Veolia did not submit PFAS emissions data, but the high temperatures likely offer an opportunity for

PFAS destruction or transformation. However, the alternative is the most highly complex of the onsite alternatives and has a large footprint requirement. Veolia did include a discussion on the potential application of primary sludge digestion to improve the dryer quality but did not provide details on the scope of the recommended digestion project or adjustments to the dryer equipment sizing. Consequently, this alternative was developed assuming undigested sludge feed to the system and that specialized staffing, likely through contract operations, would be required to manage operational complexities. The belt dryer and furnace concept at East End are shown in Figure 3-3.

- Benefits. Further mass reduction to ash, high temperature processing for potential PFAS destruction, energy recovery to drying.
- Drawbacks. Large amount of complex equipment, high operational complexity, likely operational challenges with drying undigested sludge, no PFAS emissions data available.

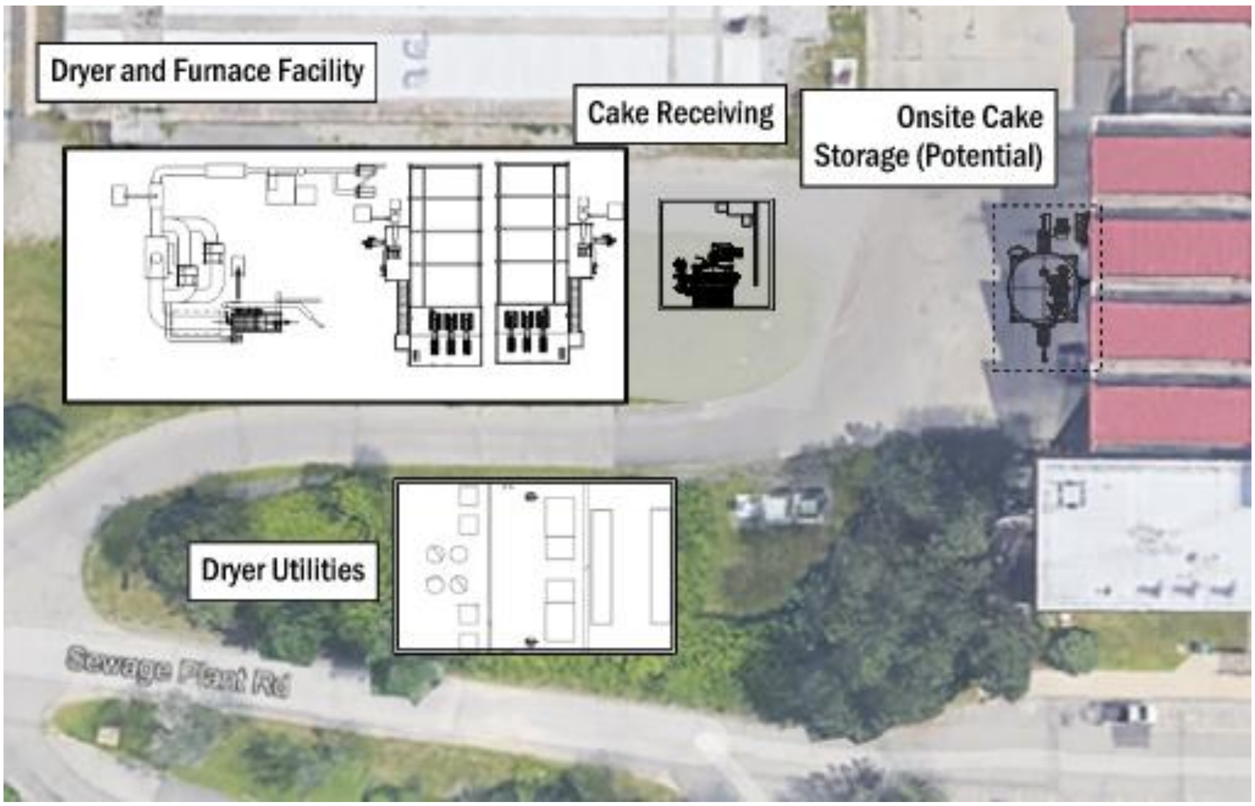

Figure 3-3. Belt dryer and furnace at East End concept sketch

3.1.2 Offsite Regional Alternatives

Thermal Hydrolysis, Digestion and Thin Film Drying. This alternative treats regional dewatered solids via thermal hydrolysis process (THP) prior to anaerobic digestion and drying and is based on the RFI response from Cambi. A cake receiving, holding, and pumping facility is included to receive and transfer solids to THP based on the Schwing RFI response. THP disintegrates solids, rendering them flowable for anaerobic digestion and more readily digestible, and submits solids to high temperatures meeting USEPA Class A requirements. This allows for digester loading at higher rates and with smaller tankage. The process is complex and requires medium pressure steam boilers with specialized operator licensing, steam process vessels, and a cooling loop prior to digestion. However, it has served as a common solution for regionalized facilities in Western Europe and is noteworthy for its ability to reliably receive and process cake from different sources. Following digestion this alternative includes a secondary dewatering step and thermal drying via the thin film dryer. Rotary drum dryers are more commonly employed for drying facilities at this larger scale in the US, however THP solids are more friable and prone to generating dust within drum dryers. Thin film dryers require less dried product handling and have been demonstrated with THP solids in Gifhorn, Germany. The requirement to reliquefy dewatered solids and then dewater them again in a secondary step after digestion does add a sizeable increase in complexity and additional processing equipment compared to the onsite PWD-only alternatives. Figure 3-4 illustrates the THP regional conceptual design.

- Benefits. Demonstrated technology for reliquefying solids, reduces scope of digestion facility, Class A digestion product.
- Drawbacks. Large amount of processes to maintain, medium pressure stream with operator licensing requirements, characteristics of THP solids limit available dryer technology.

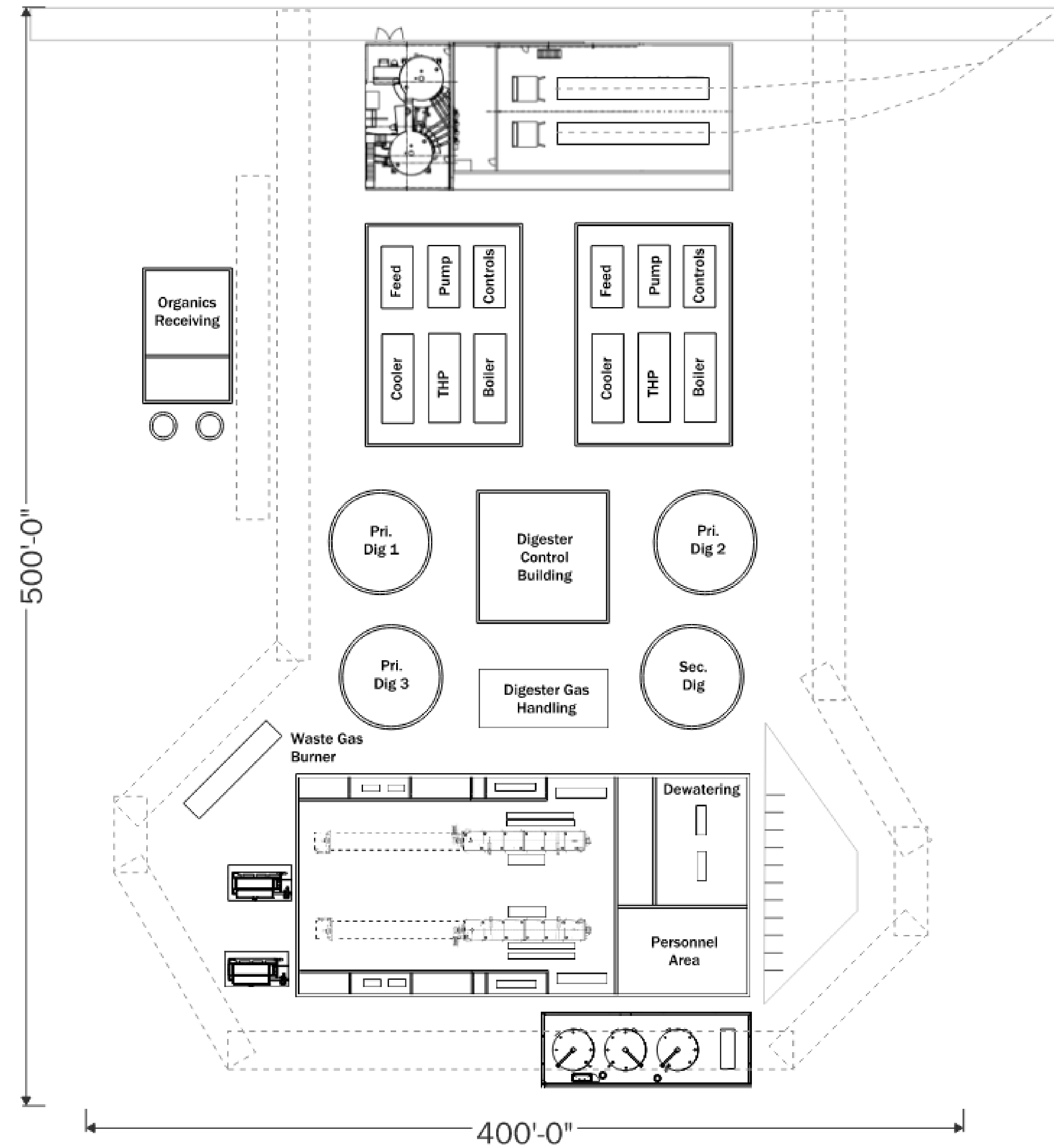

Figure 3-4. THP, digestion and thin film drying concept sketch

<u>Thermal Chemical Hydrolysis, Digestion and Thin Film Drying.</u> This alternative includes a thermal chemical hydrolysis process step (TCHP) ahead of digestion. The THCP processing step is based on Lystek's RFI response and uses a mixture of higher mechanical shearing, temperature, and alkali chemicals to disintegrate the solids and meet Class A requirements ahead of digestion. The process can use lower pressure steam to eliminate the specialty operator licensing required with THP and is operated at lower temperatures, so a cooling step is likely not necessary. Different alkali chemicals can be used. Sodium hydroxide is the most affordable option and was modelled for this scenario;

however, potassium hydroxide could also be used if it was found to support beneficial reuse market demand. Conversely, calcium hydroxide could also be used if a post-drying high temperature process were added to improve performance. Calcium hydroxide has a high melting point and acts to stabilize solids during high temperature processes, and also treats acid gases generated within the reactor. Lystek is currently being used as a regional solids processing technology at Fairfield, California however the Fairfield facility manages the product in liquid form after TCHP. One downside to this technology is that it does incur a continual chemical demand with corresponding truck traffic and annual costs. Figure 3-5 sketches the TCHP regional conceptual design.

- Benefits. Demonstrated technology for reliquefying solids, reduces scope of digestion facility, Class A digestion product, no special operator licensing
- Drawbacks. Large amount of processes to maintain, TCHP solids limit dryer technology, continual chemical demand

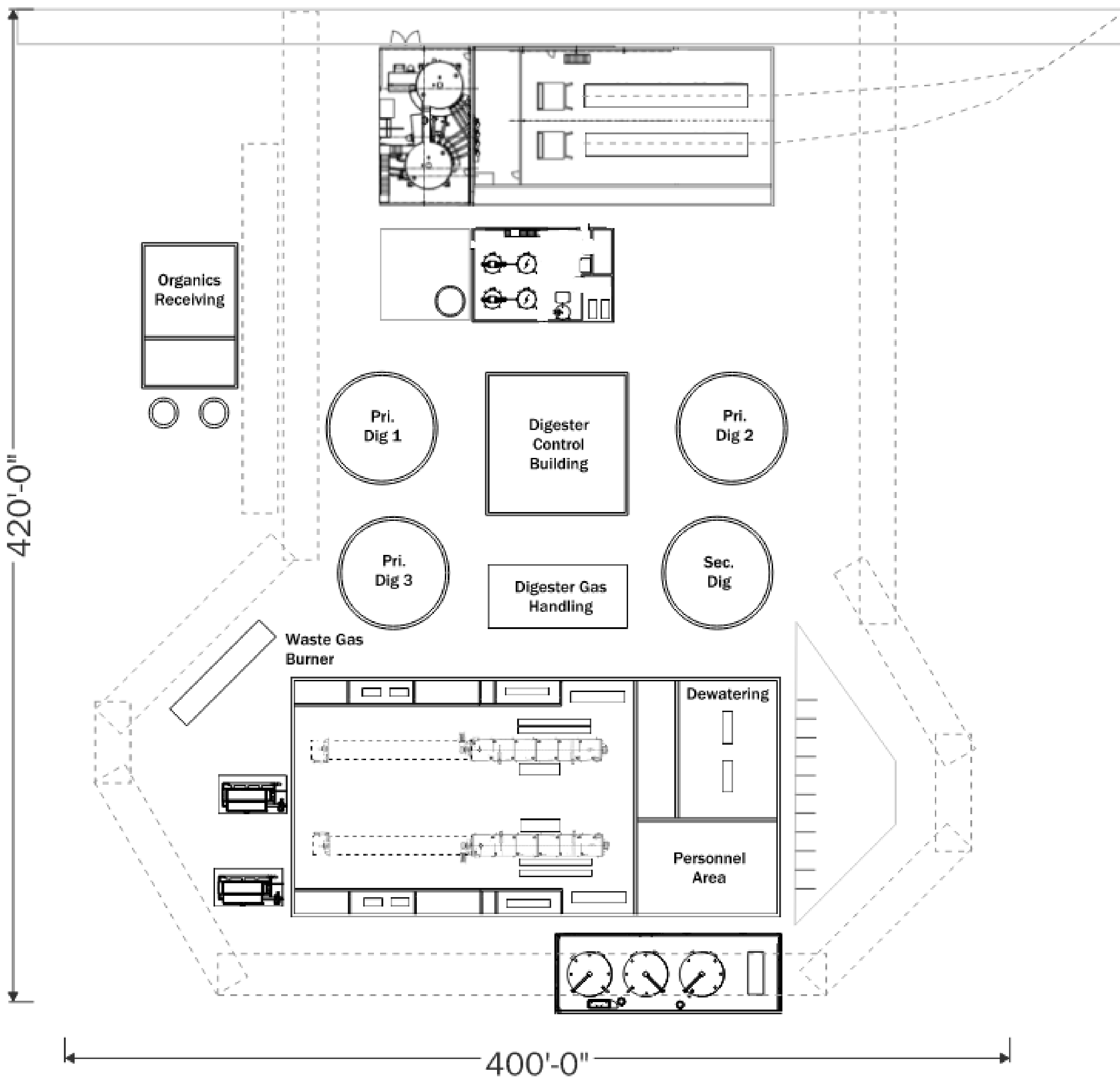

Figure 3-5. TCHP, digestion and thin film drying concept sketch

Digestion, Drum Drying and Pyrolysis. This alternative uses a mechanical slurrying system to reliquefy dewatered solids for conventional anaerobic digestion followed by a secondary dewatering step, rotary drum drying and pyrolysis. This alternative follows the proposed flow scheme from Synagro's RFI response however the technology configuration and sizing was not provided within the response and was developed by BC. Mechanical cake slurrying and reliquification is currently conducted at two regional facilities in Connecticut to support a downstream secondary dewatering step to homogenize load to an incinerator; however, it has not been demonstrated at scale to support digestion. This alternative follows the same technology configuration as the Hartford, CT reliquification facility where dewatered cake and plant effluent are mixed with a high shear propeller in batch tanks, however further investigation would be required to vet the applicability of this system to anaerobic digestion. It was assumed the reliquefied solids would be processed to conventional solids moisture content and rheological parameters ahead of digestion meaning that the digestion tankage required under this scenario is roughly double that of THP or TCHP.

Rotary drum dryers represent the most commonly applied dryer technology for large scale drying facilities. Drum dryers generate a spherical, dense pellet that has potential to access a wide variety of out of state beneficial reuse markets. Drum dryers operate with direct coupled, high temperature furnace and are thermally efficient but complex and involve several operating hazards. Drum dryers employ several specialty subsystems such as dust collection, pneumatic transfer, nitrogen inerting, and product classification and require a large operations and maintenance (O&M) team with specialized knowledge, likely procured through an operations contract. Synagro's RFI response also included application of CHAR Technologies' pyrolysis reactor which consists of an indirectly fired rotary kiln that submits dried solids to high temperatures (approximately 700 deg. C) and an offgas conditioning and combustion unit. Pyrolysis decomposes solids into an energy rich gas stream that can be combusted for heat recovery and a carbon rich end product, biochar. Biochar has soil and nutrient holding capacities with an appreciable phosphorus content and is under investigation for other industrial uses. Pyrolysis has long served as technology of interest for potential destruction of contaminants of emerging concern; however, Synagro did not provide any full scale PFAS data to confirm its destruction within the system. Figure 3-6 illustrates the regional conceptual design with pyrolysis.

- Benefits. Simplest cake reliquification concept, uses widely adopted drying technology with high quality pellet, includes pyrolysis for potential PFAS destruction.
- Drawbacks. Mechanical cake rewetting has yet to be proven for anaerobic digestion, anaerobic digesters are roughly twice as big without THP pretreatment, drum dryers are complex with unique safety hazards, pyrolysis has yet to be proven to be operationally reliable or destroy PFAS at scale.

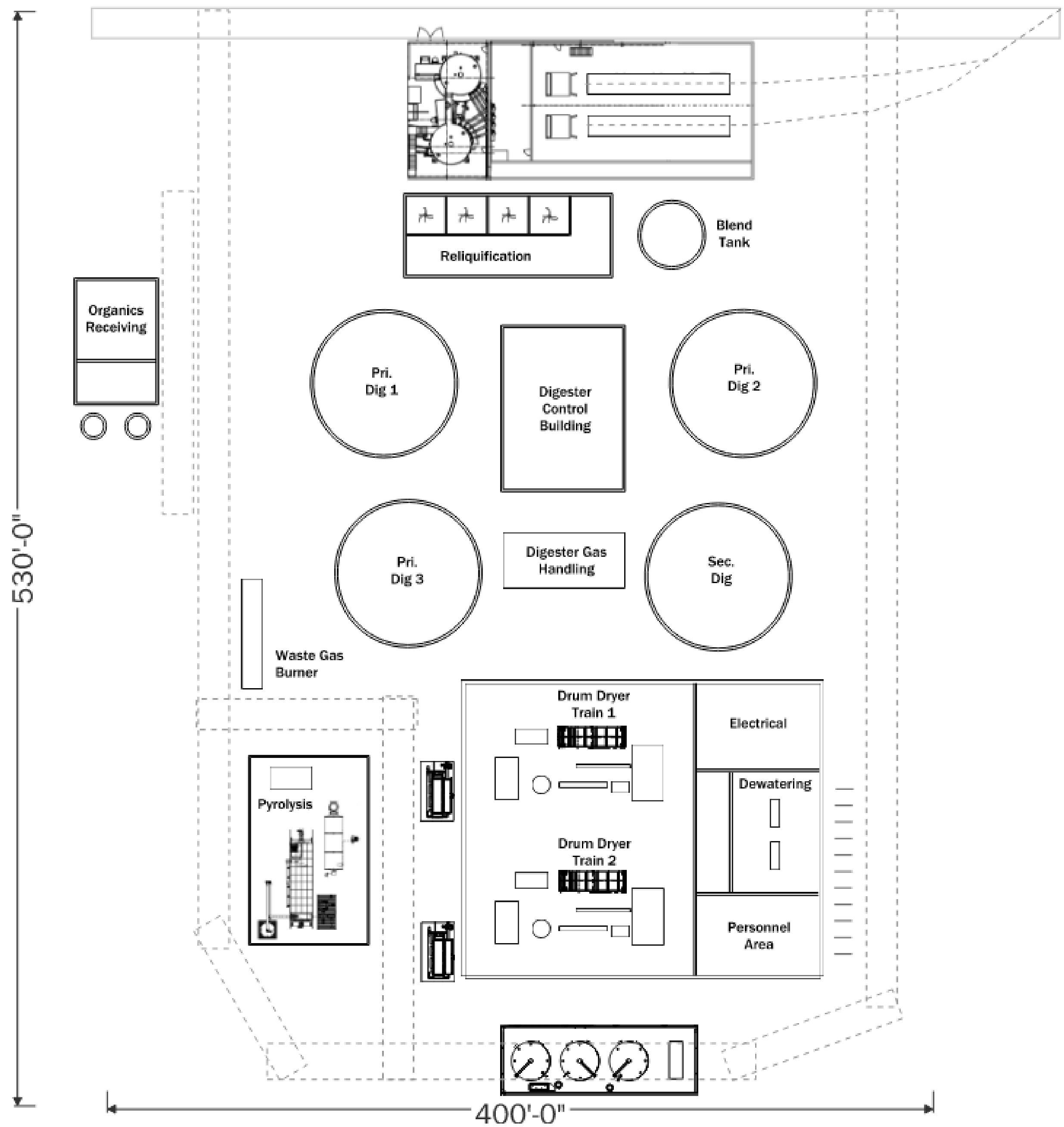

Figure 3-6. Digestion, drum drying and pyrolysis concept sketch

3.2 Business Case Evaluation

As indicated in the RFI, the BCEs were evaluated based on alternatives sized to process the maximum solids production capacity of East End and Westbrook, Table 3-1 summarizes the anticipated solids processed from PWD facilities. The table includes the current percent total solids (TS), hauled cake in wet tons per day (wtpd), and the estimated percent volatile solids (VS) based on similar facilities as PWD does not currently measure VS; therefore, a range of potential VS is provided in the table.

Table 3-1. Anticipated PWD Only Solids Loading		
	East End[a]	Westbrook
Current Solids Loads		
Cake (wtpd)	56	12
Cake solids content (%TS)[b]	20% (20 – 26%)	20% (20 – 26%)
Volatile solids content (%VS)[c]	80% (50 – 85%)	80% (50 – 85%)
Future Solids Loads		
Cake (wtpd)	91	23[d]
Cake solids content (%TS)[b]	20% (20 – 26%)	20% (20-26%)
Volatile solids content (%VS)[c]	80% (50 – 85%)	80% (50 – 85%)

a The solids at East End include the solids hauled from Peaks Island and Cape Elizabeth WWTFs

b Historical %TS from the Fournier presses is 20%. Note the solids content at East End will improve with dewatering upgrades. This is reflected in the range provided.

c The %VS content was used as a conservative assumption based on measured data from similar facilities. A range of potential %VS are included as the value could vary.

d This includes the estimated 2 wtpd at 20% TS from the future North Windham WWTF.

Table 3-2 provides the total assumed solids contribution from regional WWTF partners for the offsite regional alternatives BCE. This assumption is based on BC's experience with solids production in the southern portion of Maine and likely represents the higher side of the range of regional partners that may utilize a regional facility.

Table 3-2. Anticipated Regional Facility Solids Loading		
	PWD	Other Maine Facilities
Hauled Cake		
Cake (wtpd)	114[c]	97
Cake (wtpy)	42,000	35,000
Cake solids content (%TS)[b]	20% (20 – 26%)	21% (17 – 30%)
Volatile solids content (%VS)[a]	80% (50 – 85%)	80% (50 – 85%)

a The %VS content was used as a conservative assumption based on measured data from similar facilities. A range of potential %VS are included as the value could vary.

b Historical %TS from the Fournier presses is 20%. Note the solids content at East End will improve with dewatering upgrades. This is reflected in the range provided.

c This includes the estimated 2 wtpd at 20% TS from the future North Windham WWTF.

3.2.1 Annual costs

All of the alternatives were compared after dewatering to allow for an equitable comparison. To compare operational costs among alternatives, the annual operating costs for each alternative were developed and 20-year life cycle costs were calculated based on facility operation. Table 3-3 provides the unit cost assumptions used for calculation of the BCE and Table 3-4 summarizes the annual operating and maintenance costs at the midpoint of solids loadings projections. The 20-year life cycle costs were determined using the net rate of -2 percent, applying the present given annual

20-year calculation to the mid-year O&M annual costs. A more detailed summary of process and utility consumption parameters for each alternative is included in Appendix C.

Currently, PWD pays approximately, $3,251,000 annually at a rate of $131 per wet ton in hauling and disposal costs to manage their dewatered solids at 20 percent TS, with anticipated future increases based upon current market conditions (e.g., limited landfill capacity within the region). As shown in Table 3-4, PWD's hauling, and disposition significantly decreases with any of the proposed alternatives. Additionally, given the planning level nature of these costs, most of the proposed alternatives have comparable overall annual operational and maintenance costs to PWD's current hauling and disposal costs.

The alternatives presented have potential to reduce annual costs or provide PWD with future flexibility and diversification. For instance, the digestion process generates an energy-rich biogas that can be used to generate electricity or upgraded into renewable natural gas. While both of these utilizations would require additional capital investment, they can produce significant revenue and financial offset that could be beneficial for PWD to evaluate further. Finally, with the regional digestion alternatives and the onsite PS digestion and drying alternative, PWD could generate a high quality biosolids product, increasing the potential to access lower cost, out of state beneficial reuse options. Additionally, diversification would reduce PWD's reliance on landfill disposal, the capacity of which is limited throughout New England and currently poses a risk for PWD and other Maine utilities.

Table 3-3. Economic Unit Costs for Lifecycle Cost Analysis

Cost element	Units	Value in Model	Basis
Solids Handling and Disposition			
Solids management (hauling and tip fee)	$/wet ton	$131	blended rate based on current contract
Biochar management (hauling and tip fee)	$/wet ton	$131	based on rate for landfilling[1]
Hauling transfer fee between facilities	$/wet ton	$15	based on information provided from haulers
Electricity costs (blended rate)	$/kWh	$0.16	historical
Natural gas	$/mmbtu	$12.85	blended rate from Sept -May
Polymer cost	$/lb-polymer	$1.25	historical data
Polymer solution	%	40%	assumed based on typical polymer
Sodium hydroxide (NaOH) – 50% solution	$/lb	$0.69	assumed based on other projects
Biogas value	$/mmbtu	$3	assumed
Regional partner tip fee	$/wet ton	$130	adjustable
Operator/maintenance labor cost	$/hr	$50	loaded rate based on average PWD labor
Nominal discount rate, annual percentage	%	2.2%	based on Office of Management and Budget (OMB) Circular 94 Appendix C
Escalation rate	%	4.2%	based on OMB Cir 94 Appendix C
Net rate	%	-2.0%	Calculated
Present given annual calculation		24.89	

1. *Biochar could potentially be managed at a lower price, depending on the market developed.*

Table 3-4. Annual Operations and Maintenance for Mid-point of Life Cycle Analysis						
	PS MAD + Belt Drying	Thin Film Drying	Belt Dryer + Furnace	Regional: THP+ MAD + Drying	Regional: TCHP+ MAD + Drying	Regional: MAD + Drying + Pyrolysis [1]
Revenue	-$306,000	$0	$0	-$6,657,000	-$6,657,000	-$6,414,000
Electricity	$746,000	$654,000	$982,000	$2,111,000	$2,101,000	$3,812,000
Natural gas	$1,156,000	$1,131,000	$580,000	$1,228,000	$1,178,000	$1,771,000
Chemical	-$144,000[2]	$0	$0	$936,000	$1,269,000	$1,126,000
Operations and licensing fees	$312,000	$520,000	$832,000	$1,352,000	$1,194,000	$1,456,000
Maintenance (labor and parts/R&R)	$256,000	$198,000	$543,000	$1,034,000	$680,000	$1,164,000
PWD hauling (transfer)	$101,000	$101,000	$101,000	$556,000	$556,000	$556,000
Final hauling and landfill	$828,000	$1,024,000	$174,000	$1,155,000	$1,155,000	$561,000
Total	**$2,949,000**	**$3,628,000**	**$3,212,000**	**$1,715,000**	**$1,476,000**	**$4,032,000**
Annual Midpoint Processing Cost ($/wet ton)	**$80**	**$98**	**$87**	**$46**	**$40**	**$109**

1. Biochar was assumed to be manage at PWD's current landfilling rate; however, it could potentially be managed at a lower price, depending on the market developed.
2. The reduction in chemical cost account for the reduction of polymer use for dewatering due to reduced solids from PS MAD.

3.2.2 Capital Costs

Conceptual capital cost estimates developed for the alternatives are presented in Table 3-5 The capital costs are based on Class 5 conceptual cost estimates per the Association for the Advancement of Cost Engineering International (AACEI), which carry a level of accuracy of -50 to +100 percent. Major equipment costs were performed based on vendor budgetary estimates and comparable recent project costs. Note that there has been significant volatility in capital equipment costs in the past three years; the costs in Table 3-6 represent a snapshot in time and are subject to change above and beyond the accuracy ranges built into the Class 5 estimate. Where a vendor budgetary quote was obtained, the equipment cost was multiplied by a sequence of standard cost estimate planning factors to develop an overall estimated project cost. Table 3-6 details the capital cost estimates for the alternatives evaluated.

Table 3-5. General Project Cost Markup	
Component	Markup
Process mechanical equipment installation	20%
Misc. demolition	5%
Electrical, instrumentation & controls	30%
Misc. excavated soil disposal	5%

Table 3-5. General Project Cost Markup	
Component	**Markup**
Startup and construction sequencing	2%
General conditions	15%
Contractor overhead and profit	20%
Sales tax	5.5%
Bonds and insurance	2.5%
Engineering	10%
Construction management	10%
Estimating contingency	30%

Table 3-6. Estimated Capital and Major Equipment Costs for Alternatives in Millions of Dollars		
	Total Capital (-50%/+100%)	**Major Mechanical Equipment**
PS MAD + Belt Drying	$64M ($32M - $128M)	$13M
Thin Film Drying	$57M ($28M - $113M)	$10M
Belt Dryer + Furnace	$136M ($68M - $271M)	$27M
Regional: THP+ MAD + Drying	$252M ($126M - $503M)	$52M
Regional: TCHP+ MAD + Drying	$208M ($104M - $417M)	$34M
Regional: MAD + Drying + Pyrolysis	$258M ($129M - $516M)	$58M

3.2.3 Net Present Cost Results

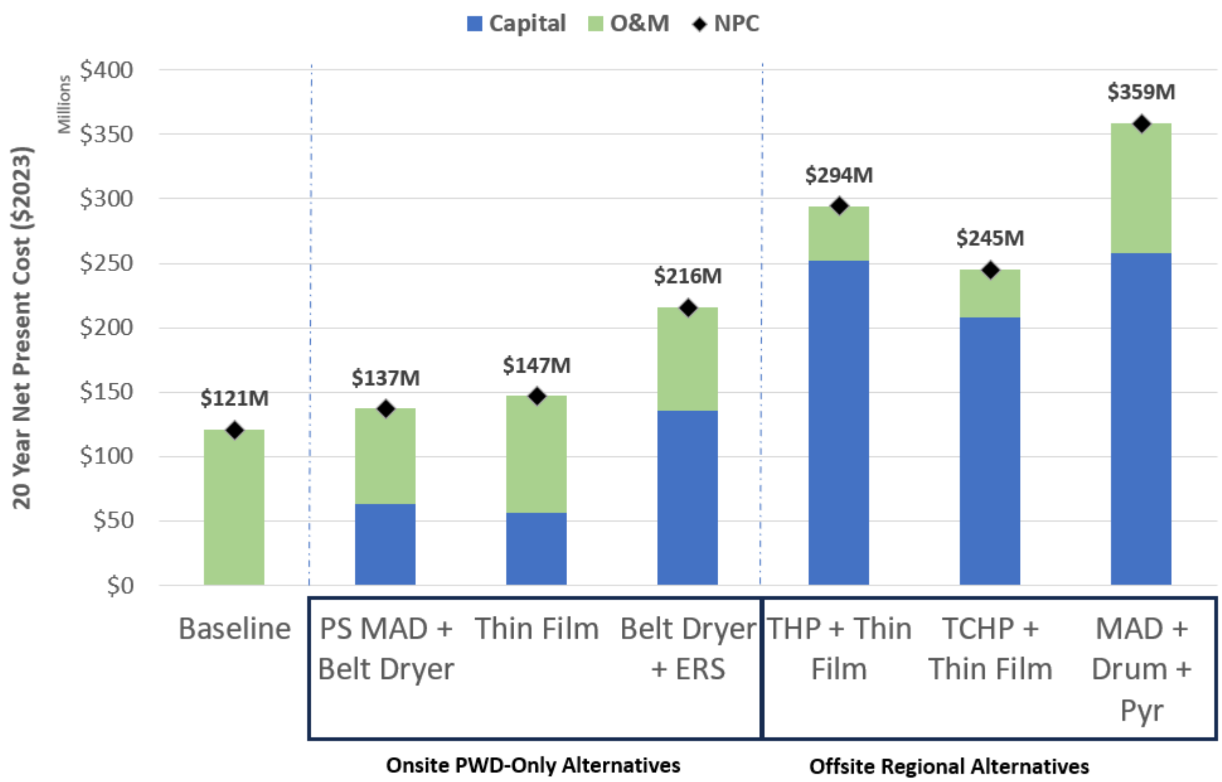

Figure 3-7 illustrates the 20-year net present cost (NPC) for PWD to manage their solids under the different alternatives evaluated. As displayed in Tables 3-4 and 3-5, the offsite regional alternatives include a tipping fee for the regional partners, developed to reflect current market pricing, that was accounted for as revenue within the three offsite alternatives. Consequently, the NPC of the offsite regional alternatives can be considered a net cost to PWD and the alternatives can be compared to onsite PWD-only processing options, and the current status quo of landfilling solids (baseline) on a uniform basis.

Based on the information developed, if PWD was to look at an onsite solution, the best option would be primary sludge mesophilic anaerobic digestion (PS MAD) with Belt Drying (PS MAD + Belt Drying) or Thin Film Drying. The Belt Dryer with Furnace solution, while reducing solids disposal costs, does not provide enough of an annual cost savings to offset the large capital outlay and adds additional complexity. At the conceptual level of the alternatives development, the difference in economics between PS MAD + Belt Drying and Thin Film Drying can be considered to be negligible, or within the expected variability of the cost estimates.

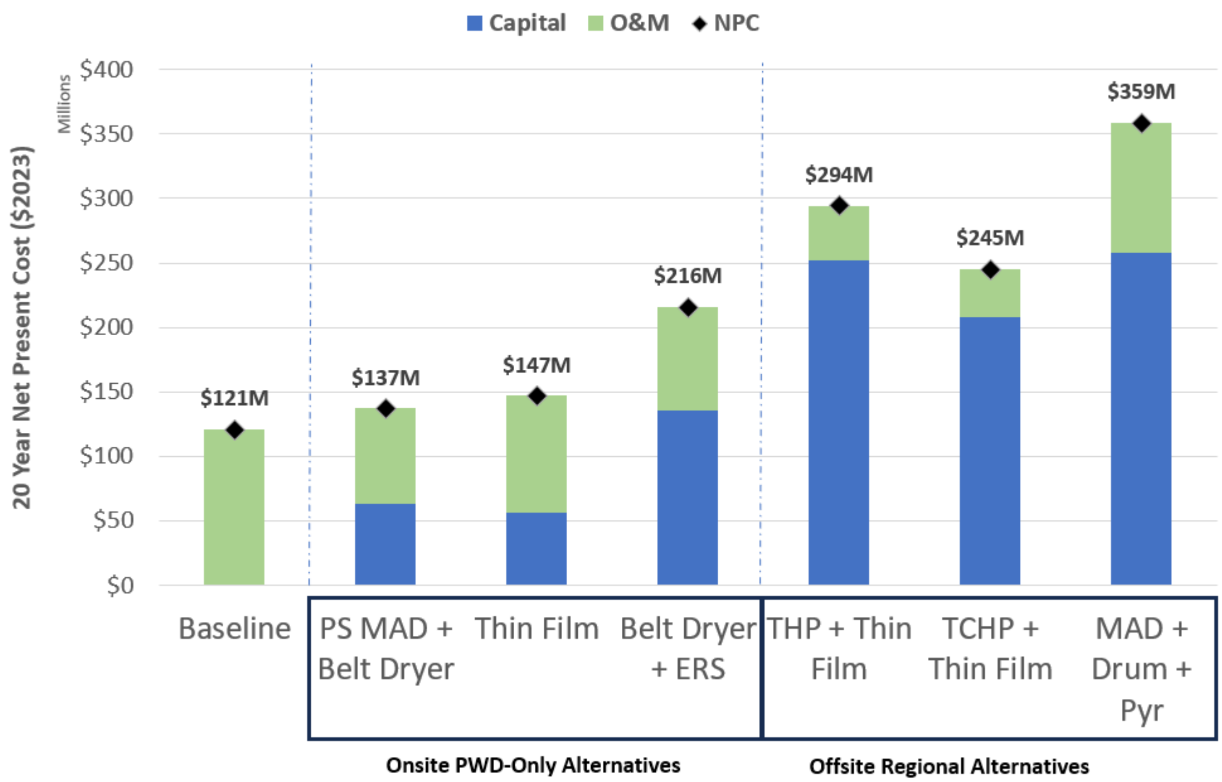

Figure 3-7. NPC results from the initial assessment

All offsite regional alternatives were substantially higher cost, at roughly 3 to 4x the NPC of the status quo. While some of this capital increase is directly attributable to larger capacity facilities (nearly twice the throughput of the onsite facilities), other elements were identified as contributing to the additional cost:

- Offsite anaerobic digestion with hauled dewatered cake requires additional unit processes (cake holding and reliquification, as well as a secondary dewatering step) that onsite facilities wouldn't have to bear.
- The offsite processing facility would require staffing 24/7 given the additional complexity of the processes involved and no other staff being available to monitor operations (as would be the case at an existing WWTF). Conversely, the first two onsite alternatives are based on technologies with a demonstrated history of unattended operation on second and third shift and incur fewer staffing costs.
- The regional facility was assumed to require greater levels of redundancy within the drying process. For a PWD-only project, PWD could likely negotiate planned and unplanned dewatered solids disposal while the dryer was down and self-perform the coordination required at those outages. However, for a regional facility there are more users that likely will have agreed on a certain processing tonnage and two, partially loaded dryers will likely be required to provide additional redundancy.

3.2.4 Alternative End Use Markets

While the beneficial reuse of biosolids is not currently allowed in Maine, there may be opportunities for land application outside of the state. Assuming Class A biosolids are produced, land application companies in the region could haul biosolids to other states such as New Hampshire, Vermont, Massachusetts, Connecticut, New York, and potentially Pennsylvania. However, there are additional considerations to hauling to these states including overall trucking distance, state-specific land application considerations (e.g., PFAS limits), additional permits required, and truck weight limitations during hauling. From conversations with haulers who operate within New England, it would cost $40-90 per ton of dried biosolids to beneficially land apply outside of Maine.

Previously, biosolids had been hauled to Canada, specifically Quebec and New Brunswick, for reuse. However, the Quebec provincial government has issued a temporary moratorium on the importation of land applied biosolids from the United States. In addition, the Canadian Food Inspection Agency (CFIA) is expected to implement a PFOS limit of 50 ppb for biosolids early in 2024, and the Quebec provincial government is expected to pass a more stringent PFOS limit than CFIA within the same timeframe.

3.3 Noneconomic Evaluations

3.3.1 Noneconomic Scoring

Noneconomic criteria are presented in Table 3-7 below to compare the programmatic impacts and benefits of the alternatives. The criteria were developed based on PWD's vision statement discussed in Section 1 and include social, environmental, and operational considerations. Definitions for the criteria are provided as follows:

- Mitigating offsite odors. Ability to limit odor generation sources and control or minimize their strength.
- Transportation logistics. Ability to reduce the amount of solids hauling or chemical delivery truck traffic.
- O&M Impacts. Ability to reduce the O&M burden on utility staff and minimize impact to other WWTF unit processes during normal operation.
- Maintenance of Plant Operations (MOPO). Ability to minimize impact to other WWTF unit processes during construction.
- Future flexibility. Ability to adapt to changing regulations or market drivers and be paired with other technologies for further, future processing if warranted.
- Reliability. Ability to deploy technologies with a proven track record of operational success.
- Regional benefits. Ability to provide a recycling outlet for other regional organic wastes and potentially support job creation.
- Resource Recovery. Ability to generate renewable fuels from wastewater solids processing and utilize for onsite or offsite energy generation or vehicle fueling.

Alternatives were scored from zero to two and a higher score represents a more positive impact.

Table 3-7. Noneconomic Criteria Assessment							
Criterion	Status Quo	Onsite PWD-Only			Offsite Regional		
		PS MAD + Belt Drying	Thin Film Drying	Belt Dryer + Furnace	THP + MAD + Drying	TCHP + MAD + Drying	MAD + Drying + Pyrolysis
Mitigating offsite odors	1	2	1	1	1	1	1
Transportation logistics	0	1	1	2	1	1	2
O&M impacts	1	1	0	0	2	2	1
MOPO impacts	1	1	1	1	2	2	2
Future flexibility	0	1	0	1	1	1	2
Reliability	1	2	1	1	2	2	1
Regional benefits	0	1	0	0	2	2	2
Resource recovery	0	2	0	1	2	2	2
Total score	4	11	4	7	13	13	13

Based on the results of the noneconomic criteria assessment, the alternatives can be organized into three categories with differing level of noneconomic value to PWD in meeting their goals and objectives.

Highest Value: Offsite Regional Alternatives. Despite a higher unit cost, the offsite regional alternatives offer a strong opportunity for PWD and regional partners to create a greenfield biosolids processing facility based on their goals and objectives. With sufficient footprint, utilities and community support, the facility can be customized to recover energy in biogas, recycle regional organics through codigestion, and generate a high-quality dried product with potential to access out of state beneficial reuse markets or fuel a high temperature processing system like pyrolysis. Additionally, the facility can be constructed outside of PWD's currently operating wastewater treatment plants, limiting impact on current facility operations and truck traffic. In summary, these alternatives all offer a consistently high potential noneconomic value to PWD.

Substantial Value: Onsite PS MAD + Belt Drying. This alternative similarly recovers energy through anaerobic digestion, generates a high-quality product with out of state beneficial reuse potential and utilizes relatively simple technology with a proven track record. However, this alternative requires siting within the constricted East End WWTF footprint. Additionally, while the equipment is proven and requires a relatively low O&M demand, new staff would still need to be hired and trained for its operation. Consequently, the alternative has more drawbacks compared to offsite regional processing but still provides substantial value.

Limited Value: Status Quo and Onsite Drying or Furnace Only. The status quo and remaining onsite alternatives offer considerably less upside than the other alternatives. The status quo leaves PWD vulnerable to continued restrictions in in-state dewatered solids disposal and resulting price increases. The thin film dryer generates a dried product easier to landfill but does not offer any additional environmental or social benefits. The belt drying and furnace option does provide energy recovery from the furnace and potential treatment of emerging contaminants at high temperatures but requires O&M of highly complex systems and an onerous air permitting process that likely would fall under SSI regulations.

3.4 Conclusions

This project was initiated to evaluate the economic feasibility of implementing an offsite, regional biosolids solution and compare the project economics and attributes to onsite alternatives, this project conducted a detailed outreach to the current market offerings for biosolids processing technology and service providers to develop comprehensive offsite alternatives with both anaerobic digestion and drying with consideration of advanced thermal processes. A summary of the alternatives, their AACE Class 5 cost estimate and associated range, and the 20-year life cycle cost. The NPC is provided in Table 3-8 below.

Table 3-8. Summary of Alternatives Advanced to Compare Onsite PWD Solids Processing and Offsite Regional Processing

Alternatives		Technologies Deployed	Total Solids Reduced (%)	Total Capital	Annual Cost ($/wet ton; Midpoint, No Capital)	20-yr NPC
Onsite PWD Solids Only	PS MAD + Belt Drying	Westbrook Cake Receiving, Primary Sludge Anaerobic Digestion, Belt Drying	22%	$64M ($32M - $128M)	$98	$154M
	Thin Film Drying	Westbrook Cake Receiving, East End Cake Storage, Thin Film Drying	0%	$57M ($28M - $113M)	$103	$152M
	Belt Dryer + Furnace	Westbrook Cake Receiving, East End Cake Storage, Belt Drying, Pellet Incineration	80%	$136M ($68M - $271M)	$101	$229M
Offsite Regional Solids	THP + MAD + Drying	Regional Cake Receiving and Storage, Thermal Hydrolysis Process, Organics Receiving, Anaerobic Digestion, Thin Film Drying	47%	$252M ($126M - $503M)	$133	$374M
	TCHP + MAD + Drying	Regional Cake Receiving and Storage, Thermal Chemical Hydrolysis Process, Organics Receiving, Anaerobic Digestion, Thin Film Drying	47%	$208M ($104M - $417M)	$117	$316M
	MAD + Drying + Pyrolysis	Regional Cake Receiving and Storage, Mechanical Cake Reliquification, Anaerobic Digestion, Drum Drying, Pyrolysis	70%	$258M ($129M - $516M)	$179	$423M

The economic comparison shows the capital cost to build an offsite regional facility is two to five times greater than that required for onsite processing and the 20-year NPC is two to three times greater. The increased cost for offsite regional processing was found to be due to (1) additional equipment needed to receive, store, and reliquefy dewatered solids and then dewater them again after digestion, (2) higher operational and maintenance demands due to more complex equipment, and (3) greater relative quantity of equipment to provide system redundancy to meet performance requirements likely associated with the facility.

The findings show that inclusion of anaerobic digestion at the offsite facility is the primary driver for the cost differential. Since evaluating the findings, several service providers have offered feedback that implementation of an offsite-drying only facility would be much more economical and in-line with estimates for onsite processing. BC's experience agrees with this assessment, however dryer projects with undigested primary sludge have a mixed track record due to the difficulty in handling the poor quality of the primary sludge, Specifically, the following examples are illustrative of the challenges with drying undigested sludge:

- Ecoremedy (Morrisville, PA): Undigested sludge was stored in receiving bay that caught fire. The fire damaged entire system and closed the facility. No root cause analysis issued, but sludge gas from cake decomposition was a potential cause.
- Veolia (Livonia, MI): This facility installed a 100 wtpd belt dryer system in an existing dewatering building. The poor sludge quality leads to excessive cleaning and maintenance and the facility is several months delayed due to the issues with a tolling agreement to pause warranty.
- Veolia (North Shore, IL): This facility operates an 80 wtpd fluid bed dryer at maximum 70 percent capacity to prevent undigested sludge from plugging. North Shore recently completed a master plan and is advancing an anaerobic digestion project.
- NEFCO/Synagro (Detroit, MI; Stamford, CT; Baltimore, MD): These three contract operated facilities that have experienced substantial fires ($5M - $20M in retrofit costs) accelerated by the high energy content of undigested sludge. Great Lakes Water Authority is advancing a digester feasibility study through their procurement process.
- Huber (Savannah, GA): This facility operates an 85 wtpd undigested sludge belt dryer that is susceptible to sludge gas formation, sludge plugging, high odors, and low-density product.
- Komline-Sanderson (Camden, NJ): This facility uses 160 wtpd paddle dryers that undergo frequent sludge fouling. Drying is regularly paused to run dryer in reverse to clean paddles. This facility recently completed design for anaerobic digestion ahead other dryers.

One solution to incorporate anaerobic digestion into an offsite project is to install anaerobic digestion onsite and then consider options for offsite drying only. While offsite digestion provides the noneconomic benefits described in this report, the findings of this analysis show the additional cost likely prohibits implementation of this option. The MP outlined a conceptual design for a limited scope digestion project (primary sludge only) that would provide the necessary enhancements to PWD's solids for compatibility with a wide variety of dryer types. Consequently, this report recommends advancement of an onsite anaerobic digestion project to further pursue options for offsite drying and potentially thermal treatment. This provides PWD with the greatest array of options for the future and also provides an opportunity to lower disposal costs now while generating a renewable fuel in biogas. Advancing preliminary design of the digester project will provide greater cost certainty in its cost estimate and support PWD in continuing coordination with potential partners to site and operate an offsite, regional dryer facility.

The offsite regional alternatives offer the highest noneconomic project value. In addition, annual costs per ton could conceivably achieve price parity with the status quo and provide financial protection if nearby landfills continue to raise disposal fees. However, capital outlay of the regional alternatives is substantially higher, compared with onsite PWD only processing options or the status quo. Understanding Federal and State financing options, as well as how best to leverage shared life cycle costs with other participating agencies, will be necessary to validate or eliminate these alternatives. In addition to grant and loan support, options to realize the full economic value of the offsite facility could include a) an end-use market assessment to identify potential cost savings from out of state beneficial reuse, and b) a biogas market value assessment to identify revenue opportunities from a biogas to vehicle fuel project using regional pipelines or vehicle fleet.

Assuming that the economics could be reconciled (through a combination of tip fee agreements and external financing), further work would be required to identify a suitable site, firm up commitments with regional solids generators within the next 6 months, ensure acceptance by nearby communities, and establish a governance model to fund, construct and manage the offsite facility. Findings from this study provide a representative facility footprint and utility consumption parameters to advance those discussions. At PWD's request, consideration was also given to the potential to incorporate a pilot into the overall plan. Beginning implementation with a pilot, delays the overall schedule, however, there could be a pathway to pilot implementation either in parallel or following the installation of the core facility discussed here.

As discussed in the BMP, we introduced the idea of 'no-regret' projects. Upgrading dewatering was recommended as a 'no-regrets' project because it would reduce the mass of solids needing to be managed and address a core, state-of-good-repair need. Given the findings of this advanced study, BC also recommends implantation of onsite PS MAD as a 'no regrets' project for the following reasons.

g. PS MAD reduces East End's solids production by approximately 22 percent, saving $1.2M per year at the current disposal cost of $131 per wet ton at the planning horizon midterm solids production projection (10-years out). Digestion also generates a renewable fuel in biogas, further reducing annual costs and onsite greenhouse gas emissions. At these assumptions, the cost to build and operate PS MAD, with resulting cost savings, is roughly equivalent to PWD's current solids management cost of $131 per wet ton. As solids management unit costs continue to increase, PS MAD's mass reduction would further increase cost savings.

h. Onsite digestion is substantially more cost effective than offsite digestion since offsite digestion requires additional facilities to reliquefy hauled solids for digester feed and re-dewatering post-digestion.

i. Without onsite anaerobic digestion, PWD's opportunities for offsite processing are limited. The top-ranking RFI responses process solids through thermal dryers for further mass reduction. Thermal drying with undigested sludge is known to cause a host of operational issues. Undigested primary sludge has poor handling characteristics, increases combustible dust generation, and has objectionable odors. Only two service providers are in operation in the United States with a demonstrated history of managing undigested primary sludge drying but operation has come at considerable cost given increased operations and maintenance requirements and substantial repairs following thermal events. Examples of undigested sludge drying facilities that have closed or paused operation due to operational issues include Springfield, MA; Schenectady, NY; Linden, NJ; Morrisville, PA; and Livonia, MI.

j. With a digested PS, PWD has a much wider array of downstream thermal drying options available. This includes onsite installation with a wider variety of dryer technologies and offsite regional solutions with a much larger pool of service providers. Additionally, much of the wastewater utilities in southern Maine are secondary treatment only facilities and do not produce a primary sludge so a regional dryer would be compatible with their feedstock as well. The thermal dryer will produce a more uniform and less odorous product that will also be more desirable for beneficial reuse. Several biosolids management companies have expressed interest in transporting dried product out of state for beneficial reuse for substantially less cost than in-state disposal options.

k. Onsite PS MAD provides several synergies with dewatering at East End. PS production follows a diurnal trend and digestion acts as an equalization tank, so PWD will have a more consistent blend of digested PS and secondary sludge to improve polymer dosing. Digested PS does not have the septicity concerns of undigested PS which provides PWD the opportunity to store digested PS ahead of dewatering for schedule control. Digestion also breaks down grease and fiber in PS, reducing maintenance requirements on the dewatering unit and downstream transfer lines.

I. Table 3-9 provides an economic breakdown for implementation of the technologies discussed in this report. PS MAD is recommended for near-term installation for the benefits described above. The PS MAD 20-year net present cost (including amortized capital, operating and product management costs) is roughly equivalent to PWD's current solids management cost and will save PWD money as solids management unit costs continue to increase. With PS MAD, PWD will have the opportunity to evaluate a wider variety of onsite dryer options, or regional drying options under a second project phase. Depending on the dried product management fee, onsite installation of a dryer is projected to result in a $148 - $168 cost per wet ton over the 20-year horizon. Offsite, regional drying is projected to cost partners $169 - $208 per wet ton over the project period. However, the offsite project costs were developed using municipal construction cost assumptions and level of redundancy. Private developers are likely to propose facilities with less redundancy and maintain contingency plans during outages for a lower project cost. If dried product management costs increase, or PWD wishes to generate an alternative biosolids-based product where contaminants have been thermally treated (e.g. biosolids biochar) a pyrolysis facility could be installed to manage the dried product at a conceptual level cost of $117 - $123 per wet ton, depending on the cost for managing the biochar.

Table 3-9. Economic Project Summary and Phasing Recommendations

Project Phasing	Location	Technology Implementation	Total Project Capital	20-Year Net Present Cost ($/wet ton-equivalent)[1]
Phase 1	Onsite	PS MAD	$24 ($12M - $48M)	$136
Phase 2a	Onsite	Belt Drying	$40M ($20M - $80M)	$148 - $168
Phase 2b	Offsite	Thin Film	$103 ($52M – ($206M)	$169 - $208
Phase 3	Offsite	Pyrolysis	$54M	$117 - $123

Note: [1] the cost includes the annual O&M and a yearly amortized capital cost assuming a 20-year loan with 1.5% interest rate.

Based on the findings from this advanced study, BC recommends PWD advance the following steps.

5. Implement PS MAD and dewatering upgrades at East End ('no-regrets' projects). Advance preliminary design of onsite dryer to refine cost estimates, verify constructability and select preferred dryer technology.
6. Engage regional partners to identify available sites for an offsite regional processing project.
7. Issue an RFP to solids processing service providers with regional partners. If no offsite location has been identified, require proposer to secure the site. Develop RFP based on service provider feedback from this project (e.g. recommendations for delivery method, governance structure, and contracting methods) and use evaluation criteria from this project to score proposals.
8. Implement most cost-effective solids processing option (either onsite thermal drying, highest-scoring offsite service provider, or continued dewatered solids management contract). Continue to monitor final product management costs and development of pyrolysis technology for potential future pyrolysis integration with a dryer project.

Section 4

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Section 5

Limitations

This document was prepared solely for Portland Water District in accordance with professional standards at the time the services were performed and in accordance with the contract between Portland Water District and Brown and Caldwell dated April 19, 2023. This document is governed by the specific scope of work authorized by Portland Water District; it is not intended to be relied upon by any other party except for regulatory authorities contemplated by the scope of work. We have relied on information or instructions provided by Portland Water District and other parties and, unless otherwise expressly indicated, have made no independent investigation as to the validity, completeness, or accuracy of such information.

This document sets forth the results of certain services performed by Brown and Caldwell with respect to the property or facilities described therein (the Property). Portland Water District recognizes and acknowledges that these services were designed and performed within various limitations, including budget and time constraints. These services were not designed or intended to determine the existence and nature of all possible environmental risks (which term shall include the presence or suspected or potential presence of any hazardous waste or hazardous substance, as defined under any applicable law or regulation, or any other actual or potential environmental problems or liabilities) affecting the Property. The nature of environmental risks is such that no amount of additional inspection and testing could determine as a matter of certainty that all environmental risks affecting the Property had been identified. Accordingly, THIS DOCUMENT DOES NOT PURPORT TO DESCRIBE ALL ENVIRONMENTAL RISKS AFFECTING THE PROPERTY, NOR WILL ANY ADDITIONAL TESTING OR INSPECTION RECOMMENDED OR OTHERWISE REFERRED TO IN THIS DOCUMENT NECESSARILY IDENTIFY ALL ENVIRONMENTAL RISKS AFFECTING THE PROPERTY.

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Appendix A: Phase I RFI Submittal Requirements

Section	Submittal Requirements
Table of Contents **No page limit**	Provide a Table of Contents that includes major headings of the Response and associated page numbers as well as lists of tables, graphics, figures, photos, and any appendices.
Executive Summary **2-page limit**	Provide a summary of the overall approach and role of the Responder and Responder's Team. The Executive Summary shall not be used to communicate information not found elsewhere in the Response.
Team Structure, Business Approach and Financial Information	
10-page limit*	**Objectives:** Ideally, PWD would like to engage a single Service Provider for receipt, processing, and generation of a biosolids product that is Landfillable and capable of transitioning to alternative beneficial use solutions. **In reviewing this section, PWD will be looking to address the following questions: 1) Are you proposing a comprehensive solution to construct, operate, and maintain a Biosolids Processing facility to receive dewatered solids and generate a Landfillable product? Or are you offering a partial solution that would be paired with a larger team or another entity? 2) If you would pair with a team or other entity, what team structure would you prefer to deliver the full suite of services and do you maintain relationships with individual entities that could be combined to form your preferred team? 3) How would the team interact to deliver the services?** **Submittal Requirements:** 1. **Team Structure**: Provide a conceptual overview of your proposed team structure. Clarify if you are proposing a complete solution or a portion of the solution. If you are proposing a portion of the solution but require that either PWD or another service provider(s) also provide a portion of the solution, please identify what services you are assuming will be provided by either PWD or another service provider 2. **Qualifications**: Provide relevant qualifications to the services being proposed. Provide references able to attest to the relevant qualifications. Prefer at least three references but not more than five.

	3. **Financial Information**: PWD wants to ensure that Responders have sufficient financial strength to deliver the proposed solution and guarantee performance. In the event that the Responder does not have sufficient financial strengths and assets, a parent or affiliated company guarantee will be required. Responders should provide one of the following (*Note that the financial submittals below are excluded from the page count for this section*): a. Financial statements for the past 3 years. PWD will keep financial data confidential, to the extent practical and allowed by law, and limited to review by the evaluation committee and PWD's financial officer. b. Letter from a surety company confirming your ability to bond/insure a project of this scale. 4. **Coordination and Communication**: Describe your proposed approach to coordinating with PWD and other Service Providers (if required) in order to successfully deliver the service(s).
Proposed Technical Approach	
10-page limit	**Objectives:** PWD is seeking a Service Provider with biosolids processing experience capable of proving a long-term, reliable Biosolids Processing Facility meeting their goals and objectives. **In reviewing this section, PWD will be looking to address the following questions: 1) Is your solution compatible with PWD's current goals? 2) What advantages does your proposed processing technology offer? 3) What is the resulting product and can it transition to alternative beneficial use solutions?** **Submittal Requirements:** 1. **Core Processing Technologies**: Describe the main processing technologies to be employed in the proposed processing train, addressing the compatibility of this technology with undigested, dewatered solids and PWD's goals for resource recovery. 2. **Potential PFAS Destruction Technologies**: If you are proposing a technology to destroy PFAS describe your processing conditions, gas handling strategy and emissions control devices. If you are proposing an emerging or unproven technology, how would you plan development and implementation? 3. **Final Product**: Describe, at a high level, the anticipated characteristics of the resulting final product. Address the desired compatibility with regional landfills. Describe potential target markets for alternative beneficial use solutions, the compatibility of the product with those target markets, and anticipated demands for the target market(s) relative to the supply under a PWD-only or PWD with Regional Solids scenario. Provide a dimensional layout drawing showing equipment footprint, working clearances and a process flow diagram(s) for your processing technology train.
Life Cycle Costs	
10-page limit	**Objectives:** PWD would like to understand and compare 10-year lifecycle costs for the processing equipment trains proposed by the Responder under the two loading scenarios; (1) a PWD-Only scenario and (2) a Regional Solids scenario. PWD is requesting Responders provide a complete set of answers to the lifecycle cost

questions below separately for the two loading scenarios per the capacity requirements provided in Table 2-1.

1. **PWD-Only**
   a. Undigested solids
   b. 50/50 split of primary sludge and conventional WAS
2. **PWD and Regional Solids plus 20,000 gallons/day of FOG**
   a. Undigested wastewater solids
   b. FOG as grease trap waste, 5%TS
   c. 25/75 split of primary sludge and conventional WAS

Submittal Requirements for Each Scenario:

1. **Equipment Cost:** Provide a breakdown of equipment costs for the equipment in your proposed processing train. Include overview and cost of recommended spare parts.
2. **Annual Cost and Revenue Factors:** Provide the following operational data for operation at the annual average loading for each scenario with as much supporting detail for each category as possible:
   a. Proposed Operational Schedule (assumes solids are received 24/7/365)
   b. Total Electricity Consumption Per Operating Day (excluding impact of potential electricity generation from biogas utilization)
   c. Total Natural Gas Consumption Per Operating Day (excluding impact of potential useful heat generation from biogas)
   d. Total Chemical Consumption Per Operating Day (e.g., ferric, polymer, dedusting oil, etc.) and expected unit costs
   e. Product Disposal Per Operating Day (provide final product mass and bulk density)
   f. Potable Water Demand Per Operating Day (provide required flow rate and pressure)
   g. Treated WWTP Effluent Demand Per Operating Day (provide required flow rate and pressure)
   h. Annual Operations Labor (provide estimated number of Full Time Equivalents required to operate the facility to provide 24/7/365 availability.
   i. Annual Maintenance Costs (provide estimated, annualized cost of replacement parts over a 10-year operating window at steady state conditions (provide as much detail as currently available; e.g., current replacement cost, expected replacement intervals)
   j. Annual Maintenance Labor (provide estimated number of Full Time Equivalents required to provide required maintenance at the facility to provide 24/7/365 availability).
   k. Potential Utility Savings from Biogas or High Temperature Processes (if applicable, provide proposed energy recovery strategies and expected generation of useful heat, electricity or renewable natural gas to offset utility costs or generate revenue).
   l. Potential Revenue from Alternative Beneficial Use Strategy (if applicable, provide estimated fee or shared revenue available from proposed alternative beneficial use solutions per ton of product generated).

PFAS Capabilities	
5-page limit	**Objectives:** PWD will work with Maine DEP to outline a PFAS permitting pathway for the Biosolids Processing Facility and seeks to implement a processing scheme that reflects the current state of the science to support the permitting process. **In reviewing this section, the PWD will be looking to address the following question: 1) Have you conducted PFAS testing on core processing technologies and/or PFAS destruction processes, and 2) do you have operating facilities at commercial scale with your proposed technologies that could be tested for PFAS emissions to support project permitting?** 1. **Existing PFAS Data**: If you have conducted PFAS testing at bench or commercial scale for the biosolids processing technologies you are proposing will you make that data available to the PWD and Maine DEP as part of the RFP process? If yes, provide an overview of the testing conducted including feed characteristics, operating conditions, test duration, sampling points and analytical techniques. 2. **Ability to Collect PFAS Data**: If requested as part of the RFP process, would you be able to perform PFAS testing at bench or commercial you're your proposed biosolids processing technology? If yes, provide a summary of the installation(s) available for testing including feed characteristics, operating conditions, operating capacity and installation date. If there are limitations on the sampling points or ability to make data public provide those clarifying details.
Availability of Service Delivery	
15-page limit	**Objectives:** PWD would like to develop a processing concept that can be advanced for facility permitting and siting. PWD is exploring several options for facility siting but is interested to understand if Service Providers have existing property, or the means to acquire property, they would recommend for consideration during this Phase 1 evaluation. **In reviewing this section, PWD will be looking to address the following question: 1) Have you considered the facility development components (i.e., siting, permitting) or are you expecting PWD to provide these elements? 2) Describe options for providing these components if willing at this time.** 1. **Site Acquisition**: If you have already secured or developed a site for processing, and are willing to share this information with PWD, describe the site and associated property rights (be clear as to whether you hold all property rights necessary to implement the solution). If you do not have a proposed site, provide an overview of the anticipated site needs that may not have been clear in the lifecycle operating cost response section. 2. **Permitting**: If you have conducted preliminary work in obtaining the permits for an Offsite Biosolids Processing Facility and are willing to share with PWD, identify the current status of permits or investigation activities. As you are willing to share, describe the steps you identified to advance the permit

	process and the type of permitting assistance that you believe would be most beneficial from PWD. 3. **Marketing and Distribution**: If you are proposing alternative beneficial use solutions have you developed a marketing and distribution plan (including any product permits/registration)? How would you expect to grow an alternative beneficial use market and mitigate risks with the current regulatory environment.
Contractual Arrangement	
5 page limit	**Objective:** At this time, PWD is flexible with regards to contractual arrangement. For example, PWD would consider entering into a long-term service agreement, a DBO Agreement for development of processing facility(ies) or an arrangement with private financing. Information submitted as part of this RFI will be used to determine the contractual arrangement(s) solicited in the Phase 2 RFP. PWD prefers a 5-year initial contract term and is currently contemplating the possibility of up to two 5-year extensions. **In reviewing this section, PWD will be looking to address whether Responders have a preferred contractual arrangement and preference regarding the contract term.** **Submittal Requirements:** 1. **Type of contract**: Responders should address the form of contract you expect to be entered into with the PWD, whether: a. an agreement for services, or b. a contract where facilities are all or partially paid for by the PWD during development, followed by services provided by the service contractor (i.e., a DBO or P3-type contract, depending on who is providing financing). c. Include your rationale for the type of contract selected, including benefits to the PWD, financing, or other implementation considerations. 2. **Contract Term**: Provide any additional input, as desired, regarding PWD's proposed contract term. 3. **Merchant Solutions**: Address whether your preferred technical solution is part of a larger, regional solution or unique to/for the PWD. If a regional solution is preferred, provide information as to what other commitments of biosolids or other organics would be required, in addition to PWD's, to make the solution feasible.
Additional Information	
5-page limit	Responders may provide any additional information deemed pertinent to evaluating the proposed solution.

Appendix B: RFI Response Scores

	Table B-1. Scores for All Responders							
Responder	Team Structure, Business Approach, and Financial Information	Technical Approach	Life Cycle Costs[a]	PFAS Data Capabilities	Availability of Service Delivery	Contractual Arrangement	Total	Score (%)
Max Points Available	20	20	20	20	5	5	90	--
374Water	17	20	18	19	4	3	90	90%
Anaergia	17	20	18	15	4	5	90	88%
Aries	12	20	10	15	4	5	90	73%
BCR and IQ Energy	8/15[b]	15	15	10	NA[b]	4	80	65%
Cambi	20	20	18	10	5	5	80	98%
C-Green	13/15[b]	12	17	20	NA[b]	4	80	83%
C-Level	13	17	18	18	5	5	90	84%
CTEC	10	12	10	10	3	3	90	53%
EcoRemedy	7/15[b]	15	20	13	2	4	80	76%
EQ Renewables	20	20	17	15	5	4	90	90%
Griffin Residuals	7	18	12	8	2	5	90	58%
Heartland	15	17	17	19	4	5	90	86%
Huber	15/15[b]	17	20	8/10[b]	NA[b]	5	70	93%
Johnson Controls	20	18	12	5/10[b]	5	5	80	81%
Komline-Sanderson	12/15[b]	16	0	8/10[b]	0	0	80	45%
LCI	15/15[b]	20	20	10/10[b]	NA[b]	5	70	100%
Lystek	16	20	20	18	4	5	90	92%
NORESCO[c]	17	15	NA	5	5	5	70	67%
Ovivo	14/15[b]	15	0	0/10[b]	NA[b]	2	70	44%

Table B-1. Scores for All Responders								
Responder	Team Structure, Business Approach, and Financial Information	Technical Approach	Life Cycle Costs[a]	PFAS Data Capabilities	Availability of Service Delivery	Contractual Arrangement	Total	Score (%)
Peaks	13	20	0	15	5	5	90	64%
PWTech	8/15[b]	15	0	0	NA[b]	0	80	29%
Schwing Bioset	11/15[b]	15	0	0/10[b]	0	5	70	44%
SEVAR	13/15[b]	18	17	10/10[b]	NA[b]	3	70	87%
Stircor	16	18	17	18	3	5	90	86%
Synagro	19	18	19	20	5	5	90	96%
Utopia	18	15	10	18	5	5	90	79%
Veolia	20	20	20	20	5	5	90	100%
Viridi	17	17	12	8/10[b]	5	5	80	80%
Waste Management	18	20	12	19	5	5	90	88%

Appendix C: Process and Cost Summary

		Baseline	PWD Only	PWD Only	PWD Only	Regional	Regional	Regional
		Baseline	PS MAD + Belt Dryer	Thin Film	Belt Dryer + ERS	THP + Thin Film	TCHP + Thin Film	MAD + Drum + Pyr
Sludge Processing								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Materials Receiving								
Electricity (Normalized)	kW		38	38	38	132	132	232
Process Water (Dilution)	GPM		-	-	-	-	-	109
THP & TCHP								
Electricity	kW		-	-	-	80	69	-
Process Heating	MMBTU/hr		-	-	-	3.7	2.3	-
Process Water (Dilution)	GPM		-	-	-	45	10	-
Chemical (Lime)	lb-lime/DT		-	-	-	-	-	-
MAD								
Electricity	kW		296	-	-	412	412	949
Process Heating	MMBTU/hr		0.7	-	-		1.0	3.2
Biogas Fuel Production	MMBTU/hr		3.0	-	-	16.0	16.0	13.6

Thermal Treatment								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Re-Dewatering								
Electricity	kW		-	-	-	323	323	360
Chemical (Polymer)	lb-polymer/DT		-	-	-	40	40	40
Drying								
Electricity	kW		129	368	571	364	368	825
Process Heating	MMBTU/hr		10.5	11	6	7	7	12
Process Water (Cooling Loop)	GPM		115	63	200	516	516	550
Product Disposition	ton/d		22	27	5	27	27	26
Pyrolysis								
Electricity	kW		-	-	-	-	-	306
Process Heating	MMBTU/hr		-	-	-	-	-	8
Syngas Production	MMBTU/hr		-	-	-	-	-	9
Process Water	GPM		-	-	-	-	-	300
Product Disposition	ton/d		-	-	-	-	-	13

Future Annual Process Summary								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Process Inputs								
Electricity (+15% Allow.)	kW		533	467	700	1,506	1,499	2,720
Natural Gas (+5% Allow.)	MMBTU/hr		12	11	6	11	11	16
Biogas Fuel Production	MMBTU/hr		3	-	-	16	16	14
Process Water Cons. (+15% Allow.)	GPM		-	-		51	11	125
Process Water Loop	GPM		115	63	200	516	516	550
Sewer Discharge	GPM		-	-	-	89	54	155
Chemical (Alkali)	lb/d		-	-	-	-	-	-
Chemical (Polymer)	lb/d		-	-	-	-	-	-
PWD Hauling (Transfer)	wtpd		23	23	23	114	114	114
Regional Loading (Revenue)	wtpd		-	-	-	97	97	97
Product Hauling and Landfill	wtpd	114	22	27	5	27	27	13
Labor (ops)	FTE		4	5	8	13	11	14

Mid-Point Annual Process Summary								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Process Inputs								
Electricity (+15% Allow.)	kW		533	467	700	1,506	1,499	2,720
Natural Gas (+5% Allow.)	MMBTU/hr		9	9	5	10	10	14
Biogas Fuel Production	MMBTU/hr		3	0	0	14	14	12
Process Water Cons. (+15% Allow.)	GPM		0	0	0	46	10	111
Process Water Loop	GPM		92	50	160	460	460	490
Sewer Discharge	GPM		0	0	0	79	48	138
Chemical (Alkali)	lb/d		0	0	0	0	0	0
Chemical (Polymer)	lb/d		0	0	0	0	0	0
PWD Hauling (Transfer)	wtpd		18	18	18	102	102	102
Regional Loading (Revenue)	wtpd		0	0	0	86	86	86
Product Hauling and Landfill	wtpd	102	17	21	4	24	24	12
Labor (ops)	FTE		3	5	8	13	11	14

		Baseline	PWD Only	PWD Only	PWD Only	Regional	Regional	Regional
		Baseline	**PS MAD + Belt Dryer**	**Thin Film**	**Belt Dryer + ERS**	**THP + Thin Film**	**TCHP + Thin Film**	**MAD + Drum + Pyr**
Annual Cost Summary Based on Mid-Point								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Process Inputs								
Electricity	$/yr	$0	$746,427	$653,966	$981,742	$2,111,410	$2,100,687	$3,812,209
Natural Gas	$/yr	$0	$1,155,555	$1,130,928	$580,431	$1,228,479	$1,178,192	$1,771,478
Biogas Fuel Value	$/yr	$0	-$305,822	$0	$0	-$1,609,207	-$1,609,207	-$1,366,740
Chemical (Alkali)	$/yr	$0	$0	$0	$0	$0	$0	$0
Chemical (Polymer)	$/yr	$0	$0	$0	$0	$0	$0	$0
Operations Labor + License Fee*	$/yr	$0	$312,000	$520,000	$832,000	$1,352,000	$1,194,000	$1,456,000
Maintenance (Labor and Parts/R&R)	$/yr	$0	$255,667	$197,807	$543,407	$1,034,290	$679,790	$1,164,366
PWD Hauling (Transfer)	$/yr	$0	$100,519	$100,519	$100,519	$556,115	$556,115	$556,115
Regional Tip Fee Revenue	$/yr	$0	$0	$0	$0	-$5,047,310	-$5,047,310	-$5,047,310
Product Hauling and Landfill	$/yr	$4,856,735	$827,532	$1,023,804	$174,047	$1,154,623	$1,154,623	
Biochar Disposition	$/yr							$560,603
Total Annual Cost	**$/yr**	**$4,856,735**	**$3,091,878**	**$3,627,024**	**$3,212,146**	**$780,400**	**$206,890**	**$2,906,720**
Present Worth	**$**	**$120,904,787**	**$76,969,995**	**$90,292,040**	**$79,963,972**	**$19,427,467**	**$5,150,363**	**$72,360,626**

Capital Cost Summary								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Process Inputs								
Equipment	$	$0	$12,783,350	$9,890,350	$27,170,350	$51,714,500	$33,989,500	$58,218,300
Total Project Costs	$	$0	$63,814,600	$56,690,000	$135,690,000	$251,700,000	$208,400,000	$258,200,000
Upper Limit of Cost Estimate (+100%)	$	$0	$127,629,200	$113,380,000	$271,380,000	$503,400,000	$416,800,000	$516,400,000
Lower Limit of Cost Estimate (-50%)	$	$0	$31,907,300	$28,345,000	$67,845,000	$125,850,000	$104,200,000	$129,100,000
Amortized Capital	$/y	$0	$3,716,928	$3,301,951	$7,903,364	$14,660,452	$12,138,411	$15,039,049

Total Economic Evaluation								
Parameter	Units	Value	Value	Value	Value	Value	Value	Value
Process Inputs								
20-YR NPC	$	$120,904,787	$140,784,595	$146,982,040	$215,653,972	$271,127,467	$213,550,363	$330,560,626
Total Cost to treat (Cap + O&M)	$/wt	$131	$184	$187	$300	$416	$333	$484
Total Cost to treat (O&M)	$/wt	$131	$83	$98	$87	$21	$6	$78

Appendix D: List of Reference Regional and Pilot Facilities

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Reference List Sludge Drying – Status 12/2020

User / Location	Country	Start up	Type of Sludge		No. of Lines / Stages		Drying Capacity per Line: Inlet Dry Solid Content %D.S.	Product Dry Solid Content %D.S.	Feed Rate lb/h	Evapo-ration Rate lb/h	Feed Rate kg/h	Evapo-ration Rate kg/h	Sludge disposal				
Wacker Chemie	DE	1985	M	I	1	1	18	45	6,600	3,960	3.000	1.800	MSI				
Ulm (Steinhäule)	DE	1986	M		2	1	20	40	9,504	4,752	4.320	2.160	MSI				
Emser Werke	CH	1986	M	I	1	1	15	90	1,320	1,100	600	500		IMW			
Cellulose Attisholz	CH	1986		I	1	1	12	30	4,026	2,420	1.830	1.100	MSI				
Nancy	FR	1986	M		1	2	28	90	5,346	3,674	2.430	1.670			AA		
Nancy	FR	1987		I	1	2	20	90	3,344	2,596	1.520	1.180			AA		
Lonza, Visp	CH	1988	M	I	1	1	20	35	14,300	6,138	6.500	2.790	MSI				
Blackburn - Meadows	GB	1988	M		1		25	30	17,600	3,740	8.000	1.700	MSI				
Nd. Krüchten	DE	1989	M		1	1	20	75	990	726	450	330			AA		
Zürich	CH	1989	M		1	2	25	90	15,708	11,352	7.140	5.160		ICK	AA		LF
Principauté de Monaco	MC	1990	M		2	1	20	80	2,200	1,650	1.000	750		IMW			
KSE/EMR Herford	DE	1990	M	I	1	1	25	50	1,760	880	800	400	MSI	IMW			
KSE/EMR Ciba Lampertheim	DE	1990	M	I	1	2	25	95	1,760	1,320	800	600		IMW	AA		LF
Agussa, Pforzheim	DE	1991		I	1	1	30	95	550	374	250	170					LF
Ciba, Lampertheim	DE	1991		I	1	2	20	90	2,970	2,200	1.350	1.000	MSI				
Rovereto	IT	1991	M		2	2	20	90	3,212	2,508	1.460	1.140			AA		
Holzminden	DE	1991	M	I	1	2	30	92	6,732	4,532	3.060	2.060					LF
Calder Valley	GB	1991	M		1		21	30	34,320	9,900	15.600	4.500	MSI				
KSE/EMR, Merck Darmstadt	D	1992	M	I	1	2	25	90	2,970	2,200	1.350	1.000	MSI	IMW	AA		LF
Verona	IT	1992	M		1	2	20	90	5,654	4,400	2.570	2.000			AA		
Sète	FR	1993	M		1	2	23	90	3,828	2,860	1.740	1.300		IMW	AA		
Akzo, Arnhem	NL	1993		I	1	1	13	70	2,552	2,068	1.160	940		IMW			
Ciba, Monthey	CH	1993		I	1	1	20	40	6,732	3,366	3.060	1.530	MSI				
Wuppertal	DE	1993	M		4	1	25	50	11,176	5,588	5.080	2.540	MSI				
Nürnberg	DE	1994	M		1	2	20	90	23,760	18,480	10.800	8.400	MSI		AA		LF
Erkelenz	DE	1994	M		1	1	30	80	1,320	1,100	600	500			AA		LF
South West Water,Barnstaple	GB	1994	M		1	2	20	95	2,794	2,200	1.270	1.000			AA		
Amsterdam	NL	1994	M		3	2	25	90	16,896	12,650	7.680	5.750					LF
Synthesia/Pardubice	CZ	1995	M	I	1	2	15	90	12,232	10,186	5.560	4.630		IMW			
Vandemoortele, Izegem	BE	1995		I	1	2	25	90	2,361	1,705	1.073	775					LF
Darmstadt	DE	1995	M	I	2	1	26	90	5,500	3,960	2.500	1.800	MSI	IMW	AA		LF
EVAS	DE	1995	M	I	1	2	25	90	2,970	2,200	1.350	1.000					LF
Rohm & Haas, Lauterbourg	FR	1995		I	1	1	25	81	3,740	2,587	1.700	1.176		IMW			
Leeds	GB	1995	M		1		20	30	30,250	9,900	13.750	4.500	MSI				
ZVA Oberes Waldachtal	DE	1996	M		1	1	30	90	1,320	1,100	600	500			AA		LF
Bad Waldsee	DE	1996	M		1	1	30	90	1,980	1,320	900	600			AA		
Belfast	IE	1996	M		1		22	30	30,008	8,250	13.640	3.750	MSI				
Kelheim Fibres, Kelheim	DE	1996		I	1	1	15	90	4,400	3,674	2.000	1.670					
Gross Gerau	DE	1997	M		1	2	25	90	2,134	1,542	970	701			AA		LF
Altensteig	DE	1997	M		1	1	28	88	2,552	1,760	1.160	800			AA		LF
Chemnitz	DE	1997	M		2	2	22	90	5,720	3,784	2.600	1.720					
Welsh Water, Nash	GB	1997	M		1	2	25	90	10,076	7,700	4.580	3.500	G				LF
South West Water, Plymouth	GB	1998	M		1	2	25	93	7,964	6,270	3.620	2.850					
Seiler, Freiberg	DE	1998		I	1	1	50	95	1,760	924	800	420					
Akzo, Rotterdam	NL	1998		I	1	1	15	85	1,100	917	500	417					
Sasol, Brunsbüttel	D	1999		I	1	1	20	95	2,640	2,083	1.200	947					
Rieti	IT	2000	M		1	1	20	80	2,200	1,650	1.000	750					LF
North West Water, Wigan	GB	2000	M		1	2	22	92	14,322	10,890	6.510	4.950					
Lichtenfels	DE	2000	M		1	1 (2)*	28	50 (90)*	1,408	623	640	283		IMW			
Innerstetal	DE	2000	M		1	2	25	90	2,200	1,588	1.000	722					LF
Belfort	FR	2002	M		1	1	20	65	2,640	1,826	1.200	830		IMW			

Reference List Sludge Drying – Status 12/2020

							Drying Capacity per Line										
User / Location	Country	Start up	Type of Sludge		No. of Lines / Stages		Inlet Dry Solid Content %D.S.	Product Dry Solid Content %D.S.	Feed Rate lb/h	Evapo-ration Rate lb/h	Feed Rate kg/h	Evapo-ration Rate kg/h	Sludge disposal				
Rieti	IT	2002	M		1	1	20	80	2,200	1,485	1.000	675					LF
Piacenza	IT	2002	M		1	1	25	65	2,200	1,364	1.000	620		IMW			
Arendal	NO	2002	M		1	1 (2)*	28	43 (90)*	2,310	807	1.050	367					
Umea	SE	2002	M		1	1 (2)*	28	43 (90)*	3,762	1,313	1.710	597					
Thionville	FR	2003	M		1	1 (2)*	21	65 (90)*	3,168	1,716	1.440	780					
Chamonix	FR	2003	M		1	1 (2)*	25	65 (90)*	3,575	2,200	1.625	1.000					
Neuburg	DE	2003	M		1	2	25	90	2,640	1,907	1.200	867		ICK			
Roquette Frères, Beinheim	FR	2004		I	2	1	10	85	2,640	2,330	1.200	1.059					
Cork	IE	2004	M		2	1 (2)*	25	45 (90)*	3,575	1,595	1.625	725					
Villefranche	FR	2004	M		1	1 (2)*	21	45 (90)*	4,455	2,383	2.025	1.083		IMW			
Visby	SE	2005	M		1	1 (2)*	26	45 (90)*	2,860	1,214	1.300	552		ICK			
Bendern	FL	2005	M		1	1 (2)*	28	45 (90)*	2,200	838	1.000	381		ICK			
Gifhorn	DE	2005	M		1	2	25	90	805	581	366	264	MSI				
Warsaw	PL	2006	M		2	1 (2)*	22	45 (90)*	5,500	2,818	2.500	1.281		IMW			
MCUA, Sayreville N.J.	US	2006	M		5	1	27	51	17,996	8,470	8.180	3.850			AA		LF
Fribourg	CH	2006	M		1	1	25	43,5	13,200	5,614	6.000	2.552	MSI				
Skelleftea	SE	2007	M	I	1	1 (2)*	22	45 (90)*	5,280	2,706	2.400	1.230					
Arcachon	FR	2007	M		2	1 (2)*	26	45 (90)*	4,941	2,092	2.246	951					
Holzminden	DE	2007	M	I	1	1	55	90	1,496	583	680	265		ICK			
Tarare	FR	2008	M	I	1	1	23	30	5,280	1,232	2.400	560	MSI				
Chongqing	CN	2009	M		3	1 (2)*	23	45 (90)*	6,534	3,190	2.970	1.450					
Suzhou I	CN	2011	M		3	1 (2)*	20	45 (90)*	10,703	5,947	4.865	2.703					
Cannes	FR	2011	M		2	1 (2)*	18	45 (90)*	4,057	2,433	1.844	1.106					
Evreux	FR	2011	M		1	1 (2)*	18	45 (90)*	2,838	1,705	1.290	775					
Ulm (Steinhäule)	DE	2012	M		1	1	22	43	17,578	8,580	7.990	3.900	MSI				
Petrochina Dushanzi	CN	2012		I	1	1	15	65	3,300	2,539	1.500	1.154	MSI				
Chengdu	CN	2013	M		2	1	20	35	18,333	7,856	8.333	3.571	MSI				
Bordeaux	FR	2012	M		2	1 (2)*	27	45 (90)*	7,128	2,860	3.240	1.300					
Chongqing	CN	2013	M		3	1 (2)*	25	50 (90)*	13,750	9,931	6.250	4.514					
Muharraq	BH	2013	M		2	1	20	40	7,260	3,630	3.300	1.650	MSI				
Tianjin Binhai	CN	2015	M														
Suzhou II	CN	2015	M														
Suzhou III	CN	2015	M														
Shenzhen	CN	A	M		4	1	20	36	18,333	8,149	8.333	3.704	MSI				
Karslruhe	DE	A	M		2	1	25	38	18,128	6,202	8.240	2.819	MSI				
Inegöl	TR	2016	M		1	1	27	90	8,250	5,775	3.750	2.625		ICK			
Suzhou XC	CN	2016	M														
Ningbo Beiqu	CN	2016		I	1	2	20	90	5,865	4,563	2.666	2.074	MSI				
Tianjin Jinnan	CN	2016	M		2	1	30	70	18,638	10,652	8.472	4.842	MSI				
PetroChina Harbin	CN	2016		I	1	1	15	65	1,008	777	458	353	MSI				
Shenhua	CN	A		I	1	1	15	70	4,840	3,804	2.200	1.729	MSI				
Fujian Gulai	CN	2016		I	1	1	20	40	8,250	4,125	3.750	1.875				IHW	
YanAn Shanxi Yanchang	CN	2017		I	1	1	18	60	2,860	2,002	1.300	910					LF
Glina	RO	A	M		3	1 (2)*	25	50 (90)*	10,707	7,733	4.867	3.515					
Obernburg am Main	DE	2017	M/I	I	1	1	26,5	45	4,400	1,808	2.000	822	MSI				
Jingling	CN	2017	M		1	1	18	70	1,839	1,393	836	633				IHW	
Thermische **V**erbrennung **M**ainz	DE	A	M		2	1	22	42	22,000	9,350	10.000	4.250	MSI				
Sinopec Shandong Qilu	CN	2019		I	1	1	20	70	13,750	9,821	6.250	4.464			ICK		
Suzhou XiangCheng II:	CN	2017	M														
Ekolojik Enerjy Inc. Istanbul	TR	A			2	1	20	40	18,335	9,167	8.334	4.167					
Shanghai ZhuYuan SMI Water	CN	2020	M		10	2	20	70	14,692	10,494	6.678	4.770	MSI			IHW	
Sinopec Zhong An	CN	2019	I		1	1	15	70	2,200	1,729	1.000	786				IHW	
BaoLai	CN	A		I	1	1	20	70	3,208	2,290	1.458	1.041	MSI				
Chengdu	CN	2020	M		1	1	18	35	20,165	8,906	9.166	4.048	MSI				
Yulin	CN	A		I	1	1	18	60	3,080	2,156	1.400	980					LF
Gulei	CN	A		I	1	1	20	70	2,750	1,965	1.250	893				IHW	
Pudong	CN	A	M		8	1	20	38	11,915	5,645	5.416	2.566	MSI				
Costa Facinosa	D	A	M		1	1	20	90	4,620	3,593	2.100	1.633					
Lijiao	CN	A	M		2	1	20	70	8,021	5,729	3.646	2.604			ICK	IHW	

Reference List Sludge Drying – Status 12/2020

User / Location	Country	Start up	Type of Sludge		No. of Lines / Stages		Drying Capacity per Line: Inlet Dry Solid Content %D.S.	Product Dry Solid Content %D.S.	Feed Rate lb/h	Evapo-ration Rate lb/h	Feed Rate kg/h	Evapo-ration Rate kg/h	Sludge disposal				
Hunan Puxiang Env/ChangSha	CN	A	M		4	1	18	35	13,750	6,677	6.250	3.035				IHW	
Quinpu	CN	A	M		4	1	20	45	10,083	5,601	4.583	2.546	MSI				
Huizhou, Huilian	CN	A		I	1	1	15	65	3,850	2,961	1.750	1.346	MSI				
Shenghong Shihua	CN	A		I	1	1	20	70	9,808	7,007	4.458	3.185	MSI				

A	=	Under construction	G	=	Gasification
			IMW	=	Incineration with Municpal Waste
M	=	Municipal	MSI	=	Mono Sludge Incineration
I	=	Industrial	ICK	=	Incineration in Cement Kiln
O	=	Oil Sludge	AA	=	Agricultural Application
*	=	Second stage / post drying by others	LF	=	Landfill
			IHW	=	Incineration with hazardous waste