1200 King County Courthouse
516 Third Avenue
Seattle, WA 98104

KING COUNTY

Signature Report

Motion 16492

Proposed No. 2023-0261.1 **Sponsors** Upthegrove

A MOTION acknowledging receipt of a biosolids thermal drying phase 2 report, prepared in accordance with the 2023-2024 Budget Ordinance, Ordinance 19546, Section 113, Expenditure Restriction ER2 and Proviso P1.

WHEREAS, the King County 2023-2024 Budget Ordinance, Ordinance 19546, Section 113, Expenditure Restriction ER2 and Proviso P1, states that $100,000 shall not be expended or encumbered until the executive transmits a biosolids thermal drying phase 2 report, and a motion that acknowledges receipt of the phase 2 report is passed by the council, and

WHEREAS, the executive has transmitted to the council the requested report entitled Biosolids Thermal Drying Phase 2 along with a motion acknowledging the receipt thereof by June 30, 2023;

NOW, THEREFORE, BE IT MOVED by the Council of King County:

Receipt of the Biosolids Thermal Drying Phase 2 Report, Attachment A to this motion, is hereby acknowledged.

Motion 16492 was introduced on 9/12/2023 and passed by the Metropolitan King County Council on 11/28/2023, by the following vote:

Yes: 9 - Balducci, Dembowski, Dunn, Kohl-Welles, Perry, McDermott, Upthegrove, von Reichbauer and Zahilay

KING COUNTY COUNCIL
KING COUNTY, WASHINGTON

DocuSigned by:
E76CE01F07B14EF...
Dave Upthegrove, Chair

ATTEST:

DocuSigned by:
Melani Hay
8DE1BB375AD3422...
Melani Hay, Clerk of the Council

Attachments: A. Biosolids Thermal Drying Phase 2 Report June 2023

Attachment A

Motion 16492

Biosolids Thermal Drying Phase 2 Report

June 2023

King County

I. Contents

II. Proviso Text

Ordinance 19546, Section 113, DNRP WTD, Expenditure Restriction ER2 and Proviso P1[1]

ER2 EXPENDITURE RESTRICTION**:** Of this appropriation, $100,000 shall be expended or encumbered solely to complete the biosolids thermal drying Phase II evaluation required by Proviso P1 of this section.

P1 PROVIDED THAT**:** Of this appropriation, $100,000 shall not be expended or encumbered until the executive transmits a biosolids thermal drying phase 2 report ("phase 2 report") and a motion that should acknowledge receipt of the phase 2 report, and a motion acknowledging the receipt of the phase 2 report is passed by the council. The motion should reference the subject matter, the proviso's ordinance number, ordinance section and proviso number in both the title and body of the motion.

In September 2022, the executive transmitted the August 2022 Biosolids Thermal Drying Report ("the report"). The report sets forth the "significant considerations" identified by Murraysmith, the consultant retained by the wastewater division to evaluate a biosolids thermal drying concept put forth by a private vendor and technology consortium called the King County Biosolids Partnership ("the Biosolids Partnership").

In response to the report, the Biosolids Partnership has revised its initial proposal, including substituting green electricity for woody material as the energy source to dry the biosolids mass and seeking to address contaminants of emerging concern ("CECs") in biosolids ("the revised proposal"), which the analysis of the report's Baseline Alternative does not. CECs, including per- and polyfluorinated alkyl substances ("PFAS") continue to gain national attention for their harmful impacts to public health. According to the report, the U.S. Environmental Protection Agency is set to finalize its risk assessment for these chemicals through its PFAS Strategic Roadmap 2021-2024 and determine their appropriateness in biosolids moving forward. To sufficiently evaluate the revised proposal, a follow-on, phase 2 report on biosolids thermal drying, built upon the report and in consultation with Murraysmith, shall include, but not be limited to, the following:

A. A description of the outreach to Biosolids Partnership to obtain from Biosolids Partnership the revisions to its initial proposal, including cost estimates to implement this revised proposal;

B. Using the same report requirements as set forth in the report, evaluation of the Biosolid Partnership's revised proposal;

C. Comparison of the actual or projected levels of CECs in the end product of the Baseline Alternative to the revised proposal; and

D. If not otherwise addressed in the phase 2 report, an assessment as to whether each of the significant considerations raised by Murraysmith in the report also apply to the revised proposal and, if so, why.

The executive should electronically file the evaluation and motion required by this proviso no later than June 30, 2023, with the clerk of the council, who shall retain an electronic copy and provide an

[1] Link to Ordinance 19546

electronic copy to all councilmembers, the council chief of staff and the lead staff for the transportation, economy and environment committee or its successor.

III. Executive Summary

Through a Proviso in the 2022 budget, the Council directed the Executive to conduct and transmit a second Phase Two independent study of the Biosolids Partnership's revised thermal drying concept.[2] The Biosolids Partnership concept is that all biosolids produced by King County's three regional wastewater treatment plants be processed in a facility located at King County's South Treatment Plant. The Biosolids Partnership recommended that biosolids be thermally dried into Class A pellets and sold through a public-private partnership for use as a fuel or fertilizer. The Biosolids Partnership cited savings in carbon emissions, use of renewable electricity, and elimination of per- and polyfluoroalkyl substances (PFAS) as benefits of its revised proposal.

This is the second report evaluating this concept. In August 2022, in response to a previous Proviso contained in Ordinance 19364, Section 83, Expenditure Restriction ER2, Proviso P5, the Executive transmitted a Biosolids Thermal Drying Report evaluating this concept.[3] The 2022 report set forth "significant considerations" identified by Consor (formerly Murraysmith), the independent consultant retained by DNRP's Wastewater Treatment Division (WTD) to evaluate the Biosolids Partnership's proposal.[4] In its 2022 report, Consor recommended that King County continue implementing its current biosolids program of using Class B biosolids land application and developing of a Class A composting program (the baseline alternative).

In response to the 2022 report, the Biosolids Partnership revised its proposal to utilize renewable energy purchased from Puget Sound Energy, with the dried Class A biosolids being sold for use as fuel for private cement plant operations. This report summarizes Consor's evaluation of the revised proposal. As directed by the King County Council, this Phase Two report uses the same evaluation criteria as the first report and assesses whether each of the "significant considerations" identified in the first report also apply to the revised proposal. The Phase Two report also includes a description of outreach to the Biosolids Partnership and a comparison of projected levels of contaminants of emerging concern (CECs) in the respective end products.[5]

Overall, Consor found that the revised Biosolids Partnership proposal has simplified the proposed biosolids drying and disposal process from the original proposal and addressed many of the challenges identified in the previous report, including the unproven application of multiple technologies in tandem, lack of redundancy, system complexity, facility size, and feedstock supply. The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis

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[2] Link to Ordinance 19546, Section 113, Expenditure Restriction ER2 and Proviso P1

[3] Link to the 2022 report to Council entitled *Biosolids Thermal Drying Report*

[4] Murraysmith was acquired by Consor in late 2022, so while WTD retained the same consultant to conduct both the 2022 and 2023 analyses, the name is different. Outside of the language in Ordinance 19546, the consultant will be referred to as Consor throughout this report.

[5] An emerging contaminant is a chemical or material characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards.

lifecycle and is incapable of meeting state biosolids regulatory requirements or complying with current county policies. Consor identified the following unresolved significant concerns:

- Public agency experience with the process is limited as there are currently only two fluidized bed driers treating biosolids in North America and both are operated by private contractors. [6]
- The scalability of drying systems is poor and major investments would be required to increase capacity.
- Significantly higher capital costs than the baseline alternative.
- Significantly higher lifecycle costs than the baseline alternative, with a potentially short total lifespan.
- Only one end-user, a local cement manufacturing plant, was identified. Other agencies producing dried pellet biosolids have had difficulty identifying end-users, so the market may be limited.[7]
- No end-users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer.[8]
- The biosolids would not be available for community use as the final product would be used as fuel for private cement plant operations.
- Energy use would increase compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase.[9]
- The process would increase carbon dioxide emissions compared to the baseline alterative.
- There would be additional costs for treatment of nitrogen load from the dryer condensate.
- The process does not conform to Washington Administrative Code (WAC) requirements for biosolids in Chapter 173-308.[10]
- The process does not meet King County biosolids policies found in King County Code (KCC) 28.86.090.[11]
- The process does not align with the County's *2020 Strategic Climate Action Plan* goals to reduce greenhouse gas emissions and achieve carbon neutral operation.[12,13]

Consor recommended that King County continue implementing the current program direction, which involves Class B land application while developing a Class A composting program. Consor also encouraged King County to continue monitoring biosolids technologies that may be able to meet regulatory requirements at a cost-effective price to maximize program reliability and minimize risk. DNRP concurs with Consor's findings and recommendations.

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[6] Fluidized bed driers are a technology that further and drastically remove the moisture content from dewatered wastewater solids.

[7] At the time of Consor's final report, only one cement manufacturing plant potential user had been identified. DNRP understands that the Biosolids Partnership continues to seek additional cement manufacturing plants.

[8] The Biosolids Partnership proposal would result in 47,700 MWh/hr of excess heat energy produced, above and beyond the treatment plant's heat needs. There are several barriers to finding an external user for this excess heat energy. This is detailed in Consor's report on page 2-16.

[9] Green Direct is a program of the Puget Sound Energy utility which provides corporate and governmental customers the ability to purchase 100 percent of their energy from a dedicated, local, renewable energy source.

[10] WAC 173-308 can be found here.

[11] King County Code Title 28 can be found here.

[12] The Section on greenhouse gas from the Strategic Climate Action Plan is here.

The County is nearing construction of a Class A compost pilot project at the South Treatment Plant as authorized by the adopted 2021-2022 King County Budget.[13] This pilot would test the marketability of a Class A compost product that would be sold locally as a soil amendment.

Following completion of their report in April 2023, Consor released a copy to the Biosolids Partnership, and there has been additional communication between the two parties. This communication is included as Appendices B and C. Overall, this additional communication does not change any of the conclusions outlined in Consor's report. DNRP concurs with the conclusions outlined in Consor's May 2023 response to Andritz (Appendix C).

IV. Background

Department Overview: The Department of Natural Resources and Parks (DNRP) works to support sustainable and livable communities and a clean and healthy natural environment. Its mission is to foster environmental stewardship and strengthen communities by providing regional parks, protecting the region's water, air, land, and natural habitats, and reducing, safely disposing of, and creating resources from wastewater and solid waste.

The Wastewater Treatment Division (WTD) of DNRP protects public health and enhances the environment by collecting and treating wastewater while recycling valuable resources for the Puget Sound region. The Biosolids Program in WTD manages the distribution and use of Loop®, a branded biosolids product created by recycling the County's wastewater.[14,15]

Key Historical Conditions: Since its inception in 1972, the King County Biosolids Program has taken a market-based approach to biosolids management, focusing on creating high-quality, marketable products and developing strong customer relationships.[16] The King County Biosolids Program has successfully produced and distributed its Loop® brand of biosolids for almost 50 years, with full regulatory compliance and beneficial use.[17]

In response to the federal Clean Water Act (CWA) of 1972, the King County Biosolids Program, in conjunction with University of Washington scientists, began researching and developing a program for biosolids to be used on forestlands and land reclaimed from other uses, such as mining. From 1978-2020, the King County Biosolids Program entered a long-standing partnership with GroCo, Inc., to compost a portion of the County's biosolids into a retail garden product until GroCo's closure in 2020.[18]

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[13] Link to the 2021-22 King County Budget Book; see pg. 420 for a listing of the compost pilot (project #1139044)
[14] The term "biosolids" refers to the solid organic matter recovered from the wastewater treatment process that can be used as a soil amendment or enhancement. Loop® is the brand name of the biosolids produced at King County's three wastewater treatment plants.
[15] Loop® is a natural soil builder and an endlessly renewable resource that returns carbon and nutrients to the land.
[16] Market-based approaches use business models and supply and demand market forces to address public interest challenges more sustainably and/or at scale.
[17] Loop® Biosolids [www.loopforyoursoil.com]
[18] GroCo, Inc. was a private company operating in King County, WA that produced compost, sawdust, and other landscaping materials for retail sale, until its closure in 2020.

Composting involves mixing biosolids with woody material, such as sawdust, yard clippings, or wood chips, so microorganisms can break down the material into a garden product called compost.[19] After nearly two decades of operations, the King County Biosolids Program added two agricultural projects in Yakima and Douglas counties.

In 1993, federal biosolids regulations were added to the CWA. Section 40 CFR Part 503 of the CWA established standards, which consist of general requirements, pollutant limits, management practices, and operational standards for the final use of biosolids generated during the treatment of domestic sewage.[20] Washington state followed suit, developing the biosolids rule in Chapter 173-308 in the Washington Administrative Code (WAC) in 1998.[21] It is important to note that the established biosolids rule "encourages the maximum beneficial use of biosolids" and "recognizes biosolids as a valuable commodity." The biosolids rule incorporates all the legal requirements in the federal rule, with additional site-specific plans for land application and public notice requirements.

Federal and State regulations established two types of biosolids: Class A and Class B. Class A biosolids have virtually no detectable pathogens and can be used without a permit from the Washington State Department of Ecology. King County produces Class B biosolids, which are treated but do contain detectable levels of pathogens and require a state permit for use.

In addition to developing a successful Class B program, the King County Biosolids Program examined opportunities for Class A options many times over the past several decades. Completed in 2020, the most recent comprehensive examination of the potential use of Class A biosolids was a report and consultant study entitled *Alternative Options for the Use of Biosolids*. This report was prepared and transmitted to the Council in response to a 2019 Council budget Proviso.[22,23] The 2020 report compared three alternative scenarios for King County's Biosolids Program using a variety of factors, including capital and operating costs, transportation costs, environmental impacts, equity and social justice factors, technical and implementation difficulty, and synergy with King County objectives and WTD priorities, and provided a triple-bottom-line score for each.[24] In general, these options have not been undertaken due to prioritization of other operational and infrastructure needs. The results of the 2020 report are summarized below in Table 1.

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[19] Composting is an aerobic biological process that uses microorganisms in the presence of air to decompose organic material and produce heat to reduce pathogens to Class A requirements. Composting biosolids involves mixing Class B biosolids with woody materials to accelerate decomposition.
[20] Information on the Clean Water Act can be found here and Section 40 is here.
[21] The biosolids rule in Chapter 173-308 of the WAC can be found here.
[22] Link to the 2020 report to the Council entitled *Alternative Options for the Use of Biosolids*
[23] Link to Ordinance 18930, Section 72, Proviso P3
[24] The triple bottom line method — an analysis method to account for environmental, economic, and social factors — is commonly used in planning or feasibility studies to evaluate King County alternatives, options, and projects. The triple-bottom-line analysis used in the 2020 report was adapted from the King County Biosolids Program Strategic Plan 2018-2037, completed in 2018. The triple-bottom-line analysis was modified to be more robust and to better align with King County priorities, through the addition of a technical category, consideration of market risk, continuation of 100 percent beneficial reuse, and expanded equity and social justice criteria. Four criteria categories were developed for this effort: social, environmental, economic, and technical.

Table 1. Summary of Results From 2020 *Alternative Options for the Use of Biosolids* Report

Alternative Scenario	Description	Triple-Bottom-Line Score
100 Percent Class A Biosolids	This option leverages different technologies to transition to a 100 percent Class A biosolids program, which includes Class A digestion at the treatment plants paired with processing at a soil blending facility, as well as composting Class B biosolids into a Class A compost.[25]	Very High
Baseline: Class B Biosolids	Continuation of the existing Class B biosolids program, including necessary capital upgrades to address future treatment capacity needs and maintenance of the treatment system that produces biosolids.	High
Pyrolysis[26]	The creation of a public-private partnership to dry and pyrolyze Class B biosolids at a new offsite pyrolysis facility.	Medium

The 2020 report also noted that any development of a Class A biosolids program would require changes to the biosolids policies in the King County Code, which currently prohibits the production and sale of anything other than Class B biosolids.[27]

In 2021, a private vendor and technology consortium called the Biosolids Partnership briefed members of the King County Council about their idea for King County to produce Class A pellets from biosolids. At that time, the Biosolids Partnership recommended that biosolids produced by all three of King County's regional wastewater treatment plants be processed in a new facility to be located at the County's South Treatment Plant. The Biosolids Partnership also recommended thermally drying biosolids into Class A pellets and selling the pellets through a public-private partnership for use as a fuel or fertilizer. The Biosolids Partnership cited savings in cost and carbon emissions as two major benefits of its concept.

The Biosolids Partnership concept has many similarities with the pyrolysis alternative discussed and analyzed in the 2020 report referenced above.[28] Through a Proviso in the 2021 budget, the Council directed the Executive to conduct and transmit an independent study of the private consortium's thermal drying concept.[29] DNRP retained Murraysmith (now Consor) to conduct this study, which was transmitted to the Council in August 2022.[30] Murraysmith identified several significant considerations, should the County choose to pursue implementation of the Biosolids Partnership thermal drying

[25] Digestion refers to the process in which microorganisms break down biodegradable material, like solids in wastewater. When it is done in the absence of oxygen, it is called anaerobic digestion. Class A digestion creates biosolids that meet U.S. Environmental Protection Agency standards by operating at a temperature of 122°F to 140°F, called thermophilic temperatures, in order to reduce pathogens to the level required for Class A biosolids. To make a marketable product, Class A digestion can be combined with soil blending, which involves mixing Class A biosolids with sand and woody materials, such as bark and sawdust, to create blends that can be used as potting mix or topsoil.

[26] Pyrolysis is a decomposition process that occurs at temperatures in excess of 572°F in the absence of oxygen. The process produces a charcoal-like soil amendment called biochar.

[27] Link to King County Code 28.86.090 Biosolids policies (BP)

[28] Link to the 2020 report to Council entitled *Alternative Options for the Use of Biosolids*

[29] Link to Ordinance 19364, Section 83, Expenditure Restriction ER2 and Proviso P5

[30] Link to the 2022 report to Council entitled *Biosolids Thermal Drying Report*

concept, including: significantly higher cost; unknown market demand; inconsistency with policy; issues with land acquisition, siting, permitting, and operations; and risk from using a single supplier of woody biomass feedstock as an energy source. Murraysmith ultimately recommended that King County continue implementing the current program, which uses Class B biosolids land application and is moving toward the development of a Class A composting program as planned, and that the Biosolids Partnership's proposal not be considered further.

Key Current Conditions: The King County Biosolids Program plays a key role in accomplishing the goals of the Clean Water Healthy Habitat initiative and the County's Strategic Climate Action Plan, primarily through carbon sequestration from land application.[31,32,33] In recent years, Loop® biosolids use has provided approximately 20 percent of the carbon offsets for the DNRP's carbon footprint.[34] When biosolids are applied to land, carbon emissions are reduced in three principal ways:

1) the biosolids' inherent carbon content is sequestered in soil;
2) the nutrients from biosolids enable plants to grow more robustly and remove more carbon from the atmosphere; and
3) the nutrients contained in biosolids allow farmers to reduce synthetic fertilizer use, which requires significant energy to produce.

Additionally, heat and biogas energy are captured and reused from the biosolids anaerobic digesters at King County's wastewater treatment plants, allowing the facilities to operate in a more energy efficient manner. At the South Treatment Plant, the biogas produced from the biosolids anaerobic digesters is sold to Puget Sound Energy, which provides revenue for DNRP's carbon emissions reduction projects. The biogas also contributes a renewable energy source for use by the community, which helps offset the region's overall carbon emissions.[35] In addition to carbon benefits, biosolids provide slow-release nutrients and improve the soil's ability to hold moisture, thereby reducing soil runoff, erosion, and associated water pollution.

King County currently produces up to 130,000 wet tons of biosolids each year from three regional treatment plants, which is equivalent to filling 8,000 King County Metro buses. Each of King County's treatment plants is slightly different, but all use a technology called mesophilic anaerobic digestion, which is done in a large, heated tank where microorganisms break down the solids, a process similar to the way a human stomach digests food. King County uses 100 percent of the Class B Loop® biosolids produced at the County's wastewater treatment plants in a beneficial manner on land, primarily as a fertilizer replacement in forestry and agriculture. However, with limited land available for forest application, the program has become more reliant on agricultural uses, which could reduce options for the King County Biosolids Program if biosolids use in agriculture declines.

Washington state farmers in Douglas, Lincoln, Benton, and Yakima counties currently use approximately 65 percent of King County's biosolids, while commercial timberland in the Cascade foothills uses approximately 35 percent. In May 2020, the King County Biosolids Program's compost partner, GroCo,

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[31] Carbon sequestration refers to the process of removing carbon dioxide from the atmosphere.
[32] The website for Clean Water Healthy Habitat can be found here.
[33] More information on the Strategic Climate Action Plan can be found here.
[34] Carbon offsets refer to actions taken to compensate for carbon dioxide emissions. Offsets can be traded as part of environmental programs.
[35] Puget Sound Energy [https://www.pse.com]

Inc. — which used one percent of King County's Loop® product as an ingredient to produce a retail garden product called GroCo compost — closed its business. While one percent is a small amount and King County did not own the final product, GroCo compost made with Loop® was the only publicly accessible biosolids product available for use by King County residents and gardeners. In addition, DNRP's Class A compost partnership with GroCo, Inc., allowed DNRP to participate in King County Equity and Social Justice initiatives by supporting community gardens in underserved areas through compost donations and an extensive outreach and education program.[36] Other composters in the region are already nearing capacity, meaning they cannot accept biosolids for use in compost and have not shown interest in partnering with the King County Biosolids Program on a new product. Several past studies of Class A technologies, including the previously cited 2020 *Alternative Options for the Use of Biosolids* and the 2022 *Biosolids Thermal Drying* reports have indicated composting as a low-cost, low-carbon-emission strategy for producing a Class A product that could be readily utilized by King County residents.[37] Compost also provides a valuable product that could boost market diversity and reduce the cost of transitioning to a 100 percent Class A program through revenue from product sales.[38,39]

King County is currently in the process of constructing a small-scale, temporary compost pilot project at the South Treatment Plant, as authorized by the 2021-2022 King County Budget.[40] The objective of the compost pilot is to explore the technical and financial attributes of eventually developing a full-scale, in-house compost facility as an alternative method to further process Class B biosolids into a marketable Class A product. Once the composting pilot is operational, the information produced will be used to demonstrate proof of concept, inform a business case for composting, develop reliable sources of feedstocks, test products and production processes, develop markets and distribution channels, assess community support, and, ultimately, collect data to inform a capital project process for a larger, permanent, off-site facility. The current cost estimate for the pilot project is $5.6 million, with project completion anticipated by spring of 2024.

In 2022, after transmittal of the Murraysmith *Biosolids Thermal Drying Report* to the Council, the Biosolids Partnership submitted a revised proposal to members of the King County Council, stating that the revised proposal would resolve the concerns identified Murraysmith's 2022 report. The Biosolids Partnership's revised proposal substitutes "green electricity" for woody material as the energy source to dry the biosolids and seeks to address CECs in biosolids.

Through a Proviso in the 2022 budget, the Council directed the Executive to conduct and transmit a second Phase Two independent study of the Biosolids Partnership's revised thermal drying concept.[41] In keeping with the Council's direction to retain the same consultant, DNRP contracted with Consor (formerly Murraysmith) and sought involvement and direct communication between the Council sponsor of the Proviso and the independent consultant. This enabled the Council to provide direct input on the scope of work and deliverables, helping to ensure the independence of the consultant review.

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[36] Link to The Determinants of Equity: Identifying Indicators to Establish a Baseline of Equity in King County, 2015.
[37] Link to the 2022 report to Council entitled *Biosolids Thermal Drying Report*
[38] Link to the 2020 report to Council entitled *Alternative Options for the Use of Biosolids*
[39] A compost market assessment showed that there is market opportunity for King County biosolids compost representing approximately 20 percent of the total biosolids production.
[40] Link to the 2021-22 King County Budget Book; see pg. 420 for listing of compost pilot (project #1139044)
[41] Link to Ordinance 19546, Section 113, Expenditure Restriction ER2 and Proviso P1

Report Methodology: DNRP contracted with Consor, the same consulting firm contracted for the 2022 *Biosolids Thermal Drying* report, to perform a second independent review of the Biosolids Partnership's revised thermal drying proposal, as compared to the status quo current direction for the Biosolids Program (Class B land application with a compost pilot).[42,43] Consor is a large, established consulting firm that works nationwide and specializes in the funding, planning, design, and construction management of water-based public infrastructure.[44] After being contracted by WTD, Consor held a meeting with King County staff and the Councilmember who included the Proviso to receive direct input on Consor's strategy and deliverables for the independent review.[45] In addition, DNRP provided Consor with access to King County documents and program staff, as well as access to the Biosolids Partnership consortium representatives so that Consor was able to obtain information it deemed necessary to conduct its evaluation.

In developing the scope of work for the independent consultant, DNRP used the same criteria for the evaluation as was used for the 2022 *Biosolids Thermal Drying* report.[46] The following evaluation criteria were developed with input from, and approval of, the Council sponsor of the Proviso:

- Issues around **Cost and Scalability** including risk and benefits, capital costs, operations and maintenance, implementation, and lifecycle cost.[47]
- **Community concerns** including social impacts, equity and social justice, odor, trucking impacts to neighborhoods, and the ability for communities (in King County or statewide) to utilize biosolids to amend and build their soils for urban or rural agriculture.
- **Environmental impacts** including air pollution, air quality, climate footprint, the overall energy use and maximization of renewable energy sources, contaminants of emerging concern (CEC) reduction[48]
- **Economic Impacts** including biosolids product marketability, either as a fertilizer product for residential/commercial use or an energy product, diversity of biosolids product user portfolio
- **Policy impacts** including compliance with local, state, and federal regulations, cohesion with current County policies and initiatives, including the Strategic Climate Action Plan (SCAP) in support of energy, water consumption, and carbon-related and greenhouse gas reduction goals.

For the 2023 report, DNRP added specific Council-requested items to the scope of work, including: a description of outreach to the Biosolids Partnership; a comparison of projected CEC levels in the end

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[42] At the time of the 2022 *Biosolids Thermal Drying* report, the consultant was named Murraysmith. Murraysmith was acquired by Consor in late 2022, so while WTD retained the same consultant to conduct both the 2022 and 2023 proviso-requested analyses, the name is different. Outside of the language in Ordinance 19546, throughout this 2023 report the consultant will be referred to as Consor, its new name.
[43] Consor general website [https://www.consoreng.com]
[44] Consor water expertise website [https://www.consoreng.com/water/]
[45] Consor conducted a participant focus group with representatives from the Council on March 6, 2023. A Councilmember and one of his staff attended.
[46] Criteria used in the 2022 report can be found on pages 68-69 of Appendix A.
[47] Lifecycle cost aggregates all costs that an organization or individual will incur over the life span of the asset, project, investment, etc. It includes the initial investment and any further investment such as operating cost, maintenance, repair, and upgrades.
[48] An emerging contaminant is a chemical or material characterized by a perceived, potential, or real threat to human health or the environment or by a lack of published health standards.

products; and an assessment of whether the significant considerations raised in the 2022 report also apply to the Biosolids Partnership's revised proposal. The deliverables for the independent consultant's Phase Two scope of work are as follows:

Phase 2 Report [shall include]:
1. *Using the same requirements in Phase 1 [listed below], evaluate the revised proposal*
    a. *Ranked table listing each alternative with its relevance to each of the criteria identified in Task 400*[49]
    b. *Analysis of Thermal Drying at South Plant*
    c. *Analysis of the current King County Class B Biosolids Program and near-term composting program*
    d. *The Thermal drying alternative will have an implementation plan including identification of budget and policy change needs.*
    e. *Class 5 cost estimate utilizing WTD's template*[50]
    f. *Clearly identify the most beneficial future state for WTD*
    g. *Other deliverables as identified through participant focus group*
2. *Comparison of the actual or projected levels of CECs in the end-product of the Baseline Alternative to the revised proposal*
3. *Evaluation of the use of green energy as the energy source to dry the biosolids mass*
4. *Assessment as to whether each of the significant considerations raised by Consor (formerly Murraysmith) in the Phase 1 report also apply to the revised proposal*
5. *Description of the outreach to the Biosolids Partnership to retrieve the new revised proposal*

V. Report Requirements

This section is organized to follow the Proviso requirements.

A. Description of the outreach to Biosolids Partnership to obtain from Biosolids Partnership the revisions to its initial proposal, including cost estimates to implement this revised proposal

Below is a list of engagement activities describing Consor's outreach to the Biosolids Partnership.

[49] Task 400 refers to the list of evaluation criteria for the consultant scope of work, as listed on page 12 of this report.

[50] WTD utilizes a form of the Association for the Advancement of Cost Engineering's Class 5 estimate standards for planning-level evaluations.

Date	Activity	Summary
1.23.23	Consor leads kickoff meeting with the Biosolids Partnership and DNRP	Discussion of the Biosolids Partnership's intent to develop a revised proposal for sludge drying facilities at the South Treatment Plant including key elements of the revised approach.[51]
2.13.23	Biosolids Partnership provides proposal document to Consor	Biosolids Partnership provided written proposal document to Consor.
3.3.23	Consor data request to Biosolids Partnership	Consor requested additional data and information from the Biosolids Partnership.
3.3.23	Biosolids Partnership provides letter of interest from local cement producer	Biosolids Partnership shared with King County staff and Consor a letter of interest from a local Seattle-area cement producer indicating a desire to use the Class A pellets potentially produced by King County in the cement manufacturing process but requested confidentiality regarding their involvement. To honor this request, Consor did not name the manufacturer in its report.
3.6.23	Consor leads meeting with the Biosolids Partnership, WTD staff, and a King County Councilmember	Discussion with the Biosolids Partnership, WTD staff, and a King County Councilmember to further discuss the revised proposal and solicit input from the King County Councilmember. Biosolids Partnership requested follow up information from King County.
3.16.23	King County provides requested follow up information to Biosolids Partnership	King County provided to Biosolids Partnership the information that was requested on 3.6.23.
3.20.23	Biosolids Partnership provides requested follow up information to Consor	Biosolids Partnership provided to Consor information that was requested on 3.3.23.

A narrative summary on outreach to the Biosolids Partnership is provided in Consor's report; subsection 2.1 of Appendix A.[52] Copies of relevant correspondence with the Biosolids Partnership are also included as an appendix to Consor's report.[53] Communication from Biosolids Partnership has continued. For example, DNRP understands that the Biosolids Partnership continues to seek additional cement manufacturers that might desire to use the pellets.

[51] Sludge drying facilities are a treatment process that evaporates water in the sludge.
[52] Appendix A, page 2-1
[53] Copies of correspondence between Consor and the Biosolids Partnership can be found beginning on page 371 of Consor's report.

B. Using the same report requirements as set forth in the [2022] report, evaluation of the Biosolids Partnership's revised proposal

Consor's 2023 report (Appendix A) details its evaluation of the Biosolids Partnership's revised proposal. A summary of Consor's quantitative evaluation of the revised proposal, as compared to the baseline alternative and the initial Biosolids Partnership proposal, is found in Consor's report, and included below.[54] A plus (+) indicates a benefit, a minus (-) indicates a detriment, and a null (0) indicates neither significant benefit nor detriment.

The table shows Consor's analysis, finding that overall, the revised Biosolids Partnership proposal has improved on some metrics over the original proposal. It also shows that the baseline alternative of continuing Class B biosolids land application plus Class A composting still meets or exceeds the Biosolids Partnership proposals on most metrics.

[54] Appendix A, page 2-24

Table 2-6 | Qualitative Evaluation Summary

Evaluation Criteria	Baseline Alternative Rating	Initial Proposal	Revised Proposal
Scalability	+	-	-
Risk & Benefits	+	-	0
Cost	+	-	-
Capital cost	+	-	-
O&M cost	-	0	0
Lifecycle cost	0	-	-
Social Impacts	0	-	-
ESJ	+	-	0
Odor	-	-	0
Air pollution	0	-	0
Trucking impacts to the community	0	-	0
Ability for communities (in King County or statewide) to use biosolids to amend/build soils for urban or rural agriculture	+	-	-
Environmental Impacts	+	-	0
Overall energy use and maximizing use of renewable energy sources	0	+	-
Climate footprint	+	-	0
Air quality	0	-	0
Water quality	0	0	0
CECs reduction[b]	0	0	+
Economic Impacts	+	-	-
Biosolids product marketability	+	-	-
Diversity of biosolids product user portfolio	+	-	-
Policy Impacts	+	-	-
Compliance with local, state, and federal regulations	+	-	-
Cohesion with current County policies and initiatives	+	-	-

Notes:

a. A **plus** (**+**) indicates a benefit, A **minus** (**-**) indicates a detriment, and a **null** (**0**) indicates no significant benefit nor detriment.

b. Full destruction is not guaranteed. Additional research on CEC destruction in cement kilns is ongoing, but current research shows potential for cement kiln CEC reduction is greater than composting or drying.

C. Comparison of the actual or projected levels of CECs in the end-product of the Baseline Alternative to the revised proposal

Consor notes in its 2023 report that currently, the main CEC of interest in biosolids are per- and polyfluoroalkyl substances (PFAS) and related compounds. Consor states that thermal treatment with combustion or incineration is known to be the primary biosolids treatment technology available to destroy PFAS and notes that variables and unknowns remain. The effectiveness of complete PFAS destruction depends on time, turbulence, and temperature.[55]

[55] Appendix A, pages 2-20 through 2-22

According to Consor, the Biosolids Partnership's thermal drying technology would not reach temperatures needed to destroy PFAS in the end-product. According to Consor, the only pathway for PFAS to potentially be destroyed in the revised proposal is through delivery to, and use in, a cement kiln. If the resulting pellets were used as fuel for cement kilns, the PFAS destruction could reach upwards of 99 percent, considering typical cement-kiln temperatures and residence times. It is not known whether the PFAS compounds are fully destroyed or merely transformed into smaller PFAS products or products of incomplete combustion. These smaller PFAS products have not been fully researched and they could remain a potential CEC.

Consor notes that, while delivery of biosolids pellets to a cement manufacturing plant is the basis of the proposal based on discussions with other biosolids drying facilities, it is unrealistic to expect that all biosolids pellets produced would be sent to this facility. Alternative end-uses for dried biosolids pellets would be land application, similar to the baseline alternative, none of which destroy PFAS. More information on CECs is provided in subsection 2.4.5.4 of Appendix A.[56]

D. Assessment of whether each of the significant considerations raised by Consor in the [2022] report also apply to the revised [Biosolids Partnership] proposal, and if so, why.

Overall, Consor found that the revised Biosolids Partnership proposal has simplified the proposed biosolids drying and disposal process from the original 2022 proposal. It also addresses many of the challenges identified in the previous report, including the unproven application of multiple technologies in tandem; lack of redundancy; system complexity; facility size; and feedstock supply.

The revised Biosolids Partnership proposal is technically feasible according to Consor. It remains fifty seven percent more expensive than the baseline alternative over the analysis lifecycle ($588 million for Biosolids Partnership revised proposal compared to $373.8 million for baseline alternative.)[57] Consor found that the proposal is incapable of meeting biosolids regulatory requirements and policies, as detailed in the bulleted list below. Consor identified the following unresolved substantial concerns:

- Public agency experience with the biosolids drying process is limited, as there are currently only two fluidized bed driers treating biosolids in North America, and both are operated by private contractors.
- The scalability of drying systems is poor; major investments would be required to increase capacity.
- Percent higher capital costs than the baseline alternative.
- Percent higher lifecycle costs than the baseline alternative, with potentially short total lifespan.
- Only one end-user, a local cement manufacturing plant, has been identified. Other agencies producing dried pellet biosolids have had difficulty identifying end-users, so the market may be limited.[58]
- No end users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer.

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[56] Appendix A, pages 2-20 through 2-22

[57] Cost information is found in Appendix A, pages 2-12 through 2-14

[58] At the time of Consor's final report, only one cement manufacturing plant potential user had been identified. DNRP understands that the Biosolids Partnership continues to seek additional cement manufacturing plants.

- The biosolids would not be available for community use.
- Energy use would increase compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase.
- The process would increase carbon dioxide emissions compared to the baseline alterative.
- There would be additional costs for treatment of nitrogen load from the dryer condensate.
- The process does not conform to Washington Administrative Code requirements for biosolids in Chapter 173-308.
- The process does not meet King County biosolids policies found in King County Code 28.86.090.
- The process does not align with the County's *2020 Strategic Climate Action Plan* goals to reduce greenhouse gas emissions and achieve carbon neutral operation.

Based on the findings of this analysis, Consor recommends that the County proceed as follows:

- Continue with implementation of the baseline alternative, which involves a combination of Class B land application and composting.
- Continue to evaluate biosolids technologies that may be able to meet regulatory requirements at a cost-effective price to maximize program reliability and reduce risk.

More information is detailed in section 3.1 of Appendix A.[59]

Following completion of their report in April 2023, Consor released a copy to the Biosolids Partnership. Following the release of the copy, Andriz, a private technology vendor associated with the Biosolids Partnership, prepared a point-by-point rebuttal to the main conclusions of Consor's report which are listed in Section D above. Andritz's rebuttal letter to Consor dated May 17, 2023, and is included as Appendix B.

In response to Andritz's rebuttal, Consor prepared a written response to each point raised by Andritz. Consor's response document dated May 23, 2023, is included as Appendix C. Overall, Consor's response further documents and explains Consor's conclusions, and does not change any of the conclusions outlined in its report. DNRP concurs with the conclusions outlined in Consor's response to Andritz.

VI. Conclusion

The independent consultant report (Appendix A) provides the following conclusions and recommendations. DNRP concurs with the conclusions reached in the consultant report. As a result, DNRP does not plan additional consideration of the specific concept put forth by the Biosolids Partnership. DNRP will continue to monitor all Class A biosolids technologies and operations that will utilize the renewable resources and reduce the County's carbon footprint, while maximizing program reliability and minimizing risk to the County.

Excerpts from the independent consultant report (Appendix A):

[59] Appendix A, page 3-1

Conclusions:
The revised Biosolids Partnership proposal has simplified the proposed biosolids drying and disposal process from the original proposal and addressed many of the challenges identified in the previous report, including the unproven application, lack of redundancy, system complexity, facility size, and feedstock supply. The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis lifecycle and is incapable of meeting biosolids regulatory requirements and policies.

VII. Appendices

Appendix A: Consor's *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal*, April 2023, King County WA
Appendix B: Andritz's [Biosolids Partnership member] rebuttal to Consor's *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal*, May 17, 2023
Appendix C: Consor's response to Andritz's rebuttal, May 23, 2023

APPENDIX A

King County, Washington

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal

April 2023

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Executive Summary

Background

In September 2021, a private entity that is comprised of several entrepreneurs, equipment manufacturers, and engineering design and construction companies known as Biosolids Partnership approached King County (County) Council with a proposal to convert all the County's Class B biosolids to a Class A product. Currently, the County produces Class B biosolids which are land applied at various locations in western and eastern Washington. A pilot system for Class A composting is currently being implemented at the South Wastewater Treatment Plant (WWTP), with construction planned to begin in 2023. The Biosolids Partnership proposal included provisions to use renewable energy to dry the biosolids to Class A requirements, supply heat to the process building and digestion operations at South WWTP, and maintain a net negative carbon impact. In response to a council request for an independent consultant evaluation of the Biosolids Partnership Proposal, an assessment of the feasibility and implementation plan of the Biosolids Partnership proposal was prepared and documented in the *King County Biosolids Class A Alternatives Analysis Final Report* (Murraysmith, June 2022), attached as Appendix A. This report evaluated the proposal and compared it against the County's existing 'baseline' plan to continue the Class B program for 80 percent of the biosolids and provide Class A composting for the remaining 20 percent of the biosolids. The conclusion of the report was that the Biosolids Partnership proposal had numerous risks and flaws that prevented it from being implemented and the baseline was a far more reasonable approach to biosolids management.

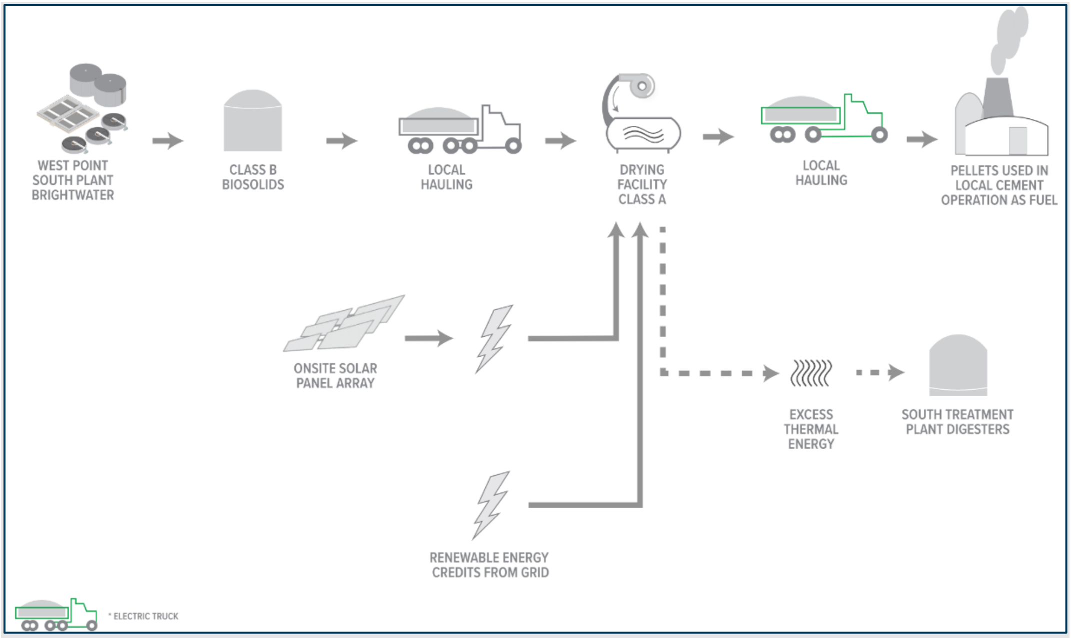
Following the publication of the *King County Biosolids Class A Alternatives Analysis Final Report*, Biosolids Partnership prepared a revised proposal with a new approach to use a fluidized bed dryer fueled with renewable energy purchased from the electrical supplier and to use the dried Class A biosolids as fuel for cement plant operation. This approach was presented to King County Wastewater Treatment Division (WTD) and Consor in January of 2023. The County requested that Consor conduct an additional evaluation of the revised proposal. The evaluation includes analysis of the feasibility of the approach, scalability, cost, environmental and climate impacts, and required changes to County policies. Like the prior report, the revised proposal was compared to the County's baseline alternative of continuing with Class B biosolids production and land application as well as producing Class A biosolids through off-site composting.

Description of Revised Alternative

As illustrated in Figure ES-1-1, the revised Biosolids Partnership proposal includes:

- Class B biosolids from all three WWTPs are hauled or conveyed to a centralized drying facility located in the northeast corner of the South WWTP using existing diesel trucks.
- Two fluidized bed driers, powered by a combination of renewable electricity from the Puget Sound Energy electric grid and on-site renewable energy, dry the biosolids to Class A requirements. Heat from the process is captured and reused to heat the anaerobic digesters.
- The dried biosolids pellets are hauled to a local cement plant using new electric trucks.
- The cement plant uses the biosolids as fuel in the kiln.

Figure ES-1-1 | Revised Class A Biosolids Proposal Diagram



Biosolids Partnership includes representatives of Andritz AG, an industrial machine design and manufacturing company that builds the type of fluidized bed dryer presented in the revised proposal. Biosolids Partnership has discussed the revised proposal with a local cement plant which has provided a letter of interest but requested to remain anonymous at this time. Additionally, Biosolids Partnership indicated that Synagro Technologies, Inc. (Synagro) is interested in partnering on the proposed centralized drying facility in a Design, Build, Operate, maintain contract or similar model.

Conclusions

The revised Biosolids Partnership proposal has simplified the proposed biosolids drying and disposal process from the original proposal and addressed many of the challenges identified in the previous report, including the unproven application, lack of redundancy, system complexity, facility size, and feedstock supply. The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis lifecycle, and it is incapable of meeting biosolids regulatory requirements and policies. These concerns are further detailed below:

- Public agency experience with the process is limited because there are currently only two fluidized bed driers treating biosolids in North America and both are operated by private contractors.
- The scalability of drying system is poor, major investments would be required to increase capacity.
- Significantly higher capital costs than the baseline alternative.
- Significantly higher lifecycle costs than the baseline alternative, with potentially short total lifespan.
- Only one end user, a local cement manufacturing plant, has been identified, and other agencies producing dried pellet biosolids have had difficulty identifying end users, so the market may be limited.

- No end users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer.
- The biosolids would not be available for community use.
- Energy use would increase compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase.
- The process would increase carbon dioxide emissions compared to the baseline alterative.
- Additional costs for treatment of nitrogen load from the dryer condensate.
- Does not conform to Washington Administrative Code requirements for biosolids in Chapter 173-308.
- Does not meet King County biosolids policies found in King County Code Title 28, Chapter 28.86.090.
- Does not align with the County's *2020 Strategic Climate Action Plan* goals to reduce greenhouse gas emissions and achieve carbon neutral operation.

Recommendations

Based on the findings of this analysis, Consor recommends that the County proceed as follows:

- Continue with implementation of the baseline alternative, which involves a combination of Class B land application and composting.
- Continue to evaluate biosolids technologies that may be able to meet regulatory requirements at a cost-effective price to maximize program reliability and reduce risk.

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CHAPTER 1

Background

1.1 Project Introduction

In September 2021, the Biosolids Partnership, a private entity that is comprised of several entrepreneurs, equipment manufacturers, and engineering design and construction companies, approached King County (County) Council with a proposal to treat all the County's biosolids. The proposal intended to convert the County's Class B biosolids from West Point Wastewater Treatment Plant (WWTP), Brightwater WWTP, and South WWTP, to a Class A product using thermal drying. The proposed system would use renewable electrical energy to produce heat for drying, and the waste heat would be reused to supply heat to the process building and digestion operations at South WWTP. The proposal claimed that the process would also produce a net negative carbon impact. In response to a Council request for an independent consultant evaluation of the Biosolids Partnership Proposal, King County Wastewater Treatment Division (WTD) contracted Consor North America Inc. (formerly Murraysmith) to perform an assessment on the feasibility and implementation plan of the Biosolids Partnership proposal, which is documented in the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022), Appendix A. This report evaluated the proposal and compared it against the County's existing 'baseline' plan to continue the Class B program for 80 percent of the biosolids and provide Class A composting for the remaining 20 percent of the biosolids. The conclusion of the report was that the Biosolids Partnership proposal had numerous risks and flaws that prevented it from being implemented and the baseline was a far more reasonable approach to biosolids management.

Following the publication of the *King County Biosolids Class A Alternatives Analysis Final Report*, Biosolids Partnership prepared a revised proposal with a new approach to use a thermal dryer fueled with renewable energy purchased from Puget Sound Energy (PSE), and to use the dried biosolids as fuel for cement plant operation. The WTD requested that Consor amend the contract with the County to provide an independent analysis of the updated proposal, which was presented to WTD and Consor in January 2023. The evaluation includes analysis of the feasibility of the approach, scalability, cost, environmental and climate impacts, and required changes to County policies. Like the prior report, the revised proposal was compared to the County's baseline alternative of continuing with Class B biosolids production and land application as well as producing Class A biosolids through off-site composting. The findings of that analysis of the revised Biosolids Partnership proposal are presented in this report.

1.2 Project Objective

The primary objective of the project is to evaluate the various components of the revised Biosolids Partnership proposal in the same manner as the initial proposal was evaluated. This includes:

- Implementation,
- Feasibility,
- Approach for utilizing renewable energy,
- Class A biosolids marketability,
- Scalability,
- Expected environmental and climate footprint, and
- Overall program cost.

Additionally, the second evaluation has areas of additional focus including:

- Elements of green energy use, which are discussed in Section 2.3 Implementation Considerations of Proposed Alternative
- Potential to address contaminants of emerging concern, which is discussed in Section 2.4.5 Environmental Impacts

The report will also identify any necessary changes to County policies and future budget adjustments that may be required for implementation of the revised proposal.

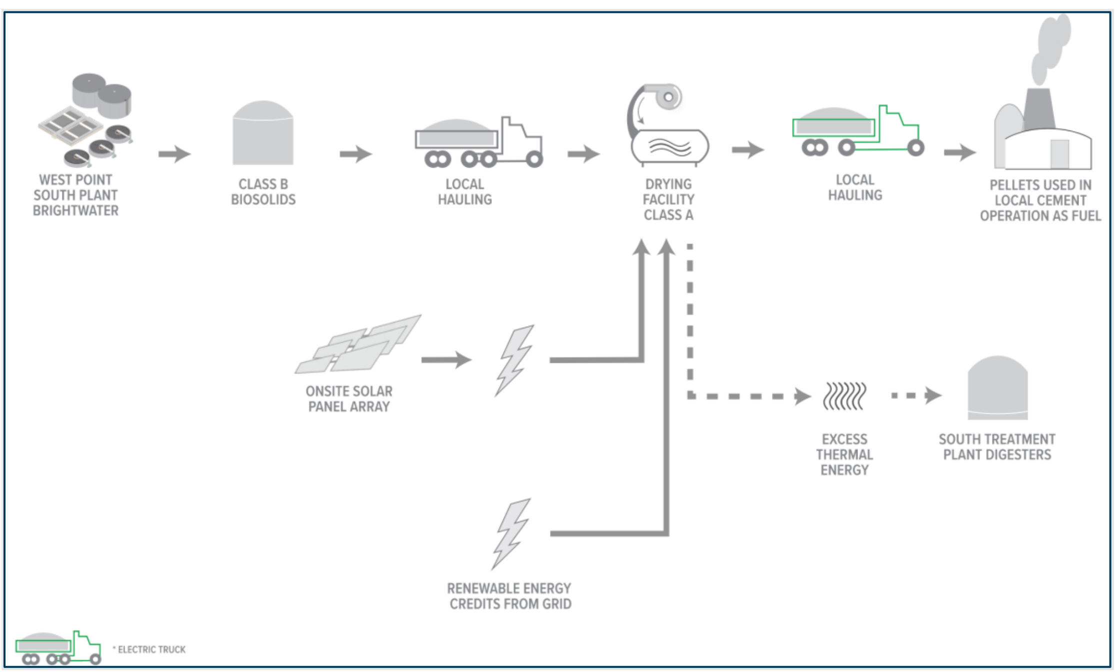
1.3 Description of Revised Alternative

The project objectives will be met by comparing the revised alternative proposed by the Biosolids Partnership with both the initial Biosolids Partnership proposal and the baseline alternative (i.e., WTD's existing Class B biosolids program with addition of a Class A composting program that is currently in the planning stages). The following section details the revised alternative. The baseline alternative and initial Biosolids Partnership proposal were previously analyzed and discussed in the *King County Biosolids Class A Alternatives Analysis Final Report* and, therefore, are not summarized again herein, but are referenced in subsequent sections for comparison to the revised alternative.

1.3.1 Revised Biosolids Partnership Proposal

The revised proposal was presented by the Biosolids Partnership in January 2023 (see **Appendix B**) and a report detailing the same proposal was provided to the County in February 2023 and is included in **Appendix C**. The proposal suggests combining solids from King County's three large WWTPs, West Point, Brightwater, and South, and drying them in a centralized dryer facility on the South WWTP property. The dried, Class A pellets would be trucked with electric trucks to a local cement manufacturing facility for use in their kilns. See **Figure 1-1**, for an illustration of the revised proposal.

Figure 1-1 | Revised Biosolids Treatment Process Proposal



The revised proposal is a simplified version of the initial proposal. The primary difference involves removal of the wood gasification system, and removal of the steam turbine power generator. The major components of the revised proposal are as follows:

- Two fluidized bed dryers, which receive heat energy via electricity,
- A chemical odor control scrubber,
- Waste heat recovery system,
- Roof mounted solar panel array,
- A fleet of electric biosolids hauling trucks,
- Truck Loading/Unloading Bay, and
- A biosolids conveyor network to move solids into and around the facility.

The proposed system is sized to accept the entire biosolids load from the three County WWTPs, and it has been sized for full redundancy at system startup. The drying system is designed to operate 24 hours per day, seven days per week. Each fluid bed dryer has the capacity to evaporate up to 11 tons of water per hour. This equates to approximately 3.5 dry tons of biosolids per hour. When run for 24 hours per day, each dryer will be capable of drying approximately 85 dry tons of biosolids. The County's three WWTPs produced an average of 84 dry tons per day (or 30,660 dry tons per year) in 2021. At system startup, the facility will have the total capacity to dry approximately 168 dry tons of biosolids per day meaning it will have full redundancy to dry all of the County's biosolids. The proposal also identifies the location of a third, equally sized dryer that would increase the total capacity of the system to 252 dry tons per day. In addition to the drying system, a fleet of electric trucks would need to be acquired by the County for hauling as suggested in the revised proposal.

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CHAPTER 2

Summary of Analysis Activities

2.1 Stakeholder Involvement

Consor participated in a January 23, 2023, kickoff meeting with the Biosolids Partnership and King County. The kickoff discussed the Biosolids Partnership's intent to develop a revised proposal for sludge drying facilities at the South WWTP and briefly presented key elements of the revised approach.

A proposal document was provided by Biosolids Partnership February 13, 2023, and Consor participated in a meeting with the Biosolids Partnership and County Council on March 6, 2023, to further discuss the revised proposal and solicit County Council input. Consor prepared a request for additional data and information from Biosolids Partnership on March 3, 2023. Biosolids Partnership requested follow-up information from the County, which was provided on March 16, 2023, and Biosolids Partnership responded to the Consor data requests on March 20, 2023. Relevant correspondence with Biosolids Partnership is included in Appendix D.

Additionally, on March 3, 2023, Biosolids Partnership provided a letter of interest from a local Seattle-area cement producer indicating a desire to use to pellets in the cement manufacturing process but requested confidentiality regarding their involvement. To honor this request, the manufacturer is not named in this report. Consor conducted phone meetings with the cement producer to better understand the details for using the dried pellets in a cement kiln.

2.2 Wastewater Agency Outreach

There are two existing fluidized bed dryers in North America that are used to dry biosolids. Both facilities have fluid bed sludge dryers manufactured by Andritz, which is a member of Biosolids Partnership and is suggested as the basis of design in the revised proposal. Consor contacted the operators of both dryer facilities to discuss the general operations and maintenance of the facilities and to gain insight into staffing requirements, operational challenges, finances, and other experiences that may be useful to the County. Consor had a meeting and exchanged email correspondence with a representative from North Shore Water Reclamation District (NSWRD) in Illinois in March of 2023. On March 28, 2023 two engineers from Consor visited the Capital Regional District (CRD) Residuals Treatment Facility (RTF) in Victoria, B.C. to have an extended on-site meeting and plant walk-through with the Plant Engineer. Additional information was provided by email after the visit.

The following sections provide further details about the information obtained by Consor engineers and discuss implications for the County's consideration.

2.2.1 Capital Regional District Residuals Treatment Facility

Capital Regional District's (RTF) is operated by Synagro under a long-term contract with CRD. The plant is in a semi-rural area approximately 11 miles (18 kilometers) northwest of the Victoria downtown city center.

Two Consor engineers visited the RTF and met with the Plant Engineer Ben Christianson, an employee of Synagro.

The RTF provides thickening, digestion, dewatering, and drying of municipal wastewater sludge. The maximum capacity of the facility is approximately 15,000 dry tons per year of biosolids delivered to the RTF; however, in 2022 the facility only produced approximately 3,500 dry tons of biosolids pellets. The maximum capacity of CRD's drying facility is approximately half of the capacity of the proposed King County system at startup.

2.2.1.1 Timeline

Capital Regional District entered a contract with Synagro, who are providing design-build facility construction, financing, and operation of the facility for a 20-year term following startup. The contractual arrangement is a "P3" public-private partnership. The contract was signed in February of 2018 and the RTF was commissioned into operation in March 2021. The facility was constructed by a Joint-Venture Design-Build Contracting Team of Bird Construction and Maple-Reinders. Design consulting services were provided by Associated Engineering, a Canadian firm.

2.2.1.2 Ownership and Operations

Capital Regional District is the nominal owner of the facility, and they pay a monthly contracted fee to Synagro for design-build-finance-operation services. The monthly contracted fee includes the debt service repayment on the initial capital cost financed by Synagro and the recurring labor costs of the Synagro operational staff. Operations and full unencumbered ownership of the facility will pass back to CRD after 20 years of operation by Synagro.

2.2.1.3 Disposition of Class A Biosolids Product

The fluidized bed dryer produces a Class A biosolids pellet with a specified size range between 0.5 millimeter (mm) and 4.0 mm in diameter. All the pellets produced by the RTF are collected and trucked by CRD from the RTF; Synagro does not provide trucking, delivery, or disposal of the pellets. Synagro estimates that currently approximately 50 percent of the RTF biosolids product is used for kiln heating at the cement plant owned and operated by Lafarge in the Richmond District of Vancouver, B.C.; however, this value is heavily dependent on the operations at the cement plant. In 2022, the reported quantity of biosolids product sent to the cement plant was only 14% of the total produced (*CRD landfilled…, Victoria News, 2022)*, due to an accident at the cement plant that forced a long term shutdown for repairs. The remaining biosolids are land-applied or landfilled. Synagro mentioned that Lafarge's use of Class A biosolids for their cement kiln heating allows Lafarge to offset some coal use.

Synagro is not involved in or informed of the financial particulars of pellet distribution and disposal by CRD, but Synagro did allude that CRD pays Lafarge to dispose of the pellets. There is currently no revenue stream to CRD or to Synagro for the sale of the pellets.

Synagro reports that the pellets meet a "6-6-0" specification for percentage nitrogen, phosphorus, and potassium, respectively.

2.2.1.4 General Process and Operational Parameters

- *General Operations:* After 2 years of continuous operation, all major systems and sub-systems are functioning. There have been occasional minor equipment replacements and warranty claims from the original construction contract. For example, the rotary valve that vents pellets from the dryer into the pellet cooler had to be re-sized and changed out. One of the high wear-and-tear equipment categories is the thermal oil heat exchangers inside the dryer; Synagro has budgeted to have these heat exchangers replaced every 5 years. The fluidized bed dryer appears to be operating in fully automatic mode using the packaged control system and on-site human machine interface (HMI) screens provided by Andritz.

- *Process Flow*: Sludge consisting of approximately 50 percent primary, 35 percent secondary, and 15 percent tertiary filtration sludge and averaging 2 percent total solids is pumped by CRD from downtown Victoria to the RTF through a 12.5-mile (20-km) pipeline. At the RTF, sludge goes through the steps of equalization, gravity-belt thickening, mesophilic digestion in three on-site anaerobic digesters, centrifuge dewatering, and finally fluidized bed drying. Gas from the digesters is used to heat the thermal oil system for the dryers, and heat from the dryers is recycled to heat the digesters. Centrate and other water removed from the process flows through a 12.5-mile (20-km) gravity pipeline back to the wastewater treatment plant near downtown Victoria.

- *Ancillary Processes*: The RTF has a two-stage odor removal system (first stage bio-trickling filter and second stage chemical odor control scrubber for polishing down to less than 1 parts per million (ppm) hydrogen sulfide), a digester gas withdrawal and purification system, a digested sludge equalization tank with a gas storage bubble, and a thermal oil heater fueled by digester gas providing heat to the fluidized bed dryer. There is also pellet storage and a dust removal system. Collected dust is re-introduced to the dewatered sludge feed to the dryer. The digester gas conditioning system includes siloxane removal, hydrogen sulfide scrubbing, chilling for removal of condensate, and gas compression to a slightly higher pressure, prior to gas conveyance into the thermal oil heater. The dryer has a nitrogen gas purging system which is deployed every time the dryer is started. There is a heat-recovery heat exchanger which captures waste heat from the dryer and uses it for on-site digester heating.

- *Operations Staff*: The plant is staffed by a Plant Manager and 3 operators during the day shifts, and by 2 operators at night. There is also a full-time maintenance technician who works weekday shifts.

- *Turndown and Sizing*: Synagro estimates that the plant may have been “overbuilt”, because it was sized for solids flows commensurate with the anticipated 10-day max seasonal influent wastewater flow to the Victoria wastewater treatment plant in Year 2040. As a result, the dryer has a nominal capacity of 6 Metric Tons of Water Evaporation/hour but currently runs at an average of about 2.7 Metric Tons of Water Evaporation/hour. Currently they “overdry” the biosolids because the dryer detention time is high at the lower sludge flows. There is an on-site storage silo for Class A pellets.

- *Coil Cleaning*: Plant staff clean the dryer coil about twice per year, and the dryer is serviced for a 2–3-day shutdown period about once per month. Within the dryer, there is a vertical transition interface between wet sludge below and dry sludge above when the dryer is operating. Synagro maintains that interface below the thermal oil heat exchangers. If wet sludge were to contact the heat exchangers, more frequent cleaning of the heat exchanger tubes would become necessary.

2.2.1.5 System Challenges

- *Digester Gas Overproduction*: The sludge received at the RTF has a higher-than-normal 85 to 90 percent volatile solids, because much of the grit is inadvertently removed in the upstream sludge conveyance to the RTF. This contributes to a high ratio of digester gas to the volume of digested sludge, and a significant percentage of the digester gas is flared. RTF plans to start sending excess digester gas off-site as a source of renewable biogas.

- *Heating Unit Sizing*: The dewatered sludge feed rate to the dryer must be balanced with the amount of thermal energy being added to the dryer. Because there is only one thermal oil heater for the facility sized for the nameplate dryer rating of 6 Metric Tons of Water Evaporation/hour, there is a limit on how much the dewatered sludge feed pumps can be turned down to maintain the hood setpoint temperature in the dryer. As a result, the dryer goes off-line on a regular basis while digested sludge is stored on-site. Synagro surmises that having two smaller thermal oil heaters, instead of one larger heater, would be a significant improvement. Having two smaller dryers instead of a single oversized dryer would also enhance turndown capability and minimize downtime by precluding or limiting batch operation.

- Synagro reported that fiber consisting mostly of human hair tends to collect in various plant systems.

2.2.1.6 Costs

- The RTF facility as a whole cost approximately $92.9M (CA $126.8M) in 2018 Canadian Dollars. This was for the design-build-finance-operation contract.

- The estimated cost for the drying portion of the facility was estimated at $16.6 (CA $22.5M) in 2018 Canadian Dollars. The drying portion of the facility is integrated into the larger facility, so is likely that this cost is less expensive than it would be to construct a stand-alone facility because of economies of scale for constructing a larger facility. The RTF is also in a more rural area than South WWTP which likely results in fewer logistical challenges and lower construction cost.

- Electricity costs for the facility in 2022 totaled $432,600 (CA $537,000) assuming an average cost of $0.63/kWh (CA $0.085/kWh).

- Ancillary fuel costs in 2022 totaled $33,274 (CA $45,150).

- Synagro considers maintenance costs proprietary information an declined to share specific information, but stated that they would consider it normal for this type of facility to be on the higher end of the typical maintenance cost range of 3%-7% of the facility’s capital cost. For the drying portion of the facility, this is an implied annual maintenance cost of approximately $1.2M.

- Synagro mentioned that one of their other Class A facilities in Philadelphia has experienced a significant demand from customers on the East Coast who are willing to pay for the Class A biosolids produced there. Of the approximately 15 Class A biosolids-producing facilities that Synagro operates in North America, only a few of the facilities have a revenue stream from sale of the biosolids. In many of these facilities, the sewer agency or their designated operator must pay to dispose of the biosolids or pay to send the biosolids to beneficial re-use.

2.2.1.7 Findings Pertaining to Revised King County Biosolids Drying Proposal

The visit to CRD illustrated the technical feasibility of sending a dried biosolids product to a cement plant for combustion within their kiln but also illustrated the logistical and financial challenges with the process. CRD is largely beholden to the operations at LaFarge and is paying for disposal, not generating revenue. Conversations with the plant engineer made it clear that consistent delivery to their end user may not be attainable.

2.2.2 North Shore Water Reclamation District

Section 2.2 of the *King County Biosolids Class A Alternatives Analysis Final Report* includes information about the North Shore Water Reclamation District (NSWRD) Biosolids Recycling Facility (BRF) in Gurnee, Illinois. The stand-alone BRF receives and treats solids from three treatment plants owned and operated by NSWRD. There is a single fluidized-bed sludge dryer which operates between 5 and 6 days per week, 24 hours per day, producing approximately 8,000 dry tons/year of Class A biosolids, which is approximately one fourth of the solids that the proposed King County system would treat. Since the BRF is one of only two fluidized-bed drying facilities for municipal wastewater sludge in North America, the BRF facility parameters are summarized in this report as a benchmark to compare and evaluate the latest Biosolids Partnership Proposal for the South WWTP. A summary of the facility is presented in this report to compare.

2.2.2.1 Timeline

The BRF was commissioned into operation in 2007. NSWRD plans to operate the facility for another 5-7 years until approximately 2028 or 2030.

2.2.2.2 Ownership and Operations

NSWRD is the nominal owner of the facility, and they pay a monthly contracted fee to Veolia for operation and disposal services. Veolia has the contractual responsibility to dispose of the product. The annual Veolia contract amount, which includes about 7 or 8 full-time Veolia plant staff, is about $1.8 Million.

2.2.2.3 Disposition of Class A Biosolids Product

Veolia pays to have the Class A product shipped and land-applied to farmland in the region. There is no revenue stream from the product.

NSWRD reports that the pellets meet a “4-5-1” specification for percentage nitrogen, phosphorus, and potassium, respectively. The average diameter of the pellets is 2 mm.

2.2.2.4 General Process and Operational Parameters

- *General Operations:* After 16 years of continuous operation, all major systems and sub-systems are functioning. NSWRD is about to renew their operations contract with Veolia, who has been operating the facility for 9 years.
- *Process Flow*: Sludge consisting of approximately 80% secondary waste-activate sludge and 20% secondary digested sludge is dewatered offsite to approximately 18-20% solids and trucked to the BRF.
- *Heating Method*: There are two thermal oil heaters fueled by natural gas, with the thermal oil circulating through a tube heat exchanger inside the dryer.
- *Coil Cleaning*: Plant staff clean the dryer coil frequently, with the most frequent cleaning occurring in the winter approximately once per week. In the winter, the dryer is shut down for approximately 2 consecutive days per week to conduct coil cleaning.
- *Odor Control and Air Permitting:* The BRF has a wet scrubbing odor control unit and an air pollution control permit with the State of Illinois.

2.2.2.5 System Challenges

- Odor: The odor of the Class A pellets limits public acceptance for small-scale farming or private gardens. Thus, the product is applied only on large-acreage agricultural land. The pellet odor results from the fact that 80 percent of the sludge entering the dryer is waste-activated, undigested sludge.

- Dust: Mineral oil is applied to the product following bulk loading, to control dust. Dust control was a problem in the past, but the dust control system in the dryer building has been retrofitted and revised to provide dust circulation back into the dryer feed. Dust is captured in a hood and run through a dust cyclone, which deposits it into a fines bin. The fines are recirculated into the sludge feed to the dryer.

- Smoldering: Smoldering is typically caused by remaining moisture in biosolids pellets resulting in self-heating of the pellets to ignition point and is a fire risk if not promptly extinguished. The facility has gone through several smoldering incidents, but plant staff have managed to keep this under control more recently.

2.2.2.6 Findings Pertaining to King County Biosolids Drying Proposal

The contracted operations cost of $1.8 Million per year is a significant benchmark to compare with the operations labor cost proposed by Andritz for King County. See Section 2.4.6 of this report for additional discussion on projected drying facility operations cost for King County.

2.3 Implementation Considerations of Revised Alternative

2.3.1 Space Requirement

A key consideration regarding the feasibility of the drying facility involves the spatial aspect of the plans. The previous proposal did not take future plant capacity expansions into consideration when laying out the proposed facility. Much of the previous assessment assumed the facility would have to be located at a remote site close to South WWTP.

The revised proposal reduces the number and footprint of intended structures. Instead of constructing multiple structures throughout the plant, the revised proposal involves a single building located in the northeast corner of the property. This area is currently used as a paved yard for biosolids truck washing, ancillary storage, truck turnaround and truck staging.

The proposed facility would be approximately 22,000 square feet (SF). This is approximately double the footprint of the drying portion of CRD's RTF, and it is about two-thirds the size of the total facility in North Shore, Ill. As discussed above, in section 2.2.1, Consor had the opportunity to tour the CRD facility. Based on that site visit and the capacity of CRD's facility, Consor believes that the proposed footprint accurately represents the size needed for the facility.

The proposed facility does not directly interfere with any other capital improvement program expansions, however, it would impact operations in a few ways:

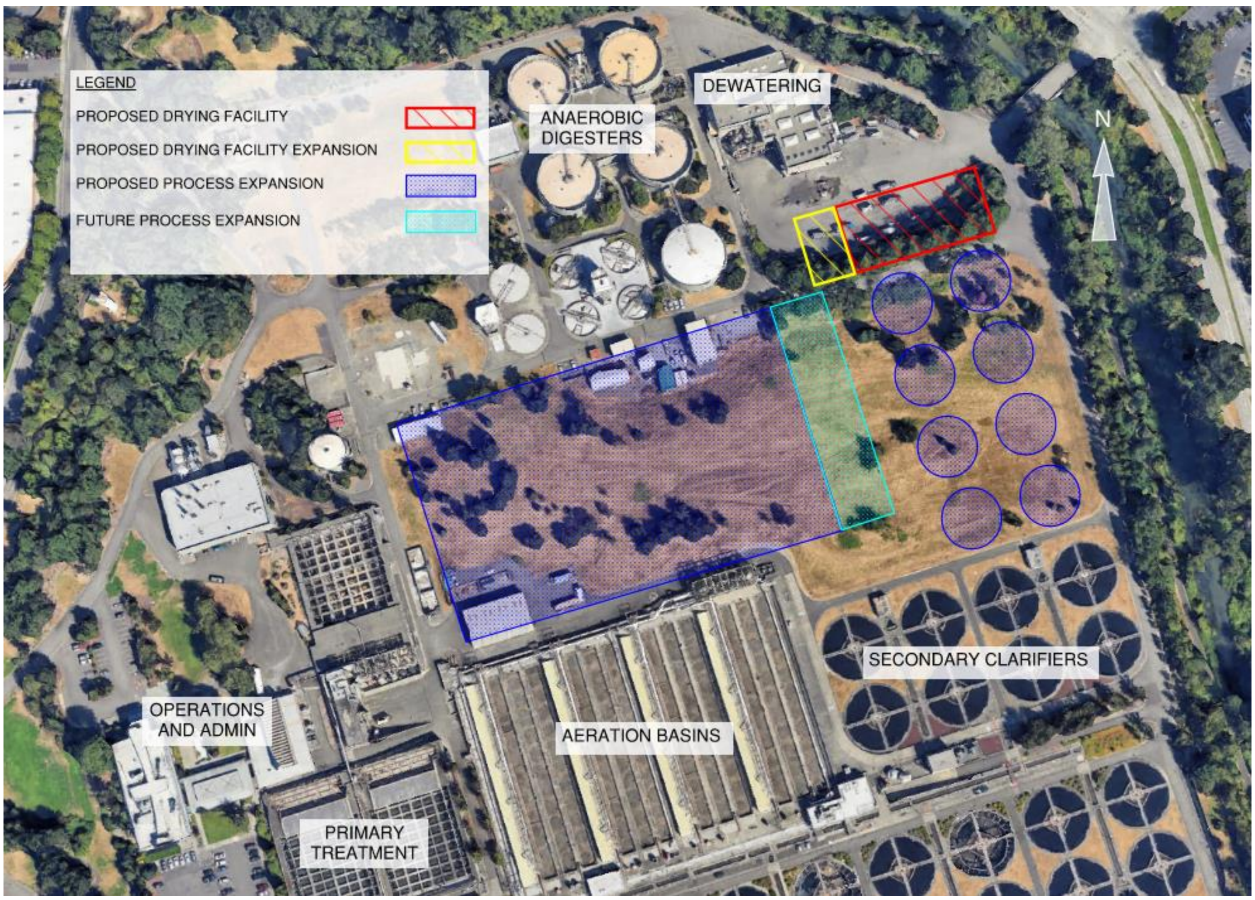
- The proposed drying facility will located in the existing paved yard area which is used for biosolids truck turnaround and staging and be removing a significant portion of this area from service. This would significantly disrupt the current Class B hauling operation, would eliminate the ability to haul Class B biosolids with tandem trucks with attached trailers, and require truck staging and wash areas to be relocated. Under the proposed operation of hauling dried biosolids to the cement plant these may be acceptable tradeoffs, but the County needed to resume hauling Class B biosolids it would be challenging.

- The road directly south of the proposed facility will likely be removed to make space for proposed process capacity expansion. With the addition of the drying facility, there will be no alternative route for this road. Input from South WWTP operators will be required to ensure plant operations can continue without this existing route.

- Clearance between proposed facilities is minimal. Additional work will be needed to ensure building foundations will not interfere with one another.

Based on the above assessment, Consor believes that this facility will fit on site; however, further work will be required to ensure plant operations are not adversely affected, and additional conversations will be required to ensure that future proposed plant expansions will have adequate room for construction and operations. A site plan of South WWTP with the proposed facilities can be seen in **Figure 2-1**, below.

Figure 2-1 | South WWTP Site Plan with Proposed Facilities



The proposed plan includes approximately 10 days of dry pellet storage at startup. As biosolids production increases, the expected storage time is expected to drop to approximately 6 days. In communicating with similar facilities, end user process interruptions can cause long delays in the acceptance of the dried product. In the case of Peirce County's Soundgro, these delays have been on the scale of a month or greater. Based on conversations with cement manufacturers, process interruptions with the kiln are a relatively common occurrence during the winter months. Provisions for additional storage will be required to improve the resilience of this alternative, however, there is no additional space available in the vicinity.

2.3.2 Expertise, Human Capital, and O&M Resources

Biosolids drying facilities are not unusual in the wastewater treatment field and the fluidized bed dryer in the revised proposal does not present a large technical step-up from other dryers across the Country. Although there are only two fluidized bed dryers in North America, training and hiring additional operators should be possible, but finding and retaining staff has been challenging across the industry and adding additional staff would further compound this challenge. These positions would need to be advertised in advance to ensure adequate staffing levels for system start-up and would likely be challenging to fill.

Existing plant operators can be trained to operate the proposed facility allowing for significant amounts of overlap between current plant operations and proposed plant operations. The primary concern is the proposed operating time of the facility. The proposed facility is designed to operate 24 hours per day, 7 days per week. Every plant that Consor reached out to always maintained staffing on-site during dryer operation. This would represent a change from the current operations staffing of the South WWTP.

To meet the staffing needs of the proposed drying facility, the County will likely need a minimum of 12 full-time equivalents (FTE) to cover three shifts over the course of 24 hours. The County could fill some of the labor needs with existing plant staff; however, changing the standard work hours and responsibilities of existing plant staff may cause job dissatisfaction and burnout.

Alternatively, the drying facility operation can be contracted out to a 3rd party operations team. This concept was mentioned in the revised proposal and Biosolids Partnership indicated in the data request response that Synagro would be interested in exploring a design, build, operate, and maintain contract. This would remove much of the difficulty regarding staffing and management of the system and would leverage Synagro's experience operating the CRD facility in Victoria; however, it may be more expensive, removes County agency of the facility, may cause union conflicts, and would not allow existing staff to be utilized for operations nor maintenance should the need arise.

2.3.3 Renewable Energy

The revised proposal includes adding solar panels on the roof of the drying facility structure to generate renewable energy on-site as well as heat recovery from the dryer to reduce the South WWTP's reliance on natural gas. The remainder of the electricity required for the dryer and not supplied by the on-site solar panels would need to be purchased from Puget Sound Energy (PSE). King County currently purchases renewable electricity from PSE's through the 'Green Direct' program. This program allows the County and other agencies to purchase renewable energy from dedicated, local renewable energy projects, meaning that a portion of the electricity purchased by King County is fully renewable energy. Energy from the Green Direct program is provided from either the Skookumchuck Wind Facility or the Lund Hill Solar Installation, but additional energy from the Green Direct program may not be available until the next project is constructed. These alternatives and their impacts on the county's zero carbon goals are explained in further detail below.

2.3.3.1 Solar Panels

The revised proposal suggests that solar panels will be placed on 780 square feet (ft^2) of the drying facility's roof. This was estimated to generate approximately 20 watts/ft^2/day, or a total of 5.7 Megawatt hours per year (MWh/yr). Consor independently verified that this is a reasonable and conservative estimate.

Compared to the energy usage of the dryer facility of 71,350 MWh/yr, solar power production would account for less than 0.1 percent of the yearly energy requirement.

Solar panels are viewed as a carbon-neutral source of electricity since no greenhouse gases are released during energy production. However, the manufacture of solar panels is not carbon neutral since energy, materials, and transportation are required. When considering both manufacturing and operation greenhouse gas emissions, solar panels produce an average 20 times lower greenhouse gas emissions than coal energy over a 30-year life span (*Life Cycle Greenhouse Gas Emissions from Solar Photovoltaics*, National Renewable Energy Laboratory (NREL, 2012)). While the solar panels will not offset the power usage from the dryer, they still help to reduce the overall greenhouse gas footprint over the facility's life span.

2.3.3.2 Heat Recovery

Biosolids Partnership is also proposing to reduce energy usage by recovering waste heat from the fluidized bed dryer for use in the South WWTP's hot water system. Boilers fueled with natural gas are used to heat a hot water loop that primarily warms the anaerobic digesters and provides hot water for heating for many of the buildings at the plant. The County is currently installing heat extractors that will use heat pumps to transfer heat from the effluent to the hot water loop, which will reduce the gas required for heating.

The Biosolids Partnership estimates that, depending on ambient temperature and conditions, approximately 17.8 million British thermal units per hour (MMBtu/h) of waste heat could be recovered for digestor heating, and approximately 5.5 MMBtu/h waste heat could be used for heating buildings. The hot water loop at the South WWTP heats both the anaerobic digesters and most of the plant buildings, and currently requires an average 6.7 MMBtu/h of energy from boiler gas as reported from the County's 2020-2021 data. Peak usage is 12.8 MMBtu/h, so waste heat should be able to completely offset the boiler gas usage.

The maximum potential energy use offset from the proposed waste heat recovery system is approximately 23.3 MMBtu/h, which is nearly double the current peak heat requirement at South WWTP. There is no clear and readily available use for the additional waste heat, but it may be feasible for the County to identify nearby industrial users that could make use of it if additional capital investments were made.

2.3.4 Market for Final Product

2.3.4.1 Typical Market Value of Class A Biosolids Used for Landscaping or Agriculture

For soil amendments and fertilizer uses, the *King County Biosolids Class A Alternatives Analysis Final Report* documented Class A biosolids market prices ranging from $10 to $15 per cubic yard, which corresponds to approximately $20 to $30 per short ton for a product with a bulk density of about 600 kilograms per cubic meter (kg/m^3). This is the typical density of the final Class A product created at the CRD RTF and likely similar to the density that King County could expect to produce.

2.3.4.2 Cement Kiln Heating

In the revised proposal, the Class A biosolids produced by a fluidized bed drying system are proposed to be used as an alternative heating fuel for cement kilns. Biosolids are widely used in Europe to heat cement kilns which produce clinker, a thermally activated limestone that contains aluminum, silicon, and iron, and it is ground into a fine powder becoming Portland cement. Traditionally, cement kilns are heated with bituminous coal, natural gas, petroleum coke, or other fossil fuels available on the open market. A large amount of energy is required to produce cement, making it a significant contributor to greenhouse gas emissions. The cement plant reported they currently use a mix of coal and natural gas and switch between fuel sources depending on market conditions.

2.3.4.3 Commodity Cost of Alternative Fuels

The commodity cost of traditional fuels such as coal and natural gas fluctuates on the open market. The current approximate commodity cost of US-sourced bituminous coal is approximately $80 per short ton (2,000 pounds) at the time of this writing (*Coal Markets* (U.S Energy Information Administration (US EIA), 2023). The intrinsic value of the biosolids can be conceptualized as some fixed percentage of the fluctuating price of bituminous coal since either can be used as fuel in the kilns. With bituminous coal trading at $80 per ton and the Class A biosolids containing 60-80 percent of the heating value of bituminous coal, the potential monetary value of the biosolids could be considered as high as 60-80 percent of the price of bituminous coal per ton.

Despite the intrinsic heating value of the Class A biosolids, the reality of monetizing the product is much less promising. The local cement producer identified by Biosolids Partnership as the end user has expressed their willingness to take the biosolids. They made it clear they would be willing to pay for the biosolids provided the delivery of the biosolids to the cement plant is covered by another entity, yet the cement producer was more reticent about the price they would pay for the product itself. It would probably be challenging to sell the project for the $20 to $30 per short ton that may be possible on the agricultural market. Conversations with Synagro confirmed that Class A biosolids pellets are not a revenue generating commodity.

The value of the final product is going to be set to some extent by the breadth of the market. The Biosolids Partnership proposal considers shipping all biosolids pellets to a single end user. This allows this single end user to set the price based on how they value the product. Based on Consor's conversations, cement manufacturers do not attribute much value to this product. The County should not assume any revenue stream could be created through this process. At best, sales of the biosolids has the potential to reduce disposal costs.

2.4 Alternative Analysis

2.4.1 Scalability

The revised proposal outlines a phased approach to the implementation of the biosolids dryer. The new facility would be in the northeast corner of the South WWTP as shown previously in **Figure 2-1**. The initial phase includes two dryers and associated appurtenances. **Figure 2-2** provides a rendering of the biosolids drying facility. As stated above in **Section 1.3.1**, each fluid bed dryer is sized to dry approximately 85 dry tons of biosolids per day. At startup, the facility will have a total capacity of 168 dry tons of biosolids per day, meaning It will have full redundancy to treat all of King County's biosolids with one dryer out of operation. The second phase of the proposal would add a third train to the facility expanding the capacity to approximately 252 dry tons of biosolids per day. This third train would be located adjacent to the proposed facility.

Figure 2-2 | Proposed Biosolids Drying Facility Rendering

The revised proposal uses two dryers, which is the same as the original proposal, so the scalability of this facility is similar to that of the previous proposal. As mentioned in Section 2.4.1 of the *King County Biosolids Class A Alternatives Analysis Final Report*, the facility can scale up as the needs of the County increase; however, the increments of scale are large. To increase capacity, the County would have to invest large sums of capital and the resulting facility would then operate well below capacity for many years.

2.4.2 Benefits and Risks

This section presents a comparison of the primary benefits and risks of the revised Class A biosolids alternative.

The primary benefits include:

- Reduction in the distance that biosolids are hauled. The current practice and baseline alternative land apply biosolids in western Washington (20% of land applied biosolids) and eastern Washington (80% of land applied biosolids), whereas the revised proposal would only require hauling within the greater Seattle metro area.
- All equipment is located on the South WWTP site.

The primary risks include:

- There is limited experience in North America with operation of fluidized bed reactors for biosolids
- There is limited experience in North America with use of dried biosolids as fuel for cement kilns
- A single end user has been identified

- There are concerns regarding final product safety. All the biosolids drying facilities that were interviewed for the *King County Biosolids Class A Alternatives Analysis Final Report* indicated they had experienced smoldering or fire accidents with their dried pellets, either during storage or application.

2.4.3 Costs

The revised Biosolids Partnership proposal suggests that the presented biosolids treatment system will have a lower capital cost and operation and maintenance cost than the baseline alternative. Consor performed a general review of the cost numbers proposed by Andritz in the revised Biosolids Partnership proposal and an independent cost estimate.

2.4.3.1 General Cost Review

2.4.3.1.1 Capital Cost

The reported $113.8 Million Capital Cost is significantly underestimated in Consor's opinion. Andritz estimated the $113.8 Million capital cost by multiplying their turnkey installed dryer system manufacturer price of $45.5 Million by a fixed multiplier of 2.5, to obtain the $113.8 Million estimate. However, based on previous cost analyses by Consor in Section 2.4.3.the *King County Biosolids Class A Alternatives Analysis Final Report*, the actual multiplier would be 5.0 or more, when the following necessary capital costs are added:

- Soft costs for engineering planning, design, and environmental permitting
- Construction cost of the dryer building
- Costs of new mechanical systems not included in the scope of Andritz's supply
- Modification of existing mechanical sludge systems to accommodate the dryer (e.g. mechanical dewatering improvements, and digester heat exchanger modifications, to accept waste heat from the dryer)
- Civil piping and sitework, including sludge conveyance piping and pumping
- Electrical and instrumentation upgrades
- Extensions and upgrades to foul air retrieval and scrubbing system
- Internal King County labor and administrative cost to execute the capital project

2.4.3.1.2 Energy Cost

The revised Biosolids Partnership proposal predicts an annual anticipated electric cost of the proposed King County dryer facility of $5.71 Million, when the facility is operating at an average daily production capacity of 108 dry tons/day. There is a significant difference between the unit energy cost of drying projected by Andritz for King County and the actual unit energy cost of drying reported by one of the existing Andritz fluidized bed drying systems already operating.

Dryer energy use is largely proportional to the Class A sludge production, since the heat energy applied to the dryer is based on the target tons per hour of water evaporation necessary to achieve the desired dryness. Consor compared the energy usage predicted by Andritz with actual operating data obtained from the Plant Manager of the NSWSD Biosolids Recycling Facility, which has been in operation since 2007. Synagro does not have the ability to directly measure gas usage to heat the dryer at the RTF, so it was not possible to compare energy use for this facility. **Table 2-1** shows a comparison of the actual energy use of the North Shore dryer and Andritz's estimated energy use for King County, on a per-ton basis.

Table 2-1 | Energy Use Comparison North Shore, Illinois Existing Dryer Facility vs. King County Numbers Proposed by Andritz

Fluidized Bed Dryer Facility	Dry Tons/Year of Class A Production	Drying Facility Electrical Usage Megajoules/Dry Ton
North Shore, Illinois	8,000[1]	17,880
Andritz Proposal for King County	31,025[2]	8,218[3]

Notes:

1. Current Production
2. "Average" annual production projected by Andritz for a "2022 to 2050" time horizon.
3. Assumes an annual electric expenditure of $5.71 Million at $0.0634/kWh, as reported by Andritz in the Feb 2023 Biosolids Partnership Proposal.

The discrepancy between the actual energy usage of the North Shore Facility and Andritz's proposed numbers cannot be accounted for based on facility capacity differences. North Shore heats their thermal oil with natural gas, instead of electric resistance heating of thermal oil as proposed by Andritz for King County. Natural gas is more efficient than electric resistance heating in terms of energy loss avoidance; thus, the difference in heating energy in Megajoules per Dry Ton cannot be attributed to efficiency differences in thermal oil heating methods. Consor concludes that electricity usage for the proposed dryer would likely be five to ten times higher than assumed by Biosolids Partnership.

2.4.3.1.3 Operations Cost

The revised Biosolids Partnership proposal suggests that the operations cost for a dryer facility at the South Plant would be approximately $950,000 annually for the initial operation, with an increase to approximately $1.67 Million annually in 2050. This stands in contrast with the current contract operations cost of $1.8 Million per year paid by NSWRD and $1.2 per year implied by Synagro for facilities with production capacity significantly less than proposed for King County. The annual operations cost of $950,000 estimated in the Biosolids Partnership proposal seems unrealistically low based on the Veolia and Synagro operations costs.

In addition, it should be noted that the North Shore management team is working on a biosolids master plan that is considering alternatives for replacement of the drying process after only 16 years of operation. They estimate the dryer will remain in service for another 5 to 7 years which gives a total lifecycle of only 21-23 years. While a lifespan in this timeframe may be acceptable for electrical equipment and smaller mechanical equipment, it is a short lifespan for a major unit process that requires major capital investment.

2.4.3.2 Cost Estimate

A cost estimate was prepared to the standards of the Association for the Advancement of Cost Engineering Class 5 estimate. This estimate provides planning-level evaluations with a range of -50 percent to +100 percent.

A detailed analysis of capital, operation and maintenance (O&M) and lifecycle costs were previously conducted to compare the baseline alternative and initial Biosolids Partnership proposal for the *King County Biosolids Class A Alternatives Analysis Final Report*. This effort was detailed in the *Basis of Cost Estimation Technical Memorandum* (Murraysmith, 2022) and the revised proposal was evaluated using the same methods for this report. The *Basis of Cost Estimation Technical Memorandum* is included in **Appendix E**, and *Detailed Construction, O$M and Lifecycle Cost Estimation for the Revised Proposal* is included in **Appendix F**.

The cost comparison between the baseline and revised proposed is summarized in **Table 2-2**. The annual O&M cost of the baseline is approximately $2 million higher than that of Biosolids Partnership proposal, due to the high cost associated with the long-distance biosolids hauling in the baseline alternative. However, the capital and lifecycle costs of the baseline are much lower than those of the revised Biosolids Partnership proposal.

Table 2-2 | Capital, O&M, and Lifecycle Costs ($ Millions)

Alternative	Capital	Annual O&M[1]	20-Year Lifecycle
Baseline	$119.9	$15.2	$373.8
Revised Biosolids Partnership Proposal	$354.1	$13.31	$588.0

Note:

1. The O&M cost associated with the drying facility has been developed based on experience from other drying facilities.

2.4.4 Social Impacts

This criterion considers whether the alternative will increase or decrease the quality of life of County residents, taking into account the vulnerability of different communities. Aligning with the County's the Determinants of Equity Report, considerations are given to healthy built and natural environments for all people that includes mixed land use that supports employment, housing, amenities, and services; trees and forest canopy; clean air, water, soil, and sediment.

2.4.4.1 Equity and Social Justice

According to the Social Vulnerability Index developed by the Centers for Disease Control and Prevention and the demographic index from the United States Environmental Protection Agency's (EPA's) Environmental Justice Screening and Mapping Tool, the community in the vicinity of South WWTP is much more vulnerable than those in the neighborhoods surrounding West Point or Brightwater. The area is populated by under-represented groups of lower socio-economic means.

The revised proposal with a thermal fluid bed drying facility will fit on the existing South WWTP site. Since no additional land will need to be acquired for the facility, this decreases the local social impacts compared to the prior alternative. Although the proposed facility is a multi-story, heavy industrial type building, since it is located on the existing WWTP site the impact to the primarily light industrial neighbors is minimal.

2.4.4.2 Odor Control

Odor control will be necessary to keep odors from the proposed drying facility to a minimum. The revised proposal contains the same suggested odor control as the initial Biosolids Partnership proposal, and as long as this odor control system is properly operated and maintained it is not anticipated there will be any significant odor impacts to nearby communities.

2.4.4.3 Air Pollution

The only potential source of air pollution from the fluidized bed dryer is through the exhaust air, which is treated with chemical scrubbing and the odor control methods outlined in the prior Biosolids Partnership Proposal analysis. The proposal includes a dust cyclone to remove dust from the exhaust. No air pollution problems are anticipated as a result of the fluidized bed dryer.

The proposal assumes that diesel powered biosolids trucks would be used to transfer biosolids from West Point and Brightwater WWTPs to South WWTP. These trucks would generate combustion-based pollutants. Air pollution generated by this trucking is not expected to be significantly different than the baseline conditions.

2.4.4.4 Trucking Impacts

The impacts of truck trips to and from the South WWTP were discussed previously in *King County Biosolids Class A Alternatives Analysis Final Report*. This effort was detailed in the *Trucking Impacts Analysis Technical Memorandum* (Murraysmith, 2022) and the revised proposal was evaluated using the same methods for this report. The *Trucking Impacts Analysis Technical Memorandum* is included in **Appendix G.**

The only change from the prior document would be the estimated weekly truck trips. Without the need to transport biochar and woody feedstock or haul biosolids from the South WWTP, the weekly trips would be anticipated to drop by 152 trips for a total of approximately 98 per week, 36 of which are proposed to be completed by electric trucks. This is almost equivalent to the baseline scenario that was evaluated at approximately 94 truckloads per week.

King County currently only has one electric truck which is owned by the Solid Waste Division and has been reported to have had several instances of being out of service. The technology for a large fleet of electric trucks that would be required as proposed by Biosolids Partnership is still in its early stages, which increases the risk of unforeseen challenges and unanticipated costs.

2.4.4.5 Ability for Communities to Utilize Biosolids

The dried pellets would be sent to a cement production facility in the revised proposal. Based on discussions with the cement plant, the County would be contractually obligated to deliver the biosolids pellets to the facility, so the biosolids pellets would not be available for community use. If this arrangement should prove unworkable and the cement plant contract was terminated, the pellets could be provided to the community as soil amendments, yet based on the experience of staff at SoundGRO and NSWD, utilizing the pellets is easier for large-scale agriculture companies than for home growers in local communities.

2.4.5 Environmental Impacts

2.4.5.1 Energy Use

A detailed analysis of energy use was previously conducted to compare the baseline alternative and initial Biosolids Partnership proposal for the *King County Biosolids Class A Alternatives Analysis Final Report*. This effort was detailed in the *Energy and Carbon Analysis Technical Memorandum* (Murraysmith, 2022) and the revised proposal was evaluated using the same methods for this report. The *Energy and Carbon Analysis Technical Memorandum* is included in **Appendix H**, and *Detailed GHG Emissions Calculations* for the revised alternative are included in **Appendix I**. The scope of this study included evaluation of the use of green energy to dry the woody biomass described in the first proposal, however, the revised proposal no longer includes use of biomass as a fuel source. Instead, solar energy would be generated on-site and renewable electric energy would be supplied by PSE from the electric grid, so the feasibility of this approach is analyzed in this section.

The facility proposed in the revised proposal will use renewable electric energy supplied by PSE and includes a heat recovery system so that the heat from the dryers can be reused for other processes. The drying facility is expected to operate 24 hours a day, 7 days a week with one dryer in service under 2022 average annual dewatered sludge production of 85 dry tons per year. The proposed energy use or production of each process is shown in **Figure 2-3**, based on the assumptions of 2022 average annual dewatered sludge production. Note this flow chart only considers critical components such as dryer, condenser, and heat exchanger. It does not show other components such as cyclones or the cooling water system.

provides a comparison of the energy use of the revised alternative and the baseline alternative. The energy demand of the system is expected to be 71,350 MWh/yr and would be provided by PSE through the electrical grid. South Plant currently uses approximately 50,000 to 60,000 MWh/yr, so the drying system in 2022 would more than double the current electricity use. As described in Section 2.3.3.1, the total production of the proposed on-site solar would not be significant compared to the total energy consumption.

Excess heat of approximately 64,800 MWh/yr will be recycled by the heat recovery unit and available to supply heating for the hot water loop. Current average energy utilized for heating digesters through hot water loop is only 17,150 MWh/yr, as discussed in **Sec 2.3.3**., so 47,700 MWh/yr of excess heat is available and would be wasted unless an alternative use can be identified.

There are several barriers to using the excess heat that will make it challenging to use:

- There are a limited number of industrial users within the immediate vicinity of South WWTP
- Industrial facilities around the plant have already been developed and may not require hot water
- The moderate temperature of the hot water loop may too low to be useful for industrial users
- Capital costs would be required to expand the heat loop
- Even if end users are identified, the amount they are willing to pay for hot water would likely not offset the entire cost incurred by the County to heat the water

Based on the 2022 biosolids load, the process is expected to consume approximately 6,550 to 54,200 MWh/yr. The County will need to use the and pay for the entire energy consumption of the drying operation and will only be able to reuse a small portion of the heat generated. Due to the challenges associated with identifying other uses for the excess heat, it is prudent to assume that net energy consumption would be at or near the upper end of this range.

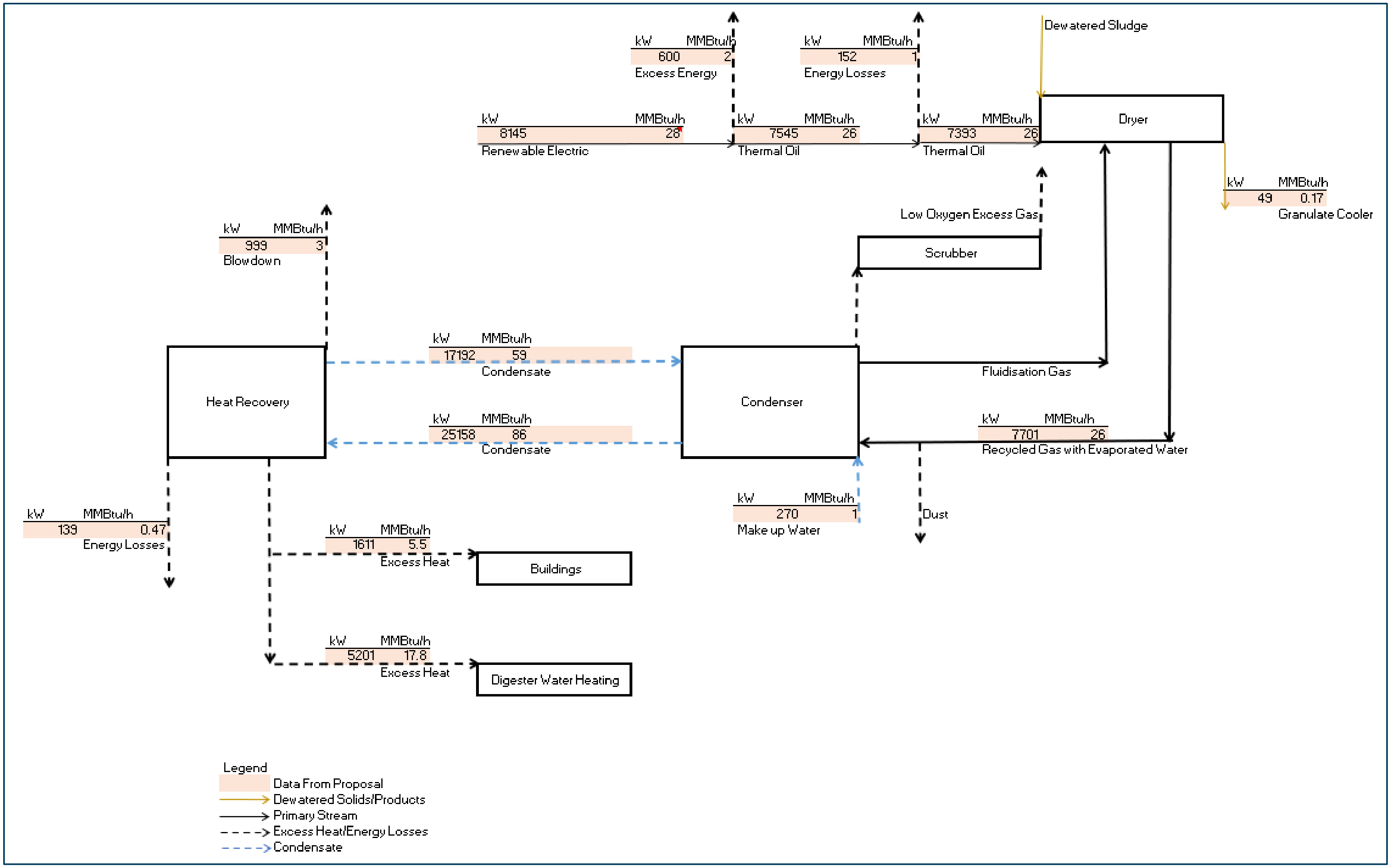
Table 2-3 | Energy Use Comparison

Energy Use or Generation	Baseline in 2050	Biosolids Partnership Proposal in 2022	Biosolids Partnership Proposal in 2050
Energy Consumption of Composting or Drying Operation	1,888 MWh/yr	71,350 MWh/yr (28 MMBtu/h)	108,830 MWh/yr (43 MMBtu/h)
Recycled Energy Available[1]	-	-64,800 MWh/yr (25.3 MMBtu/h)[2]	-98,800 MWh/yr (38.6 MMBtu/h)[3]
Average Available Recycled Energy Not Utilized[4]	-	47,700 MWh/yr (18.6 MMBtu/h)	72,600 MWh/yr (28.4 MMBtu/h)[5]
Net Energy Change	1,888 MWh/yr	6,550-54,200 MWh/yr	10,030-82,630 MWh/yr

Notes:

1. Recycled energy available is counted as a negative value since this amount reduces the plant's overall required energy if utilized.
2. As reported by Biosolids Partnership.
3. Energy efficiency is assumed to remain unchanged in 2050.
4. Recycled energy that is available but not currently utilized by the existing or proposed systems. Utilized energy is subtracted from available energy to provide the energy not utilized under the proposed system.
5. Energy usage for heating digesters through hot water loop in 2050 is assumed to scale up linearly with the increase in biosolids.

Figure 2-3 | Proposed 2022 Energy Requirement Breakdown per Process



2.4.5.2 Climate Footprint

The revised Biosolids Partnership proposal assumes that all the electrical energy required for the facility will be generated from renewable electricity and heat from the process would be completely reused, and as such, the facility has a minimal climate footprint. The validity of these claims determines how the revised proposal would impact the climate.

Greenhouse gas (GHG) emissions would be created by the diesel hauling trucks transporting biosolids from Brightwater and West Point WWTPs to South WWTP. The mileage of trucking required is lower than the baseline alternative, and no emissions result directly from hauling the biosolids to the cement plant since this is proposed to be done with electric trucks powered by renewable energy.

In the revised proposal, the dryer would be heated electrically with green energy from the Green Direct Program supplied by PSE, so no GHG emissions would be generated. However, it is unlikely that there is sufficient excess capacity in the Green Direct program to power the dryers from this energy source, in which case the County would need to investigate other alternatives to obtain renewable energy credits until another Green Direct project can be funded brought online. The solar panels on the roof of the building will also generate some renewable energy on site, which will slightly reduce the amount of energy purchased from PSE, but does not significantly affect GHG emissions.

To maintain consistency with the revised proposal as presented, it is assumed within this report that build-out of additional Green Direct capacity is possible within the timescale of the construction of the dryer facility. The GHG emissions from renewable energy sources are not actually zero when looking at the full life cycle of the energy source including production. The life cycle GHG emissions for solar and wind energy are typically 17-50 g CO_2e/kWh (NREL, 2012). However, to be consistent with the values used in prior reports which did not consider GHG emissions from any manufacturing and construction, only the GHG emissions from direct power production were included in the calculations.

The excess heat from the dryers will be captured and reused to heat the hot water loop. The hot water loop is currently heated with boilers that is fueled with natural gas, composing of methane, which is converted into carbon dioxide (CO_2) when combusted. Natural gas is a fossil fuel and is not a renewable resource. If the boiler use is completely eliminated by the dryer heat recovery unit, the CO_2 emissions would be eliminated and represents a net CO_2 savings. The County is currently replacing the boilers and installing heat extractors, which use heat pumps to extract heat from the wastewater and transfer it to the hot water loop. The heat extractors are a source of renewable energy that will reduce the amount of natural gas that the boilers use. Consor does not currently have details about how the two energy sources for the hot water loop are expected to be used. For comparison, Consor's calculations assume the best-case climate impact that would be realized if all the current boiler energy demand is fueled with natural gas and therefore would be offset by the heat recovery system if the revised proposal is implemented. This would generate the largest possible CO_2 emissions savings.

The dried pellets will be used as a fossil fuel replacement in cement kilns. The carbon that is trapped within the biosolid pellets will then be released back into the atmosphere, therefore the carbon is not sequestered compared to the baseline alternative. The CO_2 emissions factor of dried pellets is calculated as 107 kilograms of carbon dioxide per one million British thermal units (kg CO_2/MMBtu) based on the following assumptions:

- The heating value of dry pellets is 7,000 British thermal units per pound (Btu/lb) (*Drying of Wastewater Solids,* Water Environment Federation, 2014)

- The total carbon content in biosolids is 45 percent of dry weight (*2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories,* Intergovernmental Panel on Climate Change, 2006)

- The oxidation factor is 100 percent of carbon input (*2006 Intergovernmental Panel on Climate Change Guidelines for National Greenhouse Gas Inventories*)

As listed in *Emission Factors for Greenhouse Gas Inventories* (Environmental Protection Agency, 2023), the CO_2 emissions factor of natural gas and coal is 53 and 104 kg CO_2/MMBtu, respectively. Thus, the CO_2 released at the cement plant is marginally greater than if coal is used and is double compared to if natural gas is used. The biosolids are created regardless of end use and can be considered a renewable fuel, whereas the fossil fuels are extracted specifically for their energy value, so use of biosolids increases use of renewable energy, but still results in GHG emissions which has important implications for the overall climate footprint of the alternative.

In comparison, the baseline alternative causes some CO_2 emissions from the trucking of materials, the composting operation, and fugitive emissions from the compost piles, but has a large negative overall carbon balance because of the carbon sequestration from land application.

A comparison of the carbon footprint (GHG emission) of both the baseline and revised alternatives is shown in **Table 2-4**.

Table 2-4 | Carbon Footprint Comparison

GHG Emission (metric ton CO_2e/yr)	Baseline in 2050	Biosolids Partnership Proposal in 2022	Biosolids Partnership Proposal in 2050
GHG Emission from Hauling Class B	4,072	198[1]	317
GHG Emission from Hauling Class A	702	0[2]	0[2]
GHG Emission from Hauling Feedstock	270	0	0
GHG Emission from Land Application	1,413	0	0
GHG Emission from Operation	1,189	0	0[3]
Fugitive GHG Emission	1,786	0	0
GHG Sequestration from Land Application, Class B	-44,949[4]	0	0
GHG Sequestration from Land Application, Compost	-11,041[4]	0	0
GHG Change as Coal Replacement at Cement Plant	-	1,364	2,097
GHG Change as Digester Heating (Natural Gas) Replacement	-	-3,110	-4,736
Total GHG Emission	**-46,558**	**-1,362**	**-2,322**

Note:

1. Assuming the amount of dewatered sludge hauled from West Point WWTP and Brightwater WWTP to the drying facility in 2022 is the same as the amount of dewatered sludge in 2018.
2. Assumes all Class A biosolids are hauled with electric trucks that are charged at the South WWTP using Green Direct energy. Per system boundaries established in **Appendix G**, GHG emissions related to production and maintenance of the truck are not considered.
3. Assuming sufficient Green Direct energy to operate new electrical equipment using fully renewable energy.
4. The carbon sequestration numbers only quantify the amount of carbon returning to the land. No offsets for fossil fuel replacement were considered for land application.

2.4.5.3 Water Quality

The drying facility is designed to be fully enclosed. All dewatered biosolids are to be kept dry and stored under cover. The facility would be located on-site, and additional site civil work would be included to ensure all stormwater runoff from the facility is discharged in accordance with the King County Surface Water Design Manual. The proposed building is approximately 22,000 square feet, therefore it would likely trigger a Full Drainage Review and be subject to all Core Requirement and Special Requirements unless specific exemptions apply.

The drying facility represents a significant source of additional nutrient loading to the South WWTP. The proposal states that 0.13 million gallons per day (MGD) water containing 974 pounds per day (lb/d) of ammonia-N (NH_4-N) flows back to the head of the plant. **Table 2-5** summarizes the plant flow rate, solids quantity of NH_4-N, and concentration of NH_4-N before and after installing the drying system in the dry season (summer) and wet season (winter).

Table 2-5 | Water Quality Comparison

	Nitrogen Load Before Biosolids Drying System Operation	Nitrogen Added by Biosolids Drying System Operation	Nitrogen Load After Biosolids Drying System Operation
Dry Season			
Average Flow Rate (MGD)	77[1]	0.13	77.13
Average TKN Load (lb/d)	30,800[1]		
Average NH_4-N Load (lb/d)	24,000[2]	974	24,974
Average NH_4-N Concentration (mg/L)[3]	37.37	920	38.82
		Concentration Increase	**3.9%**
Wet Season			
Average Flow Rate (MGD)	98[1]	0.13	98.13
Average TKN Load (lb/d)	40,600[1]		
Average NH_4-N Load (lb/d)	32,000[2]	974	32,974
Average NH_4-N Concentration (mg/L)[3]	39.15	920	40.29
		Concentration Increase	**2.9%**

Notes:
1. Flow rates and TKN quantities were found from *King County Nitrogen Removal Study: Final Report, September 2020*.
2. Assuming NH_4-N is 78% of TKN in domestic wastewater.
3. Calculated based on flow rate and load.

The *King County Nitrogen Removal Study: Final Report* (Brown and Caldwell, 2020) evaluated several approaches to nitrogen removal at South WWTP and reported upgrades to improve nitrogen removal are expected to cost approximately $3 per year per pound of nitrogen removed from the annual load to the plant. The increase in nitrogen load from the revised proposal would result in an additional $1,067,000 in required capital expenditures per year. When assessed over a 20-year lifecycle, this amounts to $21,330,000. As noted in the study, this is an estimate, and the actual costs could be three times higher.

2.4.5.4 Contaminants of Emerging Concern

The presence of contaminants of emerging concern were discussed within section 2.4.5.5 of the *King County Biosolids Class A Alternatives Analysis*, which noted that the main contaminant of emerging concern in biosolids are per- and polyfluoroalkyl substances (PFAS) and related compounds. EPA is continuing to work on the 'PFAS Strategic Roadmap' which includes a risk assessment for perfluorooctane sulfonate (PFOA) and perfluorooctanoic acid (PFOS), the most prominent PFAS compounds, in biosolids by winter 2024. The risk assessment will serve as the basis for determining whether regulation of PFOA and PFOS in biosolids is appropriate. If EPA determines that a regulation is appropriate, biosolids standards would be implemented to improve the protection of public health and wildlife health from health effects resulting from exposure to biosolids containing PFOA and PFOS. Similarly, the Washington Department of Ecology (Ecology) is working to evaluate the presence of PFAS in wastewater treatment and biosolids management, as outlined in the *PFAS Chemical Action Plan* (Ecology, 2021). The County is also working on better understanding the presence and concentration of PFAS in the facilities they operate and recently contracted with Consor to conduct a one-year monitoring program at their WWTPs that will include biosolids testing.

Currently, the focus on PFAS at the national and state level is on drinking water, environmental PFAS contamination, and reducing or eliminating the use of PFAS in products. Efforts in all these areas should help to reduce or eliminate the presence of PFAS in wastewater and biosolids. There is currently no requirement to test for or eliminate PFAS in biosolids and the possibility of future regulations for biosolids is uncertain.

Among the current biosolids treatment technologies available, thermal treatment with combustion or incineration is known to be the primary means to destroy PFAS. The effectiveness of complete PFAS destruction depends on:

- Time,
- Turbulence, and
- Temperature of the specific thermal treatment.

Much of the research to date on PFAS destruction focuses on sewage sludge incineration (SSI) and activated carbon regeneration (*Per- and polyfluoroalkyl substances thermal destruction at water resource recovery facilities: A state of the science review*, Lloyd J. Winchell, et al. 2020). Little research has been dedicated to co-incineration within a cement kiln. The typical temperatures used in the study of SSI tend to be greater than 1000 degrees Celsius (°C), and the academic consensus is that these temperatures are the minimum required for complete destruction of PFAS (Lloyd J. Winchell, et al. 2020). Simply obtaining these temperatures does not guarantee complete degradation of all harmful products, and "incomplete destruction of PFAS compounds can result in the formation of smaller PFAS products, or products of incomplete combustion (PICs), which may not have been researched and could be a potential chemical of concern" (*Per- and Polyfluoroalkyl Substances Incineration to Manage PFAS Waste Streams,* EPA, 2020). Studies to detect PICs are incomplete due to underdeveloped measurement methods for the various fluorinated compounds (EPA, 2020).

The proposed dryer is intended to operate at 185°F. PFAS destruction will not occur at this temperature. The only pathway for PFAS to potentially be destroyed in the revised proposal is through delivery to and use in a cement kiln. While delivery to a cement manufacturing plant is the basis of the proposal, based on discussions with other biosolids drying facilities, it is unrealistic to expect that all produced biosolids pellets would be sent to this facility. Alternative end uses for dried biosolids would be land application, similar to the baseline alternative of Class B and compost, none of which destroy PFAS.

The proposed fate of the dried biosolids is combustion within a cement kiln. The kiln is expected to operate between 1450 °C (2642 °F) and 1800 °C (3272 °F) with gas residence times of several seconds. The limited studies available have found PFAS destruction could reach upwards of 99 percent after incineration at these temperatures and residence times (Lloyd J. Winchell, et al. 2020), yet it is not fully known whether these compounds are destroyed or transformed into PICs. Any PFAS or PICs that are not destroyed in the kiln may end up in several places. All ash from the combusted fuel is mineralized within the cement kiln, and it becomes a part of the cement. The constituents of flue gases that are not mineralized are sent through a fabric filter to catch particulate matter. The remaining gases are injected with ammonia and then carbon, which is intended to remove any harmful chemicals prior to discharge. Undestroyed PFAS or PICs could be captured within any of these processes, but it is also possible some compounds could pass through the treatment process unabated and be released into the atmosphere. The ultimate fate has not been widely studied.

The process of destroying PFAS through thermal degradation is generally accepted as an effective treatment technique, but co-incineration of dried biosolids pellets within a cement kiln has not been deeply studied. There is promise that this method could destroy PFAS and related compounds, but more research is needed to gain a better understanding and higher level of confidence that the compounds are fully destroyed and not released into the atmosphere. The EPA is continuing to research PFAS disposal and destruction methods and expressed interest in a 2022 presentation in conducting PFAS sampling of cement kiln incinerators, so the body of knowledge is expected to evolve in the years ahead.

2.4.6 Economic Impacts

2.4.6.1 Product Marketability

If King County decides to incur the large capital investment to implement sludge drying, the County would be well served to create competition and essentially “set the market” for this fuel source. Setting the market requires attracting interested alternative users, which, as noted in the *King County Biosolids Class A Alternatives Analysis Final Report,* has been challenging for other dried biosolids producers. As an example of an alternative user to the local cement producer, the pulp and paper industry has some biomass-fired power plants in the Puget Sound area which use hog fuel, wood lignin, and municipal wastewater sludge to fuel steam production, with steam-driven turbines generating electricity. Anywhere steam production is prevalent represents a potential user of Class A biosolids for heating. Several industrial enterprises, including refineries on the Strait of Georgia near Bellingham for example, use steam generation in their day-to-day industrial process.

It may also be possible for the County to deliver dewatered sludge cake at 18-20 percent solids directly to the local cement producer, who can finance and operate their own on-site sludge dryer facility, with a guaranteed take volume of dewatered sludge by the cement producer, with the remaining sludge from King County going to composting or land application. In this way, King County can avoid using public money to fund a sludge drying operation which, based on the experience at other existing Class A sludge drying facilities, benefits equipment manufacturers and private operations conglomerates but produces negative return-on-investment for the public entity sponsoring the project. The benefit to the local cement producer is they would receive the dewatered cake for free, they could accept sludge from a variety of sources, and the responsibility of drying the sludge would be in the cement producer’s purview and area of expertise.

2.4.6.2 Diversification

The Biosolids Partnership proposal does not improve the diversity of products for the County. Currently, the WWTP produces Class B biosolids which are land applied on one of five sites around the state. If the drying facility is implemented, the facility would then be producing Class A biosolids instead of Class B. Due to the spatial constraints that the facility would impart upon the plant, hauling of Class B would be less feasible than current operations. The cement plant indicated they would include minimum supply requirements in the contract, so the County would be obligated to provide most or all of the biosolids to the plant. While this arrangement would help ensure an end user, it also reduces the ability to diversify.

The facility also represents a large capital investment that must be implement all at once rather than incrementally. Funding this facility could limit the County's ability to fund other projects to diversify their solids profile.

2.4.7 Policy Impacts

2.4.7.1 Compliance with Local, State, and Federal Regulations

Both the Federal Rule 40 Code of Federal Regulations (CFR) Part 503, Standards for the Use or Disposal of Sewage Sludge and the Washington Administrative Code (WAC) 173-308 Biosolids Management, define treatment standards, pollutant limits, and management practices of Class A and Class B biosolids. The revised proposal uses heat drying which is an approved processes to further reduce pathogens to meet Class A biosolids standards according to these regulations.

One of the purposes of WAC 173-308-080 is to "encourages the maximum beneficial use of biosolids," where "Beneficial use of biosolids" is defined as the application of biosolids to the land for the purposes of improving soil characteristics including tilth, fertility, and stability to enhance the growth of vegetation consistent with protecting human health and the environment. WAC 173-308 does not specifically address use of biosolids as a power source, but it does not meet the definition of beneficial use. The end result of using the biosolids in a cement kiln is equivalent to biosolids incineration, which Ecology does not consider a process to achieve beneficial use of biosolids. Discussion with Ecology confirmed that use of biosolids for cement kiln fuel would not qualify as a beneficial use and therefore would not be permitted.

2.4.7.2 Cohesion with Current County Policies and Initiatives

King County's biosolids policies are discussed in King County Code Title 28 Chapter 28.86.090. Biosolids Policy 1 (BP-1) states that "A beneficial use can be any use that proves to be environmentally safe, economically sound and utilizes the advantageous qualities of the material". From this perspective, burning the dried biosolids pellets at a cement plant may meet the definition beneficial use if it can be shown to be environmentally safe and economically sound since it uses the heat capacity of the material to help produce a commodity.

BP-2 states that "Biosolids-derived products should be used as a soil amendment in landscaping projects funded by King County," and BP-6 states "The County shall continue to provide Class B biosolids and also to explore technologies that may enable the county to generate Class A biosolids cost-effectively or because they have better marketability". Implementation of the revised alternative will require these County codes to be changed since the biosolids will not be available for use as a soil amendment. The revised proposal meets BP-3 policy to "consider new and innovative technologies", but does not meet BP-4, which is to "consider diverse technologies, end products, and beneficial uses" since it is a single process and end use. Additionally, BP-5 states that "King County shall produce and use biosolids in accordance with federal, state and local regulations." As discussed previously, the revised proposal does not meet state regulations for biosolids because it does not meet beneficial use laws. BP-9 addresses minimization of noise and odor impact, which, as was discussed previously, has been addressed in the revised proposal and is not expected to be a major problem. Finally, BP-7, BP-8, and BP-10 are not applicable to the revised proposal.

In the *2020 Strategic Climate Action Plan* (King County, 2020), the County committed to meeting a county-wide GHG emissions reduction target of 50 percent by 2030 and 80 percent by 2050. The plan includes

Priority Actions that identify steps the County will take in support of the broader goals and strategies. WTD has a target of carbon-neutral operations by 2025 to meet Priority Action 1.3.3 and 1.3.4, which WTD plans to achieve primarily through carbon sequestration from land application. As noted previously in Section 2.4.5.2, the revised biosolids partnership proposal will result in much higher net CO_2 emissions than the baseline alternative. Thus, the revised Biosolids Partnership alternative does not achieve maximum greenhouse gas reduction through carbon sequestration from land application, and also would make it more difficult for WTD to meet the Priority Action goals set out in the Strategic Climate Action Plan.

2.5 Alternative Analysis Summary

A qualitative evaluation of the revised Biosolids Partnership proposal, as compared to the WTD's baseline alternative and the initial Biosolids Partnership proposal, is summarized in **Table 2-6**.

Table 2-6 | Qualitative Evaluation Summary

Evaluation Criteria	Baseline Alternative Rating	Initial Proposal	Revised Proposal
Scalability	+	-	-
Risk & Benefits	+	-	0
Cost	+	-	-
Capital cost	+	-	-
O&M cost	-	0	0
Lifecycle cost	0	-	-
Social Impacts	0	-	-
ESJ	+	-	0
Odor	-	-	0
Air pollution	0	-	0
Trucking impacts to the community	0	-	0
Ability for communities (in King County or statewide) to use biosolids to amend/build soils for urban or rural agriculture	+	-	-
Environmental Impacts	+	-	0
Overall energy use and maximizing use of renewable energy sources	0	+	-
Climate footprint	+	-	0
Air quality	0	-	0
Water quality	0	0	0
CECs reduction[b]	0	0	+
Economic Impacts	+	-	-
Biosolids product marketability	+	-	-
Diversity of biosolids product user portfolio	+	-	-
Policy Impacts	+	-	-
Compliance with local, state, and federal regulations	+	-	-
Cohesion with current County policies and initiatives	+	-	-

Notes:

a. A **plus** (+) indicates a benefit, A **minus** (-) indicates a detriment, and a **null** (0) indicates no significant benefit nor detriment.

b. Full destruction is not guaranteed. Additional research on CEC destruction in cement kilns is ongoing, but current research shows potential for cement kiln CEC reduction is greater than composting or drying.

CHAPTER 3

Conclusions and Recommendations

3.1 Conclusions

The revised Biosolids Partnership proposal has simplified the proposed biosolids drying and disposal process from the original proposal and addressed many of the challenges identified in the previous report, including the unproven application, lack of redundancy, system complexity, facility size, and feedstock supply. The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis lifecycle and is incapable of meeting biosolids regulatory requirements and policies. These concerns are further detailed below:

- Public agency experience with the process is limited because there are currently only two fluidized bed driers treating biosolids in North America and both are operated by private contractors.
- The scalability of drying system is poor, major investments would be required to increase capacity.
- Significantly higher capital costs than the baseline alternative.
- Significantly higher lifecycle costs than the baseline alternative, with potentially short total lifespan.
- Only one end user, a local cement manufacturing plant, has been identified and other agencies producing dried pellet biosolids have had difficulty identifying end users, so the market may be limited.
- No end users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer.
- The biosolids would not be available for community use.
- Energy use would increase substantially compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase.
- The process would increase carbon dioxide emissions compared to the baseline alterative.
- Additional costs for treatment of nitrogen load from the dryer condensate.
- Does not conform to Washington Administrative Code requirements for biosolids in Chapter 173-308.
- Does not meet King County biosolids policies found in King County Code Title 28, Chapter 28.86.090.

- Does not align with the County's *2020 Strategic Climate Action Plan* goals to reduce greenhouse gas emissions and achieve carbon neutral operation.

3.2 Recommendations

Based on the findings of this analysis, Consor recommends that the County proceed as follows:

- Continue with implementation of the baseline alternative, which involves a combination of Class B land application and composting.

- Continue to evaluate biosolids technologies that may be able to meet regulatory requirements at a cost-effective price to maximize program reliability and reduce risk

Appendices

A. King County Biosolids Class A Alternatives Analysis
B. Biosolids Partnership Presentation of Revised Proposal
C. Biosolids Partnership Revised Proposal
D. Relevant Correspondence with Biosolids Partnership
E. Basis of Cost Estimation TM
F. Detailed Construction, O&M and Lifecycle Cost Estimation for the Revised Proposal
G. Trucking Impact TM
H. Energy and Carbon Analysis TM
I. Detailed GHG Emissions Calculations for the Revised Proposal

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APPENDIX A

King County Biosolids Class A Alternatives Analysis

Final Report

King County, WA

Date: June 10, 2022

Project: Conceptual Planning and Analysis Services, Work Order #7

To: Drew Thompson, Resource Recovery Project Manager, King County WTD
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King County Biosolids Class A Alternatives Analysis

Executive Summary

Introduction

In September of 2021, a private entity known as Biosolids Partnership approached King County (County) Council with a proposal to convert all the County's Class B biosolids to a Class A product. The proposal included provisions to use renewable energy, supply heat to the process building and digestion operations at South Plant and maintain a net negative carbon impact.

Over the last decade, the County Wastewater Treatment Division (WTD) has been working to improve the biosolids management regime at its three regional wastewater treatment plants (WWTPs). Evaluation of the myriad biosolids management alternatives has been paramount to WTD's efforts. The most notable of these products are summarized below.

- In its 2012-2016 Biosolids Plan, WTD committed to using 100 percent of its Class B Loop® biosolids product as a soil amendment, expanding its marketing and customer base, and supporting ongoing biosolids research.
- In its 2018-2037 Biosolids Program Strategic Plan, WTD evaluated 12 biosolids management alternatives and concluded that Class A composting was the highest-ranking alternative.
- In 2020, WTD contracted Brown and Caldwell to perform a Class A biosolids technology evaluation. This report found that opportunities exist for King County to explore transition to Class A biosolids as a long-term, phased approach over many decades. Opportunities include Class A digestion at the treatment plants paired with a soil blending facility, as well as composting Class B biosolids into Class A compost.
- Between 2016 and 2020, WTD conducted two additional studies to advance the Class A Composting alternative: The first was a Composting Feasibility Study (Oct. 2016) and the second was a Loop Compost Market Assessment (Feb. 2020). Based on the findings of these studies, a compost pilot facility is being designed at South Plant, with construction scheduled in 2022–2023.

In response to a council request for an independent consultant evaluation of the Biosolids Partnership Proposal, WTD contracted Murraysmith, in January 2022, to perform an assessment on the feasibility and implementation plan of the Biosolids Partnership proposal.

Description of Alternatives

During the evaluation the Biosolids Partnership proposal was compared with the baseline alternative, i.e., WTD's existing Class B biosolids program with addition of a Class A composting program that is currently in the planning stages. The following section details these alternatives.

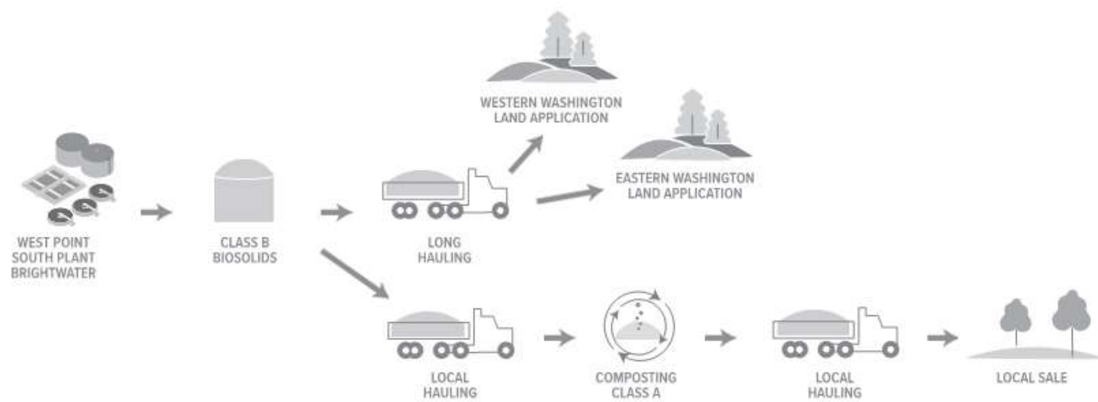
Baseline – WTD Existing Class B Biosolids Program with Class A Composting Facility

The WTD currently produces roughly 130,000 wet tons of Class B Loop biosolids annually from its three regional WWTPs. This figure is expected to increase to approximately 198,000 wet tons by 2050. In recent years, over 75 to 80 percent of Loop biosolids have been hauled to eastern Washington for land application with the remaining amount applied to forests in western Washington.

The following elements are considered a part of the baseline and illustrated in Figure ES-1:

- 80 percent of the Class B Loop biosolids are hauled to agricultural or forest land as a form of soil amendment, similar to the current operation.
- 20 percent of the Class B Loop biosolids are hauled to an off-site composting facility. The Class A compost product will be sold locally as a soil amendment.

Figure ES-1. Baseline Biosolids Treatment Process



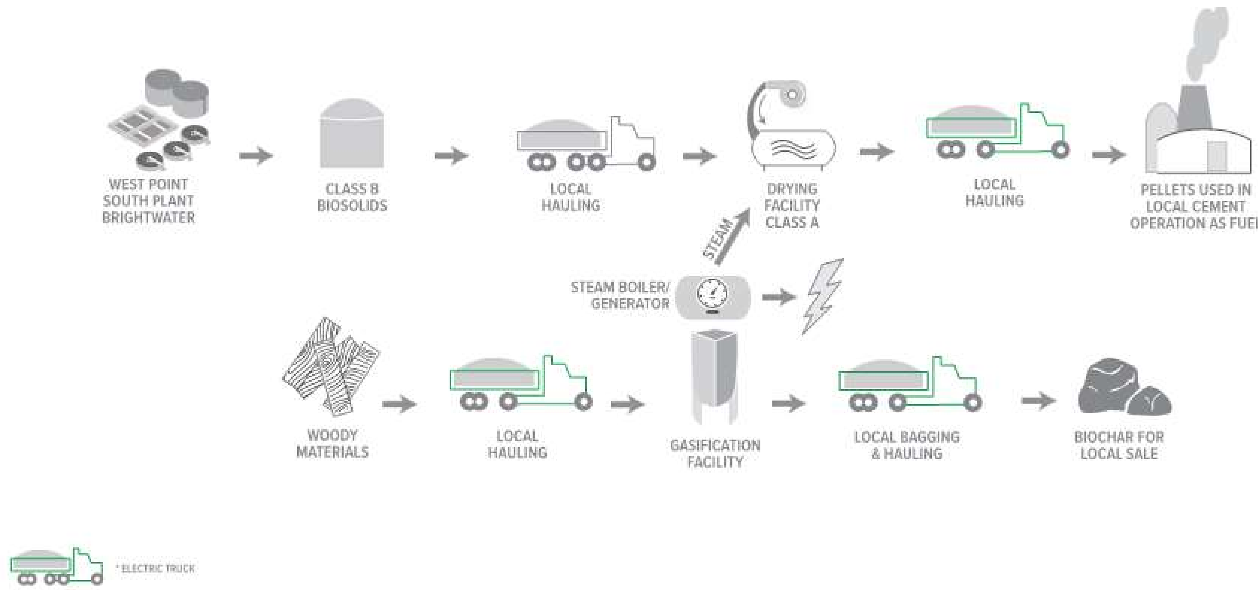
Biosolids Partnership Proposal

As illustrated in Figure ES-2, the Biosolids Partnership proposal included:

- Class B biosolids from all three WWTPs are hauled to a centralized drying facility using existing diesel trucks.
- Biomass wood from an outside source (Cedar Grove Composting) is hauled using electric trucks to a gasification facility where the biomass is converted to biochar. Biochar is hauled using electric trucks back to Cedar Grove for bagging and local distribution/sale.
- Gasification produces renewable biogas, commonly referred to as syngas. Syngas is used as fuel to generate steam. The steam is sent to a turbine to create electricity, which is intended to meet the energy demand by electric trucks and all the electric equipment required for the operation.

- Excess steam is collected and sent to the dryer to dry the Class B biosolids into Class A biosolids.
- The Class A dried pellets are then hauled, using electric trucks, to the Ash Grove Cement Plant for use as fuel for cement production.

Figure ES-2. Proposed Biosolids Treatment Process



Conclusions

The Biosolids Partnership proposal provides a long-term vision of innovation and sustainability by combining renewable energy generation and biosolids management. If implemented, it would reduce fossil fuel consumption and provide a 100 percent Class A biosolids product. However, the proposal presents many flaws and risks, detailed below, which prevent this idea from being implementable.

- Unproven application
- Lack of redundancy for the equipment and backup plan for the biosolids management
- Complex system requiring numerous, highly skilled O&M staff
- Significantly higher capital and lifecycle costs
- Significant social impact to the local community
- Locating the facility within a reasonable distance to South Plant to best utilize waste heat may not be feasible
- Additional undefined costs for treatment of nitrogen load from the dryer condensate
- Unreliable source for gasification feedstock

- Unidentified market for the biochar produced from gasification
- Unreliable market for the pellets produced from drying
- Does not conform to County's carbon sequestration initiative and 100 percent beneficially reusing biosolids as required by the Washington Administrative Code (WAC) and King County Code (K.C.C.).

Comparatively, the baseline alternative, with small incremental steps to test and verify the implementation of the compost program, provides the following benefits:

- Diversified biosolids management approaches increasing the resiliency of the program
- Proven successful experience with community outreach and local market of compost by others
- Pilot test of King County Loop compost to further verify the scalability and feasibility
- Positive social impact
- Higher climate benefit
- Insignificant environmental impact
- Relatively lower costs

Recommendations

Based on the findings of this alternatives analysis, Murraysmith recommends the following to the County:

- Continue implementing the baseline alternative, starting with the pilot compost facility, to help in making decisions about the full-scale compost facility.
- Given the flaws and risks identified in the report that are associated with the Biosolids Partnership proposal, this proposal should not be further considered. However, County should continue monitoring any Class A biosolids technologies and operations that will utilize the renewable resource and reduce the carbon footprint, while maximize program reliability and minimize risk.

Section 1 Background

1.1 Project Introduction

The Biosolids Partnership, a private entity that is comprised of several entrepreneurs, equipment manufacturers and engineering design and construction companies, has approached the King County (County) Council with a proposal to convert all of the County's Class B biosolids to a Class A product using renewable energy, while also supplying heat to the process building and digestion operations at South Plant and producing a net negative carbon impact.

Over the last decade, the Wastewater Treatment Division (WTD) of the Department of Natural Resources and Parks has been working steadily to improve the biosolids management practices at its three regional wastewater treatment plants (WWTPs)–Brightwater, West Point, and South Plant. Evaluation of the various biosolids management alternatives has been a key component of the WTD's efforts. The most notable of these work products are summarized below.

- In its 2012-2016 Biosolids Plan, WTD committed to continue using 100 percent of its Class B Loop® biosolids product as a soil amendment, while also expanding its marketing and customer base, and supporting ongoing biosolids research. Using the 2012-2016 Biosolids Plan as a starting point, the 2018-2037 Biosolids Program Strategic Plan (Plan) developed three final goals: 1) to recycle 100 percent of Loop Biosolids, 2) to diversify biosolids products and distribution, and 3) to integrate activities across the division including Biosolids, Energy, and Recycled Water programs, and Technology Assessment and Innovation Program. The Plan also defined the objectives, alternatives, strategies, and actions needed in order to achieve these goals. The Plan evaluated 12 biosolids management alternatives including the existing Class B program, existing Class B land application program with western Washington sites, as well as Class A composting, Class A thermal dryer, incineration, etc. Ultimately, Class A composting was identified as the highest-ranking alternative.
- In 2020, WTD contracted Brown and Caldwell to perform a Class A biosolids technology evaluation to support Ordinance 18930, Section 72, Proviso P3 response. The Proviso report evaluated a variety of alternatives including the baseline practice (the current Class B Program), as well as 100 percent Class A utilizing Class A digestion paired with a soil blending and composting facility, and 100 percent Class A using pyrolysis (thermal decomposition). This report found that opportunities exist for King County to explore transition to Class A biosolids as a long-term, phased approach over many decades. Opportunities include Class A digestion at the treatment plants paired with a soil blending facility, as well as composting Class B biosolids into Class A compost.
- Between 2016 and 2020, WTD conducted two studies to advance the Class A Composting alternative: The first was a Composting Feasibility Study (Oct. 2016) and the second was a Loop Compost Market Assessment (Feb. 2020). Based on the findings of these studies, a compost pilot facility is being designed at South Plant, with construction scheduled in 2022–2023. The purpose of this 400 to 800 wet-tons per year pilot facility is to explore the technical and financial feasibility of eventually developing a full-scale compost facility capable of producing a Class A biosolids product.

In response to a council request for an independent consultant evaluation of the Biosolids Partnership Proposal, WTD contracted Murraysmith, in January 2022, to perform an independent evaluation on the feasibility and implementation plan of the Biosolids Partnership proposal. The findings of that analysis are presented in this report.

1.2 Project Objective

The primary objective of the project is to evaluate the various components of the Biosolids Partnership proposal including implementation, feasibility, and approach for utilizing renewable energy, Class A biosolids marketability, scalability, expected environmental and climate footprint, and overall program cost. The project will also identify any necessary changes to County policies and future budget adjustments that may be required for program implementation.

1.3 Description of Alternatives

The above objective will be met by comparing the alternative proposed by the Biosolids Partnership with the baseline alternative, i.e., WTD's existing Class B biosolids program with addition of a Class A composting program that is currently in the planning stages. The following section details these alternatives.

1.3.1 Baseline – WTD Existing Class B Biosolids Program with Class A Composting Facility

The WTD currently produces roughly 130,000 wet tons of Class B Loop biosolids annually from its three regional WWTPs. In recent years, over 75 to 80 percent of Loop biosolids have been hauled to eastern Washington for land application with the remaining amount applied to forests in western Washington.

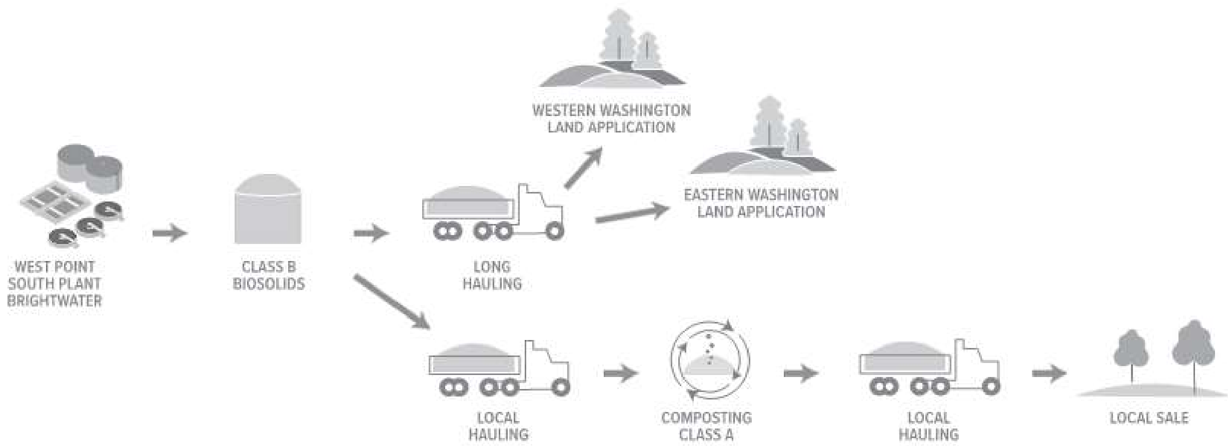
The amount of Class B Loop biosolids is expected to increase to approximately 198,000 wet tons in 2050, based on the Class A Biosolids Technology Evaluation (Brown and Caldwell, 2020). The County has nearly completed the design and will soon start the construction of a compost pilot facility at South Plant, as a first step towards a full-scale program converting Class B biosolids into Class A biosolids through composting.

For the purposes of this analysis, it was assumed that the County will transform 20 percent of Class B Loop biosolids into Class A compost when this method is fully implemented. As such, the following elements are considered a part of the baseline:

- 80 percent of the Class B Loop biosolids are hauled to agricultural or forest land as a form of soil amendment, similar to the current operation.
- 20 percent of the Class B Loop biosolids are hauled to an off-site composting facility. The Class A compost product will be sold locally as a soil amendment.

The above process is illustrated in Figure 1.

Figure 1. Baseline Biosolids Treatment Process



1.3.2 Biosolids Partnership Proposal

The proposal presented by the Biosolids Partnership in September 2021 (Appendix A) provided only a high-level concept of how a biomass gasification system might be used to power a biosolids thermal drying system for the purpose of using renewable energy to produce Class A biosolids. The presentation stated that the proposed program would generate a net negative climate impact and save the County roughly $1 million per year. However, there were no engineering data provided to support these assertions.

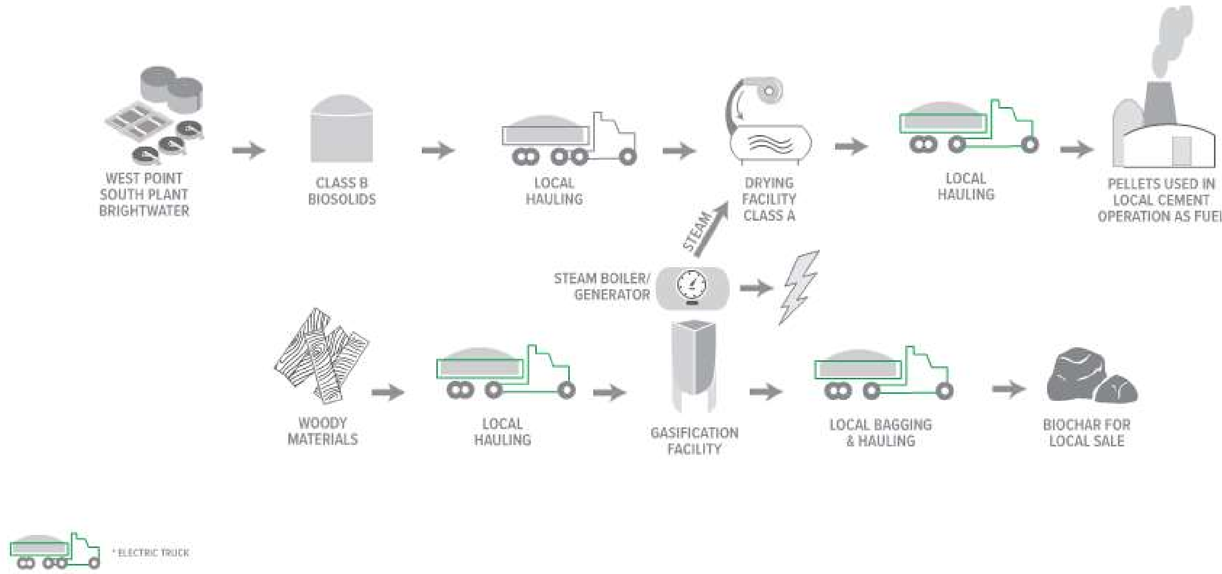
From early February to the end of April 2022, the Biosolids Partnership, primarily under the direction of Bart Lynam, assembled a team and put together a second conceptual design proposal on biosolids drying, biomass gasification, and power generation (Appendix B). The key difference between the September 2021 presentation and the April 2022 proposal was the addition of power generation, which involves a thermal oxidizer unit, selective catalytic reduction, heat recovery steam generator, and turbine generator.

As illustrated in Figure 2, the Biosolids Partnership proposal included:

- Class B biosolids from all three WWTPs are hauled to a centralized drying facility using the County's existing diesel trucks.
- Biomass wood from an outside source (Cedar Grove Composting) is hauled using electric trucks to a gasification facility where the biomass is converted to biochar. Biochar is hauled using electric trucks back to Cedar Grove for bagging and local distribution/sale.
- Gasification also produces a renewable biogas, commonly referred to as syngas. Syngas is used as fuel to generate steam, then electricity to meet the energy demand by electric trucks and all the electric equipment required for the operation.
- Excess steam is collected and sent to the dryer to dry the Class B biosolids into Class A biosolids.

- The Class A dried pellets are then hauled, using electric trucks, to the Ash Grove Cement Plant for use as fuel during cement production.

Figure 2. Proposed Biosolids Treatment Process



Section 2 Summary of Analysis Activities

2.1 Stakeholder Involvement

On February 3, 2022, Murraysmith contacted Bart Lynam at the Biosolids Partnership to request additional information that would support this analysis. Since then, Murraysmith and the Biosolids Partnership have had multiple exchanges of information as the Biosolids Partnership refined the conceptual level design of their proposed program over the next 3 months. During the process the Biosolids Partnership went through the search and change of the gasification manufacturer, as well as the change of the proposed process and equipment. Copies of the most relevant correspondence are included in Appendix C of this report.

On February 23, 2022, Murraysmith facilitated a focus group meeting with the County Council and WTD staff. The purpose of this meeting was for Murraysmith to develop an understanding of Council expectations for the project and to provide an update on the analysis and final deliverable. The meeting minutes for this meeting are included in Appendix D of this report.

2.2 Wastewater Agency Outreach

As part of the project analysis, Murraysmith conducted site visits, phone interviews, and email surveys with a variety of wastewater agencies that currently operate biosolids programs that are either similar to the WTD baseline, or similar to the Biosolids Partnership proposal. The purpose of this outreach was to collect first-hand information on operation and maintenance (O&M) requirements and product marketability from staff at each facility. The subsections below present a summary of the facilities contacted; a compilation of notes for each facility is included in Appendix E of this report.

2.2.1 Biosolids Drying Facilities

- SoundGRO® Fertilizer Manufacturing Facility, Pierce County, Wash.: This local facility is of comparable scale that operates an Andritz drum dryer to produce Class A biosolids. It has been in operation for about 16 years.
- Irvine Ranch Water District (IRWD) Biosolids and Energy Recovery Facility, Irvine, Calif.: Started up less than a year ago, it is the newest facility of comparable scale that operates an Andritz drum dryer to produce Class A biosolids.
- North Shore Water Reclamation District (NSWRD) Biosolids Recycling Facility, Zion, Ill.: One of very few facilities in North America that operates an Andritz fluid bed dryer. It has been in operation for approximately 15 years.

2.2.2 Composting and Soil Amendment Facilities

- TAGRO Facility, City of Tacoma, Wash.: The local Class A biosolids and soil amendment facility of comparable scale. It has been in operation for about 30 years.

- DC Water's Blue Drop Bloom® Program, Washington D.C.: The largest Class A biosolids and soil amendment facility in the nation. It has been in operation for approximately 7 years.

- Garden City Compost, City of Missoula, Mont.: One of the largest compost facilities in the Northwest, it uses an aerated static pile composting process, the same process the County will use for its pilot and full-scale compost facilities. City of Missoula has operated the facility since 2016.

- Various local small-scale compost facilities: General information on capacity, operation, feedstock source, and product market was collected from the compost facilities in Port Townsend, Westport, Lynden, Cheney, Richland, and Centralia, Wash., via emails.

2.3 Implementation Consideration of the Proposed Alternative

The April 2022 Biosolids Partnership proposal presented a large and comprehensive program involving three, stand alone yet inter-dependent processes–biomass gasification, power generation, and biosolids drying. Key considerations for potential implementation of this proposal are discussed in the sections shown below.

- Having enough space to house the entire facility (Section 2.3.1).

- Having enough personnel (human capital) with the expertise required to operate and maintain various processes and trucking (Section 2.3.2).

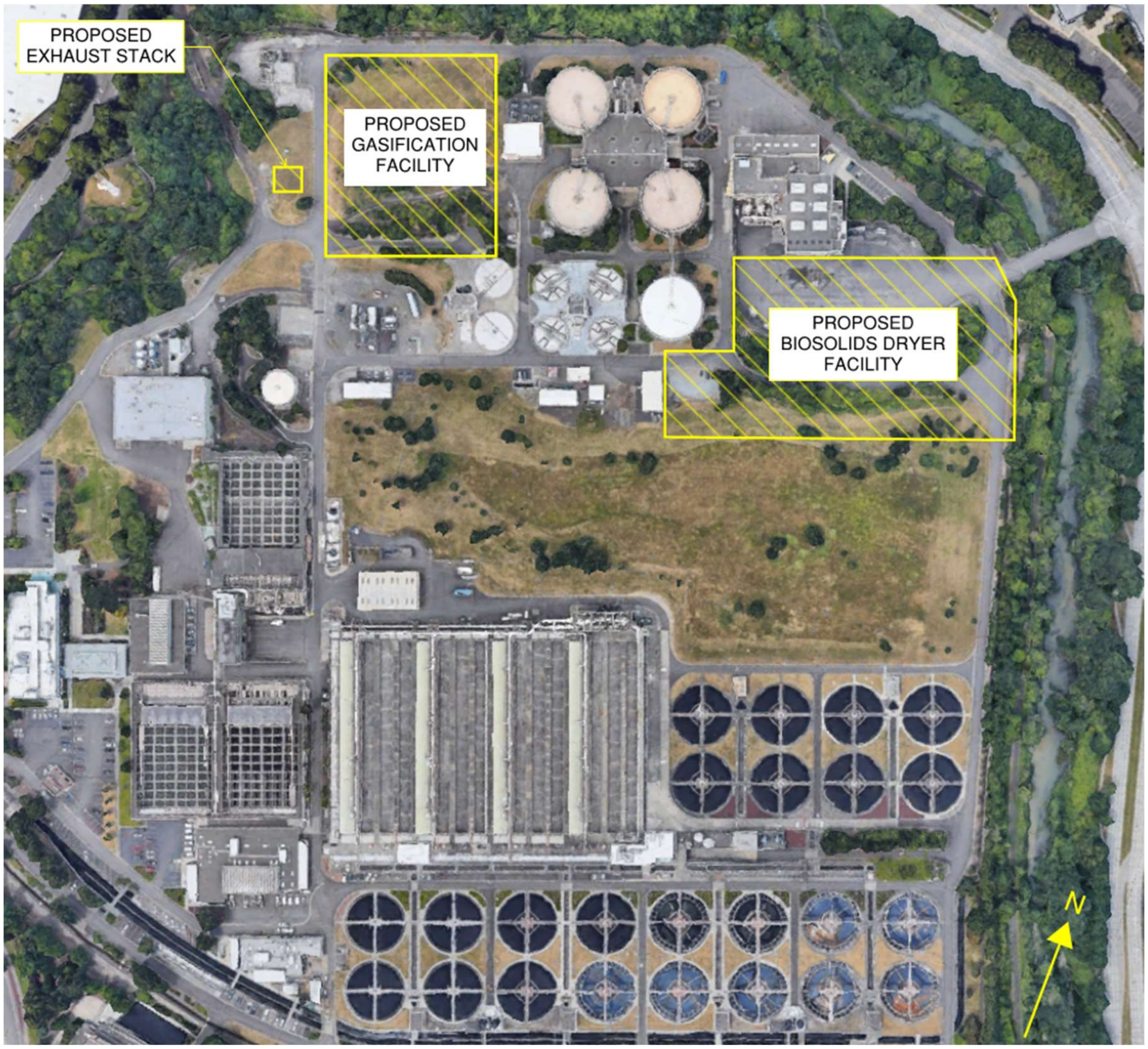
- Having a readily available source of woody materials (Section 2.3.3).

- Having a reliable market for the final product (Section 2.3.4).

2.3.1 Space Requirement

The proposed facility will require approximately 3 to 3.5 acres of land to house the necessary infrastructure, e.g., material loading and unloading, storage, equipment, odor control, access roads and parking. The Biosolids Partnership proposed to locate the drying facility and the gasification and power generation facility at different spaces within the South Plant footprint (Figure 3).

Figure 3. Proposed Facility Location at South Plant



While it appears there is enough space available in the figure above, much of it has already been allocated to other projects. For example, the proposed location for the gasification facility has been reserved for a future digester expansion, biogas treatment, and a thermal recovery project, and the proposed footprint of the drying facility will encroach upon the land reserved for the future secondary treatment expansion as well as access roads for the plant.

The facility will have to be located outside the South Plant footprint. The dryer condensate will need to be conveyed back to South Plant for treatment. Identifying and acquiring the land is an important step in the implementation plan. For the purposes of this report, it is assumed that the proposed facility will be located offsite, near existing sewer utilities, and within 10 miles of South Plant.

2.3.2 Expertise, Human Capital, and O&M Resources

None of the three processes proposed by the Biosolids Partnership are used commonly in municipal utilities and they are completely new to the County system. Each process is mechanically intensive and relies heavily on other processes for uninterrupted operation. The design, installation, and operation of the complete system will require significant skill and attention. Based on Murraysmith's interviews with staff at similar facilities, a minimum of 24, full-time equivalent (FTE) personnel will be required to operate and maintain this facility. In addition, the County will need to employ staff who have experience in operating power generation equipment, such as the gasifier and steam turbine, or train individuals to be qualified for this sort of work.

Alternatively, the County could consider contracting the operation out to a qualified third-party. Nevertheless, having operators with a specific skillset will be an important implementation consideration.

2.3.3 Source of Woody Materials

The proposed gasification process will use woody debris, cardboard, and other green waste to create syngas. The syngas is in turn combusted to generate steam to meet the demand of the steam turbine generator and dryer. Because there is no alternative or backup fuel source for the biosolids dryer, having a reliable supply of woody materials becomes critical to the Class A biosolids operation.

The exact amount of feedstock required is highly dependent on the characteristics of the woody materials and the performance of the gasification system. The Biosolids Partnership estimated the gasifier will require approximately 15 wet tons per hour of biomass wood in 2050 and indicated Cedar Grove could supply all of the material. However, it is likely that this extraordinarily high feedstock demand would have to be met by multiple sources. The County will need to foster relationships with nearby industries to meet the needs of the system. Relevant industries include:

- Sawmills
- Green waste recycling facilities
- Paper and cardboard recycling facilities
- Furniture manufacturers

2.3.4 Market for Final Products

The proposed system produces two final products–biochar from biomass gasification and pellets from biosolids drying. Reusing these products to provide the greatest benefit to the local community will require effort from the County on marketing, public outreach, and partnership acquisition. Similar to the woody material supplier, the market for the final products needs to be diversified in order to strengthen the resiliency of the program.

The Biosolids Partnership does not identify a market for the biochar, they only state the biochar will be hauled to Cedar Grove for bagging and local sale. The Biosolids Partnership proposed to send the pellets to Ash Grove Cement Plant as a fuel. More diversified markets need to be secured to facilitate a successful implementation.

2.4 Alternatives Analysis

The following section details the comparison between the Biosolids Partnership proposal and the baseline, from the perspective of scalability, risk and benefit, costs, social impacts, environmental impacts, economic impacts, and policy impacts. The results of the alternative analysis are summed in Table 3.

2.4.1 Scalability

The Biosolids Partnership used the following phased installation for their proposed system:

- Initial construction: includes two dryer trains and three gasification trains to handle the near-term biosolids loading (85 dry tons per day [DT/d]). Supporting system and infrastructure, such as the heat recovery steam generator system, steam turbine generator system, thermal oxidizer unit, drying and gasification buildings and odor control, will be constructed to handle the 2050 solids loading from the beginning.
- Future construction: One dryer train and one gasification train will be added later to handle the projected biosolids loading in 2050 (150 DT/d).

Scalability Analysis

Due to the complexity of these dryer and gasification systems, it is not economical to manufacture or operate many small units. For example, IRWD (with projected biosolids loading of 33.5 DT/d), NSWRD (currently processes 25 DT/d of biosolids), and Pierce County's SoundGRO facility (currently processes 7 DT/d) all have just one dryer system. The required increment of scaling is large and the up-front cost for upscaling the facility is high.

The baseline alternative has far greater scalability due to the simplicity and modularization of the composting. A composting facility operates by creating rows of biosolids, layered with woody debris, aerating these rows, covering them, and periodically mixing them. Expanding the composting facility requires space to create more rows, additional covers, and expanded aeration systems. The size of each compost row can be tailored to fit the facility capacity and O&M requirements. The required increment of scaling is small and the up-front cost for upscaling the composting facility is low.

2.4.2 Benefits and Risks

This section presents a comparison of the primary benefits and risks of each of the Class A biosolids alternatives analyzed in this report.

In general, the Biosolids Partnership alternative has more risks than benefits. The primary benefits include: 1) converting the County's entire Class B biosolids to Class A biosolids which have fewer restrictions for reuse; 2) utilizing renewable energy sources to power the biosolids drying operation and supplement the heat requirements at South Plant; and 3) eliminating long-distance biosolids hauling to eastern Washington. The primary risks are detailed below.

1) There is no proven track record of a similar operation. Although the individual technologies of gasification, drying, heat recovery, and power generation have been proven in successful installations and operations, combining them for biomass gasification, biosolids drying, and power generation has never been done at any scale, and certainly not at the County's scale.
2) The lack of redundancy jeopardizes overall system resiliency. As proposed, the equipment would need to be operated in sequence to treat the projected biosolids quantity. In the event of an equipment failure in any part of the process, the County would have to find another way to store, treat, or haul Class B biosolids that could not be handled at this facility.
3) The proposal identifies only a single supplier of wood biomass (required for the gasification process at extraordinarily high demand). Very preliminary discussion between the Biosolids Partnership and Cedar Grove has been made to identify them as the sole supplier of the woody material. The quantity and quality of the woody material has not been confirmed. As proposed, 360 tons per day of wood biomass would be required in 2050. This is an unrealistic amount of woody material to be secured from a single source. To illustrate, in 2009, the energy firm Seattle Steam replaced one of its gas-fired boilers with a new wood-fired boiler. The boiler consumed about 250 tons of wood waste every day. Cedar Grove was able to supply about 100 tons of this daily amount; three other waste sources were also needed to fill the demand. Together they could supply about 80 percent of the wood material needed. The wood biomass required by the County facility would be over 40 percent more than what was needed by Seattle Steam and 3.6 times of what Cedar Grove was able to supply in 2009. Furthermore, sourcing an adequate amount of woody debris may become more difficult as other technologies utilizing wood waste are adopted in the future.
4) There is just a single market for the final product. Very preliminary discussion between the Biosolids Partnership and Ash Grove Cement Plant has been made to identify the final disposition of the dried pellets. It is proposed to use the dried pellets at Ash Grove Cement Plant as the fuel. However, having just one outlet for the entire product poses a huge risk.
5) There are concerns regarding final product safety. All the biosolids drying facilities that were interviewed indicated they had experienced smoldering or fire accidents with their dried pellets, either during storage or application.

Conversely, the baseline alternative has more benefits than risks. Since 2016, WTD has completed multiple feasibility and market studies to assess the benefits and risks of the County's compost program. The main benefits include: 1) converting part of Class B biosolids to Class A, which provides more biosolids beneficial reuse opportunities to the local community; 2) increasing the diversity of Loop products and customers for WTD, thereby increasing WTD's resiliency for successful biosolids recycling; 3) recovering valuable resources for sustainable communities, through carbon sequestration of reclamation sites and degraded urban soils, and tree planting goals; and 4) allowing the County to support two determinants of equity–access to affordable, healthy, local food, and healthy built and natural environments–by having a product that can be donated or sold to local farms, parks, and gardens.

The primary risks of the baseline alternative are associated with the source of the feedstock, the success of marketing the final compost product, and the land acquisition for the compost site. The compost pilot facility, currently in the planning stage, will provide first-hand experience on the technology, market, and O&M required to mitigate these risks before a full-scale compost program is implemented.

2.4.3 Costs

A cost estimate was prepared to Association for the Advancement of Cost Engineering Class 5 estimate standards for planning-level evaluations with a range of -50 percent to +100 percent. A full explanation of the cost estimation methodology is provided in Appendix F of this report. The cost comparison between the baseline and proposed alternatives is summarized in Table 1. The annual O&M cost of the baseline is over $2 million higher than that of Biosolids Partnership proposal, due to the high cost associated with the long-distance biosolids hauling in the baseline alternative. However, the capital and lifecycle costs of the baseline are much lower than those of the Biosolids Partnership proposal.

Table 1. Capital, O&M, and Lifecycle Costs ($ million)

Alternative	Capital	Annual O&M	20-Year Lifecycle
Baseline	$119.9	$15.2	$373.8
Biosolids Partnership Proposal	$508.2	$12.8[1]	$723.6

1. The O&M cost associated with the drying facility has been developed based on experience from other drying facilities. The O&M costs associated with biomass gasification and power generation using syngas have been estimated to the engineer's best judgement due to the relative novelty of these technologies. The annual O&M costs for the Biosolids Partnership Proposal are therefore speculative in nature.

2.4.4 Social Impacts

This criterion considers whether the alternative will increase or decrease the quality of life of County residents, taking into account the vulnerability of different communities. Aligning with the County's the Determinants of Equity Report, considerations are given to healthy built and natural environments for all people that includes mixed land use that supports employment, housing, amenities, and services; trees and forest canopy; clean air, water, soil, and sediment.

2.4.4.1 Equity and Social Justice

As discussed in Section 2.3, South Plant does not have sufficient land to accommodate the full-scale compost facility or the proposed gasification and drying facility. It is assumed the new offsite facility will be located near South Plant (within 10 miles). According to the Social Vulnerability Index developed by the Centers for Disease Control and Prevention and the demographic index from the United States Environmental Protection Agency's (EPA's) Environmental Justice Screening and Mapping Tool, the community in the vicinity of South Plant is much more vulnerable than those in the neighborhoods surrounding West Point or Brightwater. The area is populated by under-represented groups of lower socio-economic means.

Compared to the composting facility, which is low-profile and pastoral in appearance, the proposed gasification, drying, heat recovery, and power generation facility is a multi-story, heavy-industrial-looking infrastructure. Just from the aesthetic and land use perspective, it would likely be less acceptable to the community.

2.4.4.2 Odor Control

The odor level emitted from the biosolids drying process would be very high due to the evaporation and diffusion of odorous compounds. The Biosolids Partnership has proposed to provide a multi-stage odor control system, which consists of a biotrickling tower, chemical scrubber, activated carbon vessel, and exhaust stack for the drying facility. Offsite odors are expected to be minimal after installation of the odor control measures.

The odor level emitted from the aerated static pile compost will be lower compared to the drying process. Odor control will be provided at the pilot compost facility. The potentially foul air is drawn from underneath the compost bunkers and sent to a biofilter for treatment. Offsite odors are expected to be minimal after odor control mitigation.

2.4.4.3 Air Pollution

The Biosolids Partnership proposal would impact the air quality of the community as follows:

- Air pollutants (e.g., nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM), and heavy metals) would be generated during gasification and drying operations, even after various pollutant control devices had been put into place.
- Dust would be generated in the biosolids drying operation.
- The proposal assumes diesel powered biosolids trucks to transfer biosolids from the WWTPs to the drying facility. These trucks would generate combustion-based pollutants.

Because the baseline alternative composting operation has no heating or combustion component, it will not produce the air pollutants generated by the proposed Biosolids Partnership alternative.

- The only potential pollutants are fugitive emissions of volatile organic compounds (VOCs) from the biosolids piles, which can be mitigated by using a biofilter odor control system.
- The pollutants generated by the biosolids trucks running on diesel fuel will be less because the amount of biosolids hauled to the compost facility is smaller.

2.4.4.4 Trucking Impacts to Communities

Both of the Class A alternatives considered in this report would be located near South Plant. As a result, any trucking to or from the area will have a disproportionate impact on more vulnerable low income and minority populations.

The anticipated number of truck trips in the neighborhood is summarized in Table 2. The trucking traffic near the proposed facility will increase by about 1.9 times under the Biosolids Partnership proposal, compared to the baseline alternative. Increased trucking will not only adversely impact the traffic, but also generate higher overall noise levels and exhaust emissions in the neighborhood. It will be important to make sure that the proposed facility is located along roads that are built for significant truck loads and away from residential zones where the impact on local communities would be greater.

Table 2. Estimated Weekly Truck Trips in the Community

Truck Trips	Baseline	Biosolids Partnership Proposal
Class B biosolids from Brightwater to facility	22	22
Class B biosolids from West Point to facility	0	40
Class B biosolids from South Plant to facility	0	60
Pellets from facility to cement plant	0	36
Woody feedstock from Cedar Grove to facility	15	82
Biochar from facility to Cedar Grove	0	10
Compost from facility to local market	57	0
Total weekly truck loads	94	250

A complete analysis of the social and environmental impacts of trucking is provided in Appendix G of this report.

2.4.4.5 Ability for Communities to Utilize Biosolids

The Biosolids Partnership proposes to combust the dried biosolids pellets at the Ash Grove Cement Plant and, as a result, the biosolids would not be available for community use. If this arrangement should prove unworkable, the pellets could be provided to the community as soil amendments. It should be noted that, based on the experience of staff at SoundGRO and NSWD, the pellets are easier for large-scale agriculture companies to utilize than for home growers in local communities.

The baseline alternative will produce Class A compost and compost soil blend available for local community use, either through donation or sale. The model is similar to the City of Tacoma's TAGRO program, which has successfully established a notable reputation and high recognition by the public. By starting and maintaining a robust and far-reaching outreach and education program, the County will be able to establish its own brand and to support communities, in King County or statewide, to use biosolids to amend and build their soils for urban or rural agriculture.

2.4.5 Environmental Impacts

The following section details the environmental impacts that may be caused by the dryer facility as compared to the baseline solids treatment. The environmental impacts assessed include the trucking of solids, the thermal drying system, and the gasification system.

2.4.5.1 Energy Use

A detailed analysis of energy use and generation for both alternatives is presented in Appendix H. The facility proposed by the Biosolids Partnership would be energy neutral, that is, the energy generated from the biomass wood would meet all of the heating requirements for the biosolids drying process, as well as all of the electrical demands from equipment to support the gasification and drying operation and the electric trucks. The steam turbine generator is designed to generate 5.5 MW of electricity for all of these purposes.

The baseline alternative will consume approximately 1,888 MWh of electricity each year based on the 2050 biosolids load. No power generation is provided in the baseline alternative. Table 3 provides a comparison of the two alternatives.

Table 3. Energy Use and Generation Comparison

Energy Use or Generation	Baseline	Biosolids Partnership Proposal
Energy Consumption of Composting or Drying Operation	1,888 MWh/yr	259,200 MWh/yr (103 MMBtu/h) [1]
Energy Generation (in the form of steam)	-	367,200 MWh/yr (145 MMBtu/h) [2]
Net Energy Change	-1,888 MWh/yr	73,440 MWh/yr (29 MMBtu/h) [3]
Maximum Power Generation from Turbine	-	5.5 MW

1. Energy consumption of the drying operation, assuming continuous operation with 10 hr per month of shutdown time
2. Energy generation from the gasification and turbine operation, assuming continuous operation with 10 hr per month of shutdown time
3. Net energy production excluding 13 MMBtu/h wasted in the condensate

Abbreviations:
MW = megawatt
MWh/yr = megawatt hours per year
MMBtu/h =million British thermal units per hour

2.4.5.2 Climate Footprint

The Biosolids Partnership proposal assumes that all of the electrical and thermal energy required for the facility will be generated on-site, and as such, the facility has a minimum climate footprint. As designed, the only greenhouse gas (GHG) emissions would be created by the biosolids trucks operated on diesel fuel and the combustion of natural gas produced during the startup of the gasifiers and dryers. Because the dried pellets will be combusted, they will not provide any carbon sequestration benefit.

The climate footprint for the baseline alternative stems primarily from the trucking of biosolids, feedstock, and compost, the composting operation, and fugitive emissions from the compost piles. Because all of the compost produced would be used as a soil amendment in land application, it offsets GHG emission by providing carbon sequestration.

Table 4 provides a comparison of the carbon footprint (GHG emission) of both alternatives. The baseline represents a significant carbon reduction benefit due to the carbon sequestration.

Table 4. Carbon Footprint Comparison

GHG Emission (metric ton CO_2e/yr)	Baseline	Biosolids Partnership Proposal
GHG Emission from Hauling Class B	4,072	384
GHG Emission from Hauling Class A	702	0
GHG Emission from Hauling Feedstock	270	0
GHG Emission from Land Application	1,413	0
GHG Emission from Operation	1,189	68
Fugitive GHG Emission	1,786	0
GHG Sequestration from Land Application, Class B	-44,949[1]	0[1]
GHG Sequestration from Land Application, Compost	-11,041[1]	0[1]
Total GHG Emission	**-46,558**	**452**

1. The carbon sequestration numbers only quantify the amount of carbon returning to the land. No offsets for fossil fuel replacement were considered in the above table.

2.4.5.3 Air Quality

The facility proposed by the Biosolids Partnership would generate a variety of air pollutants, chiefly, nitrogen oxides (NOx), sulfur oxides (SOx), carbon monoxide (CO), carbon dioxide (CO_2), particulate matter (PM), and heavy metals, through the process steps listed below. Significant air permits will be required by Puget Sound Clean Air Agency and/or the EPA.

- Biomass gasification
- Combustion of syngas in the thermal oxidizer
- Biosolids drying operation
- Biosolids drying using natural gas during start-up
- Heat recovery steam generation using natural gas during start-up
- Increased biosolids trucking in the area

Because the baseline composting operation does not involve combustion, it will not generate the air pollutants described above. The only potential pollutants are fugitive VOCs emissions from the biosolids piles. Following installation of a biofilter odor control system, these VOC emissions will be insignificant.

2.4.5.4 Water Quality

The gasification and drying systems are designed to be fully enclosed. All feedstocks are to be kept dry and stored under cover. There would not be an impact on nearby water quality.

The baseline composting facility will need to consider the impact of stormwater runoff from the site. Precipitation on and around the composting piles will collect contaminants from the piles. If not properly captured and treated, stormwater could run off into nearby lakes, streams, and groundwater. The composting facility will be built with stormwater management in mind; however, the potential for water quality issues is greater for the baseline alternative than the Biosolids Partnership proposal.

2.4.5.5 Contaminants of Emerging Concern

In recent years, the risk of introducing contaminants of emerging concern (CECs), specifically per- and polyfluoroalkyl substances (PFAS), in the biosolids to food products, livestock, and groundwater has been a controversial topic. Some states and environmental groups aggressively advocate for additional regulations for the land application of biosolids, but most states and organizations support beneficial reuse of biosolids through land application while monitoring additional research and testing being conducted. In its PFAS Strategic Roadmap 2021-2024, the EPA committed to finalizing its risk assessment for perfluorooctane sulfonate (PFOA) and perfluorooctanoic acid (PFOS), the most prominent compounds in PFAS, in biosolids by winter 2024. The assessment will serve as the basis for determining whether regulation of PFOA and PFOS in biosolids is appropriate.

Among the current biosolids treatment technologies, thermal treatment (combustion or incineration) is known to be the only way that has the potential to destroy PFAS. The effectiveness of complete PFAS destruction depends on time, turbulence and temperature of the specific thermal treatment. A sewage sludge incinerator may be less effective to destruct PFAS compared to a cement kiln and has a higher potential to generate products of incomplete combustion that are similar to PFAS in the air phase. Although gasification manufacturers claim their systems can remove PFAS, the technology has not been officially approved by the EPA. Neither composting in the baseline alternative nor the thermal drying in the proposed Biosolids Partnership alternative can remove PFAS. Although the Biosolids Partnership proposed to eventually incinerate the dried biosolids pellets in the cement plant, which may remove PFAS, this forfeits the purpose of producing Class A biosolids through the drying to enhance soil health and recycle nutrients.

2.4.6 Economic Impacts

2.4.6.1 Product Marketability

As discussed in Section 2.4.2, the Biosolids Partnership proposal has not completed a marketability analysis for the final product (pellets and biochar). They briefly mentioned the Ash Grove Cement Plant as the end user of the pellets, but did not clarify whether Ash Grove will pay, or be paid, to use them.

Although pellets could be marketed as a fertilizer or a soil amendment, their marketability is not as favorable as the compost product based on the experience of the Class A biosolids facilities that Murraysmith contacted. For example, IRWD and NSWRD are paying contractors to haul and land apply their Class A pellets, the same as Class B biosolids. Pierce County's SoundGRO facility produces 3-millimeter biosolids pellets from its drum dryer, which is of higher quality than the pellets from the fluid bed dryer in the Biosolids Partnership proposal. Despite the pellet quality, SoundGRO facility faces challenges selling all its Class A pellets as a fertilizer, and they only operate the dryer for half the year, shutting it down to produce Class B biosolids for the other half of the year. The ultimate ability to sell this product comes down to the marketing effort pursued by the County.

A Class A compost product is more easily understood and accepted by the public, therefore it should have a broader market. According to those local composting facilities and Tacoma's TAGRO, the compost or blend products are typically sold out.

2.4.6.2 Diversity of Biosolids Product User Portfolio

The Biosolids Partnership proposal considers only a single user for the entire biosolids product generated at three WWTPs. In the event that the end user stops accepting the biosolids, the County would be faced with the same, or even worse, challenge as if the County were to lose Class B biosolids land application sites. As discussed above, the County could invest in marketing to diversify the user portfolio of the pellets, however, they will not be as widely acceptable as the compost product. Few of the fertilizer spreaders used in land application farms are designed to handle the pellets. In addition, some users are hesitant to use the pellets due to the potential smoldering risk.

Comparatively speaking, the baseline alternative provides a much more diverse biosolids product user portfolio. Eighty percent of Class B biosolids can be land applied in eastern or western Washington. The remaining Class A biosolids can be donated or sold to local community, including the home growers, farmers, landscapers, nurseries, and large soil blenders.

2.4.7 Policy Impacts

The following sections detail how the two alternatives compare with regard to complying with local, state, and federal regulations, and meld with current County policies and initiatives.

2.4.7.1 Compliance with Local, State, and Federal Regulations

Both the Federal Rule 40 Code of Federal Regulations (CFR) Part 503, Standards for the Use or Disposal of Sewage Sludge and the Washington Administrative Code (WAC) 173-308 Biosolids Management, define treatment standards, pollutant limits, and management practices of Class A and Class B biosolids. Both composting and heat drying are approved processes to further reduce pathogens to meet Class A biosolids standards according to these regulations.

One of the purposes of WAC 173-308-080 is to "encourages the maximum beneficial use of biosolids". Beneficial use involves the application of biosolids to the land for the purposes of improving soil characteristics including tilth, fertility, and stability to enhance the growth of vegetation consistent with protecting human health and the environment. According to King County Code (K.C.C.) 28.86.090, “A beneficial use can be any use that proves to be environmentally safe, economically sound and utilizes the advantageous qualities of the material”. From this perspective, burning the dried biosolids pellets at a cement plant is not a beneficial use of the product. The end result is equivalent to biosolids incineration, which is not considered as a way to achieve beneficial use of biosolids.

Before implementation, both alternatives also need to apply for and comply with various permits. These include the construction and environmental permits required by State Environmental Policy Act or National Environmental Policy Act, an air permit by Puget Sound Clean Air Agency, and a building permit by the local jurisdiction. Based on the evaluation above, the permitting process for the Biosolids Partnership alternative is expected to be more complicated than the baseline.

2.4.7.2 Cohesion with Current County Policies and Initiatives

K.C.C. Title 28 Chapter 28.86.090 Biosolids Policies BP-2 states “Biosolids-derived products should be used as a soil amendment in landscaping projects funded by King County”. The BP-6 states “The county shall continue to provide class B biosolids and also to explore technologies that may enable the county to generate class A biosolids cost-effectively or because they have better marketability”. Implementation of both alternatives will require these County codes to be changed.

In its 2020 Strategic Climate Action Plan, the County committed to meeting a county-wide GHG emissions reduction target of 50 percent by 2030 and 80 percent by 2050. Additionally, WTD has set a target of carbon-neutral operations by 2025, primarily through carbon sequestration from land application. The proposed Biosolids Partnership alternative is not achieving this through carbon sequestration from land application. Comparatively, the baseline alternative aligns with the County’s Equity and Social Justice (ESJ) Initiative by supporting community gardens in underserved areas through compost donations and also by maintaining a robust and far-reaching outreach and education program.

2.5 Alternative Analysis Summary

A qualitative evaluation of the Biosolids Partnership proposal, as compared to the County WTD’s baseline alternative, is summarized in Table 5.

Table 5. Biosolids Partnership Proposal Compared to Baseline

Evaluation Criteria	Proposal vs. Baseline [a] Rating
Scalability	-
Risk & Benefits	-
Cost	
Capital cost	-
O&M cost	+

Evaluation Criteria	Proposal vs. Baseline [a] Rating
Lifecycle cost	-
Social Impacts	
ESJ	-
Odor	-
Air pollution	-
Trucking impacts to the community	-
Ability for communities (in King County or statewide) to use biosolids to amend/build soils for urban or rural agriculture	-
Environmental Impacts	
Overall energy use and maximizing use of renewable energy sources	+
Climate footprint	-
Air quality	-
Water quality	+
CECs reduction	0
Economic Impacts	
Biosolids product marketability	-
Diversity of biosolids product user portfolio	-
Policy Impacts	
Compliance with local, state, and federal regulations	-
Cohesion with current County policies and initiatives	-

a. A **plus** (+) indicates a benefit over the baseline. A **minus** (-) indicates a detriment over the baseline; a **null** (0) indicates no significant benefit nor detriment when compared to the baseline.

Section 3 Conclusions and Recommendations

3.1 Conclusions

The Biosolids Partnership proposal provides a long-term vision of innovation and sustainability by combining renewable energy generation and biosolids management. If implemented, it would reduce fossil fuel consumption and provide a 100 percent Class A biosolids product. However, the proposal presents many flaws and risks, detailed below, which prevent this idea from being implementable.

- Unproven application
- Lack of redundancy for the equipment and backup plan for the biosolids management
- Complex system requiring numerous, highly skilled O&M staff
- Significantly higher capital and lifecycle costs
- Significant social impact to the local community
- Locating the facility within a reasonable distance to South Plant to best utilize waste heat may not be feasible
- Additional undefined costs for treatment of nitrogen load from the dryer condensate
- Unreliable source for gasification feedstock
- Unidentified market for the biochar produced from gasification
- Unreliable market for the pellets produced from drying
- Does not conform to County's carbon sequestration initiative and 100 percent beneficially reusing biosolids as required by WAC and K.C.C.

Comparatively, the baseline alternative, with small incremental steps to test and verify the implementation of the compost program, provides the following benefits:

- Diversified biosolids management approaches increasing the resiliency of the program
- Proven successful experience with community outreach and local market of compost by others
- Pilot test of King County Loop compost to further verify the scalability and feasibility
- Positive social impact
- Higher climate benefit
- Insignificant environmental impact
- Relatively lower costs

3.2 Recommendations

Based on the findings of this alternatives analysis, Murraysmith recommends the following to the County:

- Continue implementing the baseline alternative, starting with the pilot compost facility, to help in making decisions about the full-scale compost facility.
- Given the flaws and risks identified in the report that are associated with the Biosolids Partnership proposal, this proposal should not be further considered. However, County should continue monitoring any Class A biosolids technologies and operations that will utilize the renewable resource and reduce the carbon footprint, while maximize program reliability and minimize risk.

Appendices

Appendix A – Biosolids Partnership Proposal in PowerPoint, September 2021

Appendix B – Conceptual design proposal on biosolids drying, biomass gasification and power generation, Venture Engineering & Construction, April 2022

Appendix C – Relevant correspondences with the Biosolids Partnership

Appendix D – Focus Group Meeting Minutes

Appendix E – Wastewater Agencies Site Visits and Meeting Notes

Appendix F – Basis of Cost Estimation TM

Appendix G – Trucking Impact Analysis TM

Appendix H – Energy and Carbon Footprint Analysis TM

References

Brown and Caldwell. Class A Biosolids Technology Evaluation Technical Memorandum. April 20, 2020.

Code of Federal Regulations (40 CFR) Part 503-Standards for the Use or Disposal of Sewage Sludge. February 19,1993. https://www.govinfo.gov/content/pkg/CFR-2018-title40-vol32/xml/CFR-2018-title40-vol32-part503.xml#seqnum503.13

HDR. Loop Compost Market Assessment. February 26, 2020.

HDR. Loop Compost Pilot at South Plant Basis of Design Report. December 2021.

HDR. South Plant Loop Pilot Compost Facility Design Drawings. December 2021.

United States Environmental Protection Agency. PFAS Strategic Roadmap: EPA's Commitments to Action 2021-2024 (https://www.epa.gov/system/files/documents/2021-10/pfas-roadmap_final-508.pdf)

Washington Administrative Code (WAC) 173-308 Biosolids Management. https://apps.leg.wa.gov/WAC/default.aspx?cite=173-308

King County Documents

2012-2016 Biosolids Plan

The Determinants of Equity Report. King County Office of Performance, Strategy, and Budget. January 2015.

Composting: A Feasibility Study. October 2016.

King County Biosolids Program Strategic Plan 2018–2037 Biosolids 2018-2037 Strategic Plan (kingcounty.gov)

Equity and Social Justice Initiatives https://kingcounty.gov/elected/executive/equity-social-justice.aspx

King County Code Title 28 Metropolitan Functions. Chapter 28.86.090 Biosolids Policies (BP) https://kingcounty.gov/council/legislation/kc_code/38_Title_28.aspx

Alternative Options for the Use of Biosolids. August 1, 2020.

2020 Strategic Climate Action Plan 2020 Strategic Climate Action Plan (SCAP) - King County

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APPENDIX B

KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Carbon neutral with Renewable Energy providing renewable fuel for Ash Grove Cement

Introduction of ReNuFuel's Concept to CONSOR Engineering

January 19th, 2023

Proven System developed to align with King County's prioritization of actions to combat Climate Change

- Eliminate trucking of Sludge to eastern WA
- Use of renewable Electricity to provide heat for drying
- Use dryer waste heat for heat digesters (no NG)
- Use dried granules for fuel at local cement plant
- Minimize risk of PFAS contamination due to land spreading of Class B biosolids

KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Alignment with King County GHG reduction goals

Reducing Sludge Hauling Truck Emissions at King County, WA	
2020 Average Day Sludge Production	85 dry TPD
2040 Average Day Sludge Production	110 dry TPD
Average over 20 years	98 dry TPD
Existing System Cake Dryness	20% DS
Total to haul	177,938 wet ton/yr
Assume truck +empty trailer weight	17 tons
Multiplier for truck weight	1.85
Average Distance to land app. Site	200 miles
Per EDF & EPA Smart Way	161.8 g CO2/short ton mile
Total CO2	10,652 metric tons CO2/year
Empty Return trips	1,779,375 Empty Truck miles
Assume truck +empty trailer weight	17 tons
Empty Truck Emissions	161.8 g CO2/short ton mile
Empty Truck Emissions	4,894 metric tons CO2/year
Total CHG due to trucking	15,547 metric tons CO2/year
Dryer System material to haul	37,461 wet ton/yr
Average Distance to land app. Site	15 miles
Per EDF & EPA Smart Way	161.8 g CO2/short ton mile
Total CO2	91 metric tons CO2/year
Empty Return trips	28,095 Empty Truck miles
Assume truck +empty trailer weight	17 tons
Empty Truck Emissions	161.8 g CO2/short ton mile
Empty Truck Emissions	77 metric tons CO2/year
Total CHG due to trucking	168 metric tons CO2/year
Saving due to Sludge Cake rucking cessation	**15,379 metric tons CO2/year**

- Digester gas is currently cleaned and diverted to the grid (RINS)
- The Dryer waste heat will serve as heating for the digesters, obviating the need to heat the digesters and buildings with Natural Gas
- Precise savings yet to be calculated due to absence of data

Note! Assumes use of diesel trucks for transport to Ash Grove Cement – electric trucks under consideration

KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Plant Sizing to meet future growth

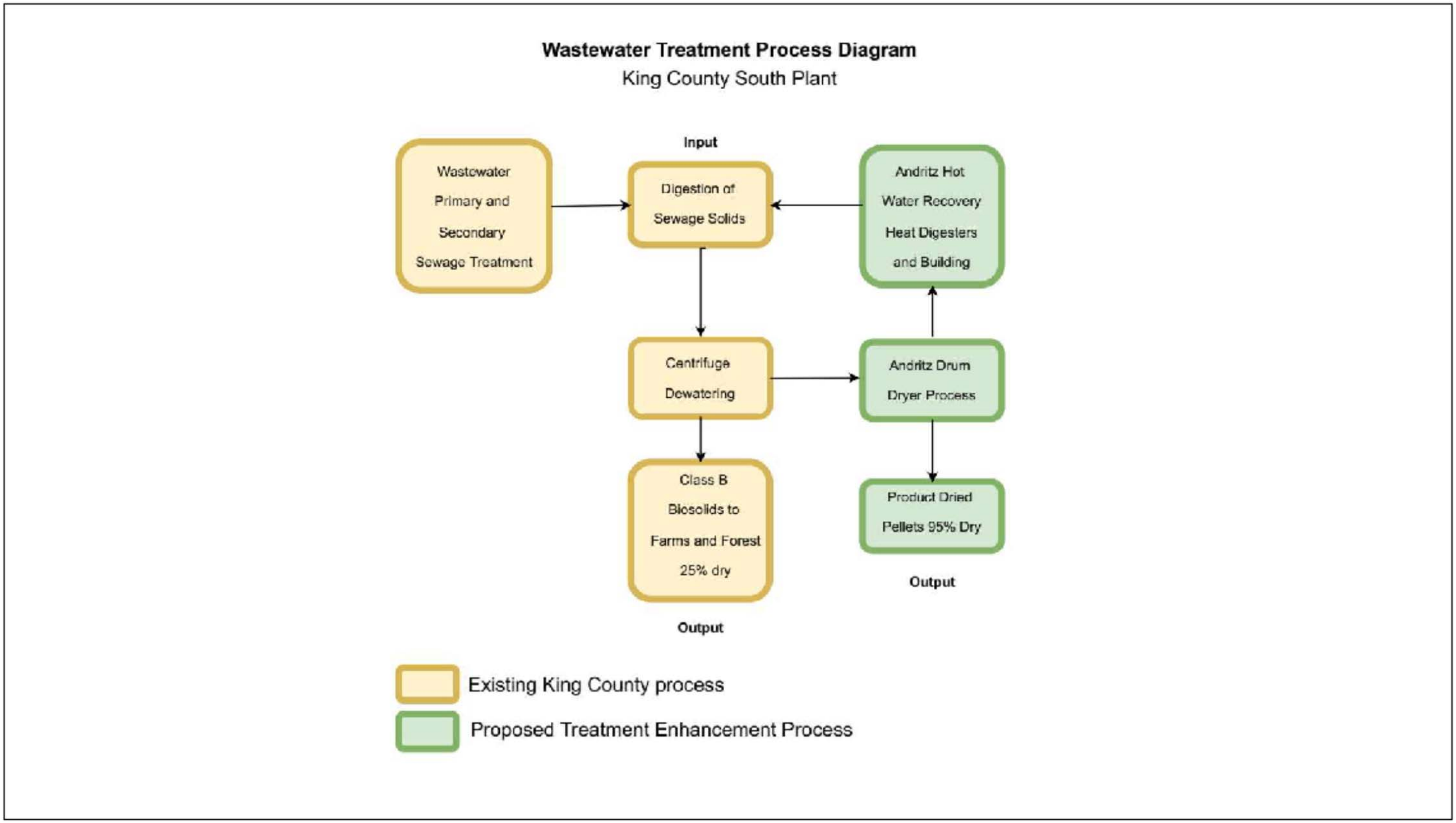
King County	2022 AA	2022 -2050 AA (Average)	2050 AA
Nominal Daily Sludge Production	85 dry tons/day	108 dry tons/day	130 dry tons/day
Cake Dryness	24% DS	22% DS	22% DS
Nominal Daily Sludge Production	354 wet tons/day	489 wet tons/day	591 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum	178,352 wet tons/annum	215,682 wet tons/annum
Dryer Operations	7 days per week	7 days per week	7 days per week
Dryer Operations	24 hours/day	24 hours/day	24 hours/day
Dryer Operations	168 hours/week	168 hours/week	168 hours/week
Dryer Capacity Required	85 dry tons/day	108 dry tons/day	130 dry tons/day
Dryer Capacity Required	354 wet tons/day	489 wet tons/day	591 wet tons/day
Final Product	95% DS	95% DS	95% DS
Final Product	89 tons/hour	113 tons/hour	137 tons/hour
Evaporation Rate	11.0 tons/hour H2O	15.6 tons/hour H2O	18.9 tons/hour H2O
Evaporation Rate	22,058 lb/hour H2O	31,290 lb/hour H2O	37,839 lb/hour H2O
Evaporation Rate	10,004 kg/hour H2O	14,190 kg/hour H2O	17,161 kg/hour H2O
No. of Drying Trains	1	2	2
Evaporation Rate/train	10,004 kg/hour H2O	7,095 kg/hour H2O	8,580 kg/hour H2O
Dryer Technology	Fluid Bed Dryer	Fluid Bed Dryer	Fluid Bed Dryer
Dryer Model Selection	10	FDS-10.0	FDS-10.0
Utlization	50%	71%	86%
Max. Evaporation Rate	10,000 kg/hour H2O	10,000 kg/hour H2O	10,000 kg/hour H2O

KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Plant Sizing matches the Shanghai sludge facility commissioned 2021 (9 lines)

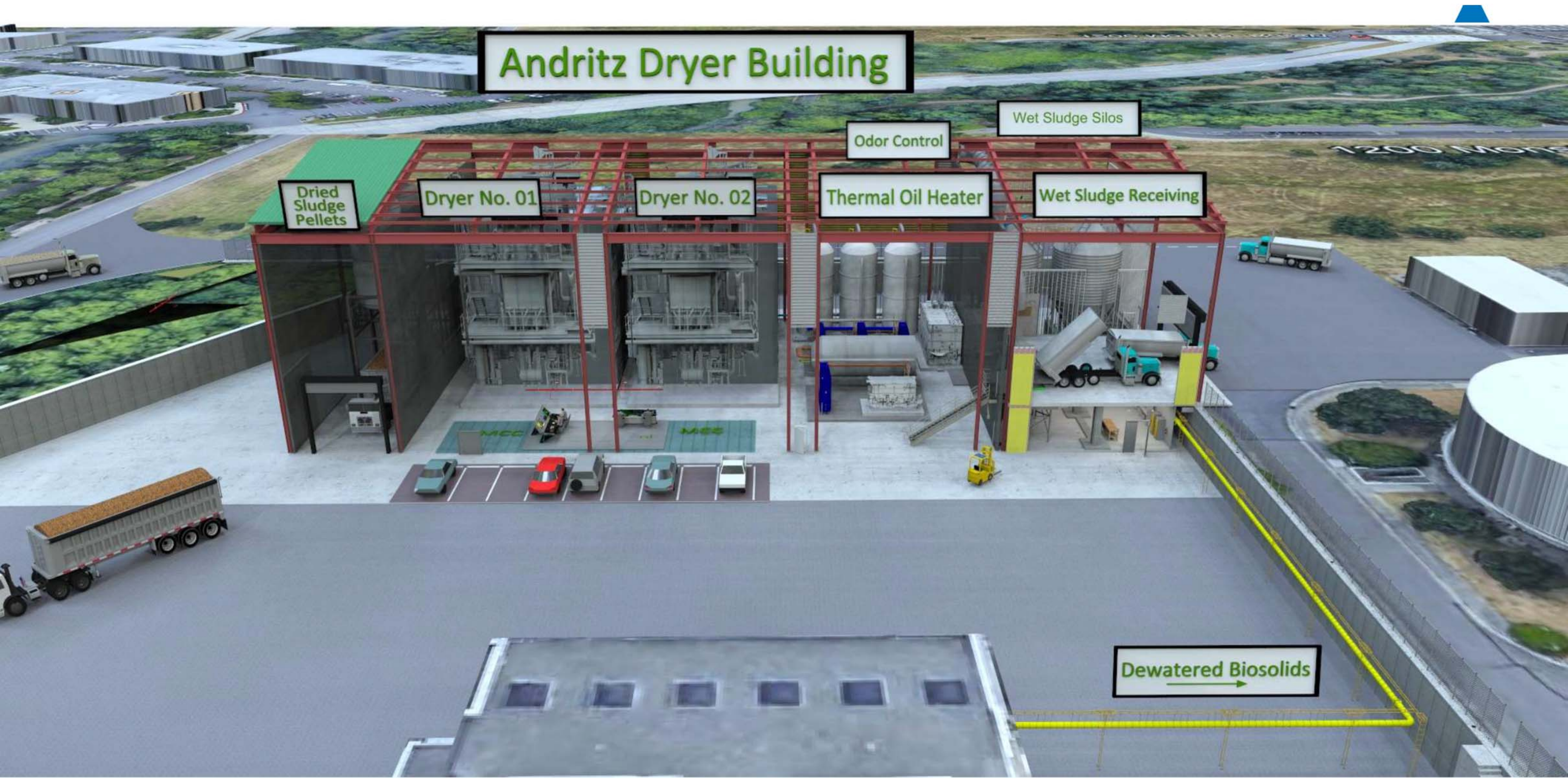
KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Plant Sizing matches the Shanghai sludge facility commissioned 2021 (9 lines)


Wastewater Treatment Process Diagram
King County South Plant
Input
Wastewater Primary and Secondary Sewage Treatment
Digestion of Sewage Solids
Andritz Hot Water Recovery Heat Digesters and Building
Centrifuge Dewatering
Andritz Drum Dryer Process
Class B Biosolids to Farms and Forest 25% dry
Product Dried Pellets 95% Dry
Output
Output
Existing King County process
Proposed Treatment Enhancement Process


1200 Monster Rd SW
Andritz Dryer Building
150 Ln-Ft
N


1200 Monster Rd SW
Andritz Dryer Building
Wet Sludge Silos
Odor Control
Dried Sludge Pellets
Dryer No. 01
Dryer No. 02
Thermal Oil Heater
Wet Sludge Receiving
Dewatered Biosolids


Andritz Dryer Building
Wet Sludge Silos
Odor Control
Dried Sludge Pellets
Dryer No. 01
Dryer No. 02
Thermal Oil Heater
Wet Sludge Receiving
Dewatered Biosolids


Andritz Dryer Building
Dryer No. 01
Dryer No. 02
Odor Control
Thermal Oil Heater
Wet Sludge Receiving
Wet Sludge Silos
Dewatered Biosolids

ANDRITZ FLUID BED DRYING SYSTEM

Proven technology in use globally since the early 1990’s

North Shore Water Reclamation District (NSWRD) is the second largest sanitary district in Illinois. Since 2006, NSWRD has operated a Biosolids Recycling Facility in Zion, IL using the ANDRITZ Fluid Bed Drying System drying upwards of 190 wet TPD from three(3) WWTP’s..

ANDRITZ FLUID BED DRYING SYSTEM

Proven technology in use globally since the early 1990's

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ANDRITZ BIOSOLIDS DRYING SYSTEMS

- Over 200 plants delivered globally

ANDRITZ BIOSOLIDS DRYING SYSTEMS

- Over 200 plants delivered globally

At Manatee County, FL ANDRITZ Designed & Built the Drum Drying Facility to serve 3 County WWTP's adjacent to the Lena Road Landfill - LFG is used directly to provide the heating

ANDRITZ BIOSOLIDS DRYING SYSTEMS

Over 200 plants delivered globally

ANDRITZ Centrifuge Dewatering and Drying System 100 dry / 450 wet TPD
Commissioned late 2022

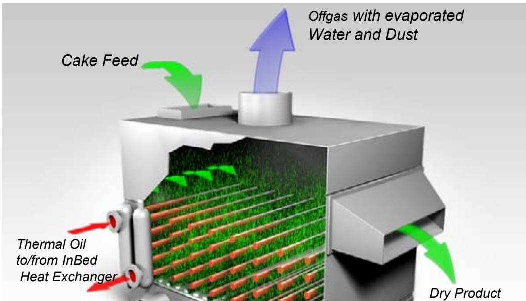
ANDRITZ BIOSOLIDS DRYING SYSTEMS

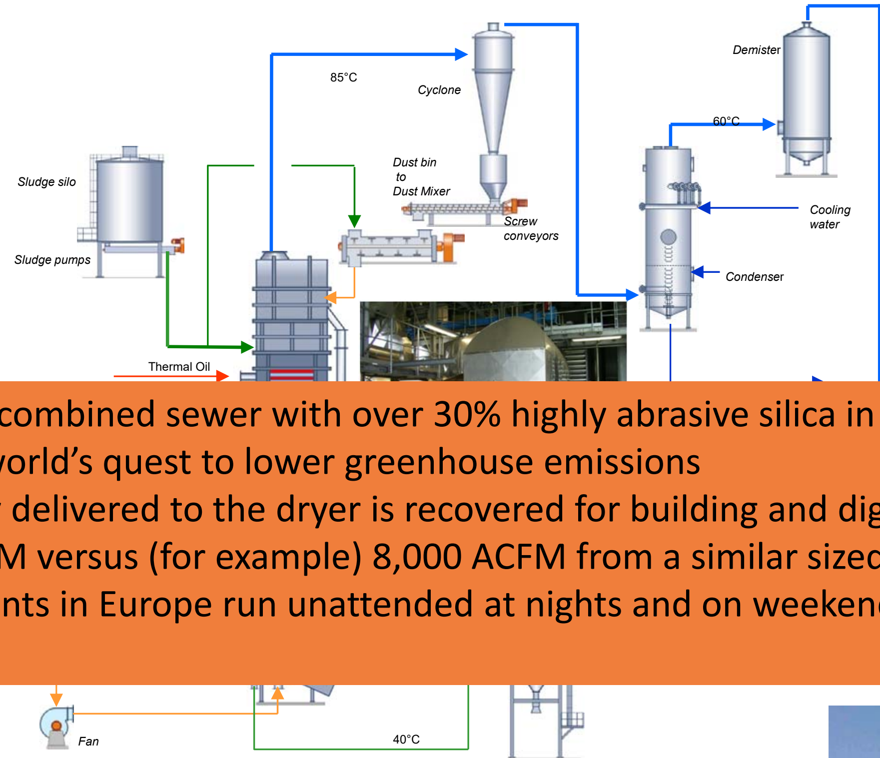
Over 200 plants delivered globally

ANDRITZ Centrifuge Dewatering and Drying System 100 dry / 450 wet TPD

Commissioned late 2022

ANDRITZ FLUID BED DRYING SYSTEM





en in the harshest environments (Shanghai is combined sewer with over 30% highly abrasive silica in the biosolids)

est thermal energy usage – significant in the world's quest to lower greenhouse emissions

ides waste heat at 65^{0}C – up to 80% of energy delivered to the dryer is recovered for building and digester heating

est off-gas flow to emission control (<200 ACFM versus (for example) 8,000 ACFM from a similar sized Drum Drying System)

to run unattended for long periods (some plants in Europe run unattended at nights and on weekends)

Fluid Bed with direct injection nozzles in foreground

Fluid Bed cooler

Class A granules

Product Silos (foreground)

ANDRITZ FLUID BED DRYING SYSTEM

Reference Plant nearby – Capital Regional District, Victoria BC

ANDRITZ FLUID BED DRYING SYSTEM

Reference Plant nearby – Capital Regional District, Victoria BC

ANDRITZ FLUID BED DRYING SYSTEM

Reference Plant nearby – Capital Regional District, Victoria BC – Odor Control

Odor Control is of prime concern at any biosolids drying facility.

As at the highly successful Victoria BC plant, at the South plant we plan to use an odor control system comprising:

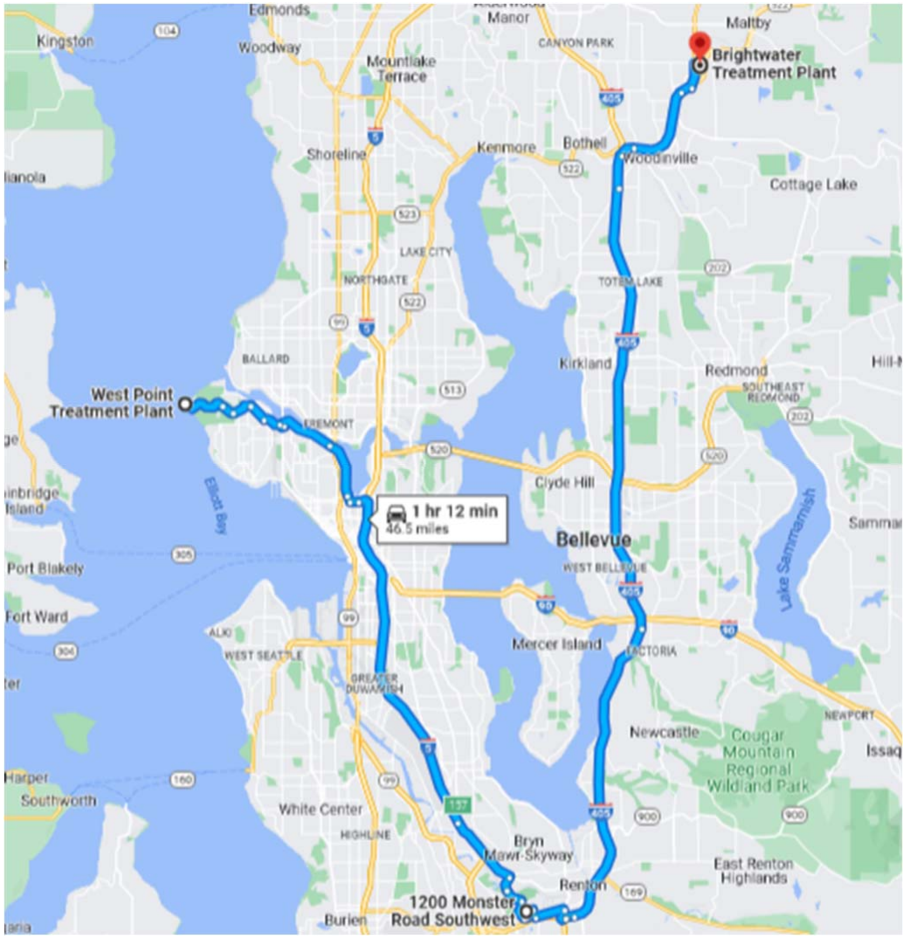
Bio-trickling Filters

Chemical Scrubbers

Activated Carbon

KING COUNTY, WA BIOSOLIDS DRYING PROJECT

Continue with King County Truck Drivers



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APPENDIX C

ReNuFuel

February 13, 2023

Consor Engineering
600 University Street, Suite #3oo
Seattle, Washington 98101
Tel: 206.462.7030

ATTENTION: Jeff Moss, PE CIVIL ENGINEER

Dear Jeff:

SUBJECT: Biosolids Thermal Drying using Renewable Electricity Proposal – South Plant Renton

We appreciate the opportunity for you to review of our Team Draft on the King County Biosolids Thermal Drying using Renewable Electricity Proposal by your CONSOR colleagues and staff from the King County Wastewater Treatment Division (WTD).

Attached, please find our working draft of the items covered that we mutually agreed upon. The proposal represents a general overview of the Thermal Drying Project with attachments together with a document from Andritz with attachments detailing cost, facility and equipment information together with the Wastewater Treatment Process Flow Diagram of the South Plant at Renton. In addition, Andritz has attached layout 3-dimensional configuration drawings of the proposed South Plant Facility.

We regard this as a working draft and look forward to working with you to answer any questions or corrections/additions to make this biosolids proposal meet what we refer to as the three E's: best economically, best environmentally, and best use of energy.

Sincerely,

Bart T. Lynam, President
ReNuFuel, LLC

Attachments:

ReNuFuel, LLC.
Environmental Engineering
9606 Wharf Street Edmonds, WA 98020-2362
Phone: 425-775-8287 - Cell: 206-612-5392
E-mail: Bart.Lynam@ReNuFuel.com

ReNuFuel's Biosolids Thermal Drying Renewable Electricity Proposal

- **Significantly lower estimated costs**

Table 1. Capital Costs, O&M, and Lifecycle Costs ($ million)

Alternative	Capital	Annual O&M	20 Year Lifecycle
Baseline	$119.9	$15.2	$373.8
Dryer Facility	$113.8	$9.5	$273.7

Thermal Drying using Renewable Electrical Energy is cheaper than Baseline Composting by $100,100,000 over the 20-year lifecycle.

This proposal provides for 100% redundancy with two (2) Andritz Dryers for the current sludge production of 85 TPD with the second line being progressively run as solids numbers increase in later years. If the second dryer line were deleted for now, we estimate a reduction in CAPEX of $30-35 million.

- **Known Market Demand**

Guaranteed Thermal Drying Process (energy from renewable electricity) with dried biosolids pellets to be used as a fuel trucked to a cement kiln, contributing to Climate Change.

- **Consistent With Policy**

Consistent with Washington Administrative Code 173-308 which encourages maximum beneficial use of biosolids and the use of sewage sludge biosolids to be "reused as a beneficial commodity". Aligns with King County Strategic Climate Action Plan to be carbon-neutral and aligns with amended WA Senate Bill 5842 passed in February of 2022 to allow biofuels from biosolids pellets.

- **Land Acquisition, Siting/Permitting and Operations.**

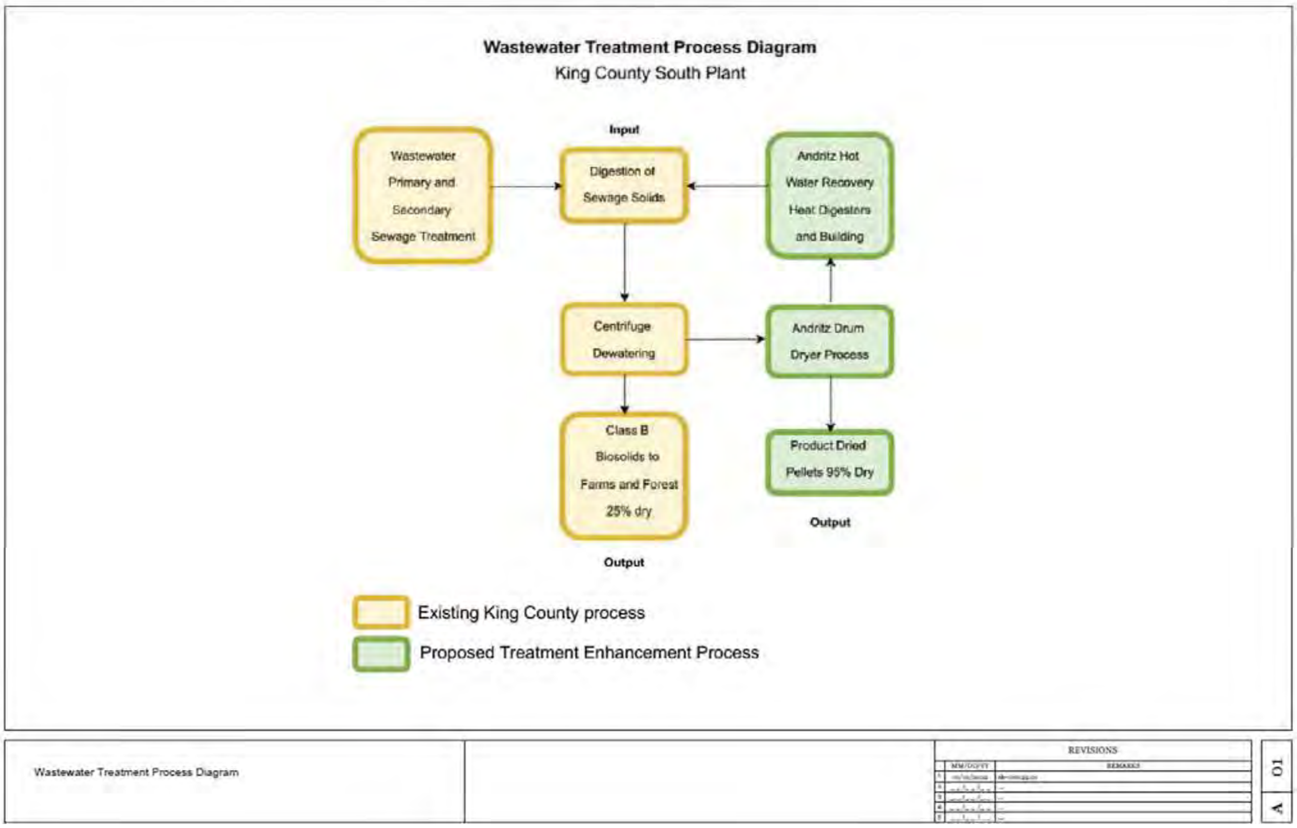
The facility will be located inside the South Treatment Plant in the area south of the existing truck load-out area. All construction, environmental and Air Permit from Puget Sound will be secured.

- **Elimination of Risks**

PFAS dangerous "forever chemicals" will be eliminated by trucking the dried pellets to a cement kiln.

PROCESS FLOW DIAGRAM

Below is a Process Flow Diagram that presents the approach to creating thermally dried pellets to be used in a cement kiln.

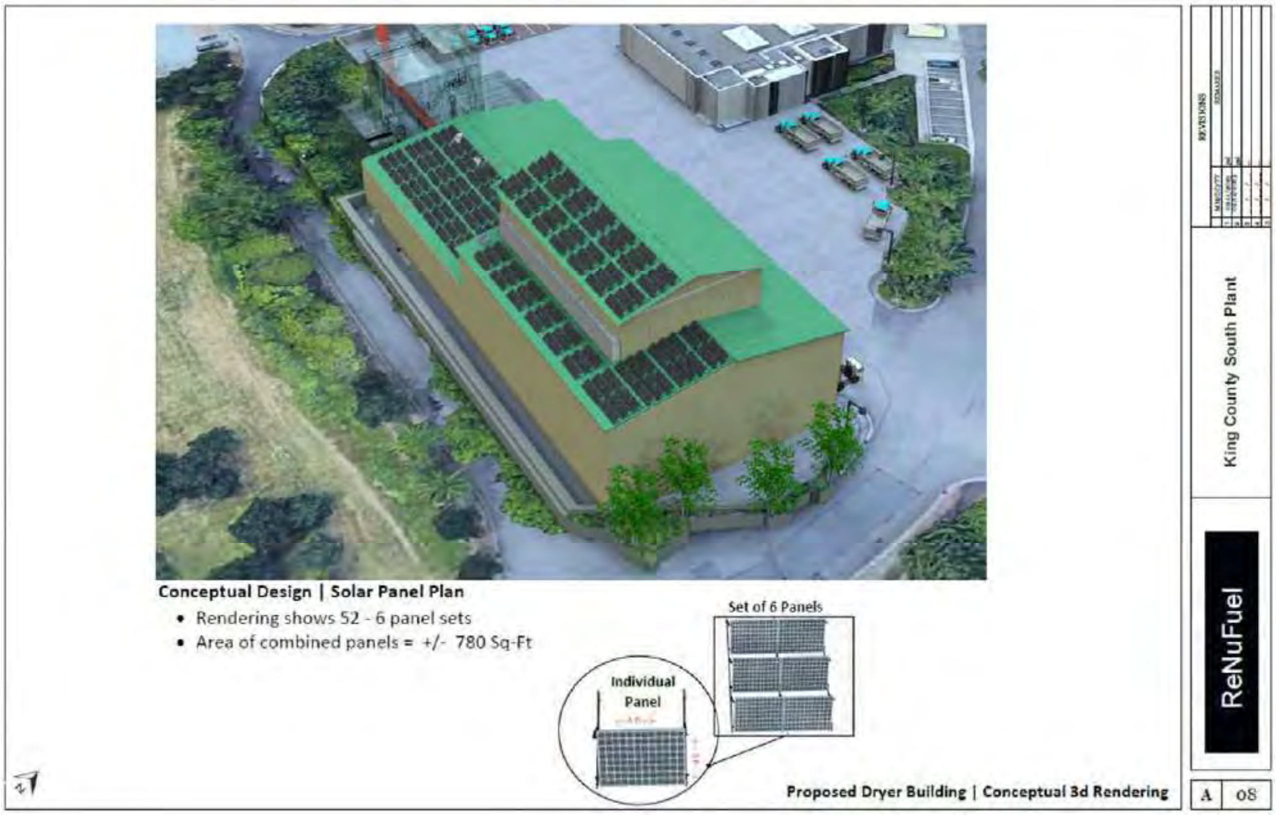


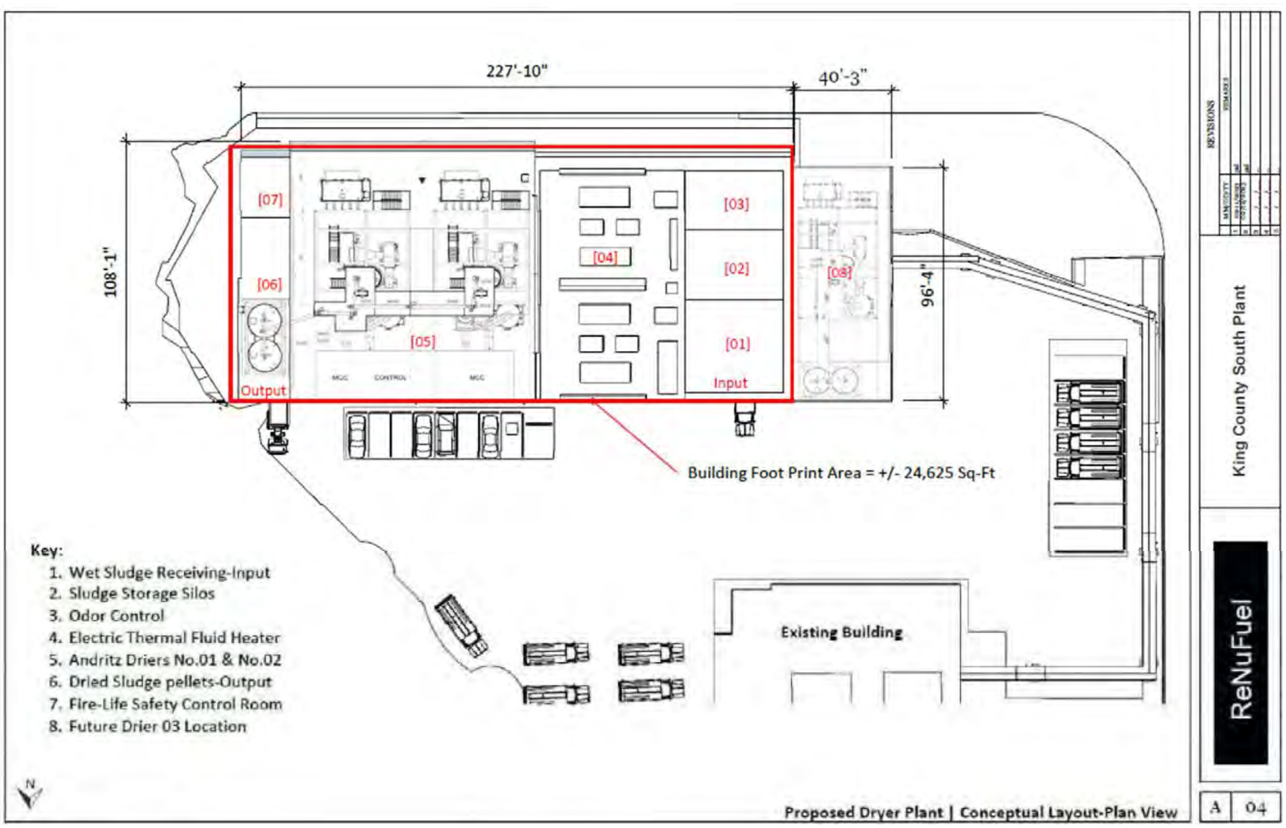
ReNuFuel

LOCATION OF FACILITY AT THE SOUTH PLANT IN RENTON

Proposed Location - Andriz Dryer Building

Proposed Dryer Building | Conceptual 3d Rendering


Conceptual Design | Solar Panel Plan
• Rendering shows 52 - 6 panel sets
• Area of combined panels = +/- 780 Sq-Ft
Set of 6 Panels
Individual Panel
Proposed Dryer Building | Conceptual 3d Rendering
King County South Plant
ReNuFuel
A
08


227'-10"
40'-3"
108'-1"
96'-4"
[07]
[06]
Output
[05]
[04]
[03]
[02]
[01]
Input
[08]
Building Foot Print Area = +/- 24,625 Sq-Ft
Key:
1. Wet Sludge Receiving-Input
2. Sludge Storage Silos
3. Odor Control
4. Electric Thermal Fluid Heater
5. Andritz Driers No.01 & No.02
6. Dried Sludge pellets-Output
7. Fire-Life Safety Control Room
8. Future Drier 03 Location
Existing Building
Proposed Dryer Plant | Conceptual Layout-Plan View
King County South Plant
ReNuFuel
A
04

King County South Plant

ReNuFuel

Proposed Dryer Building | Conceptual 3d Rendering

A 07

King County South Plant

ReNuFuel

Proposed Dryer Building | Conceptual 3d Rendering

A 05

THERMAL DRYING OF KING COUNTY BIOSOLIDS USING RENEWABLE ELECTRICITY

LOWER COSTS: Proposing drying King County's dewatered biosolids from its three plants (South Plant, Westpoint, and Brightwater) by thermal drying using renewable electricity over a 20-year lifecycle will have a lower capital cost and lower annual O&M cost. Baseline King County to cost $373.8 million. Our Thermal Drying Proposal using renewable electricity with two (2) Andritz Dryers for 100% redundancy over a 20-year lifecycle will be $100,100,000 less than the Baseline.

MurraySmith report (pg. 4) states that the $373.8 million "costs are preliminary planning level costs, which by definition have an uncertainty range wherein each estimate could increase by as much as 100 percent." The Thermal Drying Proposal will design, permit, construct, maintain and operate, and finance the project. We are proposing a heat recovery renewable energy process using renewable electricity from Puget Sound Energy (PSE) as opposed to natural gas to dry the biosolids. Biosolids pellets will be trucked via electric trucks to a cement kiln to be used as a fuel displacing a fossil fuel.

Murraysmith Phase 1 report (pg. 13) states it is proposed that, "The County could consider paying to contract the operations and maintenance to a third-party operator pursuant to potential labor negotiations." The King County Biosolids Program Strategic Plan 2018-2037 states (pg. 5 Singer), "Costs for producing biosolids compost can be variable if bulking agents must be purchased and can be expensive if an enclosed system is required." On pg. 6 of Singer states…" Management of a biosolids program with a focus on energy recovery can do a lot to support the goal….to achieve a carbon-neutral operation." The Thermal Drying Proposal achieves a carbon-neutral operation.

THERMAL DRYING REDUCES NET CARBON FOOTPRINT: Goal Achieves Carbon Neutrality

The King County Biosolids Thermal Drying Proposal reduces the net carbon footprint at the South Plant at Renton by using renewable electrical energy from Puget Sound Energy (PSE) to operate the dryers. This eliminates the use of digester gas or natural gas for heating the South Plant digesters and administration building by substituting the waste heat from the dryers. Replacing the natural gas now delivered to the plant will save 3,373 MT CO_2e per year gas to with the proposed Andritz Dryer facility King County will be able to continue to provide cleaned up digester the pipeline for sale.

The proposal includes a heat recovery renewable energy process as opposed to natural gas. When dried pellets are trucked to the cement plant to be used as a fuel, the NO_x goes down because of the ammonia in the biosolids. The biosolids pellets with its ammonia present reduce the air emissions in the cement operations. By replacing the natural gas in the dryers 4,047 MT emissions is saved. with the proposed Andritz Dryer facility. By eliminating trucking, the sludge east of the mountains, 3524 MT emissions is saved. Overall,

King County has stated that its proposed pilot composting program will be a five-year trial, treating 400 to 800 wet tons of biosolids per year and will need 10-15 acres of County land in order to spread the compost with its biosolids and bulking agents. In the meantime, King County will continue trucking its Class B partially dry biosolids to be spread on farmland and in King County forests in eastern Washington, releasing 3524 MT CO_2e per year from the trucking alone. There will also be emissions of methane and nitrous oxides, which are difficult to quantify, from the piles of dewatered biosolids in the trucks, from the piles created for storage before farm spreading and after application.

The King County Biosolids Team Proposal with its use of renewable energy and thermal drying eliminates these CO_2 emissions, thus contributing to reducing the net carbon footprint.

The Andritz Fluidized Bed Dryer proposed to dry the County's biosolids has the ability to efficiently use renewable electrical energy to dry the biosolids. The Andritz Fluidized Bed Dryer heats with electric resistance with no flame which also contributes to reducing emissions. This Andritz Dryer has filters, chemical scrubbers and activated carbon resulting in no odors.

The Biosolids Team Proposal plays a key role in the County's future sustainability and results in progress towards achieving carbon neutrality.

IDENTIFIED MARKET FOR KING COUNTY BIOSOLIDS PELLETS - NO MARKET RISK:

Dried biosolids pellets are used for fuel in cement plants in Europe, Canada and the U.S. CEMEX Philippines and Manila Water on February 8, 2023, signed a partnership allowing the use of biosolids as alternative fuels, a first in the Philippines and a major accomplishment in helping address climate change (Appendix A). There is no market risk to King County with dried biosolids pellets trucked to a cement kiln to be used as a renewable fuel. Using electric trucks avoids adding fossil fuel CO_2 emissions. A letter of intent will be submitted from the cement company to accept the dried biosolids pellets from the Renton South Plant to be used as energy to further its goal to reduce carbon emissions. As a backup, pellets can be trucked to a cement plant near Portland during down-time for repairs and maintenance.

"The International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry" was the subject of a report by Ernest Orlando Lawrence Berkeley National Laboratory, a work that was supported by the U.S. EPA and the Institute for Industrial Productivity through the U.S. Department of Energy (Appendix B).

"An Assessment of Dried Biosolids Product for Meeting Established EPA Classification Requirements for Being a Non-Waste Fuel per the NHSM Rule" was prepared by Spectrum Environmental Sciences, Inc. out of Frederick, Maryland (Appendix C).

The Federal Infrastructure Investment and Jobs Act was signed into law by President Joe Biden on November 15, 2021. This is an act to authorize funds for Federal-aid highways, highway safety programs, transit programs, and for other purposes. This trillion-dollar legislation will bring billions into Washington State which will increase the demand for cement to be used in concrete. One of the greatest contributors to pollution emissions comes from the cement industry which has as its goal to reduce carbon emissions in its cement operations.

LEHIGH CEMENT BALTIMORE SUCCESSFULLY USES BIOSOLIDS PELLETS FOR FUEL

The Lehigh Cement Plant in Baltimore processes 50,000 tons of biosolids a year or 137 tons per day. On October 12, 2021, Lehigh Hanson joined the journey to achieving carbon neutrality across the cement and concrete value chain by signing onto the Portland Cement Association's (PCA) Roadmap to Carbon Neutrality (Appendix D). Lehigh's Union Bridge Plant in Baltimore, Maryland was the winner of the Overall Environmental Excellence Award as part of the 2020 Energy and Environment Awards from the Portland Cement Association (Appendix E). In 2013, the Union Bridge Plant reduced the amount of coal burned in the kiln with greenhouse gas neutral dried biosolids. The plant avoided using 57,000 metric tons of a naturally-occurring fossil fuel and replaced it with a renewable biomass material.

The US EPA has stated that dried biosolids pellets are a non-hazardous waste. Certification was received from the Lehigh Cement Plant, Baltimore.

Kurt Deery, Lehigh's Environmental Engineer, states that since the dried biosolids pellets are considered "a biomass fuel, we are allowed to take credit for that per EPA Greenhouse Gas Rules. In testing 'bag samples' from Lehigh's stack testers of the kiln exhaust gas stream….these air samples were sent to a lab for carbon testing. The average carbon amount during burning was 1-1.5%....so, assume 1,915,000 tons CO_2 1.25% = 23,938 tons CO_2 credit." Leigh Cement has received numerous awards for its reduction in greenhouse gas emissions (Appendix F).

THERMAL DRYING USING RENEWABLE ELECTRICITY ENHANCES CLIMATE GOALS

Dryers at the South Plant will be used that use thermal heat drying which use electric resistant heat to heat the heat transfer fluid so no air emissions. Thermal Drying of the Biosolids results in a reduction in greenhouse gases and emissions; eliminates the use of natural gas by using waste heat to heat the digesters and the Renton Administrative Building that are currently heated with natural gases; and uses renewable electrical energy. Electric trucks will be purchased to haul dried biosolids pellets to a cement kiln reducing CO_2. Solar panels will be installed on the new facility's roof so electric trucks can, at least partially, run on locally generated power. For Seattle, it is assumed that 3.88 kW-hr/m2/day for the net generation, which will be about 20 watts per square foot. We have estimated that the roof will have 780 sq. ft of solar panels as shown on the facility layout.

Advantages of Thermal Drying Technology: The King County Biosolids Program Strategic Plan 2018-2037 (Appendix C of Singer Report) states, "The thermal drying technology removes water via evaporation from dewatered biosolids, reducing the volume and weight….A thermally dried Class A biosolids product has universal applications. The dried biosolids can be supplemented for fuel…." The Singer report states, "…there are no restrictions in use or sale."

Reliability of Andritz Dryers: There are 35 Andritz plants delivered globally using the proposed Fluidized Bed Dryer with 200 other Andritz plants worldwide. The Andritz Drying Plant at Zion, Illinois north of Chicago has been operating successfully since 2007 using the Fluidized Bed Dryer. Contact information Steve Waters, Plant Manager at Zion, at email stwaters@northshorewrd.org In addition, the Victoria, B.C. Plant has been operated by Synagro for 12 months with the same Fluidized Bed Dryer proposed for the South Plant in Renton – Victoria, B.C. contact is Melissa Carmichael, Senior Manager for Synagro at 808.228.5203. These plants can run unattended at night by a computerized automation program.

Advantage of Using Andritz Fluidized Bed Dryer versus Drum Dryer: The Fluidized Bed Dryer has the ability to use renewable electrical energy to dry the sludge more efficiently because it is simpler and takes up less space. For the South Plant at Renton, the two (2) Fluidized Bed Dryers can be operated 5 days per week and evaporate 15.4 tons of water per hour with 2 lines and cake receiving. The cake will be received into one of two hoppers. Access to the hoppers will be by a remotely controlled roll-up door. The bin hopper will have a lid that will be remotely activated to allow the truck to dump. The Fluid Bed Drying Process is not mechanically intensive. If the thermal drying facility were to run 5 days a week, we would need 6 people at the Renton South Plant. The Andritz Fluidized Bed Dryer has filters and a chemical scrubber to activated carbon. Victoria, B.C.'s Andritz Fluidized Bed Dryer has **no odors.**

Andritz Odor Control System: Strict odor control and air emissions control will be implemented by Andritz so all odors will be destroyed. The Andritz Odor Control System will provide for a multi-stage odor control system, which consists of a bio-trickling tower, chemical scrubber, activated carbon vessel, and exhaust stack for the drying facility. The vapors from the Andritz Fluidized Bed Dryer are condensed and returned to the main drain of the South Plant. There will be no dust generated in the biosolids drying operations. Odors will be non-existent as trucks will drive directly inside the proposed facility with the South Plant with enclosed doors and dump the sewage sludge in an airtight building with no emissions.

Redundancy of Equipment: Andritz will supply two Fluidized Bed Dryers with room planned at the South Plant for the possibility of a third dryer for increased tonnage by 2050. The dryer could be located adjacent to the proposed facility.

No Air Emissions using Electric Resistance Heat to Heat the Transfer Fluid: There is no flame with electricity. The **Andritz Dryer** has no odor pollution. Dust from the drying operations is collected and recycled with the drying plant so there is no dust. Dustrol will be used to coat the dried Class A pellets when they are being loaded into the electric trucks for transport to the cement plant for fuel.

Siting of the Proposed Plant Facility/Design/Permits: The proposed facility will be contained within the existing truck staging area for the dewatered sludge removal which is presently being used for hauling out the wet sludge cake to eastern Washington. This will not impact the existing roads or any other plans for the future.

The existing centrifuge dewatered sludge load-out operation will be modified. King County will continue to load trucks for eastern Washington and the King County forests for the Class B LOOP program until the completion of the proposed facility. The road at the South Plant will continue and there will be no encroachment for the future secondary treatment relating to the aeration and final tanks for the activated sludge process. King County will continue to maintain its existing peripheral boundary of trees. A conventional retaining wall will be built to maintain the integrity of the existing road so there will be no impact with the South Plant or the surrounding area. Design is for space for two (2) Andritz dryers with the proposed facility with room for a third dryer to be added onto the facility in the future.

All construction, environmental, and an air permit from Puget Sound Air Agency will be obtained in accordance with regulations.

Wastewater Treatment Division ENERGY PLAN February 2018: The Thermal Drying Plant will maximize the use of renewable electrical energy, a goal stated in the 2018 WTD Energy Plan. Recovered hot water from the drying process will be used to heat the digesters and buildings at the South Plant. Lighting will be installed that meets the LED requirements. The WTD Energy Plan reports that the production of concrete is one of the largest sources of greenhouse gas emissions worldwide. This proposal to use the dried biosolids pellets for a renewable fuel will have a positive impact on the reduction of greenhouse gases from the manufacturing of Portland Cement which is a component of concrete.

We appreciate receiving a Puget Sound Energy invoice which serves to confirm that the proposed facility will receive the same electricity rate as King County. The project will include an electric thermal transfer fluid heater and other electric loads such as industrial equipment, area lighting and fans. We anticipate that the electric heat load will be about 11.30 mW, 24 hours per day, 7 days a week, 52 weeks a year. The industrial equipment will draw 1.31 aMW, also 24/7/52. Room air handling and area lighting will draw a minor amount of electricity that is included in the 11.30 mW. There may be up to 10% increase in load during startup and at a few other times. Similarly, the load might drop to 90% on some occasions, but not too often. We will not be able to accept interruptible load shedding. Electric trucks will be recharged overnight. We are told by PSE there will be no need to construct a mini substation.

Stable Labor Negotiations: Rick Bender, former Washington state legislator for 18 years and former President of the Washington State Labor Council for 18 years, will help to train and transition personnel eliminated by the consolidation of the biosolids process at the Renton South Plant. Rick has held preliminary discussions with the Teamsters and has worked with every Union in the state.

PFAS CHEMICALS DESTROYED

Dangerous PFAS 'Forever Chemicals' in the Biosolids Pellets are destroyed when trucked to a cement kiln when used as a renewable energy product. Destroying the PFAS in a cement kiln occurs when the ground pellets are injected directly into the flame zone. A cement kiln is an ideal target for reuse of sewage sludge that is contaminated with PFAS and other toxic organic compounds. In the flame zone it reaches the temperatures required for destruction of the organics and the residence time of the quite long kiln provides for total destruction. The Murraysmith report Phase 1 report (pg. 42) states, "Among the current biosolids treatment technologies, thermal treatment is known to be the **only** way that has the potential to destroy PFAS."

PFAS contaminants in the biosolids are of a health and safety concern in food products, livestock, and groundwater. King County could be at risk of lawsuits for PFAS contamination. The States of Maine, Michigan, and Connecticut passed laws forbidding biosolids in fertilizer where crops are grown. The U.S. Department of Agriculture prohibits the use of biosolids on land producing organic products. Del Monte, Nestle, and Heinz forbid using sludge in its fertilizer on food crop land. McDonald's only accepts potatoes for French fries grown on sludge-free land.

Storage of Dried Biosolids Pellets: If the cement kiln is down for maintenance, pellets can be stored at Renton South Plant site, at silos at the cement plant, within existing digesters at the South Plant, West Point, and Brightwater by anticipating the need for storage by lowering the liquid level to a minimum in the mixed anaerobic digester tanks.

Consistent with Policy: Beneficial Use of Dried Biosolids Pellets

The King County Thermal Drying Biosolids Proposal is aligned with the Climate Commitment Act (RCW 70A.65), which encourages local industries to innovate in the use of alternatives to fossil fuels (005 (6)). It specifically defines biosolids from municipal wastewater treatment plants as a biosolid that can be a biofuel (-010 (11)-(12)).

The Thermal Drying proposal to thermally dry the biosolids using renewable electricity and trucking the dried pellets to a cement kiln is a beneficial use of the biosolids as the dried pellets will directly replace fossil fuels. This also aligns with the County's Strategic Climate Action Plan's goal to be carbon-neutral.

The use of biosolids as a fuel in a cement kiln is not to be mistaken with incineration, a common method of sewage sludge disposal regulated by U.S. EPA's NSPS Subpart LLL. Incineration is generally defined as the burning of a waste for the primary purpose of reduction in volume prior to disposal. More specifically, it is defined in Washington in WAC 173-434 so as to exclude "sludge from wastewater treatment plants" (-030 (3)(d)).

The use of dried biosolids pellets in a cement kiln is in practice at several sites. One example is the Union Bridge plant of Lehigh Cement Company. This use is consistent with EPA's NHSM rule (40 CFR 241.2). Union Bridge is currently feeding up to 50,000 tons of such pellets each year.

The proposed Thermal Drying facility has been calculated to result in a net reduction in CO_2 emissions at the South Plant of 2670 MT/yr.

Nitrogen Blanket Solves Smoldering: Smoldering and fire pose **no risks** because there is a quick turnover of pellets being transported to the Cement Kiln. Also, the pellets are exposed to a Nitrogen Blanket which eliminates oxygen, thus preventing smoldering and fires. . **A nitrogen injection system will be used to maintain an inert environment to eliminate any smoldering of the dried pellets within the loadout silo.**

Additional Nitrogen Load Regarding Condensate: The Andritz Fluidized Bed Drying facility at the South Plant in Renton will process the dewatered digested biosolids from the West Point Plant, Brightwater Plant, and the South Plant. The following Excel spreadsheet shows that it is estimated at 126,893 USGPD with 974 lb.NH4-N/day.

King County	2022 AA
Nominal Daily Sludge Production	85 dry tons/day
Cake Dryness	24% DS
Nominal Daily Sludge Production	354 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum
Dryer Operations	7 days per week
Dryer Operations	24 hours/day
Dryer Operations	168 hours/week
Dryer Capacity Required	85 dry tons/day
Dryer Capacity Required	354 wet tons/day
Final Product	95% DS
Final Product	89 tons/hour
Evaporation Rate	11.0 tons/hour H2O
Evaporation Rate	22,058 lb/hour H2O
Evaporation Rate	10,004 kg/hour H2O
No. of Drying Trains	1
Evaporation Rate/train	10,004 kg/hour H2O
Dryer Technology	Fluid Bed Dryer
Make up plant water to Dryer condenser	10,004 kg/hour H2O
Total flow back to head of WWTP	20,007 kg/hour H2O
Total flow back to head of WWTP	88 USGPM
Total flow back to head of WWTP	126,893 USGPD
Total NH4-N	1.84 kg NH4-N/t WE
Total NH4-N	18 kg/hour H2O
Total NH4-N	974 lb. NH4-N/day
Total NH4-N concentration	920 mg/l
Typical Influent Ammonia-N	30 mg/l
Influent	65 MGD
Influent	246 million Liters/day
NH4-N in influent	16,276 lbs/day NH4-N
Additional NH4-N from dryer	6%

The South Plant's normal flow is about 68 million gallons per day. This amounts to about 0.18% of the normal sewage flow per day.

Equity, Social Responsibility and Social Justice: The Thermal Drying Proposal addresses Social Justice to a large degree by eliminating the presence of PFAS chemicals. The social justice is that this proposal uses the dried biosolids pellets to make a cement product that is used in concrete which is a commodity that is beneficially used in many buildings and roadways. Everyone benefits from using the dried biosolids as a fuel.

The proposed facility at the South Plant is totally within the boundaries of the South Plant at Renton and will be aesthetically pleasing with solar panels on the roof. The outside of the building will look like an office building. We recognize that the area surrounding the South Plant is populated by under-represented groups of lower socio-economic means, so a facility will be constructed that will be aesthetically acceptable to the surrounding community. The neighborhood will be pleased with the reduction of greenhouse gas emissions at the thermal drying plant using renewable energy with the dried pellets at a cement plant demonstrating a beneficial use of the biosolids.

Team Members:

Peter Commerford - National U.S. Sales Manager, Drying Systems at ANDRITZ Separation, the world's leading separation company headquartered in Austria with over 150 years of experience and 25,000 employees worldwide with 200 sludge drying plants worldwide and 126 in the United States.

Rick Bender - Former President of the Washington State Labor Council for 18 years; former Washington State Legislator for 18 years and presently the Chairman of the Board of TRW. National AFL-CIO Board (2007) first ever representative from Washington State.

Dr. Michael Ruby – Completed his education with a Ph.D. in Civil Engineering at the University of Washington. Mike has had a wide degree of experience with the U.S. EPA and World Health Organization before starting Envirometrics here in Seattle in 1984. Dr. Ruby is a worldwide environmental/climate change consultant.

Dr. Prakasam Tata – Environmental Engineering and Sciences professional and presently the Executive Director of the Center for the Transformation of Waste Technology. Dr. Tata is the author of 162 publications and reports and 5 books addressing the treatment of sludge and climate change. He holds a Ph.D. from Rutgers University in Environmental Sciences and has been a faculty member at Cornell University and the Illinois Institute of Technology.

Bart T. Lynam - B.S. in Civil Engineering and an M.S. in Environmental Engineering from the Illinois Institute of Technology and has lectured on sludge management and water quality worldwide, including at Cambridge, U.K. and Oxford, England; Stockholm, Sweden; Sydney, Australia; Tokyo, Moscow, and San Paulo, Brazil. He has received many technical awards from the U.S. EPA, U.S. Water Control Federation, and the National Association of Clean Water Agencies (NACWA).

APPENDICIES ATTACHED

APPENDIX A: CEMEX Philippines and Manila Water signed a partnership on February 8, 2023, allowing the use of biosolids as alternative fuels.

APPENDIX B: Report by Ernest Orlando Lawrence Berkeley National Laboratory, a work supported by the U.S. EPA and the Institute for Industrial Productivity through the U.S. Department of Energy.

APPENDIX C: Assessment of Dried Biosolids Product for Meeting Established EPA Classification Requirements for Being a Non-Waste Fuel per the NHSM Rule.

APPENDIX D: Lehigh Hanson Cement Baltimore Co. to achieve carbon neutrality across the cement and concrete value chain by signing onto the Portland Cement Association's Roadmap to Carbon Neutrality.

APPENDIX E: Lehigh's Union Bridge Plant in Baltimore wins Overall Environmental Excellence Award as part of the 2020 Energy and Environment Awards from Portland Cement Association.

APPENDIX A

CEMEX Philippines and Manila Water signed a partnership on February 8, 2023, allowing the use of biosolids as alternative fuels.

CEMEX Philippines signs biosolids partnership

08 February 2023

CEMEX Philippines and Manila Water Co recently signed a partnership allowing the use of biosolids as alternative fuels, a first in the Philippines and a major accomplishment in helping address climate change in alignment with the Philippine government's policy.

Biosolids are organic materials coming from a sewage treatment process. Wastewater undergoes full treatment and clean water is discharged to rivers, and byproducts such as biosolids can be turned into useful resource, such as alternative fuels. Use of biosolids as alternative fuels is an important step to sustainability and developing climate-friendly energy solutions that help address climate change.

"An initial 10t of dried biosolids has been delivered from our Makati South Sewage Treatment plant to the CEMEX Antipolo plant, which we hope to scale up very soon," said Donna Cabalona-Perez, Manila Water's head of wastewater operations.

"As pioneers in the country of biosolids as alternative fuels, we have just signed what will now create the series of significant steps towards making circular economy a reality," said Christer Gaudiano, CEMEX Philippines' sustainability and public affairs director.

"This partnership is a significant step in making sure we maximise every opportunity to increase the use of alternative fuels, ensuring we are forerunners of circular economy and innovation," said Luis Franco, CEMEX Philippines president CEO.

Published under **Cement News**

Tagged Under: Philippines Cemex biosolids Alternative Fuels Southeast Asia

APPENDIX B

Report by Ernest Orlando Lawrence Berkeley National Laboratory, a work supported by the U.S. EPA and the Institute for Industrial Productivity through the U.S. Department of Energy.

LBNL-XXXX

ERNEST ORLANDO LAWRENCE
BERKELEY NATIONAL LABORATORY

International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry

Ali Hasanbeigi, Hongyou Lu, Christopher Williams, Lynn Price

China Energy Group
Energy Analysis and Environmental Impacts Department
Environmental Energy Technologies Division
Lawrence Berkeley National Laboratory

July 2012

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Disclaimer

International Best Practices for Pre-Processing and Co-Processing Municipal Solid Waste and Sewage Sludge in the Cement Industry

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Abstract

Co-processing municipal solid waste (MSW) and sewage sludge in cement kilns can both reduce the cement industry's growing fossil fuel use and carbon dioxide (CO_2) emissions and help address the increasing need for safe and environmentally sensitive municipal waste treatment and disposal.

The cement industry accounts for approximately 5 percent of current anthropogenic CO_2 emissions worldwide. Given increasing cement demand and production, the industry's absolute energy use and CO_2 emissions will continue to grow. Cement kilns typically burn fossil fuels, which are non-renewable and being depleted rapidly. Treating wastes in cement kilns, known as co-processing, can reduce the industry's reliance on fossil fuels and decrease associated CO_2 emissions. The ashes from waste co-processing will be integrated into the clinker which can result in saving the virgin raw materials. In addition, treating wastes in cement production can help alleviate the problems associated with the increase in waste generation around the world, especially in developing countries experiencing rapid urbanization. Municipalities and governments in many urban areas, especially those with underdeveloped waste management systems, face growing difficulties disposing of MSW and sewage sludge in a manner that protects human and environmental health.

The high temperatures and sufficiently long residence time in cement kilns and other characteristics of cement production make co-processing of waste materials a viable strategy. Wastes have been co-processed in cement kilns for more than 20 years, and this practice is prevalent in some developed countries such as the United States and Japan, as well as in a number of countries in the European Union. Many developing countries such as China and nations in Southeast Asia are initiating programs to promote co-processing of wastes in the cement industry. Regulations, standards, and the technical infrastructure in these developing countries are less mature than in countries that have a long experience with co-processing waste in the cement industry.

The purpose of this report is to describe international best practices for pre-processing and co-processing of MSW and sewage sludge in cement plants, for the benefit of countries that wish to develop co-processing capacity. The report is divided into three main sections. Section 2 describes the fundamentals of co-processing, Section 3 describes exemplary international regulatory and institutional frameworks for co-processing, and Section 4 describes international best practices related to the technological aspects of co-processing.

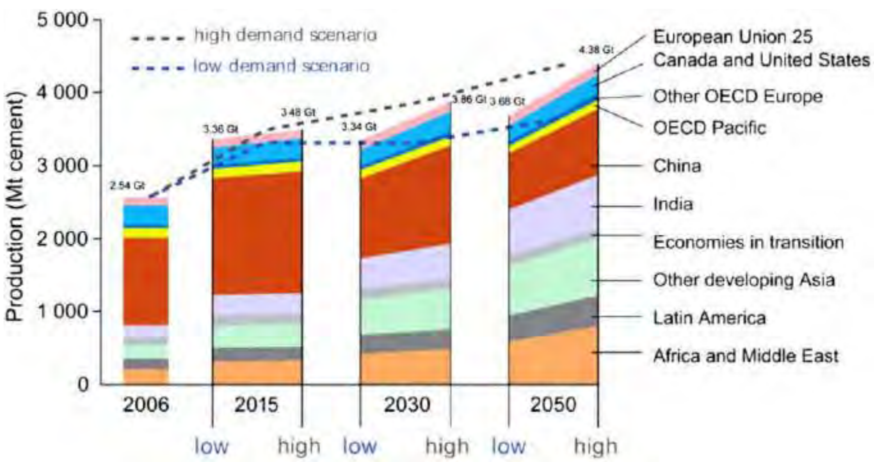
Contents

Acronyms

BAT	best available technique
$CaCO_3$	limestone
CaO	lime
CO	carbon monoxide
CO_2	carbon dioxide
CEMBUREAU	European Cement Association
CEMS	continuous emissions monitoring systems
CISWI	commercial and industrial solid waste incineration
EIPPCB	European Integrated Pollution Prevention and Control Bureau
EPAV	Environmental Protection Authority of Victoria
E-PRTR	European Pollutant Release and Transfer Register
ERT	electronic reporting tool
EU	European Union
GJ	gigajoule
HAP	hazardous air pollutant
HF	hydrogen fluoride
IPPC	Integrated Pollution Prevention and Control
ISO	International Standards Organization
kWh	kilowatt-hour
MACT	maximum achievable control technology
MBT	mechanical biological treatment
µm	micrometer
MSW	municipal solid waste
Mt	million tonnes
NCV	net calorific value
ng	nanogram
Nm	nanometer
NOx	nitrogen oxide
O_2	oxygen
NSP	new suspension preheater/precalciner
PAH	polycyclic aromatic hydrocarbon
PCDD	polychlorinated dibenzo-p-dioxin
PCDF	polychlorinated dibenzofuran
POP	persistent organic pollutant
ppm	parts per million
RDF	refuse-derived fuel
SO_2	sulfur dioxide
t	tonne
TEQ	toxic equivalency basis
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
WBCSD	World Business Council for Sustainable Development
WFD	Waste Framework Directive
WID	Waste Incineration Directive
WWTP	wastewater treatment plant

1. Introduction

The cement industry relies heavily on fossil fuels and accounts for approximately 5 percent of current anthropogenic carbon dioxide (CO_2) emissions worldwide (WBCSD/IEA 2009a). Cement demand and production are increasing; annual world cement production is expected to grow from approximately 2,540 million tonnes (Mt) in 2006 to between 3,680 Mt (low estimate) and 4,380 Mt (high estimate) in 2050. The largest share of this growth will take place in China, India, and other developing countries on the Asian continent (Figure 1) (WBCSD/IEA 2009b). This significant increase in cement production is associated with a significant increase in the industry's absolute energy use and CO_2 emissions. Use of alternative fuels can help reduce the rapid rate at which fossil fuel resources are being depleted, and, if the alternative fuels have lower CO_2 emission factors or contain biomass, can also reduce the industry's CO_2 emissions.



Note: OECD is an acronym for the Organization for Economic Co-operation and Development

Figure 1. Annual world cement production (WBCSD 2009b)

In addition to the energy use and CO_2 emissions challenges facing the cement industry, the problem of increasing waste generation is facing countries around the world. This problem is particularly significant in developing countries where major urbanization is taking place. Municipalities and governments in many countries face problems finding safe and environmentally sensitive means to dispose of growing amounts of municipal solid waste (MSW) and sewage sludge. Finally, the ashes from waste co-processing will be integrated into the clinker which can result in saving the virgin raw materials.

1.1. Municipal Solid Waste

MSW consists of everyday items that people use and then throw away, such as product packaging, furniture, clothing, bottles, food scraps, newspapers, appliances, paint, and batteries (U.S. EPA 2012a). The composition of MSW depends on its sources, the season of the year, and the lifestyles and behaviors of local residents. Raw MSW has a high moisture content, low calorific value, wide range of particle sizes, and high ash content. For these reasons, using raw MSW as fuel is difficult and unattractive. MSW can be treated in a mechanical treatment plant (MT-plant) or in a mechanical biological treatment plant (MBT-plant). Both treatment methods result in a refuse-derived fuel (RDF) that has a considerable higher heat value than the incoming raw waste.

In addition to high calorific value, RDF has the advantages of having a more uniform physical and chemical composition than raw MSW; being easier to store, handle, and transport; emitting fewer pollutants; and requiring less excess air during combustion (Nithikul 2007).

Table 1 shows the amount of MSW generated in a sample of countries around the world. Both total and per capita waste generation have been stable or decreasing in recent years in some developed countries (e.g., in the United States [U.S. EPA 2012a]). However, in some developing countries, these values have been increasing (e.g., in China [NBS 2005-2011]). Furthermore, in developed countries the waste recycling rate is often higher than that in developing countries (Zhanga et al. 2010). Figure 2 shows MSW disposal methods in China in 2006 as an example.

Table 1. MSW generation in sample of countries around the world in 2005 (Zhanga et al. 2010)

Countries	Total amount of MSW generation (1,000 tonnes)	MSW generation rate (kilograms/capita/day)
USA	222,863	2.05
France	33,963	1.48
Germany	49,563	1.64
Denmark	3,900	2.03
Switzerland	4,855	1.78
Poland	9,354	0.68
Portugal	5,009	1.29
Hungary	4,632	1.26
Mexico	36,088	0.93
Japan	51,607	1.10
Korea	18,252	1.04
China (2006)	212,100	0.98

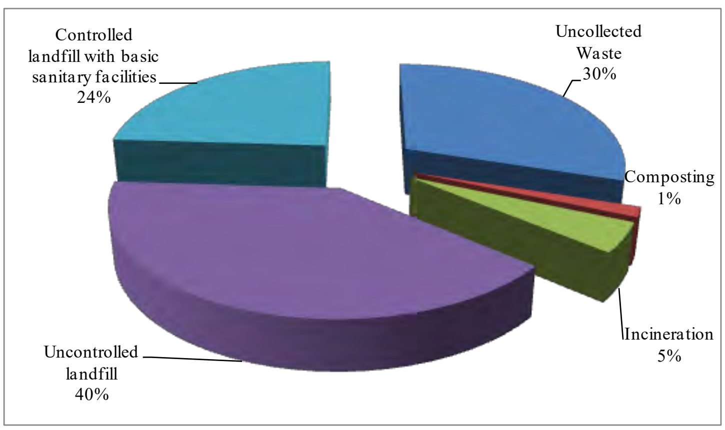


Figure 2. MSW disposal methods in China in 2006 (Zhanga et al. 2010)

1.2. Sewage Sludge

Sewage sludge is generated primarily by municipal wastewater treatment plants (WWTPs). Sewage sludge production has increased substantially in recent years because of an increase in the number and size of urban communities and as well as in the amount of wastewater discharged by industrial processes (He et al. 2007; Milieu Ltd, WRc and RPA 2008).

In the United States in 2007, 16,583 wastewater treatment facilities generated around 6.5 Mt dry sewage sludge (biosolids) (U.S. EPA 2008). Most sewage sludge generated in the United States and other countries is recycled to land or sent to landfills, not incinerated or burned for energy recovery in cement kilns (Milieu Ltd, WRc and RPA 2008).

Sludge that is applied to land must comply with strict human and environmental health standards, and sludge that is contaminated with heavy metals from industrial wastewaters is unfit for use in agriculture (Murray and Price 2008).

Developing countries, such as China and India, are rapidly expanding wastewater treatment facilities, so the quantity of sewage sludge is also rapidly increasing. In 2005, wastewater treatment plants in China generated 9 Mt of dewatered sludge; within 10 years, this amount is expected to increase to 27 Mt (Murray and Price 2008).

1.3. Co-processing: Part of the Solution

Under- or undeveloped waste management remains a problem in developing countries and countries in transition. In many of these countries, waste is discharged to sewers, buried, or burned in an uncontrolled manner, illegally dumped at unsuitable locations, or taken to landfills that do not meet requirements for environmentally sound final disposal of waste. These practices can result in contamination of soil, water resources, and the atmosphere, leading to ongoing deterioration in the living conditions and health of adjacent populations.

Co-processing of selected waste streams in cement kilns could be part of the solution to this problem (GTZ/Holcim 2006). Sewage sludge, which is often land filled or used in agriculture, can be used as an alternative fuel and raw material in the cement clinker manufacturing process. Many European countries have already started adopting this practice for sewage sludge management (CEMBUREAU 2009). Both pre-processed MSW and sewage sludge have relatively high net calorific value (NCV) in gigajoules (GJ) per dry tonne. Pre-processed MSW and sewage sludge also have a much lower CO_2 emissions factor compared to coal when treated in a cement kiln. Table 2 shows the typical characteristics of MSW and sewage sludge used as alternative fuel. However, the energy content of MSW in some developing countries often reported to be even lower than the range shown in Table 2.

Table 2. Typical characteristics of MSW and sewage sludge used as alternative fuel (Murray and Price 2008)

Fuel	Substitution rate (% of fuel)	Energy content (NCV) (GJ/dry t)	Water content (%)	CO_2 emission factor (ton CO_2/t)
Municipal solid waste (RDF fraction)	up to 30	12 - 16	10 - 35	0.95 - 1.32
Dewatered sewage sludge	20	9 - 25	75	0.29
Dried sewage sludge	20	9 - 25	20	0.88

2. Fundamentals of Co-processing Municipal Solid Waste and Sewage Sludge in the Cement Industry

The subsections below describe the cement production process, its CO_2 impacts, and various issues related to co-processing MSW and sewage sludge in the cement industry.

2.1. Cement Production

The general process by which cement is manufactured today entails quarrying and crushing or grinding the raw materials (commonly limestone [$CaCO_3$], chalk, and clay), which are then combined and passed through a kiln in the form of either a dry powder or a wet slurry. The average raw material temperature in the kiln goes up to 1,450°C. The heat fuses the raw materials into small pellets known as clinker. The cooled clinker is combined with gypsum and ground into the fine powder known as Portland cement. The American Society for Testing and Materials defines several types of Portland cement with different properties as well as several blended hydraulic cements that are made by combining materials such as Portland cement, fly ash, natural pozzolana (a siliceous volcanic ash), artificial pozzolana, and blast furnace slag (PCA 2012). The European Union has similar classifications for cements incorporating alternative cementitious material. Appendix 1 describes the process by which cement is produced in more detail, with a focus on the energy use in cement production processes.

2.1.1. CO_2 Impacts of Cement Production

Producing 1 metric ton (t) of cement releases an estimated 0.73 to 0.99 t CO_2 depending on the clinker-per-cement ratio and other factors. A major difference between the cement industry and most other industries is that fuel consumption is not the dominant driver of CO_2 emissions. More than 50 percent of the CO_2 released during cement manufacture, or approximately 540 kilograms (kg) CO_2 per t of clinker (WBCSD 2009), is from calcination, in which $CaCO_3$ is transformed into lime (CaO) in the following reaction:

$$CaCO_3 \rightarrow CaO + CO_2$$

The rest of the CO_2 emitted during cement manufacture is the result of burning fuel to provide the thermal energy necessary for calcination. Kilns in which calcination takes place are heated to around 1,450°C. An average 100 to 110 kilowatt hours (kWh) of electricity is consumed per t of cement (WWF 2008). The share of CO_2 emissions from electricity use is, on average, 5 percent of the total CO_2 emissions in the cement industry. Depending on the energy source and the efficiency with which it is used in the local electricity mix, this figure can vary from less than 1 percent to more than 10 percent. Roughly 5 percent of CO_2 emissions are associated with quarry mining and transportation (WWF 2008).

2.2. Co-processing of MSW and Sewage Sludge in the Cement Industry

The Basel Convention (2011) defines co-processing as "the use of waste materials in manufacturing processes for the purpose of energy and/or resource recovery and resultant reduction in the use of conventional fuels and/or raw materials through substitution." This is also a concept in industrial ecology, related to the potential role of industry in reducing environmental burdens throughout a product's life-cycle. The Basel Convention further defines co-processing as an operation "which may lead to resource recovery, recycling, reclamation, direct reuse or alternative uses" (Basel Convention 2011).

Waste co-processing has been practiced for more than 20 years, especially in developed countries/regions such as Europe, Japan, the United States, and Canada (GTZ/Holcim 2006; Genon and Brizio 2008). Figure 3 shows the quantities of waste co-processed in the European cement industry in 2003 and 2004. In 2006, alternative fuels other than scrap tires and solvents (e.g., MSW and sewage sludge) collectively represented about 2.5 percent of the total energy input to U.S. cement kilns (EPA, 2008). In 2009, 63 cement plants, or 70 percent of all cement plants in the United States, used alternative fuels (PCA, 2012).

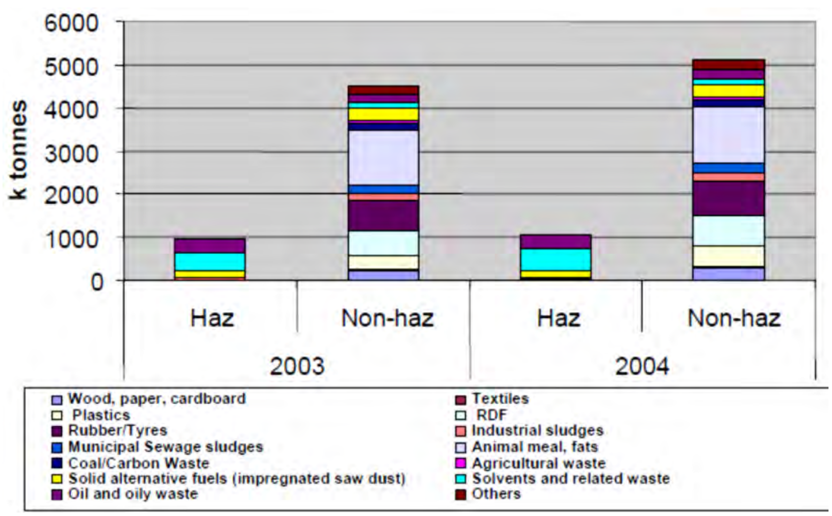


Figure 3. Co-processing of hazardous and nonhazardous waste in cement kilns in the European Union in 2003 and 2004 (EIPPCB 2010)

The European Integrated Pollution Prevention and Control Bureau (EIPPCB) (2010) identifies the following characteristics of cement production that allow for the co-processing of waste materials:

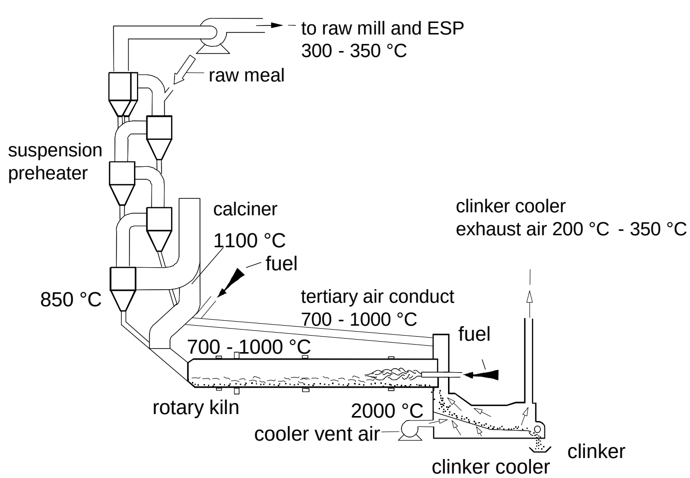
- Maximum temperatures of approximately 2,000°C (main firing system, flame temperature) in rotary kilns
- Gas retention times of about 8 seconds at temperatures greater than 1,200°C in rotary kilns
- Material temperatures of about 1,450°C in the sintering zone of the rotary kiln
- Oxidizing gas atmosphere in the rotary kiln
- Gas retention time in the secondary firing system of more than 2 seconds at temperatures greater than 850°C; in the precalciner, correspondingly longer retention times and higher temperatures
- Solids temperatures of 850°C in the secondary firing system and/or the calciner
- Uniform burnout conditions for load fluctuations because of high temperatures and sufficiently long retention times

- Destruction of organic pollutants because of high temperatures and sufficiently long retention times
- Sorption of gaseous components like hydrogen fluoride (HF), hydrogen chloride (HCl), and sulfur dioxide (SO_2) on alkaline reactants
- High retention capacity for particle-bound heavy metals
- Short exhaust-gas retention times in the temperature range known to lead to de-novosynthesis of dioxins and furans
- Complete utilization of burnt waste ashes as clinker components
- No product-specific wastes because materials are completely incorporated into the clinker matrix (some European cement plants dispose of bypass dust)
- Chemical-mineralogical incorporation of nonvolatile heavy metals into the clinker matrix

Table 3 shows temperatures and residence times during cement production. Figure 4 shows the temperature profile at different points in a rotary kiln with suspension preheater and precalciner.

Table 3. Temperatures and residence times during cement production (GTZ/Holcim 2006)

Characteristics	Value
Temperature at main burner	>1450°C: material >1800°C: flame temperature.
Residence time at main burner	>12-15 sec > 1200°C >5-6 sec > 1800°C
Temperature at precalciner	> 850°C: material >1000°C: flame temperature
Residence time at precalciner	> 2 - 6 sec > 800°C
Residence time at precalciner	> 2 - 6 sec > 800°C



* ESP: Electrostatic Precipitator. The more recent plants use bag houses

Figure 4. Typical temperature profile of a rotary kiln with suspension preheater and calciner (Schneider et al. 1996)

Not all waste materials are suitable for co-processing in the cement industry. When wastes are selected for co-processing, several factors must be considered, including the chemical composition of both the wastes and the final product (cement) and the environmental impact of co-processing. Examples of wastes that are not suitable for co-processing in the cement industry are waste from nuclear industry, infectious medical waste, entire batteries, and untreated mixed municipal waste. GTZ/Holcim (2006) gives a full list of waste materials suitable for co-processing. Appendix 3 shows an example of a decision chart for accepting or refusing waste for co-processing (CEMBUREAU 2009).

GTZ/Holcim (2006) outlines five general principles that must be followed when co-processing waste in the cement industry. Table 4 shows these principles.

Table 4. General principles for the co-processing of waste in the cement industry (GTZ/Holcim 2006)

Principle 1	**Co-processing must respect the waste hierarchy (see Figure 5):** • Co-processing should not hamper waste reduction efforts, and waste must not be used in cement kilns if ecologically and economically better methods of recovery are available. • Co-processing should be regarded as an integrated part of modern waste management, as it provides an environmentally sound resource recovery option for the management of wastes. • Co-processing must be consistent with relevant international environmental agreements, i.e., the Basel and Stockholm Conventions.
Principle 2	**Additional emissions and negative impacts on human health must be avoided:** • To prevent or keep to an absolute minimum the negative effects of pollution on human and environmental health, emissions to the air shall not be greater, on a statistical basis, than those from cement production using traditional fuel.
Principle 3	**The quality of the cement product should remain unchanged:** • The product (clinker, cement, concrete) must not be abused as a sink for heavy metals. • The product should not have any negative impact on the environment as demonstrated with leaching tests, for example. • The quality of the cement must allow end-of-life recovery.
Principle 4	**Companies engaged in co-processing must be qualified:** • Companies must have good environmental and safety compliance track records and provide relevant information to the public and the appropriate authorities. • Companies must have personnel, processes, and systems demonstrating commitment to the protection of the environment, health and safety. • Companies must comply with all applicable laws, rules and regulations. • Companies must be capable of controlling inputs and process parameters for effective co-processing of waste materials. • Companies must ensure good relations with the public and other actors in local, national, and international waste management schemes.
Principle 5	**Implementation of co-processing has to consider national circumstances:** • Regulations and procedures must reflect country-specific requirements and needs. • Stepwise implementation allows for the buildup of required capacity and the creation of institutional arrangements. • Introduction of co-processing should go along with other improvements in a country's waste management sector.

Figure 5. Waste management hierarchy (GTZ/Holcim 2006)

2.3. Reasons and Motivations for Co-processing of MSW and Sewage Sludge

Cement manufacturers around the world are using MSW, sewage sludge, and other alternative fuels to replace fossil fuels. Industrialized countries have more than 20 years of successful experience with co-processing of wastes in cement production (GTZ/Holcim 2006). The Netherlands and Switzerland, which use 83 percent and 48 percent waste, respectively, in the cement fuelstock, are among the world leaders in this practice (WBCSD 2005). In a U.S. Environmental Protection Agency (U.S. EPA) study (2008), many U.S. cement plants indicated that use of alternative fuels is important to their continued competitiveness. Co-processing MSW and sewage sludge in cement kilns has multiple benefits in addition to waste management, as explained in the subsections below.

Saving fuel costs, especially in times of rising fuel prices:
Cement plant operators are understandably concerned about future fuel costs in view of the current upward cost trend. Energy normally accounts for 30 to 40 percent of operating costs in cement manufacturing; any opportunity to save on these costs will make a plant more competitive and maintain or increase its profit margin. Costs vary with the type of waste and local conditions, while often cement plants are paid to treat waste materials; in other cases, the waste may be acquired for free or at much lower cost than the equivalent energy in coal or other fossil fuels (Murray and Price 2008).

MSW and sewage sludge must be pre-processed before being used in a cement kiln, and additional environmental equipment might also be needed to control emissions. Special control and process measures may also be needed to maintain safety, quality, and environmental standards (WBCSD 2002). The lower cost of waste fuels might offset the entire or partial cost of installing the new pre-processing and other equipment, depending on plant-specific conditions. The economics of waste co-processing as well as the technological aspects of pre- and co-processing are discussed in Section 2.6 and Section 4, respectively, of this report.

Conserving nonrenewable fossil fuels and protecting the environment:
Co-processing of MSW and sewage sludge can replace a significant amount of fossil fuel in the cement industry, conserving nonrenewable fossil fuel resources (Karstensen 2007a). Extraction of fossil fuels, such as coal, often has a significant negative impact on the landscape. To the extent that co-processing of wastes in kilns reduces the need for coal, damage to the land from coal mining can be significantly reduced.

Reducing greenhouse gas emissions:
As noted earlier, the cement industry produces approximately 5 percent of global anthropogenic CO_2 emissions worldwide. Energy-related emissions account for approximately half of this total, with about 40 percent resulting from burning of fuel and the other 10 percent resulting from electricity use and transport (WBCSD 2005). Figure 6 shows the historical and projected CO_2 emissions by the cement industry worldwide through the year 2050. Based on this figure as well as Figure 1, it is clear that the absolute CO_2 emissions of the global cement industry will increase significantly.

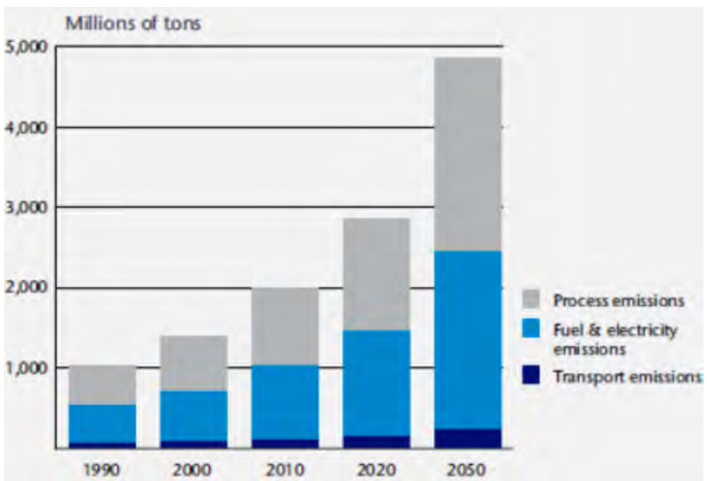


Figure 6. Historical and projected CO_2 emissions of the global cement industry (Campisano 2011)

As can be seen from Table 2 above, both MSW and sewage sludge has significantly lower carbon emission factors than coal. Therefore, replacing coal, which is the most common fuel used in the cement industry, with MSW and sewage sludge will significantly reduce CO_2 emissions. Co-processing of RDF is reported to result in a reduction of about 1.6 kilograms (kg) of CO_2 per kg of utilized RDF, compared to combustion of coal (Genon and Brizio 2008). In 2006, waste co-processing in the European cement industry resulted in an approximately 18 percent reduction in conventional fuel (mostly coal) use, a reduction of about 8Mt of CO_2 emissions each year, and a savings of about 5Mt of coal (CEMBUREAU 2009).

Avoiding negative impacts of waste incineration and landfilling:
In developed countries, MSW is often incinerated, with or without heat recovery, to reduce the need for landfills. The United States has 86 MSW incineration facilities that process more than 28 million tons of waste per year with an energy-recovery capacity of 2,720 megawatts of power. Approximately 10 percent of the original volume remains as ash after incineration of MSW (U.S.

EPA 2012b). In general, the ash contains heavy metals and is frequently categorized as a hazardous waste.

Various studies have shown the advantages of co-processing waste in the cement industry in comparison to incinerating waste. A study by the Netherlands Organization for Applied Science Research used the life-cycle assessment approach to compare the environmental impacts of using waste as an alternative fuel / raw material in the cement industry to the impacts of burning waste in hazardous waste incinerators while recovering electricity and steam. The study concluded that, for the vast majority of environmental impacts, using waste as alternative fuel in the cement industry was better for the environment than treating waste in incinerators (CEMBUREAU 2009).

Another life-cycle assessment analysis by CEMBUREAU showed that, for some MSW (e.g. spent solvent, filter cake, paint residues, and sewage sludge), the cement kiln option outperforms other options such as incineration and recycling. This study showed that co-processing of spent solvent, filter cake, paint residues, and sewage sludge yields more environmental benefits than incinerating these waste streams in waste incinerators. Moreover, the study showed that co-processing of waste plastics and waste oils maximizes the beneficial use of these two waste streams relative to conventional incineration or conversion into recycled goods (CEMBUREAU 1999).

Figure 7 shows graphically how co-processing of waste in cement kilns outperforms incineration or landfilling of waste. In addition to CO_2 emissions reduction benefits, co-processing of waste reduces landfill methane emissions. Landfill emissions consist of about 60 percent methane, a gas with a global warming potential 21 times that of CO_2 (CEMBUREAU 2009).

Dried/dewatered sewage sludge that is landfilled contains a significant amount of carbon that can produce methane (UNFCCC 2010). Co-processing of dried/dewatered sewage sludge in cement kilns can eliminate methane emissions from landfilled sludge. Figure 8 shows an example of the CO_2 balance for co-processing versus landfilling of sewage sludge.

Furthermore, Taruya et al. (2002) show that CO_2 generation decreases by 30 percent when dewatered sludge is injected directly into cement kilns instead of being incinerated at the sewage treatment plant, with the ash used as raw material for cement production.

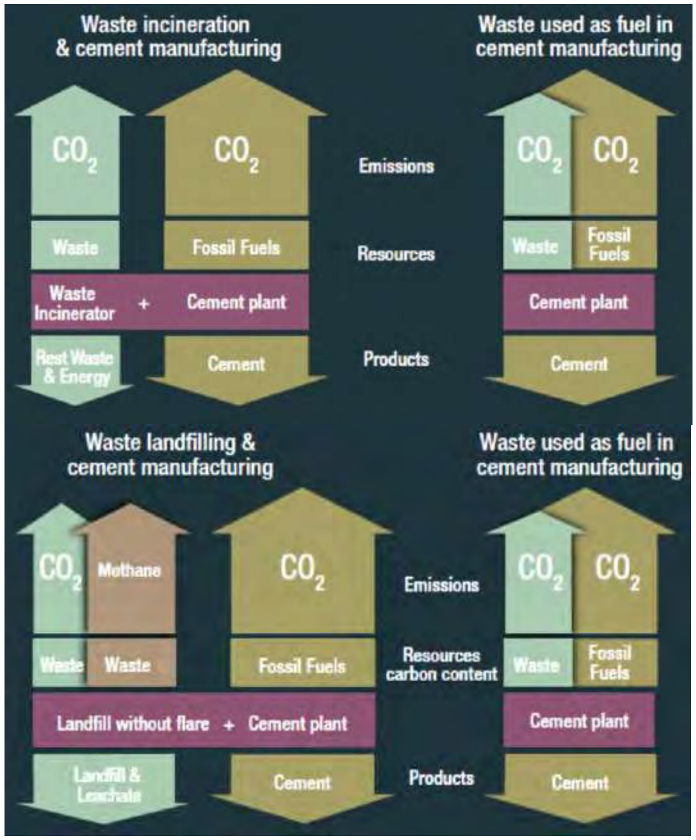
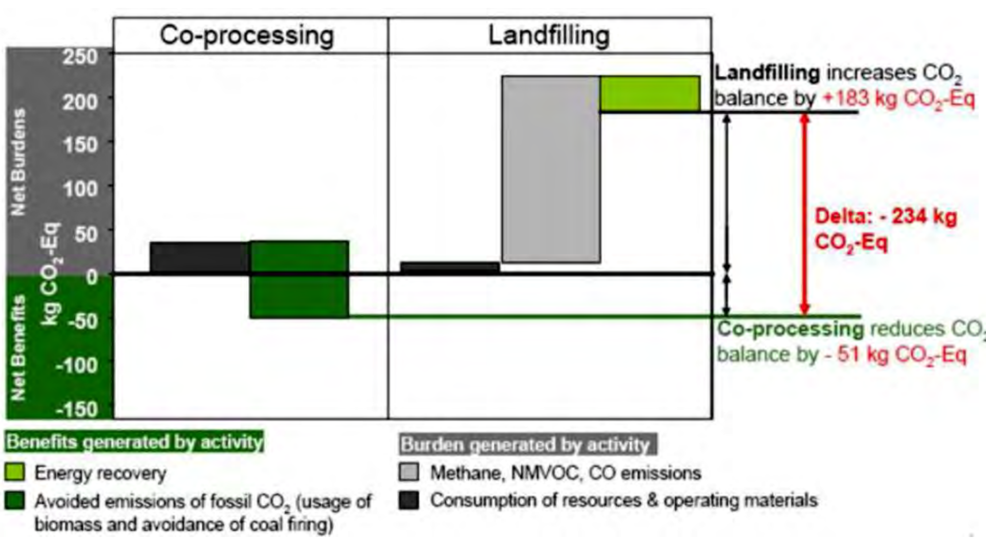


Figure 7. Greenhouse gas emissions from waste landfilling, incineration, and co-processing (CEMBUREAU 2009)



Note: CO_2-Eq: CO_2 Equivalent; NMVOC: non-methane volatile organic compounds

Figure 8. Comparison of CO_2 balance for co-processing and landfilling of 100 kg of sewage sludge (HeidelbergCement 2011)

Integrating waste ash into clinker, which saves raw materials:
The ash from MSW and sewage sludge used in co-processing often has a chemical composition that allows it to be used in place of conventional raw material for clinker making. Figure 9 shows the similar chemical compositions of ash from sludge and of cement raw materials.

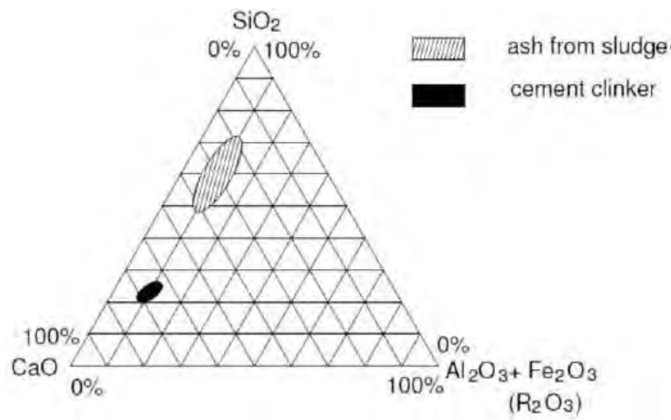


Figure 9. Chemical composition of ash from sludge and cement clinker in ternary diagram: lime (CaO) – silicon dioxide (SiO_2) – refractory oxides (R_2O_3) (Stasta et al. 2006)

In addition, waste materials that do not require significantly more heat to process can contribute part of the CaO needed to make clinker from a source other than $CaCO_3$, thereby further reducing process-related CO_2 emissions and preserving natural resources (Van Oss 2005).

Avoiding new investment in incinerators or landfill facilities:
Another advantage of co-processing is that municipalities can send waste that cannot be recycled to cement plants for use, rather than having to invest in incinerators or landfill facilities to accommodate the waste (Murray and Price 2008). Co-processing also incorporates ash residues into the clinker so that there are no end products that require further management, such as disposal in a landfill (Basel Convention 2011).

2.4. Impacts of Co-processing on Cement and Concrete Quality

When waste is treated as fuel in cement plants, residues from the waste are incorporated in the clinker and then in cement, which may affect the quality of the final product. For co-processing plants, product quality encompasses two dimensions: whether the residues from the waste fuel pose a potential environmental hazard, e.g., from leaching of the final product, and whether the residues affect the product's technical characteristics and thus its function as a building material. National and international standards address limits on residues in the final product.

The high temperature of cement kilns can completely destroy the organic components in MSW and sewage sludge, but the inorganic components, including metals, are incorporated into the end product. Thus, if there are metals in the MSW and sewage sludge, co-processing of these wastes can change the metal concentrations in the final product compared to the product that results when the plant is not fueled by wastes (EIPPCB 2010).

Because cement and concrete produced by co-processing must comply with applicable national or international quality standards, it should not be used as a sink for heavy metals or have any characteristics that would result in a negative impact on the environment. In addition, the cement should be of a quality that allows end-of-life recovery (Basel Convention 2011). Studies have shown that, on a statistical basis, waste co-processing has a marginal effect on the heavy metals content of clinker, the one exception being when tires are used as fuel in kilns, which raises zinc levels in the final product. The excessive amount of zinc causes a problem for formation of Portland cement, making it harden too quickly, and therefore need to be managed accordingly (GTZ/Holcim 2006).

The behavior of trace elements in the final product is decisive in evaluating the environmentally relevant impacts of waste co-processing in kilns (CEMBUREAU 2010). Environmental safety can be demonstrated using leaching tests. The results of leaching studies to assess the environmental impacts of heavy metals embedded in concrete showed that the leached amounts of all trace elements from concrete (during service life and recycling) are less than or close to the detection limits of the most sensitive analytical method. However, certain metals, such as arsenic, chromium, vanadium, antimony, and molybdenum, can be more mobile, especially when a mortar or concrete structure is crushed or comminuted (for example, when recycled as aggregate in road foundations or in end-of-life scenarios such as landfilling) (Basel Convention 2011).

2.5. Tradeoffs between Energy Use and Waste Co-processing

Waste co-processing in the cement industry reduces the amount of fossil fuel (e.g., coal) used in the plant and reduces GHG emissions mainly by avoiding the CO2 and CH4 emissions from landfilling and/or incinerators (see Figure 7). However, co-processing sometimes increases the overall energy use per tonne of clinker produced by the kiln. This increase could result from a number of factors, mainly the moisture content in the waste which results in additional fan electricity required for extra exhaust gas handling and bypass operation. Table 5 and Figure 10 illustrate an example of the tradeoff and show a breakdown of the extra heat consumed in co-processing.

Table 5. An example of tradeoff between energy use and waste co-processing (Hand 2007)

Item	Plant A	Plant B	Difference
	Using only fossil fuel	Using both fossil fuel and waste fuel [a] (with extra equipment for co-processing)	
Specific heat demand	2.96 GJ/t clinker [c]	3.27 GJ/t clinker	10% [b]
Specific exhaust gas amount	1.4 Nm^3/kg clinker	1.6 Nm^3/kg clinker	14%
Pressure drop at fan inlet	- 47 mbar [d]	- 68 mbar	45% [e]

[a] The type or the share of waste fuel was not provided in the reference.
[b] See Figure 10 for breakdown of this extra energy use.
[c] The specific heat demand of 2.96 GJ/t clinker for Plant A is on the very low side of the range and would be attained by a very efficient dry kiln running for a certain period, under very stable conditions, with the right raw materials, etc. However, it would be usually hardly achieved by a kiln, over a year period. The same point would apply to Plant B with co-processing of wastes.
[d] mbar: millibar
[e] The pressure drop could be associated with other factors and not only the co-processng of waste. For example, plant B shows a secondary combustion chamber which will require additional pressure drop. While the use of secondary combustion chamber is useful, it is not necessarily a requirement for co-processing.

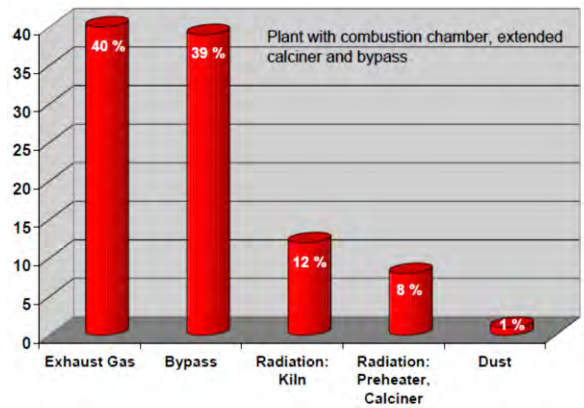


Figure 10. Breakdown of extra 10 percent heat consumption with co-processing, shown in Table 5 (Hand 2007)

2.6. Economics of Waste Co-processing

The overall cost of waste co-processing includes the capital and operating costs of the following (U.S. EPA 2008):

- Kiln and equipment upgrades
- Performance testing
- Waste pre-processing Materials acquisition and transportation: This cost can be negative, if the cement plant charges a waste co-processing fee for the service.
- Continuous emissions monitoring systems (CEMS)
- Sampling and testing of materials
- Operation, health and safety (OH&S): specific personal protective equipment and training

Sometimes, the above costs associated with pre- and co-processing of waste are greater than the energy and material value of the waste; therefore, a waste fee might need to be levied to be collected by cement plants co-processing the waste. In some cases has waste co-processing been profitable, such as in Japan where a high value is placed on waste treatment (GTZ/Holcim 2006).

Technical standards and country-specific environmental policies and incentives largely affect the economics of waste co-processing in the cement industry (GTZ/Holcim 2006). In addition, fuel prices vary from country to country and even among regions within a country. Therefore, the economics of co-processing should be assessed according to the specific location and circumstances of each plant. The type of kiln at the cement plant (wet kiln, long dry kiln, preheater kiln, or new suspension preheater [NSP] kiln) influences the financial feasibility of waste co-processing as well. Wet kiln and long dry kiln technologies are not as energy efficient as are more modern NSP kilns; thus, plants with older-technology kilns have a greater need to reduce fuel costs in order to remain competitive with newer plants (U.S. EPA 2008).

Other factors that affect the financial viability of co-processing are: the increasing costs of fossil fuels; regional, national, or international emissions caps or carbon trading schemes; the avoided cost of installing new waste incinerators or managing new landfill sites; and incentives related to alternative energy sources (Genon and Brizio 2008).

GTZ/Holcim (2006) suggests that the "polluter pays" principle should be applied in the economic analysis of waste co-processing. According to this principle, those who produce waste (e.g., industry) or are responsible for its handling (e.g., municipalities) have to ensure and pay for the best, environmentally sound management of that waste.

Some regulations can make co-processing of MSW and/or sewage sludge more economically attractive. Examples of supportive regulations include: restrictions or limits on landfill availability for MSW and / or sewage sludge, higher fossil fuel prices, carbon taxes, and carbon trading schemes. A policy prohibiting landfilling of untreated sewage sludge in California, for example, drives the beneficial use of sewage sludge in that state. In California, the sludge has to be first dried at temperatures of at least 60°C to generate "Class A biosolids," which is suitable for co-processing in cement kilns (U.S. EPA 2008). Also, in Switzerland, the agricultural use of sewage sludge is banned due to health concerns[1].

Figure 11 shows an example fuel cost profile for a cement plant and the target use of alternative (secondary) fuels. This figure shows reduced energy costs per tonne of clinker over time as a result of replacing expensive coal and other fossil fuels with lower-price alternative fuels and raw materials.

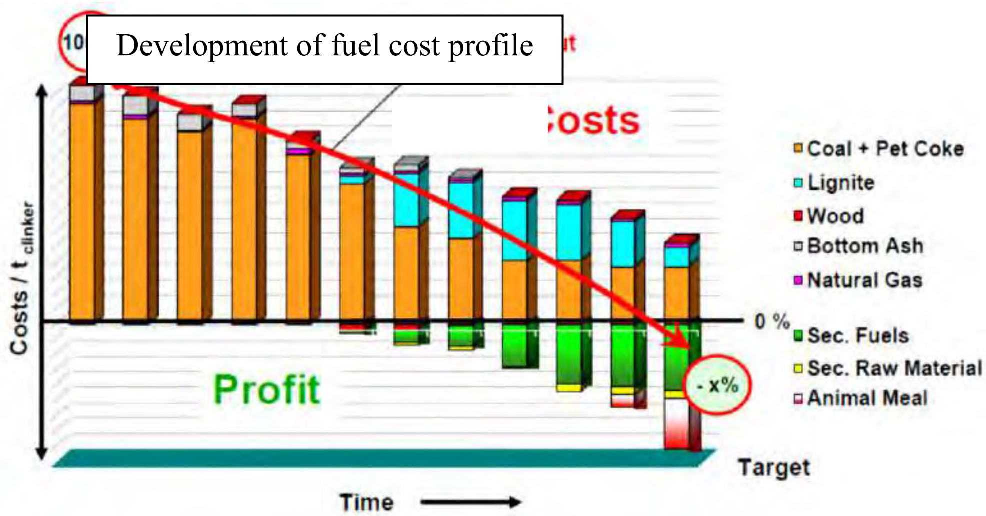


Figure 11. An example fuel cost profile for a cement plant with target use of alternative (secondary [Sec.]) fuels (Hand 2007)

The China Energy Group at the Lawrence Berkeley National Laboratory has developed a techno-economic analysis tool called Sewage Sludge Use in Cement Companies as an Energy Source (SUCCESS tool). This Excel-based tool assists decision makers in implementing sewage sludge co-processing schemes with optimal economic and environmental outcomes. The tool is in its beta version and is being tested on sewage sludge co-processing projects.[2]

[1] Bruno Fux, Holcim. Personal communication. June 2012.
[2] For further information about the SUCCESS tool, please contact Ali Hasanbeigi AHasanbeigi@lbl.gov or Lynn Price LKPrice@lbl.gov.

2.7. Health and Environmental Risks of Co-processing

Lack of emissions controls for cement kilns, especially for kilns that are co-processing waste, can result in extremely high concentrations of particulates in ambient air. Exposure of local communities to these emissions has resulted in increased cases of respiratory, skin, and gastrointestinal disease as well as eye irritation (Karstensen 2007a). Exposure to hazardous air pollutants (HAPs) in sufficient concentration for a sufficient period of time can increase the chances of cancer or other serious health effects including immune system damage and neurological, reproductive, developmental, or respiratory problems (U.S. EPA 2012d). Cement kiln emissions also have detrimental environmental impacts. For example, nitrogen oxide (NOx) emissions from cement kilns can cause or contribute to adverse environmental impacts such as ground-level ozone, acid rain, and water quality deterioration (U.S. EPA 2012d). Since the 1970s, the increasingly strict controls on emissions from cement plants have considerably reduced the potential for public exposure to and environmental impacts of hazardous emissions.

With the recent increase in waste co-processing in cement kilns, concern has been raised regarding whether the chemicals emitted when cement plants treat waste might threaten public health. This concern is largely based on the supposition that such plants emit much greater amounts of potentially toxic chemicals than those using only conventional fuel (Karstensen 2007a). If MSW and sewage sludge are co-processed correctly and according to stringent environmental and emissions standards and regulations, there are no additional health and environmental risks compared to those that result when coal is used as a fuel (Rovira et al. 2011; Zabaniotou and Theofilou 2008; Karstensen 2008). See Sections 4.5.1 and 4.6 for further details.

2.8. Key Barriers to Co-processing

Some of the key barriers to co-processing of MSW and sewage sludge in the cement industry are listed below:

- **Permitting**: Although the cement industry prefers uniform emissions standards for co-processors rather than case-by-case permitting of waste co-processing at plants, for some hazardous waste co-processing, case-by-case permitting is necessary to ensure environmental and health safety and compliance.
- **Regulations and standards**: Some countries lack specific regulations and standards for co-processing of waste in the cement industry. Inadequate enforcement of waste management regulations in many developing countries is also one of the key barriers.
- **Supportive policies**: In many case, co-processing might not be financially viable on its own if its larger societal (waste management) benefits are not taken into account. Municipalities and governments that wish to pursue co-processing should design programs and incentives based on co-processing's full benefits to the local community and environment.
- **Public acceptance**: Local residents and groups often perceive waste co-processing to be the same as waste incineration and automatically resist co-processing of MSW and sewage sludge in cement kilns. The major concern is usually the emissions from waste combustion, especially dioxin; this is a legitimate concern. Basic knowledge about waste co-processing and how it differs from waste incineration as well as its potential benefits is important to share at both national and local levels. Authorities should openly and publicly communicate

emissions monitoring data and information from co-processing cement plants to assure the community that pollutant emissions comply with permitted levels.

- **Cost**: Costs of RDF production and sewage sludge pre-processing and co-processing are usually higher than existing landfill fees. However, it should be noted that most current landfill charges do not fully account for the costs of future ground water contamination or greenhouse gas (e.g. methane) emissions. Thus, either those externality costs should be included in landfill charges or financial incentives or supportive programs must be in place to make waste co-processing financially competitive with other waste treatment/disposal options.
- **Infrastructure**:
    - Existing infrastructure for sewage sludge is largely based on applying sludge to land or landfilling. Alternative infrastructure is needed for transport and pre-processing to cement plants.
    - MSW generators (local governments) might need to install equipment and establish procedures to adequately segregate materials in MSW and generate RDF.
- **Lack of qualified workforce:** The co-processing of waste in cement plants requires highly qualified experts to install and set up the equipment and trained personnel to operate the equipment. This capacity is presently limited in most developing countries.

3. Legal, Regulatory, and Institutional Frameworks for Co-processing: International Best Practices

Effective regulatory and institutional frameworks are critical to ensure that cement industry co-processing practices do not have negative health or environmental impacts. If co-processing is conducted in an environmentally sound manner, with proper sorting and pretreatment of waste, acceptance criteria clearly defined, quality control of waste inputs, clear regulations and enforcement to prevent pollution, and rigorous systems for site selection and permitting, co-processing can be an attractive alternative to deal with these waste, using them as alternative fuel and raw material for the cement industry. However, when adequate regulations are not in place, bad practices could lead to negative human and environmental health impacts (see Section 2.7).

Many developed countries have been operating co-processing plants since the 1970s. By 2008, Germany had replaced 54 percent of conventional fuel used in the cement industry with RDF (VDZ, 2010), and the Netherlands had replaced more than 80 percent. To safeguard the health and safety of residents near and employees in plants that are co-processing waste fuel, governments have established rules, regulations, and standards to regulate, monitor, and evaluate plant performance. In countries, such as Japan, Norway, and Switzerland, where land for waste landfill is very limited and resources are constrained, co-processing has played an important role in waste management, resource conservation, and energy efficiency (WBCSD, 2005).

This section of this report summarizes best practices for two common waste fuels/raw materials in the cement industry, MSW and sewage sludge. The subsections below cover legal, regulatory, and institutional frameworks that have been established in European countries, with examples from Germany, Finland, Italy, Switzerland, Austria, and France, as well as other countries, including Japan, the United States, Australia, Brazil, and South Africa.

3.1. General Legal Frameworks

Countries and regions have established legal frameworks and regulation requirements in addressing the issue of utilizing wastes in co-processing industries. This section reviews key policies and regulations that are developed and implemented internationally, in key regions, and in selected developed and developing countries, and then discusses and compares key environmental performance requirements at different levels of different systems.

Internationally, the Basel Convention plays an important role in creating internationally accepted rules and legal frameworks for addressing hazardous wastes and the use of hazardous wastes in co-processing in the cement industry. Adopted in 1989 and effective as of May 5, 1992, the Basel Convention was established to address concerns over management, disposal and transboundary movements of hazardous wastes. Currently, 178 countries have joined the Basel Convention.

At the 10th Meeting of the Conference of the Parties to the Basel Convention in October 2011, the Parties adopted technical guidelines for the environmentally-sound co-processing of hazardous waste in cement kilns. The guidelines stipulate that "any transboundary export, import or transit is permitted only when both the movement and the disposal of the hazardous wastes are environmentally sound" (Basel Convention, 2011). Countries that are parties to the Basel

Convention are obligated to ensure the environmentally sound management of hazardous and other wastes. The technical guidelines serve as a main reference for the ongoing development of legal frameworks for the co-processing industry, for use in developing and developed countries.

Developed countries have established overarching legal frameworks in their countries for waste management that provide the basis for integrating co-processing into the waste management system. Examples of these legal frameworks in the European Union (EU), the United States, and Japan are described below.

3.1.1. European Union

Waste Framework Directive

The European Union sets its basic waste policy through the Waste Framework Directive (2008/98/EC) (WFD). All member states are required to align their national laws with the directive within a defined period of time. The WFD establishes basic concepts and definitions, including waste prevention, recovery, recycling, and management. The directive also establishes waste management principles, requiring that "waste be managed without endangering human health and harming the environment, and in particular without risk to water, air, soil, plants or animals, without causing a nuisance through noise or odors, and without adversely affecting the countryside or places of special interest" (EC, 2012a).

In addition, the WFD stipulates a waste management hierarchy (Figure 5 in Section 2.2.) that prioritizes waste prevention, followed by reuse or recycling of wastes, recovery in the form of energy, and, as a last option, disposal by landfilling. Co-processing of MSW and sewage sludge in the cement industry is regarded as energy recovery and is thus prioritized over landfilling.

Waste prevention and reuse and recycling of wastes should not been seen as competing or conflicting with co-processing. All serve the overall goal of reducing negative impacts of increasing quantities of waste. Moreover, co-processing is only feasible if municipal waste is sorted, and properly pretreated. The WFD establishes two waste recycling andrecovery targets: a re-use and recycling rate of 50 percent for household waste materials (including paper, metal, plastic, and glass) by 2020, and a reuse - recycling target of 70 percent for construction and demolition waste by 2020 (EC, 2012a).

The EU WFD also outlines general principles for waste collection and management. Based on the "polluter pays" principle, the WFD specifically requires that producers or holders of waste must carry out waste treatment themselves or have treatment carried out by a broker or establishment. The WFD also opens the waste management market through "extended producer responsibility," which shifts waste treatment responsibilities from the government to the waste-producing entities.

These principles provide strong incentives for co-processing because waste-producing facilities (such as industrial companies), and waste-handling organizations (such as municipalities) must pay the cement industry for waste treatment when waste is co-processed. The price of waste treatment varies among nations. In Japan, for example, where natural resources are heavily constrained, the price of waste treatment is usually high; therefore, co-processing plants realize high profit margins.

To ensure implementation, the WFD requires all EU member states to establish "one or more [waste] management plans" that should contain "the type, quantity and source of waste, existing collection systems and location criteria," and information on waste prevention programs. The purpose of the waste management plans is to analyze current waste management practices; identify measures to improve reuse, recycling, recovery and disposal of waste; and determine how to support the implementation of the WFD. In addition to the general WFD, the European Commission has also issued several specific directives on landfills, waste incineration, pollution, and industrial emissions, which are relevant to waste co-processing and are discussed below.

Landfill Directive

One of the most influential drivers of cement kiln co-processing in Europe was the establishment of the Landfill Directive (1999/31/EC) (EC, 2012b) in 1999. The Landfill Directive was issued in response to growing concerns about the negative effects of landfilling of wastes, including contamination of soil, water resources, and air and resulting deterioration in living conditions and human health. The ultimate goal of the directive is to implement the EU's waste hierarchy, which defines landfills as the last option for waste treatment and disposal.

The Landfill Directive introduces tight procedures for waste landfills, such as the development of landfill categories, setting up of a standard waste acceptance procedure for landfills (including detailed descriptions of waste characterization procedures, limits on waste composition, leaching behaviors, and acceptance procedures at landfill sites) (EC, 2009), and requires a landfill permitting system. The directive also imposes staged landfill reduction targets for the biodegradable fraction of MSW, liquid waste, and used tires. Member states are obliged to devise national strategies to meet the landfill reduction targets. Examples of a national strategy are Sweden's 2002 ban on landfilling of separated combustible waste and 2005 ban on landfilling of organic waste.

Because the Landfill Directive limits the landfill capacity, it has pushed the market to find alternative waste treatment measures for wastes that cannot be reused or recycled. Incineration and co-processing are two of these measures. Landfills cost vary among EU countries, ranging from 30 Euro/tonne in Greece to 126 Euro /tonne in Denmark (Eunomia Research & Consulting, 2011). To comply with the Landfill Directive, countries have introduced various measures to increase the cost of landfilling. For example, the gate fee for landfilling in Finland increased 300 percent from 1996 to 2006. Landfill taxes are also used to discourage landfilling of waste in Estonia, Finland, and Italy (European Environmental Agency, 2009).

Waste Incineration Directive

To address public concern about the health and environmental impacts of burning waste, the European Commission formulated the Waste Incineration Directive (WID) (2000/76/EC) (EC, 2009) in 2000. The goal of the WID is to minimize the negative environmental impacts of waste incineration by establishing operational and technical requirements and emission limits for waste-burning plants.

The WID merged three previous directives[3] related to waste incineration and co-processing and distinguished between incineration plants and co-processing plants. Under the WID, incineration plants in the European Union are defined as plants "which are dedicated to thermal treatment of waste and may or may not recover heat generated by combustion" (EC, 2012c) Co-incineration plants are those "whose main purpose is energy generation or the production of material products and in which waste is used as a fuel or is thermally treated for the purpose of disposal, such as cement or lime kilns" (EC, 2012c). Both types of plants are subject to the WID, and exceptions are granted to plants that are experimenting with processes to improve incineration; plants that treat fewer than 50 tonnes of wastes per year; and plants that are only treating vegetable wastes, certain wood wastes, and radioactive wastes (EC, 2011a).

The WID lays out requirements for co-processing plant permits, delivery and reception of waste, operational conditions, air emissions limits, water discharges, residues, monitoring and surveillance, access to information and public participation, reporting, and penalties. In particular, the directive imposes stricter regulations on emissions and more stringent operational conditions and technical requirements than were previously in force.

Integrated Pollution Prevention and Control Directive

In addition to the WID's emissions limits and other specific requirements, the Integrated Pollution Prevention and Control (IPPC) Directive also applies to co-processing plants. The IPPC Directive aims to reduce industrial pollution using an integrated approach that centers around an environmental permitting system and the application of "best available techniques" (BATs).

The IPPC Directive calls for the technological status of key industries to be defined and described throughout Europe at regular intervals. BAT reference documents were developed for this purpose by experts in the different sectors based on an exchange of information organized by the European Commission. One BAT reference document relates to the cement and lime industry (EIPPCB, 2010), and two BAT reference documents relate to wastes (EIPPCB, 2006); one on waste treatment industries discusses different types of waste treatment technologies, and the other on waste incineration covers best available technologies for thermal treatment of wastes, as well as reception, handling, and storage of waste. The BAT reference documents expressly acknowledge that use of suitable waste in the cement manufacturing process is a BAT.

To receive a permit, industrial facilities that are covered by the IPPC Directive must demonstrate that they use BATs and meet general obligations (such as preventing large-scale pollution, using energy efficiently, and limiting damage to the environment), specific requirements (emission limits; soil, water, and air protection measures; and waste management measures), and comprehensive plant performance requirements (EC, 2011b).

While requiring that industrial installations meet its requirements in order to minimize pollution, the IPPC Directive also gives flexibility to EU member states so that the environmental permitting authorities can take into account factors such as the technical characteristics of a facility, its geographic location, and local environmental conditions.

[3] Including the Directive for New MSW Incineration Plants (89/369/EEC), the Directive for Existing MSW Incineration Plants (89/429/EEC), and the Directive for Hazardous Waste Incineration (94/67/EC).

The IPPC Directive sees public participation as vital in the decision making process related to environmental permits and monitoring. It gives the public access to permit applications, permits, monitoring results, and the European Pollutant Release and Transfer Register (E-PRTR), a database containing emissions data reported by member states (E-PRTR, 2011).

Industrial Emissions Directive

The Industrial Emissions Directive (2010/75/EC) has been established to succeed the IPPC Directive when the IPPC Directive expires in 2013 (EC, 2011c). The Industrial Emissions Directive integrates seven existing directives[4] related to industrial emissions and restates the principles outlined in the IPPC Directive, including an environmental permitting system based on an integrated approach, required adoption of BATs, flexibility of licensing authorities, and facilitating public participation in the permitting process as well as public access to reported data on emission/pollutants.

However, unlike the IPPC Directive, the Industrial Emissions Directive requires EU member states to establish a system of environmental inspections, prepare environmental inspection plans, and conduct site visits every 1 to 3 years depending on the pollution risk posed by a site (EC, 2012d).

3.1.2. United States

Clean Air Act

Different from the EU's cement industry co-processing regulations, which originated from concerns about waste generation, pollution, and landfill shortages, the U.S. regulations for co-processing were largely the result of concerns related to environmental protection and the implementation of the 1970 Clean Air Act.

The Clean Air Act was established to protect human health and the environment from harmful emissions to the air. The act requires the U.S. Environmental Protection Agency (EPA) to set minimum national standards for air quality and assigns to the states primary responsibility for ensuring compliance with these standards. Areas that are not meeting the emission standards, called "nonattainment areas," are required to implement specific air pollution control measures. The act establishes federal standards for both stationary and mobile sources of air pollution and lists hazardous air pollutant *(*HAPs*)* and emissions that cause acid rain. In addition, the act establishes a comprehensive permit system for all sources of air pollution[5].

Section 109 of the Clean Air Act requires U.S. EPA to set national ambient air quality standards for six main pollutants, called "criteria pollutants": carbon monoxide (CO), lead (Pb), nitrogen dioxide, ozone, particulate matter 2.5 and 10 microns in size (PM 2.5 and PM10), and SO_2. Two types of standards are developed: primary standards to protect public health and secondary

[4] These include the IPPC Directive, the Large Combustion Plants Directive, the Waste Incineration Directive, the Solvents Emissions Directive, and three directives on titanium dioxide.

[5] Also, on December 7, 2009, EPA signed two distinct findings (Endangerment Finding and Cause or Contribute Finding) regarding greenhouse gases under section 202(a) of the Clean Air Act. Endangerment Finding indicates that six GHGs threaten the public health and welfare of current and future generation. However, these findings do not themselves impose any requirements on industry or other entities.

standards to protect public welfare (e.g., protection against damage to animals, crops, and buildings) (EPA, 2011a). The Clean Air Act requires U.S. EPA to review the standards every 5 years. States are responsible for establishing procedures and measures to meet the standards. Under Section 110 of the Clean Air Act, the states adopt state implementation plans and submit them to U.S. EPA.

Section 112 of the Clean Air Act also requires U.S. EPA to set standards for major sources and certain area sources emitting HAPs that are known or suspected to cause cancer or other serious health effects. A "major source" is defined as a stationary source or group of stationary sources that emit or have the potential to emit 10 tons per year or more of a HAP or 25 tons per year or more of a combination of HAPs (EPA, 2012a).

Section 112 of the Clean Air Act defines and regulates 188 HAPs. The national emission standards for HAPs require adoption of technology-based emission standards; the technologies required by these standards are referred to as maximum achievable control technologies (MACTs). U.S. EPA is required to review these standards periodically.

Because co-processing in the cement industry recovers energy from combustion of solid wastes, cement kilns that co-process MSW and sewage sludge must meet the emissions limits for the nine pollutants specified in Section 129 of the Clean Air Act:

- cadmium (Cd)
- CO
- total mass basis polychlorinated dibenzo-p-dioxin / polychlorinated dibenzofuran (PCDD/PCDF) and toxic equivalency basis (TEQ) PCDD/PCDFs
- HCl
- Pb
- mercury (Hg)
- NOx
- PM
- SO_2

3.1.3. Japan

Japan is aggressively pursuing three types of MSW and sewage sludge treatment: use of sewage sludge and MSW incinerator ash as an alternative raw material in the production of Portland cement and concrete aggregate; use of incinerator ash as an alternative raw material in specially designated cement products (Eco-cement); and use of MSW as an alternative fuel in cement kilns. These strategies were developed in response to scarce landfill area, relatively high landfill disposal fees, and a policy framework that supports research on waste reuse and gives generous economic incentives to industrial ecology projects (Hotta and Aoki-Suzuki 2010; Nakamura 2007).

Japan's Waste Management and Public Cleaning Law was established in 1970. During the past decade, Japan has developed an integrated waste and material management approach that promotes dematerialization and resource efficiency. Landfill shortage and dependency on imported natural resources have been key drivers of these changes. The 2000 Basic Law for

Establishing a Sound Material-Cycle Society integrated the environmentally sound management of waste with the "3R" (reduce, reuse, and recycle) approach. This represents a shift in emphasis from waste management to sound materials management.

3.2. Regulations and Standards

Regulations and standards are established to describe day-to-day implementation of laws and directives. For co-processing in the cement industry, rigorous regulations and standards are needed in five key areas: environmental performance, product quality, waste quality, operational practices, and safety and health requirements for employees and local residents. The subsections below describe the establishment and implementation of regulations and standards in Europe, the United States, and Japan to address these five areas.

Key factors affecting the environmental performance of co-processing plants include the behavior of individual heavy metals in the rotary kiln, waste input conditions, and the efficiency of the plant's dust collector (Bolwerk et al. 2006). Co-processing plants need to carefully control the quality of waste inputs, continuously monitor emissions parameters, adopt adequate operational controls, and establish a system of regular reporting to local government. The reported information must be transparent, and information on emissions and the quality of waste input must be publicly available to local communities (GTZ/Holcim 2006).

3.2.1. Environmental performance requirements

The high temperatures in rotary kilns ensure that organic substances in wastes are almost entirely converted to CO_2 and water and that the emissions concentrations of organic compounds, such as dioxins and furans, are very low. Nonetheless, air emissions, water discharges, and residues from co-processing plants must be carefully regulated, monitored, and reported. Many countries around the world have established emissions limits for different types of pollutants from co-processing plants, some of which are described below.

European Union

The EU WID establishes limits on the emissions of heavy metals, dioxins and furans, CO, dust, total organic carbon, HCI, HF, SO_2, and NOx from co-processing plants. Table 6 shows the EU emissions limits (daily average values for continuous measurements) for cement co-processing plants that treat nonhazardous wastes or less than 40 percent hazardous wastes. Dioxins and furans must be measured at least twice per year, and at least every 3 months for the first 12 months of a plant's operation. Dust from de-dusting equipment can be partially or totally recycled into cement manufacturing processes. If recycling is not feasible or not allowed, the dust must be evaluated before use in soil or waste stabilization or for agricultural purpose (GTZ/Holcim 2006). If dust is landfilled, the landfill design must use BAT.

The WID allows CO emissions from cement co-processing plants to be set by a "competent authority" within EU member states, i.e., government/regulators in EU member states. EU member states have incorporated the emissions limits into their national standards. For example, Germany's emission limits are set in the German Clean Air Standards (TA Luft 2002).

Table 6. Air Emissions Limits for cement co-processing plants from EU Waste Incineration Directive (EC, 2012c)

Daily Average Value[1] (in milligrams per cubic meter [mg/m^3])	Limit for Cement Co-Processing Plants
Total Dust	30
HCI	10
HF	1
NOx for existing plants	800
NOx for new plants	500
Cd + Tl	0.05
Hg	0.05
Sb + As + Pb + Cr + Co + Cu + Mn + Ni + V	0.5
Dioxins and furans	0.1
SO_2	50
TOC[2]	10
CO[2]	Set by member states

HCI: hydrogen chloride; HF: Hydrogen Fluoride; NOx: nitrogen oxides; Cd: cadmium; Tl: Thallium; Hg: mercury; Sb: Antimony; As: Arsenic; Pb: lead; Cr: Chromium; Co: Cobalt; Cu: Copper; Mn: Manganese; Ni: Nickel; V: Vanadium; SO2: sulfur dioxide; TOC: total organic compounds; CO: carbon monoxide;
Notes: [1] daily average values for continuous measurements; [2] Exceptions may be authorized by competent authority if TOC and SO_2 do not result from the incineration of waste.

The WID also regulates 11 polluting substances in discharge water from exhaust-gas cleanup at co-processing plants. The pollutants include total suspended solids, Hg, Thallium (Tl), and Pb. Emission limits for discharges of waste water are presented in Table 7.

Table 7. Emission Limits of 11Pollutes in Discharge Waste Water from Co-Processing Plants (EC, 2012c)

Polluting substances	Emission limit values expressed in mass concentrations for unfiltered samples	
Total suspended soilds as defined by Directive 91/271/EC	95% 30 mg/l	100% 45 mg/l
Mercury and its compounds (Hg)	0.03 mg/l	
Cadmium and its compounds (Cd)	0.05 mg/l	
Thallium and its compounds (Tl)	0.05 mg/l	
Arsenic and its compounds (As)	0.15 mg/l	
Lead and its compounds (Pb)	0.2 mg/l	
Chromium and its compounds (Cr)	0.5 mg/l	
Copper and its compounds (Cu)	0.5 mg/l	
Nickel and its compounds (Ni)	0.5 mg/l	
Zinc and its compounds (Zn)	1.5 mg/l	
Dioxins and furans	0.3 mg/l	

In most EU countries, test burns are usually conducted to evaluate the performance of a new technology or process to reduce emissions; the quality of the resulting clinker is also evaluated to ensure that hazardous residues from the waste-treating process do not leach from the final product and pose an environmental hazard. (GTZ/Holcim 2006).

United States

As required by the U.S. Clean Air Act, the U.S. EPA has developed a list of "source categories," including co-processing cement plants that must meet and control technology requirements for toxic air pollutants. Maximum Achievable Control Technology (MACT) standards are established under Section 112 of the Act through the national emissions standards for HAPs. The MACT Standards, such as the Portland Cement Kiln MACT, are intended to achieve "the maximum degree of reduction in emissions," while taking into account cost, non-air-quality health and environmental impacts, and energy requirements (McCarthy, 2005). For new facilities or "new sources" of air emissions, the act specifies that MACT standards "shall not be less stringent than the most stringent emissions level that is achieved in practice by the best controlled similar source." For existing facilities or "existing sources" of air emissions, the standards may be less stringent than for new sources but "must be no less stringent than the emission limitations achieved by either the best performing 12 percent of the existing sources or the best performing 5 similar sources." Typically, existing sources have 3 years after promulgation of standards to achieve compliance, with a possible 1-year extension (McCarthy, 2005). Existing sources that achieve voluntary early emissions reductions receive a 6-year extension for compliance with MACT (McCarthy, 2005).

The emission level or so-called "MACT floor" is a baseline that facilities are required to achieve throughout the industry in the United States. MACT standards in effect set mandatory emission limits across industries, and U.S. EPA can establish more stringent standards when needed. U.S. EPA states that this "technology-based" approach produces "real, measurable reductions" (EPA, 2011b). Based on the MACT standards, U.S. EPA conducts risk-based emissions assessments to determine how the technology-based emissions limits actually reduce health and environmental risks.

Emissions standards for the U.S. cement industry are specified in the Code of Federal Regulations 40 (Protection of Environment), Part 60 (Standards of Performance for New Stationary Sources), Subpart F (Standards of Performance for Portland Cement Plants). The standards apply to kilns, clinker coolers, raw mill systems, finish mill systems, raw mill dryers, raw material storage, clinker storage, finished product storage, conveyor transfer points, bagging, and bulk loading and unloading systems (Clean Air Act, 2012). Table 8 shows U.S. emissions limits for PM, NOx, and SO_2.

Table 8. Emissions Limits for U.S. Cement Plants (Clean Air Act, 2012)

Pollutant	Kilns	Clinker Coolers
Particulate Matter (PM)	0.15 kg/tonne of feed (dry basis) to the kiln	0.05 kg/tonne of feed (dry basis) to the kiln
	0.005 kg/tonne of clinker (on a 30-operating day rolling average)	0.005 kg/tonne of clinker (on a 30-operating day rolling average)
Nitrogen Oxide (NOx)	0.75 kg/tonne of clinker	-
Sulphur Dioxide (SO_2)	0.2 kg/tonne of clinker	-

The Clean Air Act Amendments of 1990 added Section 129 to address emissions from solid waste combustion units. This amendment established emissions standards for new facilities (new source performance standards) as well as standards for existing units (emission guidelines). The latter do not regulate existing emissions sources directly but require states to implement guidelines. Both the new source performance standards and the emission guidelines use a MACT approach like that used in Section 112 of the Clean Air Act (EPA, 2012b).

Prior to 2007, co-processing cement plants treating nonhazardous secondary materials in the United States were regulated under the Clean Air Act Section 112 Portland Cement Kiln MACT standard. However, in 2007, a U.S. Court of Appeals concluded that U.S. EPA "erred by excluding units that combust solid waste for purposes of energy recovery from the [Commercial and Industrial Solid Waste Incineration] rule" (EPA, 2008). In response to the court's decision, U.S. EPA proposed the "Non-hazardous Solid Waste Definition Rulemaking" to establish which nonhazardous secondary materials are considered solid waste when burned in a combustion unit. According to the definition of nonhazardous solid waste that resulted from this rulemaking, co-processing cement plants that burn nonhazardous solid wastes are regulated by the standards of performance for new stationary sources as well as the emissions guidelines for existing sources (commercial and industrial solid waste incineration [CISWI] units), under the authority of Section 129 of the Clean Air Act, rather than the Portland Cement Kiln MACT standard under Section 112.

A two-stage approach was developed to regulate CISWI emissions, including those from cement plants that burn nonhazardous solid waste. In the first stage, EPA established technology-based (MACT) emission standards. U.S. EPA is required to review these standards as necessary every five years. In the second stage, EPA is required to determine whether further revisions of the standard are necessary to "provide an ample margin of safety to protect public health" (U.S. EPA, 2011c). CISWI MACT standards for cement kilns are based on an inventory of 12 kilns, including one wet kiln, four preheater kilns, and seven preheater/precalciner kilns. Kilns that burn tires, used oil, biomass, and wood waste are not considered to fall within the scope of the CISWI standards because these fuels are not within the definition of "nonhazardous solid wastes" that resulted from the 2007 rulemaking.

The final CISWI standards were released and took effect on March 21, 2011. However, U.S. EPA received petitions from a number of groups seeking reconsideration of the rule. The agency identified several issues for reconsideration and on May 18, 2011 announced a delay in the effective date of the standards until "the proceedings for judicial review of these rules are completed or the U.S. EPA completes its reconsideration of the rule" (EPA, 2011d) On December 23, 2011, EPA announced proposed amendments to the CISWI standards, including reconsideration of subcategories (e.g., types of cement kilns), revisions to CO monitoring requirements, clarification of definitions, and proposed amendments to emission limits for co-processing cement plants. Table 9 shows the delayed 2011 CISWI standards and proposed amendments applicable to cement plant emissions.

Co-processing cement plants that treat hazardous waste are subject to the hazardous waste combustors regulation under Section 112 of the Clean Air Act. This regulation, "National Emission Standards for Hazardous Air Pollutants: Final Standards for Hazardous Air Pollutants for Hazardous Waste Combustors," was established in October 2005 and requires hazardous-waste-treating cement kilns to meet the emissions standards for HAPs, including As, beryllium, Cd, chromium, dioxins and furans, HCl, chlorine gas, Pb, manganese, and Hg (U.S. EPA, 2005).

Table 9. MACT Emission Limits in 2011 CISWI Standards for U.S. Co-Processing Kilns
(U.S. EPA 2011c and 2011e)

Pollutant (units) *	**2011 CISWI Emission Limits (Implementation Delayed)**		**2011 CISWI Emission Limits (Proposed Amendments)**	
	Existing Cement Kilns	**New Cement Kilns**	**Existing Cement Kilns**	**New Cement Kilns**
HCI (ppmv)	25	3.0	3.0	3.0
CO (ppmv)	110	90	410 (preheater/precalciner)	320 (preheater/precalciner)
Pb (mg/dscm)	0.0026	0.0026	0.0043	0.0043
Cd (mg/dscm)	0.00048	0.00048	0.00082	0.00082
Hg (mg/dscm)	0.0079	0.0062	0.011	0.0037
PM, filterable (mg/dscm)	6.2	2.5	9.2	8.9
Dioxin, furans, total (ng/dscm)	0.2	0.090	3.6	0.51
Dioxin, furans, TEQ (ng/dscm)	0.0070	0.0030	0.075	0.075
NOx (ppmv)	540	200	630	200
SO_2 (ppmv)	38	38	830	130

*ppmv: parts per million by volume; mg/dscm: milligrams per dry standard cubic meter; ng/dscm: nanograms per dry standard cubic meter.

Australia

In Australia, the state of Victoria governs the primary permitting and licensing of Australia's only sewage co-processing cement plant (at Waurn Ponds). State governments in Australia have near full control over the design and implementation of environmental regulations (Anton, 2008). Federal regulations pertinent to the operation of cement plants govern the annual reporting of emissions to the National Pollutant Inventory and compliance with the national carbon tax which comes into force July 1, 2012. Otherwise, environmental regulations such as pollutant emission limits and environmental impact assessment requirements are strictly the purview of state governments. Most waste, landfill, and work safety regulations are also the purview of the state governments. Cement and concrete product quality standards are set by a national non-governmental standards board, Standards Australia.

Boral Cement's Waurn Ponds facility in Victoria has been using alternative fuels since the early 1990s, including tires, waste oil, tallow residues, carbon waste from the aluminum industry, catalyst waste from oil refining, and waste foundry sands (Boral Cement, 2011). In 2006, the plant began studying the feasibility of reusing biosolids from a nearby wastewater treatment facility as cement kiln fuel (APP, 2010). Waste characterization studies indicated that high mercury content in the biosolids was the primary obstacle to implementing the project. Various technological solutions were explored by plant managers to ensure that use of the sewage sludge would not increase plant mercury emissions over existing levels (a limitation self-imposed by plant managers to maintain good relations with the community) (McGrath, 2012). In a trial, fuel processing and feeding were standardized, and a technology produced by Hansom Environmental Products proved successful in eliminating 98 percent of mercury emissions and significantly decreasing other pollutant emissions. Because of these pilot successes, Boral is enthusiastic about scaling up the project; however, doing so would require significant capital.

The biosolids delivered to the plant are not considered a waste, so the plant is not regulated as a waste treatment facility. Only the stack emissions are regulated under the state's environmental protection laws and permitting requirements. The plant has traditionally had a strong relationship with the local community and the state environmental regulator, the Environmental Protection Authority of Victoria (EPAV). Part of the impetus for the biosolids project was EPAV's pressure on the wastewater plant to explore cement co-processing for disposal (McGrath, 2012). Until recently, the plant's operating permits stipulated controls on the fuel inputs, with emission limits set by state law. Recently, these regulations have changed with the onus newly placed on the plant owner to use a risk-based approach to environmental management. When preparing a risk assessment, the plant must fully consider input from the community before regulators will grant a permit; community opposition can significantly delay or result in denial of a permit. Permits stipulate that the plant must provide regular reports on actual emissions and negative environmental impacts (McGrath, 2012). As a guideline, the plant's updated license (Nov. 2011) requires emissions limits in line with the EU's WID 2000/76/EC (EPA Victoria, 2011). Furthermore, the Cement Industry Federation of Australia requires that all of its member companies using alternative fuels and raw materials follow the World Business Council for Sustainable Development (WBCSD) "Guidelines for the Selection and Use of Fuels and Raw Materials in the Cement Manufacturing Process" (Cement Industry Federation, 2009). Several stakeholder meetings have been held to ensure that the local community is aware of and agrees to the biosolids project. These meetings have greatly increased incentives for the plant to keep emissions levels low. Annual reporting procedures are set by state guidelines.

South Africa

In 2009, the South Africa Department of Environment and Tourism promulgated a National Policy on the Thermal Treatment of General and Hazardous Waste (the South Africa National Policy) (Crous, 2009a). This extremely detailed policy replaces previously inconsistent requirements regarding regulation of waste co-processing at the provincial level (Karstensen, 2007b). The policy relies on the EU Incineration Directive 2000/76/EC (especially for air emissions limits) and other international policies, including co-processing guidelines by WBCSD and Holcim, as models. In addition to detailing permitting and operations requirements as set by existing laws, the policy also establishes BATs and best environmental practices for cement production, including emissions controls for co-processing. Provinces in South Africa have authority to promulgate more stringent environmental regulations than the central government and therefore can add regulatory obligations in addition to those specified in the national policy (Karstensen, 2008).

The South Africa National Policy also stipulates minimum air emissions limits for criteria air pollutants, heavy metals, dioxins, and furans for existing and new co-processors, as shown in Table 10. Existing plants currently permitted for co-processing have 10 years to bring emissions in line with the requirements that apply to new plants. Air quality management plans are required that detail the following: facility design and operations; monitoring equipment and minimum availability; requirements for the frequency of monitoring certain gases; reporting units, style and frequency (one self-assessment quarterly, and an independent audit annually); and special monitoring for heavy metals, dioxins, and furans. A separate testing and verification process is required for high-level persistent-organic-pollutant (POP)-containing waste, which, if used, must be destroyed with a minimum efficiency of 99.99%.

The South Africa National Policy provisions are among the most stringent in the world although the language could be improved to clarify whether measures are suggested or mandatory. Because South Africa is home to only 11 cement plants, it is likely that any co-processing permitting will take place in close cooperation with provincial and national regulators. Policymakers focused on co-processing of hazardous wastes rather than MSW in the formation of the South Africa policy. Separate initiatives are addressing the MSW stream in more detail, and it is unclear whether those processes will ultimately advocate MSW co-processing (Crous, 2009b).

Table 10. Air Emission Standards for the Incineration of General and Hazardous Waste in Dedicated Incinerators and for the Co-processing of General and Hazardous Wastes as AFR in Cement Production, South Africa (South Africa Department of Environmental Affairs, 2009)

Pollutant (unit)*	Air Emission Standards for the Incineration of General and Hazardous Waste in Dedicated Incinerators	Air Emission Standards for the Co-processing of Selected General and Hazardous Waste as AFR in Cement Production
PM (Total Particulate Matter)	10	30[i] (80)[ii]
TOC	10	10[iii]
CO	50	
HCI	10	10
HF	1	1
SO_2	50	50[iii]
NO_x	200	800[iv]
NH_3	10	
Hg	0.05	0.05
Cd + TI	0.05	0.05
SB, AS, Pb, Cr, Co, Cu, Mn, Ni, V (Sum total)	0.5	0.5
PCDD/PCDF (ng/Nm^3 **I-TEQ**)	0.1	0.1

*Concentration expressed as mg/Nm^3 (Daily Average) unless otherwise stated, and at 'normalized' conditions of 10% O_2, 101.3 kPa, 273 K/0 °C, dry gas. Mg/Nm^3: milligram per Normal cubic meter; I-TEQ: international Toxics Equivalents).

[i] PM limit for (a) new kilns (commissioned after promulgation of this policy) co-processing AFR, and for (b) existing kilns co-processing AFR within 10 years of promulgation of this policy.

[ii] PM limit effective after 3 years of promulgation of this policy for existing kilns co-processing AFR (excluding POPs waste), provided that current particulate emissions (as established through baseline monitoring) are not increased by the co-processing of AFR.

[iii] Limits for TOC or SO_2 do not apply where elevated emissions result from conventional fuels or raw material, i.e. not from the co-processing of AFR, provided that current TOC and SO_2 emissions (as established through baseline monitoring) are not increased by the co-processing of AFR.

[iv] NO_x limit for (a) new kilns (commissioned after promulgation of this policy) coprocessing AFR, and for (b) existing kilns co-processing AFR (excluding POPs waste) within 10 years of promulgation of this policy, provided that current NO_x emissions (as established through baseline monitoring) are not increased by the co-processing of AFR.

3.2.2. Product quality requirements

Section 2.4 describes the potential effects of using MSW and sewage sludge in the cement manufacturing on the trace element concentrations in the final product. Depending on the total input and type of wastes, the concentration of trace elements might increase or decrease relative to the composition of the cement produced with traditional fuels.

Product quality requirements are intended to ensure that the use of waste-derived fuels in the cement industry does not result in a negative impact on health or the environment or degrade the cement or clinker's material composition or the technical properties that are essential to its function as a building material.

As noted in Section 2.4, studies have identified three general principles that should be followed in developing regulations governing the quality of cement products (GTZ/Holcim 2006):

- The product (clinker, cement, concrete) must not be abused as a sink for heavy metals.
- The product should not have any negative impact on the environment.
- The quality of cement shall allow end-of-life recovery.

If co-processing is conducted in an environmentally sound manner, the use of MSW and sewage sludge reportedly has only a marginal impact on the heavy metal content of the clinker produced (GTZ/Holcim 2006). Studies from Germany have shown that heavy metals are firmly trapped in the cement brick matrix (Bolwerk et al. 2006). However, when products are stored under specific or extreme conditions, some releases have been detected at levels that could have environmental impacts (Bolwerk et al. 2006).
To avoid negative product quality impacts, the quality and type of waste input to kilns should be carefully controlled, and the heavy metal content in the waste inputs should be limited. Co-processing plants should set up quality control systems to ensure environmentally safe operation. Wastes usually require pre-processing (e.g., drying, shredding, blending, grinding, or homogenization) and quality assurance (CEMBUREAU, 2009). All of these issues can be addressed in regulations.

European Union
EU regulations require cement products from co-processing process to meet all applicable quality standards, including the harmonized standard EN 197-1: Cement composition, specifications and conformity criteria. (CEMBUREAU, 2009)

In Germany, cement products (clinker, cement, and concrete) must meet state building regulations, the Construction Products Directive, and the Construction Products Law (which is based on the EU Construction Products Directive). VDZ, the German Cement Works Association, is responsible for testing, inspection, and certification of cement products. VDZ operates a quality surveillance organization and testing laboratory and serves as the inspection and certification body (VDZ, 2010). The Research Institute of the Cement Industry's Quality Assurance Department carries out inspection and test activities, and the technical committee of VDZ's quality surveillance organization discusses the results of third-party inspection twice a year (VDZ, 2010).VDZ's quality surveillance organization has been accredited as a product certification body according to EN 45011 since 2002, and all laboratory tests are accredited in accordance with International Standards Organization (ISO) 17025. The quality surveillance organization is regularly assessed by third parties.

3.2.3. Waste quality requirements

Compared with industrial wastes, which are normally generated from mono-streams, MSW is more difficult to handle because it is not homogeneous. Studies have shown that unsorted household wastes are not suitable for co-processing in the cement plants (IMPEL Network, 1998).

Co-processing plants must develop criteria to select wastes whose characteristics, when pre-processed, allow the plant to maintain operational and product quality requirements (IPTS, 1999). Different types of wastes will have different effects on the quality of clinker or cement produced. See Appendix 3 for an example of an "accept-refuse" chart for a cement plant.

With the purpose of maintaining reliable quality while minimizing pollutant input from wastes, co-processing plant operators should develop an evaluation and acceptance procedure to collect basic information about waste origin and detailed data and information about the waste's physical and chemical properties, such as calorific value and chlorine, ash, and trace element (e.g., mercury) content. Information related to health, safety, and environmental considerations during transport, handling, and use must also be obtained. Plant operators should regularly sample and analyze input to and output of cement kilns.

Plant operators should, in particular, check for the following contents within wastes because these constituents significantly affect the quality of production (WBCSD, 2005 and GTZ/Holcim 2006):

- Phosphates, which influence setting time
- Chlorine, sulfur, and alkali, which affect overall product quality
    - Chlorine at concentrations greater than 0.7 percent can affect the strength of the clinker.
    - Chlorine can cause accelerated corrosion of the facility.
    - Chlorine affects the overall quality of cement and concrete.
- Chromium, which may cause allergic reactions in sensitive users.

Before allowing use of wastes in cement plants, regulators and plant operators should clearly understand the answers to the following questions (Bolwerk, no date):

- What types of wastes are suitable for use in the cement manufacturing process?
- What process does the waste come from?
- What pollutants does the waste contain?
- What are the following characteristics of the waste: calorific value, water content, heavy metal content, chlorine content, etc. (see list of key constituents above)?
- Can the waste provider ensure consistent quality within a defined spectrum?
- What are the expected emissions from treating the waste?
- What harmful substances might end up in the clinker or cement if the waste is used as fuel?

European Union

Germany has developed systems to assess and control the suitability of alternative fuel generated from wastes. These systems mainly focus on the trace element and the chlorine content of the waste. The acceptable chlorine concentration typically ranges from <1 percent to 2 percent and depends on the individual situation at the plant. Germany has introduced a certification label for waste-derived fuels used in the cement industry, and the Netherlands, Italy, and Finland have developed quality standards for waste-derived fuels as well.

The Swiss Agency for the Environment, Forests and Landscape published *Guidelines on Disposal of Waste in Cement Plants* in 1998; the guidelines were updated in 2005 and identify values for the pollutant content of clinker and Portland cement. If co-processing plants exceed the guidance values, they must reduce the amount of waste used.

3.2.4. Operational requirements

The EU WID requires that co-processing plants keep the co-processing gases "at a temperature of at least 850 °C for at least two seconds." The waste heat from the co-processing process must also be utilized "as far as possible." The burning process should be monitored continuously by process control technology.

Wastes containing volatile organic compounds (VOCs) must be stored and handled to allow suppression or containment of these components, such as in closed tanks or containers and appropriate air ventilation. Common techniques for capturing VOC emissions include nitrogen traps, biological treatment, activated carbon filters, and thermal treatment (GTZ/Holcim 2006).

European Union

In Germany, all processes must be designed for low emissions and monitored by recording process variables. The following requirements are suggested in Germany based on German case studies (IMPEL Network, 1998):

- The burning process must be monitored continuously using modern process control technology.
- Fixed inspections and comprehensive preliminary homogenization are needed for waste materials upon arrival.
- The main parameters for analyzing the waste material (e.g., calorific values, chemical composition) must be input to the process control system on a semi-continuous basis.
- The feed lance must be designed to inject the waste centrally.
- The control units must follow the waste fuel independently of the main fuel.
- Waste fuel may only be supplied during normal continuous operation within the rated output range.

South Africa

In South Africa, plants must also develop independently certified operational and environmental management plans (Karstensen, 2008). These plans specify responsible persons for each specific activity involved in waste receipt, handling, and treatment; training and recordkeeping; waste and alternative fuel and raw materials selection and analysis; process controls; monitoring equipment and accreditation and maintenance schedules; emissions monitoring strategies and schedules; operations procedures regarding waste feeding, startups and shutdowns, employee health checks, and environmental sampling; and procedures for updating the operational and environmental management plan. Hazardous waste treatment requires stringent and specific protocols. A waste management plan is also required in accordance with relevant national policies on handling, classification, and disposal of wastes, including specific regulations and standards regarding waste storage; transport contractors permitting requirements; and record-keeping requirements regarding waste origin, volume, physical characteristics, classification, risks (as designated by hazardous chemicals laws), caloric value, and methods for transport, storage, pre-processing, and feeding.

3.2.5. Safety and health requirements

Operations and management staff should receive sufficient resources and training to ensure that a co-processing system runs safely and efficiently. Preventative measures, such as operational and control monitoring, personal protective equipment, and storage facilities must be employed to minimize potential risk to employees and local residents.

Operations, maintenance, and safety procedures should be developed for both employees and plants and should be reviewed, updated, or modified regularly to ensure that they are fully implemented and meet the needs of changing operation conditions. Robust emergency procedures should also be developed.

As an example, to estimate the potential emissions hazards to human health and the ecosystem, Intertox Cement Company in Portugal conducted a risk assessment, which was based on a "worst-case scenario" of "cumulative less favorable occurrences" (CEMBUREAU, 2009). The assessment modeled emission levels to understand potential risks to employees' health and the environment. Holcim Cement developed the ECHO (i.e., employees chemical health and occupational safety) program in the U.S., to monitor the health of its employees that are dealing with wastes.

3.3. Institutional Frameworks

Responsibility for regulation and enforcement is delegated in various ways in different countries. In the United States, the U.S. EPA regulates emissions from U.S. cement industry co-processing or delegates this authority to state or local agencies. However, U.S. EPA retains the approval authority for emissions standards, changes in emissions test methods, changes in emissions monitoring, and changes in recordkeeping and reporting (CAA, 2012).

The overarching regulation of air emissions in the United States is the Clean Air Act, which is the comprehensive federal law established in 1970 to regulate air emissions from both stationary and mobile sources. State and local air quality agencies are designated as the primary permitting and enforcement authorities for most Clean Air Act requirements. U.S. EPA is responsible for supervision of state and local actions to "ensure national consistency and adherence to Clean Air Act legal principles" (U.S. EPA, 2011f).

In most EU member states, regulatory and enforcement responsibility is divided among a number of different "competent authorities." In several member states, such as Austria, Germany, Belgium, and Bulgaria, regulatory functions are divided between the national/federal level and the regional/state level. In other countries, such as in Denmark and Hungary, regional authorities carry out the major control functions for industrial installations. Regulatory functions are carried out at the municipal/local authority level in the Czech Republic, Netherlands, UK, and Ireland (Milieu, 2011).

3.3.1. Waste collection and management

Integrated waste management is a key concept that is widely recognized around the world; it signifies that all of the stages of waste, from generation to final disposal, should be considered when decisions are being made for any of the stages. Integrated waste management also entails considering all stakeholder perspectives: social, economic, environmental, technical, political, and institutional.

Integrated solid waste management is intended to protect clean, safe neighborhoods; increase the efficiency of resource usage; save waste management costs by reducing the amount of final waste requiring disposal; and create business opportunities and economic growth (Memon, no date).

Co-processing should be an integrated part of local and national waste management concepts and strategies (GTZ/Holcim 2006). The goal of co-processing MSW and sewage sludge in the cement industry is to increase resource efficiency, reduce fossil fuel consumption, and decrease greenhouse gas emissions. However, the use of wastes in the cement industry should not be a strategy for by-passing legislation regarding waste handling or disposal. As noted earlier, not all types of waste are suitable for co-processing.

Japan

In Japan, an integrated solid waste management plan includes the following (details are illustrated in Figure 12) (Memon, no date):

- Policies (regulatory, fiscal, etc.)
- Technologies (basic equipment and operational aspects)
- Voluntary measures (awareness/education, self regulation)
- A management system covering all aspects of waste management (waste generation, collection, transfer, transportation, sorting, treatment and disposal)
- Data and information on waste characterization and quantification (including future trends)
- Assessment of current waste management system to see if it meets the needs of operational stages

Japan's local governments are generally responsible for enforcing national air quality standards and municipal waste treatment permitting regimes and have the power to enact more stringent regulations than the national standards. Efforts to co-process municipal solid waste and incinerator ash originated in the early 1990s in Japan with the passage of the Law for the Promotion of Utilization of Recyclable Resources (the Recycling Law) and the 1991 amendments to the Waste Disposal and Public Cleansing Law (the Waste Disposal Law). Previous iterations of the Waste Disposal Law mandated that industrial waste producers (i.e., industrial firms themselves) rather than cities were responsible for the collection, treatment, and disposal of industrial wastes and urged industrial firms to reuse their wastes. Municipalities were made responsible for planning and implementation of systems for MSW collection, treatment, and disposal. For this purpose, municipalities can enact regulations requiring waste separation and set their own fees; this power was strengthened in the 1991 amendments to the Waste Disposal Law. The Recycling Law established waste reutilization and recycling goals, using an early benchmarking system to drive municipal governments to institute supportive programs for recycling. Promotion of industrial waste reuse was strengthened at the national level with the passage of the Basic Law for Establishing the Sound Material-Cycle Economy in 2000, and a considerable number of laws regarding the recycling and reuse of specific products and materials were passed in the late 1990s and early 2000s to further promote recycling (OECD 2010).

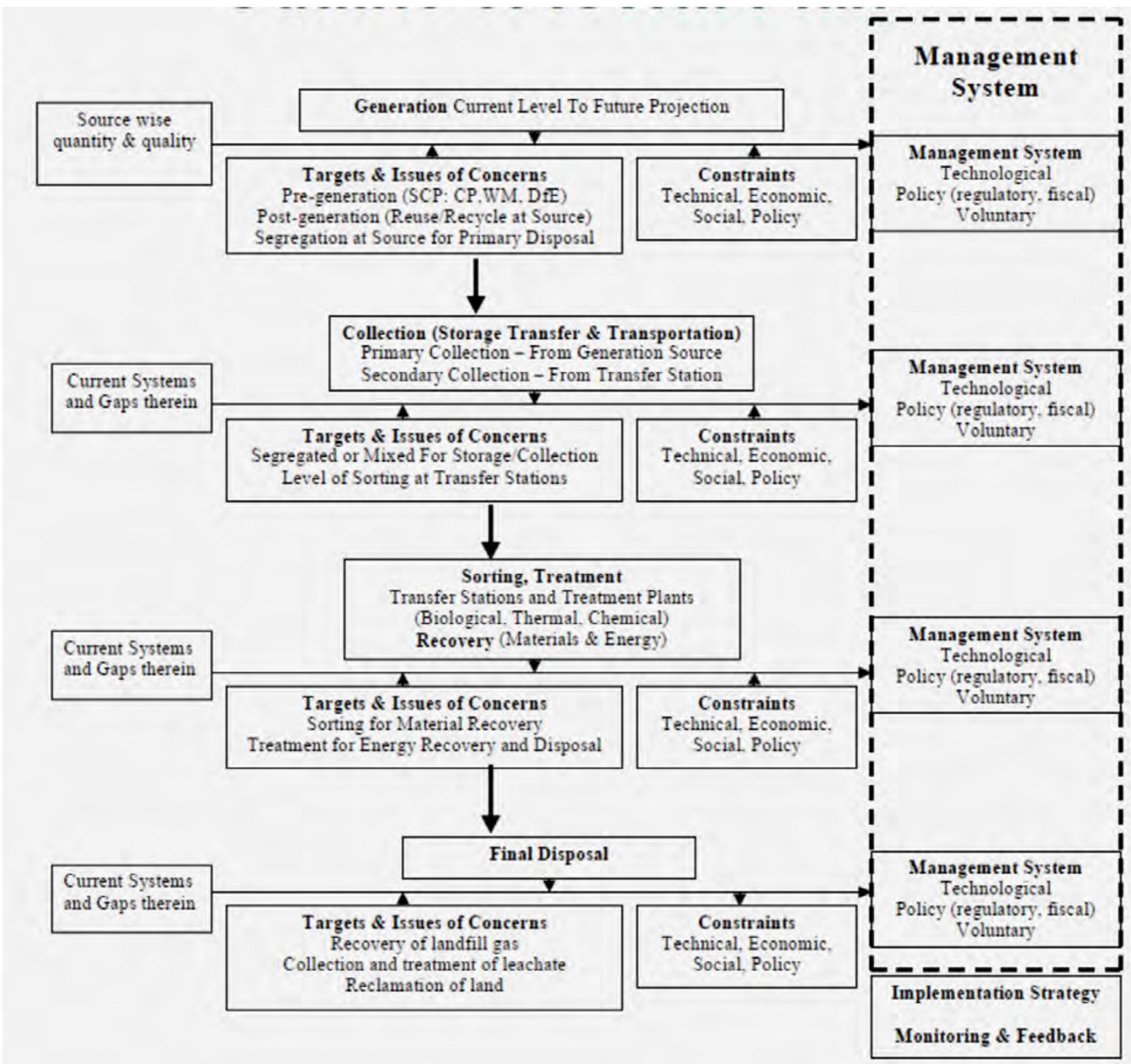


Figure 12. Outline of an Integrated Solid Waste Management Plan in Japan (Memon, no date)

Two elements of Japan's legal framework appear to have been important to the high rates of waste recycling and advances in co-processing experienced in that country in recent years: government financing for research, development, and implementation of waste management plans and technologies; and the requirement for the standardized collection and expert analysis of waste data to identify recycling and reuse opportunities. The Waste Disposal and Public Cleansing Law amendments provide financial support for municipalities to undertake waste-related work within their jurisdictions, including establishing licensing requirements for waste treatment contractors and subsidies for the construction of general waste landfills and incinerators. Municipal regulators establish standards for the construction and operation of general waste landfills for each site, with reference to national landfill standards. Industrial waste treatment facilities and landfill permitting are under the jurisdiction of provincial governments.

The 1991 Waste Disposal Law also had important information-gathering and dissemination consequences; it called for municipal leaders to undertake short- and long-term waste planning to be informed by comprehensive data collection, and expanded municipal government powers to require large waste generators to undertake similar planning activities. These efforts for expanded planning and data gathering took effect in amendments to the Waste Disposal Law passed in 2003, requiring new prefecture-level waste management plans.

To promote rapid development of recycling capacity, the 1991 Recycling Law required the central government to form committees to create recycling guidelines specific to individual industrial subsectors and products, with regular progress reviews. The Fundamental Plan for Establishing a Sound Material-Cycle Society, developed from legal mandates in 2003, requires the central government to develop economy-wide material flow indicators to monitor progress, with annual progress reviews and a major revision and strengthening effort in 2008. These data collection and standardization efforts, paired with the development of waste reduction promotion councils and industrial groups at the city level, have undoubtedly helped to make cement co-processing more attractive in Japan.

The MSW treatment market in Japan has been dominated by waste-to-energy schemes and simple incinerators (OECD 2010). A key to the transition from waste-to-energy incineration to cement co-processing in Japan has been linking municipal solid waste treatment facilities as well as producers of industrial wastes directly to cement facilities. These linkages have been both in the form of isolated efforts of towns interested in closing municipal solid waste incinerators as well as within districts planned specifically to optimize opportunities to reuse industrial waste streams (Taiheiyo Cement Corporation 2006; OECD 2010).

The majority of Japan's sewage sludge is incinerated, and large amounts of sewage sludge ash are used in standard Portland cement production (Ozaki & Miyamoto. No date). In addition to the use of incinerator ash for Portland cement, a Japanese cement company, Taiheiyo, has developed a specifically labeled co-processed cement product called eco-cement. Taiheiyo was the first company in Japan to investigate, during the 1990s, the chemical similarities between cement raw material inputs and MSW incineration ash. In 2001, the company opened Japan's first plant to incorporate MSW incineration ash on a large scale into eco-cement, supported by significant central government subsidies. Manufacturing the product required creating a new product standard in the Japan Industrial Standards, JIS R 5214:2002, which was accomplished in 2002 (Batelle 2002).

The eco-towns policy is the means by which cement co-processing has been directly incorporated into industrial planning policies in Japan in recent years. The eco-town concept[6] originated through a subsidy system established by the Japanese Ministry of Economy, Trade and Industry and the Ministry of the Environment in 1997 (Global Environmental Center Foundation 2009). City governments design plans for eco-towns with local industry stakeholders; plans are verified and approved or rejected by the two ministries acting together. Once approved, projects receive considerable financial support from the ministries and are implemented by local governments and stakeholders. Subsidies range from one-third to one-half of total project costs for "hardware" projects involving the changing of machinery to increase recycling or reuse. These planning efforts can directly link industrial and municipal waste producers with cement plants and subsidize the linkage. Pursuit of eco-towns and national government subsidies resulted in the construction of a cement plant with co-processing in Kawasaki City (Hashimoto et al. 2010).

The cement industry in Japan enjoys high prices for treating wastes in co-processing plants so the cement industry has as strong presence in waste management in Japan. By 2005, Japan had 32 cement plants, with an average production capacity of 2.19 million tonnes per year. Japan has steadily increased its usage of wastes and byproducts in cement making, with about 10 percent of fuel coming from wastes in 2005. By 2009, Japanese cement plants used about 400,000 tonnes of waste plastics and nearly 500,000 tonnes of wood chips, up from 102,000 tonnes and 2,000 tonnes in 2000, respectively (Japan Cement Association, 2010).

European Union

The "polluter pays" principle described earlier is widely recognized in most of the Organization for Economic Cooperation and Development and EU countries and is stated in the Rio Declaration on Environment and Development. This principle requires that producers of wastes or pollution must be responsible for paying for resulting damage to the environment. For example, in Switzerland the waste management system is financed through the polluter pays principle in the form of Switzerland's refuse-bag levy (Swiss Confederation, 2009).

As a result of the EU Landfill Directive, described above in Section 3.1.1, EU member states have to separate the biodegradable fraction from MSW. This is accomplished by source separation, establishment of waste-sorting plants, or diversion of wastes to other treatment methods such as co-processing (Gendebien et al. 2003).

Sorting and pre-processing of the MSW and sewage sludge is, as noted earlier, critical to the quality of the final product as well as to preventing environmental impacts. For stable operation of cement kilns, it is important that wastes have a consistent quality, including sufficient calorific value and low heavy metal content (e.g., Hg and Tl), and that it is suitable for the kiln. Unsorted municipal wastes are too heterogeneous to be used for co-processing. Combustible wastes can be separated (GTZ/Holcim 2006), and pretreated as described in the subsection above on product quality. In the European Union, waste suppliers and waste treatment facilities usually prepare the wastes and deliver them as alternative fuels to co-processing plants (CEMBUREAU, 2009).

[6] "Town" may be a misnomer; most eco-towns are in fact industrial parks in which large-scale industrial plants operate in close proximity and integrate waste streams.

The European Cement Association states that, after sorting, wastes to be co-processed must be free of contaminants, with a maximum of 1 percent of impurities remaining (CEMBUREAU, no date). To achieve this goal, waste separation and collection systems should be standardized. For example, in Austria, where all nine cement plants use solid wastes (recyclable plastics, paper, textiles, and composite materials), a steady supply of wastes that meet quality specifications being ensured by a collaboration of several cement working collaboratively with waste management companies to build waste pre-processing facilities (CEMBUREAU, 2009).

A list of wastes permitted for co-processing should be published by authorities, in consultation with experts and trade groups. The list should specify requirements that MSW and sewage sludge must meet to be acceptable for use as fuel in cement plants. The list should be tailored to local waste situations and reviewed periodically by authorities and experts.

In France, co-processing was first regulated under the French Waste Law, issued in 1975. Since then, "cradle-to-grave" follow-up is required for waste fuels used in cement plants. Pre-processing of the wastes was required starting in 1985 (Bernard, 2006).

Standard procedures should be developed for acceptance of waste by co-processing plants, including basic characterization of the waste, sampling, testing, and compliance testing. It is critical for co-processing plants to have a sufficient long-term supply of MSW and sludge with consistent characteristics because a steady input of wastes is needed to maintain normal kiln operations. Moreover, because cement plants might need to invest large amounts of capital to modify the material handling systems that are usually specifically designed for certain wastes, it is important to secure the supply of wastes to justify this expenditure.

3.4. Permitting and Performance Approval

European Union

The EU legislation requires facilities that intend to conduct waste treatment to obtain a government permit. The permit determines the categories and quantities of wastes that can be treated, technical requirements for using the wastes, safety and precautionary measures, the plant's co-processing capacity, and information and procedures for sampling, measuring, and controlling pollutants. The EU Directives also require that co-processing plants be operated at a high level of energy efficiency (EC, 2012e). Permits have a duration of 3 or 5 years. Implementation of the permits entails member states or "competent authorities" establishing specific requirements based on local conditions (EC, 2011a).

To avoid duplicate efforts, permits can be used for multiple purposes, for example regulating air and water pollutants as well as other environmental impacts. Permits can be refused if authorities consider the proposed waste treatment method does not adequately protect human health and the environment. The permit process has several stages: application, assessment, issuance, follow-up, and training/guidance/networking, as illustrated in Figure 13.

In most EU member states, co-processing plants must apply for waste/ environmental permits. In some countries, co-processing plants must apply for IPPC permits (UK), or licenses (Germany).

Environmental assessments and public consultation are required in the UK and Spain (Gendebien et al. 2003), and, in some other European countries, simplified permitting procedures (e.g., in Italy), or specific regulations (such as in Portugal) have been adopted to promote the use of MSW and sewage sludge in co-processing plants (Gendebien et al. 2003).

In the UK, the permit regulators require co-processing plant operators to submit periodic reports on emission performance. Any violation of the emissions limit must be reported to the regulator within 24 hours. Regulators also inspect co-processing plants, including checking on operational details and monitoring equipment and emissions levels. Co-processing plants face penalties for non-compliance, ranging from criminal prosecution to fines and/or imprisonment of responsible individuals (Defra, 2006).

In Germany, cement kilns are regulated by Federal Emission Control Act, which is the basis for comprehensive regulations on air quality, noise abatement, and plant safety. The emissions limits on exhaust gas from cement plants are regulated by the Technical Instructions on Air Quality Control, and waste fuels are regulated by the Ordinance on Incineration Plants Burning Wastes and Similar Substances, which is based on EU Directive 2000/76/EC.

Germany's Federal Emission Protection Act requires an environmental compatibility test for any co-processing projects that could have negative impacts on people, animals or plant life, soil, water, air, the climate, or the landscape, as well as any interactive effects. When applying for licensing, a cement plant is required to supply the following information regarding use of waste fuels (Bolwerk, no date and GTZ/Holcim 2006):

- Topographical map
- Construction documents
- Description of normal plant operations
- Description and assessment of the production process in which waste fuel would be used
- Proof that the plant is designated as a specialized waste disposal plant for the processing of residual materials
- Proof that the plant is suitable for co-processing
- Documentation of every single inorganic and organic constituent of the wastes to be used and the finished mixture of secondary waste fuels
- Description of emissions prevention methods
- Documentation of air pollution emissions (NOx, SO_2, dioxins/furans, dust, heavy metals)
- Documentation of health and safety standards
- Documentation of energy-saving measures

Operational requirements are also assessed during the licensing process, and information on the following items is required (IMPEL Network, 1998):

- Calorific value and added quantity of substitute fuel
- Pollutant content (polychlorinated biphenols, heavy metals, etc.)
- Identity of the waste materials used
- Chemical, physical-chemical, toxic, and ecotoxic properties of the materials
- Combustion conditions and destruction efficiency
- Recirculation systems that reduce environmental emissions
- Possible ways of purging and relieving recirculation systems

- Operating processes with cut-offs (CO cut-off)
- Effect and type of exhaust gas cleaning processes

Access to permit information is important so that other related governmental agencies and the public can participate and monitor plant performance. In addition to paper documentation, electronic reporting and databases can be used. Databases can be designed to provide access (with differing degrees of restriction) to the general public, local authorities, central/regional governments, and other organizations. The EU WID requires that all new permit applications must be made available to the public for comment before the local authorities reach decisions (EC, 2011a).

United States

Before being amended in 1990, the U.S. Clean Air Act (Section 165) required only new or modified stationary sources to obtain construction permits. However, the Clean Air Act Amendments of 1990 added Title V, which requires states to administer a comprehensive permitting program for sources emitting air pollutants.

U.S. cement plant permits are issued by state regulatory agencies implementing Clean Air Act programs. Cement plants generally operate under a Clean Air Act Title V Operating Permit (EPA, 2008). Permit conditions include:

- Emissions limits for key air pollutants, e.g., NOx, CO, SO_2, PM, and HAPs
- Emissions of substances regulated by MACT Standard 40 CFR 63 Subpart LLL, including PCDD/PCDFs, PM, Hg, and total hydrocarbons

States collect annual fees from emissions sources to cover the "reasonable costs" of administering the permit program, with revenues to be used to support agency air pollution control programs (McCarthy, 2005). Fees must be at least $25 per ton of regulated pollutants (excluding CO) (McCarthy, 2005). Authorities may choose not to collect fees on emissions in excess of 4,000 tons per year, and may collect other fee amounts.

Permits specify air pollutant emissions limits. Co-processing facilities must prepare permit compliance plans and certify compliance. Permit terms are limited to a maximum of 5 years and must be renewed. State authorities submit permit applications to U.S. EPA for review (McCarthy, 2005).

Co-processing cement plants in the United States must also obtain construction permits to use a new alternative fuel (including MSW and sewage sludge), in part because of capital expenditures for required modifications to plant materials handling systems. Co-processing cement plants are usually required to conduct air emissions performance testing to demonstrate that the use of alternative fuels/raw materials will not increase the air emissions (U.S. EPA, 2008). Short-term permits are usually granted to conduct this performance testing, which allows the plants to investigate both the technical performance of the alternative fuel as well as the economic and technical feasibility of using the fuel. Several U.S. regulatory agencies have reported cement plants that ended up not using the alternative fuels after testing because of technical difficulties rather than because of issues related to air emissions (U.S. EPA, 2008). In the United States, co-processing plants sometimes need to obtain other state permits, such as permits for solid waste facility. However, not every modification in plant process or every new use of alternative fuel needs to be permitted (U.S. EPA, 2008).

Brazil

As of 2007, Brazil was using alternative fuels for about 23 percent of its cement production energy needs (Inter-American Development Bank, 2010). The country's first experience with waste-derived fuels in cement plants was in the early 1990s. Initially, co-processing was unregulated, but the state environmental agencies subsequently collaborated with cement industry representatives to formulate a framework of emissions standards and burn tests for plants to receive waste incineration permits (Marigold, 2007). By 1998, Brazil's industrialized southern states (Minas Gerais, Sao Paulo, Rio de Janeiro, Parana, and Rio Grande do Sul), where 65 percent of the country's cement is produced, had promulgated their own regulations for co-processing wastes (Maringolo, 2007). It is estimated that about 80 percent of Brazil's 65 cement plants have substituted waste for either fuel or raw material inputs or both (Busato, no date).

In 1999, the Brazilian federal environmental agency promulgated the national Regulatory Act No. 264/99 "Cement Kilns – Permitting for Waste Co-processing Activities." Regulation 264/99 establishes technical and operational criteria, emissions limits, and pre-permit testing requirements for co-processing permits for cement kilns (Maringolo, 2007). The regulation applies to all wastes except gross domestic wastes and hazardous wastes such as radioactive, explosive, health services, and organochlorine pesticide wastes. In addition, co-processing plants must prove that the waste is entering the kiln as a substitute for either fossil fuels or natural raw materials, that the supply of waste is steady and consistent, and that the co-processed clinker will not leach dangerous metals to the environment.

Regulation 264/99 specifies several steps to acquire a co-processing permit; each step has comprehensive documentation requirements. An initial treatment feasibility study must document the following: general cement plant data; data on raw materials and final fuel characteristics (calorific value, viscosity for liquids, heavy metals content, ash and moisture, and classification according to Brazilian classification standards) used in the plant; a description of the process and equipment used, including flow charts; and a description of pollution control equipment. A "blank test plan" must then be prepared to benchmark pollution levels from the plant without co-processing and to indicate pollution control technologies, detection limits, and self-monitoring protocols, as well as expected emissions and waste dust composition. A test firing plan is the next requirement, which documents: the origins and specifications of all equipment, fuels, and feed streams to be used in co-processing; monitoring systems; expected emissions and outcomes; and the professional certifications of all technicians involved with the testing. A pre-test burn may be authorized to work out issues prior to the official test.

Several specific emissions parameters are given for elemental emissions and organic hazardous compounds. These parameters can be made stricter by local environmental authorities based on ambient air quality. In addition to this, National Regulatory Act 316/02, Licensing of Incineration/Co-incineration, establishes limits for emissions of dioxins and furans (0.5 nanograms per cubic nanometer [ng/Nm^3] from cement kiln co-processing. The character of the waste fuels must be thoroughly documented, and waste-to-fuel producers are covered by separate regulations. Fuels themselves may also be regulated more stringently by states; for example, in 2010, Minas Gerais state approved a new regulation for waste co-processing in cement kilns that established a minimum calorific value for used wastes (1,500 kilocalories/kg for MSW) (Kihara, 2012). In 2010, Brazil passed the National Solid Waste Policy (No. 12.305/2010), which is intended to standardize waste policy among Brazil's 26 states and calls for dramatic reductions in landfill disposal. In particular, the national policy supports implementation of waste-hierarchy-based local-level waste planning and pushes the expansion of waste recovery from MSW, including processing (Article 9, paragraph 1). The policy will be implemented over the next 5 years.

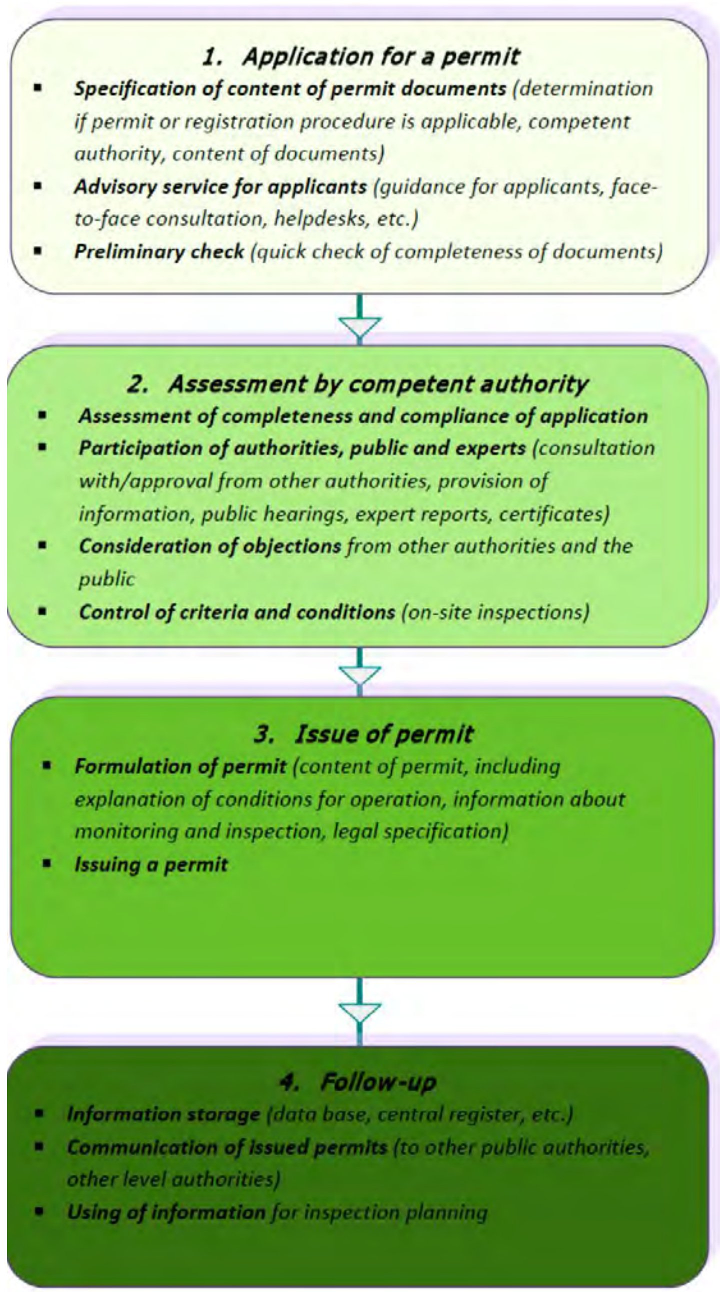


Figure 13. Key Stages in Issuing Co-Processing Permits in Brazil (Milieu, 2011)

3.5. Monitoring System Requirements

Best monitoring practices for co-processing plants include: standard measurement methods, certified instruments, certification of personnel, and accredited laboratories. Monitoring of co-processing plants has three elements: processing monitoring, emissions monitoring, and environmental monitoring (EIPPCB, 2003).

European Union

The EU waste incineration directive requires co-processing plants to install emissions and combustion measurement and monitoring systems. Air emissions and water discharges must be measured either continuously or periodically (EC, 2011a). The following parameters should be monitored continuously: NOx, CO, total dust, TOC, HCl, HF, SO_2, temperature of the combustion chamber, concentration of oxygen, pressure, and temperature and water vapor content of the exhaust gas. Periodic monitoring is required for the following substances: metals, semi-metals and their compounds, total organic substances, PCDDs/PCDFs. For plants that have a nominal capacity of 2 tonnes or more per hour, operators provide annual reports on plant functioning and monitoring. The annual reports are also made available to the public. Local authorities make public a list of plants that have a nominal capacity of less than 2 tonnes per hour (EC, 2011a).

Facilities in the European Union have to submit key environmental data to the European Pollutant Release and Transfer Register (E-PRTR) (E-PRTR, 2011). E-PRTR replaces the previous European Pollutant Emission Register (EPER) system for environmental reporting and contains annual data reported by approximately 24,000 industrial facilities covering 65 sectors in Europe, including cement industry co-processing plants. Each facility provides information on the quantity of pollutants released to air, water, and land; as well as offsite transfers of waste. E-PRTR aims to increase transparency and public participation in the environmental decision-making process. In Germany, this regulation was implemented with the PRTR Act (SchadRegProtAG) (VDZ, 2010).

EU legislation also requires co-processing plants to submit annual reports on their functioning and monitoring, including descriptions of the plants' general process, emissions to air and water, and comparison of the plant's emissions to the applicable emissions standard. Many EU member states also require plants to submit information on the types of waste co-processed and the capacity of the installation. EU legislation requires member states to report to the European Commission every 1 or 2 years. The European Commission uses a standard questionnaire (EC, 2006a) for member states to report the status of their waste incineration and co-incineration plants, including co-processing plants.

The UK uses the Operator Pollution and Risk Appraisal scheme to assess the environmental performance of cement plants. In 2004, 11 cement plants (85 percent of the total in the country) achieved an "excellent" score for operator performance, compared to 44 percent of all of British industry. All cement plants must have a formal environmental management system in place. All have ISO 14001 certification, and 10 are registered to the EU Eco-Management and Audit Scheme. All cement plant parent companies in England and Wales produce a sustainability or environmental report. In January 2008, Lafarge Cement UK was the first manufacturer to apply for permission to trail a waste derived fuel, which was produced from paper, plastics and some domestic refuse, under a new code of practice agreed with the UK Environment Agency. The permission was granted in April 2008, and the trail was successfully trailed. CEMEX completed two trails of using solid recovered fuel and received the permit to use this fuel at all of its UK cement plants. In each trail, more than 10,000 tonnes of waste were used in cement-making. By 2008, the UK cement industry has achieved an overall of 26.5% replacement of fossil fuels by waste-derived materials (MPA Cement, 2009). To monitor environmental releases from using sewage sludge, the cement sector in Catalonia, Spain signed an agreement in 2005 with the Catalan administration, trade unions, and local councils, and piloted the monitoring of the environmental impacts of using dried sewage sludge in cement plants (CEMBUREAU, 2009).

United States
The U.S. EPA established regulations to monitor air emissions (i.e., PM, NOx, and SO_2) from cement kilns through the agency's fence-line monitoring program. Each owner or operator of a cement plant in the United States that is required to install a continuous opacity monitoring system is also required to submit semiannual reports of excess emissions. Under the delayed CISWI Standards, all cement plants treating nonhazardous solid waste are required to demonstrate initial compliance with emissions limits. Existing facilities must annually inspect scrubbers, fabric filters, and other air pollution control devices. Parametric monitoring and bag Pb detection is also required if applicable. CEMS are required to monitor Hg, PM, and HCI, and annual testing is required for SO_2, NOx, CO, Pb, Cd, PCDDs and PCDFs. For new cement co-processing facilities, the monitoring requirements are the same as for existing units, but the rule also requires CEMS for CO, SO_2 and NOx.

Emissions and other compliance data are necessary for U.S. EPA review the MACT and CISWI standards, determine compliance, develop emissions factors, and determine annual emissions rates. To reduce costs and administrative burden on both regulators and plant operators, U.S. EPA receives stack test reports in electronic format rather than on paper. Operators of co-processing cement plants must submit performance test data through the Electronic Reporting Tool (ERT). ERT provides a standardized means of compiling and storing required documentation and significantly reduces the effort involved in collecting data for future activities, such as risk assessments. ERT is connected to U.S. EPA's electronic emissions database (WebFIRE) (EPA, 2012c), which was constructed to store emissions test data for use in developing emissions factors. Thus, cement plant operators can use ERT to collect and prepare data and documentation and can submit data through U.S. EPA's Central Data Exchange network for storage in the WebFIRE database.

3.6. Enforcement of Regulations

Enforcement of regulations and standards is key for a successful, environmentally safe co-processing industry. Enforcement of regulations and standards can also ensure the financing and marketing of co-processing.

European Union
In the European Union, member states must report to the European Commission every 1 or 2 years regarding achievement of waste management system targets. Reports are sent 18 months after the end of the reporting period. The commission then must report to the European Parliament and Council on the application of the WID. Plants that violate the IPPC Directive face administrative sanctions.

United States

In the United States, Section 113 of the Clean Air Act establishes federal authority to issue agency and court orders requiring compliance with the act and to impose penalties for violations. Section 114 authorizes U.S. EPA to require emissions sources to monitor emissions, certify compliance, and submit reports and authorizes U.S. EPA personnel to conduct inspections. The Clean Air Act is enforced primarily by state or local governments, which issue permits, monitor compliance, and conduct the majority of inspections.

In 2008-2010, U.S. EPA established the national "New Source Review/Prevention of Significant Deterioration (NSR/PSD)" enforcement initiative for the cement industry. The initiative was continued in the form of the national initiative "Reducing Air Pollution from the Largest Sources" for the years 2011-2013 (U.S, EPA, 2011g). U.S. EPA's Office of Enforcement and Compliance Assurance promotes compliance and works with EPA's regional offices and in partnership with state governments as well as other federal agencies to enforce environmental regulations. During fiscal year 2010, U.S. EPA initiated investigations/negotiations with 85 percent of the U.S. cement sector (U.S, EPA, 2011h). The main enforcement strategy used by the Office of Enforcement and Compliance Assurance is compliance investigation and evaluation. The primary forms of compliance investigations are (U.S. EPA, 2009):

- Written information requests
- State/local permit file reviews
- Regional file reviews
- Public information reviews
- Onsite compliance inspections
- Source emissions testing information requests
- Notices of violation
- Administrative orders, administrative penalty orders, or case referrals to the Department of Justice
- Support of referred claims
- Development of cases for filing
- Training of regional personnel to increase awareness of investigatory techniques

Clean Air Act violations can be charged as misdemeanors or felonies. Penalties for violating emission requirements may be up to $27,500 per day (U.S. EPA, 2010). U.S. EPA also has the authority to assess administrative penalties and authorizes $10,000 awards to persons supplying information leading to convictions under the act. Under the 2011 CISWI Standards (whose effective date has been delayed), new nonhazardous solid waste treating cement plants must demonstrate compliance with emission limits within 60 days after the kilns reach the operational charge rate and no later than 180 days after initial startup. Existing units must demonstrate compliance with emission limits "as expeditiously as practicable" and no later than 3 years after approval of a state plan or 5 years after promulgation of the 2011 CISWI Standards. States are responsible for establishing procedures and measures for implementing the U.S. EPA rules. State implementation plans must include emissions limits and other requirements for both new and existing units and must be submitted to U.S. EPA for review.

4. Technological Aspects of Co-processing – International Best Practices

Co-processing entails a number of technological elements, including pre-processing and treatment of wastes so that they are in a usable form for burning in cement kilns. A number of retrofits are required to enable co-processing at plant sites, and new installations and technologies for storage, conveyance, dosing, feeding, and final treatment of MSW and sewage sludge as well as measurement and control of emissions are often required (ALF-CEMIND 2012).

The subsections below describe technologies used in different stages of pre- and co-processing of MSW and sewage sludge. The "operational aspects" of co-processing are not addressed in this report; for more information about operational aspects, see GTZ/Holcim (2006), WBCSD (2005), and EIPPCB (2006).

4.1. Pre-processing Technologies and Practices

Waste materials used for co-processing in the cement industry are derived from selected waste streams. As noted earlier, wastes usually require pretreatment (e.g., dewatering, drying, shredding, blending, grinding, homogenization, etc.) and quality assurance (CEMBUREAU 2009). Mixed municipal waste must be pre-processed in waste management facilities. The extent of the waste pre-processing depends on the source and type of the waste and on cement industry requirements (EIPPCB 2010).

4.1.1. Pre-processing technologies and practices for MSW

MSW is a heterogeneous mixture of materials. Pre-processing helps to make a more homogeneous fuel (RDF) and should be part of integrated MSW management systems. Figure 14 shows an example of integrated MSW management (GTZ/Holcim 2010). The important characteristics of RDF as a fuel are the calorific value, water content, ash content, and sulphur and chlorine content. These values depend on the composition of the waste, which depends on the region of origin and varies according to the sources (e.g., households, offices, construction sites), seasons, the collection system (mixed MSW, source separated), and the pre-processing techniques applied (screening, sorting, grinding, drying) (ALF-CEMIND 2012).

There are various pre-processing methods for MSW. One common practice in developed countries is to use mechanical biological treatment (MBT) on raw municipal solid waste to be used in the cement industry (ALF-CEMIND 2012). MBT is discussed in detail below.

Mechanical biological treatment

MBT is a generic term for an integration of several processes that are commonly part of other waste management techniques (Defra 2007). The main purpose of MBT is to prepare a combustible material (RDF) from MSW. During this procedure, raw MSW is screened and separated to recover discrete recyclable materials such as metals, plastics, sizable pieces of cardboard, aluminum cans, and other material that can be reused. The remaining material, which consists largely of organic components such as plastics and biodegradable waste, is shredded to desirable sizes, producing the RDF for use as fuel in cement plants (Figure 15) (ALF-CEMIND 2012).

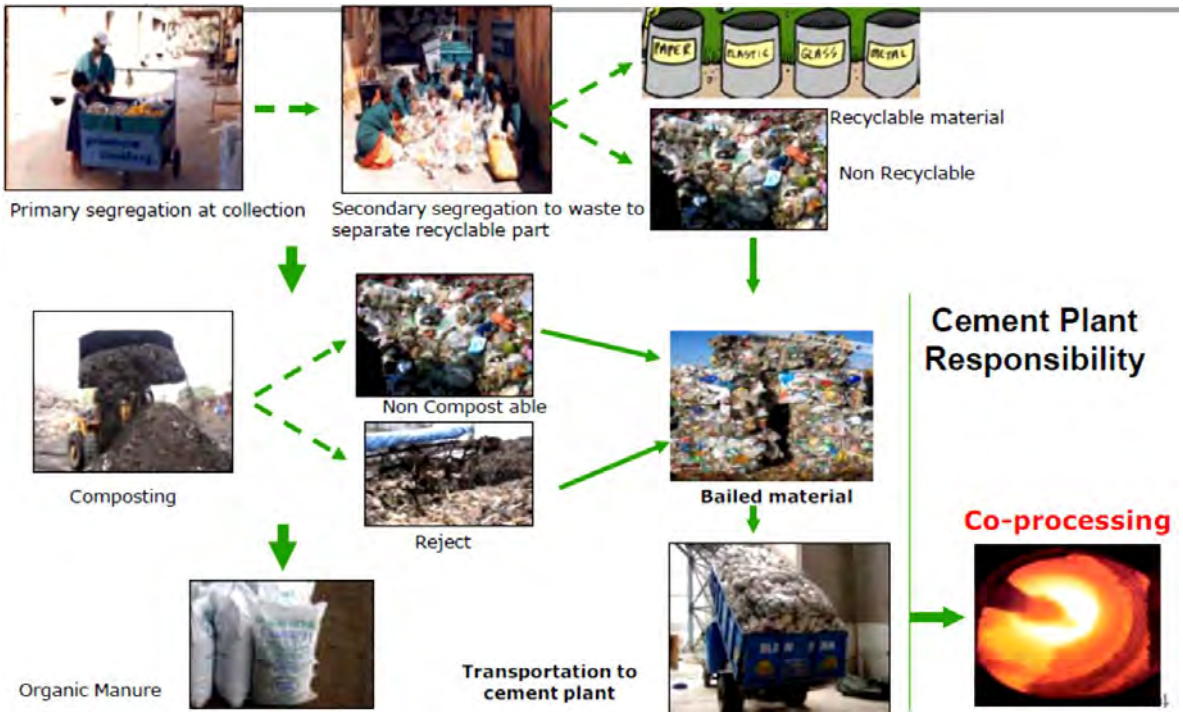


Figure 14. An example of integrated MSW management (GTZ/Holcim 2010)

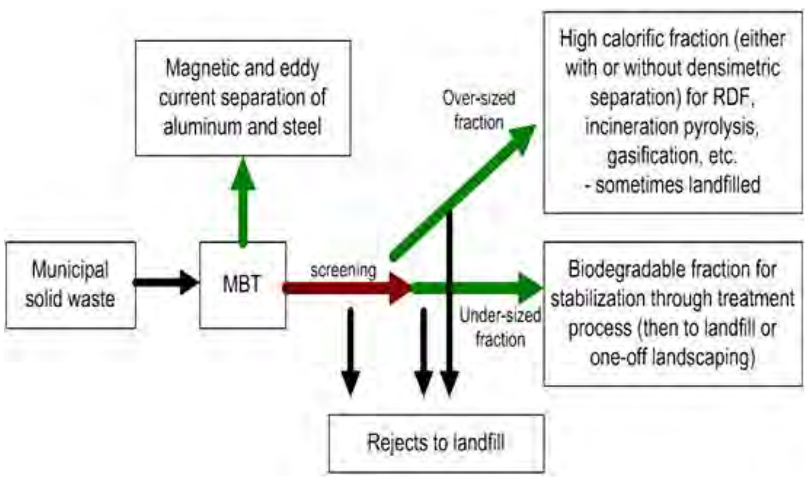


Figure 15. An example of the MBT for RDF production (ALF-CEMIND 2012)

On average, MBT of 1 tonne of municipal solid waste yields about 250 kg of RDF. Some country-specific values are: Austria 230 kg (MBT), Belgium 400-500 kg (MBT), the Netherlands 350 kg (Mechanical treatment), and UK 220-500 kg (Mechanical treatment) (ALF-CEMIND 2012).

Figure 16 shows flow diagrams of the main MBT configurations. The simplified dry stabilization technique on the right hand side can be an option to introduce MBT in emerging countries that have a large amount of organic matter in their MSW. This technique is currently being used in Thailand by the Thai-German Solid Waste Management Project (Seemann 2007).

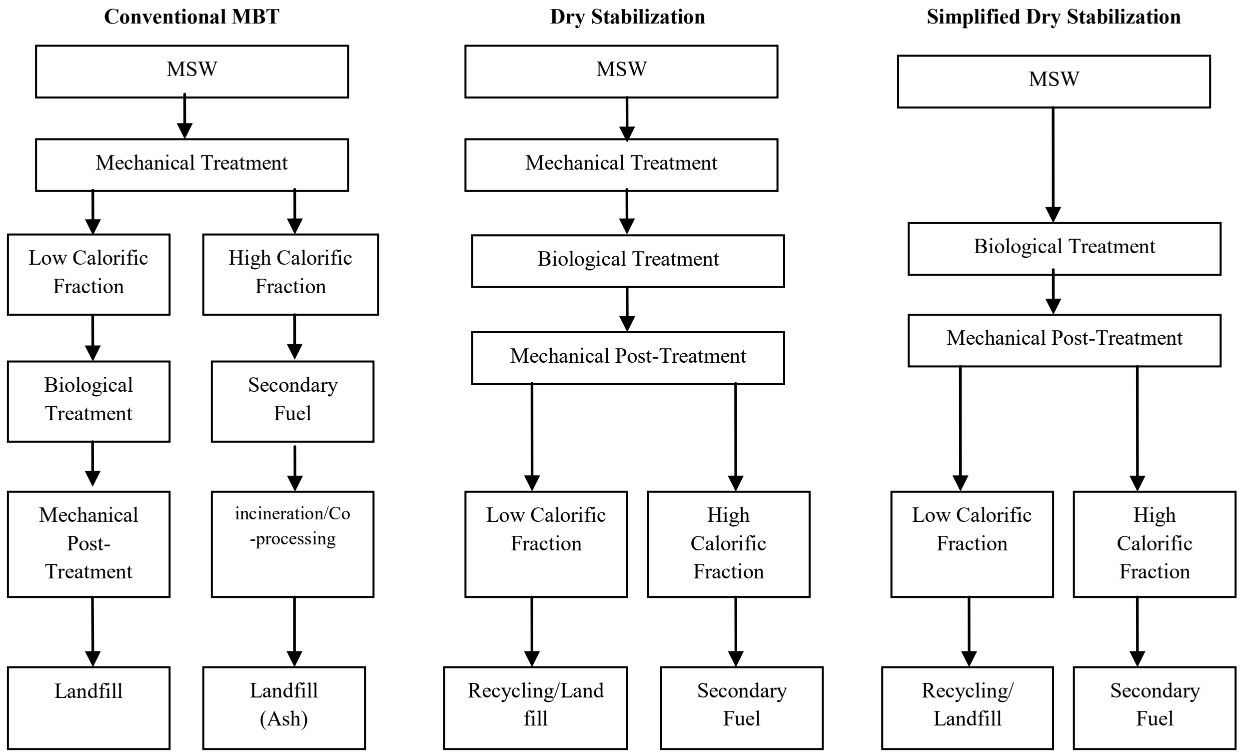


Figure 16. Flow Diagrams for Primary MBT Configurations (Seemann 2007)

MBT is commonly used for nonhazardous waste, such as MSW, commercial waste, and construction and demolition waste. The most common waste materials treated in this fashion are paper, plastic, wood, and textiles. Two major fuel types are produced by MBT: shredded or fluff-like material and densified fuels, such as pellets, cubes, and briquettes. Densified recovered solid fuel can have net calorific values up to 30 MJ/kg depending on composition. The reported minimum calorific values vary from 3 to 40 MJ/kg (EIPPCB 2006).

Individual process units in RDF production lines

RDF production lines consist of several units that separate unwanted components and condition combustible matter to achieve required fuel characteristics. Typical process units separate waste, reduce its particle size, and dry and densify it. These units can be arranged in different sequences depending on the composition of the MSW and the required quality of the RDF. Each type of RDF process unit is explained briefly below (Nithikul 2007).

Waste separation

The separation unit picks out different materials that are suitable for different end uses. Potential end uses include recycling, biological treatment, energy recovery through production of RDF, and landfill. A variety of techniques can be employed to separate waste (see Table 11). Most waste treatment facilities use a combination of several techniques. Waste separation technologies use certain properties of the materials in the waste (size, shape, etc.). Some commonly used waste separation techniques are briefly explained below. Table 13 presents the typical power requirements and capital and operational costs of several of these technologies, based on a study in Italy (Caputo and Pelagagge 2002).

Table 11. MSW Separation Techniques (Defra 2007)

Separation Technique	Separation Property	Materials targeted
Manual Separation	Visible identifying characteristics	Plastics, contaminants, oversize
Trommels and Screens	Size	Oversize – paper, plastic Small – organics, glass, fines
Magnetic Separation	Magnetic	Ferrous metals
Eddy Current Separation	Electrical Conductivity	Non-ferrous metals
Wet Separation Technology	Differential Densities	Float - plastics, organics Sink - stones, glass
Air Classification	Weight	Light – plastics, paper Heavy – stones, glass
Ballistic Separation	Density and Elasticity	Light – plastics, paper Heavy – stones, glass
Optical Separation	Diffraction	Specific plastic polymers

Manual separation. Often the first step in MSW treatment is manual sorting. Bulky items such as appliances, furniture, etc. as well as specified contaminants (e.g., hazardous waste) can be removed from mixed MSW manually by workers. Manual sorting also entails recycling paper, glass/plastic containers and aluminum cans. Equipment involved in manual separation usually includes a sorting belt or table (Nithikul 2007).

Trommel screen. A trommel is a rotary, cylindrical screen that inclines downward (Figure 17). The screening surface is either wire mesh or perforated plate. It can be used for mixed MSW prior to size reduction (pre-trommeling) or after shredding (post-trommeling). Trommel screens have proven to be quite effective and efficient for processing mixed MSW and are commonly used (Nithikul 2007).

Figure 17. Trommel screen (Doppstadt US 2012)

Magnetic separation. Magnetic separation segregates ferrous metals from MSW. Three configurations of magnetic separators are the magnetic head pulley, magnetic drum, and magnetic belt. The magnetic metal recovery per unit weight of total magnetic metal in MSW is about 80 percent for a single stage of magnets. A higher rate of recovery can be achieved using multiple-stage magnetic separation. If an air classifier (see below) is used before the magnetic separator, this can increase the recovery rate to as much as 85 to 90 percent because the air classifier removes lightweight contaminants such as paper and plastic, which interfere with the magnetic separation process (Nithikul 2007).

Air classification. Air classification relies on the differences in aerodynamic characteristics of waste. The process consists of the interaction among a moving stream of air, shredded wastes, and gravitational force. The fraction of MSW that is suspended in the air stream is referred to as the light fraction (e.g., paper and plastic), and the materials that settle are referred to as the heavy fraction (e.g., metals and glass). There are different types of air classifiers for different airflow patterns (Nithikul 2007).

Disc screen. Disc screens are often used to separate the inorganic fraction of waste. A disc screen consists of evenly spaced shafts in a horizontal plane fitted with discs. The openings between the discs allow undersized particles to fall through. All shafts rotate in the same direction and carry the wastes from one end to another (Nithikul 2007).

Waste size reduction

Size reduction (sometimes called shredding or grinding) is an essential operation in mechanical pre-processing of MSW because it results in a degree of size uniformity. Shredding of mixed waste to about 10 centimeters is common in many waste treatment facilities. Additional shredding steps might be required to produce RDF that is smaller than 10 centimeters (Defra 2007).

Table 12 presents different size reduction techniques and tools that are applicable to MSW. Two are prominently used in the management of MSW: high-speed, low-torque hammermills and low-speed, high-torque shear shredders, which are based on different principles and have advantages and disadvantages (Fitzgerald and Themelis 2009). Hammermills and shredders are discussed briefly below. The typical power requirement and capital and operational cost of these technologies are presented in Table 13 based on a study in Italy (Caputo and Pelagagge 2002).

Energy consumption is an important economic factor in the use of size reduction equipment. The required final size of the waste affects the energy intensity of the size reduction equipment; the smaller the final size, the more energy is required to process the waste. Figure 18 illustrates an example of decreasing final product size corresponding with increasing specific energy requirements for size reduction equipment.

Hammermills. There are two types of hammermills: horizontal rotor and vertical rotor. The horizontal hammermill is commonly used for mixed MSW. It consists of a shaft, hammer, grates, breaker bars, and hinged rejection chute (Figure 19). Wastes are fed into the opening of the machine and interact with the hammers and each other until reduced to a size that can pass through the grates (Nithikul 2007). Hammermills are available in a wide range of sizes and capacities; some can process up to 300 tons per hour of MSW. Capacity depends on the desired final particle size as well as the content of the raw waste. A realistic value for continuous operation of larger hammermills peaks at about 150 t/h. Hammermill specific energy consumption ranges from 6 to 22 kWh/t waste (Fitzgerald and Themelis 2009).

Table 12. MSW size reduction techniques (Defra 2007)

Tool	Technique	Key Concerns
Hammermill	Swinging steel hammers significantly reduce size of material.	Wear on hammers, pulverizing and "loss" of glass / aggregate
Shredder	Rotating knives or hooks turn at a slow speed with high torque. The shearing action tears or cuts most materials.	Damage to shredder from large, strong objects
Rotating Drum	Material is lifted up the sides of a rotating drum and then dropped back into the center. Gravity tumbles, mixes, and homogenizes the wastes. Dense, abrasive items such as glass or metal will help break down the softer materials, resulting in considerable reduction in size of paper and other biodegradable materials.	High moisture of feedstock can be a problem
Ball Mill	Rotating drum uses heavy balls to break up or pulverize the waste.	Wear on balls, pulverizing and "loss" of glass / aggregates
Wet Rotating Drum with Knives	Waste is wetted, forming heavy lumps that break against the knives when tumbled in the drum.	Relatively low size reduction. Potential for damage from large containers
Bag Splitter	This gentle shredder is used to split plastic bags while leaving the majority of the waste intact.	No size reduction; splitter may be damaged by large, strong objects.

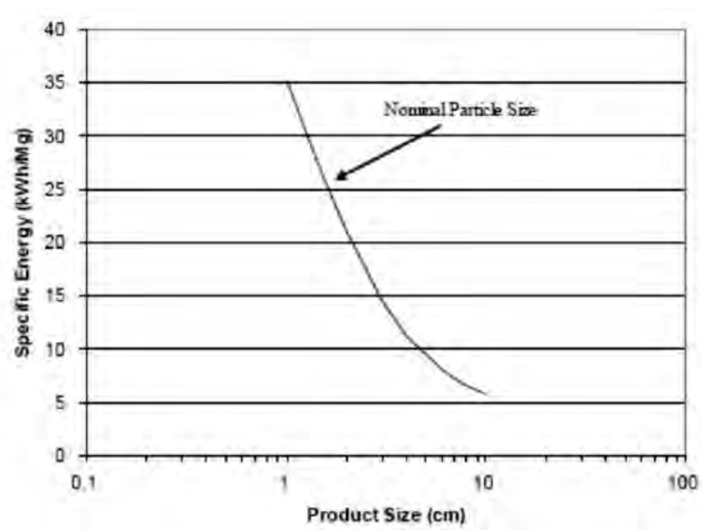


Figure 18. Specific energy requirements for MSW size reduction (Nithikul 2007)

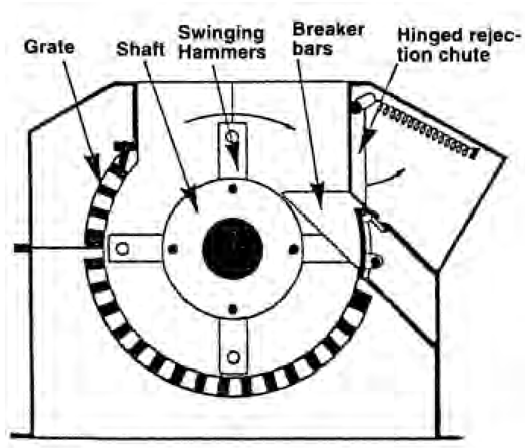


Figure 19. Schematic of horizontal hammermill (Bilitewski et al. 1997)

Shredder. A shredder operates at high torque and low speed (between 10 and 50 rotations per minute [rpm]). Shredders rely on cutting and tearing forces; little or no impact is involved. Shredders are made in single-, double-, or quadruple-shaft configurations. Increased shaft numbers produce a smaller final particle size (Figure 20). The counter-rotating shafts are fitted with cutting knives that intermesh and create large shear forces on any material trapped between them. The capacity of a shredder depends on the rotor speed and the volume between cutting knives. Available industrial shredders have capacities up to around 70 t/h. Shredder-specific energy consumption ranges from 3 to 11 kWh/t (Fitzgerald and Themelis 2009). Because of their high torque and shearing action, shredders are commonly used for materials that are difficult to shred such as tires, aluminum, and plastic (Nithikul 2007).

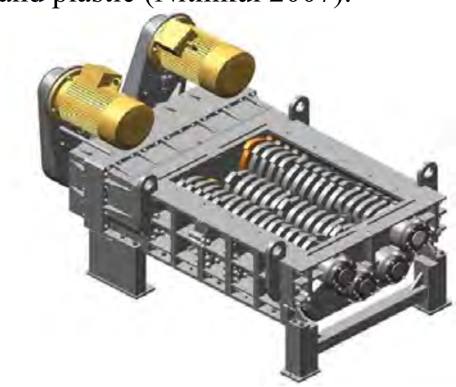


Figure 20. A schematic of a MSW shredder (Fitzgerald and Themelis 2009)

Drying and densification

Drying and densification are used to produce RDF as well as to reduce the volume of waste prior to landfilling. The objective of this process is to improve the quality of RDF. Densification produces briquettes, pellets, or cubes (Nithikul 2007). Depending on the water content and the physical characteristics of the waste, a dewatering process can be applied before drying. Dewatering techniques include: gravity thickening, centrifugal thickening, flotation thickening, and gravity belt and rotary drum thickening.

Different types of technologies are used to dry waste. Waste drying technologies can be classified as follows (Schu 2008):

- Biological dry stabilate processing (untreated MSW- shredded < 200 millimeters [mm])
- Thermal drying
    - Drum dryer (treated MSW - sieved/shredded < 60 mm)
    - Belt dryer (treated MSW- sieved/shredded < 40 mm)
    - Tunnel dryer (MSW- sieved 40 - 400 mm) (Figure 21)

Biological drying uses the intrinsic heat of the waste mixture in combination with forced ventilation and energy recirculation from a heat exchanger. Energy for drying is generated primarily by microbial processes that oxidize organic substances contained in the waste. Disadvantages of this method are a high volume of extracted airflow and a long drying period of 7 to 10 days. Also, fractions of the MSW that have high calorific value do not contain enough biogenous material for this drying method. Therefore, often, thermal drying is preferred over biological drying for waste (Schu 2008).

Thermal drying uses convection or conduction dryers. In convection (direct or adiabatic) dryers, there is direct contact between the heating medium (e.g. hot air) and the product to be dried, which removes moisture from the waste. In conduction dryers, there is no direct contact between the heating medium and the product. Heat transfer takes place through contact between the waste and a heated surface, and moisture is removed by a carrier gas or air. Conduction dryers use approximately 10 percent of the gas used in convective dryers. Therefore, conduction dryers may be preferable for dusty or odorous wastes since they have lower amount of exhaust gas compared to the convective dryers. (EIPPCB 2006).

Table 13 shows the typical power requirements and capital and operational costs of thermal drying and densification of MSW based on a study done in Italy (it is not clear what type of dryer was used in that study) (Caputo and Pelagagge 2002).

Cost of RDF production

Cost of RDF production depends on the line configuration of the size reduction, densification, and drying equipment; that configuration is determined at least in part by the desired RDF quality. Caputo and Pelagagge (2001) show that different configurations of the RDF production line affect the final cost per tonne of RDF produced (Caputo and Pelagagge 2002). Table 13 shows an example of estimated costs for different RDF production units in Italy. Appendix 4 presents the performance and total cost of different configurations of RDF production lines in Italy, as estimated by Caputo and Pelagagge (2001).

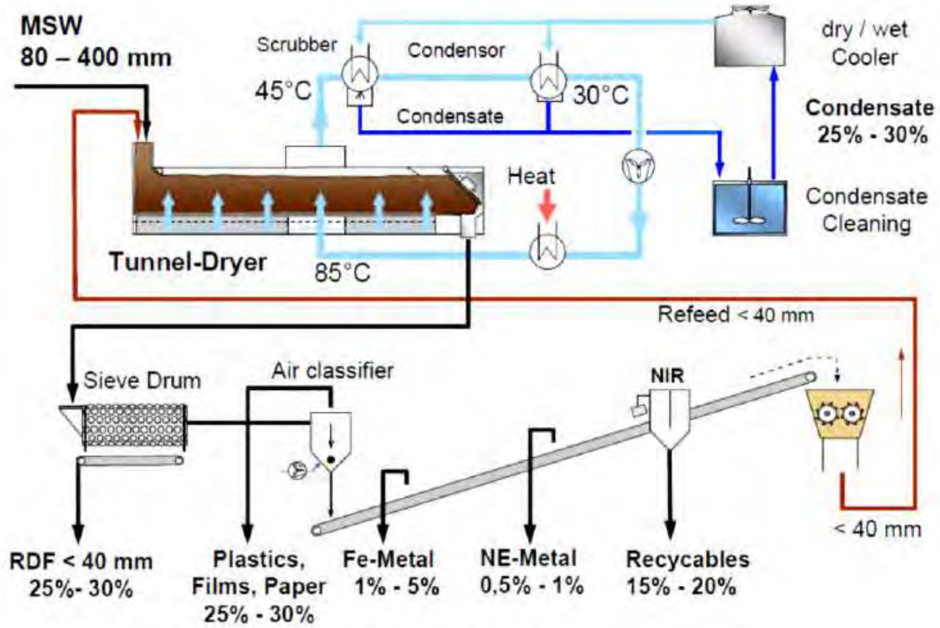


Figure 21. Process flow diagram for a low-temperature tunnel dryer (Schu 2008)

Table 13. RDF production line equipment cost (Caputo and Pelagagge 2002)

Equipment	Capacity (t/h)	Power (kW)	Cost (kEuro)	Amortization (Euro/h)	Operating cost (Euro/h)
Densifier	6	5	206.58	4.73	3.62
Air classifier	5	12	41.31	0.95	0.87
Dryer	6	140	309.87	7.09	10.12
Belt conveyor		6	15.49	0.35	0.43
Hammer mill	2	200	129.11	2.96	14.46
	4	250	144.60	3.31	18.08
	6	300	154.93	3.55	21.69
Pelletizer	4	50	206.58	4.73	3.62
Eddy current	5	2.2	7.23	0.83	0.27
separator	10	2.2	11.87	0.96	0.45
	15	2.2	14.97	1.14	0.48
Magnetic separator	5	3.75	36.15	0.17	0.16
	10	6.25	41.83	0.27	0.16
	15	6.6	49.57	0.34	0.16
Hand sorting				0.00	23.65
Shredder	6	25	56.81	1.30	1.81
	10	50	108.45	2.48	3.62
	15	50	129.11	2.96	3.62
	25	55	154.93	3.55	3.98
Trommel screen	15	20	103.29	2.36	1.45
	25	30	154.93	3.55	2.17

Note: Amortization cost was evaluated according to 10-year lifetime, operating 6 days/week, two 7-hour shifts/day. Electricity cost was estimated at 0.0723 Euro/kWh. Two operators per shift were assumed for hand sorting (Caputo and Pelagagge, 2002).

4.1.2. Pre-processing technologies and practices for sewage sludge

As shown in Figure 22, sewage sludge undergoes a mechanical dewatering process prior to pre-processing (ALF-CEMIND 2012). As the result of dewatering process, the dry solids content increases from 2 - 5 percent to 20 - 40 percent, depending on the characteristics of the raw sludge and the dewatering method applied. Appendix 5 shows a more complete flow diagram of sewage sludge pre- and co-processing from a project in Australia (EIPPCB 2006).

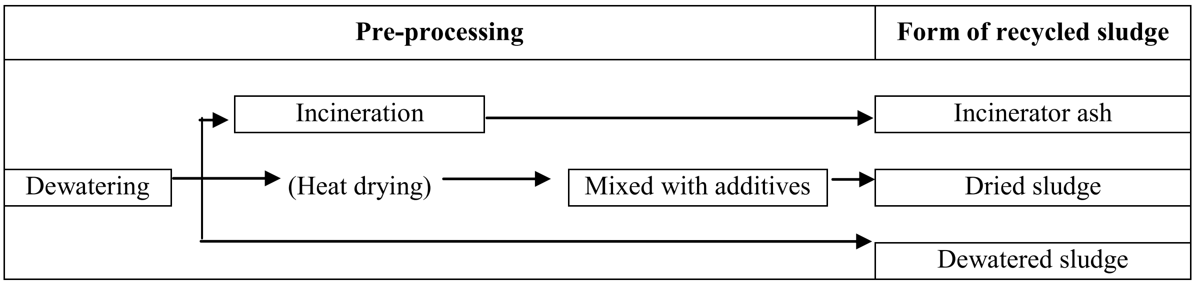


Figure 22. Schematic of sewage sludge pre-processing (Taruya et al. 2002)

Sewage sludge dewatering

Sludge dewatering increases the dry solids content of sludge, producing a sludge cake of 20 to 50 percent dry solids and an aqueous waste stream. The less additional processing required to remove contaminants from aqueous waste stream, the lower the cost of dewatering will be. To achieve more than 10 percent dry solids content from dewatering, it is necessary to use chemical conditioning, such as high-molecular-weight polymeric flocculants, to assist in separating the bound and entrained water from the sludge (EIPPCB 2006).

There are different types of dewatering processes. The type of process used depends on the nature and frequency of the solids produced and the sludge cake required. For example, filter (or plate) presses use batch processing and can be labor intensive. A filter press can produce a sludge cake with up to 40-percent dry solids. The other type of dewatering technique uses a belt press, which is a continuous process with a filter cloth running through rollers that forcefully dewater the sludge. A belt press can produce sludge cake of up to 35-percent dry solids. Centrifuges also is a continuous process and can produce a cake of up to 40-percent dry solids. Filter presses are most commonly used for sludge from wastewater treatment plants (EIPPCB 2006). The energy required to raise the dry solids content of sludge from 5 to 35 percent by mechanical dewatering is approximately 3-5 kWh. To achieve these levels of dry residual content, organic coagulating or other precipitating agents are usually added (Reimann, 1999). In China, the cost of sludge dewatering (with an increase in dry solids content from 3 to 20 percent) is reported as 8-12 Renminbi per m^3 of thickened sludge (IWA Water Wiki 2011).

In practice, dewatered sludge often contains approximately 70 to 80 percent water. This high water content can result in negative heat gain when the sludge is used in cement kilns. Using "fuel" with such a high water content can, in some cases, can cause the kiln temperature to drop below the minimum needed to create cement clinker, which will negatively affect product quality. Also, too much evaporated water increases the offgas flow rate, which could overload offgas cleaning devices and exceed fan capacity (Stasta et al. 2006). This will result into lower clinker production and eventually opportunity losses for selling cement in the local market. In addition, dewatered sludge is more costly to transport because of its large volume, and there is a risk of drainage and odors from sludge-conveying trucks. It is important to mitigate these risks when using dewatered sludge in kilns (Taruya et al. 2002).

Taruya et al. (2002) report that, of the total sewage sludge used in the cement industry in Japan in 2001 (approximately 1 million tons on a dewatered sludge basis), dewatered sludge represented more than half. However, they do not mention the average dry solid content of dewatered sludge in Japan. Also, in most places around the world, dewatered sludge is further processed by drying to increase its dry solids content before it is used in a cement co-processing plant.

Sewage sludge drying

As mentioned above, co-processing and incineration of dewatered sewage sludge are technically possible but may not be economical, so dewatered sludge is often dried to reduce its water content and increase its heat content (Onaka 2000). Sun or open air-drying are the method used to reduce moisture in dewatered sludge, which is effective if the sludge layer is thin and huge areas of land are available. Other more effective and efficient drying techniques use the following types of dryers (Flaga, no date):

1. Convective dryers, in which sludge comes into direct contact with the drying medium (e.g., hot air). Convective (direct) dryers that can be used for sludge drying are pneumatic dryers (flash dryers), rotary or drum dryers, and fluidized bed dryers.
2. Contact dryers in which sludge comes into contact only with a surface that is heated from the other side by a heating medium. Contact (indirect) dryers that can be used for sludge are paddle dryers, hollow flight dryers, disc dryers, and multi-shelf dryers.
3. Mixed convective-contact dryers.
4. Infrared dryers that use infrared radiation or high-frequency current.

Some technologies can only partially dry sludge (to less than 85 or 90 percent dry solids), and it is not always necessary to dry sludge up to 90-percent or more dry solids (Flaga, no date). Hall (1999) gives a cost range of approximately US$330-880/tonne of dry solids for sewage sludge drying. The subsections below explain several approaches for drying sewage sludge using different heat sources.

Drum dryer

In tube drum drying, dewatered sludge is transported on a chain conveyor and added to the revolving tube drum in single portions. The residence time of the dewatered sludge in the dryer and thus the dryness of the granulated sludge can be regulated by hydraulic adjustment of the tube angle. The energy used in the drying process is drawn from the waste heat of the associated cement process or incinerator.

Up to 30,000 m^3/h drying air (maximum 100 ºC) flows through the revolving tube in a direction counter to the dewatered sludge. The heat is used to evaporate water from the sludge, and the plume is extracted by suction through a dust filter and directly transferred to a bio-filter. The granulated dry sludge is discharged automatically by the drum’s rotation and loaded into large bags or other containers (EIPPCB 2006).

It is important to avoid carbonization of sludge during drying because Hg emissions are at their highest level at carbonization temperature (160 ºC). However, it also should be noted that even when drying is done at higher temperatures of the heating media, the granules itself remain on a temperature lower than 120 ºC and are not emitting Hg. Due to this physical behaviour, sewage sludge dryers are not emitting Hg. As a consequence, permits for emission control of sewage sludge dryers often do not include Hg as a value to measure. Later, when the sludge is co-processed at the cement kiln, high levels of CaO are present, which prevents rapid Hg evaporation (Zabaniotou and Theofilou 2008).

Sewage sludge drying using waste heat from cement plant flue gas

Another approach to sewage sludge drying is to use waste heat from cement plant flue gas. Stasta et al. (2006) conducted a feasibility and economic analysis of sludge drying by utilizing excess cement plant heat and found that some of the main factors affecting the economics of such a project are: profit from sludge disposal, transport costs, amount of treated dry matter, and dry matter content in sludge (Stasta et al. 2006). They calculated that approximately 10.8 GJ of heat are necessary to dry 1 tonne of wet sludge. The report also shows that, when a counter-current shaft exchanger is used, cement plant flue gas can provide this amount of waste heat for sludge drying. Stasta et al. considered the rotating disc dryer technology for sludge drying, which entailed an investment cost of approximately US$ 2.64 million for the whole project. This resulted in a payback period of approximately 5 years (Stasta et al. 2006). Another case study in Australia assessed the use of a horizontal fluidized bed dryer for sludge drying. The estimated capital cost for this type of dryer was around US$ 2.4-3.4 million for 60,000 t/year of dry sludge (APP 2011). Other case-studies for successful utilization of cement plant's waste heat for sewage sludge drying are reported in Germany, Turkey, and China. Figure 23 diagrams the use of cement plant flue gas heat for sludge drying.

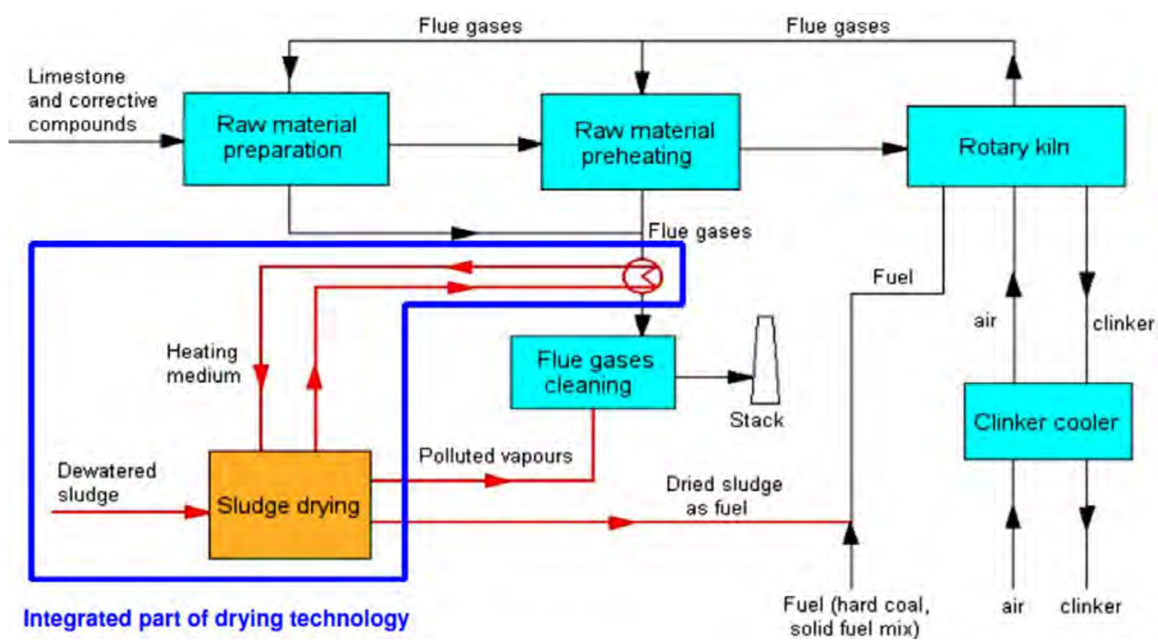
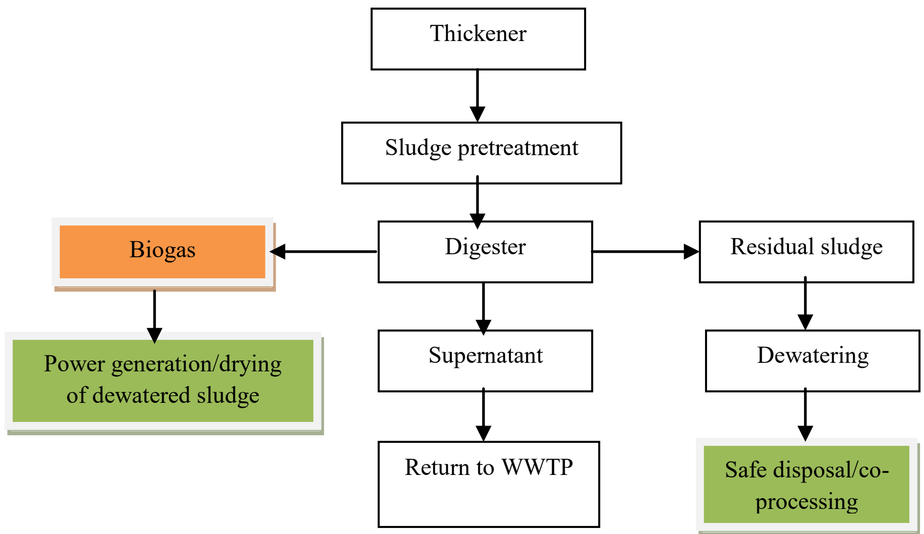


Figure 23. Using cement plant's flu gas heat for sludge drying (Stehlík et al., no date)

Use of biogas from anaerobic sludge digestion for heat drying

Anaerobic digestion is a series of processes in which microorganisms break down biodegradable material in the absence of O_2. Anaerobic digestion is used to manage waste and/or to release energy for industrial or domestic purposes. The main features of the anaerobic digestion process used for treating sludge are mass reduction, biogas production, and improved dewatering properties of the treated sludge. Figure 24 shows sludge processing with anaerobic digestion (Hanjie 2010). The biogas produced by sludge anaerobic digestion can be used for heat drying the dewatered sludge if waste heat from the cement plant is not available. This will avoid the use of conventional fuels for heat drying. The amount of gas produced by anaerobic sludge digestion is reported equal to 362 - 612 liters per kg volatile solids for primary sludge[7] and 275-380 liters per kg volatile solids for activated sludge[8] (Hanjie 2010).



WWTP = wastewater treatment plant

Figure 24. Sludge processing steps including anaerobic digestion (Hanjie 2010).

Table 14 shows the CO_2 emissions per tonne of dry sludge produced by different methods and used in HeidelbergCement plants in Turkey and China. The three sludge drying methods are: 100-percent use of natural gas, 50-percent replacement of natural gas by sludge digestion gas, and 100-percent waste heat from cement process used for sludge drying (Theulen 2011). Table 14 shows that, from a CO_2 emissions reduction perspective, co-processing of sewage sludge is preferable to sludge incineration and the greatest CO_2 emissions reduction is achieved when sludge is dried using only waste heat from the cement kiln.

Table 14. CO_2 emissions per tonne of the dry sludge produced by different methods and used in a cement plant or incinerator (Theulen 2011)

Sludge drying method	Heat source	CO_2 emissions (in CO2 equivalent) per tonne of dry sludge	
		Cement Co-processing	Incineration
100% natural gas	Natural gas network	-400 kg	+600 kg
50% natural gas, 50% sludge digestion gas	Sludge digestion	-750 kg	
100% waste heat	Cement kiln	-1,100 kg	

[7] Primary sludge is also called raw sludge and comes from the bottom of the primary clarifier. Primary sludge is easily biodegradable.
[8] Activated sludge is also called excess sludge or waste activated sludge and comes from the secondary treatment. Activated sludge is more difficult to digest than primary sludge.

Drying by blending the dewatered sludge with quicklime
Another sludge drying technique used in Nara Prefecture, Japan is blending dewatered sludge with quicklime, resulting in a usable raw material for cement production. This process dries the sludge using heat generated by the following hydration reaction:

$$CaO + H_2O \rightarrow Ca(OH)_2 + 15.33 \text{ kcal/mol}$$

The resulting product, called dried powder sludge, has a very low moisture content, is odorless, and can be used as alternative fuel and raw material in the cement industry. Figure 25 shows this drying process. Waste gas generated from the digesting and blending machine contains as much as 2,400 mg/l dust and ammonia. The waste gas is treated with a bag filter, chemical scrubbing, and activated carbon absorption processes. Using this process, dewatered sludge with 80 percent moisture content can be converted to dried sludge with 5 percent moisture. The dried sludge includes particles of approximately 100 to 200 micrometers (μm) average diameter and can be stored for more than 10 days (Taruya et al. 2002).

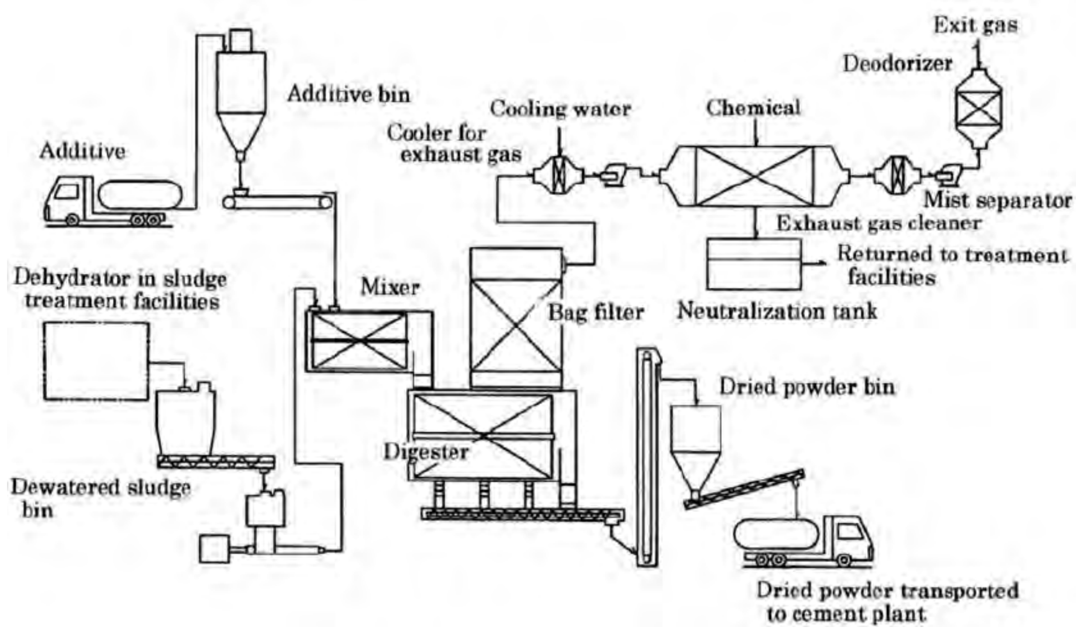


Figure 25. Powder sludge manufacturing in Nara Prefecture, Japan (Taruya et al. 2002)

Solar Drying of Sewage Sludge
In this type of dryer, the solar radiation warms the sludge's surface. The rise in the temperature forces the water molecules out into the surrounding air. The moist air transports the water and has to be evacuated. However, while the surface dries, the lower parts remain moist, and have to be dried or turned. Some systems are designed to turn over the sludge so its other side can get the sun light by a turning and conveying machine. In some other systems, the sludge is dried in a greenhouse using the solar generated heat and the bottom of the sludge is dried by a floor heating system that can be heated with waste heat from different other processes. Anlagenbau GmbH is one of the technology providers for the solar sludge drying. More than 100 systems exist worldwide and are applied mainly in rural areas, serving small communities.

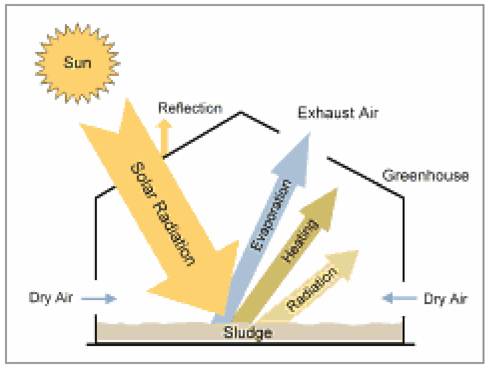


Figure 26. Schematic of open air drying beds solar sludge dryers with natural ventilation (Anlagenbau GmbH 2012)

Dried sewage sludge grinding

In particular cases it might be worthwhile to grind the dry sewage sludge before adding it to the main burner of a cement kiln. This is particularly done when the amount of alternative coarse fuels in the main burner is very high and the fineness of the sewage sludge is a key parameter to keep the flame with enough intensity. Since this was the case in the Maastricht kiln in the Netherlands, the plant decided to grind the sewage sludge until 15 to 25 percent of the sludge is 90 microns in order to have good flame performance (Takx 2002). Different grinding system can be used for this purpose.

In February 2000, ENCI Cement Plant in the Netherlands, in cooperation with Claudius Peters, installed a vertical roller mill, called a "BioMill," for milling dried sewage sludge. The mill is supplied with ambient air and consists of five large grinding balls revolving around a grinding table that is less than 2 m in diameter. The mill's energy consumption is approximately 40 kWh/t (ALF-CEMIND 2012). The grinding system has a static precipitator with manual control of the fineness of the final product. The ground sludge is stored in silos equipped with pressure-relief valves and dust filters. The bag filter has three explosion valves. The ground sludge is transported to a small (100 m^3) silo on the burner floor. This silo has a pressure-relief valve and a filter. The sludge is then fed to the kiln by a dosing system (Takx 2002) (Figure 27). In another case study in Australia, a vertical roller mill was used for grinding dried sludge before co-processing in the kiln. The estimated capital cost was approximately US$ 3.3-4.8 million for 60,000 t/year of dry sludge (APP 2011).

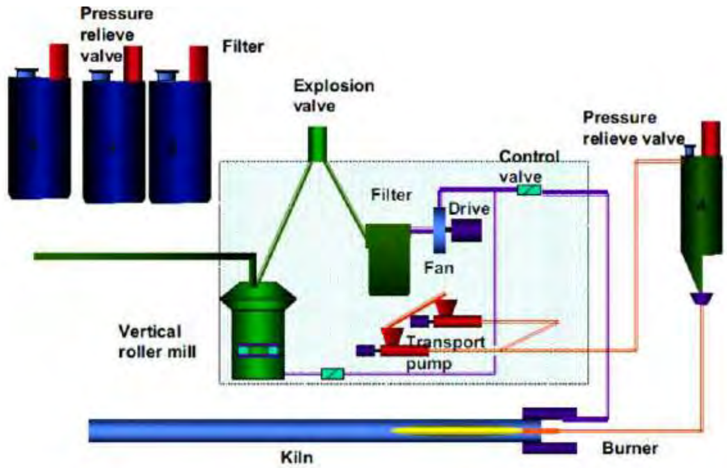


Figure 27. Dried sewage sludge grinding system (BioMill) (Takx 2002)

Cost of sewage sludge pre-processing

Treatment units used in the sewage sludge pre-processing process include mechanical screens, gravity thickeners, mechanical thickeners, decanter centrifuges, anaerobic digesters, and sludge dryers. In practice, combinations of these units might be used (Gorgun and Insel 2007). Gorgun and Insel (2007) evaluated several different process alternatives in Turkey that are made up of combinations of sludge treatment units. Table 15 shows the investment costs, annual operational costs, and payback periods for these alternatives. Steiner et al. (2002) also discuss the economic aspects of sludge management and give the cost of sewage sludge treatment plants in different developing countries.

Table 15. Investment and annual operational cost, and payback periods of several process alternatives for sludge pre-processing (Gorgun and Insel 2007)

Alternative	Description	Investment Cost (US$)	Annual Operational Cost (US$)	Payback Period
Mechanical screen (MS)	MS removes total suspended solids in influent wastewater.	170,000	17,000	5 months
MS+Mechanical thickener (MT)	In addition to MS, primary and secondary sludge are combined and subjected to MT (belt press). Approx. 20% solids content can be achieved with the addition of polymer.	290,000	29,000	8 months
MS+MT+Decanter centrifuge (DC)	Primary and secondary sludge are combined and subjected to MT, then introduced to DC. Up to 30% of solids content can be achieved with the addition of polymer.	600,000	60,000	15 months
MS+MT+DC+Sludge Drier (SD)	In comparison to the previous option, solids content can be increased up to 90%.	5,400,000	195,000	9 years
MS+MT+Anaerobic digester (AD)	ADs require 4-6% solid content for optimal operation. An AD can produce biogas to be used for power generation or sludge drying. Ads reduce the organic content of the sludge.	2,690,000	36,000*	5.5 years
MS+MT+AD+DC	In addition to anaerobic digestion, the solids content can be increased up to 90% by DC.	3,000,000	66,000*	5.7 years

* Energy recovery from AD is included

4.2. Storage, handling, and feeding systems

In most cases, special trucks transport pre-processed fuel to a storage site at the co-processing cement plant. The waste material should be properly stored at the plant site in accordance with laws and regulations. Vapor filtration and capture equipment should be in place to minimize the impact of unloading activities on the reception point and surrounding areas (WBCSD 2005). From the storage area, automatic conveyors move the waste to the feed point in the cement kiln system. A dosing system precisely controls the appropriate feed rate of the fuel into the kiln (ALF-CEMIND 2012) (Figure 28). Based on a feasibility study of using sewage sludge in a cement plant in Australia, APP (2011) says the power requirement is approximately 235 kW for receiving, storage, conveying, and feeding of dried sewage sludge in the cement plant. The estimated capital cost for the system was around US$ 6-11.5 million for 60,000 t/year of dry sludge (APP 2011).

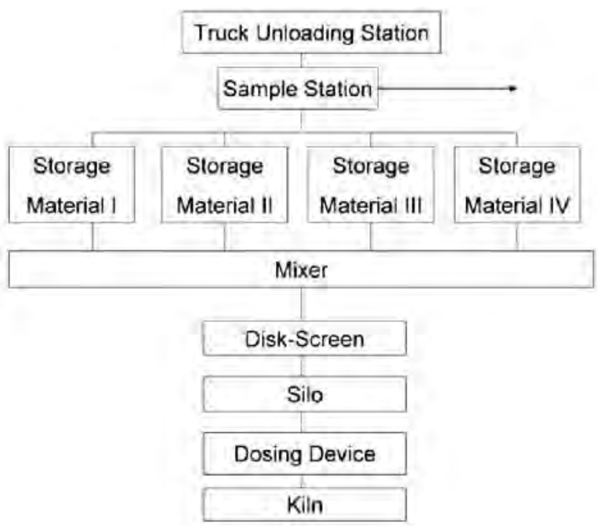


Figure 28. Handling of waste fuel at a cement plant (Reinhard 2008)

4.2.1. Storage

Different storage systems can be used for alternative fuels, including storage halls with reclaiming facilities or storage silos with discharge systems. The type of storage used might depend on the type of waste material. Storage for RDF would be in industrial hangars to preserve the RDF's moisture content and other properties and minimize visual and odor impacts as well as spillage.

Sewage sludge is very abrasive, and, depending on its solid matter content, is prone to fermentation during usage (ALF-CEMIND 2012). The brewing or self-heating quality of sludge can also cause fire or explosions in the storage and grinding system (Takx 2002). Special attention should be paid to these properties when designing handling and storage installations at the cement plant. Closed cylindrical silos with special mechanical discharge devices (cone dischargers or flat-bottomed discharge systems) are used for sewage sludge storage to minimize health impacts. Normally, storage silos are equipped with special cone dischargers (ALF-CEMIND 2012).

4.2.2. Handling and conveyors

Depending on the system configuration and waste type, pneumatic or mechanical transport system moves the waste fuels within the cement plant and feeds them into the cement kiln. A mechanical transport system is less energy intensive. For mechanical transport, different systems can be used (ALF-CEMIND 2012) (Figure 29). Solid materials handling systems need to have adequate dust control systems.

Figure 29. Mechanical transport systems (Hock 2008)

4.2.3. Feeding and dosing systems

Depending on the waste fuel feed point, different feeding systems can be used. Any type of feeding system used should ensure high accuracy and consistence, avoid down times caused by blockages, and be able to flexibly accommodate a range of fuels. Figures 30 and Figure 31 show an example of a handling and dosing system used for feeding RDF into a calciner and into a kiln, respectively.

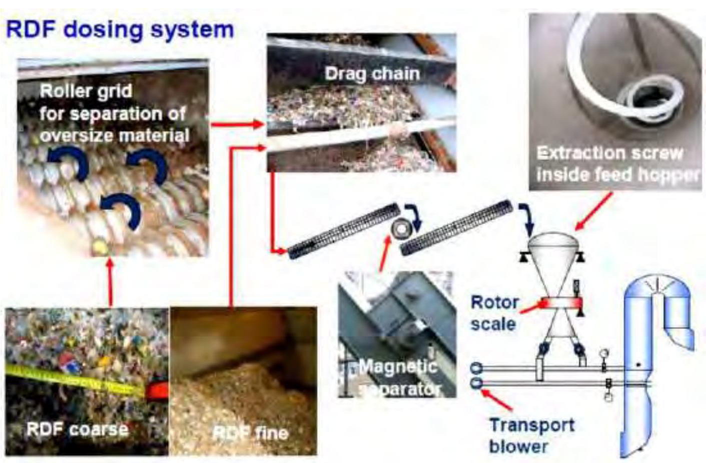


Figure 30. Example of an RDF handling and dosing system for feeding RDF into a calciner (Hempel 2011)

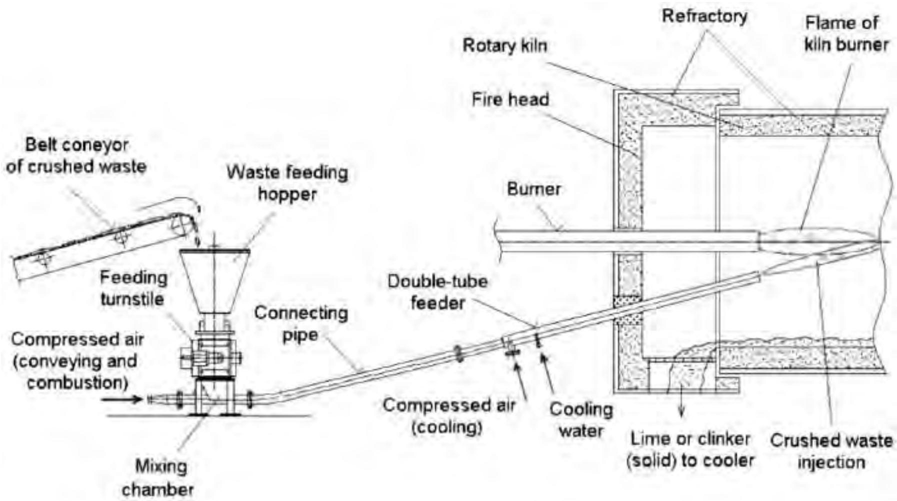
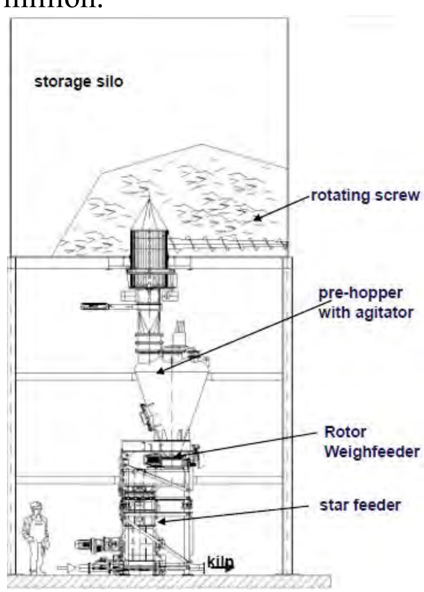


Figure 31. Example of RDF handling and dosing system for feeding RDF into a kiln's main burner (Stehlík et al., no date)

Dosing systems feed fuel to the kiln system at a predefined ratio. Depending on the waste, different types of dosing systems are used. For instance, Schenck Process offers a rotor weighfeeder, and FLSmidth PFISTER offers screw weighfeeder (Figure 32). Another example is the mid-kiln fuel injector provided by Cadence (Figure 33). Waste-derived fuels are placed on the apparatus, which rotates with the kiln. As the fuel injector reaches the vertical position, a mechanism allows the fuel to drop into the center of the kiln. This system can be quickly fitted to the cement kiln. Its payback time is 1 year or shorter (Cadence 2012a). A storage and feeding system for co-processing of sewage sludge for 45,000 t/year was installed in a cement plant in Turkey by HeidelbergCement for an investment of $2.8 million.[9]



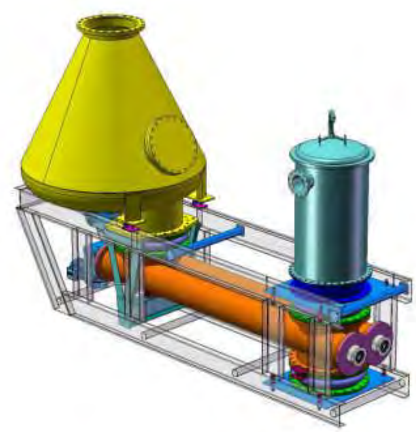


Figure 32. Rotor weighfeeders (left) and screw weighfeeders (right) for dosing solid waste fuels (Leong 2008; Schenck Process 2009)

[9] Cement Sustainability Initiative (CSI), personal communication. June 2012.

Figure 33. Cadence's mid-kiln fuel injector technology (Cadence 2012a).

4.3. Co-processing of MSW and Sewage Sludge in the Cement Kiln

Typically, RDF may replace 15-20 percent of primary fossil fuels used in cement plants around the world (ALF-CEMIND 2012) although this proportion can be as high as 30 percent (Murray and Price 2008) and in case of high quality RDF it can be up to 60%[10]. The maximal sewage sludge feed rate should not be more than 5 percent of clinker production capacity. Consequently, for a 2,000 t/day cement kiln, a maximum of 100 ton per day dry sludge could be used without degrading the clinker quality (ALF-CEMIND 2012). The European Commission (2004) indicates that sewage sludge can replace up to 20 percent of primary fossil fuels used in cement plants.

Replacing coal or pet coke with RDF results in a more than 15-perent increase in the waste gas produced. In a system with a constant blower capacity and a limit on the quantity of fumes that can be emitted, use of RDF can be accommodated in two ways: 1) thermal conditions, i.e., the temperature profile, can be maintained by providing a smaller amount of secondary air (the percentage of O_2 in the dry fumes will be smaller), or 2) the dilution factor can be maintained, resulting in the same O_2 concentration in the waste gas and a lower combustion temperature. Either of these choices can result in a reduced rate of NOx formation (Genon and Brizio 2008).

4.3.1. Selection of feed point for alternative fuels

Given the differences in temperature in different parts of the cement production process, it is important that waste materials be introduced at the correct point (feed point) in the process to ensure complete combustion or incorporation and to avoid unwanted emissions. The feed point should be selected according to the nature of the waste fuels (WBCSD 2005). The most common points at which wastes are inserted into the cement production process are (Stockholm Convention 2006):

- the main burner at the rotary kiln outlet end
- the feed chute at the transition chamber at the rotary kiln inlet end (for lump fuel)
- the secondary burners to the riser duct
- the precalciner burners to the precalciner
- the feed chute to the precalciner (for lump fuel)
- the mid kiln valve in the case of long wet and dry kilns (for lump fuel)

[10]Cement Sustainability Initiative (CSI), personal communication. June 2012.

The appropriate points for feeding waste fuel to the kiln system in relation to temperature and residence time depend on the kiln design, type, and operation (Figure 34). Overall, the kiln should operate in a way that ensures that the gas resulting from the co-processing of waste is raised, in a controlled and homogeneous fashion even under the most unfavorable conditions, to a temperature of 850°C for 2 seconds. If waste with a content of more than 1 percent of halogenated organic substances (chlorine) is co-processed, this temperature needs to be raised to 1,100°C -1,200°C for at least 2 seconds (EIPPCB 2010).

Waste fuels with highly stable molecules, such as highly chlorinated compounds, should be introduced at the main burner where the high combustion temperature and long retention time will ensure complete combustion. Waste with VOCs may be introduced at the main burner, in mid-kiln, in the riser duct, or at the precalciner but should not be introduced with other raw materials except where tests demonstrate that this will have no effect on the offgas (WBCSD 2005). Hazardous waste should be fed through either the main burner or the secondary burner of preheater/precalciner kilns. Hazardous and other wastes fed through the main burner will be decomposed under oxidizing conditions at a flame temperature of more than 1,800°C. Waste fed to a secondary burner, preheater, or precalciner will be decomposed at an expected burning zone temperature of typically more than 1,000°C (Basel Convention 2011). Wastes should be fed into the kiln system continuously except during operations such as startups and shutdowns when appropriate temperatures and residence times cannot be achieved (EIPPCB 2010).

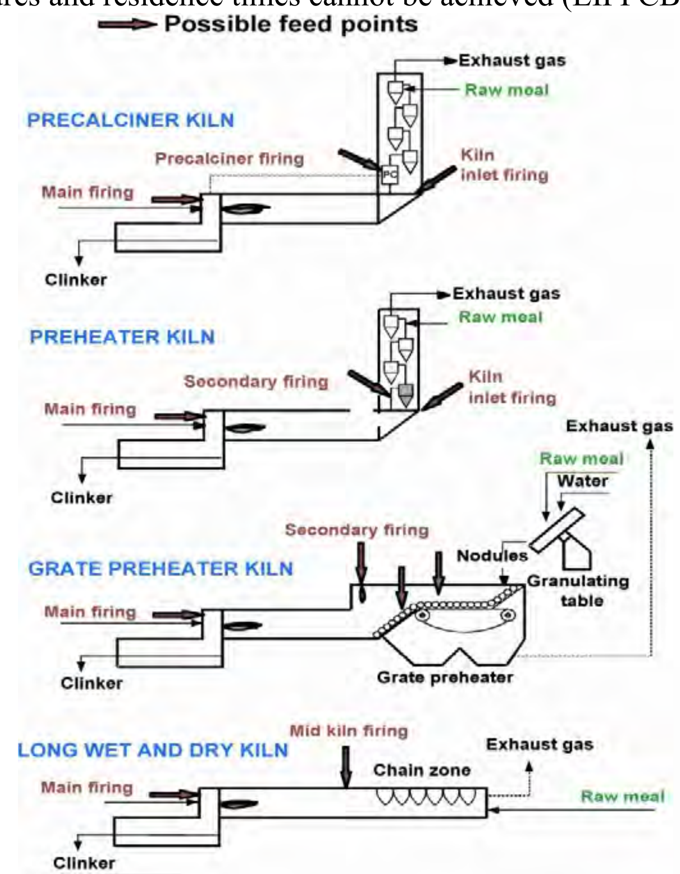


Figure 34. Typical waste feed points (Basel Convention 2011)[11]

[11] See Appendix 2 for a diagram of reaction zones for different kiln technologies.

4.3.2. Multi-fuel burners

One of the most important modifications that a cement plant must make for waste co-processing is to install a burner that can handle both traditional primary fossil fuels and waste-derived fuels. The most popular burner type today is the so called multi-fuel burner, which is offered almost by all equipment suppliers (ALF-CEMIND 2012). KHD's PYRO-Jet burner (Figure 35) is an example; this burner is used in Switzerland for multiple fuels in the following proportions (Hand 2007):

- 25 percent coal
- 19 percent oil
- 13 percent solvents
- 34 percent plastics (<10 mm)
- 9 percent sewage sludge

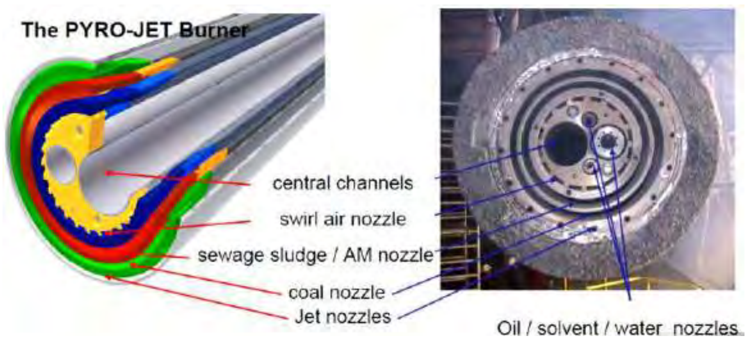


Figure 35. Cross-section view of a multi-fuel burner (Hand 2007)

Multi-fuel burners consist of concentric tubes. Air gaps between the concentric tubes enable injection of compressed combustion air. Steam is used to assist in injecting certain fuels. Inside or adjacent to the concentric tubes, tubes are installed with special nozzles for injection of secondary air and/or liquid fossil and alternative fuels. The inner tube is the channel for the solid waste fuels because it offers the most abundant cross section of all the concentric tubes (ALF-CEMIND 2012).

Some commercial multi-fuel burners are:

- SUSPENSION burner by Cadence Environmental Energy Inc.[12]
- FCT MULTI-FUEL kiln burner by FCT-Combustion[13]
- DUOFLEX burner by FLSmidth[14]
- LOW-NOx FLEXIFLAME™ burner by Greco-Enfil International S.L.[15]
- PYRO-JET® burner and PYROSTREAM® burner by KHD Humboldt Wedag GmbH[16]
- ROTAFLAM® rotary kiln burner and calcination burner by PILLARD FEUERUNGEN GmbH[17]

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[12] http://www.cadencerecycling.com/
[13] http://www.fctinternational.com/
[14] http://www.flsmidth.com/
[15] http://www.grecoenfil.com/
[16] http://www.humboldt-wedag.de/

- Clinkering zone burner by Polysius AG[18]
- M.A.S. burner and UNICAL calciner burner by Unitherm Cemcon Firingsystems GesmbH[19]

Appendix 9 contains a short list of technology providers for pre- and co-processing of alternative fuels in the cement industry.

4.3.3. Additional kiln system improvements/retrofits for co-processing

Solid alternative fuel combustion behavior differs from that of coal in several ways (Jensen 2008):

- The pyrolysis rate has a greater influence on alternative fuel burnout.
- Diffusion of oxygen limits alternative fuel combustion rate to a greater extent than it limits the combustion rate of coal.
- Temperature does not have a strong effect on burnout of alternative fuel.
- Particle size is not simply related to the sieve residue of alternative fuel.

Figure 36 shows the relationship between particle size and burnout time of different types of solid fuel. Solid alternative fuels usually have a higher burnout time because of their larger particle size compared to that of coal. This can cause operational problems in a normal cement plant unless the plant design accounts for this phenomenon (Jensen 2008).

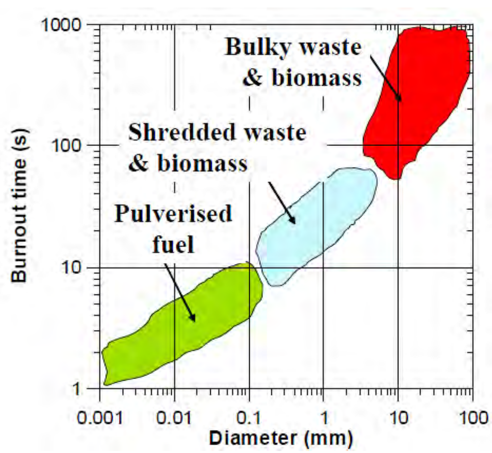

Figure 36. Relation of particle size and burnout time for different types of fuel used in cement kilns (Jensen 2008)

Calciner configurations and retrofits

Different calciner configurations facilitate use of various alternative fuels with different properties and address the abovementioned issue of burnout time (Figure 37). For shredded waste and biomass, the extended calciner residence time provides enough time for fuel burnout whereas for bulky biomass and waste streams, design changes are required (Figure 36), such as installation of additional equipment (for example, KHD Humboldt Wedag's combustion chamber or FLSmidth's HOTDISC).

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[17] http://www.pillard.de/
[18] http://www.polysius.com/
[19] http://www.unitherm.co.at/

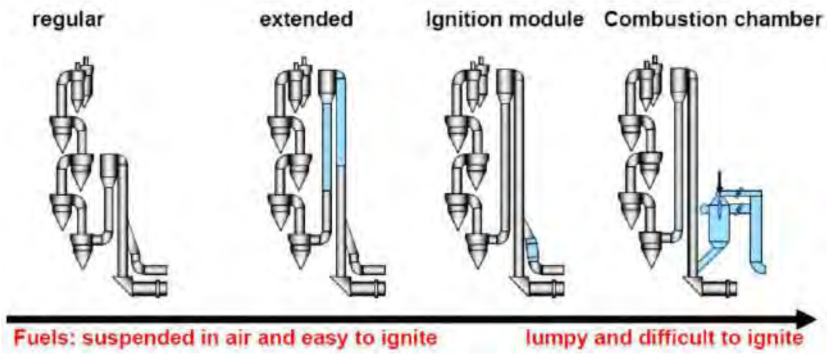

Figure 37. Different calciner configurations for co-processing alternative fuels (Hand 2007)

KHD Humboldt Wedag's combustion chamber is a new addition to kiln system components. It allows increased use of low-quality alternative fuels in co-processing (Figure 38). The combustion chamber has been in operation at a cement plant in Norway since 2004. Since the retrofit, 60 percent of the total fuel used in the kiln system is fed through the combustion chamber. The fuel composition is 6-percent coal/petcoke/animal meal mix, 16-percent solid hazardous waste, and 38-percent fluff RDF (Hand 2007).

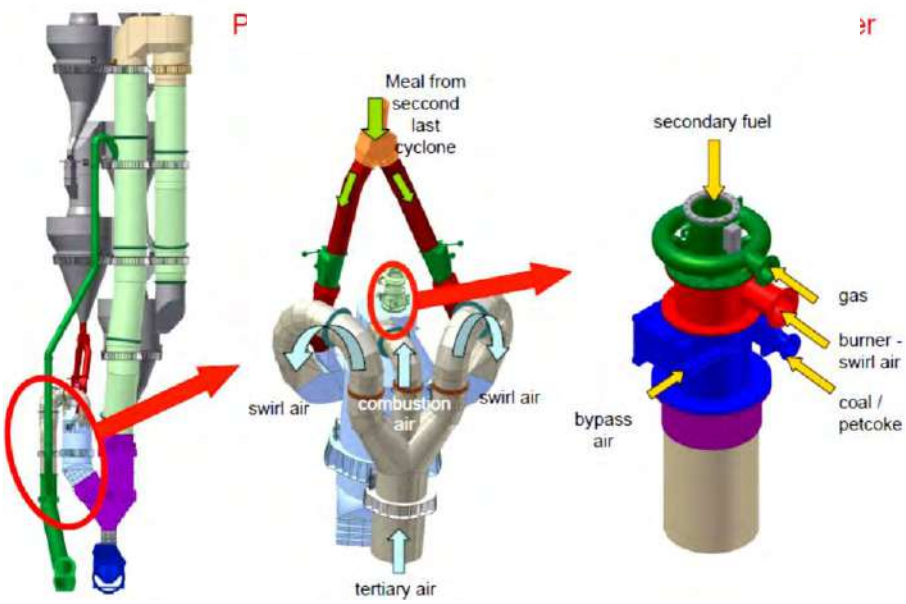

Figure 38. Precalciner with KHD Humboldt Wedag's combustion chamber (Hand 2007)

Another major cement technology supplier, FLSmidth, provides calciner solutions, including the HOTDISC, for co-processing alternative fuels (Jensen 2008). The HOTDISC is added to the calciner and functions as a moving hearth furnace. When alternative fuel, preheated raw meal, and tertiary air are fed into the HOTDISC, it produces combustion gases, partly calcined meal, and combustion residues. These are then processed in the calciner along with the other streams (Figure 39). The result is calcined meal ready for the kiln, with well-controlled emissions. The heat content of the alternative fuels is used for calcination. The extra residence time for the fuel minimizes volatile circulation and blockages at the kiln inlet (FLSmidth 2011).

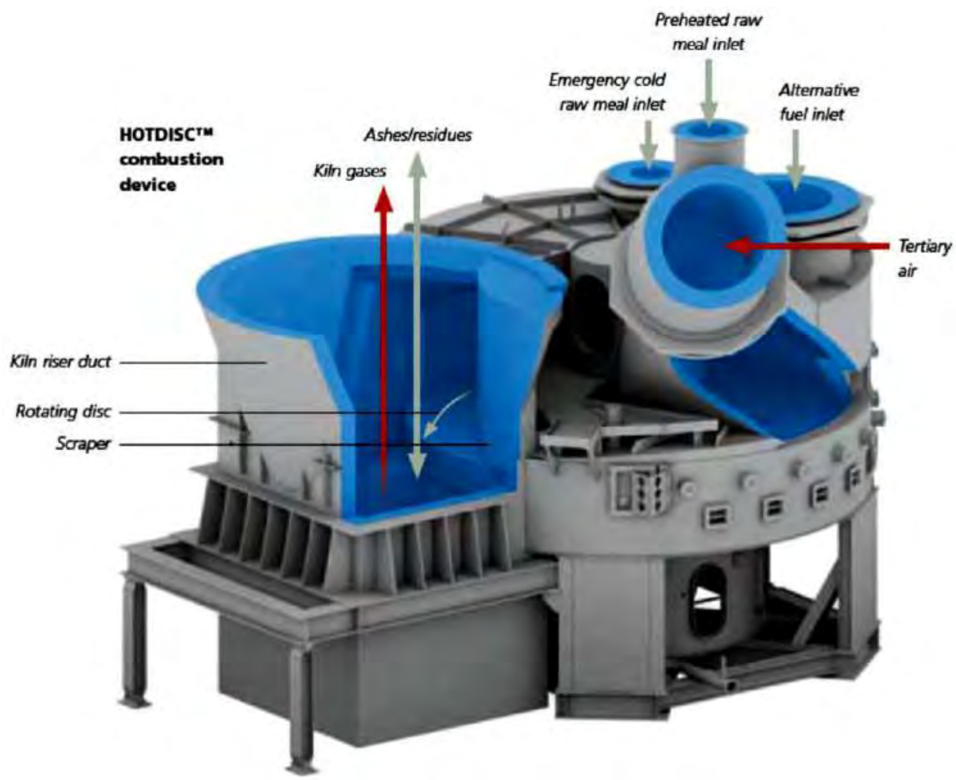

Figure 39. FLSmidth's HOTDISC (FLSmidth 2011)

Mixing air technology for the kiln

Higher-temperature O_2-rich gases tend to travel along the top of the kiln, and cooler, CO_2-rich gases tend to travel along the bottom. This gas stratification inhibits the combustion process, limits alternative fuel usage, and contributes to emissions. Adding high-velocity opposing streams of mixing air causes the stratified kiln gas layers to rotate and mix (Figure 40). This rotation improves combustion and allows for increased alternative fuel use, significant NOx reduction, lower emissions, less sulfur buildup, improved thermal efficiency, and overall better product quality (ALF-CEMIND 2012).

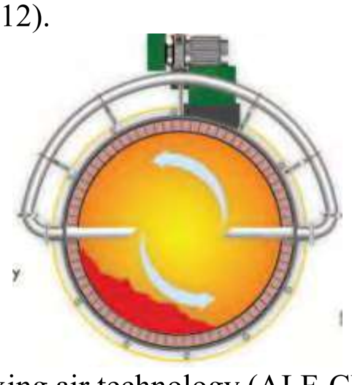

Figure 40. Mixing air technology (ALF-CEMIND 2012)

Pneumo-swirl-device for solid waste fuel co-firing

Solid waste fuels are conveyed by compressed air through a piping system to the burner. The waste fuel channel inside the burner is basically a pipe of the same diameter as the fuel conveyor pipe. The Pneumo-swirl-device can be installed at the hot end of this pipe and sets the fuel flow into a defined rotation. The air necessary to create this rotation is taken from the burner's primary air pipe system, so compressed air is not necessary. The Pneumo-swirl-device has slots around the circumference of the waste fuel pipe (ALF-CEMIND 2012). A low swirl intensity results in a large throwing length, and a high swirl intensity increases the throwing angle so that alternative fuel is deflected into the flame, and the time for burnout is extended as well (Figure 41).

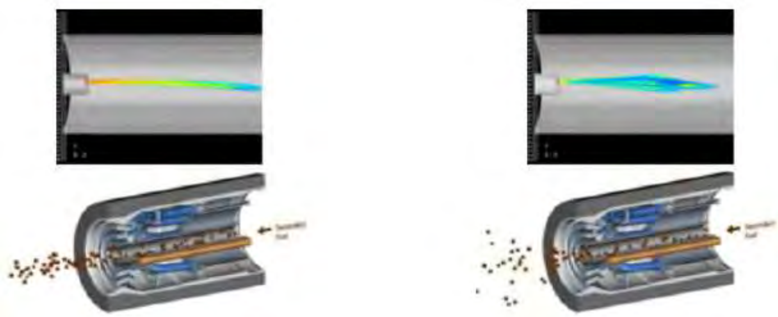

Figure 41. Low swirl intensity (left) and high swirl intensity (right) provided by the Pneumo-swirl-device (Unitherm Cemcon 2012)

4.4. Product Quality Control Systems

Depending on the amounts of alternative raw materials and fuels used in co-processing, the concentration of individual elements in the final product can increase or decrease compared to the results with traditional fossil fuels. As cement is blended with aggregate, e.g., gravel and sand for the production of concrete or mortar, the behavior of these trace elements in the building material (concrete or mortar) is a critical determinant of environmental impacts of the co-processed product as well as impacts on the product quality (CEMBUREAU 2009).

Heavy metal releases from concrete and mortar are minimal because these metals remain firmly trapped in the product. Independent tests on concrete and mortar have shown that the leaching of heavy metal concentrations is significantly below limits prescribed by national legislations. In addition, as noted earlier, according to the European Cement Industry Association, environmental releases have not been detected when products containing heavy metals are stored under extreme conditions (CEMBUREAU 2009).

Phosphate content influences cement setting time. Chlorine (which should be less than 0.1 percent in cement), sulphur, and alkali content all affect overall product quality. Thus, the amount of these elements in clinker and cement should be monitored closely at plants where waste is co-processed. Thallium and chromium content should also be monitored in cement kiln dust and final products because of possible allergic reactions in sensitive users (Stockholm Convention 2006).

4.5. Emissions and Air Pollution

Cement kiln emissions result from physical and chemical reactions of raw materials and from combustion of fuels. The main constituents of kiln exit gases are nitrogen from the combustion air, CO_2 from calcination and combustion, water from the combustion process and raw materials, and excess O_2. The exit gases also contain small quantities of dust, chlorides, fluorides, SO_2, NOx, CO, and even smaller quantities of organic compounds and heavy metals (Stantec 2011).

4.5.1. Impact of co-processing on kiln emissions

The impact of waste co-processing on emissions from cement manufacturing is relatively minor if co-processing is done correctly and in compliance with strict regulations. Nonetheless, it is important to compare the presence of nitrogen, sulphur, chlorine, and other elements in the waste fuel with the concentrations of these elements in fossil fuels. The subsections below discuss some of these important elements in more detail.

Sulphur

Because clinker has an alkaline matrix, the presence of sulphur in waste fuels does not result in critical levels of sulphur gas emissions. However, the possibility that sulphur might react with different metals in raw meal must be considered. The concentration of sulphur in substitute fuels is generally much lower than the reference value in conventional fossil fuels (0.1-0.2 percent in RDF, 3-5 percent in fossil fuels). Therefore, there is no problem of precipitation or clogging from sulphur in alternative fuels. However, issues of alkali sequestration and transfer in the clinker must be assessed (Genon and Brizio 2008).

NOx

Nitrogen is responsible for the formation of NOx. In general, formation of NOx is related to the amount of nitrogen in the fuel, the temperatures in the kiln, the residence times, and the types of burners (Genon and Brizio 2008). RDF has low nitrogen content (0.3-0.5 percent) in comparison with fossil fuels (1.5-2 percent). Overall, alternative fuels do not lead to higher NOx emissions and, in some cases, NOx emissions can even be lower when waste fuels are used (Genon and Brizio 2008). A rotary kiln in which raw materials are sintered at a temperature of 1,450°C using fossil fuel emits a large volume of NOx gas. When dewatered sludge is injected into the kiln, ammonia contained in the dewatered sludge decomposes NOx as follows:

$$2\ NH_3 + 2\ NO + 1/2\ O_2 \rightarrow 2\ N_2 + 3\ H_2O$$

where:
NH_3 = ammonia
NO = nitrogen oxide
N_2 = nitrogen dioxide
H_2O = water

Figure 42 shows an example of NOx emissions from a cement kiln where dewatered sludge is injected. Using sludge eliminates 40 percent of the NOx emitted when only traditional fuel (e.g. coal) is burned. Also, the small amount of primary air used in third-generation burners results in a low flame temperature and hinders the thermal conversion of sludge nitrogen to NOx

(Zabaniotou and Theofilou 2008). Nevertheless, the ratio of sludge in the fuel must be controlled carefully (Fytili and Zabaniotou 2008).

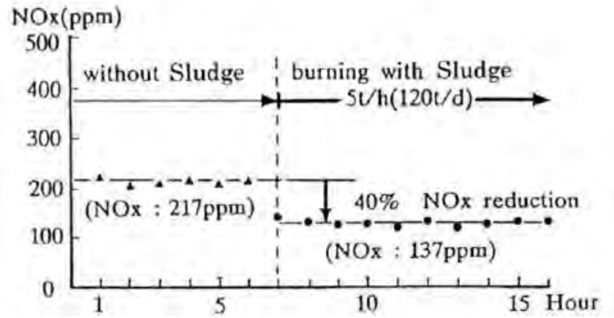

Figure 42. NOx Emissions of a cement kiln with and without co-processing of sewage sludge (Taruya et al. 2002)

Chlorine

The presence of chlorine in waste fuels can have both direct and indirect effects on cement kiln emissions and performance. Methods have been developed to manage chlorine and its potential effects, but it is important that these effects are recognized and managed. Trace levels of chlorine in feed materials can lead to the formation of acidic gases such as HCl and HF (WBCSD 2002). Chlorine compounds can also build up on kiln surfaces and lead to corrosion (McIlveen-Wright 2007). Introduction of chlorine into the kiln may also increase the volatility of heavy metals (Reijnders 2007) and foster the formation of dioxins.

Genon and Brizio (2008) indicate that the alkaline matrix of the clinker means that the presence of chlorine in substitute fuels does not result in critical levels of gaseous emissions. However, if the chlorine content of the fuel approaches 0.3-0.5 percent, this can lead to reactions between alkali and chlorine, the volatilization of chlorides and their recycling with dust, and the need to operate a bypass (extraction of part of the flue gas) to limit the chlorides in the final clinker. The high temperature of bypassed gases means increased heat consumption. Each percentage increase of bypassed gas requires approximately an additional 20-25 MJ/t of clinker, compared to a total energy consumption of 3,000-3,500 MJ/t in the cement kiln (Genon and Brizio 2008).

Heavy Metals

The use of suitable waste has only a minor influence on metal emissions because of the high retention of metals in the finished product. Non-volatile metals tend to be bound almost completely in the clinker matrix. Semi-volatile metals such as Pb or Cd tend to be captured in the clinker stream or in dust (EIPPCB 2010). A study using the U.S. EPA's toxicity characteristic leaching procedure to test the mobility of heavy metals in clinker when exposed to acidic conditions found that only Cd could be detected in the environment, and it was at levels below regulatory standards, which is 5 parts per million (ppm) (Shih 2005). Highly volatile metals such as Hg and Cd are of primary concern because they tend to vaporize and leave the kiln system (EIPPCB 2010). In traditional incineration processes, Hg (and other heavy metal) emissions are effectively controlled with the combination of a wet scrubber followed by carbon injection and a fabric filter. Similar control options are under development for cement kilns including using adsorptive materials for Hg capture (Peltier 2003; Reijnders 2007). At present, the use of dust removal devices like electrostatic precipitators and fabric filters is common practice, but these devices respectively capture only about 25 percent and 50 percent of potential Hg emissions (UNEP Chemicals 2005). The only way to effectively control the release of these volatile metals from cement kilns is to limit their concentrations in the raw materials and waste fuel (Mokrzycki et al. 2003; UNEP Chemicals 2005).

Normally, mercury in sludge comes from either the cleaning process at the sewage plant or from the incoming sewerage where it is present (Zabaniotou and Theofilou 2008). Giant Cement, in the United States, limits the Hg and Cd contents in alternative fuels for their kilns to less than 10 ppm and 440 ppm, respectively. These limits are significantly lower than those for other metals such as Pb, chromium, and zinc, which can be as high as 2,900, 7,500, and 90,000 ppm, respectively (Murray and Price 2008).

Dioxins and furans
The Stockholm Convention requires parties to reduce or eliminate releases of POPs that result from intentional production and use, from unintentional production, and from stockpiles and wastes (Stockholm Convention 2006). The formation of POPs such as PCDDs and PCDFs is a recognized concern for cement manufacturing. PCDDs and PCDFs have the potential to form if chlorine is present in the input fuel or raw materials. Formation can be repressed, however, by the high temperatures and long residence times that are standard in cement kilns (Karstensen 2008).

As noted earlier, the location at which waste materials are fed into the kiln system is an important factor. In this case, wastes that are fed into the main firing system tend to reach high enough temperatures and achieve long enough retention times to limit PCDD/PCDF emissions. Wastes fed into the secondary firing zone might not reach high enough temperatures or achieve long enough retention times (EIPPCB 2010). PCDD/PCDF formation is further minimized by limiting the concentration of organics in the raw material mix and by quickly cooling the exhaust gases in wet and long dry kilns. Evidence from several operating kilns suggests that preheater/precalciner kilns have slightly lower PCDD/PCDF emissions than wet kilns (WBCSD 2002; Karstensen 2008).

Numerous studies comparing PCDD/PCDF formation in kilns using conventional and waste-derived fuels have found no significant difference in the emissions from the two (Murray and Price 2008; EIPPCB 2010). Karstensen (2008) reviewed more than 2,000 PCDD/PCDF cement kiln measurements from various studies representing most production technologies and waste feeding scenarios. The data generally indicate that most modern cement kilns can meet an emissions level of 0.1 ng I-TEQ/m^3 and that responsible use of organic hazardous and other wastes to replace a portion of fossil fuels is not an important factor influencing the formation of PCDD/ PCDFs (Karstensen 2008).

Lafarge investigated the possible effect of feeding different wastes to the lower-temperature preheater/precalciner. Table 16 presents the results. Wastes injected at mid or feed-end locations do not experience the same elevated temperatures and long residence times as wastes introduced at the main burner. The observed concentration level of PCDD/PCDFs was low in all measurements. The reported data indicate that cement kilns can comply with an emissions level of 0.1 ng I-TEQ/Nm^3, which is the limit in several western European countries' legislation governing hazardous waste incineration plants (Karstensen 2006).

Table 16. Influence of feeding wastes to the preheater/precalciner on PCDD/PCDF emissions (Karstensen 2006)

Plant	Type of alternative fuel	PCDD/F emissions in ng I-TEQ/Nm3
1	Animal meal, plastics, and textiles	0.0025
2	Animal meal and impregnated sawdust	0.0033
3	Coal, plastic, and tires	0.0021 & 0.0041
4	Tires	0.002 & 0.0060
5	Petcoke, plastic, and waste oil	0.0010
6	Petcoke, sunflower shells, and waste oil	0.01200
7	Tire chips	0.004 & 0.02100
8	Solvents	0.0700
9	Impregnated sawdust and solvents	0.00003 & 0.00145
10	Solvents	0.00029 & 0.00057
11	Sludge	<0.0110
12	Car waste and sludge	0.0036 & 0.07 & 0.0032

For other emissions, the European Commission and CEMBUREAU summarize assumed impacts of waste co-processing as follows (CEMBUREAU 2009; EIPPCB 2010):

- Dust emissions are unaffected by co-processing wastes.
- The alkaline kiln environment removes any traces of HCI and HF produced during firing.
- CO is largely unaffected.
- There is no correlation between the use of alternative fuels and TOC emissions levels.

Table 17 shows an example of using RDF as a fuel source on the emissions profile of a typical cement kiln.

Table 17. Example of emissions profile from a cement kiln using RDF (Stantec 2011)[20]

Parameter	Measure	Individual Measurements	
		No Utilization of Wastes	Utilization of Wastes
Total Particulate	mg/m3	2.8 – 12.90	12.0 – 15.900
HCl	mg/m3	0.88 – 5.93	0.87 – 1.320
SOx	mg/m3	714 – 878.00	311 – 328.000
HF	mg/m3	0.13 – 0.23	0.02 – 0.040
NOx	mg/m3	789 – 835.00	406 – 560.000
Total Carbon	mg/m3	11.7 – 23.20	5.7 – 7.100
PAHs *	mg/m3	–	0.003
Benzene	mg/m3	0.27 – 0.540	0.45 – 0.550
Cd	mg/m3	<0.005	<0.007
Tl	mg/m3	<0.005	<0.005
Hg	mg/m3	0.014 – 0.044	0.003 – 0.006
Sum of Sb, As, Pb, Cr, Co, Cu, Mn, Ni, V, Sn	mg/m3	<0.300	<0.500
PCDD/PCDF, I-TEQ	mg/m3	0.001 – 0.002	0.005 – 0.006

* PAH = polycyclic aromatic hydrocarbon

[20] Note: although the report cited does not specify the original sources of the waste in each application, RDF in Germany is generally derived from processing MSW materials (not including specialized waste streams such as construction/demolition materials). Also it should be noted that although the monitoring approach for each parameter is not described in the report, cement kilns in the EU and North America typically use CEMs for parameters such as SOx and NOx and periodic stack testing for other parameters (PAHs, metals).

4.5.2. Emissions Control Techniques

Continuous measurement is the BAT to accurately quantify the following emissions parameters: exhaust volume, humidity, temperature at particulate matter control device inlet, dust/particulate matter, O_2, NOx, dust, SO_2, CO. Regular, periodic monitoring is the BAT for the following substances: metals and their compounds,[21] total organic carbon/organic components, HCl, HF, NH_3, PCDD/PCDF. Measurements of the following items might be required occasionally under special operating conditions (Stockholm Convention 2006):

- Destruction and removal efficiency of POPs in cement kilns
- Benzene, toluene, xylene
- Polycyclic aromatic hydrocarbons (PAHs)
- Other organic pollutants (principal organic hazardous constituents, e.g., chlorobenzenes, PCBs including coplanar congeners, chloronaphthalenes).

Figure 43 shows an overview of measurement points for cement plant emissions. Emissions control in cement kilns primarily uses bag houses to capture particulate matter from the flue gas; this also controls emissions of most heavy metals. More modern facilities or retrofitted plants may be equipped with NOx control, specifically Selective Non-Catalytic Reduction (SNCR). Emissions of other parameters, such as POPs or acid gases, are generally controlled through the operating characteristics of cement facilities (Stantec 2011).

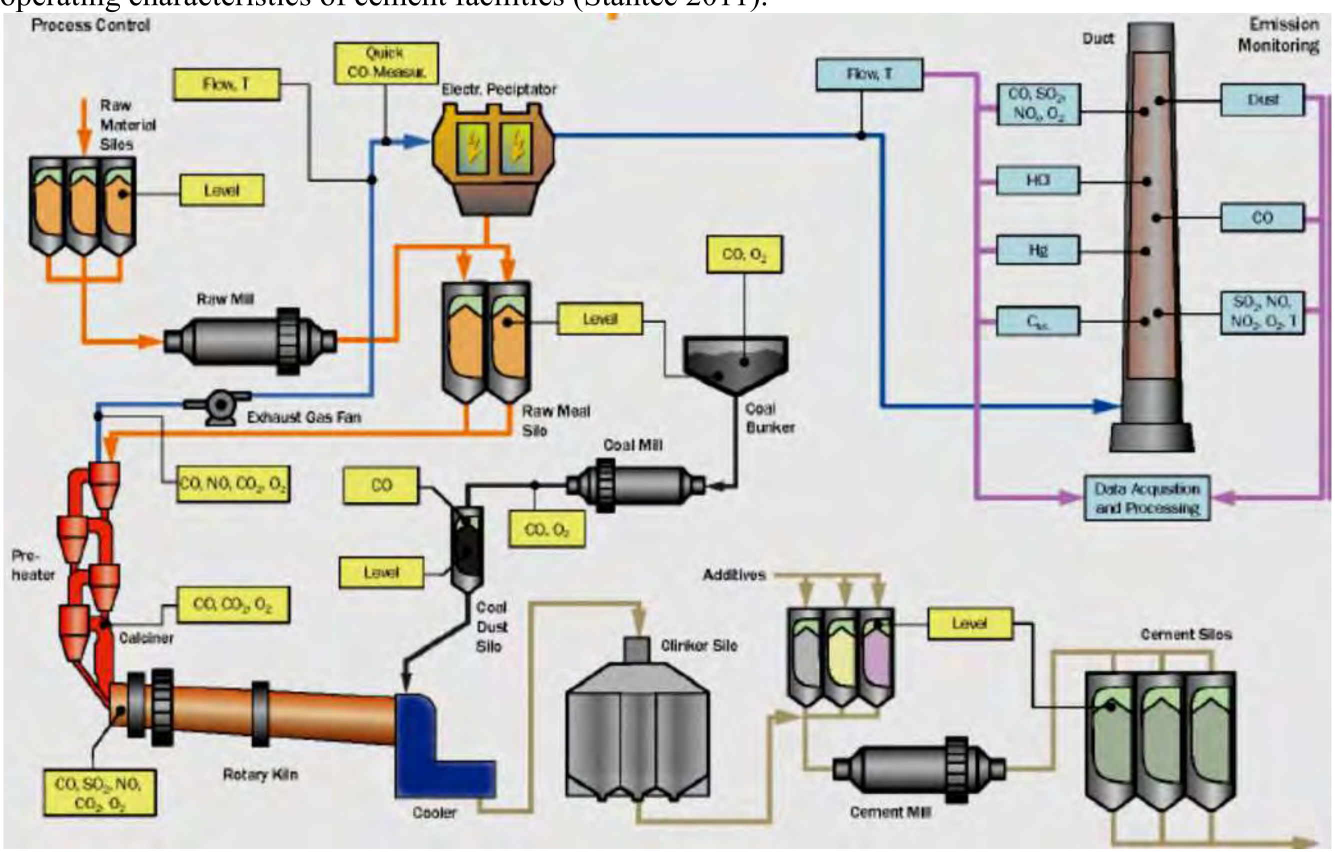

Figure 43. Overview of measurement points in a cement plant (Kolyfetis 2007)

[21] It is especially important to measure metals when wastes with higher metal content are used as raw materials or fuels.

Greer (2003) identifies existing and potential control technologies for gaseous pollutants from Portland cement manufacturing (Appendix 6). Karstensen (2007a and 2008) also explains emissions control technologies for the cement industry. IPPC provides the BAT for emissions control and associated emission levels for the cement industry in the European Union (EIPPCB 2010). In addition, guidance on BAT for preventing or minimizing the formation and subsequent release of unintentional POPs from cement kilns that co-process hazardous waste has been published by the Stockholm Convention Secretariat (UNEP, 2007).

4.5.3. Continuous emissions monitoring system

CEMS determines gas or particulate matter concentrations or emissions rates using pollutant analyzer measurements and a conversion equation, graph, or computer program to produce results in units of the applicable emissions limit or standard. CEMS is a useful tool in gathering process emissions data to demonstrate environmental compliance and to control and optimize plant processes. CEMS is required under some of the U.S. EPA and EU regulations for either continual compliance determinations or determination of exceedances of standards (U.S. EPA 2012c).

For each pollutant and parameter identified by regulations, emissions levels and values should be assessed for scenarios that occur during kiln operation: startup, shutdown, compound or direct mode (gas passing through raw mill or direct to dust collector), and for the various raw materials and fuels mixes. The measurement ranges should be set in accordance with permit conditions and expected concentrations. Particular attention should be paid to sampling, e.g., following the sampling procedures in ISO 10396:2007 "Stationary sources emissions – Sampling for the automated determination of gas emission concentrations for permanently-installed monitoring systems" (WBCSD 2012a).

Selection of CEMS technology depends on various factors such as (SICK Sensor Intelligence, No date):

- Gas conditions
- Reliability of the analyzer according to gas conditions
- Measurement task
- Type and number of measured components
- Type of fuel
- Operation costs
- Requirements imposed by local regulations (current and future)

There are different types of CEMS. Two general categories of CEMS are extractive and in-situ technologies (Figure 44). The most widely used type of CEMS is an extractive system in which a sample of gas is continuously drawn from the process point, filtered, transported, conditioned, and presented to a gas analysis system. Gas concentrations are measured, recorded and stored as data that are used to generate reports or alarms or control an aspect of the plants' process. Hardware for an extractive CEMS generally consists of the following major subsystems (K2BW 2012):

- Sample transport and conditioning

- Sample gas analysis
- Data acquisition, reporting, and system control

Extractive CEMS

In situ (right) CEMS

Figure 44. Extractive (left) and in-situ (right) CEMS technologies (SICK Sensor Intelligence no date)

Appendix 7 gives the recommended method for using CEMS to determine each type of pollutant emitted by a cement plant. Appendix 8 presents the standards for cement plant emissions measurements.

4.6. Health and Safety Practices

It has been demonstrated that waste co-processing can be accomplished in an environmentally sound manner; however, improper design or operation can result in a threat to community and worker health. Although cement kilns have all the desirable properties for efficient thermal destruction of many hazardous wastes, many cement kilns were not designed for this purpose and require modification of the fuel injection system and construction of waste-receiving facilities before they can process wastes. These facility modifications should be carefully designed and monitored to ensure that environmental and health risks are minimized (Karstensen 2007a).

After a kiln is modified to accept wastes and a test burn has demonstrated that the system operates in a manner that protects human and environmental health, a quantitative risk assessment should be conducted to determine the potential for adverse health impacts within the community and among kiln employees. Risks associated with these four major elements of the plant process should be assessed:

1. Transportation
2. Storage and handling
3. Kiln emissions
4. Clinker contamination

The first three of these risks can be evaluated in terms of three separate components: 1) risk of toxic material release, 2) risk of human exposure, and 3) risk of adverse health effects. All types of risk related to the co-processing of wastes require knowledge of the chemical properties of the waste and of the byproducts from waste combustion. This knowledge is necessary for calculating the expected fate and transport of the pollutants in the environment (Karstensen 2007a).

Easily understandable safety and emergency instructions should be provided to employees and contractors in a timely manner before co-processing begins or before new materials are added to the system. Hazards relating to new materials should be reviewed with operating staff prior to their use in the facility. Conducting a job safety analysis can be part of identifying hazards and potential exposures, along with appropriate control practices and techniques (WBCSD 2005).

Emissions to air from waste pre-processing will depend on the types of wastes treated and the processes used. Emissions must be monitored and reported according to operating permits and applicable regulations. Abatement techniques should be in place as needed. Dust is usually reduced by bag filters. Counter measures for noise and odors should be considered. Common emission control methods for VOCs include carbon adsorption, thermal treatment and, in specific cases, biological treatment (Basel Convention 2011).

Discharges of wastewater to surface water should not result in contaminant concentrations in excess of local ambient water quality criteria. Discharges to public or private wastewater treatment systems should meet the pre-treatment and monitoring requirements of the treatment system and should not interfere, directly or indirectly, with the operation and maintenance of the system, pose a risk to worker health and safety, or adversely impact characteristics of residuals from the wastewater treatment operation (Basel Convention 2011).

If co-processing of MSW and sewage sludge is done correctly and in accordance with strict environmental and emissions regulations, it should pose no additional environmental and health risk compared to using fossil fuels. Rovira et al. (2011) conducted a study in Spain showing that the human health risks for the population living around the cement plant of Vallcarca, which co-processes sewage sludge, are comparable to those in previous studies performed when petroleum coke was exclusively used as fuel. Emissions were in both cases acceptable according to international standards (Rovira et al. 2011). Another study in Spain by Schuhmacher et al. (2009) for a different cement plant confirmed that using sewage sludge in the plant did not increase health risks related to metals and PCDD/PCDFs for individuals living in the vicinity of the plant (Schuhmacher et al. 2009).

A study by Zabaniotou and Theofilou (2008) in Cyprus assessed the effects of co-processing of wet sewage sludge (moisture content 65-70 percent) at a cement kiln. Environmental gaseous emissions were measured, with emphasis on heavy metal concentrations (especially Hg). The authors concluded that co-processing of sewage sludge does not emit PCDDs/PCDFs harmful to human health (Zabaniotou and Theofilou 2008).

It should be noted that in the above examples, the cement plants were complying with the stringent environmental and emissions standards of the respective countries and were taking necessary actions to keep the emissions below the permitted levels.

For more complete discussion of the health and safety issues related to co-processing of waste in cement plants, see GTZ/Holcim (2006). For broader information on health and safety in the cement industry, see the work of the Cement Sustainability Initiative's Task Force 3 on health and safety (WBCSD 2012b).

5. Summary

This report reviews international best practices for pre-processing and co-processing of MSW and sewage sludge in cement plants. The report explains the fundamentals of co-processing, examples of best international regulatory and institutional practices related to co-processing, and best international practices related to technological aspects of pre- and co-processing.

There are different reasons and motivation for co-processing waste in the cement industry. These include: fuel cost savings particularly in the face of the rising fuel prices, conservation of nonrenewable fossil fuels and protection of the environment from the activities associated with obtaining virgin fuels, reduction of greenhouse gas emissions, advantages of co-processing over waste incineration and landfilling, integration of waste ash into clinker, and avoidance of new investment in incinerators or landfill facilities, among others.

Different studies from around the world have shown that if co-processing of MSW and sewage sludge is done correctly and in accordance with strict environmental and emissions regulations, there is no additional environmental and health risk associated with using waste fuels compared to using fossil fuels for cement production.

The polluter pays principle must be applied to the economic analysis of co-processing. This principle holds that those who produce waste (e.g., industry) or are responsible for its handling (e.g., municipalities) are responsible for and should bear the cost for environmentally sound management of that waste.

Some policies can make the use of MSW and/or sewage sludge in cement production more economically attractive. These include restricting the landfilling of MSW and or sewage sludge, increasing fossil fuel prices, enacting a carbon tax, or enacting carbon trading schemes, among others.

Effective regulatory and institutional frameworks are critical to ensure that co-processing practices in the cement industry are not harmful to health or the environment. An integrated solid waste management model and regulations and standards related to environmental performance, product quality, operations and safety, permitting, and monitoring and reporting are key elements in a regulatory framework for a sustainable co-processing industry. Experiences around the world over several decades have resulted in effective policy measures and practices. Countries that are developing a co-processing industry can learn from these experiences, many of which are cataloged in this report, in designing and implementing an environmentally sound co-processing industry.

From the technological perspective, pre-processing and treatment of waste are often required to make the waste ready for co-processing in cement kilns. A number of retrofits are required and often new installations and technologies are needed at the plant site to enable storage, conveyance, dosing, feeding, and co-processing of MSW and sewage sludge as well as the measurement and control of emissions. As much as possible, BATs should be applied to the pre- and co-processing processes in order to ensure that waste co-processing in the cement industry is environmentally sound.

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Appendices

Appendix 1. Cement Production Processes and Energy Use

Mining and Quarrying

The most common raw materials used in cement production are limestone, chalk, and clay, with limestone or chalk forming the majority of the ingredients in cement. These materials are usually extracted from a quarry adjacent or very close to the cement plant. Limestone provides calcium oxide and some of the other oxides; and clay, shale, and other materials provide most of the silicon, aluminum, and iron oxides required for the manufacture of cement. Approximately 5 percent of CO_2 emissions from cement production are associated with quarry mining and transportation (WWF 2008).

Raw Material Grinding and Preparation

Grinding raw materials for cement is an electricity-intensive step generally requiring about 25 to 35 kilowatt-hours (kWh)/t raw material. Grinding differs according to the type of process used in clinker production. In dry processing, the raw materials are ground into a flowable powder in horizontal ball mills, vertical roller mills, or roller presses. Materials might be dried using waste heat from the kiln exhaust or clinker cooler hood, or auxiliary heat from a stand-alone air heater. The moisture content in the dry feed is typically around 0.5 percent but can range from 0 to 0.7 percent. When raw materials are very moist, as is the case in some countries and regions, wet processing may be preferable. In the wet process, raw materials are ground in a ball or tube mill with the addition of water to produce a slurry whose water content ranges from 24 to 48 percent but is typically 36 percent (Worrell and Galitsky 2004).

Clinker Production

Clinker production is the most energy-intensive stage in cement production, accounting for more than 90 percent of total cement industry energy use and virtually all of the fuel use. Kiln systems evaporate the inherent water in the raw meal, calcine the carbonate constituents (calcination),[22] and form cement minerals (clinkerization). The main type of high-heat or pyroprocessing kiln used today is the dry rotary kiln. A dry rotary kiln uses feed material with low moisture content (0.5 percent). The first dry kiln process was developed in the U.S. and did not involve preheating. Later developments added multi-stage suspension preheaters (cyclones) or shaft preheaters. More recently, precalciner technology was developed in which a second combustion chamber is added between the kiln and a conventional pre-heater that allows for further reduction of kiln fuel requirements. The typical fuel consumption of a dry kiln with four, five, or six-stage preheating can vary between 2.9 and 3.5 GJ/t clinker, and almost all the process-related CO_2 emissions from cement production are associated with calcination during clinker production. Once the clinker is formed in the rotary kiln, it is cooled rapidly to minimize the formation of glass and ensure the maximum yield of alite (tricalcium silicate), an important component for the hardening properties of cement. The main cooling technologies are the grate cooler or the tube or planetary cooler. In the grate cooler, which is most common today, the clinker is transported over a reciprocating grate through which air flows perpendicular to the clinker flow (Worrell and Galitsky 2004).

[22] Calcination is the process of heating a substance to a high temperature that is below the substance’s melting or fusing point, to change the substance’s physical or chemical constitution.

Finish Grinding
To produce powdered cement, nodules of clinker are finely ground in ball mills, ball mills combined with roller presses, roller mills, or roller presses. At this stage, 3 to 5 percent gypsum is added to control the setting properties of the cement. The amount of electricity used for raw meal and finish grinding depends strongly on the hardness of the materials (limestone, clinker, pozzolana, etc.) and the desired fineness of the cement as well as the amount of additive. Blast furnace slag is harder to grind and thus requires more grinding power. Traditionally, ball mills are used in finish grinding, but many plants use vertical roller mills as well. Modern state-of-the-art approaches utilize a high-pressure roller mill or horizontal roller mill (e.g., Horomill®). Finished cement is stored in silos; tested; and bagged or shipped in bulk on cement trucks, railcars, barges, or ships (Worrell and Galitsky 2004). Figure A.1 shows the steps of the cement production process using the NSP kiln.[23]

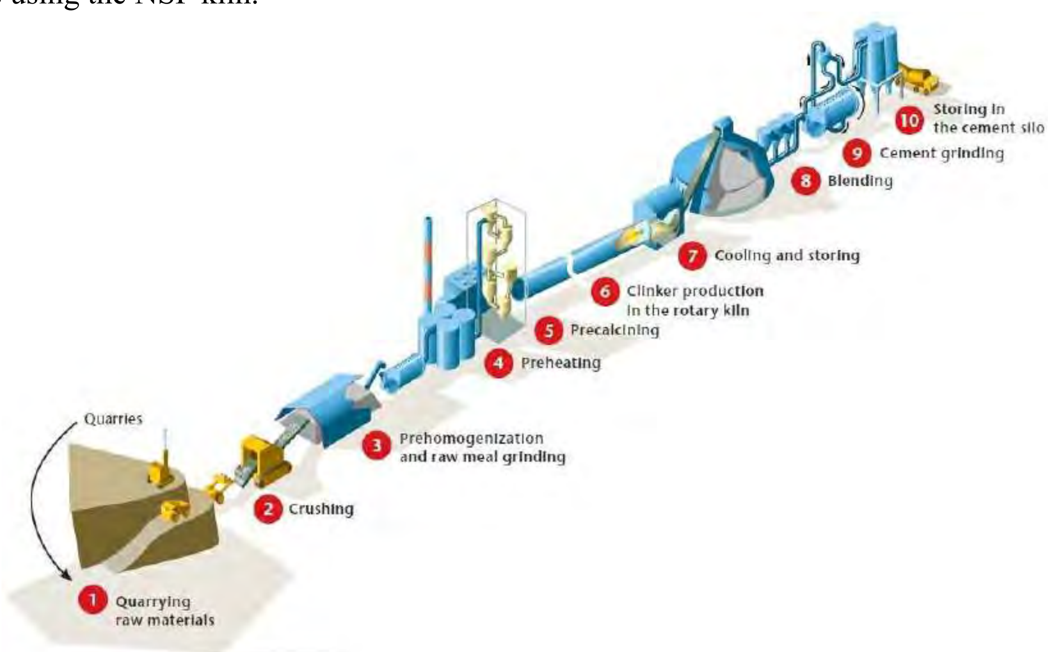
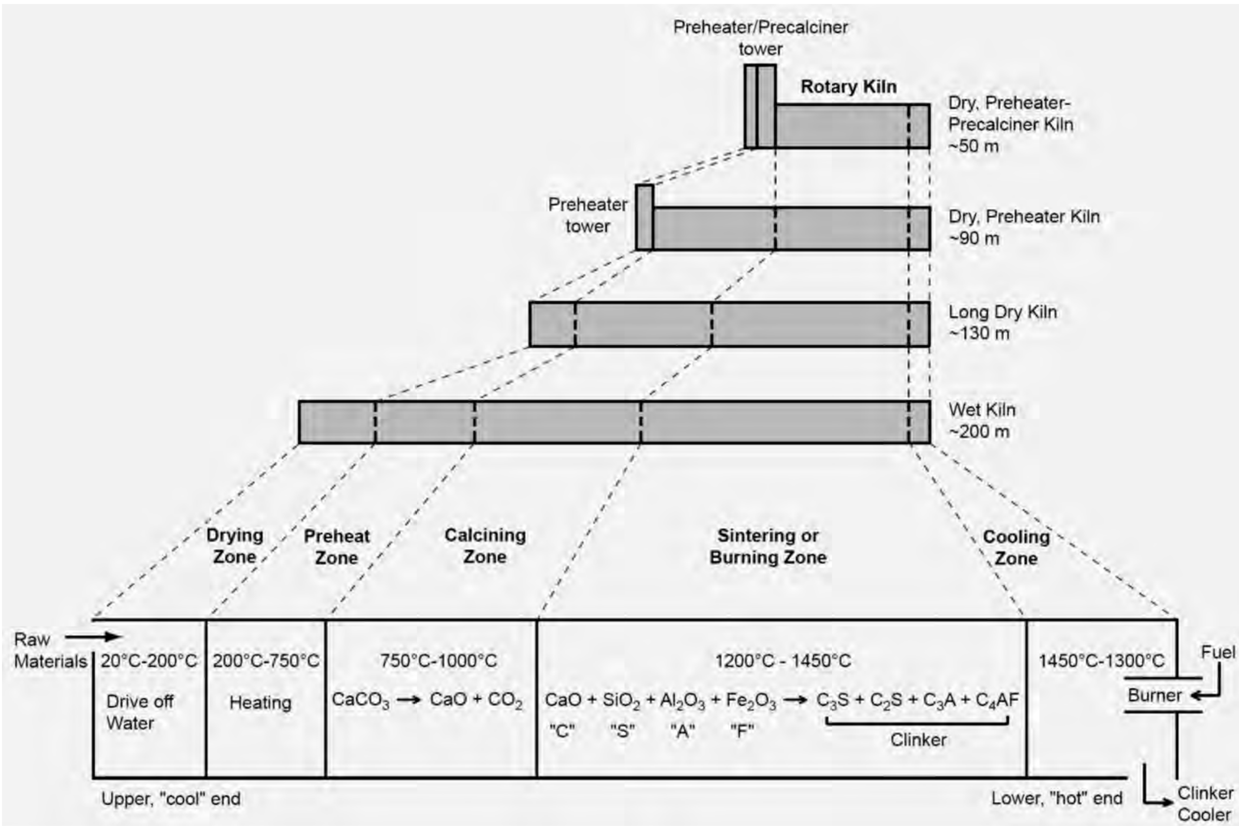


Figure A.1. Steps in the cement production process using the new suspension preheater and precalciner kiln (WBCSD/IEA 2009a)

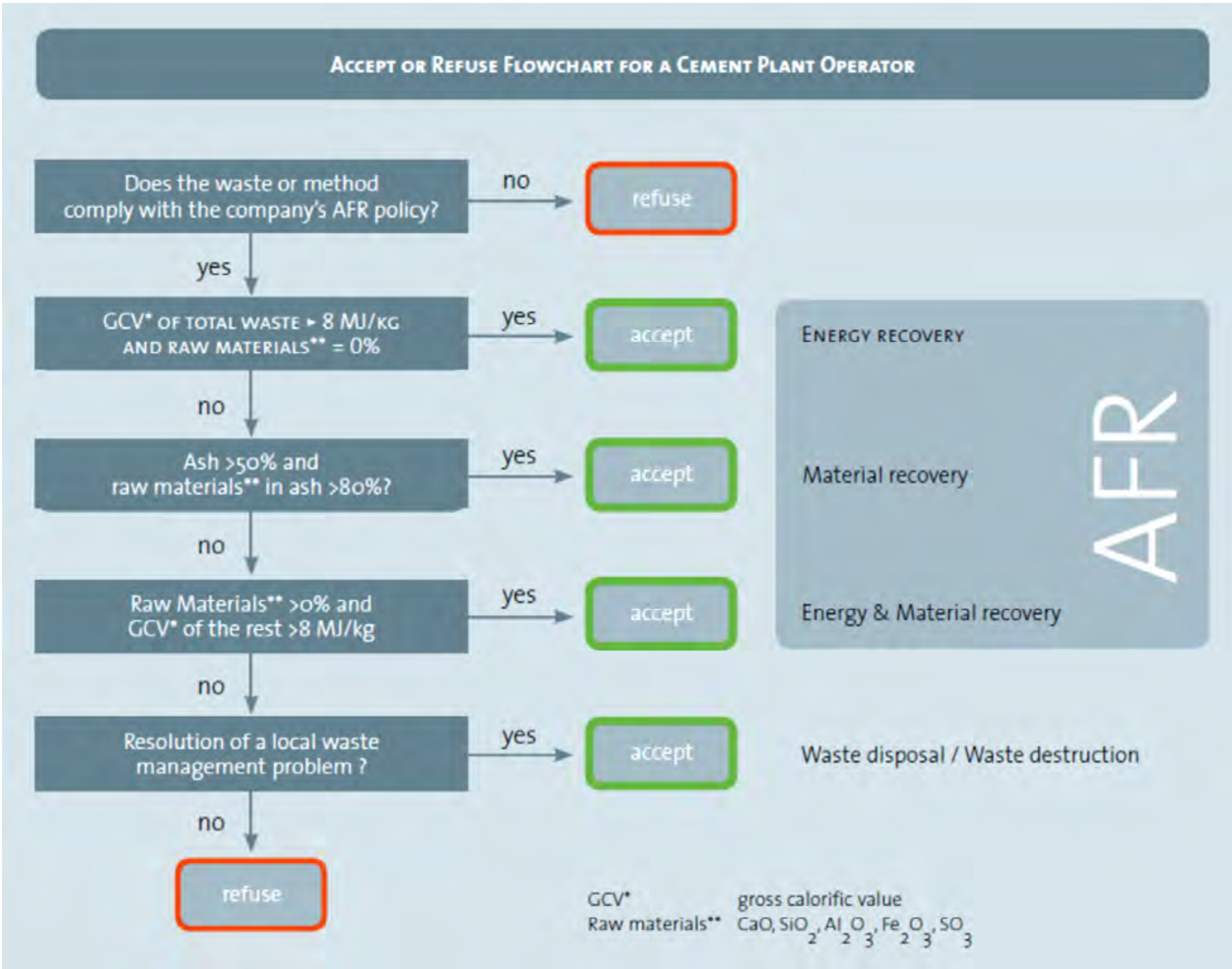
[23] This description of the cement production process is partially excerpted from Worrell and Galitsky (2004).

Appendix 2. Diagram of Reaction Zones for Different Kiln Technologies



Source: Van Oss (2005)

Appendix 3. Example of an Accept-Refuse Chart



Source: GTZ/Holcim (2006)

Appendix 4. Performance and Cost of RDF Production Lines

Table A.4.1. Performance and cost of fluff RDF production lines with varying input waste mixes (Caputo and Pelagagge 2002)

Line #	Line configuration	MSW input fraction (%)	Efficiency (%)	Moisture (%)	Ash (%)	LHV (kcal/kg RDF)	Production cost (Euro/t RDF)
1	PT–HS–MS–S–T–M–T	100	18.3	8.76	6.0	3478	16.56
2	T–HS–MS–S–T–M–T	100	24.9	9.05	6.67	3388	15.07
3	T–HS–MS–S–T–MS–M–T	100	24.3	9.0	6.28	3403	15.64
4	T–HS–MS–S–T–MS–M–T–MS	100	23.8	9.0	6.22	3406	16.18
5	T–HS–MS–S–T–ECS–M–T	100	24.1	9.1	5.3	3434	15.93
6	T–HS–ECS–S–T–ECS–M–T	100	24.0	9.1	5.28	3438	16.19
7	T–HS–MS–S–T–S–T–M–T	100	20.9	6.9	6.42	3546	20.15
8	T–HS–MS–S–T–MS–S–T–M–T	100	20.5	6.9	6.06	3559	20.78
9	T–HS–MS–S–T–ECS–S–T–M–T	100	20.3	6.9	5.23	3590	21.18
10	S–T–MS–M–T	100	30.7	10.7	8.5	3152	9.48
11	S–T–MS–S–T–M–T	100	24.7	7.4	7.7	3409	12.45
12	S–T–MS–S–T–MS–M–T	100	24.1	7.4	7.3	3424	12.97
13	S–T–ECS–S–T–MS–M–T	100	23.7	7.4	5.5	3488	13.37
14	S–T–ECS–S–T–ECS–M–T	100	23.6	7.4	5.3	3494	13.59
2	T–HS–MS–S–T–M–T	90	31.9	7.8	6.15	3792	12.26
7	T–HS–MS–S–T–S–T–M–T	90	28.2	6.0	5.9	3961	15.50
8	T–HS–MS–S–T–MS–S–T–M–T	90	27.8	5.9	5.7	3977	15.32
9	T–HS–MS–S–T–ECS–S–T–M–T	90	27.6	6.0	5.1	3999	15.60
15	T–HS–ECS–S–T–ECS–S–T–M–T	90	27.6	6.0	5.1	4001	15.76
10	S–T–MS–M–T	90	37.3	9.65	7.6	3544	9.26
11	S–T–MS–S–T–M–T	90	31.8	6.8	6.9	3804	10.17
2	T–HS–MS–S–T–M–T[a]	80	38.9	7.1	5.83	4050	11.85
10	S–T–MS–M–T	80	43.5	8.2	6.9	3846	9.68
11	S–T–MS–S–T–M–T	80	38.6	5.8	6.3	4083	10.19
2	T–HS–MS–S–T–M–T[a]	70	45.8	6.6	5.6	4230	10.47
10	S–T–MS–M–T	70	49.9	7.5	6.4	4060	7.54
2	T–HS–MS–S–T–M–T[a]	60	53.5	7.2	5.4	4310	9.12
10	S–T–MS–M–T	60	56.3	6.9	6.1	4225	6.82
2	T–HS–MS–S–T–M–T[a]	50	59.4	5.13	5.35	4499	8.47
10	S–T–MS–M–T	50	62.8	6.4	5.8	4355	6.12

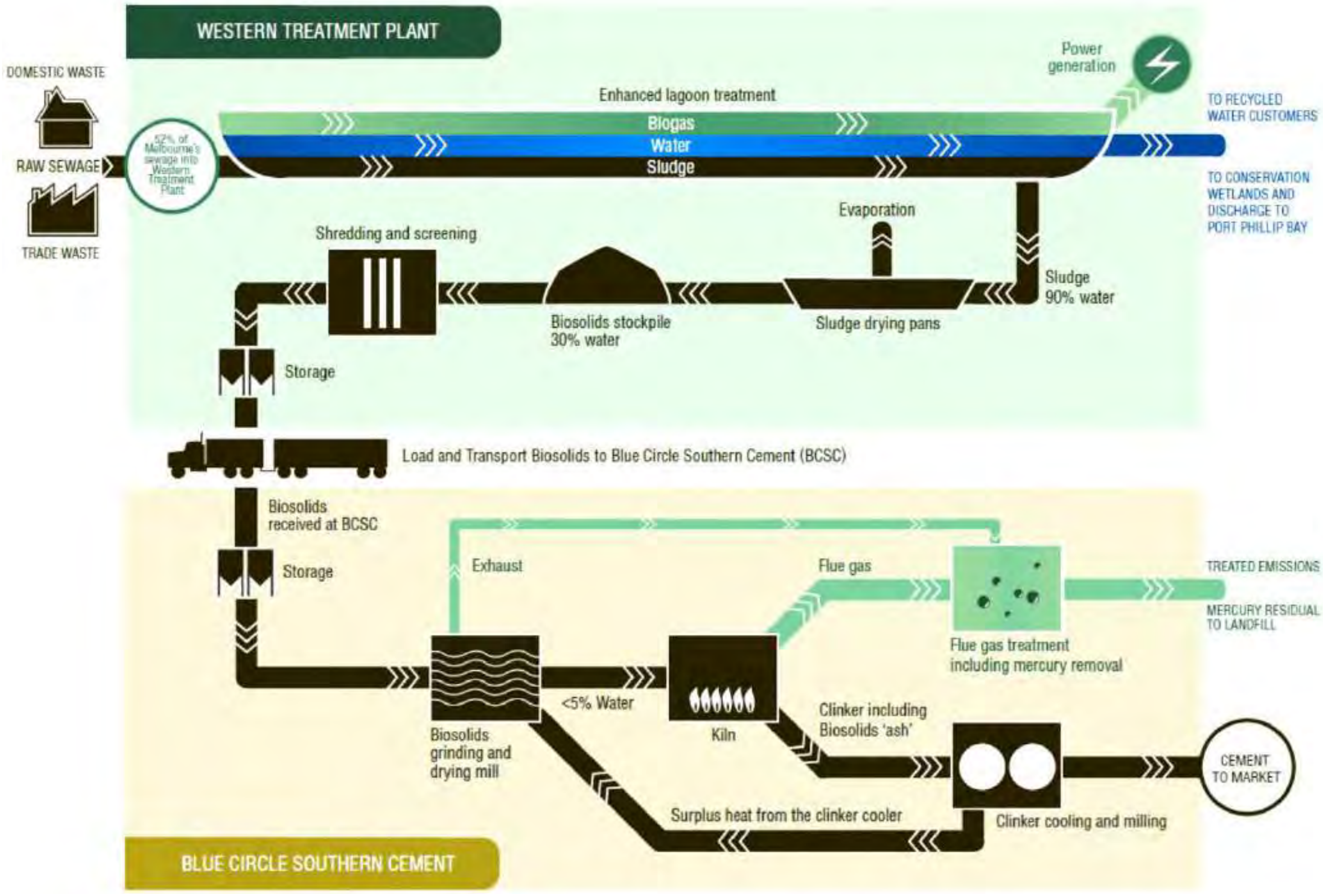
[a] Line suitable to feed a parallel compost producing plant.
ECS = eddy current separator
HS = hand sorting
LHV = low heating value
M = mill
MS = magnetic separator
PT = preliminary trommel screen
RDF – refuse-derived fuel
S = shredder
T = trommel screen

Table A.4.2. Performance and Cost of Densified RDF Production Lines with Varying Input Waste Mixes (Caputo and Pelagagge 2002)

Line #	Line configuration	MSW input fraction (%)	Efficiency (%)	Moisture (%)	LHV (kcal/kg RDF)	Production cost (Euro/t RDF)	
						Densified	Pelletized
2	T–HS–MS–S–T–M–T–DE/P[a]	80	38.9	7.1	4050	12.71	13.57
11	S–T–MS–S–T–M–T–DE/P	80	38.6	5.8	4083	11.05	11.92
2	T–HS–MS–S–T–M–T–DE/P[a]	70	45.8	6.6	4230	11.20	11.93
10	S–T–MS–M–T–DE/P	70	49.9	7.5	4060	8.21	8.88
2	T–HS–MS–S–T–M–T–DE/P[a]	60	53.5	7.2	4310	9.75	9.75
10	S–T–MS–M–T–DE/P	60	56.3	6.9	4225	7.42	7.42
2	T–HS–MS–S–T–M–T–DE/P[a]	50	59.4	5.13	4499	9.04	9.04
10	S–T–MS–M–T–DE/P	50	62.8	6.4	4355	6.65	6.65

[a] Line suitable to feed a parallel compost producing plant.
DE = densifier
HS = hand sorting
LHV = low heating value
M = mill
MS = magnetic separator
MSW = municipal solid waste
P = pelletizer
RDF = refuse-derived fuel
S = shredder
T = trommel screen

Appendix 5. Flow Diagram of Sewage Sludge Pre- and Co-processing Project in Australia



Source: Australian Cement Industry Federation (no date)

Appendix 6. Control Technologies for Gaseous Pollutants from Cement Manufacturing

Table A.6.1. Existing control technologies for gaseous pollutants from Portland cement manufacturing (Greer 2003)

Existing control technologies		Pollutant for which technology was intended	Potential effects: Synergetic	Potential effects: Counteractive
Inherent scrubbing		SO_2	Process specific	Process specific
O_2 / excess air control	Increase	SO_2, THC, CO		NOx, CO_2
	Decrease	NOx	CO_2	SO2, CO, product color and quality
Fuel substitution (lower sulfur)		SO_2	Fuel specific	Fuel specific
Raw material substitution containing	Lower sulfide	SO_2	Material specific	Material specific
	Lower organics	THC, CO	Material specific	Material specific
	Lower carbonates	CO2	Material specific	Material specific
	Lower sulfide or chloride	AG	Material specific	Material specific
Raw material alkali/sulfur balance		SO_2	Material specific	Material specific
In-line raw mill		SO_2	THC, AG, NH_3, D/F, detached plume	THC, detached plume
Preheater upper stage hydrated lime injection		SO_2	D/F	PM
Calcined feed recirculation		SO_2		NOx, CO_2
Cement kiln dust internal scrubber		SO_2	AG, D/F	
Preheater upper stage trona injection		SO_2	AG, D/F	CKD disposal
Calcium-based internal scrubber		SO_2	D/F, detached plume, waste disposal	
Pyroprocessing system design		SO_2	Process specific	Process specific
Tailpipe wet scrubber		SO_2	NH_3, HCl	AG, PM, solid waste disposal, wastewater
Decrease SO2 generation		AG	SO_2	
Indirect firing		NOx	CO_2	PM
Low-NOX burner		NOx	Burner/application specific	Burner/application specific
Mid-kiln firing		NOx	Application specific	Application specific
Process improvements		NOx	Project specific	Project specific
Process control improvements		NOx	Project specific	Project specific
Low-NOX calciner		NOx		CO
Staged combustion		NOx		CO
Semi-direct firing		NOx	PM	
Mixing air fan		NOx, THC, CO	SO_2	
Cement kiln dust insufflation		NOx		CO, CO_2, SO2
Biosolids injection		NOx		CO, NH_3, detached plume, metals
Inherent process characteristics (time, temperature, and turbulence)		THC	CO	
Pyroprocessing system design		THC, CO	Process specific	Process specific
Regenerative thermal oxidizer		THC, CO	Detached plume, D/F	NOx, CO_2, SO_3, AG, waste disposal
Good combustion practice		CO	NOx, CO_2, SO_2, THC	
Improved thermal efficiency		CO_2	Project specific	Project specific
Clinker substitution		CO_2	Reduction in all gaseous pollutants per ton of cement produced	Reduction in all gaseous pollutants per ton of cement produced
Improved electrical efficiency		CO_2	Reduction in all gaseous pollutants per ton of cement produced	Reduction in all gaseous pollutants per ton of cement produced
Mineralizers		CO_2	NOx	AG
Electricity generation from waste heat		CO_2	Reduction in all pollutants related to power generation	Reduction in all pollutants related to power generation
PMCD inlet temperature control		D/F		
Reduced residence time at temperature		D/F		

Table A.6.2. Potential control technologies for gaseous pollutants from Portland cement manufacturing (Greer 2003)

Potential control technologies		**Pollutant for which technology might be intended**	**Potential effects**	
			Synergetic	**Counteractive**
Mixing air fan		SO_2, NOx, CO, THC		
In-line raw mill hydrated lime injection		SO_2	THC, AG, D/F, detached plume	
Fabric filter absorption		SO_2	AG	
Sodium-based internal scrubber		SO_2	AG, D/F, detached plume	CKD disposal
Calcium/sodium based internal scrubber		SO_2	AG, D/F	CKD disposal
Oxygen enrichment		SO_2, THC, CO		NOx
		NOx	SO_2, CO	
Dual-alkali process (soda ash/lime)		SO_2	AG	Waste disposal
Thermal decomposition (roasting)		SO_2	THC	CO, NOx, CO_2
Tailpipe dry scrubber		SO_2, AG	AG, THC, D/F	NOx, CO, CO_2, waste disposal
Cement kiln dust tailpipe scrubber		SO_2	THC, NH_3, AG, detached plume	
Fuel substitution	Low nitrogen containing fuel	NOx	Fuel/process specific	Fuel/process specific
	High hydrocarbon containing fuel	CO_2	Fuel specific	Fuel specific
Raw material substitution containing	Lower nitrogen	NOx	Material specific	Material specific
	Lower ammonia	NH_3	Material specific	Material specific
	Lower D/F	D/F	Material specific	Material specific
Selective noncatalytic reduction		NOx		NH_3, detached plume
Modified direct firing		NOx	PM	
LoTOX ™ scrubber		NOx		Water discharges, ozone slip
Flue gas recirculation		NOx		CO, SO_2
Selective catalytic reduction		NOx		NH_3, CO_2, detached plume, solid catalyst wastes
Tri-NOX® Multi-Chem wet scrubber		NOx	SO_2, AG	Water discharges
Water/steam injection		NOx		CO, CO_2
Catalytic filtration		NOx		
		D/F	PM	
Non-thermal plasma		NOx	SO_2, THC, D/F	
Thermal desorption (roasting)		THC		SO_2, CO
Thermal oxidation		THC, CO	D/F	CO_2, NOx
Recuperative thermal oxidation		THC, CO	D/F	CO_2, NOx
Wet electrostatic precipitator		THC, AG	SO_2, NOx, PM, NH_3, D/F, detached plume	Waste disposal, water treatment
Ultraviolet light		THC, D/F		CO
Catalytic oxidization		THC, CO		CO_2, NOx
Granular activated carbon adsorption		THC, D/F	NOx, SO_2, metals	Waste disposal, high reagent consumption
Powdered activated carbon adsorption		THC, D/F	NOx, SO_2, metals	D/F, waste disposal, high reagent consumption
Electricity generation from the sun and wind		CO_2	Reduction in all pollutants related to power generation	Reduction in all pollutants related to power generation
Tailpipe wet scrubber		NH_3 AG	SO_2, THC	PM, acid mist, wastewater
Fabric filter absorption		AG	SO_2	
Tailpipe dry bicarbonate injection		AG	SO_2, D/F, detached plume	Waste disposal
Temperature control		AG	SO_2, NH_3, THC, D/F, detached plume	Water/waste disposal

Appendix 7. Recommended Method for Using CEMS to Determine Each Type of Pollutant from a Cement Plant

Pollutant	**Recommended method of determination**
Dust Concentration <20 mg/Nm^3	Scattered light method
Dust Concentration >20 mg/Nm^3	Optical transmission method
Nitrogen oxide (NO)	NDIR (cold and hot) / FTIR / DOAS-UV
Nitrogen dioxide (NO_2)	FTIR / NDIR (cold) and converter / Calculation*
SO_2	NDIR (cold and hot) / FTIR I DOAS-UV
VOCs	Flame Ionization Detector (FID)

*Alternatively, default values can be used that are either based on results of spot measurements or calculated.
NDIR: Nondispersive infrared; FTIR: Flow through infrared; UV: ultraviolet

Parameter	**Recommended method of determination**
O_2	Zirconium oxide (ZRO_2 method) / Paramagnetic method
Water content	NDIR (hot) / FTIR / Laser method / Fixed value*
Volume Flow	Ultrasonic method / Differential pressure principle
Temperature	Pt100-Sensor / In-situ analyzer implemented
Absolute Pressure	In-situ analyzer integrated / Fixed value*
Gas pressure	Separate sensor / Volume pressure) / Fixed value1 flow integrated (differential pressure) / Fixed value*

*Alternatively, default values can be used that are either based on results of spot measurements or calculated.
Source: WBCSD (2012a)

Appendix 8. Standards for Cement Plant Emissions Measurements: Sampling and Analyses

Pollutant	Standard / Reference Method	Spot/Continuous	Sampling/ Analysis
Dust	EN 13284-1:2002	Spot	Sampling and analysis
	US EPA method 5, 5i, 17	Spot	
	ISO 9096:2003	Spot	
	ISO 12141:2002	Spot	
Nitrogen Oxides (NO_x/NO_2)	EN 14792:2006	Continuous	Sampling and analysis
	US EPA method 7 E	Continuous	
	US EPA method 7 (A to D)	Spot	
	ISO 10849:1996	Continuous	
	ISO 11564:1998	Spot	
Sulfur Oxides (SO_x/SO_2)	EN 14791:2006	Spot	Sampling and analysis
	US EPA method 6 C	Continuous	
	US EPA 6, 6A, 8	Spot	
	ISO 7935:1992	Continuous	
	ISO 7934:1998	Spot	
	ISO 11632:1998	Spot	
Hg	EN 13211:2001-2005	Spot	Sampling
	EN 14884:2005	Continuous	Sampling and analysis
	US EPA method 29, 101A	Spot	
Heavy Metals	EN 14385:2004	Spot	Sampling and analysis
	US EPA method 29	Spot	
VOC / THC	EN 13649:2002	Spot	Sampling and analysis
	EN 12619:2000	Continuous	
	US EPA method 25A	Continuous	
PCDD/F	EN 1948-1/2/3/4:2006	Spot	Sampling and analysis
	US EPA method 23	Spot	
Parameter	**Standard / Reference Method**	**Spot/Continuous**	**Sampling/ Analysis**
GAS VELOCITY, MOISTURE AND OXYGEN			
Flow Rate & Velocity	US EPA 1, 2	Continuous	measurement
	ISO 10780:1994	Continuous	
Moisture (Water vapor)	EN 14790:2005	Spot	Sampling and analysis
	US EPA 4	Spot	
Oxygen	EN 14789:2006	Spot	Sampling
	US EPA 3, 3B	Spot	
	US EPA 3A	Continuous	Sampling and analysis

Source: WBCSD (2012a)

Appendix 9. Short List of Pre- and Co-processing Technology Providers for Alternative Fuels in the Cement Industry

Below is a list of some providers of technology for pre- and co-processing of alternative fuels in the cement industry. This list is not exhaustive.

Pre-processing of MSW and sewage sludge

- Anlagenbau GmbH (http://www.wendewolf.com/klsbesch.php?lang=en)
- Buss-SMS-Canzler (http://www.sms-vt.com/index.php?id=631&L=1)
- Continental Biomass Industries (http://www.cbi-inc.com/applications/msw.aspx)
- DoppstadtUS (http://www.doppstadtus.com/)
- Eurohansa, Inc. (http://www.eurohansa.com/applications.html)
- Flottweg Separation Technology (http://www.flottweg.de/)
- Franklin Miller, Inc. (http://www.franklinmiller.com/)
- Granutech-Saturn Systems (http://www.granutech.com/solid-waste-shredder.html)
- Huber Technology (http://www.huber.de/)
- Integrated Engineers Inc. (http://wecleanwater.com/)
- Klein Technical Solutions GmbH (http://www.klein-ts.com/en/)
- Peninsula Equipment (http://www.peninsulaequipment.com/Products.php)
- SludgeSolution (http://sludgesolutions.veoliaes.com/)
- SSI Shredding Systems (www.ssiworld.com)
- UNTHA shredding technology (http://www.untha.com/en)
- Vandenbroek International (http://www.vadeb.com/applications/msw-drying-rdf/)

Storage, handling, and feeding systems

- Aumund Group (http://www.aumund.com/)
- Claudius Peters Technologies GmbH (http://www.claudiuspeters.com/)
- EUREMI S.A. (www.euremi.com)
- FCB. Ciment S.A. (http://www.fcb-ciment.com)
- FLSmidth A/S (http://www.flsmidth.com/)
- Fox Valve Development Corp. (http://www.foxvalve.com)
- Geo. Robson & Co (Conveyors) Ltd. (http://www.robson.co.uk/)
- Metso Minerals Industries Inc. (www.metsominerals.com)
- Pebco Inc. (http://www.pebco.com/)
- Pfister GmbH (http://www.pfister.de/)
- PILLARD FEUERUNGEN GmbH (http://www.pillard.de/)
- Polysius AG (http://www.polysius.com/)
- Schenck Process Group (http://www.schenckprocess.com/en/)
- STAG AG (http://www.stag.net/)
- Vecoplan LLC (http://www.vecoplanllc.com/)
- WTW Engineering (http://www.mhc-engineering.de/116/)

Co-firing of MSW and sewage sludge in the kiln

- Cadence Environmental Energy Inc. (http://www.cadencerecycling.com/)
- FCT-Combustion (http://www.fctinternational.com/)
- FLSmidth (http://www.flsmidth.com/)

- Greco-Enfil International S.L. (http://www.grecoenfil.com/)
- KHD Humboldt Wedag GmbH (http://www.humboldt-wedag.de/)
- PILLARD FEUERUNGEN GmbH (http://www.pillard.de/)
- Polysius AG (http://www.polysius.com/)
- Unitherm Cemcon Firingsystems GesmbH (http://www.unitherm.co.at/)

Emissions control systems

- Ecotech (http://www.ecotech.com/)
- Sick Group (http://www.sick.com/)
- K2BW (http://www.k2bw.com/)
- Altech Environment U.S.A.(http://www.altechusa.com/)

APPENDIX C

Assessment of Dried Biosolids Product for Meeting Established EPA Classification Requirements for Being a Non-Waste Fuel per the NHSM Rule.

SPECTRUM
Environmental Sciences, Inc.
97 Thomas Johnson Drive, Suite 200 • Frederick, MD 21702 • 301.620.1200 • Fax 301.620.4118 • www.spectrumenv.com

March 11, 2015

Mr. Kurt W. Deery, REM, CSEM
Environmental Engineer
Lehigh Cement Company
Union Bridge Plant
675 Quaker Hill Road
Union Bridge, MD 21791

Subject: Assessment of Dried Biosolids Product for Meeting Established EPA Classification Requirements for Being a Non-Waste Fuel per the NHSM Rule

Dear Kurt:

Lehigh Cement Company (Lehigh) requested that Spectrum Environmental Sciences, Inc. (Spectrum) perform an independent assessment to determine if the dried biosolids product (DBS Product) currently used by the Plant as an alternate fuel meets: 1) the U.S. EPA processing definition as specified in 40 CFR 241.2, the legitimacy criteria defined in 40 CFR 241.3(d)(1), and 2) based on the results of this assessment, whether the U.S. EPA would be expected to determine that the DBS Product be considered to be a non-waste fuel per the requirements specified in the Non-Hazardous Secondary Material (NHSM) Rule. The DBS Product is currently being used as an alternate fuel at the Lehigh Union Bridge Plant (Plant).

It is understood that Lehigh can receive Class A dried biosolids from a number of surrounding dried biosolids pelletizing facilities (e.g., Synagro Baltimore, MD; Synagro Patapsco, MD; Synagro Philadelphia, PA; Synagro Hagerstown, Easton, Elkton, MD; City of Cumberland, MD and Synagro Camden, NJ and New England Fertilizer Company (NEFCO) located in Massachusetts (Fore River Pelletizing Facility). It is also understood that Synagro possesses a Maryland Sewage Sludge Utilization Permit (No. S-05-03-3579-D) associated with the distribution of treated sewage sludge from the Synagro Baltimore Pelletech Heat Drying/Pelletizing Facility located at the Back River Wastewater Treatment Plant (WWTP). The pelletizing facilities process the biosolids produced by the WWTPs and produce a heat-dried pellet (i.e., DBS Product). The DBS Product is marketed, sold, and distributed. Lehigh utilizes the DBS Product under the following permits issued by MDE: Sewer Sludge Utilization Permit, No. 2010-SIP-5360 and Title V Air Quality Permit (24-013-00012) amended for DBS utilization by the Permit to Construct, 013-0012-0256, -0331 & -0337.

The U.S. EPA has previously issued three Comfort Letters for dried biosolids for Deli Charter Township (December 2011), DTE Energy Services, Inc. (March 2012), and N-Viro International Corporation (June

2014). All three of the Comfort Letters concluded that the dried biosolids produced at their facilities, which have a very similar process to the process used by fertilizer and municipality drying facilities to produce their dried biosolids, were considered by the U.S. EPA to be a non-waste fuel and not a solid waste.

Provided below is a process description associated with the production of the DBS Product, a discussion of how the processing associated with the manufacture of the DBS Product meets the NHSM Rule definition of processing, and a legitimacy criteria analysis of the DBS Product comparing it to coal. As described below, this independent assessment clearly demonstrates that the DBS Product is considered to be a non-hazardous fuel per the NHSM Rule requirements.

- **Process Description**

Step 1: Receipt of Wastewater

Wastewater is received by a WWTP. Provided as an example, Figure 1 presents an aerial photograph of the Back River WWTP. The Back River WWTP is situated on the west shore of the Back River, a tributary of the Chesapeake Bay, and is located near the community of Essex, Maryland. The Back River WWTP was originally constructed in 1907 and is owned and operated by the City of Baltimore. Figure 1 also depicts the 466 acre site where Synagro leases 1.1 acres. The 466 acre site and has a 35 foot drop in elevation from influent to outfall, allowing wastewater to flow through the WWTP entirely by gravity.

Step 2: Treatment of Wastewater

Incoming wastewater to the WWTP undergoes a number of stages of processing (or treatment) including primary, secondary, and tertiary. Influent is the raw material that has been collected and conveyed to the WWTP for treatment. It includes all the water and debris that entered the collection system. Primary treatment is first performed to prevent damage to pumps and clogging of pipes. Raw wastewater passes through mechanically raked bar screens to remove large debris, such as rags, plastics, sticks, and cans. Smaller inorganic material, such as sand and gravel, is removed by a grit removal system. The lighter organic solids remain suspended in the water and flow into large tanks, called primary clarifiers. Here, the heavier organic solids settle by gravity. These settled solids, called primary sludge, are removed along with floating scum and grease and pumped to anaerobic digesters for further treatment. The primary effluent is then transferred to the biological or secondary stage where the wastewater is mixed with a controlled population of bacteria and an ample supply of oxygen. The microorganisms digest the fine suspended and soluble organic materials, thereby removing them from the wastewater. Stabilization of the wastewater is achieved through use of anaerobic sludge digesters.

The effluent is then transferred to secondary clarifiers, where the biological solids or sludges are settled by gravity. As with the primary clarifier, these sludges are pumped to anaerobic digesters, and the clear secondary effluent may flow directly to the receiving environment or to a disinfection facility prior to release. Tertiary, or advanced, wastewater treatment is the term applied to additional treatment that is needed to remove suspended and dissolved substances remaining after conventional secondary treatment. This may be accomplished using a variety of physical, chemical, or biological treatment processes to remove the targeted pollutants. Advanced treatment may be used to remove such things as color, metals, organic chemicals, and nutrients such as phosphorus and nitrogen.

Figure 1
Arial Photograph of the Black Water WWTP and Synagro Baltimore Pelletech Facility

The treated wastewater from the WWTP is then sent to a pelletizing facility.

Step 3: Dewatering of Biosolids
The pelletizing facilities utilize drying trains to dry liquid and cake (dewatered semi-solid) anaerobically digested biosolids received from a WWTP via pipeline or truck. The liquid biosolids are conditioned with a polymer and dewatered using single stage centrifugal action. The DBS Product pelletizing facilities receive the liquid biosolids at two to six percent total solids and produces at the eight to 28 percent total solids. The dewatered biosolids, whether produced in the dry facilities or delivered directly from the WWTPs, are then conveyed to the next step of the process.

Step 4: Conditioning of Biosolids
At the pelletizing facilities, the dewatered biosolids are conveyed to a coater/conditioning unit where they are blended with previously dried and sized biosolid pellets to obtain a total solids content of 70 percent or higher. The conditioned biosolids are then fed to the dryer/pelletizer.

Step 5: Drying/Pelletizing of Biosolids

The raking arms carry a set of scrapers which roll the biosolids across a heated metal surface of trays. Provided as an example, Figure 2 presents a view of one of the 19 oil trays located inside each of the three Dryers at the Baltimore Pelletech Facility. Also, at the Synagro Baltimore Pelletech Facility, there are 19 oil trays in each of the three Dryers for a total of 57 oil trays. There are 11 raking arms attached to the center shaft of the each of oil tray. Nine adjustable scraper blades are attached to each of the raking arms. The distance between the trays is approximately 30 to 36 inches. In total for the 3 Dryers, there are 627 raking arms and 5,643 scraper blades.

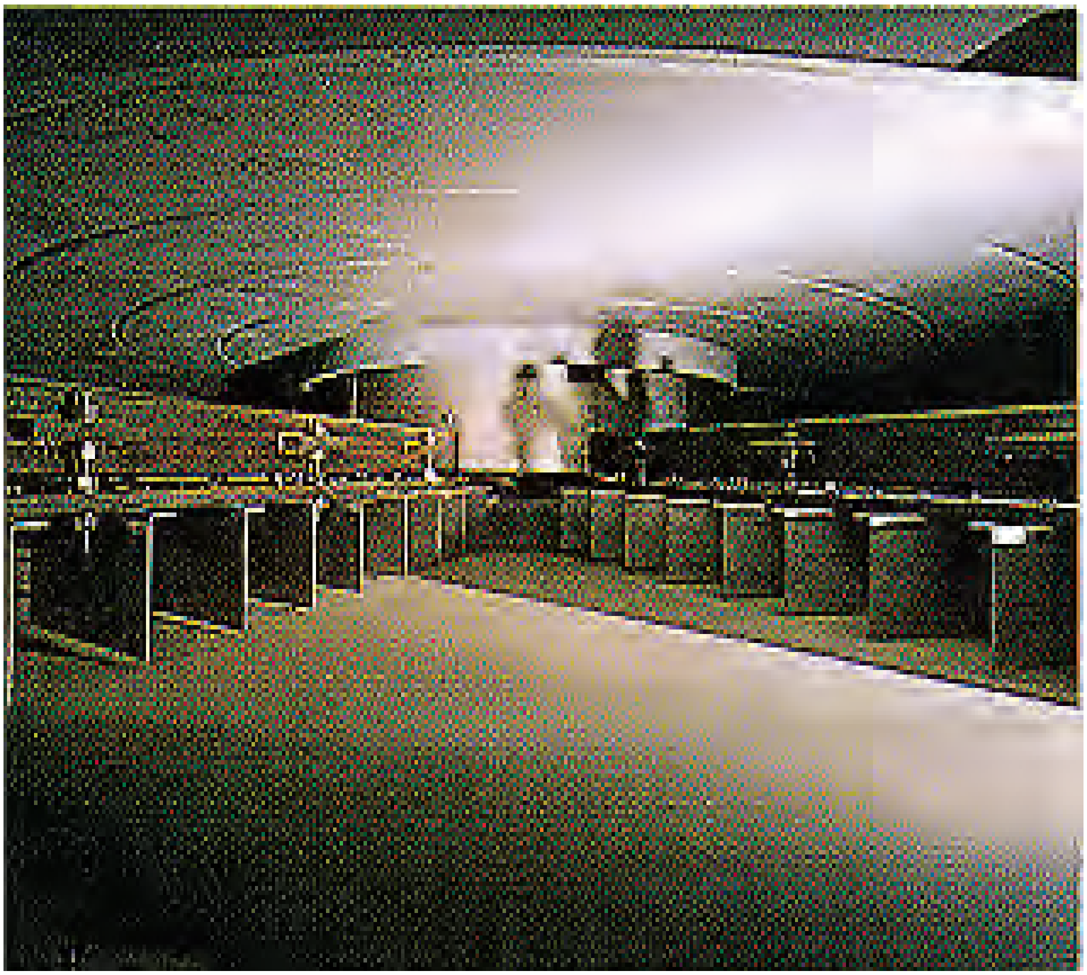


Figure 2
Oil Trays Inside the Dryer

Thermal oil which is heated to about 440°F is re-circulated inside the trays which deliver the heat required to evaporate water from the biosolids. The recirculating oil does not come into direct contact with the biosolids.

The biosolids are then transported and tumbled over the dry surface, enhancing heat and mass transfer and the formation of pellets. The biosolids are heated to temperatures in excess of 176°F during the drying process to meet Class A pathogen treatment requirements. The resulting pellets have less than 10 percent moisture at the dryer discharge.

Step 6: Sizing of the Pellets
The dried pellets pass from the dryer into a screen-type classifier where pellets of pre-selected size are separated from the oversized and small particles called fines. The fines are removed and recycled to the mixing/conditioning unit for processing (see Step 4).

Step 7: Storage of the Pellets in Dry Product Storage Silos

Lehigh receives the DBS by pneumatic truck from the pelletizing facilities. The DBS is stored in silos both at the pelletizing facilities and on-site at Lehigh. The silos are equipped with dust collection and CO2 or N fire suppression systems. Figure 3 presents a photograph of the DBS Product.

Figure 3
Dried Biosolids Pelletized Product

- **Quality Assurance/Quality Control**

Pelletizing Facilities routinely implements quality assurance (QA) and quality control (QC) practices to assure that the production of the DBS Product will meet all applicable Federal requirements for "Class A Biosolids as regulated under 40 CFR Part 503. QA/QC practices are also performed to meet the requirements specified in EPA's 503 regulations and any appropriate state level permit requirements. DBS product must also meet the Fuel Specification stipulated by Lehigh for the Union Bridge Plant. The Lehigh Fuel Specification is provided in Attachment 1.

Demonstration that the DBS Product Meets the U.S. EPA Definition of Processing

Processing as defined in 40 CFR 241.2 are operations that transform discarded NHSMs into a non-waste fuel or a non-waste ingredient and includes:

- Operations necessary to remove or destroy contaminants,
- Significantly improve the fuel characteristics by drying and sizing the biosolids utilizing the processing steps outlined above,
- Chemically improve the as-fired energy content, or
- Improve the ingredient's characteristics.

As described in detail above, the manufacture of the DBS Product's use of multiple processing steps in order to remove contaminants (i.e., the reduction of heavy metals via grit removal and reduction of volatiles via anaerobic digestion) and improvement of its fuel characteristics (i.e., removal of larger solids and grit, removal of water to improve the as-fired energy content, and the sizing of the material to allow it to be handled and fed into the Union Bridge Plant kiln system) meets the definition of processing in 40 CFR 241.2.

Legitimacy Criteria Analysis

NHSMs which are used as non-hazardous fuel in a combustion unit must meet the legitimacy criteria specified in Sec. 241.3(d)(1) of the Final CISWI/Solid Waste Rule (Rule) as published in the Federal Register on February 7, 2013. This Rule resulted in the U.S. EPA issuing final amendments to the regulations that were previously codified by the NHSM rule which were originally promulgated on March 21, 2011. The NHSM rule provided the standards and procedures for identifying whether NHSM's are a solid waste under the Resource Conservation and Recovery Act (RCRA) when used as fuels or ingredients in combustion units.

The DBS Product meets the definition of a NHSM which is not a solid waste when combusted, as stated in 40 CFR 241.3(d)(1). This demonstration is provided below.

The DBS Product will be used in a combustion unit. Also, the DBS Product is produced from biosolids contained in wastewater which meets the legitimacy criteria requirements. To meet the legitimacy criteria requirements, the non-hazardous secondary material must be:

1. Managed as a valuable commodity,
2. Have a meaningful heating value and used as a fuel, and
3. Contain contaminants at concentrations comparable to (or lower than) those in traditional fuels which the combustion unit is designed to burn.

Provided below is an analysis of each of these three legitimacy criteria.

1. Legitimacy Criteria No. 1: Managed as a Valuable Commodity

The first element to managing the "product" as a valuable commodity, as identified in the preamble to 40 CFR 241, Subpart B, is the time-frame for the storage of the product. Inbound dewatered and stabilized wastewater from WWTPs is immediately processed and then directly sent to the pelletizing facility to produce the DBS Product. Once produced, the DBS Product is stored in dry product storage silos (See Processing Step 7) for a short period of time (i.e., thirty days or less) before it is delivered to customers. Each dry product storage silo is sized to hold about four days of production (about 200 dry tons).

The dry product storage silo will result in an insignificant amount of ambient fugitive dust emissions from the pelletizing Facility. Additionally, storage of the DBS Product in the dry product storage silos will eliminate the possibility of any storm water run-off. In summary, there is expected to be negligible environmental impacts associated with the production, storage, loading, and shipping of the DBS Product. Once loaded, the trucks will deliver the DBS Product to their clients, including the Lehigh Union Bridge Plant.

The pelletized DBS Product represents a commodity fuel under contractual agreement between Suppliers of DBS and the Lehigh Union Bridge Plant. In addition, the pelletizing facilities business plan is focused on marketing the DBS as a fertilizer. Lehigh provides an additional outlet for the use of the DBS Product. As an example, Attachment 2 presents a supply agreement between Synagro and Lehigh. The DBS Product is manifested, shipped, and delivered to the Lehigh Union Bridge Plant in the same manner as any traditional fuel acquired by the Lehigh Union Bridge Plant. At the Lehigh Union Bridge Plant, the DBS Product is expected to be typically used within 48 to 72 hours of delivery and prior to its use it will be stored in a dedicated area along with other traditional fuels purchased by the Lehigh Union Bridge Plant.

2. Legitimacy Criteria No. 2: Meaningful Heat Value and Used as a Fuel

In the preamble to 40 CFR Parts 60 and 241 (Federal Register, Vol. 78, No. 26, Thursday, February 7, 2013), it is suggested that NHSM's be compared with traditional fuels to determine analogous heat values and contaminants. According to a recent literature survey, the heat value (Btu/lb) for coal ranges from 6,900 Btu/lb. for lignite to 14,380 Btu/lb. for low-volatile bituminous coal. Also, as stated in the preamble to 40 CFR Parts 60 and 241 (Federal Register, Vol. 78, No. 26, Thursday, February 7, 2013), EPA has established 5,000 Btu/lb. as a benchmark for demonstrating that a NHSM has meaningful heating value.

In order to meet the meaningful heating value legitimacy criterion, the NHSM would need to have an "as fired" minimum heating value of 5,000 Btu/lb. Samples of the DBS Product underwent analysis to determine the heat content in Btu/lb. The results of this analysis show that the average heat content (Btu/lb) of the DBS Product samples analyzed was 5,247 Btu/lb which demonstrates that the DBS Product has a meaningful heat value. The analytical laboratory data of the DBS Product samples assessed are presented in Attachment 3. All DBS entering the Lehigh Facility must meet the performance fuel specifications provided in the Lehigh contract, hence, the DBS Product must meet a heat content value of > 5,000 BTU/lb or the truck load is rejected.

3. Legitimacy Criteria No. 3: Comparison of Contaminant Levels

In the preamble to 40 CFR Parts 60 and 241 (Federal Register, Vol. 78, No. 26, Thursday, February 7, 2013), Section 241.2 – Definitions, contaminants means all pollutants listed in Clean Air Act (CAA) sections 112(b) or 129(a)(4), with the following three modifications:

(1) The definition includes the elements chlorine, fluorine, nitrogen, and sulfur in cases where non-hazardous secondary materials are burned as a fuel and combustion will result in the formation of hydrogen chloride (HCl), hydrogen fluoride (HF), nitrogen oxides (NO_x), or sulfur dioxide (SO_2). Chlorine, fluorine, nitrogen, and sulfur are not included in the definition in cases where non-hazardous secondary materials are used as an ingredient and not as a fuel.

(2) The definition does not include the following pollutants that are either unlikely to be found in non-hazardous secondary materials and products made from such materials or are adequately measured by other parts of this definition: hydrogen chloride (HCl), chlorine gas (Cl_2), hydrogen fluoride (HF), nitrogen oxides (NO_x), sulfur dioxide (SO_2), fine mineral fibers, particulate matter, coke oven emissions, opacity, diazomethane, white phosphorus, and titanium tetrachloride.

(3) The definition does not include m-cresol, o-cresol, p-cresol, m-xylene, o-xylene, and p-xylene as individual contaminants distinct from the grouped pollutants total cresols and total xylenes.

As a result, individual samples of the DBS Product were analyzed on as received basis for the following chemical constituents:

Metal Elements – ppm
Antimony (Sb)
Arsenic (As)
Beryllium (Be)
Cadmium (Cd)
Chromium (Cr)
Cobalt (Co)
Lead (Pb)
Manganese (Mn)
Mercury (Hg)
Nickel (Ni)
Selenium (Se)

Non-Metal Elements – ppm
Chlorine (Cl)
Fluorine (F)
Nitrogen (N)
Sulfur (S)

Hazardous Air Pollutant (HAP) compounds, ppm
Benzene
Toluene

The laboratory analysis of the samples of the DBS Product was conducted by a certified laboratory. Table 1 presents the results. The analytical laboratory data of the DBS Product samples assessed are presented in Attachment 3.

Averages were calculated using the results of the laboratory analysis of the DBS Product samples. Table 1 demonstrates that the averages of the DBS Product are comparable to or much less than the averages of coal, with the exception of fluorine, manganese, and arsenic.

SUMMARY AND CONCLUSIONS

The U.S. EPA has previously issued three Comfort Letters for dried biosolids which utilize a very similar, if not identical, process that DBS Pelletizing Plants use to produce their DBS Product. It was shown in these three past Comfort Letters that some of the same individual chemical constituents of dried biosolids exceeded the corresponding chemical constituent level expected from coal. Further it was concluded in these three past U.S. EPA Comfort Letters that the dried biosolids were considered by the U.S. EPA to be a non-waste fuel and not a solid waste. Copies of these letters are presented in Attachment 4.

Based on this analysis, and past U.S. EPA assessments of very similar dried biosolids product, it is concluded that overall the DBS Product demonstrates that it successfully meets the U.S. EPA legitimacy criteria. Therefore, it is our opinion that the DBS Product would be expected to be classified by the U.S. EPA as a non-hazardous fuel and not a solid waste.

If you have any questions on this analysis, please do not hesitate to contact me directly (301-620-1200).

Sincerely,

Thomas F. Iaccarino

Thomas F. Iaccarino
President

W/Attachments

TABLE 1
COMPARISON OF SYNAGRO DBS TO COAL

Contaminant	Units	Synagro DBS	Coal Range[1]	Synagro DBS < Coal?
Metal Elements - Dry Basis				
Antimony (Sb)	mg/kg (ppm)	0.50	ND - 10	**YES**
Arsenic (As)	mg/kg (ppm)	285.71	ND - 174	**NO**
Beryllium (Be)	mg/kg (ppm)	20.69	ND - 206	**YES**
Cadmium (Cd)	mg/kg (ppm)	2.77	ND - 19	**YES**
Chromium (Cr)	mg/kg (ppm)	65.20	ND - 168	**YES**
Cobalt (Co)	mg/kg (ppm)	4.91	ND - 30	**YES**
Lead (Pb)	mg/kg (ppm)	34.78	ND - 148	**YES**
Manganese (Mn)	mg/kg (ppm)	811.63	ND - 512	**NO**
Mercury (Hg)	mg/kg (ppm)	1.17	ND - 3.1	**YES**
Nickel (Ni)	mg/kg (ppm)	11.85	ND - 730	**YES**
Selenium (Se)	mg/kg (ppm)	14.81	ND - 74.3	**YES**
Non-Metal Elements - Dry Basis				
Chlorine (Cl)	mg/kg (ppm)	464.29	ND - 9,080	**YES**
Fluorine (Fl)	mg/kg (ppm)	205.00	ND - 178	**NO**
Nitrogen (N)	mg/kg (ppm)	37,428.57	13,600 - 54,000	**YES**
Sulfur (S)	mg/kg (ppm)	13,742.86	740 - 61,300	**YES**
Volatile Organic Compounds				
Benzene	mg/kg (ppm)	0.02	ND - 38[2]	**YES**
Toluene	mg/kg (ppm)	0.02	8.6 - 56[2]	**YES**
Heat Content				
Heat Content	Btu/Lb	5,247.00	> 5,000	**YES**

Notes:

1. Coal data taken from EPA document "*Contaminant Concentrations in Traditional Fuels:* Tables for comparison, November 29, 2011", available at www.epa.gov/epawaste/nonhaz/define/index.htm.
2. Fernandez-Martinez (2000).
3. 1 % = 10,000 PPM

Attachment 1
Lehigh Union Bridge Plant Fuel Specification

Lehigh Cement Company LLC
Dried Biosolid Pellets Specification
Union Bridge Plant

10/1/2012

Must meet all Federal requirements for "Class A" biosolids

	Acceptable Product	Single Shipment Reject Limits	Reference Method
Free Moisture. "As Received", %	10 Max	12 Max	Dried @ 43.3 C
Analysis on a Dry Basis			
BTU Heating Value	> 5,500 BTU		
Sulfur	< 0.5%		
Chlorine	< 0.1 ppm		
Bulk Density	35 lbs /ft3	45 lbs /ft3	
Particle Size	< 6mm	6mm Max	
Temperature at time of transport	<125° F		

Attachment 2
Lehigh and Synagro Supply Agreement

SYNAGRO

A Residuals Management Company

March 14, 2006

Mr. Kurt Deery
Engironmental Manager
Lehigh Cement Company
675 Quaker Hill Road
Union Bridge, MD 21791

RE: Supply Agreement dated January 5, 2005 by and between Synagro-WWT, Inc., and Lehigh Cement Company

Per the terms of the above referenced Supply Agreement, dried biosolid pellets will be supplied by Synagro's Back River and/or Patapsco pelletizing facilities to Lehigh for use as a raw material in the manufacture of cement. These dried biosolid pellets meet Federal EPA standards under Federal Regulations 40 CFR Part 503.

Sincerely,

Karl von Lindenberg
Plant Manager

Synagro - Baltimore L.L.C.
Baltimore Pelletech
8201 Eastern Boulevard, P.O. Box 9974, Baltimore, MD 21224 • Ph: (410) 284-9216 • Fax: (410) 284-9220

Attachment 3
Analytical Results of Synagro Product

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received From:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/5/2015

Date Received: 01/29/15

Date Reported: 02/26/15

Sample Marked:
Day 1

G&C Lab# 1016764

% TOTAL MOISTURE	9.73
% ASH DRY	43.11
% ASH RECEIVED	38.92

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	2.05	0.88	0.80
Arsenic	690.03	297.47	268.53
Beryllium	53.91	23.24	20.98
Cadmium	7.24	3.12	2.82
Chromium	156.42	67.43	60.87
Cobalt	12.04	5.19	4.69
Lead	80.82	34.84	31.45
Manganese	2108.41	908.94	820.50
Nickel	28.23	12.17	10.99
Selenium	47.38	20.43	18.44

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY ______________

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received From:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/6/2015

Date Received: 01/29/15

Date Reported: 02/26/15

Sample Marked:
Day 2

G&C Lab# 1016765

% TOTAL MOISTURE	9.82
% ASH DRY	42.52
% ASH RECEIVED	38.34

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	1.84	0.78	0.71
Arsenic	691.80	294.15	265.27
Beryllium	53.07	22.57	20.35
Cadmium	6.63	2.82	2.54
Chromium	167.45	71.20	64.21
Cobalt	12.28	5.22	4.71
Lead	86.19	36.65	33.05
Manganese	1907.51	811.07	731.43
Nickel	28.56	12.14	10.95
Selenium	40.88	17.38	15.68

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received from:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/7/2015

Date Received: 01/29/15

Date Reported: 02/26/15

Sample Marked:
Day 3

G&C Lab# 1016766

% TOTAL MOISTURE	10.00
% ASH DRY	42.51
% ASH RECEIVED	38.26

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	1.26	0.54	0.48
Arsenic	749.88	318.77	286.90
Beryllium	50.71	21.56	19.40
Cadmium	7.52	3.20	2.88
Chromium	163.87	69.66	62.70
Cobalt	11.62	4.94	4.45
Lead	85.26	36.24	32.62
Manganese	2024.40	860.57	774.52
Nickel	29.71	12.63	11.37
Selenium	37.59	15.98	14.38

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY ____________

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received From:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/8/2015

Date Received: 01/29/15

Date Reported: 02/26/15

G&C Lab# 1016767

Sample Marked:
Day 4

% TOTAL MOISTURE	9.88
% ASH DRY	43.08
% ASH RECEIVED	38.82

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	1.08	0.47	0.42
Arsenic	784.50	337.96	304.57
Beryllium	55.44	23.88	21.52
Cadmium	7.67	3.30	2.98
Chromium	180.64	77.82	70.13
Cobalt	12.44	5.36	4.83
Lead	84.82	36.54	32.93
Manganese	2123.03	914.60	824.24
Nickel	32.48	13.99	12.61
Selenium	38.27	16.49	14.86

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY

G and C Coal Analysis Lab., Inc.
1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received From:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/9/2015

Date Received: 01/29/15

Date Reported: 02/26/15

G&C Lab# 1016768

Sample Marked:
Day 5

% TOTAL MOISTURE	9.86
% ASH DRY	43.40
% ASH RECEIVED	39.12

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	1.00	0.43	0.39
Arsenic	759.83	329.77	297.25
Beryllium	55.99	24.30	21.90
Cadmium	7.57	3.29	2.96
Chromium	157.40	68.31	61.58
Cobalt	11.79	5.12	4.61
Lead	96.97	42.08	37.94
Manganese	2247.62	975.47	879.29
Nickel	31.31	13.59	12.25
Selenium	53.19	23.08	20.81

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received For:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/12/2015

Date Received: 01/29/15

Date Reported: 02/26/15

G&C Lab# 1016769

Sample Marked:
Day 6

% TOTAL MOISTURE	10.43
% ASH DRY	41.89
% ASH RECEIVED	37.52

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	0.97	0.41	0.36
Arsenic	778.28	326.02	292.02
Beryllium	53.72	22.50	20.16
Cadmium	7.07	2.96	2.65
Chromium	170.13	71.27	63.83
Cobalt	14.80	6.20	5.55
Lead	94.75	39.69	35.55
Manganese	2218.41	929.29	832.37
Nickel	31.86	13.35	11.95
Selenium	47.70	19.98	17.90

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY ________________

G and C Coal Analysis Lab., Inc.

1341 Hoffman Hollow Road
Summerville, Pa 15864
814-849-2559
Fax: 814-849-8878

Received from:

LEHIGH CEMENT COMPANY
675 QUAKER HILL ROAD
UNION BRIDGE, MD 21791

Date Sampled: 1/13/2015

Date Received: 01/29/15

Date Reported: 02/26/15

Sample Marked:
Day 7

G&C Lab# 1016770

% TOTAL MOISTURE	10.21
% ASH DRY	42.66
% ASH RECEIVED	38.30

	OF ASH MG/KG	BIOSOLIDS(DRY) MG/KG	BIOSOLIDS(AS REC) MG/KG
Antimony	0.88	0.38	0.34
Arsenic	745.17	317.89	285.43
Beryllium	53.62	22.87	20.54
Cadmium	6.77	2.89	2.59
Chromium	190.73	81.37	73.06
Cobalt	14.51	6.19	5.56
Lead	104.13	44.42	39.89
Manganese	2138.25	912.18	819.04
Nickel	33.54	14.31	12.85
Selenium	4.09	1.74	1.57

*Procedure followed using EPA-SW-846,ASTM Method 3030B,SM3111b.

The above analytical results were obtained following ASTM procedures.

G & C COAL ANALYSIS LAB., INC.

APPROVED BY

Analytical Services, Inc.

P.O. Box 237
Brockway, PA 15824-0237

Laboratory (814) 265-8749
FAX (814) 265-8749

GENERAL ANALYSIS REPORT

CUSTOMER: G & C Lab
1341 Hoffman Hollow Road
Summerville, PA 15864
Attn: Mike Chestnut

SAMPLE RECEIVED: 03/03/15 at 12:10 pm
SAMPLE DATE: 03/03/15

REPORT DATE: 03/06/15
ASI ID#: 133073

DESCRIPTION OF SAMPLE: See Below

TOTAL ANALYSIS RESULTS:

SAMPLE I.D.	PARAMETER	RESULT	UNIT	QUANTITATION LIMIT	METHOD	BY	DATE & TIME
Lehigh 1016764	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 5:40 pm
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 5:40 pm
Lehigh 1016765	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 6:12 pm
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 6:12 pm
Lehigh 1016766	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 6:44 pm
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/04/15 @ 6:44 pm
Lehigh 1016767	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 8:48 am
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 8:48 am
Lehigh 1016768	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 9:19 am
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 9:19 am
Lehigh 1016769	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 10:39 am
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 10:39 am
Lehigh 1016770	Benzene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 11:44 am
	Toluene	<0.020	mg/Kg	0.020	EPA 8260B	CC	03/05/15 @ 11:44 am

We certify that the above reported values were obtained by use of procedures appropriate for the sample as submitted.

BY: *William Sabatose* DATE: 03/06/15

FOR: William J. Sabatose, Chief Chemical Analyst

PADEP LAB ID#: 33-00411

Attachment 4
Past U.S. EPA DBS Comfort Letters

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

DEC 15 2011

REPLY TO THE ATTENTION OF

Sandra Diorka
Director of Public Services
Delhi Charter Township
2074 Aurelius Road
Holt, Michigan 48842-6320

Dear Ms. Diorka:

In your letter of June 16, 2011, you requested confirmation from the U.S. Environmental Protection Agency that sludge pellets burned in combustion units are non-waste fuels in accordance with the requirements in 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the rule requires that processing of non-hazardous secondary material (NHSM) meets the definition of processing in 40 CFR 241.2. Also, after processing, the NHSM must meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter and supporting materials, including analytical results submitted August 2, 2011 and August 15, 2011, we believe the 40 CFR part 241 regulations would identify the proposed sludge pellets that will be generated by the Delhi Charter Township (or Township) Wastewater Treatment Plant and burned in combustion units as a non-waste fuel.[1] The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSMs into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for purposes of the definition.
In your letter, you state that the Township plans to expand the processing operations at the wastewater treatment plant to create a biofuel product from its wastewater treatment sludge. The expanded process will involve removing rags and screening out solid contaminants larger than 3 mm in size; removing inorganic grit, which results in the removal of some heavy metals;

[1] Note that a non-waste determination under 40 C.F.R. Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 C.F.R. Part 241 for the purposes of determining appropriate emissions standards under the Clean Air Act for the combustion unit in which it is used.

subjecting the sludge to anaerobic digestion, which will generate Class A biosolids (the highest sludge classification) and remove volatiles and pathogenic organisms; dewatering the digested sludge, via the use of a water treatment polymer, to increase solids to approximately 20 percent; and drying and milling via solar drying in a greenhouse and mechanical tumbling, to create a final pelletized fuel product with a total solids content of at least 75 percent. In addition, the Township has a number of programs in place designed to limit the introduction of pollutants, such as mercury, pharmaceuticals, household hazardous waste, and heavy metals from industry into the wastewater stream in the first place.

Based on this description—that is, removal of contaminants (i.e., reduction in heavy metals via grit removal and reduction of volatiles via anaerobic digestion) and improvement of its fuel characteristics (i.e., removal of large solids and grit, removal of water to improve the as-fired energy content, and sizing of the material to allow it to be handled and fed to the boiler "as is"), we believe the process used to produce sludge pellets meets the definition of processing in 40 CFR 241.2.

Legitimacy Criteria

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels includes: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have meaningful heating value and be used as fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage As A Valuable Commodity

Regarding the first criterion, you state that the sludge pellets will be stored in a dry bunker until a quantity sufficient for transport accumulates—this may occur as often as multiple times daily or as little as every few months. The sludge pellets will be transported to the combustion facility in covered containers/trucks, offloaded onto the combustion facility's covered coal containment floor, mixed with coal, and burned within 24 hours of delivery. The sludge pellets will be sold to the combustion facility at a price that reflects their Btu content and the cost of processing the material.

Based on this information, we believe the sludge pellets[2] are managed as a valuable commodity: storage does not exceed a reasonable time frame and storage in dry bunkers is adequate to prevent releases. Also, management of the sludge pellets by the combustion unit appears to be analogous to the management of coal that is burned as a fuel.

Meaningful Heating Value and Used As A Fuel to Recover Energy

Regarding the second legitimacy criterion on meaningful heating value, you state that the sludge pellets will have an as-fired heating value greater than 5,000 Btu/pound, depending on the solids content of the final product. As discussed in the final rule, 5,000 Btu/pound was established as a general guideline for meaningful heating value. You submitted analytical data for one sample of sludge pellets containing the water treatment polymer (no fine screening step) and eight samples of sludge pellets from your current process (no fine screening step or addition of water treatment polymer). Because the sample containing the water treatment polymer more closely resembles the sludge pellets, we considered that sample as a proxy for the sludge pellets. The analytical data submitted on August 2, 2011 for this sample indicates a heating value of 6,500 Btu/pound on a dry basis which, according to Table 1 in your June 16, 2011 letter, translates to 5,200 Btu/pound if the sludge pellets are 80 percent solids content and 5,850 Btu/pound if the sludge pellets are 90 percent solids content. Your letter indicates that the typical product dryness will range between 80 percent and 90 percent solids content.

Based on this information, the sludge pellets will meet this criterion only if the solids content of the sludge pellets is sufficiently high to result in an as-fired heating value of at least 5,000 Btu/pound and if the sludge pellets are burned in a combustion unit that recovers energy, such as a combined heat and power plant.

Comparability of Contaminant Levels

Regarding the third criterion on contaminant levels, your letter requested confirmation that the sludge pellets meet the contaminant level criterion when compared to coal. You submitted analytical data from several samples of sludge pellets using your current process (no fine grit removal or addition of water treatment polymer), as well as analytical data for one sample of sludge pellets containing the water treatment polymer. Because the sample containing the water treatment polymer more closely resembles the sludge pellets, we considered that sample as a proxy for the sludge pellets. Please note that only those constituents identified in the contaminant definition under section 241.2 are relevant with respect to meeting the contaminants legitimacy criterion. For example, you indicated that both copper and silver show higher levels of contaminants than found in coal, but you believe they are still present at comparable levels, as

[2] As noted in the regulations, prior to final processing (drying and milling), the processed sludge may be considered a solid waste and is subject to appropriate federal, state, and local regulations.

defined under the regulations. Since neither copper nor silver are defined as contaminants under the Part 241 regulations, EPA did not consider them in our evaluation. Therefore, from the analytical data you submitted on August 2, 2011, we evaluated only those constituents identified under section 241.2 and as outlined in the materials characterization paper "Traditional Fuels and Key Derivatives." [3,4,5]

As indicated in the enclosed table, the sludge pellets meet the legitimacy criterion for contaminant levels when compared to coal. Regarding the total fluorine data you submitted on August 15, 2011, we also note that due to the water content of the sludge, the laboratory reporting limit on a dry weight basis for total fluorine exceeds the level of fluorine found in coal as reported in the referenced Materials Characterization Paper. The conclusion that the sludge pellets meet the contaminant legitimacy criterion, therefore, presumes that the actual level of fluorine, as well as additional constituents for which the sludge pellets were not tested, are present at levels comparable to or lower than those in the appropriate traditional fuel, based on your knowledge of the material.

Overall, based on the information provided, we believe that the sludge pellets that will be generated by the Township's wastewater treatment plant, as described in your June 16, 2011 letter and materials submitted on August 2, 2011, and August 15, 2011, meet both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 Part 241 regulations.

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[3] The Materials Characterization Paper on *Traditional Fuels and Key Derivatives* can be found at www.epa.gov/epawaste/nonhaz/define/index.htm.

[4] EPA notes that the contaminant values listed in the *Traditional Fuels and Key Derivatives* MCP for coal (and other traditional fuels) may be revised in the future based on the availability of new or additional data. Any future revisions to the values will not impact the conclusions made in this letter; the values are based upon the data that is available at the time EPA responds to a request.

[5] You may use other data on the contaminant levels in traditional fuels in determining whether the levels are comparable to the Township Wastewater Treatment Plant sludge pellets. That is, other data on the level of contaminants in traditional fuels that your Township has or may become aware of may also be considered in determining whether the level of contaminants in the Township's Wastewater Treatment Plant sludge pellets are comparable to those in the traditional fuel that the combustion unit is designed to burn.

If you have any other questions, please contact Julie Gevrenov of my staff at 312-886-6832.

Sincerely,

Margaret M. Guerriero
Director
Land and Chemicals Division

Enclosure

cc: The Honorable Carl Levin, United States Senate
George Faison, EPA/ORCR
Ethan Chatfield, EPA R5/ARD
Stuart Hersh, EPA R5/ORC
Duane Roskoskey, MDEQ

Enclosure: Contaminant Levels in Sludge Pellets

Constituent	Units	Measured Concentration in Sludge Pellets (containing water treatment polymer) (dry-weight basis), from 7/6/11 and 8/10/11 ALS Environment Reports	Maximum Values for Coal in EPA's Materials Characterization Paper *Traditional Fuels and Key Derivatives*	Note
antimony	mg/kg	2.5	235	
arsenic	mg/kg	8.8	80	
beryllium	mg/kg	< 0.63 (ND)	15	(non-detect at 0.63 mg/kg-dry reporting limit)
cadmium	mg/kg	2.8	5.47	
chromium	mg/kg	74	121.3	
cobalt	mg/kg	2.5	40.9	
lead	mg/kg	11	80	
manganese	mg/kg	260	300	
mercury	mg/kg	1.3	2	
nickel	mg/kg	13	50	
selenium	mg/kg	5.9	10	
total chlorine	ppm	< 2,500 (ND)	7,380	(non-detect at 0.25 wt%-dry)
total fluorine	ppm	< 1,250 (ND)	180	(non-detect at 0.030 wt%, with moisture measured at 76% of sample)
total nitrogen	mg/kg	42,000	54,000	the maximum value shown for nitrogen (54,000) is from the QAQPS emissions database for boilers & process heaters, version 6
total sulfur	ppm	11,100	43,600	(measured as 1.11% total sulfur on dry basis)
extractable organic halides	µg/g	< 160 (ND)	no data	(non-detect at 160 µg/g as Cl-dry reporting limit)
semi-volatile organic compounds	µg/kg	< 2,580 (ND)	no data	(non-detect for 18 compounds with individual reporting limits < or = 330 µg/kg-dry)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

MAR 1 6 2012

Fadi K. Mourad, P.E.
Director, Environmental Affairs
DTE Energy Services, Inc.
414 South Main Street, Suite 600
Ann Arbor, MI 48104

Dear Mr. Mourad:

In your letter of July 21, 2011, you requested confirmation from the U.S. Environmental Protection Agency (EPA) that biosolids processed using the proposed Detroit Biosolids Project will be considered a non-waste fuel when burned for energy recovery in combustion units in accordance with the requirements of 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the regulations require that processing of the non-hazardous secondary material (NHSM) meet the definition of processing in 40 CFR 241.2. After processing, the NHSM must also meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter, and supporting materials submitted on August 16, 2011, September 9, 2011, and January 11, 2012, we believe that under the 40 CFR part 241 regulations the processed biosolids—proposed to be generated by DTE Energy Services (DTEES) through the Detroit Biosolids Project and burned in the described combustion units—would be considered a non-waste fuel.[1] The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

Proposed Detroit Biosolids Project

The Detroit Biosolids Project is a proposed arrangement between DTEES and the Detroit Water and Sewerage Department (DWSD). DTEES operates the River Rouge Power Plant (RRPP) and other utility plants seeking to comply with Michigan's Renewable Energy Standard by 2015. DWSD operates its wastewater treatment plant in close proximity to RRPP, and it currently incinerates 800,000 tons of wet biosolids annually. Under the proposed arrangement, DTEES would further process the biosolids into a product fuel to be sold to RRPP and other utility plants that currently burn coal.

[1] Note that a non-waste determination under 40 CFR Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 CFR Part 241 for the purposes of determining the applicable emissions standards under the Clean Air Act for the combustion unit in which it is used.

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSM into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for the purposes of the definition.

In your letters, you state that DTEES will use rotary drum dryers to process the incoming biosolids—which are 20 to 25 percent solids and have a heating value between 1,000 and 2,000 Btu/pound—into a material that is 95 percent solids and has a heating value between 7,500 and 8,000 Btu/pound. Evaporated moisture, which includes some contaminants from the biosolids, will be condensed and recycled back to DWSD for further treatment. The dried biosolids will then exit the drum as discrete pellets in the exhaust stream, at which point they will be screened to a specified size and screened to remove certain materials such as coarse plastics (e.g. personal hygiene products), metals (e.g. nuts, bolts and screws) and other undesirable solids. The cooled product meeting specifications will be transported to storage silos. Reject material, consisting of the coarse plastic, metals and other undesirable solids, will be collected in a separate container for disposal (reject material is expected to total 2.5% to 4% of the incoming biosolids). Over-sized material will be crushed, combined with the fines, and mixed with incoming biosolids to begin the process again, including screening for undesirable solids.

Based on this description, we believe your operations meet the definition of processing in 40 CFR 241.2 and will transform the processed biosolids into a non-waste fuel , as further discussed below by significantly improving the fuel characteristics through a combination of sizing, drying, and contaminant removal.

Legitimacy Criteria

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels include: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have a meaningful heating value and be used as a fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage as a Valuable Commodity

Regarding the first legitimacy criterion, you note that the processed biosolids[2] will be sold to RRPP or other utility plants for use as a fuel at a competitive market price. You also state that

[2] As noted in the regulations, prior to final processing (drying, pelletizing, and screening), the processed sludge may be considered a solid waste and is subject to appropriate federal, state, and local regulations.

the processed biosolids will be pneumatically conveyed from the product silo at the DTEES biosolids plant to storage silos at RRPP, never being exposed to the outside atmosphere. Co-combustion with coal will then occur within four days. Coal, on the other hand, is typically stored at RRPP in a pile exposed to the atmosphere for up to one month prior to combustion.

Based on this information, we believe that the processed biosolids will be managed as a valuable commodity at both DTEES and RRPP—that is, managed in silos, with the material not being exposed to the outside atmosphere. In addition, storage would not exceed a reasonable time frame, and in fact, appears to be used in a time frame shorter than that used for fossil fuel products. If sold to utility plants other than RRPP, pneumatic conveyance to the utility may not be possible, but transport in covered trucks or railcars are examples of other acceptable transport methods you may wish to consider. However, since no information was provided as to how the processed biosolids will be managed at other utility plants, this letter does not address this aspect of the legitimacy criteria when utilized at other utility plants.

Meaningful Heating Value and Used as a Fuel to Recover Energy

Regarding the second legitimacy criterion, you note that the processed biosolids have an as-fired heating value between 7,500 and 8,000 Btu/pound. As the Agency stated in the preamble to the NHSM final rule, NHSMs with an energy value greater than 5,000 Btu/lb, as fired, are considered to have a meaningful heating value (see 76 FR 15541, March 21, 2011). Thus, we believe that the processed biosolids meet the second legitimacy criterion. You also noted that enough energy will be recovered from the use of this fuel to provide 3.5 percent of RRPP's total fuel needs displacing 91,200 tons of coal per year.

Comparability of Contaminant Levels

Regarding the third legitimacy criterion, your letter requested confirmation that the processed biosolids contain contaminants at levels comparable to or lower than levels found in coal. While we could not evaluate the actual processed biosolids—because the DTEES Biosolids Plant does not yet exist—we did evaluate oven-dried biosolids samples collected from the DWSD wastewater treatment plant as a proxy, which you indicate would be representative of the processed biosolids that will be generated by the DTEES Biosolids Plant. You submitted DWSD analytical data measuring levels of 15 elemental contaminants[3], as well as total halogens, as part of your August 16, 2011 letter and more recent data in a follow-up email on January 11, 2012.

We have prepared the enclosed table "Comparison of DTEES Dried Biosolids to Coal" to compare the analytical data you submitted for your NHSM to data for coal in our "Contaminant Concentrations in Traditional Fuels: Tables for Comparison" document. [4,5,6] For all

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[3] EPA has issued a proposed rule that amends the definition of contaminants in the final NHSM rule. The proposal revises the definition to add elemental precursors to pollutants listed in Clean Air Sections 112(b) and 129(a)(4) that form during combustion, including these 15 elemental contaminants identified in the data submittal (see 76 FR 80471).

[4] *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011* can be found at www.epa.gov/epawaste/nonhaz/define/index.htm.

contaminants other than nitrogen, straightforward comparisons for individual contaminants reveal NHSM levels that are lower than or comparable to those in coal. Regarding contaminant levels reported for fluorine, EPA notes that previous data submitted by DTEES in August 2011 indicated levels of 560 mg/dry kg based on analyses performed on one sample in 2009. Believing this one data point not to be representative of the levels of fluorine in your materials, you collected additional data in January 2012 and submitted this information to the Agency. New data submitted indicates fluorine levels of 195 mg/dry kg -- the highest fluorine concentration of analyses found in 3 samples taken in January 2012. Such levels of 195 mg/dry kg are comparable to the fluorine levels listed for coal (ND- 178 ppm) as indicated in the enclosed table.[7]

Regarding nitrogen, the processed biosolids have somewhat higher levels of total nitrogen than coal. However, as you argue in your September 9, 2011 letter, total nitrogen is not an appropriate way to assess this contaminant—*in your specific situation*—that will form NOx during combustion. Specifically, you note that ammonia and organic nitrogen, which will be rapidly converted into ammonia early in the combustion process, should not be considered as contaminants provided the combustion unit has a Low NOx firing system (i.e., Low NOx burners with Overfire Air). You also state that the majority of nitrogen in the processed biosolids is in fact ammonia or organic nitrogen. Due to the oxygen-deficient nature and flame temperatures characteristic of Low NOx firing systems, introducing ammonia into the combustion chamber via the processed biosolids will actually *reduce* NOx emissions. This would happen as the ammonia reacts with existing NOx—always present in some amount due to nitrogen's presence in air—to form nitrogen gas and water. As such, we agree that total nitrogen is not an appropriate contaminant to consider for your processed biosolids, but this finding only applies in situations where the combustion unit receiving the fuel is equipped with a Low NOx firing system. This is the case at RRPP.

As discussed in the previous two paragraphs and the attached table, the processed biosolids meet the contaminants legitimacy criterion when compared to coal. This conclusion presumes that additional contaminants for which the biosolids were not tested are present at levels comparable to or lower than those in the appropriate traditional fuel, based on your knowledge of the material.

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[5] EPA notes that the contaminant values listed in the *Contaminant Concentrations in Traditional Fuels: Tables for Comparison* document for coal may be revised in the future based on the availability of new or additional data. Any future revisions to the values will not impact the conclusions made in this letter; the values are based upon the data that is available at the time EPA responds to a request.

[6] You may use other data on the contaminant levels in traditional fuels in determining whether the levels are comparable to those in DTEES' processed biosolids. That is, other data on the level of contaminants in traditional fuels that your company has or may become aware of may also be considered in determining whether the level of contaminants in DTEES' dried and pelletized biosolids are comparable to those in the traditional fuel that the combustion unit is designed to burn.

[7] As discussed in the final NHSM rule, the comparable to or lower than standard means any contaminants present in the NHSM that are within a small acceptable range, or lower than the contaminant in the traditional fuel. An example of a small acceptable range is given as an NHSM containing 500 ppm lead, while the traditional fuel burned in the unit contains 475 ppm lead. (76 FR 15523). As indicated in the enclosed table, reported fluorine and lead levels in the processed biosolids compared to coal within a small acceptable range.

Conclusion

Overall, based on the information provided, we believe that the processed biosolids that DTEES will generate through the Detroit Biosolids Project, as described in your letters, meet both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 Part 241 regulations.

If you have any other questions, please contact Kenneth Dixon of my staff at 703-308-1848.

Sincerely,

James R. Berlow, Director
Program Implementation and Information Division

Enclosure

Enclosure

Comparison of DTEES Dried Biosolids to Coal

Contaminant	Units[1]	Dried Biosolids[2]	Coal[3]	Result of Comparison
Antimony (Sb)	ppm	4.3 - 5.6	ND - 10	Lower than coal
Arsenic (As)	ppm	0.8 - 10.1	ND - 174	Lower than coal
Beryllium (Be)	ppm	0 - 1.8	ND - 206	Lower than coal
Cadmium (Cd)	ppm	6.1 - 17.0	ND - 19	Lower than coal
Chromium (Cr)	ppm	74.7 - 140.0	ND - 168	Lower than coal
Cobalt (Co)	ppm	5.4 - 22.5	ND - 25.2	Lower than coal
Lead (Pb)	ppm	31.2 - 153.3	ND - 148	Comparable to coal
Manganese (Mn)	ppm	87.9 - 136	ND - 512	Lower than coal
Mercury (Hg)	ppm	0.4 - 1.1	ND - 3.1	Lower than coal
Nickel (Ni)	ppm	27.7 - 122.0	ND - 730	Lower than coal
Selenium (Se)	ppm	3.0 - 29.4	ND - 74.3	Lower than coal
Sulfur (S)	ppm	5100 - 6200	740 - 61,300	Lower than coal
Chlorine (Cl)	ppm	1,047	ND - 9,080	Lower than coal
Fluorine (F)	ppm	195	ND - 178	Comparable to coal
Total Halogens	ppm	1,670	at least 9,080	Lower than coal
Total Nitrogen (N)	ppm	50,300 - 60,700	13,600 - 54,000	See "Comparability of Contaminant Levels" section of text for explanation.

Notes:

1. All contaminant analyses—biosolids and coal—are on a dry weight basis.
2. DWSD BIOSOLIDS RANGE Data is from Detroit Water and Sewerage Department's (DWSD) monthly sampling, per DWSD Residual Management Program. The samples were obtained from three separate sources (24 sample analyses, sampling Period May 2008 through January 2009). Results were obtained by Test Method EPA SW 846-6010A. Chlorine and Fluorine data was obtained from 3 individual sample analyses performed in January 2012; Data for Cobalt, Manganese and Antimony was obtained from DWSD's quarterly duplicate sampling (8 samples for four quarters of year 2003).
3. Coal data taken from EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011,* available at www.epa.gov/epawaste/nonhaz/define/index.htm.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 4 2014

OFFICE OF
SOLID WASTE AND
EMERGENCY RESPONSE

Mr. Timothy Kasmoch
N-Viro International Corporation
2254 Centennial Road
Toledo, Ohio 43617

Dear Mr. Kasmoch:

In your letter of January 18, 2013, you request confirmation from the U.S. Environmental Protection Agency (EPA) that N-Viro International's N-Viro Fuel® is a non-waste fuel when burned in combustion units in accordance with the requirements in 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the rule requires that discarded non-hazardous secondary material (NHSM) undergo processing as defined in 40 CFR 241.2. Also, after processing, the NHSM must meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter, and follow-up correspondence and conference calls, we believe the N-Viro Fuel® produced by N-Viro International and burned in coal-fired combustion units for energy recovery would constitute a non-waste fuel under 40 CFR part 241 when substituting for 20% or less of the coal fuel required to operate the combustion unit. The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

A non-waste determination under 40 CFR Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 CFR Part 241 for the purposes of determining the applicable emissions standards under the Clean Air Act for the combustion unit in which it is used.

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSM into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for the purposes of the definition.

The determination of whether a particular operation or set of operations constitutes sufficient processing to meet the definition in 40 CFR 241.2 is necessarily a case-specific and fact-specific determination. This determination applies the regulatory definition of processing to the specific discarded material(s) being processed, as described in correspondence and supporting materials, taking into account the nature and content of the discarded material, as well as the types and extent of the operations performed on it. Thus, the same operations may or may not constitute sufficient processing under the regulation in a particular circumstance, depending on the material being processed and the specific facts of the processing. In some cases, certain operations will be sufficient to "transform discarded non-hazardous secondary material into a non-waste fuel," and in other cases, the same operations may not be sufficient to do so.

In your letter, in a subsequent email dated May 3, 2013, and follow-up conference calls,[1] you state that N-Viro International processes various blends of biosolids from multiple waste water treatment facilities to produce N-Viro Fuel®.[2] Specifically, you indicate that the biosolids are first screened for debris (i.e., inorganic grit and plastics) and dewatered prior to arrival at your facility.[3] After receipt and inspection of the material at the facility, any additional debris (i.e., plastics, large solids) still remaining will be removed by facility personnel. The dewatered biosolids are then mechanically mixed in measured amounts with materials, referred to as "Admixtures," (e.g., fly ash, cement kiln dust, lime kiln dust, or lime),[4] which react with the moisture in the dewatered biosolids to elevate the pH and generate heat for disinfection purposes.[5] In addition, material exiting the drier—finished product— is reintroduced during the mixing phase as a recycle function in order to reduce the particle size and increase the total percent solid, as well as boost the organic content and fuel value of the N-Viro Fuel®. After thoroughly mixing the biosolids and "Admixtures," the blend is then conveyed through a single pass rotary drum dryer. The dryer thermally evaporates water to help raise the overall heating value of the product fuel as well as other contaminants, such as nitrogen and sulfur that are contained in the biosolids.[6]

According to the information you provided, as the blend exits the rotary drum dryer, the blend then enters a multi-stage cyclonic separation system. The mixing and drying process eliminates large or oversize particles, while the cyclone separation system separates the desired fuel into a size similar to pulverized coal. The smallest particles are removed by subsequent cyclones or a venturi scrubber designed to capture fines and return them to the mixer (as discussed above) for remixing to improve product uniformity. The remixing enhances the efficiency of the drying system, maximizes heating value while sending on the best sized material as finished product. Finished fuel will be screened and/or inspected to ensure no foreign debris is present. The final product, which is set to have a final solids

[1] May 3, 2013 email from Bob Bohmer to George Faison and Mike Svizzero. Conference calls were held on May 3, 2013 and August 28, 2013.

[2] In the material provided to EPA, you indicate that animal manure may also be used as feedstock to produce N-Viro Fuel®. This letter only addresses N-Viro Fuel that is produced from biosolids.

[3] As noted in June 4, 2010 proposed NHSM rule, EPA does not consider dewatering, by itself, to meet our definition of adequate or sufficient processing. For example, dewatering sewage sludge would likely be required processing as part of normal waste management activities (e.g., prior to landfilling, or prior to burning the sludge for disposal in an incinerator). As such, we do not view dewatering alone to be sufficient processing to convert discarded materials into non-waste fuel products.

[4] Approximately 2 to 10 percent of Admixture is used depending on the characteristics of the material and the admixture used.

[5] While pathogens are not included as a contaminant identified in 40 CFR Part 241, you indicate that this process would also create a material that meets or exceeds Class A under the 40 CFR part 503 regulations for pathogens.

[6] While not a factor in determining whether the material has been sufficiently processed, we note that air control equipment will treat exhaust air from the dryer in a multi-stage process. The treatment will remove particulates through cyclone separation, treat ammonia and amines in the first stage packed bed scrubber, and reduce hydrogen sulfides in the second stage packed bed scrubber. The process will also spray odor masking chemicals in the final containment area.

content of between 75 and 95 percent, is granular in appearance and has less volume and weight than the original biosolids.

Regarding the use of "Admixtures," you also state that the addition of "Admixtures" modifies the ignition profile of N-Viro Fuel® making it more compatible in the boiler than simply dried biosolids. As dried biosolids have a very low ignition temperature making their use in commercial power units problematic, you indicate that this patented process modifies the ignition profile of N-Viro Fuel® to more closely resemble the ignitability of coal. In addition, the presence of oxides of calcium in the "Admixtures" makes calcium hydroxide available for SO_x reduction when the fuel is combusted.

Based on this description—that is, removal of contaminants (i.e., removal of plastics, reduction in heavy metals via grit removal, as well as other contaminants in the drier) and improvement of its fuel characteristics (i.e., removal of large solids and grit, removal of water to improve the as-fired energy content, addition of Admixtures to improve ignition, and sizing of the material to allow it to be handled and fed to the boiler "as is"), we believe the process used to produce N-Viro Fuel ® meets the definition of processing in 40 CFR 241.2, and thus, transforms the dewatered biosolids into a non-waste fuel provided it meets the legitimacy criteria.

As noted in your letter of January 13, 2013 and follow-up calls, tests to determine impacts on performance, emissions, and byproduct constituents were based on a 10% or 20% substitution of N-Viro Fuel® for the primary fuel for which it substitutes—coal. Accordingly, the determination that N-Viro Fuel® would constitute a non-waste fuel under 40 CFR part 241 is predicated on a substitution of N-Viro Fuel® of 20% or less of the coal fuel required for the combustion unit.

Legitimacy Criteria

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels include: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have a meaningful heating value and be used as a fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage As A Valuable Commodity

Regarding the first criterion, N-Viro Fuel® is stored on-site in a temporary indoor curing area, silo or bunker so that the material is not exposed to the outside atmosphere. Within a short time (hours or days), the N-Viro Fuel® will be conveyed or trucked to the end user, making sure that such material is not exposed to the environment. Once received by the power plant, it will be blended with other solid fuels of similar consistency and BTU content in the Active Fuel Storage Building. The mixed fuel will then be processed and burned as fuel in a circulating fluidized bed boiler.

Based on this information, the N-Viro Fuel® is managed as a valuable commodity and storage does not exceed a "reasonable time frame" as discussed in the NHSM final rule (40 CFR 241.3(d)(1)(i)(A).[7,8]

Meaningful Heating Value and Used As A Fuel to Recover Energy

Regarding the second legitimacy criterion, you indicate that the N-Viro Fuel® has an as-fired heating value of between 5,500 and 6,000 Btu/pound and will be used as a fuel in a combustion unit that recovers energy. As the Agency stated in the preamble to the NHSM final rule, NHSMs with an energy value greater than 5,000 Btu/lb, as fired, are considered to have a meaningful heating value (see 76 FR 15541, March 21, 2011). Thus, we believe that N-Viro International's N-Viro Fuel® meets the second legitimacy criterion.

Comparability of Contaminant Levels

Regarding the third criterion on contaminant levels, your letter requests confirmation that the N-Viro Fuel® meets the contaminant legitimacy criterion when compared to coal, the traditional fuel for which the combustion unit is designed to burn. In the enclosure to your January 2013 letter, you compared contaminant data for N-Viro Fuel® to contaminant data for coal as outlined in the "Contaminant Concentrations in Traditional Fuels: Tables for Comparison."

A direct contaminant-to-contaminant comparison, based on the information provided in your enclosure, is presented in Table 1. As noted in footnote a, the table compares samples of both digested and undigested biosolids that have been processed into N-Viro Fuel®. Based on this comparison, all contaminants in N-Viro Fuel® are comparable to or lower than those contaminants in coal, with the exceptions of manganese and fluorine. One of seven reported manganese values was higher than typically found in coal, while two of five reported fluorine values were higher than typically found in coal.

The EPA previously stated that for the purposes of contaminant comparisons, it may be appropriate to group contaminants sharing similar physical and chemical properties that influence behavior in the combustion unit prior to the point where emissions occur. Although not included in the Agency's sample approach,[9] grouping of low-volatile metals and the total halogens chlorine and fluorine would be appropriate as contaminants within each of these groups share key physical and chemical properties and would be expected to behave similarly in a combustion unit prior to the point where emissions occur. For example, a significant portion of low-volatile metals can be expected to remain in the bottom ash after combustion relative to other contaminants. The halogens chlorine and fluorine are highly reactive and form acid gases when bonded with hydrogen in the combustion chamber. Nevertheless, there may be circumstances in which grouping of low-volatile metals and the total halogens chlorine and fluorine would not be appropriate and the EPA will evaluate each instance on a case-by-case basis.

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[7] As discussed in the NHSM final rule (76 FR 15520) "reasonable time frame" is not specifically defined as such time frames vary among the large number of non-hazardous secondary materials and industry involved.
[8] Regarding the management of N-Viro Fuel and the type of boiler design at the end user, the information provided addresses the Scrubgrass Generating Plant, an 80 megawatt waste coal plant located in Kennerdell, Pennsylvania. To the extent that the N-Viro Fuel is sent to another power plant, no information was provided as to how the N-Viro Fuel will be managed or the boiler technology used and thus, this letter does not address this aspect of the legitimacy criteria at other end users.
[9] See 78 FR 9146.

Enclosed, Table 2 provides grouping data for a comparison of low-volatile metals (including manganese), and Table 3 provides grouping data for a comparison of total halogens (including fluorine). The data show that, for each of the groups of contaminants, the range of the totals present in N-Viro Fuel® is within the range found in coal. This conclusion assumes that N-Viro Fuel® was tested for any constituents expected to be present. Additional constituents for which N-Viro Fuel® were not tested must, as is the case for those tested, be present at levels comparable to or less than those in coal, based on your knowledge of the material.

Conclusion

Overall, based on the information provided in your letter, we believe the facts indicate that N-Viro Fuel® meets both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 CFR Part 241 regulations when substituting for 20% or less of the coal fuel required to operate the combustion unit.

If you have any other questions, please contact George Faison of my staff at 703-305-7652.

Sincerely,

Betsy Devlin

Betsy Devlin, Director
Materials Recycling and Waste Management Division
Office of Resource Conservation and Recovery

Enclosures

cc: John Armstead
EPA Region III, Land and Chemicals Division

Margaret Guerriero
EPA Region V, Land and Chemicals Division

Enclosure

Table 1. Data Supplied by N-Viro International Corporation

Contaminant	N-Viro Fuel® N-Viro Fuel® ® Contaminant Levels and Heating Value[a]										Coal Range[b]	Comparison Results
	Sample 1 Undigested	Sample 1 Digested	Sample 2 Undigested	Sample 3 Digested	Sample 4 Digested	April 2011 Composite	April 2009 Composite	Feb 2012 Test A	Feb 2012 Test B	Max		
Metal Elements (ppm - dry basis)												
Antimony	<5.76	<6.88	<10.9	<10.1	<5.63					<10.9[c]	ND - 10	Comparable. Highest detection limits slightly above range.
Arsenic	<5.76	<6.88	14.8	15.7	<5.63	29.4	<5			29.4	ND - 174	Within range.
Beryllium	1.26	1.42	<0.00820	0.534	1.46		<5			1.46[d]	ND - 206	Within range.
Cadmium	0.587	0.722	0.897	1.35	0.72	1.95	<5			1.95[e]	ND - 19	Within range.
Chromium	16	19.3	12.9	47.9	17.9	23.5	30			47.9	ND - 168	Within range.
Cobalt	4.38	4.53	3.27	4	4.41					4.53	ND - 25.2	Within range.
Lead	8.66	8.55	18.2	62.3	10.5	46.3	<5			62.3	ND - 148	Within range.
Manganese	54.3	52.8	609	384	64	309	253			609	ND - 512	One sample higher than coal range.
Mercury	0.3982	0.5577	0.7375	0.6761	0.3334	1.9	0.227			1.9	ND - 3.1	Within range.
Nickel	14	16.7	14.4	24.3	16.1	32.1	110			110	ND - 730	Within range.
Selenium	7.61	8.82	<10.9	<10.1	8.37	7.24	<5			8.82[f]	ND - 74.3	Within range.
Non-metal Elements (ppm - dry basis)												
Chlorine	6,740	7,551	2,728	2,329	5,002		3,542			7,551	ND - 9,080	Within range.
Fluorine	130.5	177	483.6	159.7	390.8					483.6	ND - 178	Two samples higher than coal range.
Nitrogen	32,250	33,340	36,850	34,380	28,980	22,054				36,850	13,600 - 54,000	Within range.
Sulfur	13,900	13,000	13,800	14,700	14,500	22,530				22,530	740 - 61,300	Within range.
Volatile Organic Compounds (VOC) (µg/kg)												
Benzene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	ND - 38,000	Within range.
Ethylbenzene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	700 - 5,400	Lower than coal range.
Styrene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	1,000 - 26,000	Lower than coal range.
Toluene	<55.3	<54.3	13.9	29.4	<47.9					29.4[g]	8,600 - 56,000	Lower than coal range.
Xylenes	<55.3	<54.3	4.92	16.1	<47.9					16.1[g]	4,000 - 28,000	Lower than coal range.
Heating Value												
BTU/lb	5,580	4,510	5,260	4,870	4,350		5,017	6,099	6,097			

Notes:

a. Data provided by N-Viro International Corporation on January 18, 2013. Samples include both digested sludges (sludges that have undergone anaerobic digestion) and undigested sludge.
b. Ranges for Coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.
c. All samples were below detection limits, so the actual value (if known) would be less than 10.9 ppm and would be comparable to the range of coal.
d. Highest detection limit was 5 ppm.
e. Detection limit was 5 ppm.
f. Highest detection limit was 10.9 ppm, but the sample was below the detection limit.
g. Highest detection limit was 55.3 ppm, but the sample was below the detection limit.

Table 2. Contaminant Comparison, Low-Volatile Metals (LVM) Group

Low Volatile Metal[a]	Units	Range	
		N-Viro Fuel® ®[b]	Coal[c]
Antimony (Sb)[d]	ppm	ND	ND - 10
Arsenic (As)	ppm	ND - 29.4	ND - 174
Beryllium (Be)	ppm	ND - 1.46	ND - 206
Chromium (Cr)	ppm	12.9 - 47.9	ND - 168
Cobalt (Co)	ppm	3.27 - 4.53	ND - 30
Manganese (Mn)	ppm	52.8 - 609	ND - 512
Nickel (Ni)	ppm	14 - 110	ND - 730
Total LVMs[e]	ppm	<101 - 665	ND - 767

Notes:

a. Low-volatile metals as identified in 40 CFR 63.1219(e)(4)—National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors.
b. Based on data provided by N-Viro International Corporation on January 18, 2013. Some LVMs included in these averages and totals were not detected. In these cases, the detection limit value was used to calculate averages and totals, and the results are denoted with a "<" symbol.
c. Data for coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.
d. All samples were below detection limits.
e. The high and low ends of each individual metal's range do not necessarily add up to the total LVM range. This is because maximum and minimum concentrations for individual metals do not always come from the same sample.

Table 3. Contaminant Comparison, Total Halogens Group

Halogen	Units	Range	
		N-Viro Fuel®[a]	Coal[b]
Chlorine	ppm	2,329 - 7,551	ND - 9,080
Fluorine	ppm	130.5 - 483.6	ND - 178
Total Halogens[c]	ppm	2,489 - 7,728	ND - 9,080

Notes:

a. Represents data provided by N-Viro International Corporation on January 18, 2013.
b. Data for coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.
c. The high and low ends of each individual halogen's range do not necessarily add up to total halogens range. This is because maximum and minimum concentrations for individual halogens do not always come from the same sample.

APPENDIX D

Lehigh Hanson Cement Baltimore Co. to achieve carbon neutrality across the cement and concrete value chain by signing onto the Portland Cement Association's Roadmap to Carbon Neutrality.

Heidelberg Materials

10.12.2021

Lehigh Hanson Joins Roadmap to Carbon Neutrality by 2050

Lehigh Hanson, Inc. today joined an ambitious journey to achieving carbon neutrality across the cement and concrete value chain by signing onto the Portland Cement Association's (PCA) Roadmap to Carbon Neutrality. In collaboration with PCA's other member companies and experts, the Roadmap demonstrates how the U.S. cement and concrete industry can collectively address climate change, decrease greenhouse gases and eliminate barriers that are restricting environmental progress. Given the significant role of cement in society and anticipated infrastructure development, it is critical that the industry comes together and acts now to create sustainable building solutions in the decades to come.

"Today marks a critical step in transforming the cement industry and building a more sustainable future," said Chris Ward, President and CEO of Lehigh Hanson. "We are excited to partner with PCA to drive policy in support of this dynamic transition while also investing in technology and innovation to achieve carbon neutrality."

The Roadmap focuses on a comprehensive range of reduction strategies for stakeholders to adopt across all phases of the material's life cycle, such as reducing CO_2 from the manufacturing process, decreasing combustion emissions by changing fuel sources and shifting toward increased use of renewable electricity.

Many of the solutions included in the PCA Roadmap are products, technologies and approaches that exist today – and by bringing together a variety of collaborators, PCA intends to ensure the adoption of these solutions on a broad scale. This will accomplish near-term benefits while constantly striving toward the long-term success of reaching carbon neutrality.

With aggressive emission reductions targets charted in its own roadmap, Lehigh Hanson has already made significant strides in the journey to carbon neutrality, including increased focus on alternative fuels and supplementary cementitious materials as well as innovative carbon

FEATURED

Lehigh Hanson Joins Roadmap to Carbon Neutrality by 2050

RECENT

Lehigh Hanson Joins Roadmap to Carbon Neutrality by 2050

capture storage and use research. Lehigh Hanson has also led the push for lower carbon cement products with its EcoCem®PLC and EcoCem®PLUS cements which provide strength and durability while significantly reducing the carbon footprint of concrete.

Industry experts, researchers, policymakers and companies along the value chain are imperative to realize the multitude of solutions that must be developed across policies and regulations, technology, innovation and demand generation – creating both near-and long-term CO_2 reduction opportunities and constantly striving toward carbon neutrality.

Additionally, cement and concrete companies worldwide have committed to achieve carbon neutrality across the value chain by 2050. Addressing climate change is a global task, but each country presents specific opportunities and unique challenges, and the PCA Roadmap presents a plan tailored to the U.S. cement and concrete industry. PCA is aligned with the Global Cement and Concrete Association's Roadmap.

View the full Roadmap here.

FIND A LOCATION

Search by City or Zip

- - -

APPENDIX E

Lehigh’s Union Bridge Plant in Baltimore wins Overall Environmental Excellence Award as part of the 2020 Energy and Environment Awards from Portland Cement Association.

Archived News

September 04, 2014

Cement Industry Honors Lehigh Hanson and Its Union Bridge Cement Plant for Environmental Performance and Energy Efficiency

SKOKIE, Ill. – The Portland Cement Association (PCA) and *Cement Americas* magazine recognized Lehigh Hanson, Inc., and its Lehigh Cement Company Union Bridge cement plant in Union Bridge, Md., with the Environmental Performance Award as part of the 2014 Cement Industry Energy & Environment Awards. The award was presented at PCA's Fall Meeting in Chicago.

Lehigh Hanson implemented a mercury reduction program at its Union Bridge plant as part of a voluntary effort to protect and enhance the Chesapeake Bay Watershed. The program will help the plant meet new national emission regulatory limits.

In 2013, the Union Bridge plant reduced the amount of coal burned in the kiln and calciner with greenhouse gas neutral dried biosolids. The plant avoided using 57,000 metric tons of a naturally occurring fossil fuel and replaced it with a renewable biomass material.

Proposed in 2012 and completed in 2013, the Union Bridge plant experimented with using dried biosolids in the preheater tower as part of efforts to increase its use of alternative fuels. As a direct result, the Union Bridge plant nearly doubled the amount of fossil fuel avoided between 2012 and 2013.

The Environmental Performance Award honors facilities that take steps beyond those contained in environmental laws, regulations, permits and requirements to minimize their impact on the environment. The Union Bridge plant was also a runner up for the energy efficiency, innovation, land stewardship and overall environmental excellence categories.

The Energy & Environment Awards honor individual cement facilities that exemplify the spirit of continuous environmental improvement and support this spirit with action. These plants go beyond government regulations and local laws to ensure that their processes contribute to making their communities better places to live and work. Five categories are recognized: outreach, environmental performance, land stewardship, innovation, and energy efficiency. Additionally, PCA presents a special honor to a plant demonstrating excellence in multiple categories.

The award program was created in 2000 by the Portland Cement Association as part of its environment and energy strategic plan for the U.S. cement industry. The awards honor activities conducted during the previous calendar year, and the program is open to any cement manufacturing plant in North America. Judges for the 2014 awards Program included representatives from U.S. EPA-ENERGY STAR, Wildlife Habitat Council, U.S. Geological Survey, World Wildlife Fund, and *Cement Americas*.

About PCA

Based in Washington, D.C., with offices in Skokie, Ill., the Portland Cement Association represents cement companies in the United States. It conducts market development, engineering, research, education, and public affairs programs. More information on PCA programs is available at www.cement.org.

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ANDRITZ FLUID BED DRYING SYSTEM FOR BIOSOLIDS (FDS)
BUDGET PROPOSAL USING RENEWABLE ELECTRICITY/HEAT RECOVERY
RENUFUEL TEAM PROPOSAL FOR KING COUNTY, WA

Proposal No.: 3743670-1
Version No: Rev. 0

Inquiry No.: N/A
Date: February 13, 2023

ANDRITZ Biosolids Fluid Bed Drying System

ENGINEERED SUCCESS

Customer: ReNuFuel LLC
Attention: Bart Lynam
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Seattle, WA 98101
p: 206'612.5392
bart.lynam@renufuel.com

Provider: ANDRITZ Separation Technologies Inc.
Contact: Peter Commerford
1010 Commercial Blvd. S
Arlington, TX 76001
p: 817.271.2855
peter.commerford@andritz.com

ANDRITZ

Monday, February 13, 2023. sent via email: bart.lynam@renufuel.com

ReNuFuel LLC
9600 Wharf Street
Seattle, WA 98101
p: 206'612.5392

ATTENTION: Bart Lynam

SUBJECT: ANDRITZ Fluid Bed Drying System for Biosolids (FDS)
Budget Proposal Using Renewable Electricity/Heat Recovery
ReNuFuel Team Proposal for King County, WA

We take pleasure in providing this Budget Proposal for Equipment and Systems per your request.

Having delivered over 200 biosolids drying plants globally, including 40 in North America, over a time span of 40 years, Andritz has a uniquely deep understanding of the requirements in the development of facilities to economically and sustainably dry biosolids, and their subsequent reuse.

The biosolids drying plant offered to the ReNuFuel team for King County South Plant leverages this experience to deliver a facility that is demonstrably lower in cost than its compost alternative and addresses the goal of King County to take bold action on climate change by reducing greenhouse gas (GHG) emissions.

Through the cessation of trucking Class B dewatered sludge to eastern Washington, the use of renewable electricity to provide heat for thermal drying and digester heating, and the use of the dried biosolids as a fossil fuel replacement in cement plants, GHG emissions will be substantially reduced.

The ANDRITZ Fluid Bed Drying System offered for this facility is a mature and highly evolved technology, having been first delivered in the early 1990's, and recently commissioned at the world's largest biosolids facility, processing up to 3,000 wet TPD, in Shanghai, China.

We have two facilities using this technology for drying biosolids in North America – North Shore (north of Chicago) and Victoria BC – both plants are described within, with the latter plant featuring digester heating from the dryer waste heat, as offered here.

Thank you for your consideration. We look forward to the next steps in this process – please feel free to contact me with any questions or comments.

Sincerely

Peter Commerford
Manager, Drying Systems
+1 (817) 271-2855
ANDRITZ Separation Technologies, Inc.
1010 Commercial Blvd S.
Arlington, TX 76001 USA

cc: Steve Huff President steve.huff@andritz.com

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1 Why Biosolids Drying at South Plant using Renewable Energy?

1.1 Lower Life Cycle Cost than The Alternatives

1.1.1 Comparing Net Present Value of the RenuFuel Team Plan with Composting

To calculate the 20-year Ownership cost of the ANDRITZ Fluid Bed Drying System with renewable electricity, the average yearly cost (using 3% compound inflation on all items) was calculated for year 1 and year 20and averaged over the 20 years – the NPV was calculated with the same factors used in the Murraysmith report The dryer option is estimated to save about $100,100,000 over the 20 year life of the project versus the Baseline compost case.

MurraySmith Table1	Capital Costs	O&M Costs/yr	20 Year O&M KC PV	Total 20-year Lifecycle Cost
Baseline	$119.9	$15.2	$253.9	$373.8
Dryer Facility per MurraySmith	$508.2	$12.8	$215.4	$723.6
Revised Dryer Facility (Fuel to Cement Plant)	$113.8	$9.5	$159.9	$273.7
Savings over Baseline				**$100.1**

King County	2022 AA	2022 -2050 AA (Average)	2050 AA
Nominal Daily Sludge Production	85 dry tons/day	108 dry tons/day	130 dry tons/day
Cake Dryness	24% DS	24% DS	24% DS
Nominal Daily Sludge Production	354 wet tons/day	448 wet tons/day	542 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum	163,490 wet tons/annum	197,708 wet tons/annum
Dryer Operations	7 days per week	6 days per week	6 days per week
Dryer Operations	24 hours/day	24 hours/day	24 hours/day
Dryer Operations	168 hours/week	144 hours/week	144 hours/week
Dryer Capacity Required	85 dry tons/day	125 dry tons/day	152 dry tons/day
Dryer Capacity Required	354 wet tons/day	523 wet tons/day	632 wet tons/day
Final Product	95% DS	95% DS	95% DS
Final Product	89 tons/hour	132 tons/hour	160 tons/hour
Evaporation Rate	11.0 tons/hour H2O	16.3 tons/hour H2O	19.7 tons/hour H2O
Evaporation Rate	22,058 lb/hour H2O	32,546 lb/hour H2O	39,358 lb/hour H2O
Evaporation Rate	10,004 kg/hour H2O	14,760 kg/hour H2O	17,849 kg/hour H2O
No. of Drying Trains	1	2	2
Evaporation Rate/train	10,004 kg/hour H2O	7,380 kg/hour H2O	8,925 kg/hour H2O
Dryer Technology	Fluid Bed Dryer	Fluid Bed Dryer	Fluid Bed Dryer
Dryer Model Selection	10	FDS-10.0	FDS-10.0
Utlization	100%	74%	89%
Max. Evaporation Rate	10,000 kg/hour H2O	10,000 kg/hour H2O	10,000 kg/hour H2O

Equipment CAPEX	$45,532,000		
Facilty CAPEX X'r 2.50	$113,830,000		
Heat Energy Requirement	7.55 mW (th)	11.13 mW (th)	13.46 mW (th)
Electrical Consumption	60 kW-hr/tonne H2O	60 kW-hr/tonne H2O	60 kW-hr/tonne H2O
Electrical Consumption	600 kw-hr/hr	886 kw-hr/hr	1,071 kw-hr/hr
Total Electrical Consumption	8,145 kw-hr/hr	12,018 kw-hr/hr	14,534 kw-hr/hr
Electrical Unit cost	$0.0634 /kw-hr	$0.0634 /kw-hr	$0.1112 /kw-hr
Demand Charge	$400,000		$701,402
Annual Electric Cost	$4,911,326.03	$5,705,500.56	$12,800,024.47
Maintenance Cost	2.0% of Equip. CAPEX	2.0% of Equip. CAPEX	2.0% of Equip. CAPEX
Annual Maintenance Cost	$910,640		$1,596,812.75
Operations Personnel	10		10
Chemical for Scrubber	$100,000		$175,351
Natural Gas Price	$6/MM BTU		$11/MM BTU
Digester Heating Savings (74,941 MMBTU/yr)	($449,646)		($788,457)
Operations Personnel Cost	$950,000		$1,665,830.75
Trucking cake - West Point/Brightwater	Truck/mile cost $2.90		Truck/mile cost $5.09
149,000 Truck miles/annum	$432,100.00		$757,689.97
Revenue from Fuel Sale	$10 /ton		$25 /ton
Revenue from Fuel Sale	$326,579		$1,248,684
Total Operations and Maintenance Cost	$5,617,201	$9,489,478	$13,361,755

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1.2 Sustainability through lowering of Greenhouse Gas Emissions

1.2.1 Cessation of Trucking Dewatered Sludge Cake to Eastern WA

Historical Diesel fuel use for hauling biosolids ....345,197 gal/yr\
Historical diesel fuel usage for land application ....40,000 gal/yr
Product distribution (LOOP program)...1,815 gal/yr
Total diesel fuel usage for Class B sludge ....387,012 gal/yr
Climate registry value for diesel usage ....10.21 kgCO_2/gal.
Saving due to cessation of trucking to eastern Washington ....3,951 metric tons CO2/year

1.2.2 Capturing low grade waste heat from drying to provide digester heating

Per the Heat and Mass balance (see section 5) the dryer can displace up to 24 MM BTU/h of natural gas used for heating digester and buildings
However, King County reports average monthly usage of natural gas as ..62.451 therms/month
Convert to yearly BTU consumption of natural gas...................................74,941 MMBTU/yr
Combusting 1 million BTU of gas results in 52.91 kg of CO2 emitted
GHG savings due to heat recovery is 52.91 x 74,951 ....3,965 metric tons CO2/year

1.2.3 Conversion of Dewatered Class B Sludge Cake to Class A Biosolids Granules

Reducing the volume of sludge to reused, and making it suitable for cement plant, mitigates the risk associated with PFAS contamination.
Most recent Seattle Times Article

1.2.4 Using Renewable Electricity to provide thermal heat for drying

In Washington state, hydroelectric power is the dominant renewable resource, accounting for approximately two-thirds of the total electricity produced, according to the Energy Information Administration. With the development of wind and solar resources, Renewable Electricity is a relatively cheap source of thermal energy.
The CHG savings for the South Plant at King County by electing to use renewable electric in place of natural gas is calculated as follows:
Annual Average dry TPD biosolids through 2050 ....98 dry TPD
Thermal Energy used as Electric ....8,698 kWh/h
Equivalent in Natural Gas..29.71 MM BTU/h
Operating time ....8760 hours
Annual Natural Gas Usage deferred ....260,232 MMBTU
CO2 generated if Natural Gas used ....52.91 kg/MMBTU
CO2 saving due to the selection of renewable electricity.....................13,768 metric tons CO2

1.2.5 Use of Class A pathogen free granules for fuel in Cement Plants

Refer to the materials provided in the ReNuFuel Team Proposal Appendices

1.3 Proven System for Biosolids Drying

Having delivered over 200 biosolids drying plants globally, including 40 in North America, over a time span of 40 years, Andritz has a uniquely deep understanding of the requirements in the implementation of these facilities for the long term – many ANDRITZ biosolids drying plants have over 25 years of continuous operations.

1.4 Leveraging the facilities available at South Plant to serve all Of King County

1.4.1 View of the Proposed Facility showing minimal impact to current WWTP Operations)

1.4.2 Cutaway view of the Facility (Third Dryer to be added in later years)

1.4.3 Aerial View of Facility with Cake Receiving in foreground

1.4.4 Aerial View showing Solar Panel array

2 Biosolids Drying Plant Sizing for the future with redundancy

2.1 Dryer Size Selection

King County	2022 AA	2022 -2050 AA (Average)	2050 AA
Nominal Daily Sludge Production	85 dry tons/day	108 dry tons/day	130 dry tons/day
Cake Dryness	24% DS	24% DS	24% DS
Nominal Daily Sludge Production	354 wet tons/day	448 wet tons/day	542 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum	163,490 wet tons/annum	197,708 wet tons/annum
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Dryer Operations	24 hours/day	24 hours/day	24 hours/day
Dryer Operations	168 hours/week	168 hours/week	168 hours/week
Dryer Capacity Required	85 dry tons/day	108 dry tons/day	130 dry tons/day
Dryer Capacity Required	354 wet tons/day	448 wet tons/day	542 wet tons/day
Final Product	95% DS	95% DS	95% DS
Final Product	89 tons/hour	113 tons/hour	137 tons/hour
Evaporation Rate	11.0 tons/hour H2O	13.9 tons/hour H2O	16.9 tons/hour H2O
Evaporation Rate	22,058 lb/hour H2O	27,897 lb/hour H2O	33,735 lb/hour H2O
Evaporation Rate	10,004 kg/hour H2O	12,652 kg/hour H2O	15,299 kg/hour H2O
No. of Drying Trains	1	2	2
Evaporation Rate/train	10,004 kg/hour H2O	6,326 kg/hour H2O	7,650 kg/hour H2O
Dryer Technology	Fluid Bed Dryer	Fluid Bed Dryer	Fluid Bed Dryer
Dryer Model Selection	FDS-10.0	FDS-10.0	FDS-10.0
Utlization	50%	63%	76%
Max. Evaporation Rate	10,000 kg/hour H2O	10,000 kg/hour H2O	10,000 kg/hour H2O

2.2 Sludge Characteristics – Fluid Bed Dryer

Project Name.. ReNuFuel at King County
Project Location.. South Plant, Renton, WA
Type of WWTP .... Municipal
Origin of Sludge.. South Plant, West Point, Brightwater WWTP's

- Type... Anaerobically Digested
- Fats, Oil and Grease Content.................................. <5% by weight
- Fiber Content (+150 mesh) .... <25% by weight
- Ash Content.. <35% by weight
- pH 6-7
- Temperature .... 60°F to 95°F
- Cake Solids Concentration...................................... 24% Design (21 – 25% TS range)
- Cake Solids Concentration Variation........................ 1% DS in any one hour (max.)
- Metals Content .... < limits imposed by EPA 40CFR Part 503 regulations
- BTX (benzene, toluene, xylene)............................... < 50 mg/kg DS

Safety systems are based upon the following sludge dust characteristics

- Max. explosion pressure .... ≤ 8 bar
- K_{st} value .... ≤ 150 bar m/s
- Dust classification St1
- Limiting O2 concentration 10%
- Minimum explosible dust concentration .... 60 g/m³

2.3 Facility Design Criteria – Fluid Bed Dryer

Design Basis...
Dried Pellet Moisture Content .... 95% DS
Dryer Proposed .... ANDRITZ Fluid Bed Drying System
Dryer Size.. FDS 10.0
No. of Dryer Trains .... Two (2)
Dried Pellet Moisture Content .... 10,000 kg/h H_2O each train
Heat Exchange Fluid .... Thermal Oil
Primary Energy for the Dryer... Renewable electric
Non-Potable Filtered Plant Effluent Water .... 68°F, 70 psig (min.)
Electric Power.. 480V, 60 Hz, 3-phase, 3-wire
Estimated Oil Heater Electric Consumption .... 8,000 kW
Estimated Wastewater Discharge Quantity

Note: No performance guarantees are being supplied at this time. All performance values listed above are indicative for reference only obtained from ANDRITZ experience from similar installations and laboratory testing. Laboratory testing of specific sludge is required to determine actual performance capabilities for specific installations. It is highly recommended that a sludge sample be obtained and sent into Andritz laboratory for testing to benchmark sludge properties.

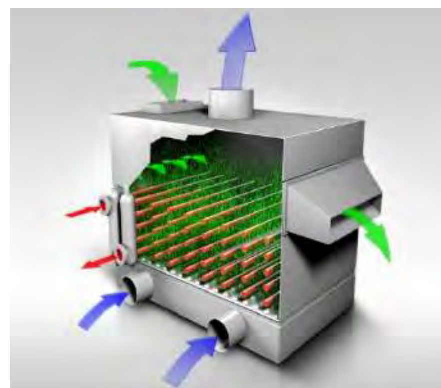
3 Fluid Bed Drying System

3.1 Process Narrative

The Fluid Bed Drying System (FDS) is designed for the drying of mechanical dewatered sludge in the fluidized bed. The dewatered sludge is processed directly in the fluid bed without requiring the use of a recycle system (add back material) in a granulation unit. This direct sludge feeding system enables a fully automatic operation of the sludge dryer.

The fluidized bed drying system with direct sludge feeding has been successfully applied in more than thirty (35) installations worldwide.

The drying system is designed for treating pumpable dewatered sludge from municipal wastewater treatment plants when equipped with:



- Mechanical screening (< 6 mm openings) to remove waste (plastics, wood, long fibers) from the incoming water. The dewatered sludge should be free of sludge foreign material and particles > 0.38" (10 mm) (e.g. screws, bolts, waste), otherwise the equipment can be damaged and the availability of the drying process decreased.
- A primary and secondary treatment process
- With or without digestion
- Mechanical dewatering to produce a cake

The fluid bed drying process produces a final product with a minimum dried solids content of 90% TS which greatly reduces the overall Biosolids volume and allows for reduced shipping and storage volume.

The dry product generated by this process can be beneficially used:

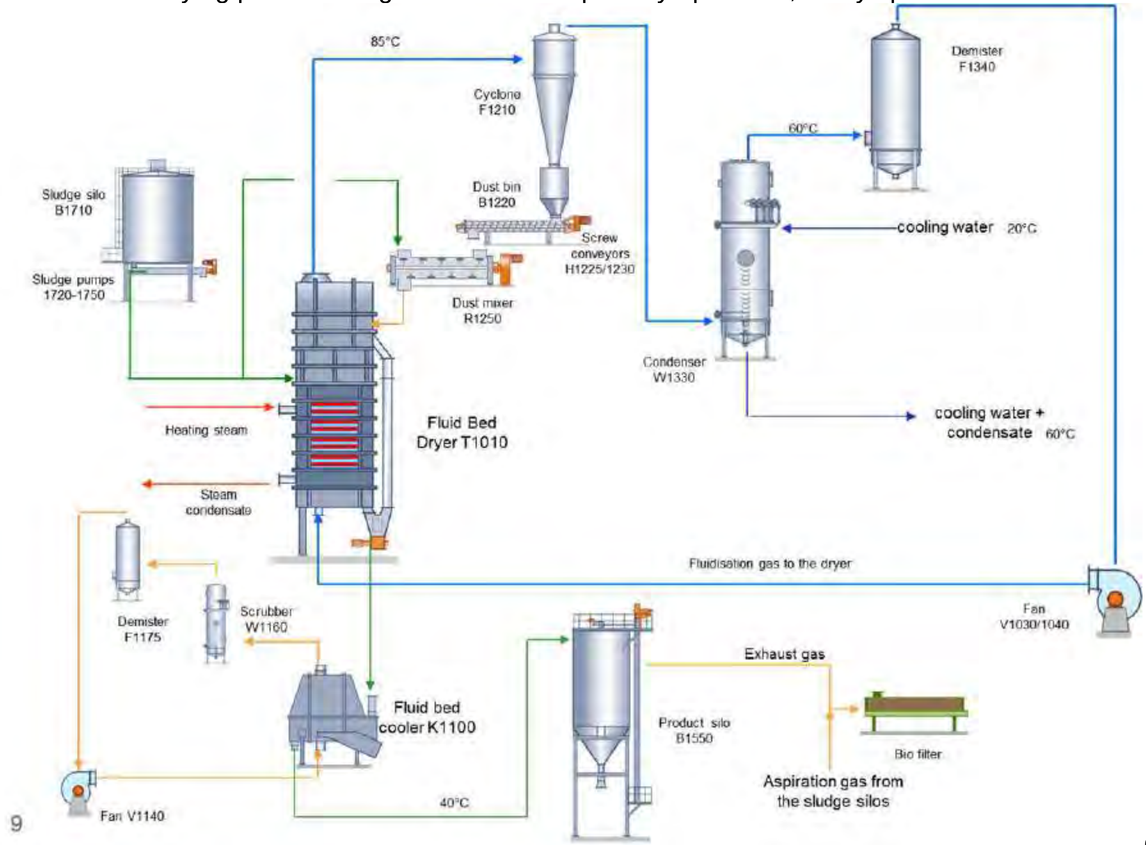
- For thermal utilization as a fuel (cement kilns, power plants, waste incinerators, etc.)
- As Class A biosolids for agricultural applications.

The final product characteristics may vary depending on the sludge treatment process, composition, history, additives, chemical pre-treatment, and other influences.

ANDRITZ Fluid Bed Drying System – YouTube presentation

Drying Process

The fluid bed drying plant is designed for 24 hour per day operation, 7 days per week

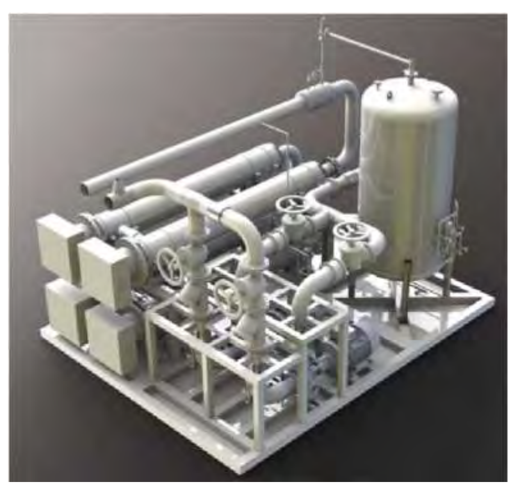


ek

Typical Flow sheet of the Fluid Bed Drying Plant for dewatered sludge;

Heating Source

Fluid bed dryers are typically heated from either a saturated steam boiler or from a dedicated thermal oil boiler system. For this application, a heating source rated for approx. 6,900 kW (~ 27 M Btu/hr) for each fluid bed dryer will be required for sludge drying operation on a sustained 24/7 operation basis.

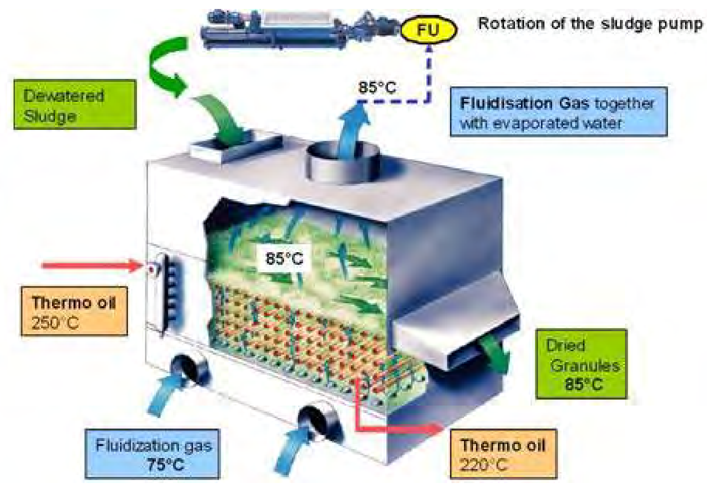


Dewatered Sludge Handling
The dewatered sludge with dry substance of 22% TS is dosed directly from the sludge cake storage bin (B-1710) by five (5) cake feed pumps (P-1720 – P-1760).

The sludge cake bin is connected to the aspiration system (by others). The ambient air is sucked through the bin to avoid accumulation of explosive gas (mainly methane) inside the bin.

Drying Principle of the Fluidized Bed Dryer
A fluid bed is characterized by the movement of the granules, achieved by a gas stream passing through the product layer.

Particle in floating motion



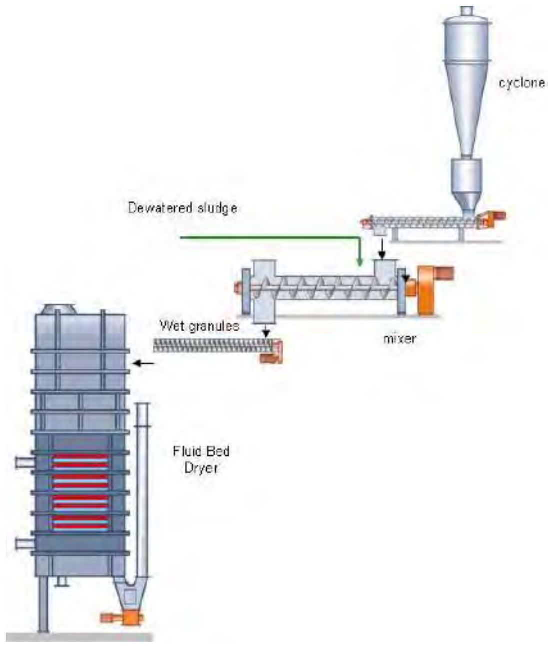
Principle of the fluid bed dryer

The fluid bed dryer (T-1010) consists of three different sections:

- The wind box with a gas distribution plate which distributes the fluidization gas uniformly across the area of the dryer in order to keep the dry granules in an evenly floating motion.
- The middle section houses the heat exchanger which is immersed in the fluidized layer. This heat exchanger transfers the energy necessary for evaporating the water from dewatered sludge. Steam is used as a heat transfer medium for the in-bed heat exchangers.
- The gas leaves the dryer through the hood, carrying the evaporated water and some dust for further treatment.

The fluid bed dryer is filled with dry granules and the granules are in a floating motion. The dewatered sludge is fed into a fluidized bed of dried granules by pumps and is cut into small pieces by a special device inside the dryer. The wet granules are immediately mixed with the already dry granules of the fluid bed. Due to the good heat and mass transfer conditions the water contained in the sludge particles evaporates and the granules are dried to a minimum of 90% TS dry solids. Granulation occurs by water evaporation and the particle movement in the fluidized layer.

The final product is structured within the fluidized layer resulting in stable particles. The classifying effect of the fluid bed allows fines to be carried out of the fluidized layer with the fluidization gas, so that nearly dust-free granules leave the dryer through the normal discharge by the rotary airlock valves (X-1020 and X-1021).



The properties of the fluidizing bed layer assure a consistent temperature and drying profile. Due to the long residence time and large amount of heated product inside the fluid bed dryer, uniform drying is assured, even with some fluctuation in feed quality and/or moisture content.

Dust Separation

Dust is separated from the fluidizing gas in the cyclone (F-1210). The cyclone is fitted with a dust bin (B-1220) equipped with level measurement.

The dust is mixed with dewatered sludge to form wet granules returning into the dryer in the following way:

The screw bottom (H-1225) doses the dust from the dust bin (B-1220) into the bucket elevator (H-1235) and via screw conveyor (H-1230 and H-1240) into the mixer (R-1250). There the dust is mixed with dewatered sludge dosed by the pump. The mixer forms wet granules which are fed back into the fluid bed dryer by the conveyor (H-1260).

The dust recycling to the dryer is not continuously in operation. The dust granulation is started and stopped by the level in the dust bin (B-1220).

Dryer Gas Recycle System

The recycle gas which is used for fluidization carries dust and evaporated water from the fluid bed dryer. The dust is separated in the cyclone (F-1210) and the evaporated water is condensed out of the gas stream in the condenser (W-1330) using counter-current direct water spray. This means that the gas is submitted to a double cleaning procedure, dry process (cyclone) and wet process(condenser)

The recycle gas from the cyclone is put in direct contact with the cooling water which is sprayed via nozzles in the condenser. The gas carrying the evaporated water enters the condenser at a temperature of approximately 185°F (85 °C) and is cooled to approximately 140°F (60 °C). The condensed water is removed from the recycle gas and discharged. Effluent from the wastewater treatment plant is used for cooling water. Condenser Water Recirculation is employed duty and standby plate and frame heat exchangers using a fin-fan cooler to exhaust heat.

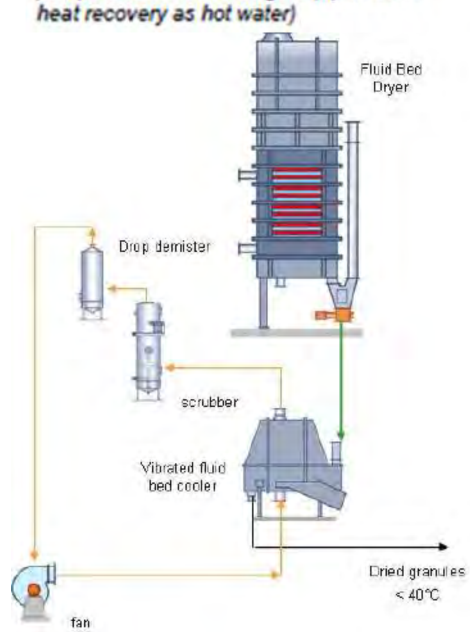
Spray Condenser with heat recovery pumps and heat exchangers (up to 75% heat recovery as hot water)

Dry Product Cooling

The dry product is discharged from the fluid bed dryer (T-1010) by airlock valves (X-1020 and X-1021) with a minimum dry solids content 90 % TS. The final product is discharged directly from the air lock valves into a vibrated fluid bed cooler (K-1110) and is cooled by a gas stream to a temperature of

<104°F (40°C). Granulate cooling is carried out in a low oxygen gas loop system. The heated gas from the fluid bed cooler is cooled in the scrubber W-1160 with cooling water and recycled by the fan V-1140 to the fluid bed cooler K-1110.

The cooling gas system is fed by the low oxygen content excess gas from the fluid bed dryer gas recycle system.



Dry Product Transport

The dried and cooled product is discharged from the fluid bed cooler to the bucket elevator H-1410. The bucket elevator H-1410 discharges to reversing screw conveyor H-1420. Reversing screw conveyor H-1420 feeds the dry granules to either screw conveyor H-1425 or H-1450. Screw conveyor H-1425 is used to feed the start-up silo.

Process Heat Supply

The thermal energy required for the evaporation of water from the dewatered sludge is provided by a thermal oil heater system supplied by ANDRITZ. The thermal oil circulates through the dryer heat exchanger and heat is transferred to the fluidized bed of product moving around the heat exchanger coils which evaporated the water from the sludge.

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Aspiration System

The odorous gases from the sludge cake bin, drying system, and gas from the final product loading spouts are collected by the fan V-0410 and transferred to the exhaust air treatment system.

Inert Gas System

No nitrogen is consumed during normal plant operation because low oxygen gas is generated during the sludge drying process. Nitrogen is required for system start-up inertization and silo maintenance during plant shutdowns.

Dry Storage and Load-out of Final Product

As an option, the final product pellets can be pneumatically conveyed to the final product storage silo by means of an elevator or dense-phase pneumatic conveyance system. Typically one or two final product storage silos are provided.

The final product storage silo and associated material handling system will have the following features:

- Two storage silos will be out loaded using a telescopic unloading spout. Aspiration air will be vented to a baghouse for dust collection. Activated carbon canister to control odors – by others.
- Product level in the silos will be monitored and controlled via ultra-sonic continuous level detection.
- The silo contents will be continuously monitored for temperature using thermocouple ropes.
- In the event of a temperature rise in the silo, nitrogen will be introduced to displace oxygen in the silo and stabilize temperatures.

Typical: Product Storage Silos

Final Product

The ANDRITZ FDS technology is currently in use at more than 30 installations around the world and is a proven technology for recycling biosolids into high quality fertilizer or fuel.

The granules can be used for a wide range of fuel or fertilizer applications from the most basic, such as agricultural fertilizer filler, to the more sophisticated such as the feeding of sensitive turf and ornamental plants. The proposed facility will convert the biosolids into a fuel or fertilizer.

Dried granules from Fluid Bed Dryer

The following are typical major product quality characteristics for anaerobically digested sludge:

- Low moisture content with greater than 90% total solids, Class A biosolids.
- Nutrient content (N-P-K, micronutrient, organic content): except for volatilizing ammonia, the drying and pelletizing process will not alter the nitrogen - phosphorous - potassium (N-P-K), micronutrient (including trace metals), and organic matter content of the digested and dewatered solids.
- Granule size range from 0.5 - 5 mm in size with minimum dust or foreign matter.
- Typical granule bulk density is expected to range from 30 to 55 pounds/cubic foot.
- Durability

Pellets will withstand the normal rigors of transportation, handling and mixing without producing excessive levels of dust.

- Pathogen and vector attraction reduction

The US EPA 40 CFR Part 503 Regulations define processing conditions which enable a biosolids product to meet Class A (PFRP) standards. The proposed drying process meets Class A pathogen and vector attraction reduction requirements as specified in §503.32(7)(ii) Appendix B and §503.33(a)(8). *"Dewatered sludge cake is dried by direct or indirect contact with hot gases, and moisture content is reduced to 10 percent or lower. Sludge particles reach temperatures well in excess of 80°C, or the wet bulb temperature of the gas stream in contact with the sludge at the point where it leaves the dryer is in excess of 80°C."*

Vector attraction reduction requirements under Part 503 regulations are achieved by drying the biosolids to at least 90% DS [§503.33(a)(8)].

3.2 Reference Facility – Victoria, BC

Facility Owner.. Capital Regional District
Facility Design Build participants .... ANDRITZ/Maple Reinders/Bird/Synagro
Commercial Operations 2022
Operations by.. Synagro - 20-year term
Contact.. Melissa Carmichael (808) 228-5203
Dryer Type... Fluid Bed Drying System
Dryer Capacity... FDS-6.0
Dryer Heating.. Thermal Oil (fired by Biogas)

Noteworthy points:

- Sludge is pumped 18 km from the WWTP, newly constructed adjacent to Victoria Harbour
- The facility site is adjacent to Hartland landfill
- Site has no Natural Gas – relies on biogas from digestion for all heating needs
- Sludge is thickened to 5-6% on ANDRITZ Gravity Belt Thickeners
- Sludge is anaerobically digested in three (3) 7,000 m^3 mesophilic digesters
- Digested sludge is dewatered on ANDRITZ high solids centrifuges
- Dewatered sludge is converted to Class A biosolids in a Fluid Bed Drying System
- Dried granules are shipped to a cement plant in Vancouver, BC

Thickening, Dewatering and Drying buildings centrally located on the site. Odor control to the left

3.3 Reference Facility – North Shore (Zion, IL)

Facility Owner.. North Shore Water Reclamation District
Facility Design Build participants .... ANDRITZ/Donohue
Commercial Operations 2007
Operations by.. Veolia (10 -year term)
Contact... David Swarthout (414) 235-1203
Dryer Type.. Fluid Bed Drying System
North Shore Contact .... Steve Waters
Dryer Capacity... FDS-6.0
Dryer Heating .... Thermal Oil (fired by Natural Gas)

Noteworthy points:

- Sludge is trucked from three (3) wastewater treatment plants
- The facility site is not located on a wastewater treatment site
- Truck receiving facility has two 30 yd3 road hoppers and two 300-ton dewatered cake storage silos
- The cake intake, building change air and dryer exhaust is handled by chemical scrubber
- Dewatered Sludge is pumped from these silos to the Fluid Bed Drying System using PC pumps
- Dewatered sludge is converted to Class A biosolids in a Fluid Bed Drying System
- Dried granules are shipped locally for use as a soil amendment

3.4 Reference Facility – Brussels, Belgium

Facility Owner.. Aquafin N.V.
Facility Design Build participants .... ANDRITZ/ DECKX N.V
Commercial Operations 2001
Operations by .... Aquafin
Contact .... Johan van der Velde +32 476 967 902
Dryer Type.. Fluid Bed Drying System
Dryer Capacity.. FDS-4.0
Dryer Heating .... Steam from a Trash to Energy plant

Noteworthy points:

- Sludge is trucked from approx. twenty (20) wastewater treatment plants
- The facility site is located on a wastewater treatment site
- Truck receiving facility has two 30 yd3 road hoppers and two 300-ton dewatered cake storage silos
- Dewatered Sludge is pumped from these silos to the Fluid Bed Drying System using PC pumps
- Dewatered sludge is converted to Class A biosolids in a Fluid Bed Drying System
- Dried granules are shipped to a cement plant for use as a coal replacement.
- Dryer operates nights and weekends unattended

3.5 Reference Facility – Bailonggang II (Shanghai) China

Facility Owner.. City of Shanghai
Facility Design Build participants .... ANDRITZ/SMEDI
Commercial Operations 2021
Operations by .... Municipality
Dryer Type.. Fluid Bed Drying System
Dryer Capacity.. Nine (9) FDS-10.0
Dryer Heating .... Steam from ANDRITZ Ecofluid BFB Boilers

Noteworthy points:

- The Shanghai Bailonggang Wastewater Treatment Plant is the largest sewage treatment plant in Asia and one of the largest in the world. With a capacity of 2.8 million cubic meters per day, the facility handles around a third of the municipal wastewater produced by the Shanghai metropolitan area, serving more than 7 million residents.
- The technology supplied by ANDRITZ includes sludge handling, nine fluidized bed dryers, six Eco-Fluid bubbling fluidized bed boiler lines including the entire flue gas cleaning, as well as full plant automation. The scope of supply further comprises engineering, manufacturing, delivery, and supervision of both installation and commissioning.
- wet sludge from Bailonggang wastewater plant at 18 – 22% DS
- 2 external dried sludge sources at 60-70% DS
- NCV of incoming sludge varies with season and rainfall 9 to 16 MJ/Kg DS (combined sewer)
- The dried sludge granules are stored in 100 ton silos and fed to the BFB as needed to maintain the desired NCV

3.6 Reference Plant – City of Fort Worth, TX

Facility Owner.. City of Fort Worth, Texas
Facility Design Build participants .... ANDRITZ/Archer Western/Synagro
Commercial Operations 2022
Operations by .... Synagro - 20-year term
Contact .... Matt Busch
Dryer Type.. Drum Drying System
Dryer Capacity.. DDS-140
Dryer Heating .... Direct fired with Biogas

Noteworthy points:

- Sludge is pumped 1 km from the nominal 120 MGD Village Creek WWTP
- Sludge is thickened to 5-6% on ANDRITZ Rotary Drum Thickeners
- Sludge is anaerobically digested in a mesophilic digestion complex.
- Digested sludge is dewatered to 22% DS on ANDRITZ high solids centrifuges
- Dewatered sludge is converted to Class A biosolids in a single Drum Drying System, the largest single drying line globally, processing 450 wet TPD
- Dried granules are stored in two (2) 500-ton silos, blanketed with Nitrogen
- Dried granules are shipped locally for use as a soil amendment
- Synagro also operates ANDRITZ Biosolids Drying plants at Pinellas County, FL. Sacramento, CA, Honolulu, HI, Stamford, CT, Philadelphia, PA, Hamilton ONT and Victoria, BC

ANDRITZ Biosolids Dewatering and Drying Complex, completed as a Design Build at a cost of $60 million.

4 Scope of Supply

4.1 Scope Overview

a. ANDRITZ will furnish, provide installation advice, and test all the equipment listed to provide a complete biosolids drying system including all ancillary equipment as defined below, capable of producing a dried product from a partially dewatered, wastewater sludge.

b. The work included under this Specification will be the design, supply of materials, fabrication, testing, and loading for shipment for two (2) sludge drying trains with accessories as required for a complete and operable unit for the capacities as herein specified. Also included is installation advice, commissioning services and performance testing.

c. Assembly of the Andritz drying system equipment will be by the General Contractor hired by Buyer.

d. The general area available for the drying system is shown on the drawings.

e. It is the intent of this Specification to describe the process and mechanical components comprising the sludge drying system and to establish minimum quality standards for materials and process performance.

f. ANDRITZ will furnish a complete Instrumentation and Control system for the sludge drying system. The system includes all materials and documentation required to install, test and place in operation a complete and operable instrumentation and control system as specified. The system will include all measuring elements, control devices, signal converters, transmitters, local control panels, motor control centers, digital hardware and software, operation workstations, and communication networks to provide the functions indicated.

g. Items to be included in each Andritz Fluid Bed Drying system will include:

1) Dewatered Cake truck dump hoppers with sliding frame feeder into positive displacement cake feed pumps
2) Wet cake storage and feed equipment to introduce dewatered sludge cake into the dryer. Includes wet material bin, with sliding frame feeder into positive displacement cake feed pumps.
3) Electrically Heated thermal oil heating system
4) Fluid bed dryer to produce a dried sludge product granule.
5) Cyclone equipment for removing the small, dried sludge particles from the process gas stream.
6) Fluid bed product cooler.
7) Conveying equipment for transporting cooled product into two (2) storage silos.
8) Two (2) 450-ton dried product storage silos, mass flow design with live bottom screws, and mixing screw with pellet oil mixing system.
9) distribution screw conveyor fitted with loadout spouts.
10) Dust controlled loading spouts (3) for product loading into trucks.
11) Condenser wet scrubber for removal of moisture from the gas stream and a mist eliminator.
12) Fan(s) required for the conveyance of air through the process units.
13) Dust collection system servicing the storage silo and the truck loading system area.
14) Nitrogen inertization system for start-up of the dryer and maintenance ofinert atmosphere in the silo during shut down periods.
15) Deflagration venting system and/or isolation systems.
16) Electrical system components to include motors, motor control center, with variable frequency drives for the ANDRITZ scope of supply.

17) Equipment access including platforms, catwalks, ladders, handrails and stairways, as shown on the drawings.
18) Dryer Instrumentation and Controls package including all control panels, PLC, MCC, and field instruments required for the ANDRITZ scope of supply.
19) Electrical system components to include motors, motor control center, with variable frequency drives for the ANDRITZ scope of supply.
20) Equipment access including platforms, catwalks, ladders, handrails and stairways, as shown on the drawings.
21) Complete Instrumentation and Controls package including all control panels, PLC, MCC, and field instruments required for the ANDRITZ scope of supply.

4.2 Work By Others and System Interfaces

a. The sludge drying system, specified herein, will be installed by the General Contractor within a new solids processing building. ANDRITZ will provide installation advice during the installation of the sludge drying equipment.

b. The equipment will be unloaded at the plant site by the General Contractor.

c. The sludge drying system will be fed with dewatered cake from the South Plant dewatering equipment by others to the wet cake receiving bin supplied by ANDRITZ. ANDRITZ will provide process equipment downstream of the wet sludge receiving bin inlet flanges.

d. No major component of the sludge drying system will be supported from the building roof or walls except the stacks. Any stacks will require lateral supports from the building wall. Piping and ductwork to and from the dryer will be supported from the building as required. Bucket elevator supports are supplied by the General Contractor.

e. ANDRITZ will design and furnish to the General Contractor all control components that are an integral part of the sludge drying system, including motors, motor control centers, and variable frequency drives.
The General Contractor will provide conduits, raceways, wire and other appurtenances not provided by ANDRITZ. The General Contractor will provide grounding and bonding of all equipment and electronic controls.

f. ANDRITZ will provide recommended line sizes for piping systems that are an integral part of the sludge drying system. The General Contractor will provide all piping and supports. Piping systems sized by ANDRITZ are limited to those required within equipment package envelope, sludge drying system.

g. *The General Contractor will provide the solids processing building and equipment foundations and support pedestals. ANDRITZ will coordinate the location of utility connections and penetrations with the General Contractor. All flashing and seals required through building walls, roofs and foundations shall be supplied by the General Contractor*.

h. ANDRITZ' pricing does not include the following:

1) Solids Processing Building

2) Concrete work

3) Drains and drain piping

4) Supply and/or installation of any utility piping and supports, including but not limited to:

   a) Potable water.
   b) Non-potable water.
   c) Compressed air, including control air.
   d) Nitrogen gas and supply system.
   e) Thermal oil or heat energy system delivery to dryers.

5) All field wiring, including conduit, electrical service to the motor control center, connection to all instruments and motors, installation of instruments and motors, local disconnects and emergency stops, connection of instruments to PLC cabinet, wiring between panels, network cabling, etc.

6) Lateral supports for the bucket elevators and TO stacks.

7) Overhead building crane

8) State, Local and Federal taxes.

9) Ground bonding jumpers.

10) Building service utilities including lighting, comfort HVAC, utility stations, convenience power, ventilations, etc.

11) Truck scale.

12) Heat tracing

13) Insulation and cladding

i. Clarifications to the ANDRITZ' Scope of Supply.

All support pads by the General Contractor.

Some components require assembly on-site. The ANDRITZ installation advisor will work closely with the General Contractor during assembly of these components.

ANDRITZ equipment delivery will be 9 to 12 months after receipt of Notice to Proceed (NTP) for manufacturing.

ANDRITZ will provide an Installation Advisor per the specification herein. Any calendar days exceeding (60) will be at the expense of others per ANDRITZ standard rate sheets.

ANDRITZ will provide services to field test, start-up and train plant personnel in the operation of the plant.

The Operator will provide mechanical and electrical support personnel for the “shakeout” period expected to run for 6 weeks.

4.3 Operating and Design Conditions

PROJECT DATA - PROJECT SIZING in Section 2 of this proposal

4.4 Performance Requirements

To be advised later

4.5 Codes and Standards

a. IRI - Industrial Risk Insurers.

b. NFPA - National Fire Protection Association.

c. NEC - National Electrical Code.

d. NEMA - Standards of National Electric Manufacturers Association.

e. OSHA - Occupational Safety and Health Act.

f. AISC - Manual of Steel Construction.

g. ASME - Standards of American Society of Mechanical Engineers

h. AGMA - American Gear Manufacturers Association

i. ANSI - American National Standards Institute

j. ASTM - American Society of Testing and Materials

k. AWS - American Welding Society

l. CEMA - Conveyor Equipment Manufacturers Association

m. FM - Factory Mutual

n. IEEE - Institute of Electrical and Electronics Contractors

o. ISA – International Society of Automation

4.6 Documentation

a. ANDRITZ proposed documentation schedule is as follows:

b. Preliminary Design Submittals: 90 working days after executed Purchase Order

c. Final Design Submittals: 120 - 180 working days after executed Purchase Order

d. Operation and Maintenance Manuals: 30 days after delivery of equipment

e. Operations and Maintenance Manuals. will be provided in accordance with the procedures and requirements set forth below:

- Two (2) CD-ROM or DVD versions of the final manual will be submitted. The CD-ROM manuals will contain a fully indexed table of contents with hot-links from the table of contents to the applicable information. Information will be stored in the form of ADOBE portable document files.
- Final manuals will include all operating instructions, troubleshooting guides, recommended spare parts and all equipment specifications and as-built drawings.

- Preliminary/For Approval manuals will be submitted electronically per item b.

f. Operating Information is intended to assist in the operation and adjustment of the equipment. This O&M manual will:

- Contain an Index and Table of Contents.
- Contain a schematic with identifying numbers for valves, switches, controls, etc.
- Contain a definition of the operating sequence. This will include such items as “TURN ON”, “TURN OFF”, “RESET”, etc.
- Contain “Safety Cautions and Warnings” to insure proper protection of personnel and equipment.

g. Maintenance Information is intended to aid in troubleshooting, servicing, and maintenance of the equipment. The O&M manual will include identification of spare parts along with the ordering information. It will have drawings or sketches to indicate the assembly relationship of critical components, as well as schematics, photos, catalog cuts, etc. The O&M manual will:

- Contain lubrication and greasing instructions (listing type and frequency of lubrication), and oil filter changes or flushing information.
- Contain data on service to pneumatic, hydraulic, electrical, gearing, belts, and any other type of equipment that comprises the unit.
- Contain supplier catalogs for maintenance instructions on all commercial equipment.
- Contain special instructions for removal and replacement of critical items as well as alignment and adjustments. Troubleshooting procedures for those items where the failure is not obvious to a skilled workman will also be contained in the manual.
- Contain a sample Maintenance Log including the manufacturer's recommended preventive maintenance schedules.
- ANDRITZ will supply a list of recommended spare parts.

4.7 Expected Performance and Warranty

Mechanical Warranty -- See Warranty Clause of the Term and Conditions included in section 6.3 of this proposal

Performance Expectations – to be advised later

4.8 Quality Assurance

Products that are specified by manufacturer, trade name or catalog number establish a standard of quality.

It is the intent of these Specifications and associated Contract Drawings to secure high quality materials and equipment in order to facilitate operations and maintenance of the sludge drying facility. All equipment and materials will be new and the products of reputable recognized suppliers having adequate experience in the manufacturing of these particular items. Generally, only one manufacturer will be used for each type of product. All equipment will be of rugged construction, of ample strength for all stresses which may occur during fabrication, transportation, erection and during continuous or intermittent operation.

4.9 Review Meetings

ANDRITZ will conduct one detailed review (kick-off) meeting for the project to ensure design compliance with all process equipment and instrumentation and control requirements. Other supplemental design review meetings may be held as required to resolve specific problems, to provide positive assurance that the design conforms to contractual requirements, or to allow for concurrent planning activities which are dependent upon the as-built system configuration/operation. ANDRITZ will include in its cost for two (2) review meetings at the designated location. Meetings conducted on ANDRITZ premises in Arlington, Texas will not count towards the above totals.

4.10 The Services of Andritz Technical Representative

The services of a qualified ANDRITZ technical representative will be provided. The technical representative will provide advice on the installation and conduct final testing of all equipment, components and accessories furnished under this Contract. ANDRITZ' technical representative will instruct the operating personnel in all sludge drying system maintenance and operation procedures.

The services of the technical representative(s) will be as follows:

a. Installation Advisor to guide the General Contractor through installation. ANDRITZ to provide (60) workdays onsite installation advice. These must be scheduled by the General Contractor in two (2) week increments.

b. Once installation is complete, and the General Contractor has completed the required checks, the system will be turned over to ANDRITZ for field testing and performance testing as outlined in Part 3. ANDRITZ will provide reasonable access for the operating personnel to accompany and observe all field and performance testing operations.

c. ANDRITZ will provide the following training for the operating personnel:

- Following acceptance of the sludge dryer system provide three (3) consecutive days of 8-hour training. The training will include training on all components of the sludge dryer system, including all auxiliary systems (dust collection systems, storage silos, truck loading systems, etc.). The training will include instructions on start-up and shutdown, normal operating procedures, safety precautions, emergency conditions and procedures, maintenance procedures and schedules, and operation and usage of the dryer digital control system.

- All training specified herein will take place at the final installation location.
- The ANDRITZ Operation and Maintenance (O&M) Manual will be used during all training sessions.

4.11 Tools, Supplies and Spare Parts

Spare Parts are not included in this offer.

Parts will be completely identified with a numerical system to facilitate parts inventory control and stocking. Each part will be properly identified by a separate number. Those parts, which are identical for more than one size will have the same part number.

Spare parts will be packed in individual, suitable containers clearly labeled with the part number, name, quantity, and the equipment with the project number and purchase order number for which they are intended. All spare parts will be furnished in moisture-proof boxes designed to provide ample protection for the contents.

Spare parts used in start-up and prior or to substantial completion will be restocked by the General Contractor.

4.12 Equipment Inspections

ANDRITZ will inform the General Contractor when specific equipment for this Contract goes into production, so that the General Contractor, at their option, may visit premises, prior to shipment of any equipment.

4.13 Preparation For Shipment

All surfaces of equipment, both interior and exterior, will be cleaned of grease, chips, dirt and other foreign material. Threaded connections will be inspected, and irregularities corrected. Threads will be given a rust preventative coating and will be protected from damage. Openings will be closed with substantial covers for shipment. Machined surfaces such as flange faces, shafting, etc., will be coated with a suitable rust preventative material which can be readily removed but which will withstand weather elements in shipment. Exposed machined surfaces will be protected by wood blocks, wood covers, or other means to prevent damage in transit and handling. Special handling instructions will be conspicuously placed on all equipment requiring unusual handling or shipping care.

4.14 Equipment Delivery

ANDRITZ will provide preliminary estimates for delivery of all material to jobsite. Equipment will be shipped in sections, which are as large as practical to minimize field assembly.

ANDRITZ will clearly identify all contents of all boxes, crates and packages.

The General Contractor is responsible for off-loading and proper storage of equipment.

4.15 Testing

All commissioning and performance testing will be conducted in accordance with the provisions set forth in Part 3 of this specification.

4.16 Identification and Tagging

ANDRITZ will identify each unit of equipment with equipment item numbers. A corrosion resistant tag or nameplate, securely affixed in a conspicuous place on each unit will give the equipment item number, manufacturer's name or trademark and such other information as the manufacturer may consider necessary, or as specified to complete the identification.

4.17 Lubricants

ANDRITZ will submit a list of standard lubricants that may be used for each type of lubricant required. Lubricant for initial start-up will be provided by ANDRITZ.

4.18 Control System Performance

The Control System will be designed to minimize operator requirements and movement in the control of the sludge drying and storage equipment. A centralized control location is required from which the entire system can be started, stopped and operated under normal conditions.

The control system will be a PLC based system utilizing an operator interface for input to system operation.

From the operator interface terminal, the operator will be able to initiate start and stop sequences for the system. The operator will also be able to adjust key system sludge dryer system parameters.

The control system will be complete and inclusive of all items supplied by ANDRITZ for the drying system.

4.19 Commercial Terms

See Section 6 of this Proposal

4.20 Dryer Process Equipment List

ANDRITZ Dryer process equipment list included in this section reflects ANDRITZ scope of supply limits of the process equipment outlined in the Process and Instrumentation Drawings (P&ID's). section 8 of this proposal.

Item. No.	Designation	Description	Material	Motor Power
		Sludge Handling		
B1710	2x Wet Cake Bin	For 3 hours storage of dewatered wet cake and dosing of sludge to dryer. Accessories: - guard railing - access opening connections for: - aspiration air - level control sensor - separate overflow safety device Min. Volume: ~1,900 ft^3	Wetted materials of construction are 304SS unless otherwise noted. Steel structures carbon steel	NA
H 1712	2x Sliding Frame	For force feeding cake to the sludge feed pump throat from the silo B 1710 sliding frame discharge capacity: 265 gpm (60 m^3/h) equipped with: - special profiles with guiding beam and casing fabricated in stainless steel - double acting hydraulic cylinder - cylinder counter bearing - special gasket unit driven by hydraulic power pack H1714	Carbon Steel	N/A
H 1714	2x Hydraulic Power pack	For actuating the sliding frame hydraulic power pack, complete with all necessary valves, fittings and level and temperature control, hydraulic tubes and hoses	Carbon Steel	15 HP (11 kW)
	8x Bin Discharge Slide Gates	For removal of dewatered solids from bin discharge mechanisms. Pneumatically actuated by air cylinders.	304SS unless otherwise noted.	NA
P1720 - P1790	8x Progressive cavity sludge feed pumps	For continuous wet sludge feed to the dryer T1010 and dust mixer R2151, Pumps are installed below the Wet Cake bin B1710 Operation conditions - dewatered sludge: 23.5 % TS - flow rate: 10 – 15 gpm - 300 psi discharge, 4 stage Material: Housing: Rotor: Stator: Drive: complete with gear motor: suitable for variable frequency drive fitted with zero speed switch	carbon steel 1.2436 Perbunan	15 HP

				(11) kW each
Item. No.	**Designation**	**Description**	**Material**	**Motor Power**
		Sludge Drying		
T1010	2 x Fluid Bed Dryer	Stationary design, welded construction, comprised of: Wind box: equipped with a special nozzle plate for the distribution of fluidizing gas. nozzle plate is rigid design with openings and pressure measurements Intermediate section: equipped with the heat exchanger, designed to hold the in-bed heat exchangers, overflow weir and rotary discharge valve, heat exchanger: packages integrated in the dryer, designed for use with IC engine heated thermal oil brought to the dryer by customer pumps & piping. suction hood: equipped with manhole for maintenance and all necessary connections. Includes connections for 8 sludge dispersing devices. Equipped with required temperature and pressure connections for monitoring process and controls. Sight glasses are installed for manual viewing.	Stainless steel carbon steel carbon steel Stainless steel	-
X1011 – X1018	8x Sludge Dispersing Devices	For the continuous distribution of cake pumped into the dryer. Attached to the fluid bed dryer complete with gear motor variable frequency driven.	carbon steel, abrasion resistant	5.4 HP (4 kW)
X1020 & X1021	4x Rotary air lock valves	For discharge of dried product material: - housing : - wheel: external bearings complete with gear motor	Cast iron carbon steel	2 HP (1.5 kW)

Item. No.	Designation	Description	Material	Motor Power
V1030 V1040	4 x fans	Centrifugal fan for the recycling of fluidizing gas; 70360 & 62870 m3/h Factory balanced Coupling: elastic coupling with OSHA guard Grease lubricated or sleeve oil bearings Direct coupled motor with variable frequency drive	carbon steel	425 HP (315 kW) each
		Product Cooling		
K1110	2x Fluid Bed Cooler	For the cooling of dried product by cooled inert gas, welded construction Windbox: equipped with a special nozzle plate for the distribution of fluidizing gas. nozzle plate is rigid design with openings and pressure measurements Suction hood: equipped with man hole for maintenance and all necessary connection nozzles for product, Equipped with required temperature and pressure connections for monitoring process and controls. Sight glasses are installed for manual viewing. temperature of granules: input: 185°F (85 °C), out < 104°F (40°C) complete with gear motor:	carbon steel	3 HP (2.2 kW)
X1120	2x Rotary air lock valve	For discharge of dried product material: - housing : - wheel: external bearings complete with gear motor:	Cast iron carbon steel	2 HP (1,5 kW)
V1140	2x Centrifugal fan	For the recycle of cooling gas to the fluid bed cooler Factory balanced Coupling: elastic coupling with OSHA guard Grease lubricated or sleeve oil bearings Direct coupled motor with variable frequency drive	carbon steel	30 HP (22 kW)
W1160	2x Scrubber	For cooling of loop gas after the cooling screw conveyor; D=1800 mm Complete with inspection opening, cooling water: - input: 68°F (20°C) - output: 75°F (23°C) instrumentation: level switch	304L Stainless steel	-

Item. No.	Designation	Description	Material	Motor Power
F1175	2x Demister	For the separation of water drops carried with the gas stream from the scrubber. D= 1400 mm Low pressure drop design. Complete with inspection opening, water outlet: to the scrubber A33W01 instrumentation: level switch	Stainless steel	-
DUST SEPARATION				
F1210	4x Cyclone	For dust separation from the recycled gas stream exiting the drier. Equipped with spiral hood, Inspection opening, dust discharge to the dust bin Thermal insulation.	Carbon steel with tile lining	-
B1220	2x Dust bin	For collection, storage and dosing of the separated dust. 2400 kg Equipped with inspection opening, temperature and level indicators, and bridge breaker, A34X01, to avoid material bridges	304L Stainless steel	0.5 HP (0,37 kW)
H1225	2x Live screw bottom	For discharge and dosing of the dust from the dust bin to the screw conveyor Consists of 3 screws with inspection openings Bearings: outside Trough: Screw: Insulated gear motor:	Stainless steel Carbon steel wear resistant	2 HP (1,5 kW)
H1230	2x Screw conveyor	For the dust transport from the dust bin live bottom screw, H1225 to the bucket elevator H1235 DN 250 mm, 350 kg Equipped with inspection openings Bearings: outside Trough: Screw: Insulated gear motor:	Stainless steel Carbon steel wear resistant	3 HP (2,2 kW)

Item. No.	Designation	Description	Material	Motor Power
H1235	2x Bucket elevator	For transport of dust for addition back to drying process. width 140 mm, height 10 m Equipped with inspection openings. bearings: outside housing: belt: antistatic, thermo resistant buckets: back-run safety mechanism gear motor with zero speed switch	stainless steel stainless steel with boot section shroud	3 HP (2,2 kW)
H1240	2x Screw conveyor	For the dust transport from the elevator to the dust granulation mixer. width 250 mm, 320 kg Equipped with inspection openings Trough: Screw: Bearings: outside gear motor:	Stainless steel Carbon steel	3 HP (2,2 kW)
R1250 R1251	2x Mixer	For the mixing of dust from the cyclone with sludge cake to form granules and add back to the drying system. Equipped with two inspection openings mixing shovels: bolted into the sockets of the shaft tipped with hard metal alloy shaft bearing: outside of the mixing area. Volume: ~1200 liters horizontal cylindrical drum: gear motor: knife unit: gear motor	stainless steel / carbon steel with wear liner	50 HP (37 kW) 7.5 HP (5,5 kW)
H1260	2x Double Screw conveyor	For the transport of wet granules from the mixer to the dryer Double screw for wet granules 290 kg 2x DN250, 3 m3/h Equipped with inspection openings Trough: Screw: Bearings: outside gear motor	Stainless steel Carbon steel	3 HP (2,2 kW)

Item. No.	Designation	Description	Material	Motor Power
		CONDENSATION		
W1330	2x Condenser	For condensation of evaporated water in recycle gas stream from the dryer. D= 3.6 m, height 5.1 m Complete with inspection opening and nozzles cooling water: 1078 GPM input: max 77°F (25 °C) output: 140°F (60° C) instrumentation: level switch steel structure excluded.	stainless steel	-
F1340	2x Demister	For separation of water drops from the recycle gas after the condenser. D = 2,2 m, height 6.8 m Complete with inspection opening. water outlet: to the condenser instrumentation: level switch	stainless steel	-
		FINAL PRODUCT HANDLING		
H1410	2x Bucket elevator	For transport of dry product from the cooler K1110 to the screw conveyor H1420 Buckets 200 mm Equipped with inspection openings - housing - bearings: outside - belt: anti-static, thermo-resistant - buckets: - back-run safety mechanism - gear motor: - zero speed switch	Carbon steel stainless steel	5 HP (3 kW)
H1420	2x Screw conveyor	For transport of dried material to the final product silos or startup silo DN400, pipe, 660 kg Equipped with inspection openings Bearings: outside gear motor:	carbon steel	3 HP (2,2 kW)
H1420B	2x Screw conveyor	For transport of dried material to the final product silos or startup silo DN400, pipe, 2300 kg Equipped with inspection openings Bearings: outside gear motor:	carbon steel	10 HP (7.5 kW)

Item. No.	Designation	Description	Material	Motor Power
H1450	2x Screw conveyor	For transport of dried material to the final product silos or startup silo DN250, pipe, 390 kg Equipped with inspection openings Bearings: outside gear motor:	carbon steel	3 HP (2,2 kW)
F1340	2x Start-up silo	Product storage for filling of the dryer after a service or inspection V = 30 m3, 2760 kg Equipped with level and temperature sensor Approx. Volume: 1060 ft^3 (30 m^3)	carbon steel	
H1440	2x Screw conveyor	For transport of dried material from the start up silo into the cooler k1110 DN250, pipe, 390 kg Equipped with inspection openings Bearings: outside gear motor:	carbon steel	5 HP (3 kW)
A41H06	2x Screw conveyor	For transport of dried material to the final product silos or startup silo DN400, pipe, 2300 kg Equipped with inspection openings Bearings: outside gear motor:	carbon steel	10 HP (7.5 kW)
		Dried Product Storage Silos		
A45H01	1x Screw conveyor	For transport of dried material to the final product silos DN200, pipe, 2300 kg; 7,5 m Equipped with inspection openings Bearings: outside gear motor:	carbon steel	10 HP (7.5 kW)
‘021.000.1 & ‘021.000.2	2x Dried Product Storage Silos	450 ton dry storage silos, mass flow design of the dried final product for loadout to customer trucks, with: - inspection opening, - connection piece for inert gas - discharge and nitrogen feed - level and temperature sensors - bin activator (bridge breaker) - under-/ overpressure safety Material Approx. Volume: 450 Ton each	carbon steel	

Item. No.	Designation	Description	Material	Motor Power
022.1 & 022.2	2x Live Bottom Screw Conveyors	Screw feeder, each approx. 12" dia. x 15'-0" foot long, for mass flow feeding out of storage silos 021.000.1 & 021.000.2 into Mixing screw conveyor 630.000.1 discharge capacity: 2,500 CFH Each conveyor supplied with a single 10HP 460/3/60 gearmotor. All electrical components to be rated for non-classified environment. Powered by (2) VFD in MCC	Stainless steel	10 HP (7.5 kW) each
630.000.1 & 630.000.2	2x oil Mixing Screw conveyors	For mixing of final product with oil. Equipped with nozzles & ball valve for oil injection Bearings: outside gear motor:	Carbon steel	10 HP (7,5 kW) each
025.1.1	1x Distribution Screw conveyor	24" dia x ~ 65 ft L for transport of dried material into the (3) load out spouts. Equipped with inspection openings Bearings: outside gear motor:	Stainless steel	25 HP (18.6kW)
'099.000.1, .2 & .3	3x Loading spouts	For dust-free loading of dried product into a truck. • Includes dust collector with fan and rotary valve.	Carbon steel	3 HP (2,2 kW) each
B 0420	1x Nitrogen storage tank	For storage of nitrogen gas, 6000 gal	Carbon steel	
D 0430	1x Nitrogen vaporizer	For vaporizing nitrogen gas	Stainless steel	
D 0435	1x Nitrogen heater	For heating of nitrogen gas	Stainless steel	
B 1510	1x Oil Tank	For storage of oil for final product	Carbon steel	
P 1515	1x Oil pump	For pumping of oil to mixing conveyor		2 HP (1,5 KW)
D 1520	1x Oil heater	For heating of oil for final product		
A45F11	1x Dust Collection	Dust bag house with dust bags, 160 sf media for silos		
A45V11	1x Fan	For conveying of aspiration air from the dried sludge storage silos, loading spout, siphon and exhaust gas from the silo 021.000.1 & .2 - Air flow: 1,000 ACFM Material: - Housing: - Impeller: - spark protection drive: direct coupled motor	 carbon steel carbon steel	7.5 HP (4 kW)

Item. No.	Designation	Description	Material	Motor Power
THERMAL HEAT SUPPLY				
B0990	1x Expansion tank	horizontal arrangement for plant volume: 20 m3	carbon steel	
B0980	1x Collection tank	horizontal arrangement for plant volume: 20 m3	carbon steel	
P0995	4x Thermal oil recirculation pump	for the circulation of thermal oil from the heat exchanger to the dryer equipped as a spiral casing pump, suitable for pumping of thermal oil with a temperature < 250 °C Pressure: max. 85 PSIG	carbon steel, Cast iron	
P0940	1x Thermal oil filling pump	to fill and empty the thermal oil system gear pump with armature - flow: 1,0 m^3/h power:		1.5 HP (1.1 kW)
W0950 V0935	2 x Thermal oil boiler system 1 x hydraulic balancer	Each consisting of 2 x 4.5 mW heaters		125 HP (92 kW)

4.21 Products

4.21.1 General

a. The sludge drying system will be complete with all required and necessary supports, equipment, access provisions, safety guards, thermal insulation, controls and instrumentation, control panels, motor control centers, sensors, interconnecting ducting, and valves required for an operable system as specified herein.
b. Anchor bolts for anchoring equipment components and their accessories to their concrete base will be Type 316 stainless steel. ANDRITZ will furnish anchor bolts and standardize bolt diameter and embedment depth if possible. Epoxy specification will be provided by ANDRITZ. The General Contractor will be responsible for installation of the anchor bolts.
c. Materials and details of constructions will be ANDRITZ's standard for service conditions and performance requirements specified unless noted otherwise in this specification.
d. Sampling ports, permanently mounted, will be provided as required for sampling solid and air streams within the process units. The sampling ports will be arranged in a manner that allows safe sample collection and minimizes material leakage or spillage during sampling.
e. Access ports will be provided at convenient locations to allow removal of solid objects trapped within the process units. The ports will be adequately sized and will be equipped with removable bolted and gasketed doors.

4.21.2 Dryer Heat Energy Source

The drying train will be designed to operate using thermal oil. .The dryer system will be equipped with a separate thermal oil system furnished by Andritz

4.21.3 Fluid Bed

The fluid bed dryer is stationary design comprised of three (3) main sections: the wind box, the intermediate section, and the upper hood. All of the main sections of the fluid bed dryer are constructed of carbon steel.
The wind box is equipped with a special nozzle plate for the distribution of the fluidizing gas.
The intermediate section houses the heat exchangers. The heat exchangers will be designed for operating with thermal oil. A rotary valve is supplied for the final product discharge and control of the material level.
The upper hood is equipped with the sludge injection points for feeding the wet cake into the fluid bed. A gas discharge connection is located in the top of the hood for carrying the evaporated water and a small amount of dust with the gas stream. A hatch is provided for maintenance.

4.21.4 Double Cyclone System

A majority of the smaller particles carried in the process gas stream will be removed by a double cyclone system.
The cyclone will be constructed of carbon steel with ceramic tile lining.
The double cyclone will be equipped with a common dust collection bin.
The cyclone inlet and outlet will be flanged and connections to the process gas stream system ductwork will be bolted and gasketed in a manner suitable to the pressure and temperature of the cyclone operation at design conditions.

The exterior surface of the cyclone will be insulated. The insulation will be covered with an aluminum jacket.

4.21.5 Dust Bin And Live Bottom Screws

The dust bin will store dried material removed by the double cyclone. The dust return system does not operate continuously.

The dust bin will be equipped with level sensors. The high and low level sensors will transmit continuous level signals to the main control system. The level sensors will determine the automatic operation of the dust add back system.

The dust bin bottom will be fitted with a three screw discharge conveyor.

The screw conveyor speed will be controlled by a variable frequency drive to allow metering of the dust to the mixer. The drive unit will be located on the discharge end of the screw conveyor for maintenance access.

The dust bin screw conveyor will discharge the dust to a screw conveyor for feeding the bucket elevator and returning dust to the mixer.

4.21.6 Main Process Fans

The main process fans will be a heavy-duty industrial, centrifugal type.
The fan drive motor, base plates, and other ancillary equipment will be shop assembled for fit up.
The blower wheel, shaft, and blades will be constructed of material suitable for the service requirements.
The fan housing will be all welded construction. The fan housing will be adequately reinforced with access for wheel removal.
The shaft will be supported by heavy-duty grease lubricated spherical roller bearings or sleeve oil bearings.
The fan will include OSHA approved drive guards, shaft seal, housing drain connection, and expansion joints at the fan inlet and outlet connections.
The fan drive motors will be variable speed. A variable frequency drive (VFD) will be supplied for the fan drive motor.
The fans will be furnished with a vibration sensor and bearing temperature sensor.

4.21.7 Fluid Bed Final Product Cooler

The fluid bed product cooler is a vibrating design comprised of two (2) main sections: the wind box and hood. Each section of the fluid bed cooler is constructed of carbon steel.
The wind box is equipped with a special nozzle plate for the distribution of the fluidizing gas.
The product cooler receives material from the discharge of rotary valve X 1120.
A gas discharge connection is located in the top of the hood. A hatch is provided for maintenance.
The final product cooling is done in a low oxygen gas loop. The heated gas from the fluid bed cooler is cooled in a wet scrubber and the gas stream is recycled.

4.21.8 Wet Material Bin And Dosing Screw

The wet material bin will be constructed of welded carbon steel plate with ASTM A36 carbon steel reinforcement. The bin will include a minimum 24-inch access hatch located on top. All parts of the bin that come in contact with wet material will be coated with coal tar epoxy or equivalent paint system.
The bin walls will be designed to resist the maximum applied loads.
The wet material bin will include a sealed roof. A ladder and guardrails will be supplied to allow safe access to the top of the bin.
The wet material bin will be equipped with two (2) continuous level sensors. The level sensors will transmit a continuous level signal to the main control system.
A minimum 4-inch diameter stub connection will be provided in the wet material storage bin to allow for connection to air ductwork, for positive ventilation of gas from the bin.
Drain connections will be provided in the cake pump housings.
The dosing system will include a sliding bed live bottom assembly with hydraulic power pack.

4.21.9 Mixer

The mixer will be of a horizontal, continuous flow unit designed to homogeneously combine dewatered residuals from the wet material bin with dried residuals from the dust bin.
The single-shaft enclosed mixer will be constructed of abrasion resistant steel. The single, main shaft is mounted on outboard, anti-friction, tapered roller bearings. The mixer plows are constructed of wear resistant carbon steel, and will be partially lined with ceramic tiles to prevent erosion. Plows will be capable of being replaced without replacing entire shaft.
Mixer housing will have top mounted flanged loading port, and two hinged and safety interlocked clean-out doors. Mixer shaft will have stuffing box packing at the ends.
The mixer will be direct driven by one motor operating at 1800 rpm. Mixer motor will be constant speed.

4.21.10 Condenser and Mist Eliminator

The condenser will remove excess water from the process gas stream.
The condenser shell will be constructed of all welded, 304L stainless steel. The condenser will be a vertical flow unit where the process gas stream enters at the bottom of the unit and exits from the top of the unit.
The condenser will be equipped with nozzles appropriate for the service requirements.
The condenser will have a flooded p-trap at the base of the unit. The lowest point of the flooded trap will be equipped with an emergency drain.
The condenser will be equipped with a bolted access door to allow access to all trays and the mist eliminator during repair or maintenance of the unit.
The condenser will be designed to withstand the full shutoff pressure of the fan. Access doors and inlet and outlet ductwork connections will be bolted and gasketed in a manner suitable to the pressure and temperature of the condenser.
The primary function of the mist eliminator will be the capture of particulate laden water droplets from the process gas stream exiting the condenser. A secondary function of the mist eliminator will be the additional removal of water evaporated from the dryer. The mist eliminator will be 304 stainless steel construction.
The condenser inlet and outlet process gas connections are field welded to the process duct by others.

4.21.11 Rotary Airlocks

All rotary airlocks will be equipped with a proximity switch type motion detector for indication of running condition. Airlocks will be sized for 50% volumetric efficiency with an operating speed less than 25 RPM.
All rotary airlock bodies and end plates will be constructed of carbon steel or cast iron.
All rotor shafts will be sealed with packed gland stuffing box arrangement.
Geared motors will be hollow shaft direct coupled with a mechanical service factor of 1.5 based on connected power.

4.21.12 Process Gas Stream System

The process gas stream system will include the air distribution equipment and materials, ductwork, flexible duct connections, duct insulation and metal jacketing.
Ductwork and plenums will conform to SMACNA standards.
The type, pressure rating and location of this ductwork will be in accordance with the system operating requirements.
Unless otherwise specified, duct supports, will be fabricated of painted or galvanized carbon steel.
Test ports will be provided in the ducts and plenums as appropriate locations. Openings will be equipped with removable, tight-fitting caps or covers suitable for the intended service.
Flexible duct connections and expansion joints will be provided to fans. The flexible duct connectors will be resistant to acids, alkalis, chlorides, gases and all chemicals and reaction by-products. All splices will be vulcanized. All nuts, bolts, and washers will be stainless steel.
Sheet metal rectangular and circular joints and seams will be continuously welded. Gasket material will be EPDM. All bolts, nuts, and washers will be zinc plated carbon steel. All joints and seams, including field welds, will be continuously welded in accordance with AWS D9.1 for stainless steel.
All process gas stream ducts will be externally insulated, as necessary, to maintain a maximum exterior temperature of 140°F per NAIMA 3E Plus computer program. Ductwork insulation will not be less than 2 inches thick. Ductwork insulation will be jacketed with aluminum.

4.21.13 Final Product Storage Silos

The product storage system will include the mass flow design silos (2) sized for 450 dry ton, each with live bottom screws, isolation slide gates, load-out chutes, nozzles, instrumentation and other accessories.
The final product storage silos will consist of:
Each final product storage silo will be of cylindrical shape with a bottom hopper with a minimum 60° slope. Product storage capacity will be based on a 25° angle of repose for stored pellets.
The product storage silo will be constructed of ASTM A36 steel and plate. Design and construction will comply with the latest revisions of AISC and AWS. Silo interior will be smooth with minimal protruding flanges, instrumentation, or structural members impeding material flow. The silos will accommodate flow by the utilization of a vibrating bin activator.
A silo structural steel support will be provided allowing truck drive through under the silo discharge chute, adequately designed for rated loads and conditions. The supports will allow for adequate drive under truck clearance.
The silo roof will be designed to allow mounting of all necessary hardware. Connection nozzles through the silo roof will be arranged in a manner to allow convenient access for repair and maintenance. The silos will be of sufficient structural strength with bracing and stiffeners as required to support the weight of the stored material, expected maximum pressure and vacuum conditions, and the live and dead loads of all equipment and operator on the roof of the silo. The silos will have a pressure rating coordinated with the operating requirements.
A 24-inch diameter inspection manway with gasketed and bolted cover will be provided.
Nozzle opening and connections will be provided for all required piping, equipment and instrumentation.
Each silo will be dust-tight and kept at low oxygen level by system exhaust gas or nitrogen gas injection.
Each silo will have suitably located thermocouples to allow monitoring of pellet temperatures during storage.

Each silo will be monitored for carbon monoxide and oxygen level.
Silos will be supplied with a factory applied coating. Final coating to be furnished by the General Contractor.
One (1) motorized truck load-out chute will be furnished for each silo. The load-out chute will be designed to minimize emissions of dust particles during pellet discharge from the silo.
The truck load-out chute will be constructed of conical abrasion resistant steel sections suspended on stainless steel wire rope and surrounded by a vinyl coated polyester sleeve. The dried pellet product will flow through an inner chute, while dust created during unloading is captured from the annular section between the outer sleeve and the inner chute.
Each truck load-out chute will be connected to a dust collector system. A damper that closes and opens at the beginning and end of load-out operations will be provided.
Extension and retraction of the load-out chute will be controlled through a cable hoisting system powered by an electric motor with level sensor.
Access platforms will be provided allowing access to the silos at the truck load-out level. Silos will be connected by a platform at the discharge chute level.

4.21.14 Silo Load Out Chute Dust Collector

ANDRITZ will provide a dust collector system for the load out chutes. The storage silo chute DS will be constructed to operate independently. The DS will include, as a minimum, the following items: suction ducting, dust bag house with dust bags, and dust fan. Discharge ducting will be routed to the plant odor control scrubber supplied by the General Contractor.
The storage silo chute dust collector will be designed to operate during the storage silo loading and emptying operation. The system will be capable of allowing manual operation.
The dust collector will be provided with deflagration venting in accordance with NFPA68.
The dust collector will remove 99% of dust 2.0 micron or larger from the air stream. The baghouse will include inlet and outlet flanges, bag housing, hopper with outlet flanges, leg extensions, control air solenoids, pulse air valves, operator air piping from solenoid valve to air outlet over bags, and hinged bag access door.
The baghouse is designed to withstand the vacuum present in the system.
Minimum 10-gauge welded steel construction. Provide a 1/4-inch AR-320 target wear plate opposite the baghouse inlet to protect bags from excessive wear. Provide one clean-out door at the hopper.
Filter bags will be anti-static type with copper, stainless steel or aluminum wires incorporated in the fabric for grounding. Bags will be made of abrasion resistant polyester or nylon felt material suitable for dried solids service. Bag cloth will not be less than 16-ounces per square yard.
Cleaning of the baghouse plenum and baghouse hopper will be by compressed air. Provide pulse air valve with factory mounted pilot operator. Furnish solid state timer to control duration and frequency of pulse air cleaning.
Dust collected will be discharged into a container.
Dust collector will be provided with sensors allowing measurement of pressure differential across the baghouse to detect baghouse clogging.
A dust collection system fan will be furnished with the baghouse.

4.21.15 Screw Conveyors

ANDRITZ will furnish screw conveyors required to convey the solids within the sludge drying system.

All conveyors to be enclosed to avoid being an odor source.
External lubrication points, easily accessible, will be furnished for all conveyors.
Screw conveyor drive will be suitable for AGMA Class II operation. The motors will be constant or adjustable speed type selected in conformance with process requirements. Screw conveyor drives to be sized to start in a fully loaded condition.
All conveyors will have zero speed switches.

4.21.16 Bucket Elevators

Bucket elevators will be belt type centrifugal discharge designed to be classified dust-tight and weather-tight.
Casings: Elevator casings will be designed to meet the service conditions indicated. Intermediate casing sections will be standard lengths, fabricated of 10-ga. minimum stainless steel or carbon steel and suitably reinforced. Sections will be field welded together.
Bucket elevators will be operated at low oxygen levels to prevent deflagrations.
Buckets will be stainless steel.
Belts will be furnished complete with mounting hardware.
Loading Boots: Boot section will be stainless steel or carbon steel complete with loading leg, flanged and gasketed. Adjustable bottom shroud to be provided on dust elevator to prevent buildup in the corners.
Head Sections: The head sections will be stainless steel or carbon steel made in the length necessary to complete the casing. The head section will have a flanged discharge chute with all connections flanged and gasketed.
Shafts: Head and tail shafts will be cold rolled steel. Shaft diameters will be the manufacturer's standard. Dust seals with easy access will be provided for all shaft openings in the casing. All the shaft bearings will be anti-friction type with fittings for lubrication.
Take-ups: Bottom adjustable type with adjustable dust seals.
Elevator Supports: Elevators will be designed to be self-supporting, with all lateral bracing installed by the General Contractor in the field.

4.21.17 Pellet Oil Coating System.

The pellet oil coating system consists of oil pump, oil heater, pipe heat tracing as required, oil storage tank, oil mixing screw, and all other appurtenances specified or required for proper operation. The pellet oil coating system shall reduce dust by coating pellets with a film of oil as the pellets are discharged from the storage silos. The oil coating system shall be sized to provide coating of 0.25 to 4 gallons of oil per ton of pellets during loadout.
Spray points for the pellet oil system shall be located in the pellet oil mixing screw conveyor.
Oil storage tank is UL-142 listed, double walled.
The oil pump shall be gear type with a capacity to deliver 0.25 to 4 gallons of oil per ton of pellets with a pressure as required for suitable system operation.
The pellet oil coating system shall be provided with an electric powered, tank mounted oil heater controlled by an internal thermostat to provide a minimum oil temperature of 100 degrees Fahrenheit at the heater discharge.
The pellet coating system shall be provided with a control panel with a NEMA 4X stainless steel enclosure, including manual/auto switch, heater control switch, termination box, pressure relief valve, pressure gauge, injection nozzle pressure regulator, and injection nozzle pressure gauges.

The pellet oil coating system shall be provided with the following instrumentation to send a signal back to the dryer control system for monitoring and system control:
Oil pump motor operating status.
Heater operating status.
Automatic supply valve position.
Oil storage container level transmitter.
Pellet oil mixing screw zero speed switch.

4.21.18 Nitrogen Purge System.

The sludge drying system shall be provided with a nitrogen purge system, which shall supply nitrogen gas to the drying gas loop for start-up and the product storage silos as required to maintain a low oxygen level during start-up and shutdown. The nitrogen purge system shall consist of liquid nitrogen storage tank, two (2) vaporizers in parallel, and injection nozzles. The system shall include pipe fill and discharge connections, isolation valves, vent valves, safety relief valves, liquid level and pressure gauges, line pressure regulators, and all other appurtenances specified or required for proper operation. The nitrogen storage tank and vaporizers shall be designed for outdoor installation on a concrete foundation.
The nitrogen storage tank shall be designed and constructed in accordance with the ASME Code for Unfired Pressure Vessels, shall bear the code stamp, and shall have a 250 psig design pressure. The storage tank shall have a double wall construction with the outer wall fabricated from carbon steel and the inner wall fabricated of Type 304 stainless steel. The annular space between the inner and outer walls shall be filled with insulation and evacuated to a high vacuum.
The vaporizers shall be of the high pressure, ambient type. The vaporizers shall be constructed of aluminum. The vaporizers shall be designed and constructed in accordance with the ASME Code for Unfired Pressure Vessels, shall bear the code stamp, and shall have a 400 psig design pressure.
The nitrogen storage tank shall be provided with the following instrumentation to send a signal back to the dryer control system for monitoring and system control:

1. Level transmitter to indicate amount of liquid nitrogen stored.
2. Nitrogen low pressure switch.

4.21.19 Access Platforms, Walks And Stairways

Furnish equipment access provisions consisting of access platforms, catwalks, ladders, guardrails, stairways, and other necessary items as required to conform to OSHA codes.
Access to major equipment platforms will be by stairs or ladders.
Structural steel members will be free standing and will be supported from the floor slab only.
Guardrails will be two rail, welded galvanized steel with toeboard. Rails and posts nominal 1-1/2 inch diameter. Post spacing maximum 5-feet.
All metal grating provided will be aluminum bar type grating, designed for foot traffic, 100 pounds per square foot minimum uniform service load, maximum deflection 1/4-inch.
Ladders will be welded galvanized steel construction sized for concentrated load of 250 pounds. Rungs will have a no slip surface.
Structural steel members will be fabricated in accordance with AISC specifications. Rolled plates, shapes, and bars will be ASTM A36 or ASTM A992. Structural steel pipe will be ASTM A501 or ASTM A53, Type E or S, Grade B. Structural tubing will be ASTM A500, Grade B. Welding materials will be according to AWS D1.1. Surface preparation by abrasive blast, one coat of 2

minimum DFT rust inhibitive primer. The General Contractor will provide touch up and final field finish.

4.21.20 Deflagration Prevention System

ANDRITZ will furnish a deflagration prevention system. Design and size the systems in accordance with NFPA 69 for main dryer system and NFPA 68 for silos and silo discharge chute dust collector.
Deflagration prevention measures will be provided as follows:
Inertization - The fluid bed, cyclone, fan, condenser, screw conveyors, bucket elevators, and scrubber are protected from deflagration during operation of the plant as a result of the inert atmosphere generated by evaporation of water from the sludge and by nitrogen purge during start-up.

4.21.21 Anchor Bolts

ANDRITZ will furnish all anchor bolts required for anchoring equipment components, accessories, and structural steel members to their concrete supports and foundation.
Anchor bolts will be 316 stainless steel.
Anchor bolts will be properly sized to match loads associated with anchored equipment.
ANDRITZ will provide recommended epoxy specification.
ANDRITZ will provide the General Contractor drawings showing arrangement and location of anchor bolts in concrete supports and foundations.
ANDRITZ will coordinate installation of anchor bolts with the General Contractor to match the equipment installed.
Anchor bolt threaded rod will be supplied in standard bulk length for cutting to length in the field by the General Contractor.

4.21.22 Painting

Unless specified otherwise, factory surface prepare, prime, and finish exposed exterior ferrous metal surfaces for all equipment and accessories of the sludge drying system.
Standard Coating - For equipment with surface temperatures below 250°F a standard coating system will be provided. Prepare surface to receive coating by abrasive blasting or centrifugal wheel blast. Prime with one coat of 2.5 minimum DFT epoxy primer. Finish with one coat of 3.0 minimum DFT polyurethane enamel.
Thermal Coating #1 - For equipment with surface temperatures between 250°F and 450°F a thermal coating system will be provided. Prepare surface to receive coating by abrasive blasting or centrifugal wheel blast. Prime with one coat of 2.5 minimum DFT inorganic zinc primer. Finish with two coats of 2.0 minimum DFT silicone acrylic.
Thermal Coating #2 - For equipment with surface temperatures between 450°F and 700°F a thermal coating system will be provided. Prepare surface to receive coating by abrasive blasting or centrifugal wheel blast. Prime with one coat of 2.5 minimum DFT inorganic zinc primer. Finish with one coat of 2.0 minimum DFT silicone.
Surfaces not requiring painting include non-ferrous and corrosion-resistant alloys, such as copper, bronze, Monel, aluminum, chromium plate, and stainless steel.

4.21.23 Thermal Insulation

The exterior surface of all hot system components, unless otherwise specified, will be insulated by ANDRITZ after the General Contractor has completed installation and leak testing. The insulation will be covered with an aluminum jacket.
The insulation will be chemically and thermally stable mineral wool with a maximum K factor of 0.90 at 600°F.

4.21.24 Electrical

General Electrical Provisions
Reduced voltage or electronic soft start starter will be provided for all motors above 99 HP.
Motor circuit protector breakers will be provided for all motors.
ANDRITZ will provide ON/OFF/AUTOMATIC control switches for all motors and mechanical equipment in each bucket of the MCC's. In the "ON" position, the equipment will run. In the "OFF" position, the equipment will not run. In the "AUTOMATIC" position, the PLC will control the equipment. PLC station monitoring will also be provided in the "AUTOMATIC" switch position.
Motors
All motors will be TEFC rated.
Motors will have a suitable service factor for the application.
Motors will have Class F insulation.
Motors 1/4 horsepower and smaller will be single phase 115V
Motors 3/4 horsepower and larger will be three phase 460V.
Electrical system frequency will be 60 hertz.
Motors are generally Baldor ECP premium efficiency, chemical duty or equivalent.
Motor Control Centers
Provide complete motor control center (MCC) with all necessary accessories to control all motors provided under this specification. Unless specifically noted otherwise, all motor control center equipment will be housed in the motor control center. Provide the following features:

- Combination starters with magnetic trip only circuit breakers.
- Individual 120V control power transformers with two primary fuses for each starter.
- Red "ON" light and green "OFF" light status lights on front of each starter.
- Feeder only units to use molded case circuit breakers.
- Provide tin plated copper horizontal and vertical power buses.
- Provide three phase, three wire MCC (no neutral bus).
- Provide copper ground bus entire width of MCC.
- Provide MCC rated for 65 kA interrupting capacity.
- Provide 600V rating.
- Provide NEMA Class I, Type B, wiring.
- Provide NEMA 250, Type 1, gasketed enclosure.

f. Variable Frequency Drives

Variable frequency drives (VFDs) will be provided as an integral portion of the MCC.

Drive system will convert incoming three phase, 60-hertz AC power to variable voltage, adjustable frequency output for adjustable speed operation of a standard AC induction squirrel cage motors, using the pulse width modulation (PWM) technique to produce the adjustable frequency output.
VFDs will be rated based on the actual motor full load nameplate current rating.
Rated continuous operating capacity will be not less than the full load current rating of the driven motor as indicated on the motor nameplate, and suitable for operation at 115% overload for one minute and 150% for three seconds.
Provide 5% incoming line reactor to minimize harmonic distortion.

4.21.25 Control System

The sludge drying system's data acquisition and control activities will be performed by a PLC based control system. Operator interface to the PLC will be through personal computer with a widescreen LCD monitor. The system will include a printer to be used for screen copying and for shift reports.
ANDRITZ will furnish a fully programmed control and display system including PLC logic, system pictorial graphic displays with real-time data, alarm monitoring and logging software, operator interfaced software, and all other services required for the operation and monitoring of this plant.
The sludge drying system's control system will include the following components:
Programmable Logic Controller (PLC) subsystem including processor, remote I/O panels, power supplies, racks, I/O modules, and all required accessories.
One (1) PC based operator control station per dryer train will be provided in the main control room. This computer will operate the Human Machine Interface (HMI) software for the sludge dryer system.
One (1) PC based local control operator station per train will be provided housed in a NEMA 4X enclosure with industrial exposure pointing device, keyboard, and monitor will be provided adjacent to each sludge dryer in the operating area and will be functionally identical to the main unit in the control room. The local control operator station will be mounted in a NEMA 4X stainless steel enclosure (Monitor is a standard LCD type housed in the NEMA 4x enclosure).
Un-interruptible Power Supply (UPS) subsystem will be provided to power the PLC and HMI computers and all instruments for a minimum duration of 30 minutes following a power outage.
Truck Load-Out Panel (TLP) subsystem will be provided in a NEMA 4X stainless steel enclosure with remote I/O racks in the panel as required.
Integrated firewall and VPN appliance, to facilitate remote support.
PLC System Equipment
General
The PLC will be of a modular expandable design.
The PLC CPU and I/O will be mounted and pre-wired in the same or contiguous front access cabinets. This equipment will be located in the control or MCC room.
The PLC cabinets will be furnished complete with all the power supplied necessary for PLC and I/O operation, including sensing power for 2-wire transmitters and contact inputs.
Field wiring will not terminate directly on the I/O cards. The PLC cabinet will be equipped with terminal strips for this purpose. I/O cards will be protected via circuit breakers.
The CPU will be sized with sufficient capacity such that 85% CPU loading will not be exceeded under normal operating conditions. The CPU will be fully capable of executing ladder logic, analog signal conversion, PID control, alarm generation and all other activities associated with the operation of the plant.

The PLC will be equipped with bi-directional communication capability with the personal computer based operator station. Communications will be based on TCP/IP Ethernet protocol.
The processor will be Allen Bradley, Control Logix.
Input/Output Subsystems (I/O)
The system will be supplied with a minimum of 25% spare active I/O points and will have space for at least one additional card of each type of I/O required for this plant.
Discrete input I/O will be optically isolated.
Discrete outputs will be the triac type with a minimum continuous contact rating of 0.5 Amp at 120 VAC. For loads greater than 0.5 amp interposing relays will be provided.
Analog input I/O will be a 4-20 mAdc from both externally powered and loop powered type transmitters.
Analog output I/O will be PLC sourced 4-20 mADC.
Thermocouple input I/O will be 2 wire type T.
The I/O system will be Allen Bradley, Control Logix.
Operator Interface Terminals
The control room operator terminal will be an HP or equal personal computer and will include at a minimum the following features:
1 x Core 2 Duo, 3.16 GHz.
4 GB RAM memory
One (1) 500 GB hard drive
Parallel port
Mouse
Widescreen LCD monitor
Any additional items recommended by the operator interface software supplier.
Operating System will be Windows 7 Pro or equal
DVD drive
1 GB ethernet
2 USB Ports
The hardened operator terminal located adjacent to each dryer will be an HP or equal personal computer and will include the following features:
1 x Pentium dual core E5200/2.5 GHzIV processor, 2.5 Ghz.
2 GB RAM memory
One (1) 80 GB hard drive
Parallel port
Mouse
Widescreen LCD touchscreen (Stealthview or equal)
Any additional items recommended by the operator interface software supplier.
Operating System will be Windows 7 Pro or equal
1 DVD Drive
2 USB Ports
NEMA 4X 316 stainless steel enclosure.
1 x GB ethernet capable
Software
The operator terminal will be supported by commercially available Windows based process control and monitoring software. The software will support the following activities:
Operator interface to the PLC.
Dynamic pictorial process graphic displays.
Loop tag displays.

Alarm and events monitoring.
Trending and logging.
Reports and generation.
PLC system diagnostics.
Acceptable suppliers of process control software are:
Intouch Wonderware version 10.x requires Windows 7 Pro.
The control system will include the motor control center. The MCC will be provided with a PLC and pre-wired and tested by the system integrator or ANDRITZ. It will be broken down into the largest practical pieces for shipment and reassembled at the site.
The integrated firewall and VPN device will be an eWon VPN or equal. See attached:
Configurable firewall protects the system from unauthorized access from "outside ". The Stateful Inspection Firewall filters data packets based on the originating and target address, blocking undesired data traffic – also from "inside".
VPN for secure data transmission via public networks.
The eWon is equip1ped with a 4 port 10/100 TX Ethernet switch which distributes the security functionality to a maximum of four network segments.

4.21.26 Miscellaneous

All processing equipment to have zero speed switches mounted on the non-driver drive shaft end and used for interlock logic in PLC programs.
All equipment, vessels, piping and ductwork in drying system handling dry material will be bonded and grounded per NFPA. Metal to metal bolted connections will be considered bonded. The General Contractor will install bonding jumpers.

4.22 Execution

4.22.1 General Verification of Conditions

ANDRITZ will inspect and test the sludge to ensure it meets the design criteria.
All fuel and water utilities required for the testing specified in this Part will be supplied by the General Contractor at the rate and in the quantities designated within this Specification.

4.22.2 Installation

The General Contractor will erect the equipment in accordance with approved ANDRITZ' drawings and instructions. ANDRITZ will furnish necessary oil and grease for initial operation and making final adjustments to place the equipment in operable condition.
Equipment will be rigidly and accurately anchored into position and carefully coordinated with all connecting pieces of equipment. ANDRITZ will supply anchor bolts. Shims and grout are to be supplied by the General Contractor.

4.22.3 Field Testing - General

Field tests will consist of Mechanical Run Tests, I/O Checks/Software Test, Performance Tests.
Air Emission Tests by Others.
The Operator will have available to ANDRITZ, sufficient personnel of relative trades to assist with the mechanical tests, adjustments, and integrated systems test as well as perform punch list items.

ANDRITZ will provide sufficient skilled operators to conduct the mechanical, software, system and process performance tests.
Software will verify that all stated equipment and computer inputs, outputs and control algorithms are in the working condition specified.

4.22.4 Mechanical Tests

Conduct a mechanical test of each installed piece of equipment. The mechanical run will demonstrate that each unit:

- Has not been damaged by transportation or installation.
- Has been properly installed.
- Has no mechanical defect.
- Is free of overheating of any parts.
- Is free of all objectionable vibration.
- Is free of overloading of any parts.
- Is free of excessive noise.
- Has all interlocks operating correctly.
- No handling or processing of either dewatered sludge cake or recycle material by any equipment and/or system will take place during the mechanical test.

ANDRITZ will mechanically test all major pieces of equipment and systems.

4.22.5 I/O Check

The complete control system as specified herein will be tested to confirm that the system meets the specified requirements.

- Signal verification (check or correct voltages, current polarity, contact “sensor”, etc.).
- Database verification (check for correct range, alarm limits, message repairs, etc.). Completed during offsite Factory Acceptance Test (FAT).
- Operator input to the controls system. Completed during offsite Factory Acceptance Test (FAT).
- Verification of application software. Completed during offsite Factory Acceptance Test (FAT) with final test completed on site.
- Alarm log and display generation. Completed during offsite Factory Acceptance Test (FAT) with final test completed on site.
- Man-machine interface. Completed during offsite Factory Acceptance Test (FAT).

All field instrumentation and controls that are an integral part of the equipment being testing will also be tested during the I/O test.

4.22.6 Software Test

Upon completion of the Mechanical check, I/O check, and required correction, a software test will be conducted.
The software test will demonstrate successful functioning of the Sludge Drying System and all its elements and software capabilities with actual system on-line operating conditions.
Process and control functions will be tested, as well as designated combinations and logical sequence.
During the software test, the Sludge Drying System will process dewatered sludge and demonstrate that the System can function continuously and reliably and produce a dried product.

ANDRITZ will notify the General Contractor at least 96 hours prior to the software test so that arrangements can be made for supplying dewatered sludge to the system during the test period. Completed tests, malfunctions, and corrective measures will be chronologically logged.
The software test will be completed before ANDRITZ conducts the Process Performance Test as specified in Paragraph 3.7 of this Section.
During the software test, ANDRITZ will provide personnel to operate the system to perform the test and collect samples. Loadout and weighing of final product to be provided by others.

4.22.7 Process Performance Test

The Performance Test shall be conducted to demonstrate that the sludge drying system is operating properly and capable of meeting the specified performance and design requirements. ANDRITZ will submit a Performance Test Plan no later than 90 days prior to the initiation of the test. The test plan shall include the followings:

- Performance test requirements
- Test prerequisites
- Pre-test activities
- Testing procedures, including sample locations
- How data will be analyzed, including equations
- Personnel and testing responsibilities
- Quality control procedures

The testing protocol will be jointly reviewed and agreed upon before the test.
Performance Test Report
Within 30 days after completion of the performance tests and submittal of data from the analytical laboratory, six (6) copies of a report will be submitted with the following information:

- The date and time of the performance test for the dryer.
- A description of all samples collection and measurement techniques.
- Raw data and original copies of all laboratory reports for all parameters.
- Descriptions of operations problems, unusual conditions, equipment failures or malfunctions, and other factors adversely affecting performance of the sludge drying and system.

4.22.8 Acceptance

The System will comply with the performance requirements, as set forth in EXHIBIT E, to pass the Performance Test. If the System fails the Performance Test, ANDRITZ will make whatever adjustments are determined to be necessary at no cost and run the Performance Tests again. ANDRITZ will be allowed three (3) attempts to pass the Performance Test.

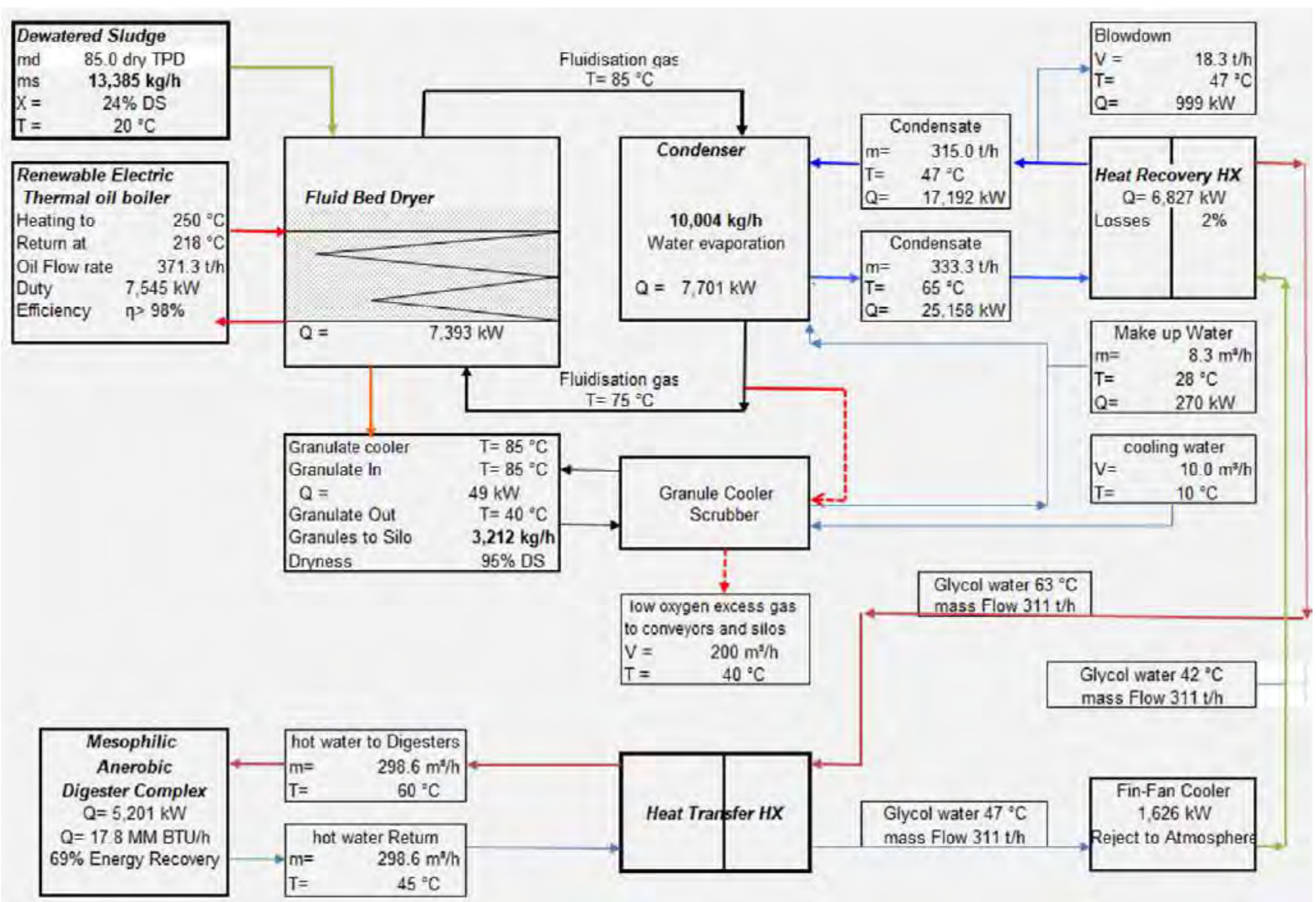
5 Heat and Mass Balance

5.1 Calculation Basis

Daily Sludge Production	85 dry TPD
Average Cake Dryness	24% DS
Daily Dewatered Cake	354 wet TPD
Basis of Operations	24/7
No. of Dryers Trains in Operation	One (1)
No. of Dryer Trains on Standby	One (1)
Plant Water temperature	68ºF
Digester Operating Temperature	100 ºF

5.2 Calculation Results

Renewable Electricity Consumption	7,545 kW
Recovered waste heat for digester use	17.8 MM BTU/h (ambient temperature dependent)
Available waste heat for buildings	5.5 MM BTU/h



ANDRITZ

5.3 Estimate of Ammonia-N loading from Dryer Facility

King County	2022 AA
Nominal Daily Sludge Production	85 dry tons/day
Cake Dryness	24% DS
Nominal Daily Sludge Production	354 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum
Dryer Operations	7 days per week
Dryer Operations	24 hours/day
Dryer Operations	168 hours/week
Dryer Capacity Required	85 dry tons/day
Dryer Capacity Required	354 wet tons/day
Final Product	95% DS
Final Product	89 tons/hour
Evaporation Rate	11.0 tons/hour H2O
Evaporation Rate	22,058 lb/hour H2O
Evaporation Rate	10,004 kg/hour H2O
No. of Drying Trains	1
Evaporation Rate/train	10,004 kg/hour H2O
Dryer Technology	Fluid Bed Dryer
Make up plant water to Dryer condenser	10,004 kg/hour H2O
Total flow back to head of WWTP	20,007 kg/hour H2O
Total flow back to head of WWTP	88 USGPM
Total flow back to head of WWTP	126,893 USGPD
Total NH4-N	1.84 kg NH4-N/t WE
Total NH4-N	18 kg/hour H2O
Total NH4-N	974 lb. NH4-N/day
Total NH4-N concentration	920 mg/l
Typical Influent Ammonia-N	30 mg/l
Influent	65 MGD
Influent	246 million Liters/day
NH4-N in influent	16,276 lbs/day NH4-N
Additional NH4-N from dryer	6%

This calculation:

ignores the Ammonia-N generated in the digestion process and discharged to the WWTP from the dewatering machine (centrifuge) centrate

6 Commercial

6.1 Budget Pricing

All non-binding prices are shown in U.S. Dollars.

Two (2) off ANDRITZ FDS-10.0 Fluidized Bed Dryer System ....Included

Per Scope section 4, generally consisting of:

Two (2) off Cake dump hoppers with sliding frame & cake feed pumps ....Included

Two (2) off Wet material bin with sliding frame & cake feed pumps ....Included

Two (2) off FDS 10.0 Fluid Bed Dryers and coolers..Included

Two (2) off Electric Thermal Oil Heater sets with pumps and tanks ....Included

Two (2) off Condensers with Heat Recovery Heat Exchangers..Included

Two (2) off heat transfer heat exchangers with fin-fan coolers ....Included

Two (2) off lots of Support steelwork, service platforms, guardrails, access walkways ....Included

Two (2) off lots of associated process ductwork ....Included

Two (2) off lots of all instruments, motors & MCC's for supplied equipment....................................Included

Two (2) off lots of PLC's and operator interface implementation ....Included

Two (2) off Dried Product Storage silos, 2x 450 Ton mass flow design...Included

One (1) off truck loading system with discharge screw and pellet oil mixing system........................Included

One (1) off odor control system per section 10 ....Included

1 lot Engineering Services including Field Services and training ....Included

Two (2) off Submittal Data per attached Drawings and Data Requirements ....Included

Payment and Performance Bond ....Excluded

Final O&M Manuals (two (2) CD sets)...Included

Freight to Jobsite ....Included

TOTAL AMOUNT OF NON-BINDING PRICE $45,532,420

6.2 Price basis

Price is current day, budgetary and not valid for acceptance. Andritz's internal formal risk review and approval by Andritz's Board of Directors is required prior to any proposal being offered as valid for acceptance.

6.2.1 Currency and Escalation

Price is quoted in US Dollars.

The quoted price in this proposal/order has been calculated based on the current market prices required to manufacture the quoted equipment and services pursuant to regulations, duties and law in effect as of the date of this proposal. The quoted price shall be subject to the following. In the event that the introduction of new tariffs, levies, duties, taxes, regulations, or any type of legislation by a domestic or foreign government has the effect of increasing the price of the quoted equipment or services, Andritz reserves its right to adjust its quoted Price in order to reflect these increases in cost. Nothing in this document, or in any of the applicable contractual documentation shall be construed as a waiver of this right.

6.2.2 Taxes and duties

Supplier's prices do not include value added tax, customs or any other taxes, duties, levies and fees in the state or country of destination. Supplier's price includes customary payroll taxes only. Details are per Andritz's attached standard commercial terms of sale.

6.2.3 Terms of delivery and delivery time

The equipment shall be delivered DDP jobsite
For delivery time please consider a staggered supply of 10 lines. E.g. 2 lines every one or two months. To be discussed.

6.2.4 Terms of payment

- 30% with order placement, due immediately.
- 40% due 30 days after submittal of the installation information and general arrangement drawing
- 30% upon notification of 'ready for shipment', due immediately.

Payments shall be made without any deductions such as discounts, bank charges, taxes, fees, charges and other expenses. Prices do not include any applicable tax of any kind.

6.3 Pre-conditions

The Supplier shall commence its works – and thus the delivery time will commence – when the Customer's Purchase Order has been received and acknowledged by Supplier.

6.4 Terms and Conditions

This proposal is based upon acceptance of Andritz's standard terms of sale (see 10.4.1 below) (including but not limited to provisions regarding guarantee remedies, and "takeover" and testing details).

6.4.1 ANDRITZ SEPARATION STANDARD TERMS AND CONDITIONS

TERMS APPLICABLE

(a) These Terms and Conditions of Sale are the only terms which govern the sale of the products, equipment, or parts ("Products") pursuant to the quotation or acknowledgement of the Andritz entity supplying the same ("Seller") or Buyer's purchase order or other written document issued by Buyer. These Terms and Conditions of Sale control, supersede and replace any and all other additional and/or different terms and conditions of Buyer, and Seller hereby objects to and rejects all such terms and conditions of Buyer without further notification, except to the extent Seller expressly agrees to such conditions in writing. Buyer's authorization for Seller to commence work under the Agreement or Buyer's acceptance of delivery of or payment for any Products covered by this Agreement, in whole or in part, shall be deemed Buyer's acceptance of these Terms and Conditions of Sale. The term "Agreement" as used herein means (1) these Terms and Conditions of Sale, (2) Seller's quotation or acknowledgment together with any attachment thereto and any documents expressly incorporated by reference, and (3) Buyer's purchase order or other written document issued by Buyer, together with any attachment thereto and any documents expressly incorporated by reference (but excluding any Buyer terms and conditions attached thereto or incorporated therein by reference).. In the event of a conflict between any documents forming the Agreement, such documents shall be construed in the above-listed order of precedence.

(b) Prior to Buyer's acceptance of any Seller quotation in which these Terms and Conditions of Sale are incorporated, in the event that the introduction of new tariffs, levies, duties, taxes, regulation, or any type of legislation by a domestic or foreign government has the effect of increasing the price of the quoted Products, Seller reserves its right to adjust its quoted price in order to reflect these increases in cost. Nothing in this document, or any of the applicable contractual documentation shall be construed as a waiver of this right.

2. DELIVERY; RISK OF LOSS AND TITLE

(a) Delivery dates are good faith estimates and do not mean that "time is of the essence." Buyer's failure to promptly make advance or interim payments, supply technical information, drawings and approvals will result in a commensurate delay in delivery. If the parties have agreed to liquidated damage in this Agreement for Seller's delay in achieving certain milestones, (i) the parties acknowledge and agree that Buyer's damages for Seller's delay are difficult to predict with any certainty, and such liquidated damages are not a penalty but a reasonable estimate of Buyer's delay damages; (ii) such liquidated damages shall not exceed an aggregate value of five percent (5%) of the Agreement price and shall be Buyer's exclusive remedy for any delay by Seller in performing any of its obligations under this Agreement; and (iii) Buyer agrees Seller shall not be liable for liquidated damages if Seller's delay in achieving a milestone subject to liquidated damages has not delayed Buyer's ability to use the applicable Products.

(b) Upon and after delivery, risk of loss or damage to the Products shall be Buyer's. Delivery of the Products hereunder will be made on the terms agreed to by the parties as set forth in this Agreement, according to INCOTERMS 2010. If no INCOTERM is agreed elsewhere in the Agreement, delivery of the Products will be made FCA. Title to the Products shall transfer to Buyer upon final payment therefor.

3. WARRANTY

(a) Seller warrants to Buyer that the Products manufactured by it will be delivered free from defects in material and workmanship. This warranty shall commence upon delivery of the Products and shall expire on the earlier to occur of 12 months from initial operation of the Products and 18 months from delivery thereof (the "Warranty Period"). If during the Warranty Period Buyer discovers a defect in material or workmanship of a Product and gives Seller written notice thereof within 10 days of such discovery, Seller will, at its option, either deliver to Buyer, on the same terms as the original delivery was made, according to INCOTERMS 2010, a replacement part or repair the defect in place. Any repair or replacement part furnished pursuant to this warranty are warranted against defects in material and workmanship for one period of 12 months from completion of such repair or replacement, with no further extension. Seller will have no warranty obligations for the Products under this Paragraph 3(a): (i) if the Products have not been stored, installed, operated and maintained in accordance with generally approved industry practice and with Seller's specific written instructions; (ii) if the Products are used in connection with any mixture or substance or operating condition other than that for which they were designed; (iii) if Buyer fails to give Seller such written 10 day notice; (iv) if the Products are repaired by someone other than Seller or have been intentionally or accidentally damaged; (v) for corrosion, erosion, ordinary wear and tear or in respect of any parts which by their nature are exposed to severe wear and tear or are considered expendable; or (vi) for expenses incurred for work in connection with the removal of the defective articles and reinstallation following repair or replacement.

(b) THE EXPRESS WARRANTIES SELLER MAKES IN THIS PARAGRAPH 3 ARE THE ONLY WARRANTIES IT WILL MAKE. THERE ARE NO OTHER WARRANTIES, WHETHER STATUTORY, ORAL, EXPRESS OR IMPLIED. IN PARTICULAR, THERE ARE NO IMPLIED WARRANTIES OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE.

(c) The remedies provided in Paragraph 3(a) are Buyer's exclusive remedy for breach of warranty.

(d) With respect to any Product or part thereof not manufactured by Seller, Seller shall pass on to Buyer only those warranties made to Seller by the manufacturer of such Product or part which are capable of being so passed on.

4. LIMITATION OF LIABILITY

Notwithstanding any other provision in this Agreement, the following limitations of liability shall apply:

(a) In no event, whether based on contract, tort (including negligence), strict liability or otherwise, shall Seller, its officers, directors, employees, subcontractors, suppliers or affiliated companies be liable for loss of profits, revenue or business opportunity, loss by reason of shutdown of facilities or inability to operate any facility at full capacity, or cost of obtaining other means for performing the functions performed by the Products, loss of future contracts, claims of customers, cost of money or loss of use of capital, in each case whether or not foreseeable, or for any indirect, special, incidental or consequential damages of any nature resulting from, arising out of or connected with the Products or this Agreement or from the performance or breach hereof.

(b) The aggregate liability of Seller, its officers, directors, employees, subcontractors, suppliers or affiliated companies, for all claims of any kind for any loss, damage, or expense resulting from, arising out of or connected with the Products or this Agreement or from the performance or breach hereof, together with the cost of performing make good obligations to pass performance tests, if applicable, shall in no event exceed the Agreement price. The foregoing notwithstanding, Seller's aggregate and sole liability for any claims for (a) delay in delivery shall not exceed 5% and (b) failure to achieve performance requirements, shall not exceed 10% of the contract price.

(c) The limitations and exclusions of liability set forth in this Paragraph 4 shall take precedence over any other provision of this Agreement and shall apply whether the claim of liability is based on contract, warranty, tort (including negligence), strict liability, indemnity, or otherwise. The remedies provided in this Agreement are Buyer's exclusive remedies.

(d) All liability of Seller, its officers, directors, employees, subcontractors, suppliers or affiliated companies, resulting from, arising out of or connected with the Products or this Agreement or from the performance or breach hereof shall terminate on the third anniversary of the date of this Agreement.

(e) In no event shall Seller be liable for any loss or damage whatsoever arising from its failure to discover or repair latent defects or defects inherent in the design of goods serviced (unless such discovery or repair is normally discoverable by tests expressly specified in the scope of work under this Agreement) or caused by the use of goods by the Buyer against the advice of Seller. If Seller furnishes Buyer with advice or assistance concerning any products or systems that is not required pursuant to this Agreement, the furnishing of such advice or assistance will not subject Seller to any liability whether in contract, indemnity, warranty, tort (including negligence), strict liability or otherwise.

5. CHANGES, DELETIONS AND EXTRA WORK.

Seller will not be required to make changes in the Products unless Buyer and Seller have executed a written Change Order for such change. Any such Change Order will include an appropriate adjustment to the Agreement price and/or schedule. If the change impairs Seller's ability to satisfy any of its obligations to Buyer, the Change Order will include appropriate modifications to this Agreement. Seller shall be entitled to a Change Order adjusting the Agreement price, schedule and/or any affected obligations of Seller if after the effective date of this Agreement (a) a change in applicable law, tariffs, levies, duties, taxes, regulations or ordinances or (b) any act or omission of Buyer or any other party for whom Buyer is responsible, or any error or change in Buyer-provided information should require a change in the Products or cause an increase in the cost or change in the schedule to supply the Products.

6. TAXES

Seller's prices do not include any sales, use, excise or other taxes. In addition to the price specified herein, the amount of any present or future sales, use, excise or other tax applicable to the sale or use of the Products shall be billed to and paid by Buyer unless Buyer provides to Seller a tax-exemption certificate acceptable to the relevant taxing authorities.

7. SECURITY INTEREST

Seller shall retain a purchase money security interest and Buyer hereby grants Seller a lien upon and security interest in the Products until all payments hereunder have been made in full. Buyer acknowledges that Seller may file a financing statement or comparable document as required by applicable law and may take all other action it deems reasonably necessary to perfect and maintain such security interest in Seller and to protect Seller's interest in the Products.

8. SET OFF

Neither Buyer nor any of its affiliates shall have any right to set off claims against Seller or any of its affiliates for amounts owed under this Agreement or otherwise.

9. PATENTS

Unless the Products or any part thereof are designed to Buyer's specifications or instructions and provided the Product or any part thereof is not used in any manner other than as specified or approved by Seller in writing or modified by Buyer without the written consent of Seller, (i) Seller shall defend against claims made in a suit or proceeding brought against Buyer by an unaffiliated third party that any Product infringes a device claim of a patent issued as of the effective date of this Agreement in the country in which the Product will be operated, and limited to the field of the specific Products provided under this Agreement; provided Seller is notified promptly in writing and given the necessary authority, information and assistance for the defence of such claims; (ii) Seller shall satisfy any judgment (after all appeals) for damages entered against Buyer on such claims so long as such damages are not attributable to willful conduct or sanctioned litigation conduct; and (iii) if such judgment enjoins Buyer from using any Product or a part thereof, then Seller will, at its option: (a) obtain for Buyer the right to continue using such Product or part; (b) eliminate the infringement by replacing or modifying all or part of the Products; or (c) take back such Product or part and refund to Buyer all payments on the Agreement price that Seller has received for such Product or part. The foregoing states Seller's entire liability for patent infringement by any Product or part thereof.

10. SOFTWARE LICENSE, WARRANTY, FEES

If Buyer and Seller have not entered into a separate license agreement, the following Software Terms and Conditions apply to any embedded software produced by Seller and furnished by Seller hereunder:

(a) The Software, as described in the Agreement ("Software"), and all written materials or graphic files that are fixed in any tangible medium and that relate to and support the Software ("Documentation"), and all present and future worldwide copyrights, trademarks, trade secrets, patents, patent applications, mask work rights, moral rights, contract rights, and other proprietary rights recognized by the laws of any country inherent therein, including all changes and improvements requested or suggested by Buyer in the support and maintenance of the Software are the exclusive property of Seller ("Seller's Intellectual Property Rights"). All rights in and to the Software not expressly granted to Buyer in the Agreement are reserved by Seller. Nothing in this Agreement will be deemed to grant, by implication, estoppel, or otherwise, a license under any of Seller's existing or future patents. Software will not include any upgrades, new versions, releases, enhancements, or updates to the Software, unless agreed to by Seller in writing and at its sole discretion. To the extent any upgrades, new versions, releases, enhancements, or updates to the Software are provided by Seller, the term "Software" shall be deemed to include such upgrades, new versions or releases, enhancements or updates. To the extent any ownership right arises in Buyer with respect to the above, Buyer hereby assigns all of its right, title, and interest in and to any intellectual property embodied in in the Seller's Intellectual Property Rights, including enforcement rights, to Seller without the payment of any additional consideration thereof either to Buyer, or its employees, agents, or customers and agrees to execute any documents Seller deems necessary to effect such assignment.

(b) Seller hereby grants to Buyer a non-exclusive, non-transferable, non-sub-licensable, revocable license to install, run, and use the Software, and any modifications made by Seller thereto only in connection with configuration of the Products and operating system for which the Software is ordered hereunder, and for the end-use purpose stated in the Documentation. Buyer agrees that neither it nor any third party shall modify, reverse engineer, decompile or reproduce the Software, except Buyer may create a single copy for backup or archival purposes in accordance with the Documentation (the "Copy"). Buyer's license to use the Software and the Copy of such Software shall terminate upon any breach of this Agreement by Buyer. All copies of the Software, including the Copy, are the property of Seller, and all copies for which the license is terminated shall be returned to Seller, or deleted from Buyer's computer systems, with written confirmation after termination.

(c) Seller warrants that, on the date of shipment of the Software or the Products containing the Software to Buyer: (1) the Software media contain a true and correct copy of the Software and are free from material defects; (2) Seller has the right to grant the license hereunder; and (3) the Software will function substantially in accordance with the related Seller operating documentation. In no event does Seller warrant that the Software is error free or that Buyer will be able to operate the Software without impairments or interruptions. In addition, due to the continual development of new techniques for intruding upon and attacking networks, Seller does not warrant that the Software or any equipment, system, or network on which the Software is used will be free of vulnerability to intrusion or attack.

(d) If within 12 months from the date of delivery of the Products containing the Software, Buyer discovers that the Software is not as warranted above and notifies Seller in writing prior to the end of such 12 month period, and if Seller determines that it cannot or will not correct the nonconformity, Buyer's and Buyer's Seller-authorized transferee's exclusive remedies, at Seller's option, are: (1) replacement of the nonconforming Software; or (2) termination of this license and a refund of a pro rata share of the Agreement price or license fee paid.

(e) If any infringement claims are made against Buyer arising out of Buyer's use of the Software in a manner specified by Seller, Seller shall: (i) defend against any claim in a suit or proceeding brought by an unaffiliated third party against Buyer that the Software violates a registered copyright or a confidentiality agreement to which Seller was a party, provided that Seller is notified promptly in writing and given the necessary authority, information and assistance for the defence and settlement of such claims (including the sole authority to select counsel and remove the Software or stop accused infringing usage); (ii) Seller shall satisfy a final judgment (after all appeals) for damages entered against Buyer for such claims, so long as such damages are not attributable to willful conduct or sanctioned litigation conduct; and (iii) if such judgment enjoins Buyer from using the Software, Seller may at its option: (a) obtain for Buyer the right to continue using such Software; (b) eliminate the infringement by modifying the Software or replacing it with a functional equivalent (in which case, Buyer shall immediately stop use of the allegedly infringing Software), or (c) take back such Software and refund to Buyer all payments on the Agreement price that Seller has received. However, Seller's obligations under this Paragraph 10 shall not apply to the extent that the claim or adverse final judgment relates to: (1) Buyer's running of the Software after being notified to discontinue; (2) non-Seller software, products, data or processes; (3) Buyer's alteration of the Software; (4) Buyer's distribution of the Software to, or its use for the benefit of, any third party not approved in writing by Seller; or (5) Buyer's acquisition of confidential information (a) through improper means; (b) under circumstances giving rise to a duty to maintain its secrecy or limit its use; or (c) from a third party who owed to the party asserting the claim a duty to maintain the secrecy or limit the use of the confidential information. Buyer will reimburse Seller for any costs or damages that result from actions 1 to 5. THE FOREGOING PROVISIONS OF THIS SECTION 10(e) STATE THE ENTIRE LIABILITY AND OBLIGATIONS OF SELLER AND THE EXCLUSIVE REMEDY OF BUYER, WITH RESPECT TO ANY VIOLATION OR INFRINGEMENT OF ANY PROPRIETARY RIGHTS UNDER SECTION 10, INCLUDING BUT NOT LIMITED TO PATENTS AND COPYRIGHTS, BY THE SOFTWARE OR ANY PART THEREOF.

(f) This warranty set forth in subparagraph (c) above shall only apply when: (1) the Software is not modified by anyone other than Seller or its agents authorized in writing; (2) there is no modification in the Products in which the Software is installed by anyone other than Seller or its agents authorized in writing; (3) the Products are in good operating order and installed in a suitable operating environment; (4) the nonconformity is not caused by Buyer or a third party; (5) Buyer promptly notifies Seller in writing, within the period of time set forth in subparagraph (c) above, of the nonconformity; and (6) all fees for the Software due to Seller have been timely paid. SELLER HEREBY DISCLAIMS ALL OTHER WARRANTIES, EXPRESS OR IMPLIED, WITH REGARD TO THE SOFTWARE, INCLUDING BUT NOT LIMITED TO IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, COURSE OF DEALING AND USAGE OF TRADE.

(g) Buyer and its successors are limited to the remedies specified in this Paragraph 10.

(h) Any subsequent modifications or enhancements to the Software made by Seller are, at Seller's option, subject to a fee.

11. TERMINATION

(a) Buyer may terminate this Agreement upon breach by Seller of a material obligation hereunder and Seller's failure to cure, or to commence a cure of, such breach within a reasonable period of time (but not less than 30 days) following written receipt of notice of the same from Buyer.

(b) Buyer may only terminate this Agreement for Buyer's convenience upon written notice to Seller and upon payment to Seller of Seller's termination charges, which shall be specified to Buyer and shall take into account among other things expenses (direct and indirect) incurred and commitments already made by Seller, overhead, and an appropriate profit. In case of such termination, the licenses granted in Paragraphs 10 and 12 hereof shall terminate.

(c) Seller shall have the right to suspend and/or terminate its obligations under this Agreement if payment is not received within 30 days of due date. In the event of the bankruptcy or insolvency of Buyer or in the event of any bankruptcy or insolvency proceeding brought by or against Buyer, Seller shall be entitled to terminate any order outstanding at any time during the period allowed for filing claims against the estate and shall receive reimbursement for its cancellation charges.

12. INTELLECTUAL PROPERTY; CONFIDENTIALITY

(a) All intellectual property embodied in the Products and Software provided to Buyer is the property of Seller, and any intellectual property developed, at least in part, by Seller under this Agreement is and remains the sole and exclusive property of Seller.

(b) Buyer acknowledges that the information that Seller submits to Buyer in connection with this Agreement and the performance hereof is Seller's confidential and proprietary information. Buyer agrees not to disclose such information to third parties without Seller's prior written consent. Seller grants to Buyer a non-exclusive, royalty-free, non-transferrable license to use Seller's confidential and proprietary information for the purpose of the installation, operation, maintenance and repair of the Products that are the subject of this Agreement only; provided, however, that Buyer further agrees not to, and not to permit any third party to, analyze, measure the properties of, or otherwise reverse engineer the Products or any parts thereof, fabricate the Products or any parts thereof from Seller's drawings or to use the drawings other than in connection with this Agreement. Buyer will defend and indemnify Seller from any claim, suit or liability based on personal injury (including death) or property damage related to any Product or part thereof which is fabricated by a third party without Seller's prior written consent and from and against related costs, charges and expenses (including attorneys' fees). All copies of Seller's confidential and proprietary information shall remain Seller's property and may be reclaimed by Seller at any time in the event Buyer is in breach of its obligations under this Paragraph 12, or in case of Buyer's termination pursuant to Paragraph 11(b).

13. END USER

If Buyer is not the end user of the Products sold hereunder (the "End User"), then Buyer will use its best efforts to obtain the End User's written consent to be bound to Seller by the provisions hereof. If Buyer does not obtain such End User's consent, Buyer shall defend and indemnify Seller and Seller's agents, employees, subcontractors and suppliers from any action, liability, cost, loss, or expense for which Seller would not have been liable or from which Seller would have been indemnified if Buyer had obtained such End User's consent.

14. FORCE MAJEURE

(a) Force Majeure Defined. For the purpose of this Agreement "Force Majeure" will mean all events, whether or not foreseeable, beyond the reasonable control of either party which affect the performance of this Agreement, including, without limitation, acts of God, acts or advisories of governmental or quasi-governmental authorities, laws or regulations, strikes, lockouts or other industrial disturbances, acts of public enemy, wars, insurrections, riots, epidemics, pandemics, outbreaks of infectious disease or other threats to public health, lightning, earthquakes, fires, storms, severe weather, floods, sabotage, delays in transportation, rejection of main forgings and castings, lack of available shipping by land, sea or air, lack of dock lighterage or loading or unloading facilities, inability to obtain labor or materials from usual sources, serious accidents involving the work of suppliers or sub-suppliers, thefts and explosions.

(b) Suspension of Obligations. If either Buyer or Seller is unable to carry out its obligations under this Agreement due to Force Majeure, other than the obligation to make payments due hereunder, and the party affected promptly notifies the other of such delay, then all obligations that are affected by Force Majeure will be suspended or reduced for the period of Force Majeure and for such additional time as is required to resume the performance of its obligations, and the delivery schedule will be adjusted to account for the delay.

(c) Option to Terminate. If the period of suspension or reduction of operations will extend for more than four (4) consecutive months or periods of suspension or reduction total more than 6 months in any 12 month period, then either Buyer or Seller may terminate this Agreement.

15. INDEMNIFICATION AND INSURANCE

(a) Indemnification. Seller agrees to defend and indemnify Buyer from and against any third-party claim for bodily injury or damage to tangible property ("Loss") arising in connection with the Products provided by Seller hereunder, but only to the extent such Loss has been caused by the negligence, wilful misconduct or other legal fault ("Fault") of Seller. Buyer shall promptly tender the defense of any such third-party claim to Seller. Seller shall be entitled to control the defence and resolution of such claim, provided that Buyer shall be entitled to be represented in the matter by counsel of its choosing at Buyer's sole expense. Where such Loss results from the Fault of both Seller and Buyer or a third party, then Seller's defence and indemnity obligation shall be limited to the proportion of the Loss that Seller's Fault bears to the total Fault.

(b) Insurance. Seller shall maintain commercial general liability insurance with limits of $2,000,000 per occurrence and in the aggregate covering claims for bodily injury (including death) and physical property damage arising out of the Products. Seller shall also provide workers' compensation insurance or the like as required by the laws of the jurisdiction where the Services will be performed, and owned and non-owned auto liability insurance with limits of $1,000,000 combined single limit. Seller will provide a Certificate of Insurance certifying the existence of such coverages upon request.

16. U.S. EXPORT CONTROL

Buyer recognizes that any Products that are the subject of Agreement and originate in the U.S. remain subject to U.S. export laws and regulations even after such Products are exported from the U.S. (if applicable). Buyer certifies that such Products will not be diverted, transhipped, re-exported, or otherwise transferred in contravention of U.S. export laws and regulations. Buyer further affirms that such Products will not be used, directly or indirectly, in any application involving missile technology, nuclear proliferation, or chemical and biological weapons proliferation.

17. GENERAL

(a) Seller represents that any Products or parts thereof manufactured by Seller will be produced in compliance with all applicable federal, state and local laws applicable to their manufacture and in accordance with Seller's engineering standards. Seller shall not be liable for failure of the Products to comply with any other specifications, standards, laws or regulations.

(b) This Agreement shall inure only to the benefit of Buyer and Seller and their respective successors and assigns. Any assignment of this Agreement or any of the rights or obligations hereunder, by either party without the written consent of the other party shall be void.

(c) This Agreement contains the entire and only agreement between the parties with respect to the subject matter hereof and supersedes all prior oral and written understandings between Buyer and Seller concerning the Products and any prior course of dealings or usage of the trade not expressly incorporated herein.

(d) This Agreement may be modified, supplemented or amended only by a writing signed by an authorized representative of Seller. Seller's waiver of any breach by Buyer of any terms of this Agreement must also be in writing and any waiver by Seller or failure by Seller to enforce any of the terms and conditions of this Agreement at any time, shall not affect, limit or waive Seller's right thereafter to enforce and compel strict compliance with every term and condition hereof.

(e) All terms of this Agreement which by their nature should apply after the cancellation, completion or termination of this Agreement, including, but not limited to, Paragraphs 4, 12, 16 and 17, shall survive and remain fully enforceable after any cancellation, completion or termination hereof.

(f)(i) If Seller's office is located in the United States, this Agreement and the performance hereof will be governed by and construed according to the laws of the State of Georgia.

(ii) If Seller's office is located in Canada, this Agreement and the performance hereof will be governed by and construed according to the laws of the Province of New Brunswick...

(g) (i) In the circumstances of f(i) above, any controversy or claim arising out of or relating to this Agreement, or the breach hereof, or to the Products provided pursuant hereto, shall be definitively settled by arbitration, to the exclusion of courts of law, administered by the American Arbitration Association ("AAA") in accordance with its Construction Industry Arbitration Rules in force at the time this Agreement is signed and to which the parties declare they will adhere (the "AAA Rules"), and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction over the party against whom enforcement is sought or having jurisdiction over any of such party's assets. The arbitration shall be conducted in Atlanta, Georgia by a panel of three members, one of whom will be appointed by each of Buyer and Seller and the third of whom will be the chairman of the panel and will be appointed by mutual agreement of the two party appointed arbitrators. All arbitrators must be persons who are not employees, agents, or former employees or agents of either party. In the event of failure of the two party appointed arbitrators to agree within 45 days after submission of the dispute to arbitration upon the appointment of the third arbitrator, the third arbitrator will be appointed by the AAA in accordance with the AAA Rules. In the event that either of Buyer or Seller fails to appoint an arbitrator within 30 days after submission of the dispute to arbitration, such arbitrator, as well as the third arbitrator, will be appointed by the AAA in accordance with the AAA Rules.

(ii) In the circumstances of f(ii) above, any controversy or claim arising out of or relating to this Agreement, or the breach hereof, or to the Products provided pursuant hereto, shall be definitively settled under the auspices of the Canadian Commercial Arbitration Centre ("CCAC"), by means of arbitration and to the exclusion of courts of law, in accordance with its General Commercial Arbitration Rules in force at the time the Agreement is signed and to which the parties declare they will adhere (the "CCAC Rules"), and judgment on the award rendered by the arbitrator(s) may be entered in any court having jurisdiction over the party against whom enforcement is sought or having jurisdiction over any of such party's assets. The arbitration shall be conducted in Saint John, New Brunswick by a panel of three arbitrators, one of whom will be appointed by each of Buyer and Seller and the third of whom will be the chairman of the arbitral tribunal and will be appointed by mutual agreement of the two party appointed arbitrators. All arbitrators must be persons who are not employees, agents, or former employees or agents of either party. In the event of failure of the two party appointed arbitrators to agree within 45 days after submission of the dispute to arbitration upon the appointment of the third arbitrator, the third arbitrator will be appointed by the CCAC in accordance with the CCAC Rules. In the event that either of Buyer or Seller fails to appoint an arbitrator within 30 days after submission of the dispute to arbitration, such arbitrator, as well as the third arbitrator, will be appointed by the CCAC in accordance with the CCAC Rules.

(h) In the event this Agreement pertains to the sale of any goods outside the United States or Canada, the parties agree that the United Nations Convention for the International Sale of Goods shall not apply to this Agreement.

(i)The parties hereto have required that this Agreement be drawn up in English. Feb. 2019

6.5 Field Service Rates for Erection Consultant, Start-Up Assistance, Training, Repair & Maintenance, and Engineering Services

Andritz, Inc. ("ANDRITZ") shall furnish all field services in an advisory capacity on a time and expenses basis in accordance with the terms specified below. ANDRITZ will make available the services of personnel for temporary duty in the field to provide advisory assistance for (1) erection consultation, (2) plant or equipment start-up, (3) operator training, (4) repair, maintenance or trouble-shooting of equipment and systems provided by ANDRITZ, and (5) engineering. Availability of qualified personnel is at times subject to prior commitment, and service requests will only be processed upon receipt of a written agreement.

Fees: (Rates are valid through 2024 and are given in US Dollars)

Personnel Classification	Daily Rate	Premium Hourly Rate A	Premium Hourly Rate B
Erection Consultant	$1902.00	$356.63 per hour	$475.50 per hour
Start-Up Assistant	$1902.00	$356.63 per hour	$475.50 per hour
Training Assistant	$2949.00	$552.94 per hour	$737.25 per hour
Repair & Maintenance	$1902.00	$356.63 per hour	$475.50 per hour
Engineering Services	$2547.00	$477.56 per hour	$636.75 per hour
Andritz Sub-Vendors	Actual + 25%	Actual + 25%	Actual + 25%

A. Service rates above are for domestic service
B. The daily rate shall be charged for each calendar day or fraction thereof that ANDRITZ's personnel leaves his basing point up to and including the hour of his return to his basing point, and while personnel remain on standby for the Purchaser.
C. Premium Rate A will apply for all time exceeding 8 hours per weekday (other than Sunday) and for all time on Saturdays.
D. Premium Rate B will apply for work performed on Sundays and holidays
E. Travel time and layover time are cumulative with work time for purposes of determining overtime.
F. For safety, the maximum standard service to be provided per employee is 12 hours per day and 84 hours per week.
G. Time required for report preparation will be invoiced on a straight time basis.
H. Expenses in connection with preparation of ANDRITZ's personnel for departure (passport, visa, medical, etc.) will be charged at cost plus ten percent.

Travel Expense:

A. Travel expense from point of origin to the site of the field work and return, will be billed at cost plus ten percent.
B. All travel time, from point of origin to the site of the field work and return, will be billed in accordance with the Fee schedule. ANDRITZ personnel home travel and shift patterns are on a three weekly cycle; sub-vendor shifts and travel will reflect specific vendor terms
C. Private or company car mileage will be billed at prevailing rate per mile (currently $ 0.55) plus ten percent.

D. Air travel, rental cars, or other transportation expenses will be documented by carrier's receipt.
E. Air travel will be economy class (if available) for travel within North America. International travel will be business class.

Living Expenses:

Living Expenses:

A. Unless provided by Purchaser, a charge per the US Government per diem rate for the project location will be made to cover meals, laundry, tips and other normal living expenses for each day an ANDRITZ personnel is away from their home base.
B. Lodging expenses will be billed at cost plus ten percent, documented by a receipt.
C. If living expenses, including lodging and local transportation, are provided completely and directly by Purchaser, a charge of $ 43.00 per day will be made to cover out of pocket miscellaneous expenses.
D. For foreign assignments, lodging and local travel are to be arranged by Purchaser at Purchaser's expense.
E. Any other costs incurred by ANDRITZ representative, due to special requests or requirements at the jobsite, are to be reimbursed by the Purchaser at cost plus ten percent, with such costs documented via receipts.

Payments:

A. Payments for the services of ANDRITZ personnel shall be made in U.S. Dollars
B. Invoices for Fees and expenses will be submitted monthly with payment due net 30 days.
C. All rates shown above are valid through 2020.
D. Fees beyond 2024 will be billed at the rates prevailing at the time services are rendered.

Additional Provisions - General

- General Definitions (to be adjusted to the final contract wording to the extent required)
- **Technical Supervisors** shall mean the technical personnel of the Supplier performing the Technical Supervisory Services described in the table on page 1 of this document, above.
- **Erection Site** shall mean the premises dedicated by the Purchaser for the installation of the Plant in accordance with this Contract.
- **Installation Contractor or Installation Contractors** shall mean those companies contracted by the Purchaser for the mechanical and electrical installation of the Plant and all other goods provided by the Purchaser or third parties.
- **Installation Work** shall mean the installation work of the Plant to be performed by the Installation Contractor(s).
- **Parties**: Purchaser and Supplier
- **Plant** shall mean the goods, materials and equipment as delivered by the Supplier to the Purchaser under this Contract
- **Purchaser** shall mean the company acting as the contractual counter-part of the Supplier under this Contract.
- **Supplier** shall mean the company contracted by the Purchaser under this contract to deliver the Plant to the Purchaser (i.e. Andritz AG, Andritz Oy, Andritz (China Ltd., etc.).

- **Technical Supervisory Services** shall mean the services provided by the Supplier in line with this Contract and in particular this Annex.

The Supplier shall provide the Technical Supervisory Services for the Plant as detailed herewith

The Supplier's Technical Supervisors shall be responsible for giving advice on the planning, organizing and performance of the Installation Work for the installation of the Plant; the installation itself is being performed by the Purchaser's Installation Contractor(s).

In this connection, the Technical Supervisors shall perform the following tasks:

1. To be the Supplier's representative to advise on the Installation Work of the Plant as well as auxiliary systems engineered by the Supplier, taking into account, however, the obligations of the Purchaser in terms of equipment delivered by other suppliers or contractors than the Supplier. Regardless of the foregoing, the Supervisor shall not be responsible for supervision of any health and safety related issues of any party under the Purchaser's responsibility.
2. To assist the Purchaser respectively the Purchaser’s Installation Contractors in planning and scheduling the sequence of the Installation Work of the Plant.
3. Spot check on random basis the timely execution as well as the correctness and quality of the Installation Work related to the Plant.
4. Spot check on random basis the Plant at arrival on the Erection Site. Check is limited to a visual inspection of completeness against shipping documents and visible defects and transportation damages.
5. Spot check on random basis if the Plant is correctly installed, tested and commissioned according to the documents submitted by the Contractor.
6. On spot check on random basis of the quality of the Installation Work of the Plant.

The Purchaser will select and pay the Installation Contractors under separate agreements. The Purchaser is responsible for its Installation Contractor’s ability to carry out the Installation Work and the Purchaser will undertake to cause these Installation Contractors to furnish in time the necessary human and material resources of sufficient quality and skills as required for the performance of the Installation Work. If the Supplier reasonably believes that one or more of the selected Installation Contractors is not sufficiently manned and/or experienced to perform the Installation Works in the required quality and time, the Supplier must immediately notify the Purchaser. The Purchaser shall be responsible for the overall time schedule, and, should the circumstances so require, the Purchaser shall take actions to replace such Installation Contractors in due time with new ones to secure the time schedule.

In connection with rendering services of the Technical Supervisors as specified herein, the responsibility of the Supplier shall include the correctness and completeness of the advice given by the Technical Supervisors as well as to the inspection of the Installation Work performed by the Purchaser's Installation Contractor to establish that such Installation Work has been completed in accordance with the advice given. Should the
advice of the Technical Supervisors not be complied with, the Supplier shall alert the non-compliance to the Purchaser without delay, which shall constitute the Supplier’s sole obligation and liability in respect to this matter.

In the above described manner, the Technical Supervisors shall have the responsibility for taking into account the time schedule and report to the Purchaser delays or threatening delays in the progress of Installation Work by the Purchaser's Installation Contractor(s)

Limitations of Supplier’s responsibilities

The Supplier shall in no event be liable for:

- any non-compliance with time schedules by the Purchaser's Installation Contractor
- any delay in completion of the Installation Work or any subsequent tasks as specified herein as forming part of the Technical Supervisory Services, unless the Supplier has acted in gross negligence or willful misconduct in its position as Technical Supervisor
- any non-compliance with or deviation from drawings, specifications or Technical Supervisor's advice on the part of Purchasers Installation Contractor unless such non-compliance is specifically observed by Suppliers Technical Supervisors and not timely reported to Purchaser
- -
- any performance or liability excluded from the Suppliers liability through limitations of liability or other provisions in the Contract
- Technical Supervisors shall only be liable for the accuracy of instructions and advice provided

If the installation time schedule is in the end in delay for reasons not solely attributable to the Supplier, the Supplier undertakes to keep its Technical Supervisory team at the Erection Site for an additional time period to be agreed between the Parties against compensation as specified in Annex hereto.
However, if the installation time schedule is at the end in delay due to reasons solely attributable to the Supplier in accordance with the Contract, the Supplier shall be obliged to remain at Erection Site until the Technical Supervisory Services are completed.
If a delay in the installation time schedule is partly caused by the Supplier and the Purchaser including the Installation Contractor, the Parties shall agree on a reasonable compensation of the Supplier for any extended Technical Supervisory Services which may be needed to complete the Installation works.
The Technical Supervisory Services of the Installation Work of the Plant shall be deemed completed when the installation inspection has been completed and approved in writing by the authorized representatives of the Parties.

Description of Technical Supervisory Services:

The Technical Supervisors' responsibilities related to the various phase of Installation Work (as applicable to the scope of services procured by Purchaser) are:

Installation Period

Provide advice concerning the technical content of installation drawings and other technical documents to assist the proper installation of Plant during the installation phase.
Advise on the sequencing for proper technical assembly and installation of the equipment.
Observe the Installation Work being carried out by the Installation Contractor(s) and provide feedback to the Purchaser concerning the work.
Review and provide recommendations based upon the quality control documents provided by the Installation Contractor concerning the Plant installed during the installation.

Installation Check-Out - Completion

Provide advice concerning the technical content of installation drawings and other technical documents to assist the checking of the installation of Plant during the check-out phase.

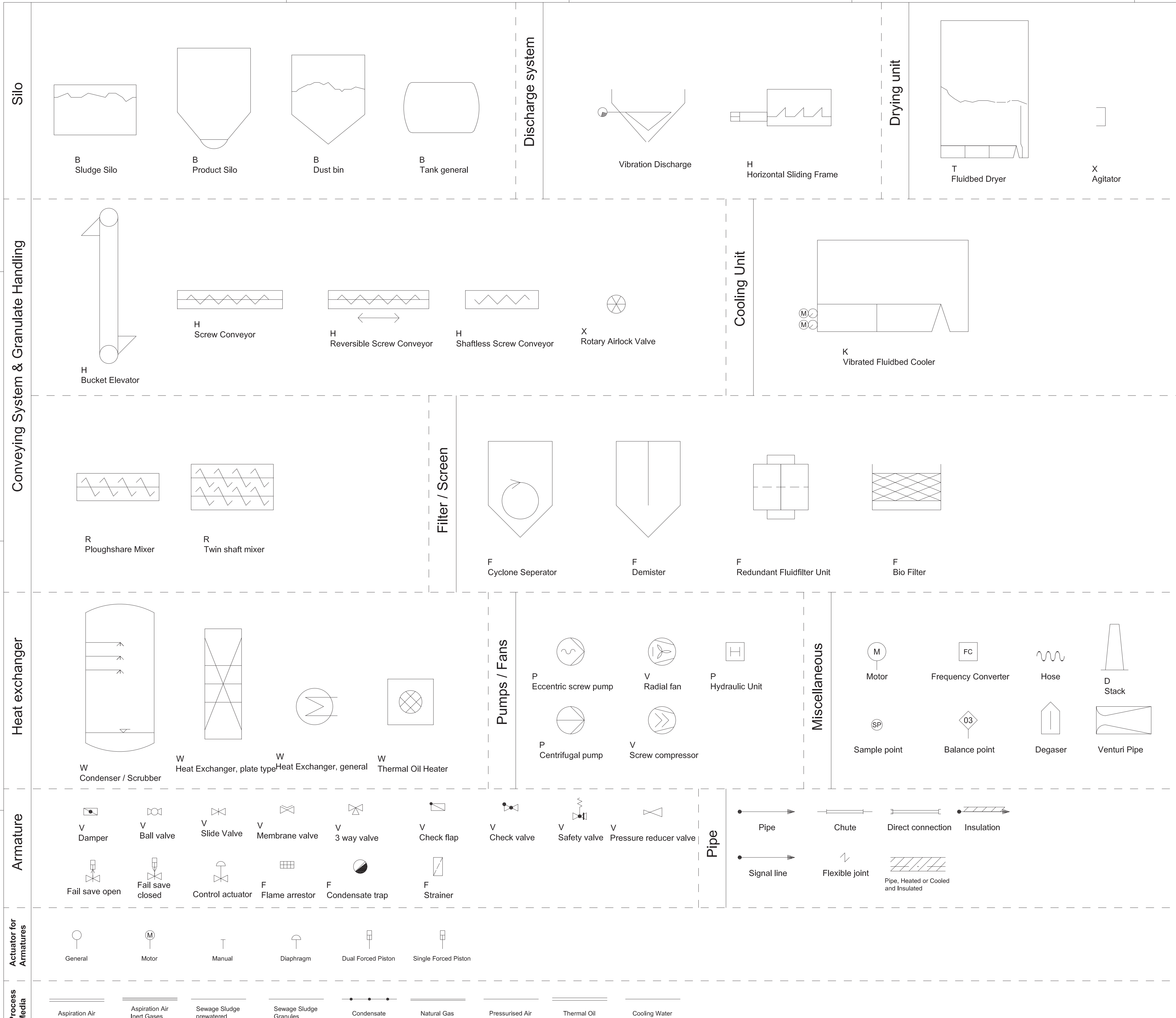
Observe the check-out work being carried out by the Installation Contractor(s) and provide feedback to the Plant concerning the Installation Work.
Review and provide recommendations based upon the quality control documents provided by the Installation Contractor(s) concerning Plant installed during the check-out of the installation.

General obligations and authority of Suppliers Technical Supervisors

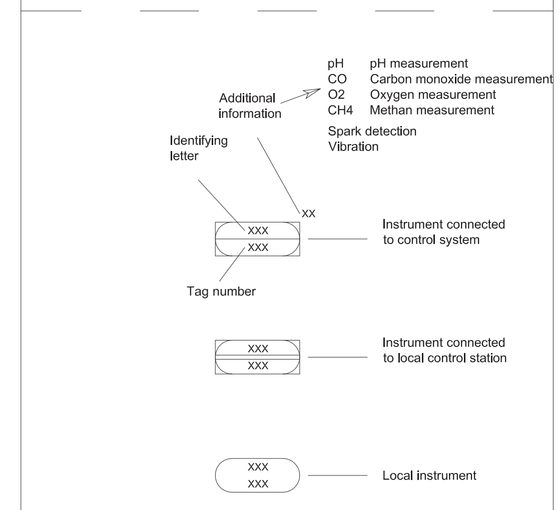
- The Technical Supervisors shall comply at the Erection Site with all of the safety rules and regulations applicable at the Erection Site.
- Interface with other parties at the Erection Site according to the requirements of the Contract.
- Technical Supervisory Services do not include:
    - give direct orders or instructions to, directly supervise, or manage in any other manner, any employee of the Purchaser's Installation Contractors
    - request any employee of the Purchaser's Installation Contractor to perform work on behalf of Supplier without the expressed approval of the Purchasers responsibility for the time schedule (program) of the on-site activities
    - perform any mechanical or electrical work for the Purchaser's Installation Contractor or the Purchaser
        - construction/installation management
        - progress monitoring
        - quantity monitoring
        - quality monitoring and control

8 P&I Drawings

The P&I drawings attached are indicative only, and have been modified to reflect the project intent at South Plant,



Instruments



Identifying letter	Group 1 Measured variable or other input variable, correcting element — as first letter	as modifier	Group 2 Processing as succeeding letter
A			Fault signal
B			
C	Control	Control	Control
D	Density	Difference	
E	Electrical variables		Recorder function
F	Flow, troughput	Ratio	
G	Clearence, length, position, expansion, amplitude		
H	Manual input, manual intervention		Upper limiting value (high)
I			Indication
J		Measuring point interrogation	
K	Time		
L	Level (including of separating layer)		Lower limiting value (low)
M	Humidity		
N			
O	Automatic		Visual signal, yes/no indication (no fault signal)
P	Pressure		
Q	Property of substance, quality variables, analysis	Integral, sum	
R	Radiation variable		Registration
S	Speed, rotational speed, frequency		Switching, sequential control, logic control
T	Temperature		Transducer function
U	Assembled variables		Combined drive function
V	Viscosity		Correcting unit function
W	Weight, mass		
X	Interface, vibration		
Y			Computing function
Z			Emergency intervention, protection by release, protection device safety signal
+			Upper limiting value
/			Intermediate value
-			Lower limiting value

DEFINITIONS OF 8-3.1-012X-10-NO PIPE IS:
- 8 - NOMINAL DIAMETER 8 mm
- 3.1 - WALL THICKNESS IN mm
- 012X - PIPE NUMBERING
- CS - CARBON STEEL
- 10 - NOMINAL PRESSURE IN BAR
- NO PIPE - CHUTE OR TUBE (FLEXIBLE CONNECTION)

DUCTING: EXAMPLE - 125-3.9-04 12-SS-10-21:
- 125 - NOMINAL DIAMETER
- 3.9 - CODE NUMBER FOR EXHAUST GAS
- 0412 - PIPE NUMBER
- SS - STAINLESS STEEL
- 10 - 10 BARS
- 21 - THIN WALL PIPE

SYMBOLS CREATED ACCORDING TO DIN EN ISO 10628 AND DIN 19227-1

PRELIMINARY ONLY – NOT FOR DESIGN

ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: BB DATE: 12/7/12
CHECKED BY: ATTI DATE: 12/7/12
APPROVED BY: ATTI DATE: 1/25/13
SCALE: NONE FILE: 1621323001
SIZE: FDS

JOB NAME: SYNAGRO
TITLE: PROCESS FLOW DIAGRAM
PROJECT NUMBER: 1621323
DRAWING NUMBER: 300012001 REV: A
SHEET 1 OF 1

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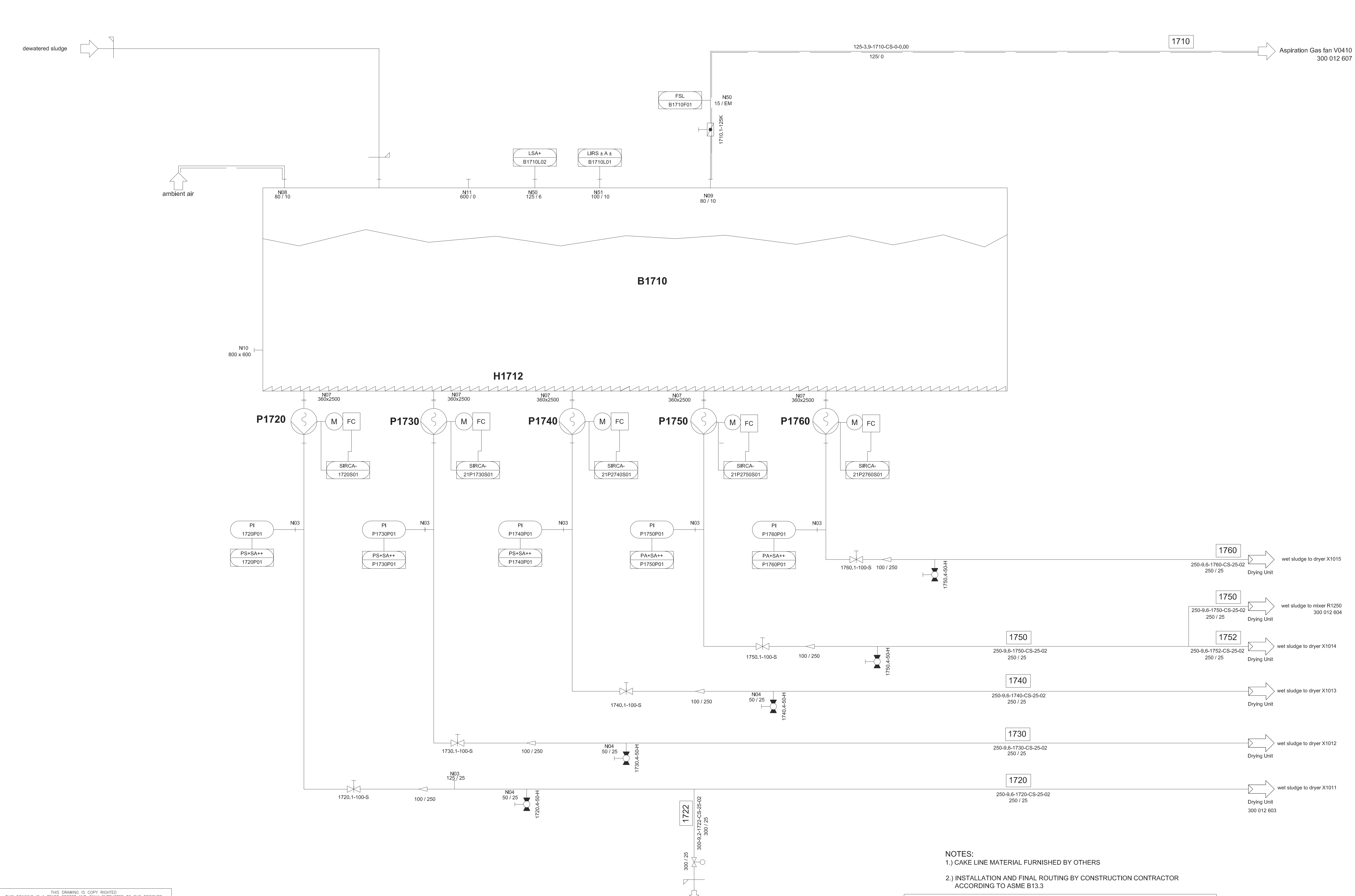

NOTES:
1.) CAKE LINE MATERIAL FURNISHED BY OTHERS

2.) INSTALLATION AND FINAL ROUTING BY CONSTRUCTION CONTRACTOR ACCORDING TO ASME B13.3

PRELIMINARY ONLY – NOT FOR DESIGN

ANDRITZ

ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY: BB | DATE: 4/25/13
CHECKED BY: ATTI | DATE: 4/25/13
APPROVED BY: ATTI | DATE: 4/25/13
SCALE: NONE | FILE: 1621323602

FDS

JOB NAME: SYNAGRO
TITLE: SLUDGE STORAGE FLOW DIAGRAM

PROJECT NUMBER: 1621323
DRAWING NUMBER: 300012602 REV A
SHEET 1 OF 1

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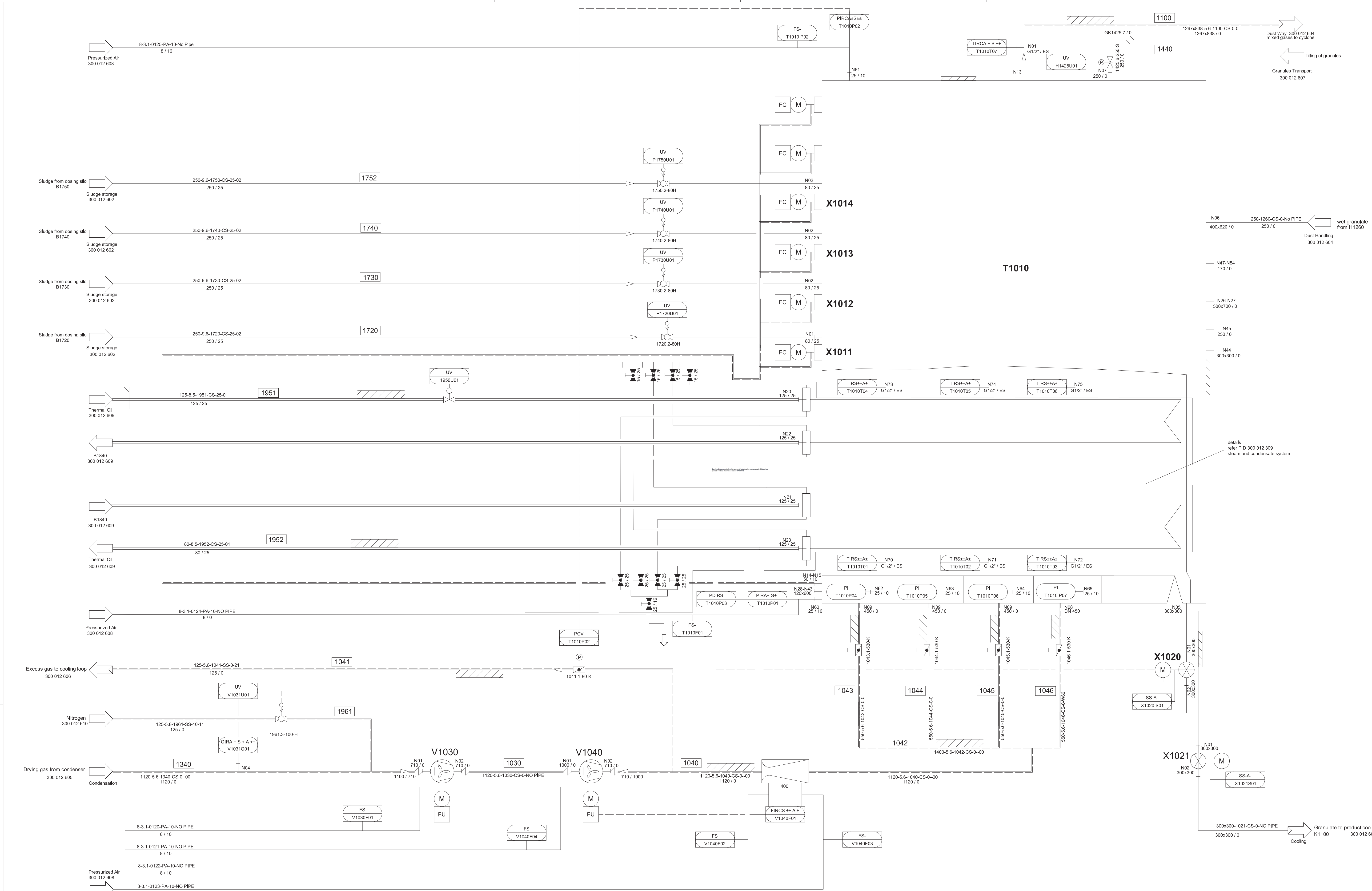

PRELIMINARY ONLY – NOT FOR DESIGN

ANDRITZ
ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

DRAWN BY:	BB
DATE:	4/25/13
CHECKED BY:	
DATE:	4/25/13
APPROVED BY:	
DATE:	4/25/13
SCALE:	NONE
FILE	1621323603
JOB NAME	SYNAGRO
TITLE	DRYING FLOW DIAGRAM
SIZE	FDS
PROJECT NUMBER	1621323
DRAWING NUMBER	300012603
REV	A
SHEET	1 OF 1

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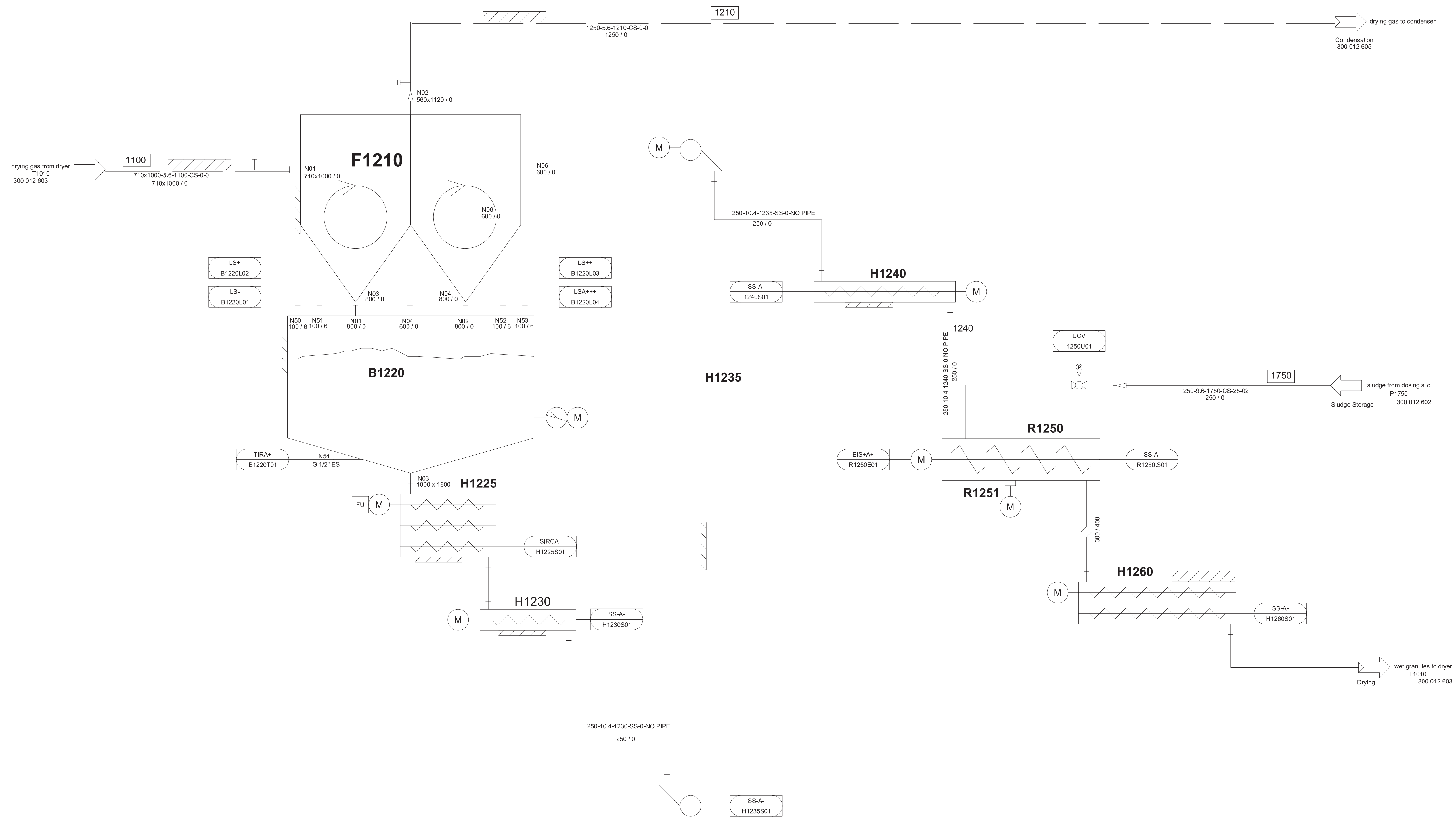

NOTES:
1.) DUCT MATERIAL FURNISHED IN BULK BY ANDRITZ FOR FIELD INSTALLATION BY OTHER.

PRELIMINARY ONLY – NOT FOR DESIGN

ANDRITZ SEPARATION, INC.
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611

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APPROVED BY: ATT	DATE: 4/25/13
SCALE: NONE	FILE: 1621323 604
SIZE	FDS

REV	REVISION	DATE

JOB NAME: SYNAGRO

TITLE: DUST HANDLING FLOW DIAGRAM

PROJECT NUMBER: 1621323

DRAWING NUMBER: 300012604 REV: A

SHEET 1 OF 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE

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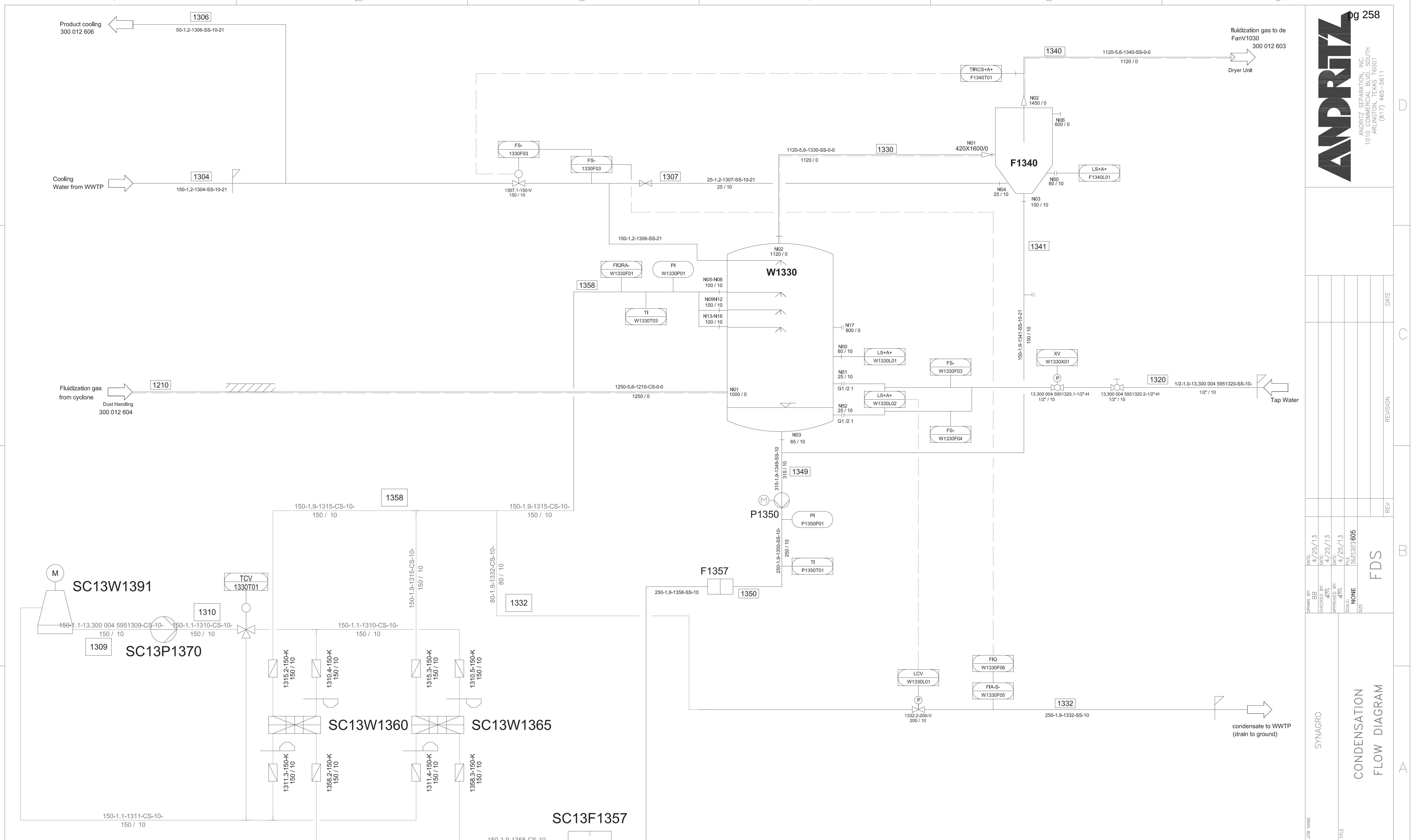
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Cooling
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1330F03
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fluidization gas to de
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Dryer Unit
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100 / 10
N13-N16
100 / 10
N17
800 / 0
N50
80 / 10
LS+A+
W1330L01
FS-
W1330F03
XV
W1330X01
Fluidization gas
from cyclone
Dust Handling
300 012 604
1210
1250-5,6-1210-CS-0-0
1250 / 0
N01
1000 / 0
N51
25 / 10
G1 /2 1
LS+A+
W1330L02
N52
25 / 10
G1 /2 1
FS-
W1330F04
13.300 004 5951320.1-1/2"-H
1/2" / 10
13.300 004 5951320.2-1/2"-H
1/2" / 10
1320
1/2-1,0-13,300 004 5951320-SS-10-
1/2" / 10
Tap Water
N03
65 / 10
315-1,9-1349-SS-10
315 / 10
1349
P1350
PI
P1350P01
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250 / 10
TI
P1350T01
1358
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150 / 10
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80 / 10
1332
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1350
SC13W1391
TCV
1330T01
1310
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1310.4-150-K
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1310.5-150-K
150 / 10
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SC13W1365
1311.3-150-K
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150 / 10
1311.4-150-K
150 / 10
1358.3-150-K
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150 / 10
SC13F1357
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150 / 10
1350
LCV
W1330L01
FIQ
W1330F06
FIA-S-
W1330F05
1332.2-200-V
200 / 10
1332
250-1,9-1332-SS-10
condensate to WWTP
(drain to ground)
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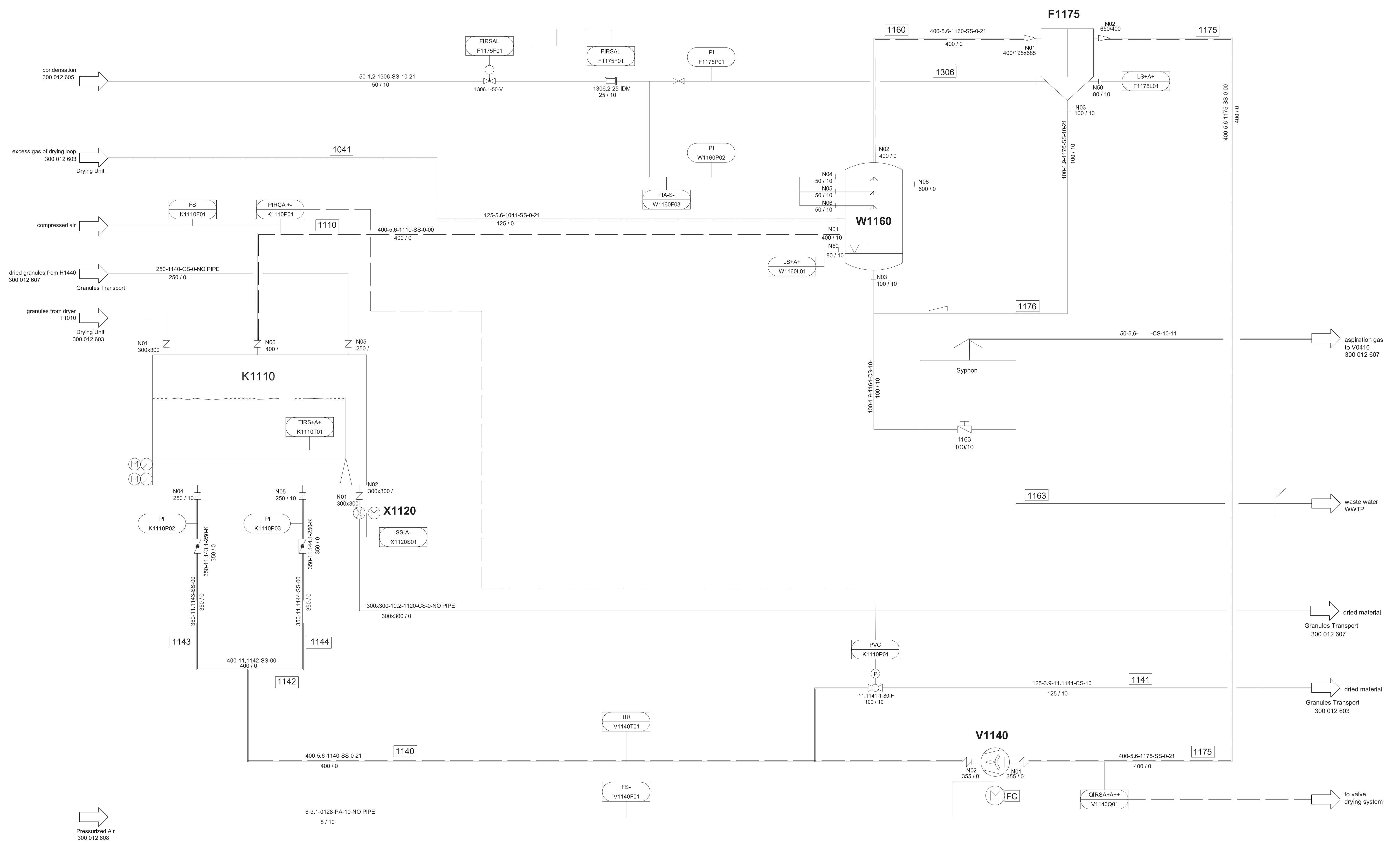
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611
DATE
REVISION
REV
DRAWN BY: BB
DATE: 4/25/13
CHECKED BY: ATM
DATE: 4/25/13
APPROVED BY: ATM
DATE: 4/25/13
SCALE: NONE
FILE: 1621323605
FDS
SYNAGRO
CONDENSATION
FLOW DIAGRAM
PROJECT NUMBER
1621323
DRAWING NUMBER
300012605
REV A
SHEET 1 OF 1



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CHECKED BY: | DATE: 4/25/13
APPROVED BY: | DATE: 4/25/13
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FILE: 1621323606
SIZE:

FDS

JOB NAME: SYNAGRO

TITLE: PRODUCT COOLING FLOW DIAGRAM

PROJECT NUMBER: 1621323
DRAWING NUMBER: 300012606
REV: A
SHEET 1 OF 1

IF THIS BAR DOES NOT MEASURE 1" THEN DRAWING IS NOT TO SCALE. 0 1"

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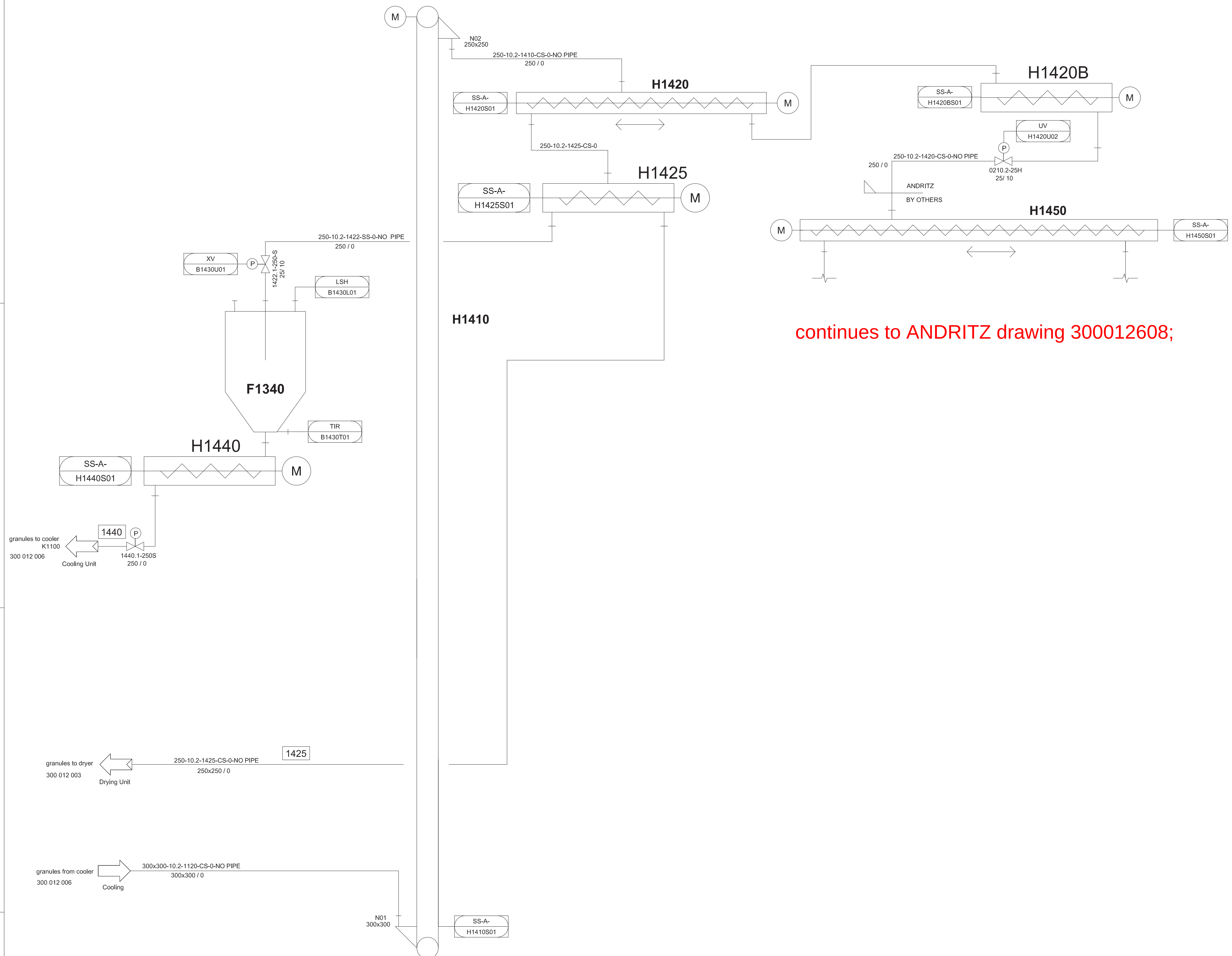
\\ARLSMS003\Arlington\01 Environment\00 Opportunities\S\Synagro\Landfill Project in PA - Dryer Inquiry\PROPOSAL\BUDGET\FBD\Drawings\PIDs\1621323 Synagro FDS.dwg



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ARLINGTON, TEXAS 76001
(817) 465-5611

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CHECKED BY: ATT	DATE: 12/7/12
APPROVED BY: ATT	DATE: 1/25/13
SCALE: NONE	FILE: 1621323607
SIZE	FDS

JOB NAME: SYNAGRO

TITLE: GRANULES TRANSPORT FLOW DIAGRAM

PROJECT NUMBER: 1621323

DRAWING NUMBER: 300012607 REV: A

SHEET 1 OF 1

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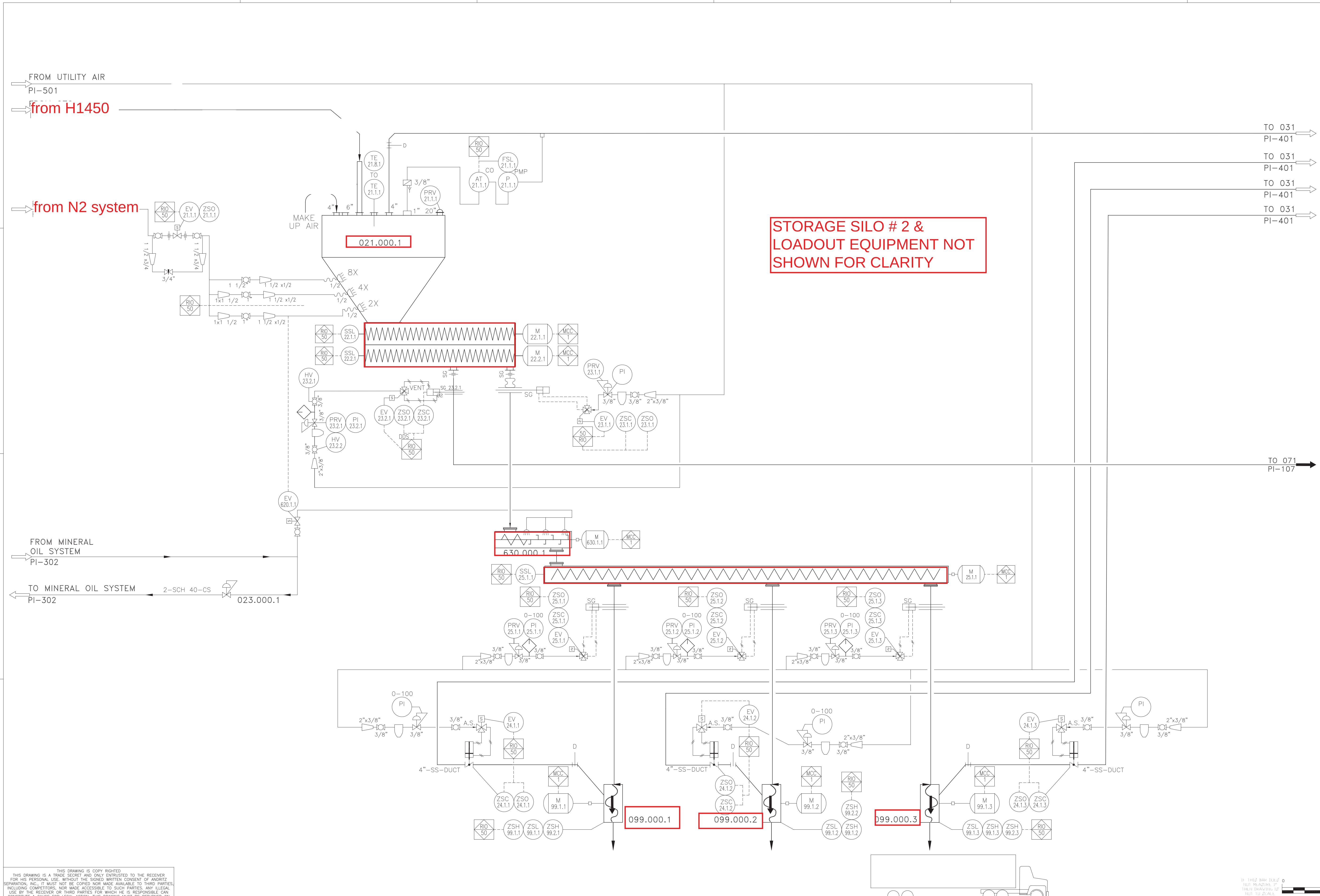
\\ARLSMS003\Arlington\01 Environment\00 Opportunities\S\Synagro\Landfill Project in PA - Dryer Inquiry\PROPOSAL\BUDGET\FBD\Drawings\PIDs\1621323 Synagro FDS.dwg



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REV	REVISION	DATE
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DRAWN BY: W.C.H. DATE: 03/08/2016
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APPROVED BY: DATE:
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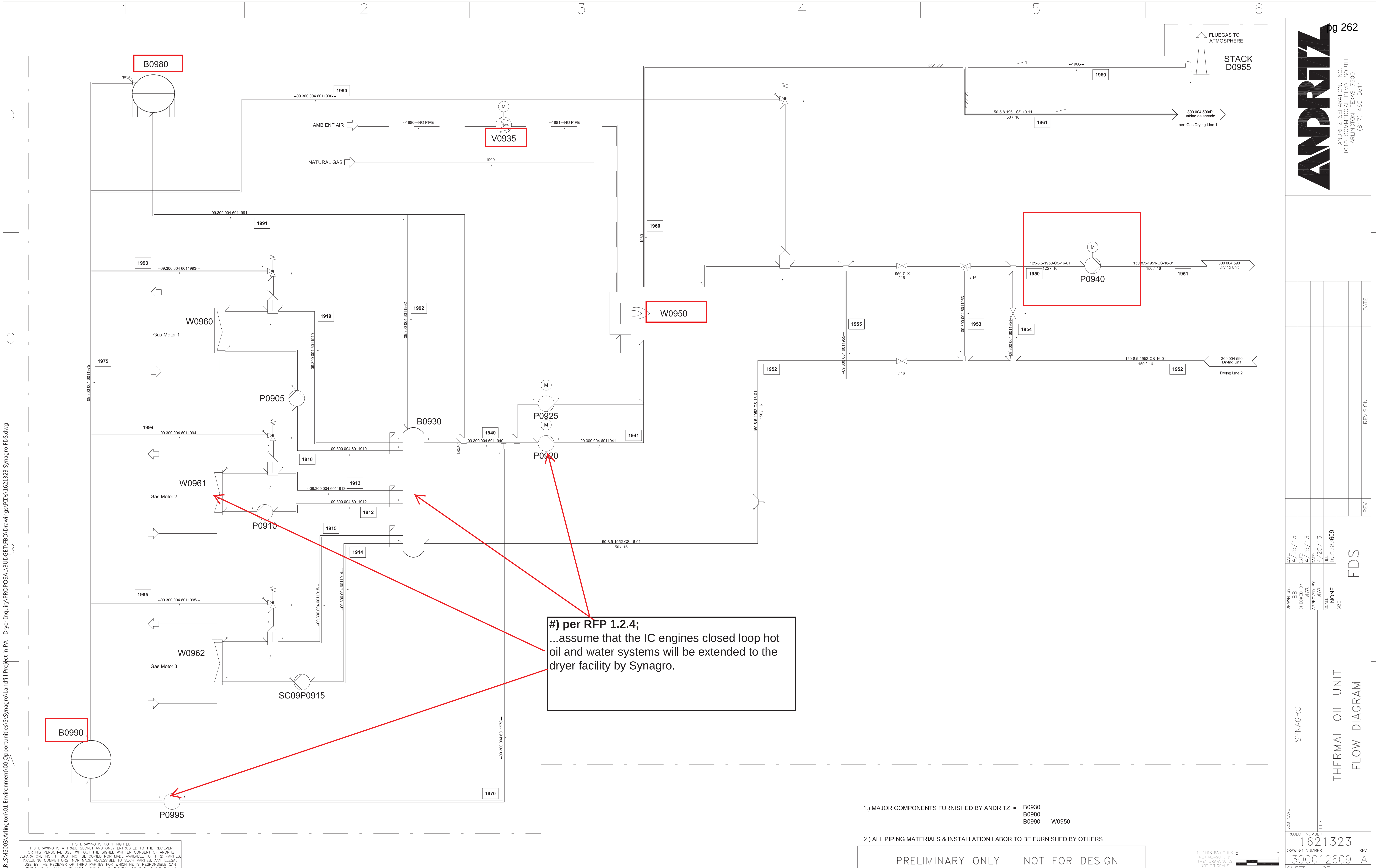
SIZE

JOB NAME
TITLE
MECHANICAL FLOW DIAGRAM
FINAL PRODUCT AND LOADING

PROJECT NUMBER 1757357
DRAWING NUMBER 300012608 REV
SHEET 1 OF 1

\\ARLSMS003\Arlington\01 Environment\00 Opportunities\H\Hamilton, ON\1757357 Hamilton, ON Dryer Team\DRAWINGS\PID\PI301.dwg, Adobe PDF


B0980
AMBIENT AIR
NATURAL GAS
V0935
FLUEGAS TO ATMOSPHERE
STACK D0955
Inert Gas Drying Line 1
W0950
P0940
Drying Unit
Drying Line 2
W0960
Gas Motor 1
P0905
B0930
P0925
P0920
W0961
Gas Motor 2
P0910
W0962
Gas Motor 3
SC09P0915
B0990
P0995
#) per RFP 1.2.4;
...assume that the IC engines closed loop hot oil and water systems will be extended to the dryer facility by Synagro.
1.) MAJOR COMPONENTS FURNISHED BY ANDRITZ = B0930 B0980 B0990 W0950
2.) ALL PIPING MATERIALS & INSTALLATION LABOR TO BE FURNISHED BY OTHERS.
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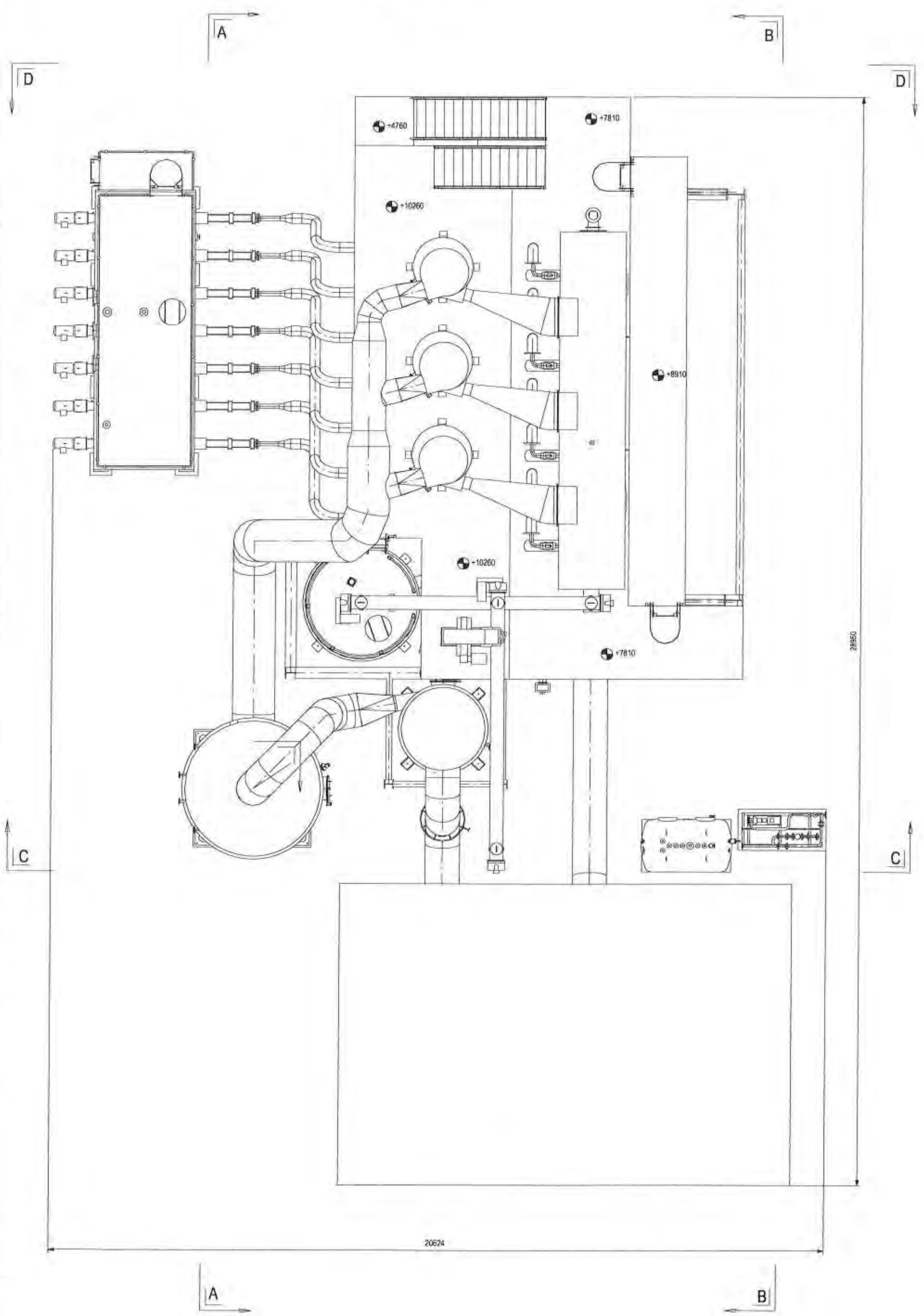
1010 COMMERCIAL BLVD. SOUTH
ARLINGTON, TEXAS 76001
(817) 465-5611
SYNAGRO
THERMAL OIL UNIT FLOW DIAGRAM
FDS
PROJECT NUMBER 1621323
DRAWING NUMBER 300012609
REV A
THIS DRAWING IS COPY RIGHTED
THIS DRAWING IS A TRADE SECRET AND ONLY ENTRUSTED TO THE RECIEVER FOR HIS PERSONAL USE, WITHOUT THE SIGNED WRITTEN CONSENT OF ANDRITZ SEPARATION, INC., IT MUST NOT BE COPIED NOR MADE AVAILABLE TO THIRD PARTIES, INCLUDING COMPETITORS, NOR MADE ACCESSIBLE TO SUCH PARTIES. ANY ILLEGAL USE BY THE RECIEVER OR THIRD PARTIES FOR WHICH HE IS RESPONSIBLE CAN CONSTITUTE A CAUSE FOR LEGAL ACTION. THIS DRAWING MUST BE RETURNED ON REQUEST OF THE COMPANY.

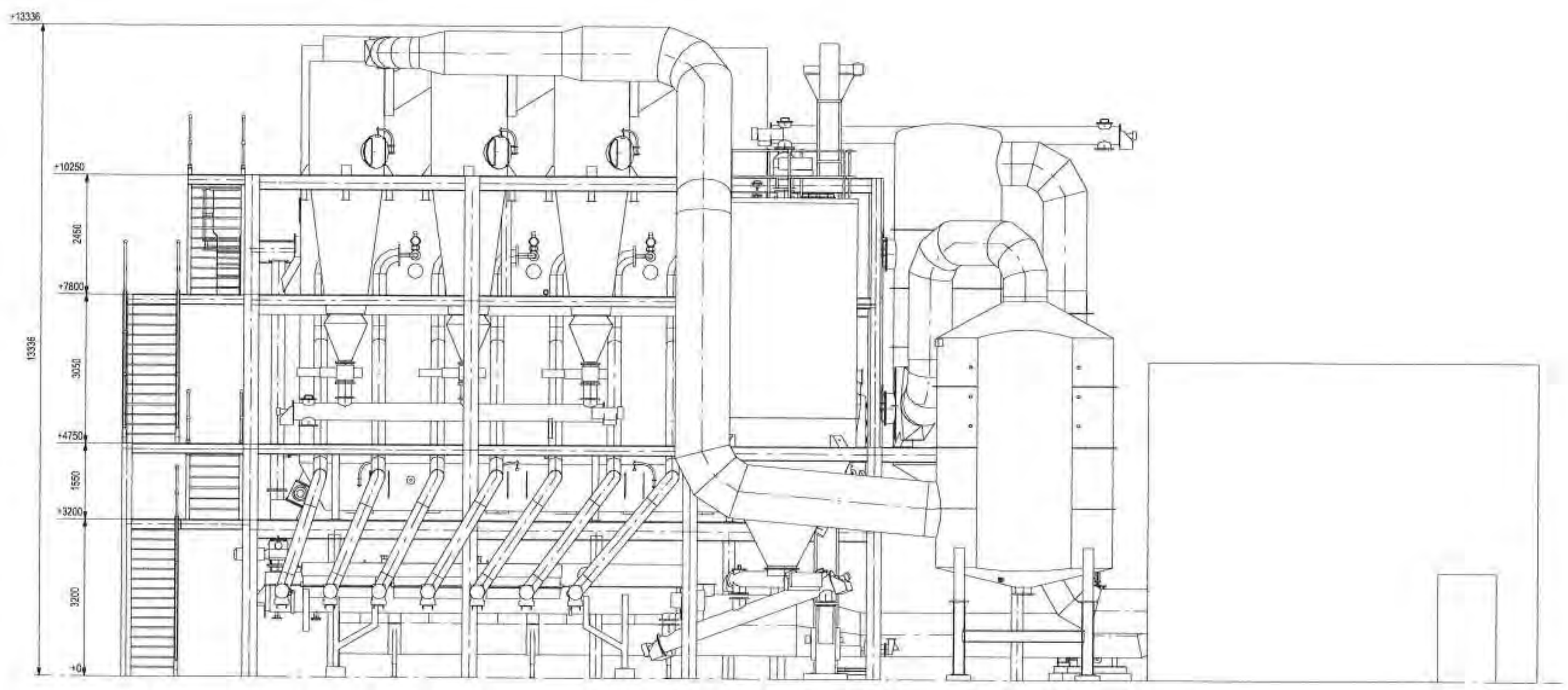
9 General Arrangement Drawings

The drawings attached are from the Bailonggang II – Shanghai project, and were used as a basis for laying out the Biosolids drying facility at South Plant,

TOP VIEW



SECTION A-A



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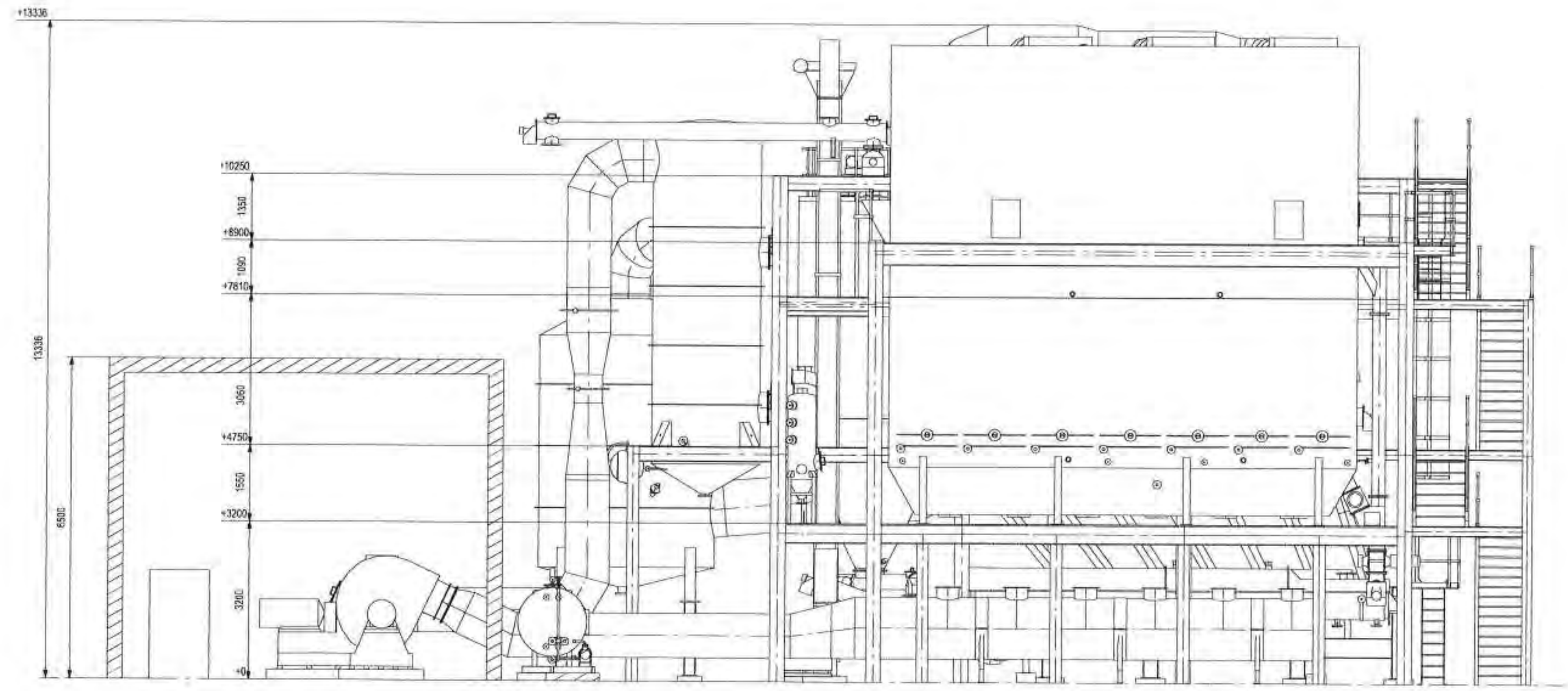

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Stand / Updated: 08.02.2017

ANDRITZ FLIESSBETT SYSTEME GmbH

Kunde/Client: Shanghai Sewage Sludge

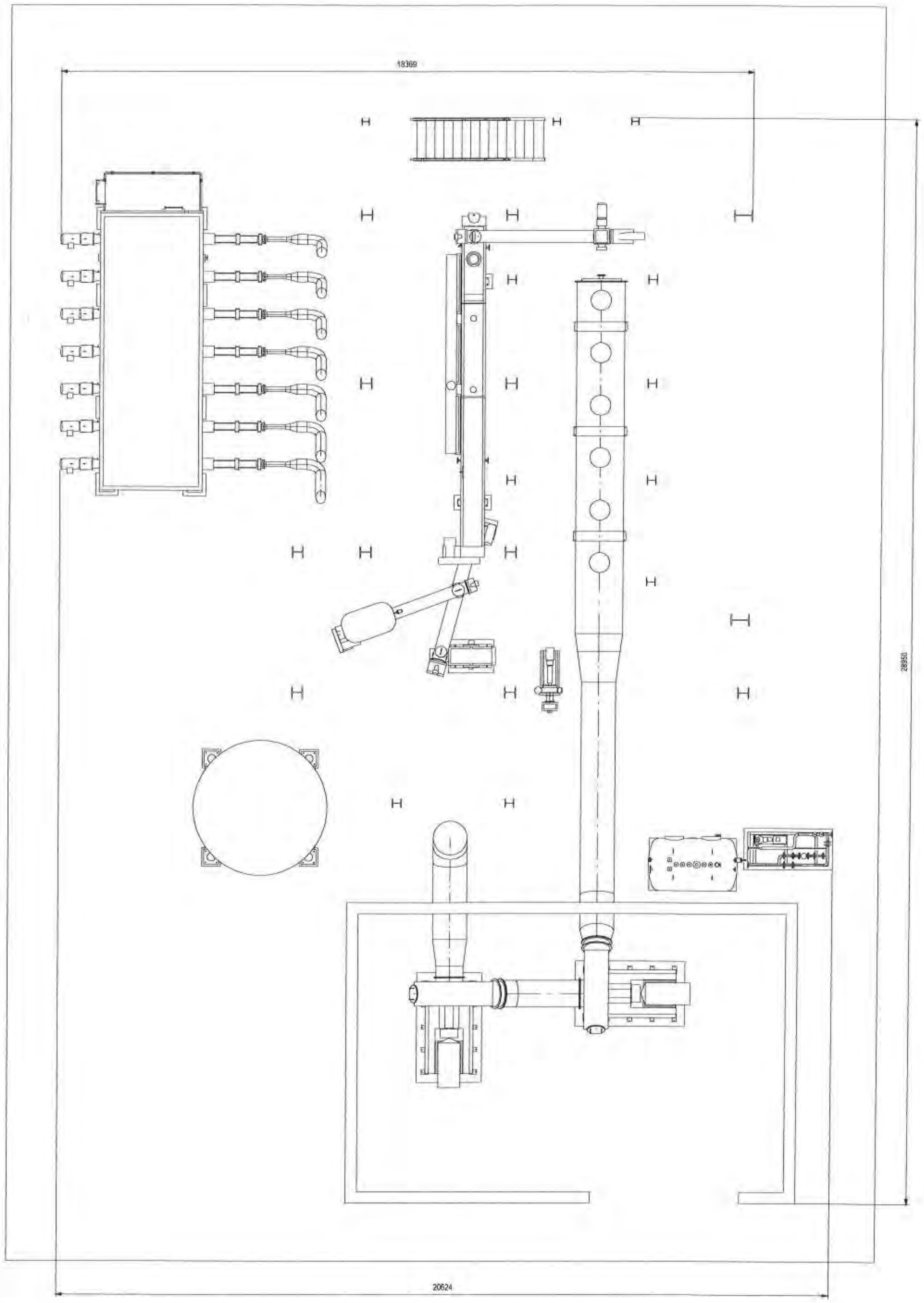
Anlage/Project: Bailonggang 2

CONCEPT LAYOUT

DRYING OF SEWAGE SLUDGE
6 LINES

1798867	507168788	A0	1:50	3/4	0

SECTION +2800



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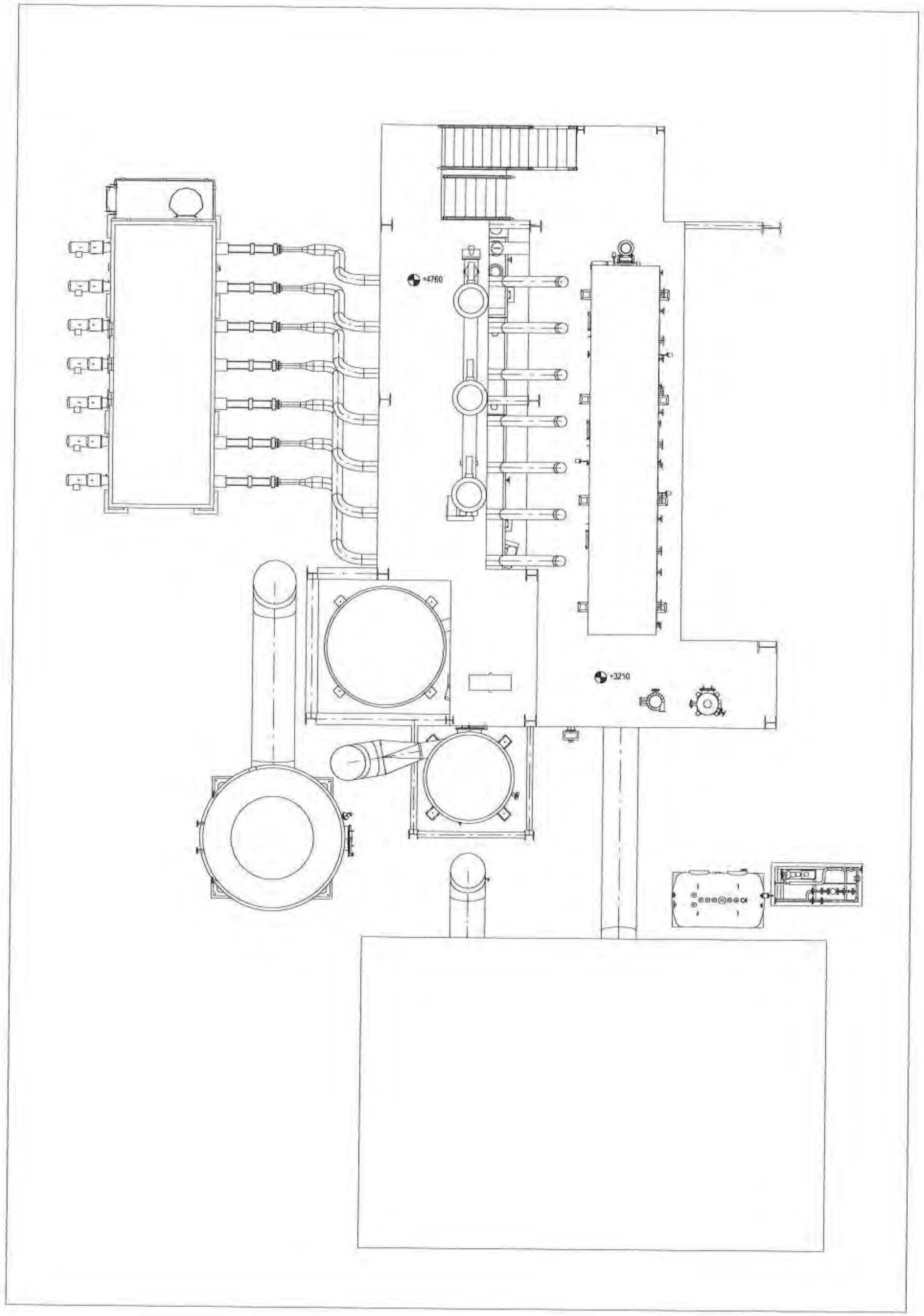

Stand/Updated	08.02.2017
	JE 08.02.2017
Kunde/Client	Shanghai Sewage Sludge
Anlage/Project	Bailonggang 2
	CONCEPT LAYOUT
	DRYING OF SEWAGE SLUDE
	6 LINES
Auftrags-Nr./Order no.	1798867
Zeichnungs-Nr./Drawing No.	507168788
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Scale	1:50
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Rev.	0

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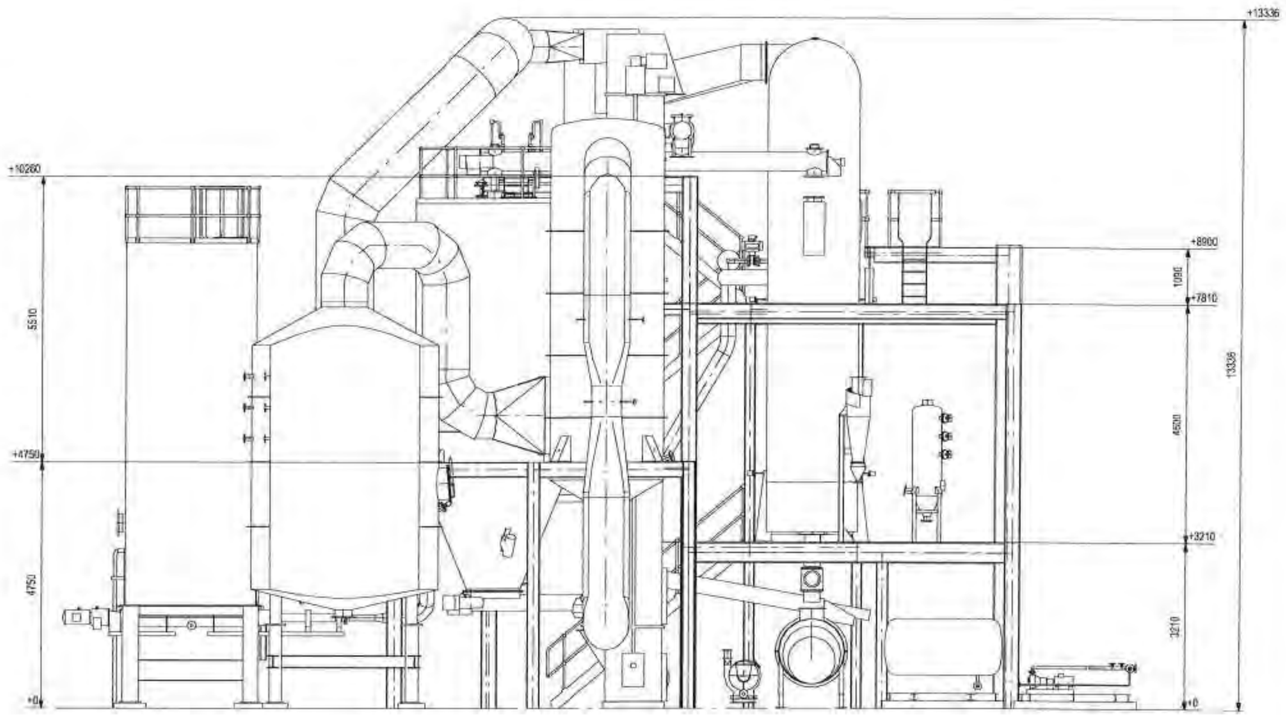
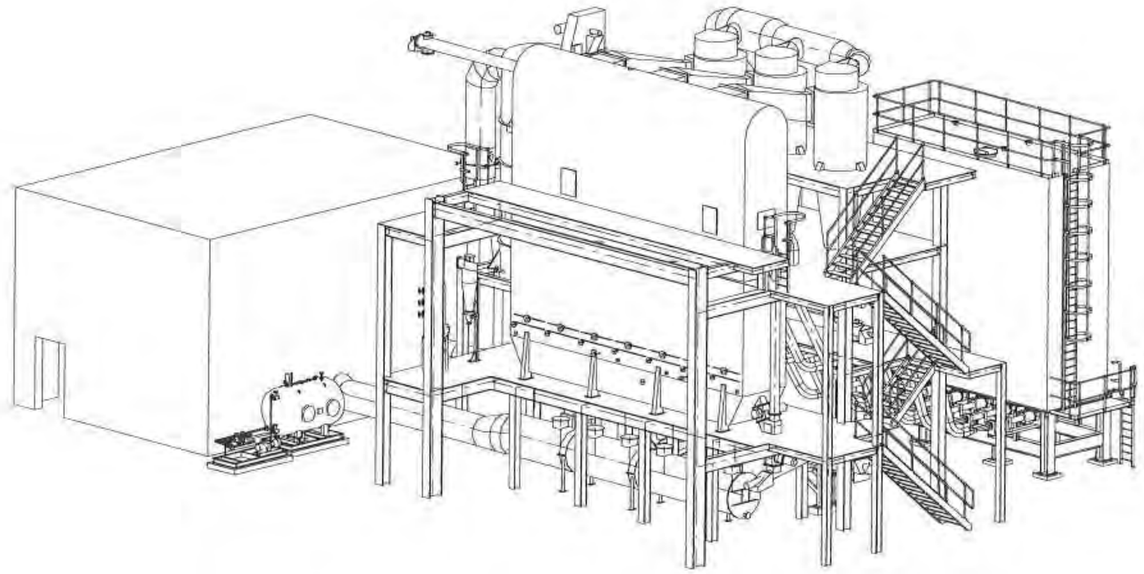
SECTION C-C





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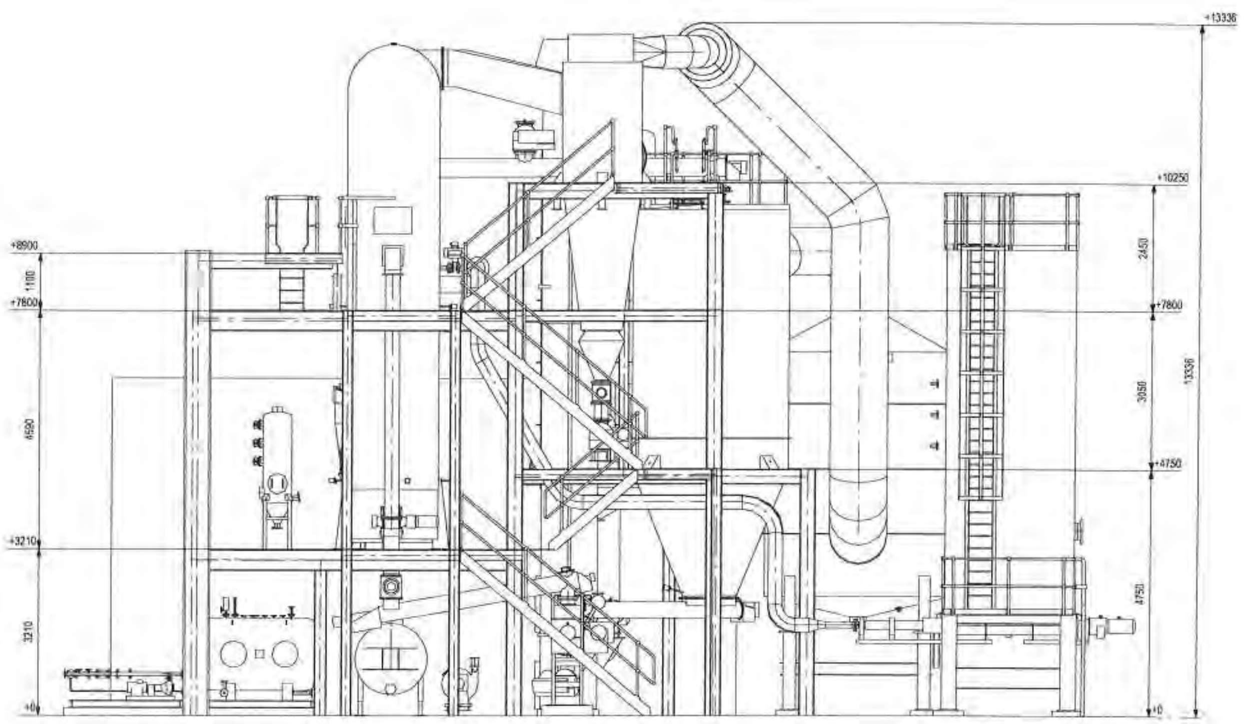

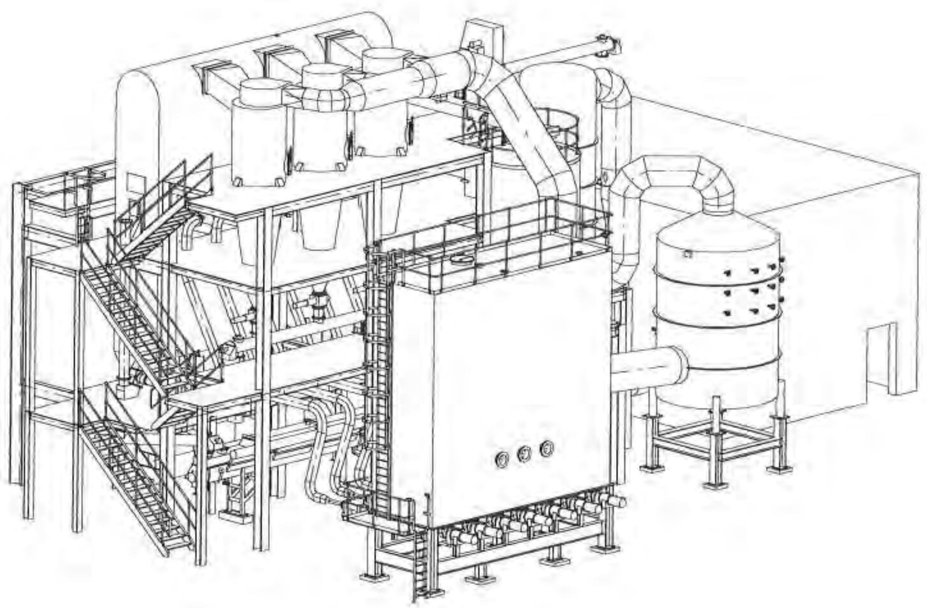

Stand/Updated: 08.02.2017

JE 08.02.2017

ANDRITZ FLIESSBETT SYSTEME GmbH

Kunde/Client: Shanghai Sewage Sludge

Anlage/Project: Bailonggang 2

CONCEPT LAYOUT

DRYING OF SEWAGE SLUDGE
6 LINES

Auftrags-Nr./Order No.	Zeichnungs-Nr./Drawing No.	Format	Maßstab/Scale	Blatt/Sheet	Rev.
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PRELIMINARY INDICATIVE FOR REFERENCE ONLY - NOT FOR DESIGN NOR CONSTRUCTION !

10 Odor Control System

The ANDRITZ Fluid Bed Drying System (FDS) will be designed to operate throughout the life of this project on a 24/7 operations basis. This approach will maximize the use of the heat recovery system, providing a constant supply of heat recovered from the FDS condensing system as heat for the facility hot water loop.

Dewatered cake, held in a nominal 100m3 storage and metering bin, will be delivered using four PC pumps directly to the fluidized bed where granules will form, and water will be evaporated. Dried product at minimum of 95 per cent DS will discharge at a rate controlled by the delta P measurement across the bed to a separate fluidized bed product cooler. The dried product will then be discharged at < 40°C for subsequent mechanical conveying to the dried product storage silos or directly.

The FDS features a closed loop fluidizing gas loop that operates at < 2% O2 and consists of the dryer vessel, a pair of cyclones for the removal of entrained dust, a condenser/scrubber and demister to cool and condense the evaporated water, and the fluidizing fans. Due to the gas-tight design of this loop, leak air is minimized, and gases are entrained in the dewatered cake and constitute a small condensable gas stream of about 200-250 ACFM. This stream is used to inertize the downstream product cooler gas loop, the mechanical conveying systems, and the dried product silos and is ultimately discharged to the plant odor and emissions control system.

Proposed odor control system

The odor collection system layout is based on conveying sources, with various odor characteristics, to a central odor control system. Room air for process and non-process areas where all potential odor sources are enclosed will be discharged to the atmosphere by the building's HVAC system.

The odor control system design incorporates the Multiple Barrier Approach, allowing each target odor compound to be removed by more than one odor control process in the treatment train. The central odor treatment system will consist of bio trickling towers, a three-stage chemical scrubber, and GAC adsorption towers. The exhaust from the GAC towers will be discharged at elevation via a stack to provide the necessary level of dispersion required to meet the odor units per cubic meter criteria (to be agreed upon) at the property boundary.

The Multiple Barrier Approach incorporates redundancy in the design of the odor treatment train, enabling all odor compounds typically associated with a residual handling process to be treated, even if one odor treatment process is completely offline for maintenance. Full redundancy is incorporated into the design of ancillary systems, (such as fans, chemical feed pumps and recirculation pumps), to allow for switchover to the standby unit if the duty unit fails.

Construction materials for odor collection and control equipment will be selected to ensure a reliable system that minimizes the potential for corrosion and could significantly impact the operating life and life cycle cost of the process equipment. The odor collection and control equipment will be designed and operated to minimize the potential for leaks and fugitive emissions that could have an impact on the odor level achieved at the property boundary

ANDRITZ proposes to provide an odor control system complete with two bio trickling filter systems, each sized for 1/2 of the required air flow rate, followed by one chemical scrubber sized for the whole air flow rate, followed by two carbon adsorber systems (with mist eliminator), each sized for ½ of the required air flow rate.

	BTF	LO/PRO	Carbon	Overall
Odor Unit Removal Efficiency	90%	99%	90%	99.9% or 100 OU
H2S Removal Efficiency	99%	99.9%	99%	99.9% or 0.1 ppm
RSC Removal Efficiency	80%	95%	90%	99.9% of 0.1 ppm (compound dependent)
Ammonia Removal Efficiency	50%	99%	N/A	99.9% or 0.1 ppm

11 Notes on Dewatered Sludge Characteristics

This table is intended to be read in conjunction with the **Specification of Sludge Feed Parameters and Safety Characteristics of Dried Granulate** and the minimum and maximum values of the individual parameters defined there.

11.1 CHEMICAL AND PHYSICAL SLUDGE PARAMETERS:

	Dewatering	*Drying*
1. Solids Concentration	**Too Low** • Require too much polymer • Unable to achieve cake formation in dewatering equipment and required dry solids or throughput • Filtrate/Centrate quality becomes worse	**Too Low** • Require too much energy for drying • Unable to achieve guaranteed solids or throughput • Feed granulate too large and sticky • Conveyors not designed for such solids loads • Unable to achieve sufficient backmixing • Granulate DS may fall below 90% - risk of humid material entering the granulate handling processes – risk of self heating due to material agglomeration • Risk of increased pathogen content
	Frequent fluctuations within short time/e.g. segregation in liquid sludge silo or hopper: • Unstable operation of dewatering equipment • Formation of sticky cake due to overdosing of polymer	**Frequent fluctuations within short time in cake DS (e.g. due to instable operation of dewatering equipment; segregation in sludge cake silo, water break through from improper centrifuge dewatering):** • Unstable operation of drying plant • Formation of sticky granulate • Risk of material agglomeration, bridging in silos and chutes • Risk of self heating due to material built up in granulate and product handling as well as in storage silos
	Too High • Pumps not designed for such solids loads • Conveyors not designed for such solids loads • Centrifuges limited in max. solids load.	**Too High** • Dust and subsequent handling problems • Conveying problems

	Dewatering	***Drying***
2. Ash Content	**Too High** • Unable to achieve performance (polymer efficiency changes, possibly new polymer type required, cake DS, etc.) **Too Low** • Unable to achieve performance (polymer efficiency changes, possibly new polymer type required , cake DS, etc)	**Too High** • Problems with dust formation • Particle size distribution will change towards fine product **Too Low** • Unable to achieve dry solids content in granulate • Unable to achieve sufficient back mixing • Granulate DS may fall below 90% - risk of humid material entering the granulate handling processes – risk of self heating due to material agglomeration • Risk of increased out of spec. granulate discharged from process into oversized bin – loss of material • Risk of increased pathogen content
3. Total Fiber Content	**Too High** • Equipment blockage • Formation of loose cake with low density • Unable to achieve performance (polymer efficiency changes, possibly new PE type required , cake DS, etc.)	**Too High** • Particle size distribution changes towards more fines and lumps, less particles in expected range for final product • Unable to form granules in mixer • Unable to achieve guaranteed dry solids content • Decrease in bulk density and subsequent handling and conveying problems due to low density (blocking of chutes, screen, aspiration pipes, bridging in silos, etc.) • Change of explosion and flammability characteristics (risk of fire increased)
4. Long Fiber Content (> 0.8mm)	**Too High** • … same as Total Fibre Content	**Too High** • ….same as total fibre content
5. Short Fiber Content (0.2 – 0.8 mm)	**Too High** • ….same as Total Fiber Content	**Too High** • ….same as Total Fibre Content

	Dewatering	*Drying*
6. pH	**Too Low** • Corrosion of equipment, piping, etc. • Polymer coagulation problems and resultant issues achieving guarantees; polymer type may need to be changed **Too High** • Corrosion, • Chemical decomposition of materials • PE coagulation problems and resultant issues achieving guarantees; PE type	**Too Low** • Corrosion of equipment, piping, etc. **Too High** • Corrosion • Chemical decomposition of materials
7. Non-volatile lipophilic substances (Fat, oil and grease)	**Too High** • Equipment blockage • Increased maintenance • Generation of explosive gases	**Too High** • High backmix ratio required which may cause overload of handling equipment in backmix circuit • Filter blockage – reduced life time of filter bags in product handling system • Increased risk of conflagration • Increased risk of fire • Increased maintenance and equipment blockage • Generation of explosive gases
8. Chloride	**Too High** • Corrosion	**Too High** • Corrosion
9. Fluoride	**Too High** • Corrosion	**Too High** • Corrosion
10. Sulphur	**Too High** • Corrosion	**Too High** • Conflagration • Corrosion • Increased risk of fire • Emission limits may not be met • Risk of increased H2S formation – safety problem due to toxic and explosive atmospheres

	Dewatering	***Drying***
11. Silica Content	**Too High** • Abrasion	**Too High** • Abrasion
12. Iron	**Too High** • Corrosion	**Too High** • Corrosion • Reduction of the self ignition temperature (increased risk of self heating) and storage time till self ignition reduced
13. Organically bound Nitrogen	**Too High** • Increased sludge “stickiness” and resultant conveying and plugging problems	
14. Conductivity	**Too High** • High salt levels can lead to corrosion	
15. BTX (Benzene, Toluene, Xylene)	**Too High** • Pollution of centrate • Generation of explosive gases • Contamination and risk of adverse effect on waste water treatment if centrate is fed back	
16. Total PCBs (Polychlorinated Biphenyls)	**Too High** • Increased sludge “stickiness” • Unable to achieve sufficient backmixing to form required range of particle sizes • High backmix ratio required which may cause overload of granulate handling equipment in backmix circuit • Influence on particle size distribution due to tendency of large granulate formation • Increased risk of material agglomeration and bridging in silos and chutes	**Too High** • Generation of explosive gases • Increased fire risk • Contamination and risk of adverse effect on waste water treatment if condensate is fed back • Contamination of granulate – risk for disposal • Risk for granulate out of spec. as fertilizer • Emission limits may not be met • Risk of exceeding max. permissible workplace concentrations

	Dewatering	*Drying*
17. Total PAH (Polyaromatic hydrocarbons)	**Too High** • High salt levels can lead to corrosion	**Too High** • Generation of explosive gases • Increased fire risk • Contamination and risk of adverse effect on waste water treatment if condensate is fed back • Contamination of granulate – risk for disposal • Risk for granulate out of spec. as fertilizer Risk of exceeding max. permissible workplace concentrations • Emission limits may not be met • Risk of exceeding max. permissible workplace concentrations
18. AOX (Adsorbed organic halogens)	**Too High** • Generation of explosive gases • Risk of exceeding max. permissible workplace concentrations • Increased fire risk • Contamination and risk of adverse effect on waste water treatment if condensate is fed back • Contamination of granulate – risk for disposal • Risk for granulate out of spec. as fertilizer • Emission limits may not be met	**Too High** • Generation of explosive gases • Increased fire risk • Contamination and risk of adverse effect on waste water treatment if condensate is fed back • Contamination of granulate – risk for disposal • Risk for granulate out of spec. as fertilizer • Emission limits may not be met • Risk of exceeding max. permissible workplace concentrations

	Dewatering	Drying
19. Total Hydrocarbons	**Too High** • Pollution of centrate • Generation of explosive gases • Contamination and risk of adverse effect on waste water treatment if centrate is fed back	Too High • Generation of explosive gases • Increased fire risk • Contamination and risk of adverse effect on waste water treatment if condensate is fed back • Contamination of granulate – risk for disposal • Risk for granulate out of spec. as fertilizer • Emission limits may not be met • Risk of exceeding max. permissible workplace concentrations

consor

APPENDIX D

Jeff Moss

From:	Commerford Peter <Peter.Commerford@andritz.com>
Sent:	Friday, March 17, 2023 3:38 PM
To:	Jeff Moss; bart.lynam@renufuel.com
Cc:	Erika Schuyler
Subject:	RE: King County Biosolids Proposal Additional Data Request
Attachments:	Biosolids Partnership Data Request Tracking - Initial request sent on 3-3-23 reply March 17 2023.pdf

Good afternoon Jeff,

We converted the Excel sheet to a Document and have it attached with the responses from our Biosolids Partnership Team for your consideration. Note that the attachment referred to in Q4 is still under preparation, and we expect to have it for you Monday morning.

Thanks,

Peter Commerford
ANDRITZ
817-271-2855

From: Jeff Moss <Jeff.Moss@consoreng.com>
Sent: Friday, March 3, 2023 2:48 PM
To: bart.lynam@renufuel.com
Cc: Erika Schuyler <Erika.Schuyler@consoreng.com>; Commerford Peter <Peter.Commerford@andritz.com>
Subject: King County Biosolids Proposal Additional Data Request

Hello Bart,

Please find attached the data request that Consor has generated following our initial review of the draft revised proposal. We look forward to receiving additional information to assist with our review. As a reminder, the project schedule assumes a two week or less response time.

Best wishes,

-Jeff

Jeff Moss, **PE** (He/Him/His)
PROFESSIONAL ENGINEER
o: +1.206.462.7030
m: +1.719.432.9798

consoreng.com

ReNuFuel

Friday, March 17, 2023

Consor Engineering
600 University Street, Suite #300
Seattle, Washington 98101
Tel: 206.462.7030

ATTENTION: Jeff Moss, PE CIVIL ENGINEER

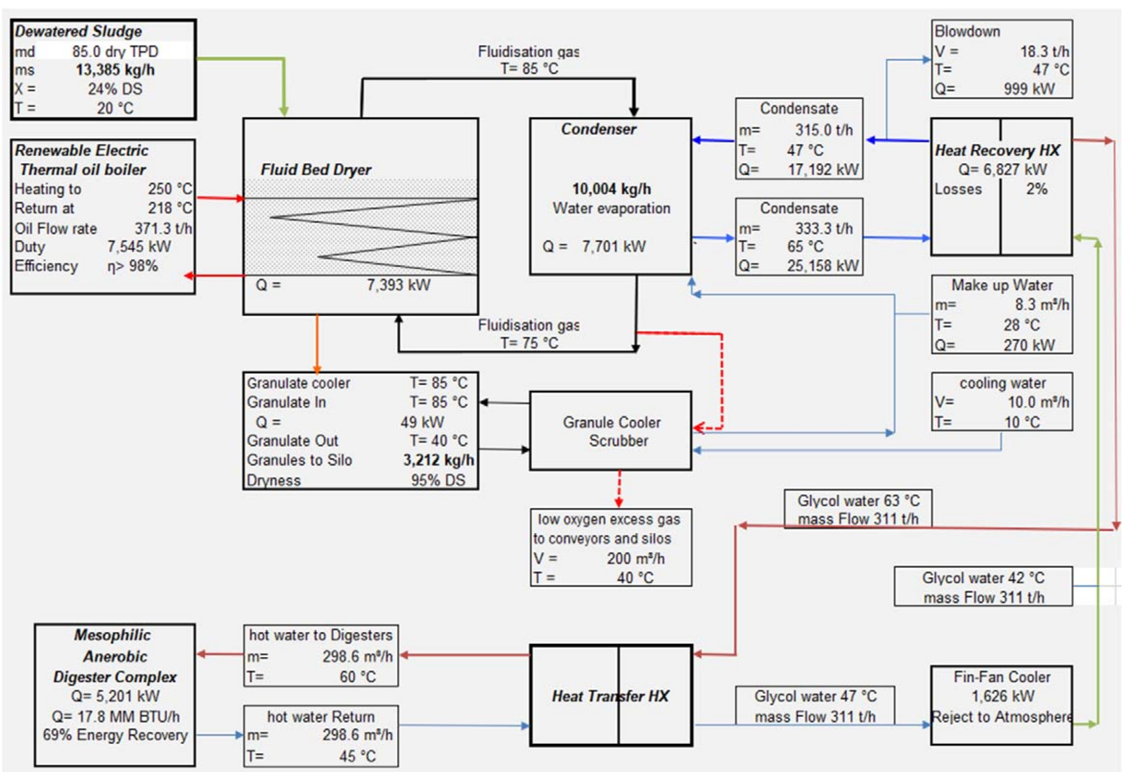
Dear Jeff:

SUBJECT: Biosolids Thermal Drying using Renewable Electricity Proposal – South Plant Renton
Biosolids Partnership Data Request Tracking - Initial request sent on 3/3/23

Thank you for your review and subsequent questions – we can respond as follows:

1 Provide equipment cutsheets and capacities of major components
Equipment for this plant is custom designed - cut sheets will be available and will be submitted for approval when detail design engineering proceeds after award of a contract. (See Equipment list pp 215-223).

2 Mass balance of the entire process, including biomass, biochar, biogas, sludge and pellets, etc.
The Mass and Energy Balance was provided on page 239 (ANDRITZ page 58 of 81) and incorporated here for convenience,



ReNuFuel, LLC.
Environmental Engineering
9606 Wharf Street Edmonds, WA 98020-2362
Phone: 425-775-8287 - Cell: 206-612-5392
E-mail: Bart.Lynam@ReNuFuel.com

3 Energy balance of the entire process, including biochar, biogas, renewable electricity, hot water, thermal oil, etc.

See answer to Q,2.

4 Carbon footprint calculation for the entire process

Attached is a "gate-to-gate" greenhouse gases emissions analysis for the proposed plant consistent with the WRI and TCR protocols for Scope 1 and Scope 2 emissions. The spreadsheet includes all assumptions and references to data sources.

5 "Life cycle, capital, or O&M cost assessments [itemized detailed breakdowns] of the proposed Class A biosolids facility.

What is the assumed discount rate percentage [opportunity cost of capital] for the life cycle cost analysis?

On page 6 of the Andritz proposal, does ""3% compound inflation"" actually refer to the discount rate, which is different than inflation?"

As explained on page 6, to calculate the 20-year Ownership cost of the ANDRITZ Fluid Bed Drying System with renewable electricity, the average yearly cost (using 3% compound inflation on all items) was calculated for year 1 and year 20, assuming a steady growth of solids processed from 85 dry TPD up to 130 dry TPD and averaged over the 20 years. We used the same multiplier used by Murraysmith in Table 1 of their report (16.7) to calculate the NPV – this equates to about a 3% opportunity cost of capital.

6 Odor control requirement and sizing

In Section 10 of the ANDRITZ proposal (page 267), we outlined that the odor control system design incorporates the Multiple Barrier Approach, allowing each target odor compound to be removed by more than one odor control process in the treatment train. The central odor treatment system will consist of bio trickling towers, a three-stage chemical scrubber, and GAC adsorption towers. The exhaust from the GAC towers will be discharged at elevation via a stack to provide the necessary level of dispersion required to meet the odor units per cubic meter criteria (to be agreed upon) at the property boundary.

The Multiple Barrier Approach incorporates redundancy in the design of the odor treatment train, enabling all odor compounds typically associated with a residual handling process to be treated, even if one odor treatment process is completely offline for maintenance. Full redundancy is incorporated into the design of ancillary systems, (such as fans, chemical feed pumps and recirculation pumps), to allow for switchover to the standby unit if the duty unit fails.

7 "Do the capital and operating costs presented include the cost of the Heat Recovery and Heat Transfer HX Systems shown on page 58 of the Andritz proposal?

Yes, the capital and operating costs for the proposed heat recovery system are included.

Will the existing digester heating HX systems at the South Plant need to be upgraded or improved to accommodate the waste heat from the dryer process?"

- We did not have the details of the South Plants digester heating HX systems, so were unable to determine if the proposed 65ºC/150ºF hot water, designed to service a 60ºC/140ºF heating loop, conforms to the current setup. (we have just received information from King County (Drew Thompson) that “the supply temperature setpoint ranges from 110 – 160 degree F (depending on the time of year and demand”). Amore detailed appraisal of the system is necessary to determine if any upgrade is necessary)

8 Does BP have operators to manage the system, if not, who will operate?

As explained, the proposed drying plant was designed, and the NPV was calculated, as if it would be operated and maintained by King County. However, BP has reached out to Synagro, a company with extensive experience and resources available to operate the proposed facility. Synagro has indicated that, should King County have interest in delivery of the drying facility using a Design-Build-Operate and Maintain (DBOM) or similar model, it would be very interested in engaging with the key stakeholders to discuss the project.

To date, ANDRITZ and Synagro have partnered on DBOM delivery of eight biosolids drying projects, including: Pinellas County, FL, Sacramento, CA, Honolulu, HI, Stamford, CT, Philadelphia, PA, Hamilton, ONT, Fort Worth, TX, and Victoria, BC.

Synagro has an impressive history of delivering projects on schedule and on budget while enabling cities and counties to minimize risks while maximizing the value of the design-build-operate procurement approach. Synagro is trusted because they remove risks while keeping the logistics clean.

Synagro has a long history of maintaining and operating various biosolids operations. Synagro started in 1986. Through Synagro’s substantial, continuous investments in research and development and partnering with other biosolids management providers, the company grew rapidly. Synagro has the most biosolids processing facilities, and most comprehensive geographic footprint, in the industry.

What is the annual cost and proposed term duration of the contract operations contract that Andritz or the Biosolids Partnership is proposing to King County for operation of the dryer facility?

The total contract term of 20 years is typical for a 3rd party, such as Synagro, to deliver a DBOM Biosolids Processing Facility. Regarding annual costs, BP needs additional time with CONSOR to engage with Synagro on a more detailed response to this question. We would appreciate direction from the consultant so that we can have a more in-depth discussion involving Synagro. For calculation of the initially provided NPV, an average annual operating cost of $9.5 million was provided and BP reaffirms that annual cost estimate. The final project scope, treatment of utilities, and other factors will influence the final operating cost.

As validation of the estimated annual drying facility operation and maintenance costs, consider the City of Fort Worth, Texas biosolids drying project. Fort Worth's Village Water Reclamation Facility generates approximately 26,000 dry tons of biosolids per year. A team of Andritz and Synagro was selected to design-build-and operate a new biosolids dewatering and drying facility at the Village Creek WRF. The new facility, construction of which was completed in late 2022, features four Andritz centrifuges and a single process train of the Andritz Drum Drying System. The firm contractual cost to design and construct the facility was approximately $58.0 million and the annual operation and maintenance costs are approximately $235 per dry ton, inclusive of dewatering, drying, and utilities consumption, or approximately $6.1M per year. As noted, these are the results of a recent competitive public procurement and are therefore indicative of true market costs generated by experienced firms via a design-build-operate type procurement.

9 Clarify the specified WAC reference. In slides there is a reference to WAC 308? In paper it appears to be WAC 173-434. WAC 173-434 is clear, but what is the reference to WAC 308 supposed to refer to?

There was a reference to 308 in the most recent proposal. It should have been a reference to WAC 173-308. This is the regulation relating to wastewater biosolids management. As described in the response to Question 12, 173-308 does not apply to this project. WAC 173-434 relates to incineration. This rule also does not apply to this project as it specifically excludes combustion of "sludge from wastewater treatment plants" (434-030 (3)(d)).

10 Has the Biosolids Partnership received any guidance from the Washington Dept of Ecology regarding the potential use of the dried biosolids product in a cement plant kiln?

.In Washington the Department of Ecology is the primary agency with respect to wastewater, solid wastes and hazardous wastes but local agencies are the primary agency for most air emissions (specific exceptions for pulp and paper mills, refineries and similar facilities place them within a division of Ecology). The Puget Sound Clean Air Agency (PSCAA) issues the Air Operating Permit for cement plant kilns in the four-county central Puget Sound region. The Air Operating Permits describe the allowed fuels and any restrictions on these fuels. PSCAA has previously granted permit modifications to burn alternative fuels, such as used oil and tire-derived fuel. It will be necessary for PSCAA to grant authorization for the use of any additional alternative fuels. There have not been any discussions with PSCAA regarding its interests in dried biosolids or what restrictions they might apply. PSCAA's actions will be consistent with U.S. EPA guidance, such as is discussed in response to Question 15.

11 What is the range in operating temperatures of the kiln at the Ash Grove cement plant?

Cement kilns typically operate in the hottest section of the kiln up to 1,500 degrees C and above 1,000 degrees C at the kiln exit. The residence time above 1000 C exceeds 5 seconds. (https://ordspub.epa.gov/ords/guideme_ext/f?p=guideme:gd:::::gd:dioxin_4_3)

The Ash Grove kiln is not significantly different from the typical kiln.

12 Beneficial use is not mentioned within WAC 173-434. Can you point to any WAC where beneficial use is mentioned and how it impacts the requirements for a kiln looking to burn biosolid pellets?

In a search of Washington laws and regulations we found some 4,200 references to “beneficial use”. Most of these references are to the provisions of Western water law, that is, the preference ranking of various claimants for apportionment of river or lake water resources. The only other regulations where it is mentioned are WAC 173-350 (solid waste handling standards), WAC 173-308 (biosolids management) and WAC 173-305 (hazardous waste fees).

WAC 173-350-021(3)(d) states that those regulations do not apply to any product that has a positive market value, as is the case here with the produced pellets being acquired for their potential heat value and biogenic carbon. Any discussion of “beneficial use” in those regulations would not apply to these pellets. The potential market value of dried biosolids as a biogenic fuel is illustrated by the high value of Climate Commitment Act carbon allowances recently auctioned by Washington Department of Ecology (https://apps.ecology.wa.gov/publications/summarypages/2302022.html)

WAC 173-308-020(2)(b) states that those regulations do not apply to any sewage sludge that is disposed of in a manner other than in a municipal landfill, so any discussion of “beneficial use” in those regulations would not apply to dried biosolids utilized as a fuel.

In WAC 173-305-020(18) "recycled for beneficial use" is defined as “the use of hazardous waste, either before or after reclamation, as a substitute for a commercial product or raw material”, but does not include its use as a fuel, which is separately regulated through EPA regulations 40CFR63 Subpart EEE or 40CFR264 Subpart O. However, in order for this regulation (or EPA regulations) to apply to a product it must first be a “dangerous waste” or an “extremely hazardous waste”. Dangerous wastes generally are acutely toxic, corrosive, flammable or explosive. Extremely hazardous wastes present long-term toxic risks, build toxicity through the food chain or cause genetic damage. King County has not designated sewage sludge from the King County Metro wastewater treatment plants as dangerous or extremely hazardous wastes. The remainder of this regulation only describes fees that must be paid by persons who work with hazardous wastes.

13 Please provide original data to support the following statement on page 8 of the Andritz proposal: "King County reports average monthly usage of natural gas as 62.451 therms/month".

The source of these data is provided in the GHG emission inventory spreadsheet.

14 Please provide the actual URL link to the Seattle Times article referenced on page 8 of the Andritz proposal.

https://www.seattletimes.com/seattle-news/environment/sea-tacs-legacy-of-pfas-chemicals-foam-showers-sick-firefighters-and-contaminated-water/

https://www.seattletimes.com/nation-world/how-widespread-are-these-toxic-chemicals-theyre-everywhere/

15 Can the Biosolids Partnership point us to other State of Washington installations in which a Class A biosolids product is being subsequently combusted in compliance with relevant air permits?

There are other sewage treatment plants and fuel producers in the US that have been approved for such use of sewage sludge biosolids in combustion units. Attached are copies of guidance from the U.S. EPA. The first is from EPA Region 5 approving of dried sewage sludge pellets generated by the Delhi Charter Township wastewater treatment plant for use in an unspecified combustion facility. The second is from the EPA Office of Solid Waste and Emergency Response approving of dried sewage sludge pellets generated by the Detroit Water and Sewage Department for use in a coal-fired power plant. The third is also from the EPA Office of

Solid Waste and Emergency Response. It approves the use of dried sewage sludge pellets generated by N-Viro International from sewage sludge obtained from various wastewater treatment plants for sale to power plants. These letters indicate the sort of considerations and evidence that must be provided to obtain such authorization.

The use of municipal sludge as an alternative fuel is common in Europe – in fact, ANDRITZ has dryer plants located in three (3) separate cement plants in Germany, using waste heat to dry dewatered cake and subsequently using the dried sludge as an alternative fuel in the cement kiln.

Sincerely

Bart T. Lynam

Bart T. Lynam, President

ReNuFuel, LLC

Attachment 4
Past U.S. EPA DBS Comfort Letters

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5
77 WEST JACKSON BOULEVARD
CHICAGO, IL 60604-3590

DEC 15 2011

REPLY TO THE ATTENTION OF

Sandra Diorka
Director of Public Services
Delhi Charter Township
2074 Aurelius Road
Holt, Michigan 48842-6320

Dear Ms. Diorka:

In your letter of June 16, 2011, you requested confirmation from the U.S. Environmental Protection Agency that sludge pellets burned in combustion units are non-waste fuels in accordance with the requirements in 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the rule requires that processing of non-hazardous secondary material (NHSM) meets the definition of processing in 40 CFR 241.2. Also, after processing, the NHSM must meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter and supporting materials, including analytical results submitted August 2, 2011 and August 15, 2011, we believe the 40 CFR part 241 regulations would identify the proposed sludge pellets that will be generated by the Delhi Charter Township (or Township) Wastewater Treatment Plant and burned in combustion units as a non-waste fuel.[1] The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSMs into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for purposes of the definition.
In your letter, you state that the Township plans to expand the processing operations at the wastewater treatment plant to create a biofuel product from its wastewater treatment sludge. The expanded process will involve removing rags and screening out solid contaminants larger than 3 mm in size; removing inorganic grit, which results in the removal of some heavy metals;

[1] Note that a non-waste determination under 40 C.F.R. Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 C.F.R. Part 241 for the purposes of determining appropriate emissions standards under the Clean Air Act for the combustion unit in which it is used.

subjecting the sludge to anaerobic digestion, which will generate Class A biosolids (the highest sludge classification) and remove volatiles and pathogenic organisms; dewatering the digested sludge, via the use of a water treatment polymer, to increase solids to approximately 20 percent; and drying and milling via solar drying in a greenhouse and mechanical tumbling, to create a final pelletized fuel product with a total solids content of at least 75 percent. In addition, the Township has a number of programs in place designed to limit the introduction of pollutants, such as mercury, pharmaceuticals, household hazardous waste, and heavy metals from industry into the wastewater stream in the first place.

Based on this description—that is, removal of contaminants (i.e., reduction in heavy metals via grit removal and reduction of volatiles via anaerobic digestion) and improvement of its fuel characteristics (i.e., removal of large solids and grit, removal of water to improve the as-fired energy content, and sizing of the material to allow it to be handled and fed to the boiler "as is"), we believe the process used to produce sludge pellets meets the definition of processing in 40 CFR 241.2.

Legitimacy Criteria

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels includes: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have meaningful heating value and be used as fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage As A Valuable Commodity

Regarding the first criterion, you state that the sludge pellets will be stored in a dry bunker until a quantity sufficient for transport accumulates—this may occur as often as multiple times daily or as little as every few months. The sludge pellets will be transported to the combustion facility in covered containers/trucks, offloaded onto the combustion facility's covered coal containment floor, mixed with coal, and burned within 24 hours of delivery. The sludge pellets will be sold to the combustion facility at a price that reflects their Btu content and the cost of processing the material.

Based on this information, we believe the sludge pellets[2] are managed as a valuable commodity: storage does not exceed a reasonable time frame and storage in dry bunkers is adequate to prevent releases. Also, management of the sludge pellets by the combustion unit appears to be analogous to the management of coal that is burned as a fuel.

Meaningful Heating Value and Used As A Fuel to Recover Energy

Regarding the second legitimacy criterion on meaningful heating value, you state that the sludge pellets will have an as-fired heating value greater than 5,000 Btu/pound, depending on the solids content of the final product. As discussed in the final rule, 5,000 Btu/pound was established as a general guideline for meaningful heating value. You submitted analytical data for one sample of sludge pellets containing the water treatment polymer (no fine screening step) and eight samples of sludge pellets from your current process (no fine screening step or addition of water treatment polymer). Because the sample containing the water treatment polymer more closely resembles the sludge pellets, we considered that sample as a proxy for the sludge pellets. The analytical data submitted on August 2, 2011 for this sample indicates a heating value of 6,500 Btu/pound on a dry basis which, according to Table 1 in your June 16, 2011 letter, translates to 5,200 Btu/pound if the sludge pellets are 80 percent solids content and 5,850 Btu/pound if the sludge pellets are 90 percent solids content. Your letter indicates that the typical product dryness will range between 80 percent and 90 percent solids content.

Based on this information, the sludge pellets will meet this criterion only if the solids content of the sludge pellets is sufficiently high to result in an as-fired heating value of at least 5,000 Btu/pound and if the sludge pellets are burned in a combustion unit that recovers energy, such as a combined heat and power plant.

Comparability of Contaminant Levels

Regarding the third criterion on contaminant levels, your letter requested confirmation that the sludge pellets meet the contaminant level criterion when compared to coal. You submitted analytical data from several samples of sludge pellets using your current process (no fine grit removal or addition of water treatment polymer), as well as analytical data for one sample of sludge pellets containing the water treatment polymer. Because the sample containing the water treatment polymer more closely resembles the sludge pellets, we considered that sample as a proxy for the sludge pellets. Please note that only those constituents identified in the contaminant definition under section 241.2 are relevant with respect to meeting the contaminants legitimacy criterion. For example, you indicated that both copper and silver show higher levels of contaminants than found in coal, but you believe they are still present at comparable levels, as

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[2] As noted in the regulations, prior to final processing (drying and milling), the processed sludge may be considered a solid waste and is subject to appropriate federal, state, and local regulations.

defined under the regulations. Since neither copper nor silver are defined as contaminants under the Part 241 regulations, EPA did not consider them in our evaluation. Therefore, from the analytical data you submitted on August 2, 2011, we evaluated only those constituents identified under section 241.2 and as outlined in the materials characterization paper "Traditional Fuels and Key Derivatives." [3,4,5]

As indicated in the enclosed table, the sludge pellets meet the legitimacy criterion for contaminant levels when compared to coal. Regarding the total fluorine data you submitted on August 15, 2011, we also note that due to the water content of the sludge, the laboratory reporting limit on a dry weight basis for total fluorine exceeds the level of fluorine found in coal as reported in the referenced Materials Characterization Paper. The conclusion that the sludge pellets meet the contaminant legitimacy criterion, therefore, presumes that the actual level of fluorine, as well as additional constituents for which the sludge pellets were not tested, are present at levels comparable to or lower than those in the appropriate traditional fuel, based on your knowledge of the material.

Overall, based on the information provided, we believe that the sludge pellets that will be generated by the Township's wastewater treatment plant, as described in your June 16, 2011 letter and materials submitted on August 2, 2011, and August 15, 2011, meet both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 Part 241 regulations.

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[3] The Materials Characterization Paper on *Traditional Fuels and Key Derivatives* can be found at www.epa.gov/epawaste/nonhaz/define/index.htm.

[4] EPA notes that the contaminant values listed in the *Traditional Fuels and Key Derivatives* MCP for coal (and other traditional fuels) may be revised in the future based on the availability of new or additional data. Any future revisions to the values will not impact the conclusions made in this letter; the values are based upon the data that is available at the time EPA responds to a request.

[5] You may use other data on the contaminant levels in traditional fuels in determining whether the levels are comparable to the Township Wastewater Treatment Plant sludge pellets. That is, other data on the level of contaminants in traditional fuels that your Township has or may become aware of may also be considered in determining whether the level of contaminants in the Township's Wastewater Treatment Plant sludge pellets are comparable to those in the traditional fuel that the combustion unit is designed to burn.

If you have any other questions, please contact Julie Gevrenov of my staff at 312-886-6832.

Sincerely,

Margaret M. Guerriero
Director
Land and Chemicals Division

Enclosure

cc: The Honorable Carl Levin, United States Senate
George Faison, EPA/ORCR
Ethan Chatfield, EPA R5/ARD
Stuart Hersh, EPA R5/ORC
Duane Roskoskey, MDEQ

Enclosure: Contaminant Levels in Sludge Pellets

Constituent	Units	Measured Concentration in Sludge Pellets (containing water treatment polymer) (dry-weight basis), from 7/6/11 and 8/10/11 ALS Environment Reports	Maximum Values for Coal in EPA's Materials Characterization Paper *Traditional Fuels and Key Derivatives*	Note
antimony	mg/kg	2.5	235	
arsenic	mg/kg	8.8	80	
beryllium	mg/kg	< 0.63 (ND)	15	(non-detect at 0.63 mg/kg-dry reporting limit)
cadmium	mg/kg	2.8	5.47	
chromium	mg/kg	74	121.3	
cobalt	mg/kg	2.5	40.9	
lead	mg/kg	11	80	
manganese	mg/kg	260	300	
mercury	mg/kg	1.3	2	
nickel	mg/kg	13	50	
selenium	mg/kg	5.9	10	
total chlorine	ppm	< 2,500 (ND)	7,380	(non-detect at 0.25 wt%-dry)
total fluorine	ppm	< 1,250 (ND)	180	(non-detect at 0.030 wt%, with moisture measured at 76% of sample)
total nitrogen	mg/kg	42,000	54,000	the maximum value shown for nitrogen (54,000) is from the QAQPS emissions database for boilers & process heaters, version 6
total sulfur	ppm	11,100	43,600	(measured as 1.11% total sulfur on dry basis)
extractable organic halides	µg/g	< 160 (ND)	no data	(non-detect at 160 µg/g as Cl-dry reporting limit)
semi-volatile organic compounds	µg/kg	< 2,580 (ND)	no data	(non-detect for 18 compounds with individual reporting limits < or = 330 µg/kg-dry)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

MAR 1 6 2012

OFFICE OF
SOLID WASTE AND EMERGENCY
RESPONSE

Fadi K. Mourad, P.E.
Director, Environmental Affairs
DTE Energy Services, Inc.
414 South Main Street, Suite 600
Ann Arbor, MI 48104

Dear Mr. Mourad:

In your letter of July 21, 2011, you requested confirmation from the U.S. Environmental Protection Agency (EPA) that biosolids processed using the proposed Detroit Biosolids Project will be considered a non-waste fuel when burned for energy recovery in combustion units in accordance with the requirements of 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the regulations require that processing of the non-hazardous secondary material (NHSM) meet the definition of processing in 40 CFR 241.2. After processing, the NHSM must also meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter, and supporting materials submitted on August 16, 2011, September 9, 2011, and January 11, 2012, we believe that under the 40 CFR part 241 regulations the processed biosolids—proposed to be generated by DTE Energy Services (DTEES) through the Detroit Biosolids Project and burned in the described combustion units—would be considered a non-waste fuel.[1] The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

Proposed Detroit Biosolids Project

The Detroit Biosolids Project is a proposed arrangement between DTEES and the Detroit Water and Sewerage Department (DWSD). DTEES operates the River Rouge Power Plant (RRPP) and other utility plants seeking to comply with Michigan's Renewable Energy Standard by 2015. DWSD operates its wastewater treatment plant in close proximity to RRPP, and it currently incinerates 800,000 tons of wet biosolids annually. Under the proposed arrangement, DTEES would further process the biosolids into a product fuel to be sold to RRPP and other utility plants that currently burn coal.

[1] Note that a non-waste determination under 40 CFR Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 CFR Part 241 for the purposes of determining the applicable emissions standards under the Clean Air Act for the combustion unit in which it is used.

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSM into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for the purposes of the definition.

In your letters, you state that DTEES will use rotary drum dryers to process the incoming biosolids—which are 20 to 25 percent solids and have a heating value between 1,000 and 2,000 Btu/pound—into a material that is 95 percent solids and has a heating value between 7,500 and 8,000 Btu/pound. Evaporated moisture, which includes some contaminants from the biosolids, will be condensed and recycled back to DWSD for further treatment. The dried biosolids will then exit the drum as discrete pellets in the exhaust stream, at which point they will be screened to a specified size and screened to remove certain materials such as coarse plastics (e.g. personal hygiene products), metals (e.g. nuts, bolts and screws) and other undesirable solids. The cooled product meeting specifications will be transported to storage silos. Reject material, consisting of the coarse plastic, metals and other undesirable solids, will be collected in a separate container for disposal (reject material is expected to total 2.5% to 4% of the incoming biosolids). Over-sized material will be crushed, combined with the fines, and mixed with incoming biosolids to begin the process again, including screening for undesirable solids.

Based on this description, we believe your operations meet the definition of processing in 40 CFR 241.2 and will transform the processed biosolids into a non-waste fuel , as further discussed below by significantly improving the fuel characteristics through a combination of sizing, drying, and contaminant removal.

Legitimacy Criteria

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels include: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have a meaningful heating value and be used as a fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage as a Valuable Commodity

Regarding the first legitimacy criterion, you note that the processed biosolids[2] will be sold to RRPP or other utility plants for use as a fuel at a competitive market price. You also state that

[2] As noted in the regulations, prior to final processing (drying, pelletizing, and screening), the processed sludge may be considered a solid waste and is subject to appropriate federal, state, and local regulations.

the processed biosolids will be pneumatically conveyed from the product silo at the DTEES biosolids plant to storage silos at RRPP, never being exposed to the outside atmosphere. Co-combustion with coal will then occur within four days. Coal, on the other hand, is typically stored at RRPP in a pile exposed to the atmosphere for up to one month prior to combustion.

Based on this information, we believe that the processed biosolids will be managed as a valuable commodity at both DTEES and RRPP—that is, managed in silos, with the material not being exposed to the outside atmosphere. In addition, storage would not exceed a reasonable time frame, and in fact, appears to be used in a time frame shorter than that used for fossil fuel products. If sold to utility plants other than RRPP, pneumatic conveyance to the utility may not be possible, but transport in covered trucks or railcars are examples of other acceptable transport methods you may wish to consider. However, since no information was provided as to how the processed biosolids will be managed at other utility plants, this letter does not address this aspect of the legitimacy criteria when utilized at other utility plants.

Meaningful Heating Value and Used as a Fuel to Recover Energy

Regarding the second legitimacy criterion, you note that the processed biosolids have an as-fired heating value between 7,500 and 8,000 Btu/pound. As the Agency stated in the preamble to the NHSM final rule, NHSMs with an energy value greater than 5,000 Btu/lb, as fired, are considered to have a meaningful heating value (see 76 FR 15541, March 21, 2011). Thus, we believe that the processed biosolids meet the second legitimacy criterion. You also noted that enough energy will be recovered from the use of this fuel to provide 3.5 percent of RRPP's total fuel needs displacing 91,200 tons of coal per year.

Comparability of Contaminant Levels

Regarding the third legitimacy criterion, your letter requested confirmation that the processed biosolids contain contaminants at levels comparable to or lower than levels found in coal. While we could not evaluate the actual processed biosolids—because the DTEES Biosolids Plant does not yet exist—we did evaluate oven-dried biosolids samples collected from the DWSD wastewater treatment plant as a proxy, which you indicate would be representative of the processed biosolids that will be generated by the DTEES Biosolids Plant. You submitted DWSD analytical data measuring levels of 15 elemental contaminants[3], as well as total halogens, as part of your August 16, 2011 letter and more recent data in a follow-up email on January 11, 2012.

We have prepared the enclosed table "Comparison of DTEES Dried Biosolids to Coal" to compare the analytical data you submitted for your NHSM to data for coal in our "Contaminant Concentrations in Traditional Fuels: Tables for Comparison" document. [4,5,6] For all

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[3] EPA has issued a proposed rule that amends the definition of contaminants in the final NHSM rule. The proposal revises the definition to add elemental precursors to pollutants listed in Clean Air Sections 112(b) and 129(a)(4) that form during combustion, including these 15 elemental contaminants identified in the data submittal (see 76 FR 80471).

[4] *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011* can be found at www.epa.gov/epawaste/nonhaz/define/index.htm.

contaminants other than nitrogen, straightforward comparisons for individual contaminants reveal NHSM levels that are lower than or comparable to those in coal. Regarding contaminant levels reported for fluorine, EPA notes that previous data submitted by DTEES in August 2011 indicated levels of 560 mg/dry kg based on analyses performed on one sample in 2009. Believing this one data point not to be representative of the levels of fluorine in your materials, you collected additional data in January 2012 and submitted this information to the Agency. New data submitted indicates fluorine levels of 195 mg/dry kg -- the highest fluorine concentration of analyses found in 3 samples taken in January 2012. Such levels of 195 mg/dry kg are comparable to the fluorine levels listed for coal (ND- 178 ppm) as indicated in the enclosed table.[7]

Regarding nitrogen, the processed biosolids have somewhat higher levels of total nitrogen than coal. However, as you argue in your September 9, 2011 letter, total nitrogen is not an appropriate way to assess this contaminant—*in your specific situation*—that will form NOx during combustion. Specifically, you note that ammonia and organic nitrogen, which will be rapidly converted into ammonia early in the combustion process, should not be considered as contaminants provided the combustion unit has a Low NOx firing system (i.e., Low NOx burners with Overfire Air). You also state that the majority of nitrogen in the processed biosolids is in fact ammonia or organic nitrogen. Due to the oxygen-deficient nature and flame temperatures characteristic of Low NOx firing systems, introducing ammonia into the combustion chamber via the processed biosolids will actually *reduce* NOx emissions. This would happen as the ammonia reacts with existing NOx—always present in some amount due to nitrogen's presence in air—to form nitrogen gas and water. As such, we agree that total nitrogen is not an appropriate contaminant to consider for your processed biosolids, but this finding only applies in situations where the combustion unit receiving the fuel is equipped with a Low NOx firing system. This is the case at RRPP.

As discussed in the previous two paragraphs and the attached table, the processed biosolids meet the contaminants legitimacy criterion when compared to coal. This conclusion presumes that additional contaminants for which the biosolids were not tested are present at levels comparable to or lower than those in the appropriate traditional fuel, based on your knowledge of the material.

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[5] EPA notes that the contaminant values listed in the *Contaminant Concentrations in Traditional Fuels: Tables for Comparison* document for coal may be revised in the future based on the availability of new or additional data. Any future revisions to the values will not impact the conclusions made in this letter; the values are based upon the data that is available at the time EPA responds to a request.

[6] You may use other data on the contaminant levels in traditional fuels in determining whether the levels are comparable to those in DTEES' processed biosolids. That is, other data on the level of contaminants in traditional fuels that your company has or may become aware of may also be considered in determining whether the level of contaminants in DTEES' dried and pelletized biosolids are comparable to those in the traditional fuel that the combustion unit is designed to burn.

[7] As discussed in the final NHSM rule, the comparable to or lower than standard means any contaminants present in the NHSM that are within a small acceptable range, or lower than the contaminant in the traditional fuel. An example of a small acceptable range is given as an NHSM containing 500 ppm lead, while the traditional fuel burned in the unit contains 475 ppm lead. (76 FR 15523). As indicated in the enclosed table, reported fluorine and lead levels in the processed biosolids compared to coal within a small acceptable range.

<u>Conclusion</u>

Overall, based on the information provided, we believe that the processed biosolids that DTEES will generate through the Detroit Biosolids Project, as described in your letters, meet both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 Part 241 regulations.

If you have any other questions, please contact Kenneth Dixon of my staff at 703-308-1848.

Sincerely,

James R. Berlow, Director
Program Implementation and Information Division

Enclosure

Enclosure

Comparison of DTEES Dried Biosolids to Coal

Contaminant	Units[1]	Dried Biosolids[2]	Coal[3]	Result of Comparison
Antimony (Sb)	ppm	4.3 - 5.6	ND - 10	Lower than coal
Arsenic (As)	ppm	0.8 - 10.1	ND - 174	Lower than coal
Beryllium (Be)	ppm	0 - 1.8	ND - 206	Lower than coal
Cadmium (Cd)	ppm	6.1 - 17.0	ND - 19	Lower than coal
Chromium (Cr)	ppm	74.7 - 140.0	ND - 168	Lower than coal
Cobalt (Co)	ppm	5.4 - 22.5	ND - 25.2	Lower than coal
Lead (Pb)	ppm	31.2 - 153.3	ND - 148	Comparable to coal
Manganese (Mn)	ppm	87.9 - 136	ND - 512	Lower than coal
Mercury (Hg)	ppm	0.4 - 1.1	ND - 3.1	Lower than coal
Nickel (Ni)	ppm	27.7 - 122.0	ND - 730	Lower than coal
Selenium (Se)	ppm	3.0 - 29.4	ND - 74.3	Lower than coal
Sulfur (S)	ppm	5100 - 6200	740 - 61,300	Lower than coal
Chlorine (Cl)	ppm	1,047	ND - 9,080	Lower than coal
Fluorine (F)	ppm	195	ND - 178	Comparable to coal
Total Halogens	ppm	1,670	at least 9,080	Lower than coal
Total Nitrogen (N)	ppm	50,300 - 60,700	13,600 - 54,000	See "Comparability of Contaminant Levels" section of text for explanation.

Notes:

1. All contaminant analyses—biosolids and coal—are on a dry weight basis.
2. DWSD BIOSOLIDS RANGE Data is from Detroit Water and Sewerage Department's (DWSD) monthly sampling, per DWSD Residual Management Program. The samples were obtained from three separate sources (24 sample analyses, sampling Period May 2008 through January 2009). Results were obtained by Test Method EPA SW 846-6010A. Chlorine and Fluorine data was obtained from 3 individual sample analyses performed in January 2012; Data for Cobalt, Manganese and Antimony was obtained from DWSD's quarterly duplicate sampling (8 samples for four quarters of year 2003).
3. Coal data taken from EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, D.C. 20460

JUN 4 2014

OFFICE OF
SOLID WASTE AND
EMERGENCY RESPONSE

Mr. Timothy Kasmoch
N-Viro International Corporation
2254 Centennial Road
Toledo, Ohio 43617

Dear Mr. Kasmoch:

In your letter of January 18, 2013, you request confirmation from the U.S. Environmental Protection Agency (EPA) that N-Viro International's N-Viro Fuel® is a non-waste fuel when burned in combustion units in accordance with the requirements in 40 CFR part 241.3(b)(4). To be designated as a non-waste fuel under that section, the rule requires that discarded non-hazardous secondary material (NHSM) undergo processing as defined in 40 CFR 241.2. Also, after processing, the NHSM must meet the legitimacy criteria for fuels in 40 CFR 241.3(d)(1). Based on the information provided in your letter, and follow-up correspondence and conference calls, we believe the N-Viro Fuel® produced by N-Viro International and burned in coal-fired combustion units for energy recovery would constitute a non-waste fuel under 40 CFR part 241 when substituting for 20% or less of the coal fuel required to operate the combustion unit. The remainder of this letter provides the basis for our position. *If there is a discrepancy in the information provided to us, it could result in a different interpretation.*

A non-waste determination under 40 CFR Part 241 does not preempt a state's authority to regulate a non-hazardous secondary material as a solid waste. Non-hazardous secondary materials may be regulated simultaneously as a solid waste by the state, but as a non-waste fuel under 40 CFR Part 241 for the purposes of determining the applicable emissions standards under the Clean Air Act for the combustion unit in which it is used.

Processing

Processing is defined in 40 CFR 241.2 as operations that transform discarded NHSM into a non-waste fuel or non-waste ingredient, including operations necessary to: remove or destroy contaminants; significantly improve the fuel characteristics (e.g., sizing or drying of the material, in combination with other operations); chemically improve the as-fired energy content; or improve the ingredient characteristics. Minimal operations that result only in modifying the size of the material by shredding do not constitute processing for the purposes of the definition.

The determination of whether a particular operation or set of operations constitutes sufficient processing to meet the definition in 40 CFR 241.2 is necessarily a case-specific and fact-specific determination. This determination applies the regulatory definition of processing to the specific discarded material(s) being processed, as described in correspondence and supporting materials, taking into account the nature and content of the discarded material, as well as the types and extent of the operations performed on it. Thus, the same operations may or may not constitute sufficient processing under the regulation in a particular circumstance, depending on the material being processed and the specific facts of the processing. In some cases, certain operations will be sufficient to "transform discarded non-hazardous secondary material into a non-waste fuel," and in other cases, the same operations may not be sufficient to do so.

In your letter, in a subsequent email dated May 3, 2013, and follow-up conference calls,[1] you state that N-Viro International processes various blends of biosolids from multiple waste water treatment facilities to produce N-Viro Fuel®.[2] Specifically, you indicate that the biosolids are first screened for debris (i.e., inorganic grit and plastics) and dewatered prior to arrival at your facility.[3] After receipt and inspection of the material at the facility, any additional debris (i.e., plastics, large solids) still remaining will be removed by facility personnel. The dewatered biosolids are then mechanically mixed in measured amounts with materials, referred to as "Admixtures," (e.g., fly ash, cement kiln dust, lime kiln dust, or lime),[4] which react with the moisture in the dewatered biosolids to elevate the pH and generate heat for disinfection purposes.[5] In addition, material exiting the drier—finished product— is reintroduced during the mixing phase as a recycle function in order to reduce the particle size and increase the total percent solid, as well as boost the organic content and fuel value of the N-Viro Fuel®. After thoroughly mixing the biosolids and "Admixtures," the blend is then conveyed through a single pass rotary drum dryer. The dryer thermally evaporates water to help raise the overall heating value of the product fuel as well as other contaminants, such as nitrogen and sulfur that are contained in the biosolids.[6]

According to the information you provided, as the blend exits the rotary drum dryer, the blend then enters a multi-stage cyclonic separation system. The mixing and drying process eliminates large or oversize particles, while the cyclone separation system separates the desired fuel into a size similar to pulverized coal. The smallest particles are removed by subsequent cyclones or a venturi scrubber designed to capture fines and return them to the mixer (as discussed above) for remixing to improve product uniformity. The remixing enhances the efficiency of the drying system, maximizes heating value while sending on the best sized material as finished product. Finished fuel will be screened and/or inspected to ensure no foreign debris is present. The final product, which is set to have a final solids

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[1] May 3, 2013 email from Bob Bohmer to George Faison and Mike Svizzero. Conference calls were held on May 3, 2013 and August 28, 2013.

[2] In the material provided to EPA, you indicate that animal manure may also be used as feedstock to produce N-Viro Fuel®. This letter only addresses N-Viro Fuel that is produced from biosolids.

[3] As noted in June 4, 2010 proposed NHSM rule, EPA does not consider dewatering, by itself, to meet our definition of adequate or sufficient processing. For example, dewatering sewage sludge would likely be required processing as part of normal waste management activities (*e.g.*, prior to landfilling, or prior to burning the sludge for disposal in an incinerator). As such, we do not view dewatering alone to be sufficient processing to convert discarded materials into non-waste fuel products.

[4] Approximately 2 to 10 percent of Admixture is used depending on the characteristics of the material and the admixture used.

[5] While pathogens are not included as a contaminant identified in 40 CFR Part 241, you indicate that this process would also create a material that meets or exceeds Class A under the 40 CFR part 503 regulations for pathogens.

[6] While not a factor in determining whether the material has been sufficiently processed, we note that air control equipment will treat exhaust air from the dryer in a multi-stage process. The treatment will remove particulates through cyclone separation, treat ammonia and amines in the first stage packed bed scrubber, and reduce hydrogen sulfides in the second stage packed bed scrubber. The process will also spray odor masking chemicals in the final containment area.

content of between 75 and 95 percent, is granular in appearance and has less volume and weight than the original biosolids.

Regarding the use of "Admixtures," you also state that the addition of "Admixtures" modifies the ignition profile of N-Viro Fuel® making it more compatible in the boiler than simply dried biosolids. As dried biosolids have a very low ignition temperature making their use in commercial power units problematic, you indicate that this patented process modifies the ignition profile of N-Viro Fuel® to more closely resemble the ignitability of coal. In addition, the presence of oxides of calcium in the "Admixtures" makes calcium hydroxide available for SO_x reduction when the fuel is combusted.

Based on this description—that is, removal of contaminants (i.e., removal of plastics, reduction in heavy metals via grit removal, as well as other contaminants in the drier) and improvement of its fuel characteristics (i.e., removal of large solids and grit, removal of water to improve the as-fired energy content, addition of Admixtures to improve ignition, and sizing of the material to allow it to be handled and fed to the boiler "as is"), we believe the process used to produce N-Viro Fuel ® meets the definition of processing in 40 CFR 241.2, and thus, transforms the dewatered biosolids into a non-waste fuel provided it meets the legitimacy criteria.

As noted in your letter of January 13, 2013 and follow-up calls, tests to determine impacts on performance, emissions, and byproduct constituents were based on a 10% or 20% substitution of N-Viro Fuel® for the primary fuel for which it substitutes—coal. Accordingly, the determination that N-Viro Fuel® would constitute a non-waste fuel under 40 CFR part 241 is predicated on a substitution of N-Viro Fuel® of 20% or less of the coal fuel required for the combustion unit.

<u>Legitimacy Criteria</u>

Under 40 CFR 241.3(d)(1), the legitimacy criteria for fuels include: 1) management of the material as a valuable commodity based on the following factors—storage prior to use must not exceed reasonable time frames, and management of the material must be in a manner consistent with an analogous fuel, or where there is no analogous fuel, adequately contained to prevent releases to the environment; 2) the material must have a meaningful heating value and be used as a fuel in a combustion unit that recovers energy; and 3) the material must contain contaminants at levels comparable to or less than those in traditional fuels which the combustion unit is designed to burn.

Manage As A Valuable Commodity

Regarding the first criterion, N-Viro Fuel® is stored on-site in a temporary indoor curing area, silo or bunker so that the material is not exposed to the outside atmosphere. Within a short time (hours or days), the N-Viro Fuel® will be conveyed or trucked to the end user, making sure that such material is not exposed to the environment. Once received by the power plant, it will be blended with other solid fuels of similar consistency and BTU content in the Active Fuel Storage Building. The mixed fuel will then be processed and burned as fuel in a circulating fluidized bed boiler.

Based on this information, the N-Viro Fuel® is managed as a valuable commodity and storage does not exceed a "reasonable time frame" as discussed in the NHSM final rule (40 CFR 241.3(d)(1)(i)(A).[7,8]

Meaningful Heating Value and Used As A Fuel to Recover Energy

Regarding the second legitimacy criterion, you indicate that the N-Viro Fuel® has an as-fired heating value of between 5,500 and 6,000 Btu/pound and will be used as a fuel in a combustion unit that recovers energy. As the Agency stated in the preamble to the NHSM final rule, NHSMs with an energy value greater than 5,000 Btu/lb, as fired, are considered to have a meaningful heating value (see 76 FR 15541, March 21, 2011). Thus, we believe that N-Viro International's N-Viro Fuel® meets the second legitimacy criterion.

Comparability of Contaminant Levels

Regarding the third criterion on contaminant levels, your letter requests confirmation that the N-Viro Fuel® meets the contaminant legitimacy criterion when compared to coal, the traditional fuel for which the combustion unit is designed to burn. In the enclosure to your January 2013 letter, you compared contaminant data for N-Viro Fuel® to contaminant data for coal as outlined in the "Contaminant Concentrations in Traditional Fuels: Tables for Comparison."

A direct contaminant-to-contaminant comparison, based on the information provided in your enclosure, is presented in Table 1. As noted in footnote a, the table compares samples of both digested and undigested biosolids that have been processed into N-Viro Fuel®. Based on this comparison, all contaminants in N-Viro Fuel® are comparable to or lower than those contaminants in coal, with the exceptions of manganese and fluorine. One of seven reported manganese values was higher than typically found in coal, while two of five reported fluorine values were higher than typically found in coal.

The EPA previously stated that for the purposes of contaminant comparisons, it may be appropriate to group contaminants sharing similar physical and chemical properties that influence behavior in the combustion unit prior to the point where emissions occur. Although not included in the Agency's sample approach,[9] grouping of low-volatile metals and the total halogens chlorine and fluorine would be appropriate as contaminants within each of these groups share key physical and chemical properties and would be expected to behave similarly in a combustion unit prior to the point where emissions occur. For example, a significant portion of low-volatile metals can be expected to remain in the bottom ash after combustion relative to other contaminants. The halogens chlorine and fluorine are highly reactive and form acid gases when bonded with hydrogen in the combustion chamber. Nevertheless, there may be circumstances in which grouping of low-volatile metals and the total halogens chlorine and fluorine would not be appropriate and the EPA will evaluate each instance on a case-by-case basis.

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[7] As discussed in the NHSM final rule (76 FR 15520) "reasonable time frame" is not specifically defined as such time frames vary among the large number of non-hazardous secondary materials and industry involved.

[8] Regarding the management of N-Viro Fuel and the type of boiler design at the end user, the information provided addresses the Scrubgrass Generating Plant, an 80 megawatt waste coal plant located in Kennerdell, Pennsylvania. To the extent that the N-Viro Fuel is sent to another power plant, no information was provided as to how the N-Viro Fuel will be managed or the boiler technology used and thus, this letter does not address this aspect of the legitimacy criteria at other end users.

[9] See 78 FR 9146.

Enclosed, Table 2 provides grouping data for a comparison of low-volatile metals (including manganese), and Table 3 provides grouping data for a comparison of total halogens (including fluorine). The data show that, for each of the groups of contaminants, the range of the totals present in N-Viro Fuel® is within the range found in coal. This conclusion assumes that N-Viro Fuel® was tested for any constituents expected to be present. Additional constituents for which N-Viro Fuel® were not tested must, as is the case for those tested, be present at levels comparable to or less than those in coal, based on your knowledge of the material.

Conclusion

Overall, based on the information provided in your letter, we believe the facts indicate that N-Viro Fuel® meets both the processing definition and the legitimacy criteria outlined above. Accordingly, we would consider this NHSM a non-waste fuel under the 40 CFR Part 241 regulations when substituting for 20% or less of the coal fuel required to operate the combustion unit.

If you have any other questions, please contact George Faison of my staff at 703-305-7652.

Sincerely,

Betsy Devlin

Betsy Devlin, Director
Materials Recycling and Waste Management Division
Office of Resource Conservation and Recovery

Enclosures

cc: John Armstead
EPA Region III, Land and Chemicals Division

Margaret Guerriero
EPA Region V, Land and Chemicals Division

Enclosure

Table 1. Data Supplied by N-Viro International Corporation

Contaminant	N-Viro Fuel® N-Viro Fuel® ® Contaminant Levels and Heating Value[a]										Coal Range[b]	Comparison Results
	Sample 1 Undigested	Sample 1 Digested	Sample 2 Undigested	Sample 3 Digested	Sample 4 Digested	April 2011 Composite	April 2009 Composite	Feb 2012 Test A	Feb 2012 Test B	Max		
Metal Elements (ppm - dry basis)												
Antimony	<5.76	<6.88	<10.9	<10.1	<5.63					<10.9[c]	ND - 10	Comparable. Highest detection limits slightly above range.
Arsenic	<5.76	<6.88	14.8	15.7	<5.63	29.4	<5			29.4	ND - 174	Within range.
Beryllium	1.26	1.42	<0.00820	0.534	1.46		<5			1.46[d]	ND - 206	Within range.
Cadmium	0.587	0.722	0.897	1.35	0.72	1.95	<5			1.95[e]	ND - 19	Within range.
Chromium	16	19.3	12.9	47.9	17.9	23.5	30			47.9	ND - 168	Within range.
Cobalt	4.38	4.53	3.27	4	4.41					4.53	ND - 25.2	Within range.
Lead	8.66	8.55	18.2	62.3	10.5	46.3	<5			62.3	ND - 148	Within range.
Manganese	54.3	52.8	609	384	64	309	253			609	ND - 512	One sample higher than coal range.
Mercury	0.3982	0.5577	0.7375	0.6761	0.3334	1.9	0.227			1.9	ND - 3.1	Within range.
Nickel	14	16.7	14.4	24.3	16.1	32.1	110			110	ND - 730	Within range.
Selenium	7.61	8.82	<10.9	<10.1	8.37	7.24	<5			8.82[f]	ND - 74.3	Within range.
Non-metal Elements (ppm - dry basis)												
Chlorine	6,740	7,551	2,728	2,329	5,002		3,542			7,551	ND - 9,080	Within range.
Fluorine	130.5	177	483.6	159.7	390.8					483.6	ND - 178	Two samples higher than coal range.
Nitrogen	32,250	33,340	36,850	34,380	28,980	22,054				36,850	13,600 - 54,000	Within range.
Sulfur	13,900	13,000	13,800	14,700	14,500	22,530				22,530	740 - 61,300	Within range.
Volatile Organic Compounds (VOC) (µg/kg)												
Benzene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	ND - 38,000	Within range.
Ethylbenzene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	700 - 5,400	Lower than coal range.
Styrene	<55.3	<54.3	<4.86	<5.41	<47.9					<55.3[c]	1,000 - 26,000	Lower than coal range.
Toluene	<55.3	<54.3	13.9	29.4	<47.9					29.4[g]	8,600 - 56,000	Lower than coal range.
Xylenes	<55.3	<54.3	4.92	16.1	<47.9					16.1[g]	4,000 - 28,000	Lower than coal range.
Heating Value												
BTU/lb	5,580	4,510	5,260	4,870	4,350		5,017	6,099	6,097			

Notes:

a. Data provided by N-Viro International Corporation on January 18, 2013. Samples include both digested sludges (sludges that have undergone anaerobic digestion) and undigested sludge.
b. Ranges for Coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011,* available at www.epa.gov/epawaste/nonhaz/define/index.htm.
c. All samples were below detection limits, so the actual value (if known) would be less than 10.9 ppm and would be comparable to the range of coal.
d. Highest detection limit was 5 ppm.
e. Detection limit was 5 ppm.
f. Highest detection limit was 10.9 ppm, but the sample was below the detection limit.
g. Highest detection limit was 55.3 ppm, but the sample was below the detection limit.

Table 2. Contaminant Comparison, Low-Volatile Metals (LVM) Group

Low Volatile Metal[a]	Units	Range	
		N-Viro Fuel® ®[b]	Coal[c]
Antimony (Sb)[d]	ppm	ND	ND - 10
Arsenic (As)	ppm	ND - 29.4	ND - 174
Beryllium (Be)	ppm	ND - 1.46	ND - 206
Chromium (Cr)	ppm	12.9 - 47.9	ND - 168
Cobalt (Co)	ppm	3.27 - 4.53	ND - 30
Manganese (Mn)	ppm	52.8 - 609	ND - 512
Nickel (Ni)	ppm	14 - 110	ND - 730
Total LVMs [e]	ppm	<101 - 665	ND - 767

Notes:

a. Low-volatile metals as identified in 40 CFR 63.1219(e)(4)—National Emission Standards for Hazardous Air Pollutants from Hazardous Waste Combustors.

b. Based on data provided by N-Viro International Corporation on January 18, 2013. Some LVMs included in these averages and totals were not detected. In these cases, the detection limit value was used to calculate averages and totals, and the results are denoted with a "<" symbol.

c. Data for coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.

d. All samples were below detection limits.

e. The high and low ends of each individual metal's range do not necessarily add up to the total LVM range. This is because maximum and minimum concentrations for individual metals do not always come from the same sample.

Table 3. Contaminant Comparison, Total Halogens Group

Halogen	Units	Range	
		N-Viro Fuel®[a]	Coal[b]
Chlorine	ppm	2,329 - 7,551	ND - 9,080
Fluorine	ppm	130.5 - 483.6	ND - 178
Total Halogens[c]	ppm	2,489 - 7,728	ND - 9,080

Notes:

a. Represents data provided by N-Viro International Corporation on January 18, 2013.

b. Data for coal from a combination of EPA data and literature sources, as presented in EPA document *Contaminant Concentrations in Traditional Fuels: Tables for Comparison, November 29, 2011*, available at www.epa.gov/epawaste/nonhaz/define/index.htm.

c. The high and low ends of each individual halogen's range do not necessarily add up to total halogens range. This is because maximum and minimum concentrations for individual halogens do not always come from the same sample.

Jeff Moss

From: Commerford Peter <Peter.Commerford@andritz.com>
Sent: Monday, March 20, 2023 10:36 AM
To: Jeff Moss; bart.lynam@renufuel.com
Cc: Erika Schuyler
Subject: RE: King County Biosolids Proposal Additional Data Request
Attachments: Attachment for Consor's Question 4.pdf; GHG Analysis for Biosolids Drying 031923.xls

Jeff
Attached is the Attachment for Q4. (The PDF tabulation was compiled from the spreadsheet to be more printer – friendly)
Note that the data referred to in Question 13 and our response came from an earlier readout from DNRP, but the data used in the current spreadsheet comes from an email received from Drew Thompson on 3/17, as noted
Thanks
Peter Commerford

From: Commerford Peter
Sent: Friday, March 17, 2023 4:38 PM
To: Jeff Moss <Jeff.Moss@consoreng.com>; bart.lynam@renufuel.com
Cc: Erika Schuyler <Erika.Schuyler@consoreng.com>
Subject: RE: King County Biosolids Proposal Additional Data Request

Good afternoon Jeff,

We converted the Excel sheet to a Document and have it attached with the responses from our Biosolids Partnership Team for your consideration. Note that the attachment referred to in Q4 is still under preparation, and we expect to have it for you Monday morning.

Thanks,

Peter Commerford
ANDRITZ
817-271-2855

From: Jeff Moss <Jeff.Moss@consoreng.com>
Sent: Friday, March 3, 2023 2:48 PM
To: bart.lynam@renufuel.com
Cc: Erika Schuyler <Erika.Schuyler@consoreng.com>; Commerford Peter <Peter.Commerford@andritz.com>
Subject: King County Biosolids Proposal Additional Data Request

Hello Bart,

Please find attached the data request that Consor has generated following our initial review of the draft revised proposal. We look forward to receiving additional information to assist with our review. As a reminder, the project schedule assumes a two week or less response time.

Best wishes,

-Jeff

Jeff Moss, **PE** (He/Him/His)
PROFESSIONAL ENGINEER
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consor

consoreng.com

ReNuFuel

Attachment for Question 4
Biosolids Sludge to Pellet GHG Emissions

This tabulation provides a "gate-to-gate" summary of greenhouse gases emissions estimated for the Sludge to Pellet production facility at the Metro South Plant. Primary assumptions are described on the Notes sheet.

Summary	**Scope 1** (MT CO2e) Direct	**Scope 2** (MT CO2e) Purchased	**Net Scope 1 + 2**
2027			
Electric boiler, Andritz dryer, odor control	-0.1138	0.0923	-0.0214
2037			
Electric boiler, Andritz dryer, odor control	0.0000	0.0000	0.0000

Notes

This report follows the most recent The Climate Registry's General Reporting GHG Protocol version 3.0 (May 2019) (Very similar to WRI protocol).https://theclimateregistry.org/registries-resources/protocols/
and default emission factors from TCR May 2022 https://theclimateregistry.org/registries-resources/protocols/

Timing

Although it would be preferable if construction could begin earlier, to be conservative on the time it takes to complete bidding and contracting, it is assumed that the dryer facility could begin construction 1st qtr 2025 and would take 18 months to complete. The first full year of operation would be 2027. If the expected initial operation contract is for 20 years, the mid-point year would be 2037.
The facility is in the Puget Sound Energy (PSE) service area. Its 2022 final Clean Energy Implementation Plan is currently in an adjuticative process with the Utilities and Transportation Commission. PSE proposes to be 63% renewable energy by 2025 and 100% by 2030.
https://www.cleanenergyplan.pse.com/
The transition from 2025 to 2030 is not described but can be assumed to be linear. This suggests PSE electric supply would be 78%.renewable energy in 2027 In 2027 the remainder would be fossil gas combustion. Electric supply in 2037 would be 100% renewable energy
Facility availability 99%
Annual hours of operation 8672 hours
The organizational boundaries and assumptions for this report are .... Facility gate-to-gate
Operating emissions from the point of receipt of digested sludge from the three King County wastewater treatment plants to the point of discharge of the dried biosolids in bulk to transport trucks of/to final user
The TCR protocol catalogues emissions as Scope 1, Scope 2 and Scope 3
Scope 1 .... Direct emissions within the project boundaries and under the ownership and control of the project
Scope 2 .... Indirect emissions within the project boundaries from the supply chain not under the direct control of the project. Most commonly this is electricity,
....
Scope 3 .... Optional reporting of indirect emissions that are auxiliary to the project, such as employee commuting emissions, up/downstream transportation and distribution by others, fuel and energy related emissions - such as biogenic emissions - not reported as Scope 1 or Scope 2, and other life cycle emission calculations, such as carbon sequestration. This presentation does not include any Scope 3 GHG emissions.
No calculation is made for the value of natural gas replaced in 2037 as the status of natural gas in 2037 is not yet determined

Equivalent CO_2 (CO_2e)
Emissions of CH_4 are calculated as equivalent to 25 times the same mass of CO_2 (IPCC AR4 2007)
Emissions of N_2O are calculated as equivalent to 298 times the same mass of CO_2 (IPCC AR4 2007)These are Scope 1 only for combustion on site. For combustion by a utility they will be included in the fuel combustion CO_2e

Abbreviations and conversion factors

SP .... South King County wastewater treatment plant
WP .... West Point King County wastewater treatment plant
BW .... Brightwater King County wastewater treatment plant
Ton .... 2000 lbs
MT .... metric ton (2200 lbs)
KWh .... kilowatt hour = 3409.5 British Thermal Units (BTU)
Hph....... .... horsepower hours = 0.7457 KWh
Therm... .... 99,976.1 BTU
Annual hours of operation...................................... .... 8672 hrs
CO2e of 1 kWh of electricity from Puget Sound Energy...... 3.2E-09 MT CO2e/kWhr (2027)
CO2e of 1 kWh of electricity from Puget Sound Energy...... 0.00000 MT CO2e/kWhr (2037)
CO2e of natural gas combined cycle combustion turbine 3.70E-06 MT CO2e/MMBTU (TCR default Table1.5) Includes system efficiency
CO2e of natural gas combusted in boiler .... 1.80E-06 MT CO2e/MMBTU (TCR default Table1.5)

Sources of data

The Climate Registry (TCR)
(1) King County Dept of Natural Resources
(2) MurraySmith report pg 33
(3) Andritz Separation Inc.

ReNuFuel

Biosolids Sludge to Pellet GHG Emissions - Facility			Scope 1 (MT CO2e)	Scope 2 (MT CO2e)
Conveyance of digested sewage sludge from SP to facility				
Quantity of annual wet sludge 2027	148,528	wet tons/yr (2)		
Quantity of annual wet sludge 2037	169,629	wet tons/yr (2)		
% dry solids	23.80%	'(2)		
Distance of conveyor to plant	625	ft		
Power consumption 2027	7.5	kWhr/hr (3)		
Annual power consumption 2027	64,635	kWhr/yr		
Power consumption 2037	8.5	kWhr/hr		
Annual power consumption 2037	73,818	kWhr/yr		
PSE emission factor 2027	3.23E-09	MT CO2e/kWhr		0.0002
PSE emission factor 2037	0.0000	MT CO2e/kWhr		0.0000
Electricity for operation of Andritz dryer, associated fans, etc.				
Total annual wet sewage sludge 2027	148,528	wet tons/yr		
Andritz dryer motors, pumps, fans 2027	759	kWhr/hr (3)		
Total annual equipment power 2027	6,582,352	kWhr/yr		
Total annual wet sewage sludge 2037	169,629	wet tons/yr		
Andritz dryer motors, pumps, fans 2037	867	kWhr/hr (3)		
Total annual equipment power 2037	7,517,500	kWhr/yr		
PSE emission factor 2027	3.23E-09	MT CO2e/kWhr		0.0213
PSE emission factor 2037	0.0000			0.0000
Electricity for other operations within the facility				
Room air exhaust fans to odor control	1,084,050	kWhr/yr		
Area lighting, office, etc.	346,896	kWhr/yr		
PSE emission factor 2027	3.23E-09	MT CO2e/kWhr		0.0046
PSE emission factor 2037	0.0000			0.0000
Heat to the dryer provided electric boiler				
Average heat output required 2037	7.56 MM BTU/hr	MMBTU/hr		
Excess heat required for SP - winter 2037	0.43 MM BTU/hr	MMBTU/hr (1)		
Boiler sized to	9 MMBTU/hr	heat output (peak load)		
Electricity to power boiler 2027	1.92E+07	kWhr/yr (2)		
Electricity to power boiler 2037	2.19E+07			
PSE emission factor 2027	3.23E-09	MT CO2e/kWhr		0.0620
PSE emission factor 2037	0.0000	MT CO2e/kWhr		0.0000
Credit for SP natural gas combustion replaced by heat provided to SP from facility 2027				
Scaled natural gas used at SP 2027	52,683	therms/month (1)	-0.1138	
Heat value of natural gas	5,267	MMBTU/month		
Delivered heat value of steam	4846	MMBTU/month		
Excess natural gas required for SP for winter 2027	3,026	therms/month (1)		
Heat value of natural gas	303	MMBTU/month		
Delivered winter heat value of steam	278	MMBTU/month		
Natural gas combustion emission factor	1.80E-06	MT CO2e/MMBTU		

Biosolids Sludge to Pellet GHG Emissions - Facility			**Scope 1** (MT CO2e)	**Scope 2** (MT CO2e)
Operation of scrubbers/carbon bed for odor control				
Electricity for odor control equipment	1300860	kWhr/yr		
PSE emission factor 2027	3.23E-09	MT CO2e/kWhr		0.0042
PSE emission factor 2037	0.0000	MT CO2e/kWhr		0.0000
	Scope 1 total	2027	-0.1138	
	Scope 2 total	2027		0.0923
	Scope 1+2 total			-0.0214
	Scope 1 total	2037	0	
	Scope 2 total	2037		0.0000

ReNuFuel

Supporting Calculations

PSE emission factor						
	from PSE CETA report	GHG 2027 (MT/MMBTU)				
Coal	0%	0				
Renewables	78%	0				
Natural Gas	16%	5.750E-07	BPA purchase		Open Market	
Market	10%	3.649E-07	0.00%	coal		
BPA	4%	6.796E-09	84.69%	hydro		
Total		9.467E-07	2.96%	solar		
			0.00%	natural gas	100%	assume natural gas
			10.92%	nuclear		
		1.624E-07	4.39%	unspecified (assume natural gas)		
Annual Sludge to be treated (2)						
Year	Wet Tons					
2018	129537	2027	148528	ratio	1.14660773	
2050	197061	2037	169629	ratio	1.14206905	
Assume linier increase over time period						
% dry solids	23.8%					
Scaling natural gas demand from 2021-2022 to 2027						
2018	1	2022		137978	2027 ratop	1.0765
Conversion from MMBTU to kWhr						
1 BTU	0.0002931	kWhr				
1 MM BTU	293.071	kWhr				
PSE GHG	3.230E-09	MT/kWhr				

Daily average SP boiler gas use from King Co 3/17/23 for Jan 2020 to Jan 2022 1609 therms
Annual total 587,285
Recalculated for average total annual and excess winter load
Scaling natural gas demand from 2020-2021 (call it 2022) to 2027 by sludge quantities in years
2018 1 2022 137978 2027 ratio 1.0765

APPENDIX E

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APPENDIX E

Basis of Cost Estimation

Date:	May 20, 2022
Project:	King County Biosolids Class A Alternatives Analysis
To:	King County Council; King County WTD
From:	Patrick Davis, PE, Murraysmith
Reviewed By:	Miaomiao Zhang, PE, PMP, Murraysmith
Re:	Basis of Cost Estimation

Introduction

As part of the King County Biosolids Class A Alternatives Analysis, cost differences between two Class A biosolids management strategies have been evaluated. The baseline assumes 20 percent of King County's Class B biosolids will be hauled to a local compost facility for processing into Class A compost and then local beneficial reuse. The remaining 80 percent of Class B biosolids would be trucked to eastern and western Washington for land application. The second alternative comprises of wood gasification to power and heat a fluid bed drying system, which will create dry biosolid pellets. This alternative assumes one hundred percent of King County's biosolids are treated through this facility.

Both alternatives focus on the management of biosolids after Class B biosolids are generated at the three wastewater treatment plants. Since the digestion capacity improvement requirement at the individual wastewater treatment plants (WWTPs) will be the same for both alternatives, the costs associated with solids digestion improvements are not included in this estimate.

Capital Cost Estimation Methodology

Biosolids Partnership Proposal

Venture Engineering and Construction provided a cost estimate considering a two-phased approach to the project. The first phase assumes a facility with capacity for 85 dry tons per day. The second phase would add additional equipment bringing the capacity to 150 dry tons per day, which is the projected 2050 biosolids load. To maintain parity with the baseline, the costs associated with buildout are used in this estimation. The estimate included:

- Mechanical equipment and mechanical installation
- lump sums for civil and structural development and installation
- Lump sum electrical installation

The estimate that was provided had markups assuming a design build project. It is likely that this project will follow a typical design, bid, build methodology. The markups that Venture provided were not used in favor of the standard markups in King County's Waste Treatment Division (WTD) PRISM cost model. Further discussion of the project markups can be found below.

Baseline

The composting facility in the baseline is evaluated in a report by Brown and Caldwell titled *Class A Biosolids Technology Evaluation,* August 2020. In the report Scenario 4 assumes that all the solids from Brightwater WWTP will be processed to Class A through composting. This amounts to approximately 20 percent of the total biosolids produced from King County's three regional WWTPs. The costs for the composting facility in the baseline were taken directly from that report, validated, and marked up where appropriate.

Applied Markups

The same markups from WTD's PRISM cost model were applied to both alternatives. These markups include both direct construction markups and indirect costs stemming from the projects. The direct construction cost markups are as follows:

- General conditions 10%
- Contractor mobilization/demobilization 10%
- Overhead, and profit of 8%
- Insurance 1.5%
- Bonding 1.0%

In addition to the direct construction cost markups, additional direct and indirect construction costs were applied to both cost proposals. These markups include costs for local sales tax, engineering, legal, and administration, County labor costs, and various contingencies.

Operations and Maintenance Cost Estimation Methodology

Biosolids Partnership Proposal

The costs for operations and maintenance (O&M) were developed based on Murraysmith's interviews with other drying facilities to determine the required number of full-time equivalent (FTE) personnel and maintenance costs required for operation. The assumptions made for the O&M of the dryer facility are as follows:

- 24 FTEs to run the gasification, drying and power generation facility
- 9 FTEs required to haul biosolids, woody debris, and dried pellets.
- An average of $1.5M per year is to be spent on consumables for the facility (odor control chemicals, lubricants, replacement parts, modifications, etc.)

Baseline

In a similar vein to the capital costs, the O&M costs for the baseline composting facility are similar to the costs of composting in Scenario 4 developed by Brown and Caldwell. These numbers were validated, updated, and applied to this assessment. The main assumptions include:

- Approximately 18 FTEs to run the composting facility
- 4 FTEs required to haul biosolids, feedstock and compost
- 17 FTEs required to drive the Class B Loop biosolids trucks to eastern and western Washington

Lifecycle Cost Estimation Methodology

The yearly cost to own and operate each of the alternatives over their 20 year lifecycle was determined using Present Value method of valuation, which is calculated as follows:

$$PV = \sum \frac{C}{(1+i)^k}$$

The variable *i* represents the discount rate. The discount rate used was 5%, which is King County standard. The variable *k* represents the project lifecycle. In this case, 20 years is used. The variable C represents the yearly O&M cost.

The resulting calculation is then summed up over 20 years to represent the total cost to own and operate each of the alternatives over their full lifecycle.

Compiled Cost Estimate

The estimated cost for both alternatives are compiled below in Table 1. These represent the capital and O&M costs for both projects in 2022 dollars.

Table 1. Cost Estimate ($ million)

	Capital Costs	O&M Costs/yr	20 Year O&M KC PV	Total 20-year Lifecycle Cost
Baseline	$119.9	$15.2	$253.9	$373.8
Dryer Facility	$508.2	$12.8	$215.4	$723.6

The above cost estimate was prepared to American Association of Cost Engineers (ACCE) Class 5 estimate standards for planning-level evaluations with a range of -50 percent to +100 percent. The construction cost estimate is an opinion of cost based on information available at the time of the estimate. Final costs will depend on several factors including actual field conditions, actual material and labor costs, market conditions for construction, regulatory factors, schedule, and other variables.

This estimate reflects Murraysmith's professional opinion of accurate costs based on currently available information, and it is subject to change as the project design matures. Murraysmith has no control over variances in the cost of labor, materials, equipment; nor services provided by others, Contractor's means and methods of executing the work or of determining prices, competitive bidding or market conditions, practices, or bidding strategies. Murraysmith cannot and does not warrant or guarantee that proposals, bids, or actual construction costs will not vary from the costs presented as shown. See Attachment 1 for the detailed cost estimates.

Based on the above information, the O&M costs for the baseline condition are higher than the O&M costs for the drying system. The disparity in cost is largely based on the assumption that 80 percent of the biosolids are still trucked to Eastern and Western Washington. These costs account for approximately 60% of the total O&M costs for the baseline. The validity of the claim that the drying facility will save the County $1M dollars per year depends on several factors. If yearly O&M costs are evaluated in a vacuum, then, based on the above table, the dryer facility will cost less to operate year over year; however, the capital cost of the dryer facility is such that it pushes the total 20 year lifecycle cost to approximately two times the equivalent cost for the baseline.

Attachment

Attachment 1 – Detailed Construction, O&M and Lifecycle Cost Estimates

Estimate - AACEI Class 5

Project Name:	KC Class A Biosolids Tech Evaluation	**Date:**	5/11/2022
Location:	King County - South End, Site To be Determined	**Estimator:**	PMD
Description:	Gassification and Biosolids Drying Facility	**Version:**	Revision 01

DIRECT: SUBTOTAL CONSTRUCTION COSTS

Item No.	Item Description	Quantity	Units	Unit Cost	Item Cost
1	Site Prep	1	LS	$ 2,169,123	$ 2,169,123
2	Site Perimeter - Chain Link Fencing	4,496	LF	$ 30	$ 133,995
3	Water / Sewer / Electrical Services to Site	1	LS	$ 312,500	$ 312,500
4	Civil Install and Ancillary	1	LS	$ 3,380,405	$ 3,380,405
5	Structural Subtotal	1	LS	$ 14,099,535	$ 14,099,535
6	Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)	1	LS	$ 37,200,000	$ 37,200,000
7	Andritz Fluid Bed Dryers (3rd future train)	1	EA	$ 14,880,000	$ 14,880,000
8	EV Trucks (qty 3)	3	EA	$ 400,000	$ 1,200,000
9	HRSG & Turbine-Generator Systems (B&W / Elliott)	1	EA	$ 3,000,000	$ 3,000,000
10	Aries Downdraft Gasifiers (3 initial trains)	3	EA	$ 5,000,000	$ 15,000,000
12	Aries Downdraft Gasifiers (4th future train)	1	EA	$ 5,000,000	$ 5,000,000
13	Mechanical install	1	LS	$ 8,676,492	$ 8,676,492
14	Additional Mechanical Subtotal	1	LS	$ 37,176,156	$ 37,176,156
15	Electrical install	1	LS	$ 10,845,616	$ 10,845,616
				Construction Cost Markup	$ 46,687,516
				Subtotal Construction Costs	***$ 199,761,338***
				Allowance for Indeterminates (Design Allowance)	$ 49,940,334
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 249,701,672***
	DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS				
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 24,970,167
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 274,671,839***
				Construction Sales Tax	$ 27,467,184
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 302,139,023***
	DIRECT: SUBTOTAL OTHER CAPITAL CHARGES				
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 549,344
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 302,688,000***
	INDIRECT: NON-CONSTRUCTION COSTS				
				Design and Construction Consulting	$ 48,308,731
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 1,373,359
				Right-of-Way	$ -
				Misc. Service & Materials	$ 4,944,093
				Non-WTD Support	$ 2,334,711
				WTD Staff Labor	$ 26,239,272
				Subtotal Non-Construction Costs	***$ 83,200,166***
				Project Contingency	$ 115,766,560
				Initiatives	$ 6,551,308
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 205,518,034***
				TOTAL PROJECT COST	***$ 508,206,401***

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation		**Date:**		5/11/2022
Location:	King County - South End, Site To be Determined		**Estimator:**		PMD
Description:	Gassification and Biosolids Drying Facility		**Version:**		Revision 01

CONSTRUCTION COSTS

Item No.	Item Description	Quantity	Units	Unit Cost	Item Cost
1	**Site Prep**	**1**	**LS**	**$ 2,169,123.11**	**$ 2,169,123**
2	**Site Perimeter - Chain Link Fencing**	**4,496**	**LF**	**$ 29.80**	**$ 133,995**
3	**Water / Sewer / Electrical Services to Site**	**1**	**LS**	**$ 312,500.00**	**$ 312,500**
4	Site Perimeter - New Landscape	170,023	SF	$ 8.40	$ 1,428,194
5	Civil Install	1	LS	$ 1,952,210.70	$ 1,952,211
	Civil Install and Ancillary				**$ 3,380,405**
6	RC - Slab on Grade	1087	CY	$ 500.00	$ 543,500
7	RC - Walls	100	CY	$ 600.00	$ 60,000
8	RC - Elevated Slab	100	CY	$ 1,000.00	$ 100,000
9	Grout Pad	100	CY	$ 100.00	$ 10,000
10	CMU Building (for both drying and gasification buildings)	44000	SF	$ 250.00	$ 11,000,000
11	Structural Install	1	LS	$ 2,386,035.30	$ 2,386,035
	Structural Subtotal				**$ 14,099,535**
12	**Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)**	**1**	**LS**	**$ 37,200,000.00**	**$ 37,200,000**
13	**Andritz Fluid Bed Dryers (3rd future train)**	**1**	**EA**	**$ 14,880,000.00**	**$ 14,880,000**
14	Digester Heating Upgrades Equipment (HXs/Pumps)	1	EA	$ 1,000,000.00	$ 1,000,000
15	Drying Building	0	EA	$ 2,500,000.00	$ -
16	**EV Trucks (qty 3)**	**3**	**EA**	**$ 400,000.00**	**$ 1,200,000**
17	Truck Trailors (qty 3)	3	EA	$ 88,718.58	$ 266,156
18	Charging Station (qty 1)	1	EA	$ 60,000.00	$ 60,000
19	Truck Scale (qty 2)	2	EA	$ 250,000.00	$ 500,000
20	**HRSG & Turbine-Generator Systems (B&W / Elliott)**	**1**	**EA**	**$ 3,000,000.00**	**$ 3,000,000**
21	**Aries Downdraft Gasifiers (3 initial trains)**	**3**	**EA**	**$ 5,000,000.00**	**$ 15,000,000**
22	**Aries Downdraft Gasifiers (4th future train)**	**1**	**EA**	**$ 5,000,000.00**	**$ 5,000,000**
23	Wood Processing, Screening and Conveying (3 initial trains)	3	EA	$ 1,000,000.00	$ 3,000,000
24	Wood Processing, Screening and Conveying (1 future trains)	1	EA	$ 1,000,000.00	$ 1,000,000
25	Dryers (2/gasifier x 3 initial trains)	3	EA	$ 1,000,000.00	$ 3,000,000
26	Dryers (2/gasifier x 1 future trains)	1	EA	$ 1,000,000.00	$ 1,000,000
27	Inclined Inlet Conveyors w/ Metals Removal (3 initial)	3	EA	$ 250,000.00	$ 750,000
28	Inclined Inlet Conveyors w/ Metals Removal (1 future)	1	EA	$ 250,000.00	$ 250,000
29	Cooling Screw Conveyors (3/train x 3 initial trains)	3	LS	$ 1,500,000.00	$ 4,500,000
30	Cooling Screw Conveyors (3/train x 1 future trains)	1	LS	$ 1,500,000.00	$ 1,500,000
31	Product Conveyors (2/train x 3 initial trains)	3	LS	$ 200,000.00	$ 600,000
32	Product Conveyors (2/train x 1 future trains)	1	LS	$ 200,000.00	$ 200,000
33	Product Silos (3 initial)	3	EA	$ 500,000.00	$ 1,500,000
34	Product Silos (1 future)	1	SF	$ 500,000.00	$ 500,000
35	Truck Scale (qty 2)	2	SF	$ 250,000.00	$ 500,000
36	Thermal Oxidizer (future sized w/ turndown)	**1**	**LS**	$ 1,500,000.00	$ 1,500,000
37	Heat Recovery Exchangers (3 initial)	3	EA	$ 200,000.00	$ 600,000
38	Heat Recovery Exchangers (1 future)	1	EA	$ 200,000.00	$ 200,000
39	SCR System (TBD)	1	EA	$ 3,000,000.00	$ 3,000,000
40	Stack	1	EA	$ 250,000.00	$ 250,000
41	Cooling Towers System	1	EA	$ 4,000,000.00	$ 4,000,000
42	Electrical controls/SCADA/Power Dist.	**1**	**LS**	$ 5,000,000.00	$ 5,000,000
43	Fire Detection and Suppression	1	**LS**	$ 2,500,000.00	$ 2,500,000
44	**Mechanical install**	**1**	**LS**	**$ 8,676,492.46**	**$ 8,676,492**
	Additional Mechanical Subtotal				**$ 37,176,156**
45	**Electrical install**	**1**	**LS**	$ 10,845,615.57	$ 10,845,616
				Item Subtotal Construction Costs (Year 2022)	$ 153,073,822

DIRECT: CONSTRUCTION COST MARK-UPS

General Conditions	10%	1.1	$ 15,307,382.20
Mobilization/Demobilization	10%	1.1	$ 15,307,382.20
Overhead & Profit (OHP)	8%	1.08	$ 12,245,905.76
Insurance	1.5%	1.015	$ 2,296,107.33
Bonding	1.0%	1.01	$ 1,530,738.22
Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
		Item Subtotal Construction Costs (Year 2022)	$ 199,761,338
		Direct: Subtotal Construction Costs	***$ 199,761,000***

Estimate - AACEI Class 5							
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**			5/11/2022
Location:	King County - South End, Site To be Determined			**Estimator:**			PMD
Description:	ASP Composting Facility			**Version:**			Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS							
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**		**Item Cost**	
1	Primary Composting	44,018	SF	$	157	$	6,905,580
2	Secondary Composting	69,728	SF	$	125	$	8,747,068
3	Process/Maintenance Buildings	67,750	SF	$	75	$	5,081,231
4	Office/Administration Building	7,500	SF	$	150	$	1,125,000
5	Admin Parking, Roads, Truck Access, Maintenance Yard, Curing and Storage, Screening	178,153	SF	$	8	$	1,425,221
6	Dry Wood Storage	26,999	SF	$	25	$	674,963
7	Ponds and Collection System	111,409	SF	$	20	$	2,228,184
8	Equipment Purchases (ECS)	1	LS	$	1,955,000	$	1,955,000
9	Install Equipment Purchases (ECS)	1	LS	$	1,225,000	$	1,225,000
10	Site Preparation / Demolition	629,055	SF	$	1	$	933,091
11	Site Mass Grading (whole site using avg. of 2.5' of cut to fill)	58,246	CY	$	5	$	262,106
12	Water / Sewer / Electrical Services to Site	1	LS	$	250,000	$	312,500
13	Site Perimeter - Chain Link Fencing	4,496	LF	$	30	$	133,995
14	Site Perimeter - New Landscape	170,023	SF	$	8	$	1,428,194
					Construction Cost Markup	$	9,893,326
					Subtotal Construction Costs	***$***	***42,330,460***
					Allowance for Indeterminates (Design Allowance)	$	11,288,865
					Street Use Permit	$	-
					ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$***	***53,619,325***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS							
					Mitigation Construction Contracts	$	-
					Construction Change Order Allowance	$	5,644,432
					Material Pricing Uncertainty Allowance	$	-
					Subtotal Primary Construction Amount	***$***	***59,263,757***
					Construction Sales Tax	$	5,985,639
					Owner Furnished Equipment	$	2,825,000
					Outside Agency Construction	$	-
					Subtotal KC Contribution to Construction	***$***	***68,074,396***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES							
					KC/WTD Direct Implementation	$	-
					Misc. Capital Costs	$	124,178
					TOTAL DIRECT CONSTRUCTION COSTS	***$***	***68,199,000***
INDIRECT: NON-CONSTRUCTION COSTS							
					Design and Construction Consulting	$	14,228,182
					Other Consulting Services	$	-
					Permitting & Other Agency Support	$	310,444
					Right-of-Way	$	-
					Misc. Service & Materials	$	1,117,598
					Non-WTD Support	$	527,754
					WTD Staff Labor	$	6,941,389
					Subtotal Non-Construction Costs	***$***	***23,125,367***
					Project Contingency	$	27,482,780
					Initiatives	$	1,099,310
					TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$***	***51,707,457***
					TOTAL PROJECT COST	***$***	***119,906,031***

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	5/11/2022
Location:	King County - South End, Site To be Determined			**Estimator:**	PMD
Description:	ASP Composting Facility			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Primary Composting**	**44,018**	**SF**	$ 156.88	**$ 6,905,580**
2	Primary Compost Process Area	1	LS	$ -	$ -
3	**Secondary Composting**	**69,728**	**SF**	$ 125.45	**$ 8,747,068**
4	Secondary ASP Area	1	LS	$ -	$ -
5	**Process/Maintenance Buildings**	**67,750**	**SF**	$ 75.00	**$ 5,081,231**
6	Pre-process & Tip Building	44,821	SF	$ 75.00	$ 3,361,594
7	Maintenance Building	5,000	SF	$ 75.00	$ 375,000
8	Bagging Building	17,929	SF	$ 75.00	$ 1,344,638
9	**Office/Administration Building**	**7,500**	**SF**	$ 150.00	**$ 1,125,000**
10	**Admin Parking, Roads, Truck Access, Maintenance Yard, Curing and Storage, Screening**	**178,153**	**SF**	$ 8.00	**$ 1,425,221**
11	Admin Parking	2,500	SF	$ 8.00	$ 20,000
12	Roads	59,112	SF	$ 8.00	$ 472,896
13	Truck Access	26,893	SF	$ 8.00	$ 215,142
14	Maintenance Yard	8,964	SF	$ 8.00	$ 71,714
15	Screening Area	13,446	SF	$ 8.00	$ 107,571
16	Curing and Storage Area	67,237	SF	$ 8.00	$ 537,898
17	**Dry Wood Storage**	**26,999**	**SF**	$ 25.00	**$ 674,963**
18	**Ponds and Collection System**	**111,409**	**SF**	$ 20.00	**$ 2,228,184**
19	Contact Water Pond and Collection System	36,409	SF	$ 15.00	$ 546,138
20	Storm water Pond	75,000	SF	$ 5.00	$ 375,000
21	**Equipment Purchases (ECS)**	**1**	**LS**	$ 1,955,000.00	**$ 1,955,000**
22	Wood Grinder (mid-large Horizontal)	1	EA	$ 500,000.00	$ 500,000
23	Mixer System (ECS/LuckNow 2295)	2	EA	$ 260,000.00	$ 520,000
24	Screen (MultiStar L3 Type)	1	EA	$ 550,000.00	$ 550,000
25	Bagging Equipment (RotoChopper Go-Bagger 250)	2	EA	$ 60,000.00	$ 120,000
26	Radial Stacking Conveyors	3	EA	$ 195,000.00	$ 585,000
27	**Install Equipment Purchases (ECS)**	**1**	**LS**	$ 1,225,000.00	**$ 1,225,000**
28	Install Mixer System (ECS/LuckNow 2295)	2	EA	$ 520,000.00	$ 1,040,000
29	Install Bagging Equipment (RotoChopper Go-Bagger 250)	1	EA	$ 120,000.00	$ 120,000
30	Install Radial Stacking Conveyors	3	EA	$ 195,000.00	$ 585,000
31	**Site Preparation / Demolition**	**629,055**	**SF**	$ 1.48	$ 933,091
32	Demo Existing Building (1/4 of site size)	1,315,759	CF	$ 0.50	$ 657,879
33	Demo Existing Hard Surfaces (1/2 of site size)	314,528	SF	$ 0.75	$ 235,896
34	Demo Existing Landscape/Trees (1/4 of site size)	157,264	SF	$ 0.25	$ 39,316
35	**Site Mass Grading (whole site using avg. of 2.5' of cut to fill)**	**58,246**	**CY**	$ 4.50	**$ 262,106**
36	**Water / Sewer / Electrical Services to Site**	**1**	**LS**	$ 250,000.00	**$ 312,500**
37	**Site Perimeter - Chain Link Fencing**	**4,496**	**LF**	$ 29.80	**$ 133,995**
38	**Site Perimeter - New Landscape**	**170,023**	**SF**	$ 8.40	**$ 1,428,194**
				Item Subtotal Construction Costs (Year 2022)	$ 32,437,134
DIRECT: CONSTRUCTION COST MARK-UPS					
		General Conditions	10%	1.1	$ 3,243,713.38
		Mobilization/Demobilization	10%	1.1	$ 3,243,713.38
		Overhead & Profit (OHP)	8%	1.08	$ 2,594,970.71
		Insurance	1.5%	1.015	$ 486,557.01
		Bonding	1.0%	1.01	$ 324,371.34
		Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2022)	$ 42,330,460
				Direct: Subtotal Construction Costs	***$ 42,330,000***

Project: **King County Class A Biosolids Analysis**
Client: King County WTD
Project No.: 20-2900.07
Date: 5/25/2022

Unit Process - Biosolids Composting Facility

Item No.	Item		Unit	QTY	Unit Cost	Total
Compost Hauling and Transport						
1	Biosolids - local haul	Hauling Cost	$/yr	1	$262,293	$262,292.60
2	Biosolids - local haul	Fuel Cost (Diesel)	$/yr	1	$35,895	$35,895.31
3	Woodchips	Hauling Cost	$/yr	1	$341,348	$341,348.38
4	Woodchips	Fuel Cost (Diesel)	$/yr	1	$102,255	$102,255.10
			Subtotal			$741,791.39
Operations and Maintnence						
5	Composting	Operation and Maintenance	$/yr	1	$5,592,946	$5,592,945.99
6	Composting	Equipment Upgrades	$/yr	1	$80,000	$80,000.00
			Subtotal			$5,672,945.99
Electricity and Fuel Consumption						
7	Composting	Electricity Costs	$/yr	1	$143,101	$143,101.10
8	Composting	Fuel Consumption (Diesel)	$/yr	1	$450,045	$450,045.00
			Subtotal			$593,146.10
Class B Biosolids Land Application						
9	Land Application Eastern WA	Fuel Cost (Diesel)	$/yr	1	$9,988,835	$9,988,834.90
10	Land Application Western WA	Hauling Cost	$/yr	1	$1,432,195	$1,432,195.00
			Subtotal			$11,421,029.90
Revenue						
11	Woodchips	Tipping Fee	$/yr	1	-$880,000.00	-$880,000.00
12	Sales of Class A biosolids/Soil ammendment	Commercial	$/yr	1	-$1,046,000.00	-$1,046,000.00
13	Sales of Class A biosolids/Soil ammendment	Consumer	$/yr	1	-$982,000.00	-$982,000.00
14	Class B Land Application Eastern WA	Revenue	$/yr	1	-$250,553.00	-$250,553.00
15	Class B Land Application Western WA	Revenue	$/yr	1	-$122,461.00	-$122,461.00
						-$3,281,014.00
Construction Material & Labor Subtotal:						**$15,147,899.39**
Present Value in 2022 - WTD Discount Rate, 20 Year Lifecycle						**$253,924,558.08**
Present Value in 2022 - OMB Discount Rate, 20 Year Lifecycle						**$216,082,944.53**
Total Cost including 20 year PV						**$373,830,589.08**

Project: **King County Class A Biosolids Analysis**
Client: King County WTD
Project No.: 20-2900.07
Date: 5/25/2022

Unit Process - Biosolids Drying Facility

Item No.	Item		Unit	QTY	Unit Cost	Total
Hauling and Transport						
1	Vehical charging cost - Electricity		kWhr/yr	435558	$0.00	$0.00
2	Biosolids	Hauling Cost	$/yr	1	$1,415,071.47	$1,415,071.47
3	Biosolids	Fuel Cost (Diesel)	$/yr	1	$170,502.70	$170,502.70
4	Biomass Wood and Biochar	Hauling Cost	$/yr	1	$855,000.00	$855,000.00
5	Biomass Wood	material cost	TON	131765	$25.00	$3,294,125.00
6	Dried Pellets	Hauling Costs	$/yr	1	$570,000.00	$570,000.00
			Subtotal			$6,304,699.16
Operations and Maintnence						
7	Operation and Maintenence of Facility - Wage and benefits		LS	1	$7,560,000.00	$7,560,000.00
8	Spare Parts and Replacement		LS	1	$1,500,000.00	$1,500,000.00
			Subtotal			$9,060,000.00
Electricity and Fuel Consumption						
9	Dryer Facility - Inclusive	Electricity Demand	kWhr/yr	2522000	$0.00	$0.00
10	Dryer Facility - Inclusive	NG Demand	THERM	1272	$1.00	$1,272.00
			Subtotal			$1,272.00
Revenue						
11	Sales of Pellets		TON	57670	$0.00	$0.00
12	Sales of Biochar		TON	16790	-$150.00	-$2,518,500.00
						-$2,518,500.00
Total O&M Cost						**$12,847,471.16**
Present Value in 2022 - WTD Discount Rate, 20 Year Lifecycle						**$215,362,437.39**
Present Value in 2022 - OMB Discount Rate, 20 Year Lifecycle						**$183,267,621.59**
Total Cost including 20 year PV						**$723,568,838.39**

consor

APPENDIX F

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	4/3/2023
Location:	King County - South WWTP			**Estimator:**	PMD
Description:	Biosolids Drying Facility			**Version:**	Revision 01
DIRECT: SUBTOTAL CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	Site Prep	1	LS	$ 71,865	$ 71,865
2	Water / Sewer / Electrical Services to Facility	1	LS	$ 230,000	$ 230,000
3	Civil Install and Ancillary	1	LS	$ 784,772	$ 784,772
4	Structural Subtotal	1	LS	$ 9,643,838	$ 9,643,838
5	Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)	1	LS	$ 45,532,420	$ 45,532,420
6	Andritz Fluid Bed Dryers (3rd future train)	1	EA	$ 13,659,726	$ 13,659,726
7	EV Trucks and Trailors (qty 3)	3	EA	$ 488,718	$ 1,466,154
8	Mechanical install	1	LS	$ 13,700,429	$ 13,700,429
9	Additional Mechanical Subtotal	1	LS	$ 9,560,000	$ 9,560,000
10	Electrical install	1	LS	$ 10,845,616	$ 10,845,616
				Construction Cost Markup	$ 32,175,920
				Subtotal Construction Costs	***$ 137,670,740***
				Allowance for Indeterminates (Design Allowance)	$ 34,417,685
				Street Use Permit	$ -
				ESTIMATED PROBABLE COST OF CONSTRUCTION BID	***$ 172,088,425***
DIRECT: SUBTOTAL ADDITIONAL CONSTRUCTION COSTS					
				Mitigation Construction Contracts	$ -
				Construction Change Order Allowance	$ 17,208,842
				Material Pricing Uncertainty Allowance	$ -
				Subtotal Primary Construction Amount	***$ 189,297,267***
				Construction Sales Tax	$ 18,929,727
				Owner Furnished Equipment	$ -
				Outside Agency Construction	$ -
				Subtotal KC Contribution to Construction	***$ 208,226,994***
DIRECT: SUBTOTAL OTHER CAPITAL CHARGES					
				KC/WTD Direct Implementation	$ -
				Misc. Capital Costs	$ 378,595
				TOTAL DIRECT CONSTRUCTION COSTS	***$ 208,606,000***
INDIRECT: NON-CONSTRUCTION COSTS					
				Design and Construction Consulting	$ 35,567,726
				Other Consulting Services	$ -
				Permitting & Other Agency Support	$ 946,486
				Right-of-Way	$ -
				Misc. Service & Materials	$ 3,407,351
				Non-WTD Support	$ 1,609,027
				WTD Staff Labor	$ 18,762,106
				Subtotal Non-Construction Costs	***$ 60,292,696***
				Project Contingency	$ 80,669,485
				Initiatives	$ 4,534,200
				TOTAL INDIRECT NON-CONSTRUCTION COSTS	***$ 145,496,382***
				TOTAL PROJECT COST	***$ 354,101,970***

Estimate - AACEI Class 5					
Project Name:	KC Class A Biosolids Tech Evaluation			**Date:**	4/3/2023
Location:	King County - South WWTP			**Estimator:**	PMD
Description:	Biosolids Drying Facility			**Version:**	Revision 01
CONSTRUCTION COSTS					
Item No.	**Item Description**	**Quantity**	**Units**	**Unit Cost**	**Item Cost**
1	**Site Prep**	**1**	**LS**	**$ 71,865.00**	**$ 71,865**
2	**Water / Sewer / Electrical Services to Facility**	**1**	**LS**	**$ 230,000.00**	**$ 230,000**
3	Site Perimeter - New Landscape	71,865	SF	$ 8.40	$ 603,666
4	Civil Install	1	LS	$ 181,106.20	$ 181,106
	Civil Install and Ancillary				**$ 784,772**
5	RC - Slab on Grade	1067	CY	$ 650.00	$ 693,550
6	RC - Walls	154	CY	$ 700.00	$ 107,981
7	RC - Elevated Slab	25	CY	$ 1,000.00	$ 25,000
8	Grout Pad	100	CY	$ 100.00	$ 10,000
9	Steel Framed Building (for drying buildings)	28800	SF	$ 250.00	$ 7,200,000
10	Structural Install	1	LS	$ 1,607,306.30	$ 1,607,306
	Structural Subtotal				**$ 9,643,838**
11	**Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)**	**1**	**LS**	**$ 45,532,420.00**	**$ 45,532,420**
12	**Andritz Fluid Bed Dryers (3rd future train)**	**1**	**EA**	**$ 13,659,726.00**	**$ 13,659,726**
13	Cake dump hoppers with sliding frame and cake feed pump	2	EA	$ -	$ -
14	Wet material bin with sliding frame and cake feed pump	2	EA	$ -	$ -
15	FDS 10.0 Fluid Bed Coolers	2	EA	$ -	$ -
16	Electric thermal oil heater sets with pumps and tanks	2	EA	$ -	$ -
17	Condensers with Heat Recovery Heat Exchangers	2	EA	$ -	$ -
18	Heat transfer heat exchangers with fin-fan coolers	2	EA	$ -	$ -
19	Support steelwork, service platforms, guardrails, access walkways	2	EA	$ -	$ -
20	associated process ductwork	2	EA	$ -	$ -
21	all instruments, motors & MCC's for supplied equipment	2	EA	$ -	$ -
22	PLC's and operator interface implementation	2	EA	$ -	$ -
23	Dried Product Storage silos, 2x 450 Ton mass flow design	2	EA	$ -	$ -
24	Truck loading system with discharge screw and pellet oil mixing system	1	EA	$ -	$ -
25	Odor control system	1	EA	$ -	$ -
26	Digester Heating Upgrades Equipment (HXs/Pumps)	1	EA	$ 1,000,000.00	$ 1,000,000
27	**EV Trucks and Trailors (qty 3)**	**3**	**EA**	**$ 488,718.00**	**$ 1,466,154**
28	Charging Station (qty 1)	1	EA	$ 60,000.00	$ 60,000
29	Product Silos (1 future)	1	SF	$ 500,000.00	$ 500,000
30	Truck Scale (qty 2)	2	SF	$ 250,000.00	$ 500,000
31	Electrical controls/SCADA/Power Dist.	**1**	**LS**	$ 5,000,000.00	$ 5,000,000
32	Fire Detection and Suppression	1	**LS**	$ 2,500,000.00	$ 2,500,000
33	**Mechanical install**	**1**	**LS**	**$ 13,700,429.20**	**$ 13,700,429**
	Additional Mechanical Subtotal				**$ 9,560,000**
34	**Electrical install**	**1**	**LS**	**$ 10,845,615.57**	**$ 10,845,616**
				Item Subtotal Construction Costs (Year 2023)	$ 105,494,820
DIRECT: CONSTRUCTION COST MARK-UPS					
		General Conditions	10%	1.1	$ 10,549,481.97
		Mobilization/Demobilization	10%	1.1	$ 10,549,481.97
		Overhead & Profit (OHP)	8%	1.08	$ 8,439,585.58
		Insurance	1.5%	1.015	$ 1,582,422.30
		Bonding	1.0%	1.01	$ 1,054,948.20
		Escalation Multiplier from ENR-CCI	0%	1.0000	$ -
				Item Subtotal Construction Costs (Year 2023)	$ 137,670,740
				Direct: Subtotal Construction Costs	***$ 137,671,000***

Project: **King County Class A Biosolids Analysis**
Client: King County WTD
Project No.: 20-2900.07
Date: 4/7/2023

Unit Process - Biosolids Drying Facility

Item No.	Item		Unit	QTY	Unit Cost	Total
Hauling and Transport						
1	Vehical charging cost - Electricity		kWhr/yr	435558	$0.00	$0.00
2	Biosolids	Hauling Cost	$/yr	1	$1,415,071.47	$1,415,071.47
3	Biosolids	Fuel Cost (Diesel)	$/yr	1	$170,502.70	$170,502.70
4	Dried Pellets	Hauling Costs	$/yr	1	$570,000.00	$570,000.00
			Subtotal			$2,155,574.16
Operations and Maintnence						
5	Operation and Maintenence of Facility - Wage and benefits		LS	1	$3,780,000.00	$3,780,000.00
6	Spare Parts and Replacement		LS	1	$1,500,000.00	$1,500,000.00
			Subtotal			$5,280,000.00
Electricity and Fuel Consumption						
7	Dryer Facility - Inclusive	Electricity Demand	kWhr/yr	71350200	$0.08	$5,708,016.00
8	Dryer Facility - Inclusive	NG Demand	THERM	0	$1.00	$0.00
			Subtotal			$5,708,016.00
Revenue						
9	Sales of Pellets		TON	57670	$0.00	$0.00
10	Sales of Biochar		TON	16790	$0.00	$0.00
						$0.00
Total O&M Cost						**$13,143,590.16**
Present Value in 2022 - WTD Discount Rate, 20 Year Lifecycle						**$233,941,316.55**
Present Value in 2022 - OMB Discount Rate, 20 Year Lifecycle						**$180,596,283.79**
Total Cost including 20 year PV						**$588,043,286.55**

APPENDIX G

Trucking Impacts Analysis

Date:	May 20, 2022
Project:	King County Biosolids Class A Alternatives Analysis
To:	King County Council; King County WTD
From:	Shanna Myers, PE, Murraysmith
Reviewed By:	Patrick Davis, PE; Miaomiao Zhang, PE, PMP, Murraysmith
Re:	Social and Environment Impacts of Trucking

Introduction

As part of the King County Biosolids Class A Alternatives Analysis, differential trucking impacts between two Class A biosolids management alternatives have been evaluated. This technical memo analyzes the environmental, social, and staffing/contracting impacts of trucking for King County's Wastewater Treatment Department (WTD). The first alternative is the Baseline. This assumes a build-out of WTD's existing Class B biosolids program to 2050 production numbers and Class A composting of 20 percent of the produced biosolids. The second alternative, proposed by the Biosolids Partnership, utilizes wood gasification to thermally dry 100 percent of WTD's Class B biosolids creating Class A biosolids. The biosolids can then be sold as is, blended with other soil amendments, or, in this case, used as biofuel. Trucking of biosolids, compost, gasifier feed material, and Class A biosolids were considered for both cases, and the comparative impacts are explained in the memo below.

Trucking Distance and Quantity Assumptions

Both alternatives were assumed to use 2050 biosolids production values calculated by Brown and Caldwell in 2020. These values, shown in Table 1, are broken up by facility. Trucks were assumed to be capable of carrying 31 wet tons of solids, based on conservative interpretation of 2018 trucking data. Class B biosolids were assumed to be 24 percent total solids. Trucks were assumed to operate 7 days per week, but it was assumed for workload estimations that truck drivers would only work 5 days per week

Table 1 | Annual Biosolids Production 2018 vs 2050, Wet Tons

Treatment Plant	Dewatered Sludge Wet Tons (2018 annual production)	Dewatered Sludge Wet Tons (2050 estimated annual production)
West Point	49,258	64,784
Brightwater	15,948	35,998
South Plant	64,332	96,279
Total	129,537	197,061

For the baseline, biosolids are digested to Class B biosolids at each treatment plant just as before. After digestion, it is assumed that 20 percent of the Class B biosolids, from West Point and South Treatment plant, are trucked to local land application in western WA, an average of 35 miles away, and 80 percent of the Class B biosolids, from West Point and South Treatment plant, are trucked to eastern WA for land application, an average of 210 miles away. All biosolids from Brightwater are transported locally for composting creating Class A biosolids. These composted biosolids are anticipated to be picked up locally by residents and local landscapers, or else delivered to local companies to be sold. Since the exact method of distribution and end location are unknown, milage for compost distribution is assumed average approximately 10 miles.

For the Biosolids Partnership proposal, all biosolids are still digested to Class B quality as in the baseline. Solids are then transported from the West Point and Brightwater to a location at or near South Plant for further processing. A gasifier fed by woodchips/woody debris from a local source provides the energy to heat and power the dryer that produces Class A biosolid pellets. It is assumed that 100 percent of the woodchips/woody debris come from Cedar Grove Composting, which has two locations. One location is approximately 7 miles away from South Plant, and one location is 12 miles from South Plant averaging 9.5 miles of travel. After gasification the woody debris will be turned into biochar, which will be trucked back to Cedar Grove Composting. An approximate average of 361 tons/day of woody debris needs to be trucked to the proposed gasification and drying facility to transform all Class B biosolids into Class A dried pellets, producing 46 tons per day of biochar. Although there are multiple uses for Class A biosolids, it is assumed that all Class A biosolids pellets will be transported to Ash Grove cement plant 10 miles away to be used as biofuel.

Distance, travel time, and annual truck trips assumed for the above trucking operations are broken down in Table 2.

Table 2 | Annual Mileage, Trucking of Biosolids, Products, and Feedstock

	2018 Current Operation	2050 Baseline	2050 Biosolids Partnership Proposal
Class B Transportation Brightwater to Facility near South Plant	0	62,748	62,748
Class B Transportation West Point to Facility near South WTP	0	0	83,600
Class B Transportation South Plant to nearby Facility	0	0	31,060
Western Washington Class B solids application	56,700	89,010	0
Eastern Washington Class B solids application	1,393,140	1,745,860	0
Cement plant Class A product transportation	0	0	32,220
Woody feedstock transportation	0	124,773	85,060
Biochar transportation	0	0	10, 840
Class A Local Distribution	0	59,380[1]	0
Total annual miles	**1,449,840**	**2,006,123**	**310,490**

Notes:
1. Assuming 20 tons per truck with an average haul of 20 miles

Environmental Impacts

The greenhouse gas (GHG) emissions for transportation alone in 2018 were estimated to be approximately 3,138 metric tons of CO_2/year using the same assumptions as Brown and Caldwell used for diesel truck emissions for their future operations. This assumption includes an emissions value of 3.14 kg CO_2 emissions per liter of diesel. Fuel economy for diesel vehicles is assumed to be 4.18 miles/gallon when a truck is full and 8.0 miles/gallon for empty trucks. The calculations within this TM do not include the carbon sequestration from land application. The breakdown of GHG emissions for each alternative can be seen in Table 3 at the end of this section.

Using the same assumptions and still excluding offsets, the 2050 baseline is estimated to have emissions equivalent to approximately 5,009 metric tons of CO_2/year if all transportation occurs using diesel trucks and including the assumed mileage for local distribution of Class A compost.

The Biosolids Partnership proposes using diesel trucks to haul Class B biosolids between facilities. Electric trucks are assumed haul woody debris from the Cedar Grove facility and Class A biosolids to the local cement plant. The total GHG emissions from this alternative were estimated to be 384 metric tons of CO_2/year, or a reduction of over 2,500 metric tons of CO_2/year compared to the baseline. This reduction comes from no longer needing to truck solids to eastern Washington as well as from utilizing an electric fleet for part of the transportation.

The emissions for electric vehicles are based on the average GHG emissions for the energy mix used at each facility, and it is subject to change if the percentage of renewable energy used at each facility changes. In the Biosolids Partnership proposal, electric vehicles would be housed and recharged at South Plant which utilizes 100% renewable energy and has net zero carbon emissions per kWh of electricity used. These estimations do not consider the GHG emissions associated with the production and repair/maintenance of vehicles. Scania's life cycle assessment estimates double the emissions from battery electric vehicle (BEV) production compared to internal combustion engine vehicle (ICEV). Battery production makes up a large portion of the GHG emissions, with an estimated 22.2 metric tons of CO_2 for a 300 kWh battery[i].

Travel distance on a full charge for an electric truck is still somewhat limited. Scania electric trucks have a range of approximately 155 miles on a 300 kWh lithium-ion battery, but battery efficiency is significantly impacted by a truck's load.[ii] Batteries typically last for 1000 discharges before their capacity reduces to about 90% and begin to see capacities of 80% or lower than their original capacity around 2000-2500 charge-discharge cycles.[iii] The estimated total miles driven per year for all facilities is approximated to require 275 charge-discharge cycles, or less than 15% of the cycles required to reduce capacity below 80% for one 300 kWh battery, and this mileage would be divided by the number of vehicles in the fleet to estimate the load on a single battery. However, vehicles would likely be charged each day they are driven, possibly increasing the number of charge-discharge cycles per year. Even if all batteries underwent over 300 charge-discharge cycles per year, vehicles would not be anticipated to reach reduced capacity until 6-7 years have passed. Battery technology will also have further improved by 2050, likely increasing the useful lifespan of electric vehicle batteries. It is therefore assumed that batteries would not need to be changed very often, and that the GHG emissions for battery replacement would be negligible.

The GHG emissions from trucking for current conditions, the 2050 baseline, and the Biosolids Partnership proposal are compared and summarized in Table 3.

Table 3 | Greenhouse Gas Equivalent of Transportation Options

		2018 Current Operation	2050 Baseline	Biosolids Partnership Proposal
Internal Biosolids Transportation	Brightwater -> proposed facility	0	100	136
	West Point -> proposed facility	0	0	181
	South Plant -> proposed facility	0	0	67
External Biosolids Transportation	to Western WA	123	157	0
	to Eastern WA	3,015	3,779	0
Feedstock and Product Transportation	Woody Debris Feedstock	0	270	0[1]
	Biochar	0	0	0[1]
	Class A Biosolids	0	702	0[1]
Total GHG Emissions	**(metric tons CO_2/yr)**	**3,138**	**5,009**	**384**

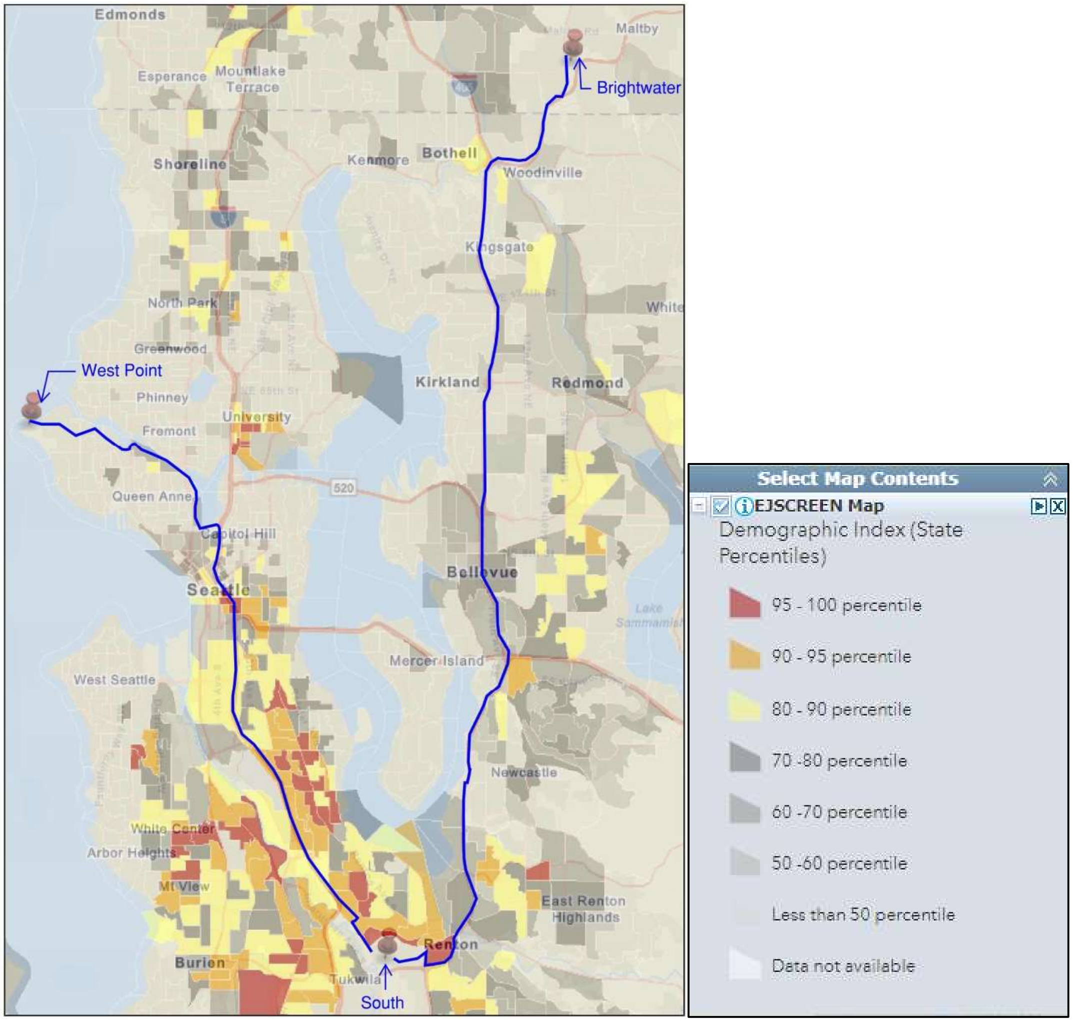
Notes:
1. Assumes the loads are carried by an electric vehicle fleet operates out of, and recharges at, the South Plant which uses 100% renewable energy for power. GHG emissions from vehicle production were not considered for this analysis.

Social Impacts

A map of the demographics for the three treatment plants, their surrounding areas, and the most likely trucking routes from Brightwater and West Point to the South plant are shown in Figure 1. This image was taken from the EPA's Environmental Justice Screening and Mapping Tool and the demographic index is defined as, "a combination of percent low-income and percent minority, the two demographic factors that were explicitly named in Executive Order 12898 on Environmental Justice. For each Census block group, these two numbers are simply averaged together." The formula is as follows:

$$Demographic\ Index = \frac{(\%\ Persons\ of\ Color + \%\ Low\ Income\ Individuals)}{2}$$

Figure 1 | Trucking Routes to South Treatment Plant



As can be seen in **Figure 1**, the South treatment plant is located in an area with more concentrated low income and minority populations. Therefore, any trucking of solids to or from the South treatment plant will have a disproportionate impact on low income and minority populations.

The anticipated increase of trucks coming to and from the South Plant is outlined in **Table 4**. The truck load near the proposed facility will increase at least fourfold under the Biosolids Partnership proposal compared to the baseline. It is therefore important to make sure that the proposed facility is located along roads that are built for significant truck loads and away from residential zones where the impact on local communities would be greater.

Table 4 | Weekly Truck Trips near South Plant

	2018 Current Operation	2050 Baseline	2050 Biosolids Partnership
Class B transportation Brightwater to off-site Facility	0	22	22
Class B transportation West Point to off-site Facility	0	0	40
Class B transportation from South WTP	39	0	60[1]
Class A product transportation (Commercial Vehicles)	0	57[2]	36
Woody feedstock transportation	0	15	82
Biochar transportation	0	0	10
Total weekly truck loads	39	94	250

Notes:

1. Assumes off-site drying facility
2. Assumes 20 ton capacity commercial vehicle

Staffing/Contractual Work Impacts

The impacts of differences in biosolids handling on the number of full-time truck drivers the County would need to employ or contract was also considered. The estimated number of truckers calculated in this section should be used for comparative purposes only and not for staffing decisions, as many simplifying assumptions were made to develop with these numbers.

As of 2018 data, the County trucked approximately 2500 wet tons of solids per week, or approximately 80 truckloads. Roughly 80% of these biosolids went to agricultural land application in eastern Washington and 20% to forests in western Washington. As a rough assumption, local truckloads can be assumed to have a round trip of up to 4 hours for 2 trucks/day per driver and truckloads to eastern Washington can be assumed to have a full workday round trip (8+ hours). Based on these assumptions, the 2018 hauling was assumed to require approximately 15 full-time truck drivers working 5 days/week.

A total of 3800 wet tons of solids per week is estimated to be produced in 2050. Looking at the baseline, with 80 percent of West Point and South Treatment Plant solids being applied in eastern Washington, 20 percent of West Point and South Treatment Plant in western Washington, and Brightwater solids composted and distributed locally, hauling of Class B biosolids would require approximately 21 full-time drivers working 5 days/week.

Trucking between the County's Treatment Plants to produce Class A biosolids would remove the need to truck biosolids to eastern Washington. However, truck drivers would be needed to haul between the Treatment Plants, to haul woody material to the gasifier, to haul biochar from the drying facility, and to haul Class A biosolids to the cement plant.

Based on 2050 annual average biosolids production shown in Table 1 and the assumptions listed previously, trucking solids from West Point to South Plant in the future will require approximately six trips per day. The round trip takes approximately 1 hour 30 minutes, not including loading and unloading time. Using the same assumptions, trucking solids from Brightwater to South Plant requires approximately 4-5 trips per day. The round trip takes approximately 1 hour 20 min, not including loading and unloading time. After factoring in loading and unloading times, four drivers will be required to consistently truck solids from the West Point and Brightwater to the South Plant.

It is estimated that 361 wet tons/day of woody debris will be required to power the gasifier, or 12 truck trips per day. Another 46 wet tons/day, or 1-2 loads/day, of biochar will be returned to the local composting facility to be bagged and sold. The round trip to the composting facility, not including loading time, takes 30-60 minutes. For distribution of Class A biosolids, the increase in percent solids from 24 percent for Class B to 95 percent for Class A from the trucking assumptions section means that the 3800 wet tons per week of Class B biosolids would result in approximately 960 wet tons per week of Class A biosolids. This would result in approximately 6 truckloads per day to the nearby cement plant, approximately 40 minutes round trip not including loading times. After factoring in loading times, 5 full time drivers should be able to handle the combined woody debris, biochar, and dry pellets routes.

Summed up, the staff requirement for 2018 trucking was assumed to be 15 full time truckers. The 2050 baseline was estimated to require 21 full time truckers, and the Biosolids Partnership proposal was estimated to require 11 full time truckers. Most of the reduction in staff requirements came from removing the need to truck solids to eastern Washington. These staffing estimates are listed in Table 5.

Table 5 | Approximate Weekly Trucking Hours

Weekly Hours per Route[1]		2018 Current Operation	2050 Baseline	2050 Biosolids Partnership Proposal
Between Facilities	Brightwater -> South	0	60 hours	56 hours
	West Point -> South	0	0	100 hours
	South -> Drying Facility	0	0	89
External Solids Transportation	Western WA	60 hours	80 hours	0
	Eastern WA	510 hours	640 hours	0
Feedstock/Product Transportation	Woody Debris	0	8 hours	120 hours
	Biochar	0	0	20 hours
	Class A Biosolids	0	29 hours	50 hours
Total Truckers	FTE[2]	15	21	11

Notes:
1. Travel times approximated for average traffic conditions, approximated loading and unloading as half an hour of time.
2. 1 FTE is assumed to be 40 hours per week. All FTE values were rounded up to the nearest whole number.

It was assumed that electric vehicles did not need to be charged during the day, as charging vehicles would increase the amount of time it takes to perform a round trip. It should also be noted that it is outside the scope of this analysis to determine if the same truck drivers could be redirected from eastern Washington trucking to local trucking or if new contracts or new hiring would be required.

Summary

Continuing along the current trajectory toward the baseline will result in a gradual increase in trucking hours and distance, and therefore an increase in GHG emissions from transportation that will require additional carbon credits to offset. The Biosolids Partnership proposal would significantly reduce the trucking hours and distance and the greenhouse gas emissions from transportation compared to current levels and the baseline in year 2050 . However, the Biosolids Partnership proposal would also increase truck traffic within the vicinity of South Plant and could have negative social impacts on minority communities if the biosolids drying facility location and transportation routes to and from the facility are not chosen carefully.

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[i] Scania, Life cycle assessment of distribution vehicles: battery electric vs diesel driven, 2021. https://www.scania.com/content/dam/group/press-and-media/press-releases/documents/Scania-Life-cycle-assessment-of-distribution-vehicles.pdf

[ii] Scania, "Scania launches fully electric truck with 250 km range", 2020. https://www.scania.com/group/en/home/newsroom/press-releases/press-release-detail-page.html/3768729-scania-launches-fully-electric-truck-with-250-km-range

[iii] National Renewable Energy Laboratory, Predictive Models of Li-ion Battery Lifetime, 2014. https://www.nrel.gov/docs/fy14osti/62813.pdf

Attachment

Attachment 1 - Detailed Trucking Analysis

APPENDIX H

Energy and Carbon Analysis

Date: May 20, 2022

Project: King County Biosolids Class A Alternatives Analysis

To: King County Council; King County WTD

From: Xinyi Xu, EIT, Murraysmith

Reviewed By: Patrick Davis, PE; Miaomiao Zhang, PE, PMP, Murraysmith

Re: Energy and Carbon Analysis

Introduction

As part of the King County Biosolids Class A Alternatives Analysis, Murraysmith has been contracted to evaluate the energy and carbon requirements of the gasification and drying facility proposed by Biosolids Partnership and Venture Engineering. The proposed Class A solids handling facility includes three distinct components:

- Biomass Gasification
- Steam and Power Generation
- Biosolids Drying

Gasification is a process involving heat, steam, and oxygen/air to convert green waste into synthetic gas (syngas), and biochar. The syngas is sent to a Thermal Oxidizer Unit (TOU) to combust the syngas producing heat. A portion of the combusted syngas returns to the gasifier providing thermal energy for the process to continue. The remaining combustion product is sent to a Heat Recovery Steam Generator (HRSG) to create steam. The resulting steam is sent to a turbine to produce electricity for the facility. After flowing through the steam turbine, a portion of the steam is directed to the dryer, which evaporates the water in the dewatered sludge. This process converts the dewatered sludge into granules with 90 to 95 percent dry solids content. This tech memo evaluates the energy and carbon balance for the entire system.

Energy Requirements

Overview

According to Brown and Caldwell's study, under the 2050 average annual flow conditions, 130 dry ton per day (dry ton/d) of dewatered solids is produced at King County's three treatment plants – Brightwater, West Point, and South Plant. The biosolids have an average solids content of 24%.

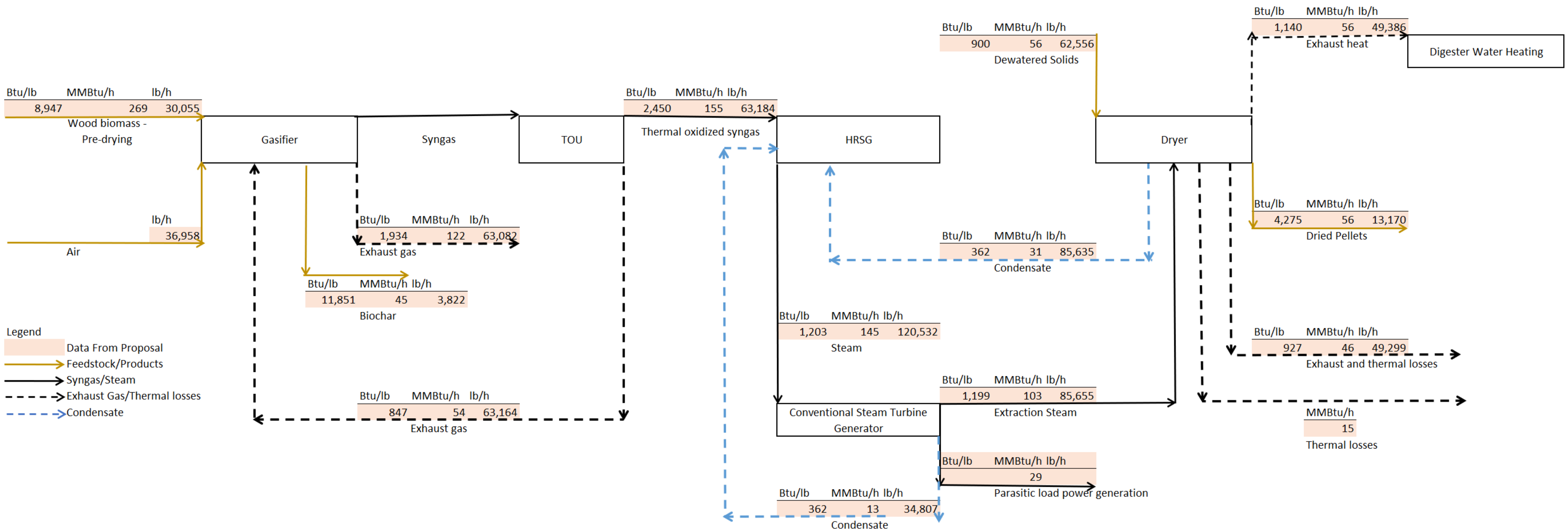
Under the maximum month flow conditions, the projected total dewatered solids produced will be 152 dry ton/d, with a solids content of 24%.

Biosolids Partnership and Venture Engineering and Construction developed a proposal, which assumes:

- The biosolids from all three plants are trucked to a single facility located at or near South plant
- The buildout capacity for the facility is 150 dry ton/d

Based on the above assumptions, the proposal estimated the required energy of each process, as shown in **Figure 1**. Note this flow chart only considers critical components such as dryer, gasifier, HRSG, TOU, and steam turbine. It does not show other components such as condensers or cooling tower.

Figure 1. Mass and Energy Flow Chart



Thermal Drying

Assuming a conservative solids content of 20%, the quantity of water within the dewatered solids is 1,200,000 lb/d. If the biosolids dryer can achieve a solids content of 95%, the quantity of water decreases to 16,000 lb/d. The total weight of dried biosolids drops to 316,000 lb/d. Overall, approximately 1,184,000 lb/d water will be evaporated during the thermal drying process. According to the Biosolids Partnership proposal, the heat energy that the fluid bed dryer requires to evaporate water is approximately 1,200 Btu/lb water. The thermal efficiency of the dryer is expected to be 85%. The calculated energy expected for water evaporation is 86 MMBtu/h.

According to the proposal, the HRSG will be fed with 63,184 lb/h thermal oxidized syngas, which produces 155 MMBtu/h. Approximately 94% (145 MMBtu/h) of the heat energy will be converted to steam and then sent to the turbine. Approximately 71% (103 MMBtu/h) of the steam will be supplied to the dryer to support the drying process, which is more than the estimated minimum energy required for the drying operation (86 MMBtu/h). Approximately 9% of the steam (13 MMBtu/h) will be converted to condensate and sent back to HRSG. The rest of the energy (29 MMBtu/h) will be used for parasitic load power generation.

Electrical Energy

The facility is intended to have a steam turbine installed to offset the electrical loads for the facility and electrical trucks. The proposed turbine is designed to produce up to 29 MMBtu/h of energy, which is equivalent to 5.5 MW of electrical power. This amount of electrical power is assumed to be sufficient to power the entire gasification/drying facility, as well as provide sufficient energy to charge the electric trucks.

Table 1 summarizes the energy requirement and generation for both alternatives. The energy requirement for the baseline is based on the Class A Biosolids Technology Evaluation Technical Memorandum, by Brown and Caldwell (2020). The energy requirement and generation for the Biosolids Partnership proposal is based on the information provided by Venture Engineering and Construction.

Table 1. Energy Consumption Comparison

Energy	Baseline	Biosolids Partnership Proposal
Energy Consumption during Operation	(1,888) MWh/yr	259,200 MWh/yr (103 MMBtu/h) [1]
Energy Generation (in the form of steam)	-	367,200 MWh/yr (145 MMBtu/h) [2]
Net Energy Change	**(1,888) MWh/yr**	**73,440 MWh/yr (29 MMBtu/h) [3]**
Power Generation	**n/a**	**5.5 MW**

1. Energy consumption of the drying operation, assuming continuous operation with 10 hr per month of shutdown time
2. Energy generation from the gasification and turbine operation, assuming continuous operation with 10 hr per month of shutdown time
3. Net energy production excluding 13 MMBtu/h wasted in the condensate

Abbreviations:
MW = megawatt
MWh/yr = megawatt hours per year
MMBtu/h =million British thermal units per hour

Gasification System – Feedstock Requirements

The thermal oxidized syngas is used to supply thermal heat for both HRSG and gasifier. As mentioned above, the energy that sent to HRSG is 155 MMBtu/h. Therefore, the syngas that is produced by the gasifier will need to be able to produce this amount of energy. To achieve this goal, the gasifier that Venture Engineering proposes will require 15 wet tons per hour (wet ton/h) of wood biomass and 18.5 ton/h of air.

Carbon Footprint Analysis

Start-up

During gasification and thermal drying, combusted syngas is used for every process. It is assumed no net carbon is emitted. The only instances of net carbon production occurs during the start-up of gasifier. Under normal operating conditions, the gasifier will utilize a portion of the thermally oxidized syngas to provide heat energy to maintain the gasification process. However, based on the conversations with other drying facilities, the system will need to be shut down for maintenance activities. These maintenance cycles can occur up to once per month. The gasifier will then require outside energy to re-start. The startup requirements assume the following:

- The start-up process will take 2 hours
- 53 MMBtu/h is required to power the gasifier

Based on the above assumptions, 1,272 MMBtu/year of energy will be required. It is assumed that natural gas (NG) will be used as a source of start-up energy. According to the EPA Greenhouse Gas Emission Factors, NG produces 53.06 kg CO_2/ MMBtu, therefore 67,500 kg CO_2, which equivalent to 67.5 metric ton CO_2, will be produced over the course of a year

Carbon Sequestration

The entire gasification/drying process has been developed to be a closed loop for both power and carbon, and the only source of net carbon production occurs for a short period during start-up. The drying process creates biosolids pellets, which can be used for numerous purposes. If the pellets were used as soil amendment, or otherwise land applied, the carbon bound within the pellets would be sequestered, and net negative carbon balances could be considered; however, these pellets are intended to be combusted in a kiln of a cement manufacturing company. The carbon that is trapped within the biosolid pellets will then be released back to the atmosphere. While this does not produce any net carbon, it does not sequester carbon either.

For the cement plant, utilizing a net zero fuel source will reduce the carbon footprint of the plant, yet the exact details surrounding the intended fuel makeup for that cement plant are still in the conceptual phase. Quantifying, the amount of carbon reduced because of the fuel switch is outside of the scope of this project.

The gasification process produces biochar, which can be distributed to the local market and used for land application. Theoretically net carbon balances could be considered; however, given biochar is produced from wood biomass, and the wood biomass would have otherwise been applied to the land, the total amount of carbon does not change overall. Thus, there is no carbon sequestration happening during the gasification and biochar land application.

Table 2 summarizes the carbon footprint (GHG emission) estimate for both alternatives. The GHG emissions for the baseline are based on the Class A Biosolids Technology Evaluation Technical Memorandum, by Brown and Caldwell (2020). The GHG emission for the Biosolids Partnership proposal are based on the discussion above. The detailed GHG emission calculation is included in **Attachment 1**.

Table 2. GHG Emission Comparison

GHG Emission (metric ton CO_2e/yr)	Baseline	Biosolids Partnership Proposal
GHG Emission from Hauling Class B	4,072	384
GHG Emission from Hauling Class A	702	0
GHG Emission from Hauling Feedstock	270	0
GHG Emission from Land Application	1,413	0
GHG Emission from Operation	1,189	68
Fugitive GHG Emission	1,786	0
GHG Sequestration from Land Application, Class B	-44,949[1]	0[1]
GHG Sequestration from Land Application, Composting	-11,041[1]	0[1]
Total GHG Emission	**-46,558**	**452**

1. The carbon sequestration numbers only quantify the amount of carbon returning to the land. No offsets for fertilizer replacement, nor fossil fuel replacement were considered in the above table.

Attachment

Attachment 1 - Detailed GHG emission calculation

APPENDIX I

GHG Emissions Inventory			1	2	3	3
GHG Emissions Inventory			Base-case	Biosolids Partnership Gassification and Drying w/ Soil Blending	Biosolids Partnership Fluid Bed Drying in 2022	Biosolids Partnership Fluid Bed Drying in 2050
Element			Scenario 1	Scenario 2	Scenario 3	Scenario 3
West Point Treatment plant						
Hauling and Transportation						
	Hauling	Average Hauled, wet tons/yr	64,784	64,784	49,258	64,784
	Hauling	Dry Solids, %	28.5%	28.5%	28.5%	28.5%
	Hauling	Trucks per year	2,090	2,090	2,090	2,090
	Hauling	Off-site Processing, Total Miles	0	83,600	63,560	83,600
	Hauling	Fuel Usage Round Trip, gal/yr	0	15,225	11,575	15,225
	Hauling	Emissions, kg CO2e/yr	0	180,948	137,568	180,948
	Hauling	Eastern Washington, Total Miles	702,240			
	Hauling	Fuel Usage Round Trip, gal/yr	127,890			
	Hauling	Emissions, kg CO2e/yr	1,519,960	To Dryer Facility	To Dryer Facility	To Dryer Facility
	Hauling	Western Washington, Total Miles	29,260			
	Hauling	Fuel Usage Round Trip, gal/yr	5,329			
	Hauling	Emissions, kg CO2e/yr	63,335			
		Subtotal, kg CO2e/yr	1,583,294	180,948	137,568	180,948
Land Application						
	Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	18,519			
	Agriculture	Emissions, kg CO2e/yr	220,097			
	Forestry	KC Fuel for Forestry (Western) Application, gal/yr	2,826			
	Forestry	Emissions, kg CO2e/yr	33,585			
		Subtotal, kg CO2e/yr	253,682			
	Agriculture	N2O and CH4 Emissions, kg CO2e/yr	316,760			
	Forestry	N2O and CH4 Emissions, kg CO2e/yr	35,196	To Dryer Facility	To Dryer Facility	To Dryer Facility
		Subtotal, kg CO2e/yr	351,955			
Carbon Offsets						
	Agriculture	Land App Carbon Sequestration, kg CO2e/yr	-18,680,671			
	Forestry	Land App Carbon Sequestration, kg CO2e/yr	-1,660,504			
		Subtotal, kg CO2e/yr	-20,341,175			
WP GHG Solids Total						
	Hauling Class B	CO2 Emissions, mt CO2e/yr	1,583	181	138	181
	Emissions from Land App	CO2 Emissions, mt CO2e/yr	606			
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	-20,341	0	0	0
	Solids Total	CO2 Emissions, mt CO2e/yr	-18,152	181	138	181
South Treatment plant						
Hauling and Transportation						
	Hauling	Average Hauled, wet tons/yr	96,696	96,696	0	0
	Hauling	Dry Solids, %	22.9%	22.9%	22.9%	22.9%
	Hauling	Trucks per year	3,285	3,285	3,285	3,285
	Hauling	Off-site Processing, Total Miles	0	31,060	0	0
	Hauling	Fuel Usage Round Trip, gal/yr	0	5,657	0	0
	Hauling	Emissions, kg CO2e/yr	0	67,233	0	0
	Hauling	Eastern Washington, Total Miles	1,043,616			
	Hauling	Fuel Usage Round Trip, gal/yr	190,060			
	Hauling	Emissions, kg CO2e/yr	2,258,844	To Dryer Facility	To Dryer Facility	To Dryer Facility
	Hauling	Western Washington, Total Miles	43,484			
	Hauling	Fuel Usage Round Trip, gal/yr	7,919			
	Hauling	Emissions, kg CO2e/yr	94,117			
		Subtotal, kg CO2e/yr	2,352,961	67,233	0	0
Land Application						
	Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	27,882			
	Agriculture	Emissions, kg CO2e/yr	331,379			
	Forestry	KC Fuel for Forestry (Western) Application, gal/yr	4,255			
	Forestry	Emissions, kg CO2e/yr	50,566			
		Subtotal, kg CO2e/yr	381,945			
	Agriculture	N2O and CH4 Emissions, kg CO2e/yr	383,206			
	Forestry	N2O and CH4 Emissions, kg CO2e/yr	42,578	To Dryer Facility	To Dryer Facility	To Dryer Facility
		Subtotal, kg CO2e/yr	425,784			
Carbon Offsets						
	Agriculture	Land App Carbon Sequestration, kg CO2e/yr	-22,599,279			
	Forestry	Land App Carbon Sequestration, kg CO2e/yr	-2,008,825			
		Subtotal, kg CO2e/yr	-24,608,104			
SP GHG Solids Total						
	Hauling Class B	CO2 Emissions, mt CO2e/yr	2,353	67	0	0
	Emissions from Land App	CO2 Emissions, mt CO2e/yr	808	0	0	0
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	-24,608	0	0	0
	Solids Total	CO2 Emissions, mt CO2e/yr	-21,447	67	0	0

Brightwater Treatment Plant						
Hauling and Transportation						
	Hauling	Average Hauled, wet tons/yr	35,998	35,998	15,948	35,998
	Hauling	Dry Solids, %	20.0%	20.0%	20.0%	20.0%
	Hauling	Trucks per year	1,162	1,162	1,162	1,162
	Hauling	Off-site Processing, Total Miles	62,748	62,748	27,810	62,748
	Hauling	Fuel Usage Round Trip, gal/yr	11,427	11,427	5,065	11,427
	Hauling	Emissions, kg CO2e/yr	135,809	135,809	60,197	135,809
	Hauling	Eastern Washington, Total Miles	To Off-site Composting	To Dryer Facility	To Dryer Facility	To Dryer Facility
	Hauling	Fuel Usage Round Trip, gal/yr				
	Hauling	Emissions, kg CO2e/yr				
	Hauling	Western Washington, Total Miles				
	Hauling	Fuel Usage Round Trip, gal/yr				
	Hauling	Emissions, kg CO2e/yr				
		Subtotal, kg CO2e/yr	135,809	135,809	60,197	135,809
Land Application						
	Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	To Off-site Composting	To Dryer Facility	To Dryer Facility	To Dryer Facility
	Agriculture	Emissions, kg CO2e/yr				
	Forestry	KC Fuel for Forestry (Western) Application, gal/yr				
	Forestry	Emissions, kg CO2e/yr				
		Subtotal, kg CO2e/yr				
	Agriculture	N2O and CH4 Emissions, kg CO2e/yr				
	Forestry	N2O and CH4 Emissions, kg CO2e/yr				
		Subtotal, kg CO2e/yr				
Carbon Offsets						
	Agriculture	Land App Carbon Sequestration, kg CO2e/yr				
	Forestry	Land App Carbon Sequestration, kg CO2e/yr				
		Subtotal, kg CO2e/yr				
SP GHG Solids Total						
	Hauling Class B	CO2 Emissions, mt CO2e/yr	136	136	60	136
	Emissions from Land App	CO2 Emissions, mt CO2e/yr	0	0	0	0
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	0	0	0	0
	SolidsTotal	CO2 Emissions, mt CO2e/yr	136	136	60	136
Off-Site Composting						
Hauling and Transportation						
	Hauling	Feedstock (Sawdust), wet tons/yr	24,175			
	Hauling	Large Trucks per year	779.8			
	Hauling	Feedstock to Off-site Processing, Total Miles	124,773			
	Hauling	Fuel (Diesel) Usage Round Trip, gal/yr	22,723			
	Hauling	Emissions, kg CO2e/yr	270,065			
	Hauling	Commercial/Donation Usage, wet tons/yr	47,504			
	Hauling	Medium Trucks per year	7,038			
	Hauling	Off-site Processing to Customer, Total Miles	175,941			
	Hauling	Fuel (Diesel) Usage Round Trip, gal/yr	20,900			
	Hauling	Emissions, kg CO2e/yr	248,400			
	Transportation	Residential Usage, wet tons/yr	11,876			
	Transportation	Vehicles per year	42,754			
	Transportation	Fuel (Gasoline) Usage Round Trip, gal/yr	42,754			
	Transportation	Emissions, kg CO2e/yr	453,104			
		Subtotal, kg CO2e/yr	971,568			
Fuel Emissions						
	Composting	Machinery Fuel Consumption (Diesel), gal/day	274			
	Composting	Emissions, kg CO2e/yr	1,188,609			
		Subtotal, kg CO2e/yr	1,188,609			
Electrical Emissions						
	Composting	Electricity Consumption, MWh/yr	-1,888			
	Composting	Electricity Purchased, MWh/yr	1,888			
	Composting	Emission, kg CO2e/yr	0			
		Subtotal, kg CO2e/yr	0			
Process Fugitive Emissions						
	Composting	Biosolids, dry lb/hr	1,637.3			
	Composting	N2O Emissions, kg CO2e/yr	691,058.6			
	Composting	CH4 Emissions, kg CO2e/yr	1,095,262.7			
		Subtotal, kg CO2e/yr	1,786,321.3			
Carbon Offsets						
	Land Application	Land App Carbon Sequestration, kg CO2e/yr	-11,040,853			
		Subtotal, kg CO2e/yr	-11,040,853			
	Hauling Class A	CO2 Emissions, mt CO2e/yr	702			
	Hauling Feedstock	CO2 Emissions, mt CO2e/yr	270			
	Operations Emissions	CO2 Emissions, mt CO2e/yr	1,189			
	Fugitive Emissions	CO2 Emissions, mt CO2e/yr	1,786			
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	-11,041			
	Solids Total	CO2 Emissions, mt CO2e/yr	-7,094			

South Plant Gassification Thermal Drying						
Hauling and Transportation						
	Hauling	Woody Biomass, wet tons/yr		131,765.0		
	Hauling	Biochar, wet tons/yr		16,790.0		
	Hauling	Large Trucks per year		4,793.0		
	Hauling	Fuel (Diesel) Usage Round Trip, gal/yr		0.0		
	Hauling	Emissions, kg CO2e/yr		0.0		
		Subtotal, kg CO2e/yr		0.0		
Electrical Emissions						
	Solids Treatment	Electricity Production, MWh/yr		48,180.0		
	Solids Treatment	Electricity Sold, MWh/yr		0.0		
	Solids Treatment	Emissions Offset, kg CO2e/yr		0.0		
	Solids Treatment	Electricity Consumption, MWh/yr		48,180.0		
	Solids Treatment	Electricity Purchased, MWh/yr		0.0		
	Solids Treatment	Emission, kg CO2e/yr		0.0		
		Subtotal, kg CO2e/yr		0.0		
Natural Gas Emissions						
	Solids Treatment	Thermal Consumption, MMBtu/yr, Startup only		1,272		
	Solids Treatment	External Natural Gas, scf/yr		127,200		
	Combustion	Emission, kg CO2e/yr		67,500		
		Subtotal, kg CO2e/yr		67,500		
Process Fugitive Emissions						
	Boiler	Fugitive Emissions, kg CO2e/yr		0.0		
		Subtotal, kg CO2e/yr		0.0		
Carbon Offsets						
	Land Application	Land App Carbon Sequestration, kg CO2e/yr		0		
		Subtotal, kg CO2e/yr		0		
	Hauling Emissions	CO2 Emissions, mt CO2e/yr		0		
	Energy Emissions	CO2 Emissions, mt CO2e/yr		68		
	Fugitive Emissions	CO2 Emissions, mt CO2e/yr		0		
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr		0		
	SolidsTotal	CO2 Emissions, mt CO2e/yr		68		

South Plant Thermal Drying						
Hauling and Transportation						
	Hauling	Woody Biomass, wet tons/yr			0.0	0.0
	Hauling	Biochar, wet tons/yr			0.0	0.0
	Hauling	Large Trucks per year			0.0	0.0
	Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			0.0	0.0
	Hauling	Emissions, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Electrical Emissions						
	Solids Treatment	Electricity Production, MWh/yr			71,350.0	108,830.0
	Solids Treatment	Electricity Sold, MWh/yr			0.0	0.0
	Solids Treatment	Emissions Offset, kg CO2e/yr			0.0	0.0
	Solids Treatment	Electricity Consumption, MWh/yr			71,350.0	108,830.0
	Solids Treatment	Electricity Purchased, MWh/yr			0.0	0.0
	Solids Treatment	Emission, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Natural Gas Emissions						
	Solids Treatment	Thermal Consumption, MMBtu/yr, Startup only			0	0
	Solids Treatment	External Natural Gas, scf/yr			0	0
	Combustion	Emission, kg CO2e/yr			0	0
		Subtotal, kg CO2e/yr			0	0
Process Fugitive Emissions						
	Boiler	Fugitive Emissions, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Recycled Heat as Digester Heating (Natural Gas) Replacement						
	Digester Heat	Thermal Saving from Natural Gas, MMBtu/yr			58,679.0	113,415.0
	Digester heat	GHG Change, kg CO2e/yr			-3,109,987	-6,010,995
		Subtotal, kg CO2e/yr			-3,109,987	-6,010,995
	Hauling Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Energy Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Fugitive Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Carbon Offsets	CO2 Emissions, mt CO2e/yr			-3,110	-6,011
	SolidsTotal	CO2 Emissions, mt CO2e/yr			-3,110	-6,011

Cement Plant Fuel						
Hauling and Transportation						
	Hauling	Woody Biomass, wet tons/yr			0.0	0.0
	Hauling	Biochar, wet tons/yr			0.0	0.0
	Hauling	Large Trucks per year			0.0	0.0
	Hauling	Fuel (Diesel) Usage Round Trip, gal/yr			0.0	0.0
	Hauling	Emissions, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Electrical Emissions						
	Solids Treatment	Electricity Production, MWh/yr			0.0	0.0
	Solids Treatment	Electricity Sold, MWh/yr			0.0	0.0
	Solids Treatment	Emissions Offset, kg CO2e/yr			0.0	0.0
	Solids Treatment	Electricity Consumption, MWh/yr			0.0	0.0
	Solids Treatment	Electricity Purchased, MWh/yr			0.0	0.0
	Solids Treatment	Emission, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Natural Gas Emissions						
	Solids Treatment	Thermal Consumption, MMBtu/yr, Startup only			0	0
	Solids Treatment	External Natural Gas, scf/yr			0	0
	Combustion	Emission, kg CO2e/yr			0	0
		Subtotal, kg CO2e/yr			0	0
Process Fugitive Emissions						
	Boiler	Fugitive Emissions, kg CO2e/yr			0.0	0.0
		Subtotal, kg CO2e/yr			0.0	0.0
Biosolids as Coal Replacement						
	Dried Pellets	Production, tons/yr			32,485.0	58,400.0
		Thermal Production, MMBtu/yr			454,790.0	817,600.0
	Cement Plant	GHG Change, kg CO2e/yr			1,364,370	2,452,800
		Subtotal, kg CO2e/yr			1,364,370	2,452,800
	Hauling Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Energy Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Fugitive Emissions	CO2 Emissions, mt CO2e/yr			0	0
	Carbon Offsets	CO2 Emissions, mt CO2e/yr			1,364	2,453
	SolidsTotal	CO2 Emissions, mt CO2e/yr			1,364	2,453

APPENDIX B

May 17, 2023 sent via email to: jeff.moss@consoreng.com

Consor Engineering
600 University Street, Suite #300
Seattle, Washington 98101
Tel: 206.462.7030

ATTENTION: Jeff Moss, PE CIVIL ENGINEER

Dear Jeff:

SUBJECT: Biosolids Thermal Drying using Renewable Electricity Proposal – South Plant Renton
Consor Report - Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal

We refer to your above-mentioned report of April 2023, pages numbered 1 through 446. we wish to address your conclusions as enumerated on pages 8-9.

1. The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis lifecycle, and it is incapable of meeting biosolids regulatory requirements and policies. **This is not factually correct. We believe the Biosolids Partnership Proposal Costs are, in fact, lower than the Baseline/Composting alternative it is compared to. (The baseline is defined by Consor as continuing with 80% biosolids trucked to eastern Washington with 20% composting, an unfair comparison, by any measure, as 100% of the biosolids from King County are proposed to be dried and sent to the cement kiln).**

Although the estimated cost of the Biosolids Partnership for the drying facility was lower than the $137,671,000 as estimated by Consor (page 421), the Biosolids Partnership agrees to use the Consor estimate of $137,671,000 for the construction cost of the drying facility.

We believe it unrealistic, and unjustified, to inflate the Project Construction Cost of $137,671,000 by adding $216,430,970 for, amongst others, Change Orders, Design and Construction Consulting, Project Contingencies, resulting in Consor's estimated total Capital Cost of $354,101,970 (page 420).

As background, the 2022 Andritz/Synagro Design-Build-Operate-Maintain (DBOM) Ft. Worth, Texas Biosolids Drying Plant is an example of the DBOM approach and was completed for a guaranteed cost of $58 million for 99 dry tons/day processing capacity. This $58 million cost included 4 centrifuges. It was built by Andritz/Synagro with NO Change Orders and has been successfully operating since its commissioning.

Although we believe the Andritz/Synagro Capital Cost, Annual O&M Costs, and the 20-Year Lifecycle Costs will come in lower in a bid, we are accepting the $137,670,740 Consor number for the Capital Cost and Consor's $13.31 Annual O&M Cost. (we disagree with your analysis of energy consumption at North Shore, and that of the relative efficiencies of gas fired versus electrically heated thermal oil systems)

Corrected Table 2-2 Capital, O&M, and lifecycle Costs ($Millions) – per above

Alternative	**Capital**	**Annual O&M**	**20 year Lifecycle**
Baseline	$119.9	$15.2	373.8
Revised Biosolids Partnership Proposal as above	137.7	$13.31	318,3
Savings over the Baseline alternative			**$55.5**
Consor Lifecycle Cost per the April Report	$354.1	$13.31	$588.0

The Biosolids Partnership Proposal results in a total 20 Year Lifecycle Cost savings to King County of $55.5 million for the 20-year lifecycle. Synagro/Andritz will have an installed and operating

biosolids drying system that will dry all of King County's biosolids from the 3 plants converting the biosolids into a renewable fuel using renewable electricity. The Baseline/Composting is basically to continue with 80% of the Class B biosolids trucked to eastern Washington with 20% composting.

2. *Public agency experience with the process is limited because there are currently only two fluidized bed driers treating biosolids in North America and both are operated by private contractors.* – **There are over 200 Andritz dryers operating successfully worldwide, There are over 20 fluidized bed dryer installations globally, including the largest biosolids processing plant in the world using the fluidized bed dryer. Synagro is an active participant in many of these projects. Many of these plants are operated by the municipality.**

3. *The scalability of drying system is poor, major investments would be required to increase capacity.* **Andritz/Synagro provides 100% redundancy which is provided for at commencement of operations. The third train may never be required.**

4. *Significantly higher capital costs than the baseline alternative.* **Consor has unreasonably added $216.4 million of contingencies and Change Orders to the base construction cost. Refer to Item 1 herein.**

5. *Significantly higher lifecycle costs than the baseline alternative, with potentially short total lifespan.* **We refer you to Item 1. The reference to North Shore Fluid Bed Drying system needing to be replaced is not justified. It only needs additional metal to be installed in the Fluid Bed Box. Andritz has Biosolids Drying plants in the USA that have been operating for 25+ years, with upgrades-based changes in regulations being carried out that will extend the operating life by at least 10 years.**

6. *Only one end user, a local cement manufacturing plant, has been identified, and other agencies producing dried pellet biosolids have had difficulty identifying end users, so the market may be limited.* **This is incorrect: We have received two (2) Letters of Intent from a nearby Seattle cement plant and also from Heidelberg Lehigh who have submitted Letters of Interest in taking King County's dried biosolids pellets to be used as a fuel; thus, enhancing Climate Change.**

7. *No end users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer.* **75% of the recovered heat will be used by the existing anaerobic digesters and the South Plant buildings. The future digesters will be heated with the additional heat from the hot water recovered so that almost all of the hot water recovered will be utilized.**

8. *The biosolids would not be available for community use.* ***We refer you to the many newspaper articles academic papers,*** **and media reports** ***on PFAS "Forever Chemicals".*** **It is not likely that the community will want to use the compost.** ***The use of the dried*** **biosolids** ***pellets as a source of renewable energy in a cement plant is an important step towards being carbon neutral.***

9. *Energy use would increase compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase.* **Incorrect. It is proposed that the renewable electricity will be obtained from PSE through a regular supply, which is required by state law to achieve carbon free emissions by 2030. It is reasonable to assume that PSE will succeed in ramping up to that point, rather than relying on the Green Direct program to deliver zero-carbon power. The first year of operation is only three years before the deadline, so the emissions reported as Scope 2 herein on the spreadsheet provided to Consor is reasonable.**

10. *The process would increase carbon dioxide emissions compared to the baseline alterative.*

Incorrect. See attached 5 pages of Biosolids Sludge to Pellet GHG Emissions which is a gate-to-gate greenhouse gases emission analysis of the proposed plant consistent with the WRI and TCR protocols for Scope 1 and Scope 2 emissions. The spreadsheet includes all assumptions and references to data sources. Consor's analysis is flawed. The discussion of the Carbon Footprint

analysis begins on page 2-18 (or pg 32) of the Consor document. It is summarized in Table 2-4. Although the table reports in the second column GHG emissions in 2022, it is more correct to report these as 2027.

In the second paragraph the text reports emissions from the diesel trucks that will carry the sludge from Brightwater and West Point. While this is outside the scope of the project, it is a Metro GHG emission needed for comparison to the Baseline case, which also includes hauling emissions.

The third paragraph states that PSE's Green Direct program would be used to provide the electric power. However, it is proposed that power will be obtained from PSE through a regular supply, which is required by state law to achieve carbon free emissions by 2030. It is reasonable to assume that PSE will succeed in ramping up to that point, rather than relying on the Green Direct program to deliver zero-carbon power. The first year of operation is only three years before the deadline, so the emissions reported as Scope 2 in the spreadsheet provided to Consor is reasonable.

While it is correct that the spreadsheet does not calculate the embedded carbon in the development and construction of the wind and solar farms, the calculation of operating GHG emissions generally does not include embedded carbon, as this is still a developing technique and the results vary widely depending on the availability of reliable data. This is a problem that stretches across the economy and does need further work to standardize so data are comparable where some calculations can be made and where they cannot.

The project to recover heat from the wastewater could be an important step in reducing GHG emissions from the South plant. When this project is successful, it would have the impact suggested in the report. This would significantly reduce the GHG savings from the use of down cycle hot water from the project.

The calculation of carbon emissions from the burning of the pellets in the cement kiln is misplaced. The source of the pellet carbon is entirely biogenic and is not fossil-based. The GHG emissions from their combustion is limited to the N2O generated in the combustion process and does not include the CO2. Reducing the carbon emissions from cement plants will most likely involve the use of biogenic fuels. There should be no GHG emissions ascribed to the combustion of the pellets. The elimination of the emissions from coal, tires, natural gas and the other fuels currently used will be credited to the cement kiln and not to the project.

The credits claimed for the land application of Class B biosolids and compost are highly controversial. We submit that a certain fraction of the applied carbon will be released back into the atmosphere by biological processes in the soil, which are highly variable with soil type. With time the continued application of the biosolids will increase the fraction that is released. In addition, N2O will also be generated by the processes. The CO2 will be biogenic so it is not a positive emission but it is not correct to claim all of the carbon is sequestered. Nor is it at all clear that sequestering biogenic carbon should be counted in a carbon footprint calculation.

In conclusion, the project would be entirely consistent with the County's GHG emission goals and will also contribute to reductions in emissions in the private sector in the County.

11. Additional costs for treatment of nitrogen load from the dryer condensate. **True - we submit this is a small price to pay for the benefits of emission reduction and PFAS destruction afforded to the County by this solution.**

12. Does not conform to Washington Administrative Code requirements for biosolids in Chapter 173-308. **WAC 173-308 does not apply and is irrelevant. This chapter of the WAC applies only to biosolids that are to be applied to land or in municipal landfills (WAC 173-308-020(2)(b). The appropriate reference for this proposal is the Climate Commitment Act, which in RCW 70A.65.010 (11) and (12) clearly states that biosolids from municipal wastewater plants qualify as a biofuel. Although these biosolids are lower in heat content than the currently used coal, they do qualify under this provision.**

Using biosolids in a cement kiln is not equivalent to biosolids incineration as waste incineration is defined as combustion for the purpose of volume reduction. The purpose here is the use of biogenic fuels in place of fossil carbon fuels to reduce fossil carbon emissions. Using dried biosolids as a fuel in a cement kiln has been approved by the US EPA for the Lehigh Union Bridge Plant in Baltimore, MD, which has been operating successfully since 2010. There are other treatment plants and fuel producers in the US that have been approved for such use of sewage sludge biosolids in combustion units with EPA Comfort Letters. Biosolids pellets are used for fuel in cement plants in Europe, Japan and the Philippines.

13. Does not meet King County biosolids policies found in King County Code Title 28, Chapter 28.86.090. **This project is specifically consistent with the following sections of KCC 28.86.090.**

BP-1: King County shall strive to achieve beneficial use of wastewater solids. A beneficial use can be any use that proves to be environmentally safe, economically sound and utilizes the advantageous qualities of the material.

BP-3: King County shall consider new and innovative technologies for wastewater solids processing, energy recovery, and beneficial uses brought forward by public or private interests. King County shall seek to advance the beneficial use of wastewater solids, effluent, and methane gas through research and demonstration projects.

BP-6….The county shall…explore technologies that may enable the county to generate class A biosolids cost-effectively or because they have better marketability. Future decisions about technology, transportation and distribution shall be based on marketability of biosolids products.

The dried pellets will be used as a fuel in a local Seattle cement plant's kiln replacing natural gas and other fossil carbon fuels and will produce reduced GHG emissions as required by the Carbon Commitment Act. The temperatures in the kiln will eliminate the PFAS 'dangerous chemicals' in the sludge, which been widely covered in *The Seattle Times.* There are no fossil GHG emissions to be counted in the combustion of the pellets. Solar Panels will be placed on the proposed facility roof generated 5.7 Megawatt hours per year which will help to reduce the overall greenhouse gas footprint over the facility's life span. Electric trucks will haul the biosolids pellets to a nearby cement plant. By 2030, Puget Sound Energy will be providing fossil-fuel free electricity.

14. Does not align with the County's 2020 Strategic Climate Action Plan goals to reduce greenhouse gas emissions and achieve carbon neutral operation. **The County's Strategic Action Plan does not focus on activities that involve external parties, so actions by industry are encouraged but there are no specific action items in the plan. In the discussion of a circular economy, which is strongly endorsed by the plan, the chart on Consor's page 136 does cite "Transition toward renewable energy and away from fossil fuels" as one of the critical elements in building the circular economy. In short, although the plan does not address specific actions by industry to support the plan, the proposal is consistent with the plan in, overall, reducing fossil fuel greenhouse gas emissions in King County and achieving more carbon neutral processes in the private sector.**

SUMMARY OF BIOSOLIDS PARTNERSHIP PROPOSAL

Biosolids Partnership Proposal Costs are Cheaper than Baseline/Composting

Biosolids Partnership agrees with Consor's estimated cost of $137,671,000 for the cost of the drying facility which results in a $55.5 million LOWER than Consor Costs for the total 20 year Lifecycle. Consor inflated the BP $137,671,000 cost by adding $216,4330,970 of additional costs for Change Orders, Design and Construction Consulting, Project Contingencies and other unrealistic or unjustified costs. Andritz and Synagro would guarantee the total construction costs of $137,670,740 as estimated by Consor. The 2022 Andritz/Synagro Design-Build-Operate-Maintain (DBOM) Ft. Worth, Texas Biosolids Drying Plant was built for $58 million (which can produce up to 110 dry tons per day) with NO CHANGE ORDERS.

Elimination of Risks

The reality of the drying plant Capital Costs will occur when a guaranteed contractual Capital Costs secured by a Bond is submitted to King County. The risk of contaminating drinking water with PFAS will be eliminated by destroying the PFAS in the cement kiln. Consor reports the thermal drying process is technically feasible and will recover hot water to heat the digesters and all South Plant buildings replacing natural gas. Consor agrees that the proposed Facility fits within the site proposed with no odors and no air pollution from the fluidized bed dryer.

Known Market Demand

End users of the dried biosolids pellets have been identified with Letters of Intent, including a nearby cement company and its affiliate near Portland and Heidelberg/Lehigh. Biosolids pellets used for fuel at Lehigh's Baltimore, MD Plant have run successfully since 2010 processing 137 tons **of biosolids** per day. The Lehigh Plant has received awards from the U.S. EPA for energy efficiency. There are other sewage treatment plants and fuel producers across the US that have been approved for such use of sewage sludge biosolids in combustion units with EPA Comfort Letters. Biosolids pellets are used for fuel in cement plants in Europe, Japan, and the Philippines.

Climate Change – Carbon Footprint Emission Reduction

Recovering waste heat from the wastewater reduces GHG emissions from the South Plant. There are no GHG emissions ascribed to the combustion of the pellets. Thermal drying is consistent with County's GHG emission goals and will contribute to reductions in emissions in the private sector as well. Best practices in GHG reporting state you don't mix biogenic emissions and fossil GHG emissions. The former are Scope 3 emissions and the latter are Scope 1 emissions. They are reported separately. Solar Panels will be placed on the proposed facility roof generating 5.7 Megawatt hours per year which will help to reduce the overall greenhouse gas footprint over the facility's life span. Electric trucks will haul the biosolids pellets to a nearby cement plant. The Biosolids Thermal Drying Proposal using Renewable Electricity is aligned with the WTD 2018 Energy Plan renewable energy goals.

Biosolids Partnership – Andritz and Synagro

Andritz has built over 200 drying plants world-wide with **20** fluidized bed dryers. Synagro has extensive experience and resources available to operate the proposed facility. Andritz and Synagro have partnered on Design-Build-Operate and Maintain (DBOM) plants on 8 biosolids drying projects, including Pinellas County, Fl, Sacramento, CA, Honolulu, HI, Stamford, CT, Philadelphia, PA, Hamilton, ONT, Fort Worth, TX, and Victoria, BC.

Consistent with Policy

The project would be entirely consistent with the County's GHG emission goals and will also contribute to reductions in emissions in the private sector in the County. This aligns with King County Strategic Climate Action Plan to be carbon-neutral and also aligns with amended WA Senate Bill 5842 passed in 2022 to allow biofuels from biosolids pellets. The use of dried biosolids pellets as a biofuel as a substitute for fossil fuels is described in the Climate Commitment Act which sees biosolids as a potential biofuel (RCW 70A.65.010 (11) and (12). The end result of using the biosolids in a cement kiln is not equivalent to biosolids incineration as incineration is defined as combustion for the purpose of volume reduction. WAC 173-308-020(2)(b) states that those regulations do not apply to any sewage sludge that is disposed of in a manner other than in a municipal landfill, so any discussion of “beneficial use” in those regulations would not apply to dried biosolids utilized as a fuel.

Labor Relations – Rick Bender

Rick Bender, past President of the Washington State Labor Council for 18 years, has volunteered to work with the unions regarding job retraining and relocation of any positions affected by the Thermal Drying proposal. Rick has spoken to the Teamsters and received their cooperation.

Sincerely,

Peter Commerford

Manager, Drying Systems
M: +1 (817) 271-2855
peter.commerford@andritz.com
ANDRITZ Separation Technologies, Inc.
1010 Commercial Blvd S.
Arlington, TX 76001 USA
cc: Steve Huff

APPENDIX C

consor

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal

Andritz Rebuttal Response

King County, WA

Date:	May 23, 2023
Project:	Conceptual Planning and Analysis Services, Work Order #7
To:	Drew Thompson, Resource Recovery Project Manager, King County WTD
	Erika Kinno, Research & Policy Project Manager, King County WTD
From:	Jefferson Moss, PE, Consor
Prepared By:	Jefferson Moss, PE, Consor
Reviewed By:	Erika Schuyler, PE, PMP Consor

Consor

600 University St, #300
Seattle, WA
98101

Background and Objective

The Biosolids Partnership, a private entity that is comprised of several entrepreneurs, equipment manufacturers, and engineering design and construction companies, approached the King County (County) Council with a proposal to convert all of the County's Class B biosolids to a Class A product using renewable energy, while also supplying heat to the process building and digestion operations at South Plant and producing a net negative carbon impact in September 2021. In response to a council request for an independent consultant evaluation of the Biosolids Partnership Proposal, King County Wastewater Treatment Division (WTD) contracted Murraysmith to perform an assessment on the feasibility and implementation plan of the Biosolids Partnership proposal, which is documented in the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022).

Following the publication of that report, Biosolids Partnership prepared a revised proposal with a new approach to use a fluidized bed dryer fueled with renewable energy purchased from the electrical supplier and using the dried biosolids as fuel for cement plant operation. WTD requested that Murraysmith, which had since changed names to Consor, amend the contract with the County to provide an independent analysis of the updated proposal. The findings of that analysis are presented in the *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal,* which was provided to WTD in April of 2023 and mistakenly sent to Biosolids Partnership on May 1, 2023. Following receipt of the analysis, Andritz, a member of Biosolids Partnership, prepared a rebuttal letter on May 17, 2023.

This memorandum reviews and addresses the items of disagreement raised by Andritz in their rebuttal letter. Andritz has responded to each of the 14 main conclusions of the report that are found on in the Executive Summary on page 8 of 446, and Section 3.1 Conclusions on page 39 of 446. For the sake of clarity, the text from Andritz' rebuttal is copied herein, with the rebuttal comments from Andritz shown in bold and the response from Consor in roman (normal) text.

Item 1:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"The revised proposal is technically feasible but remains much more expensive than the baseline alternative over the analysis lifecycle, and it is incapable of meeting biosolids regulatory requirements and policies."

Andritz Rebuttal:

This is not factually correct. We believe the Biosolids Partnership Proposal Costs are, in fact, lower than the Baseline/Composting alternative it is compared to. (The baseline is defined by Consor as continuing with 80% biosolids trucked to eastern Washington with 20% composting, an unfair comparison, by any measure, as 100% of the biosolids from King County are proposed to be dried and sent to the cement kiln).

Although the estimated cost of the Biosolids Partnership for the drying facility was lower than the \$137,671,000 as estimated by Consor (page 421), the Biosolids Partnership agrees to use the Consor estimate of \$137,671,000 for the construction cost of the drying facility.

We believe it unrealistic, and unjustified, to inflate the Project Construction Cost of \$137,671,000 by adding \$216,430,970 for, amongst others, Change Orders, Design and Construction Consulting, Project Contingencies, resulting in Consor's estimated total Capital Cost of \$354,101,970 (page 420).

As background, the 2022 Andritz/Synagro Design-Build-Operate-Maintain (DBOM) Ft. Worth, Texas Biosolids Drying Plant is an example of the DBOM approach and was completed for a guaranteed cost of $58 million for 99 dry tons/day processing capacity. This $58 million cost included 4 centrifuges. It was built by Andritz/Synagro with NO Change Orders and has been successfully operating since its commissioning.

Although we believe the Andritz/Synagro Capital Cost, Annual O&M Costs, and the 20-Year Lifecycle Costs will come in lower in a bid, we are accepting the $137,670,740 Consor number for the Capital Cost and Consor's $13.31 Annual O&M Cost. (we disagree with your analysis of energy consumption at North Shore, and that of the relative efficiencies of gas fired versus electrically heated thermal oil systems)

Corrected Table 2-2 Capital, O&M, and lifecycle Costs ($Millions) – per above

Alternative	Capital	Annual O&M	20 year Lifecycle
Baseline	$119.9	$15.2	373.8
Revised Biosolids Partnership Proposal as above	137.7	$13.31	318,3
Savings over the Baseline alternative			$55.5
Consor Lifecycle Cost per the April Report	$354.1	$13.31	$558.0

The Biosolids Partnership Proposal results in a total 20 Year Lifecycle Cost savings to King County of $55.5 million for the 20-year lifecycle. Synagro/Andritz will have an installed and operating biosolids drying system that will dry all of King County's biosolids from the 3 plants converting the biosolids into a renewable fuel using renewable electricity. The Baseline/Composting is basically to continue with 80% of the Class B biosolids trucked to eastern Washington with 20% composting.

Consor Response to Andritz, May 2023:

Addition of markups to the construction cost to account for total project cost is standard procedure for public works cost estimating in the engineering planning and design process because there are significant costs incurred by public agencies that extend beyond the costs incurred by a contractor. Consor applied identical markups to both the baseline alternative and Biosolids Partnership revised proposal alternative to generate the costs reported in Table 2-2 on sheet 28 of 446 in *the Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal* (April 2023). The estimates for both alternatives were completed using King County's PRISM cost estimating model, which includes standard markup rates for design allowance, change order allowance, sales tax, design and construction consulting, permitting and agency support, miscellaneous service and materials, non-WTD support, WTD staff labor, contingency, and art and sustainability initiatives. The "revised" comparison Andritz prepared in the table above does not apply any of these standard markups to the revised alternative, but does include them for the baseline alternative, therefore it is not an equal comparison of costs.

The detailed Construction, O&M, and Lifecycle Cost estimates developed for the *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal* (April 2023) are provided in Appendix F, see page 420 of 446. These estimates can be compared to the estimates that were previously developed in the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022) for the Baseline Alternative and the Initial Proposal found in Attachment 1 of Appendix E, see pages 413 and 415 of 446.

The referenced energy consumption at the North Shore Water Reclamation District (NSWRD) is reported in Table 2-1 on page 27 of 446. The data reported for the North Shore facility was received directly from the plant manager and the data for the Andritz proposal is calculated based on Andritz own data using stated electrical expenditure, as noted. Without additional detail as to why Andritz believes these values may be incorrect it is not possible to draw any conclusion other than that there is a significant discrepancy between the actual energy use observed by NSWRD and that predicted by Andritz for the proposed King County installation.

Consor does not agree with Andritz' conclusion and maintains that the cost presented in Table 2-2 on sheet 28 of 446 in *the Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal* (April 2023) provides a fair and realistic analysis of probable project cost.

Item 2:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Public agency experience with the process is limited because there are currently only two fluidized bed driers treating biosolids in North America and both are operated by private contractors."

Andritz Rebuttal:

There are over 200 Andritz dryers operating successfully worldwide, There are over 20 fluidized bed dryer installations globally, including the largest biosolids processing plant in the world using the fluidized bed dryer. Synagro is an active participant in many of these projects. Many of these plants are operated by the municipality.

Consor Response to Andritz, May 2023:

Consor understands that Andritz has installed various types of dryers across the world and has also installed fluidized bed dryers outside North America. Within North America, there are two fluidized bed dryers which are both operated by private contractors, as described in Section 2.2 on page 15 of 446. Experience with public agency operation on the continent is relevant in that it provides experience from similar organizations that may be available for assistance if needed. Private companies are not always willing or able to collaborate with public agencies, and coordination outside the continent introduces considerable language, time zone, and travel barriers.

Consor's statement in the Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (April 2023) is factually accurate and relevant for the County to consider when evaluating the viability of the proposal.

Item 3:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"The scalability of drying system is poor, major investments would be required to increase capacity."

Andritz Rebuttal:

Andritz/Synagro provides 100% redundancy which is provided for at commencement of operations. The third train may never be required.

Consor Response to Andritz:

Scalability is not the same as redundancy. Scalability is the ability to increase the capacity if needed, or 'scale up' the system and is discussed in Section 2.4.1 of the *Biosolids Class A Analysis of the Revised*

Biosolids Partnership Proposal (April 2023) on page 24 of 446, and the same section of *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022) on page 59 of 446. In contrast, redundancy is the inclusion of multiple pieces of equipment that exceed the minimum required capacity so that one or more piece of equipment can be removed from service while the remaining equipment provides full capacity.

Although the revised proposal from Biosolids Partnership does include redundancy as Andritz states and as acknowledged in the report, the scalability of the system is poor. The dryer system can only increase capacity by adding a third dryer with 85 dry tons of drying capacity, which is half the total size of the system that is proposed for initial installation. The initial installation is estimated to cost approximately $354 million, so adding another dryer may cost approximately $177 million. The third dryer will almost certainly be needed as King County currently produces an average of 84 dry tons per day and the dryers are each rated to process 85 tons per day. Any increase in biosolids from current levels will require the third dryer to be constructed to maintain redundancy. Therefore, Consor maintains that the scalability of the dryer system is poor and major investments would be required to increase capacity.

Item 4:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Significantly higher capital costs than the baseline alternative."

Andritz Rebuttal:

Consor has unreasonably added $216.4 million of contingencies and Change Orders to the base construction cost. Refer to Item 1 herein.

Consor Response to Andritz, May 2023:

Please see discussion for Item 1.

Item 5:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Significantly higher lifecycle costs than the baseline alternative, with potentially shorter total lifespan."

Andritz Rebuttal:

We refer you to Item 1. The reference to North Shore Fluid Bed Drying system needing to be replaced is not justified. It only needs additional metal to be installed in the Fluid Bed Box. Andritz has Biosolids Drying plants in the USA that have been operating for 25+ years, with upgrades-based changes in regulations being carried out that will extend the operating life by at least 10 years.

Consor Response to Andritz, May 2023:

The *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal* (April 2023) does not state that the NSWRD dryer needs to be replaced. Section 2.4.3.1.3 on page 27 of 446 describes that NSWRD is currently working on a biosolids master plan that is considering replacement. This information was reported by the plant manager and would result in a 21-23 year lifecycle for the dryer, so it is reasonable to note potential for a short lifespan of the equipment. Even if the equipment can be rehabilitated to operate for 35 years as suggested by Andritz, this is still a shorter lifespan than can be expected from the baseline alternative. Consor maintains that the statements made in the report regarding NSWRD are accurate and that the revised alternative has a potentially shorter total lifespan than the baseline alternative.

Item 6:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Only one end user, a local cement manufacturing plant, has been identified, and other agencies producing dried pellet biosolids have had difficulty identifying end users, so the market may be limited."

Andritz Rebuttal:

This is incorrect: We have received two (2) Letters of Intent from a nearby Seattle cement plant and also from Heidelberg Lehigh who have submitted Letters of Interest in taking King County's dried biosolids pellets to be used as a fuel; thus, enhancing Climate Change.

Consor Response to Andritz, May 2023:

Biosolids Partnership provided the letter of intent from Heidelberg on 4/28/2023, as Consor was in the process of finalizing and delivering the report, so it could not be updated to reflect this change. Some additional analysis of this second option for biosolids use is provided herein.

The Heidelberg plant is located in Delta, British Columbia, which presents a few challenges. The feasibility of shipping biosolids across international borders is uncertain. In Canada, biosolids are regulated at the provincial level, so approval from the relevant authorities in British Columbia would need to be obtained. The Capital Regional District facility in British Columbia is already using biosolids for cement production, so there is regulatory precedent for allowing the biosolids to be used in this manner. The Washington *Statewide General Permit for Biosolids Management* only allows for export of exceptional quality biosolids outside of the state and states that "*the biosolids generator is responsible for ensuring the safe and properly documented transportation of the biosolids they generate from the time of generation through the time of final use or disposal*," which potentially creates a liability conflict where the County is responsible for the dried pellets even after they cross the Canadian border, are under the jurisdictional authority of British Columbia, and are controlled by the Heidelberg plant.

The border crossing may present logistical challenges related to customs enforcement, inspection, long border crossing times, truck and driver licensing requirements, and border closures (as occurred for an extended time during the COVID-19 pandemic). The analysis Consor completed assumed hauling of biosolids a relatively short distance to the local cement plant with electric trucks, but hauling to Delta, British Columbia is a much further distance which may make it not feasible to use electric trucks. The local cement producer indicated that investments would be required at their facility and that they would seek a contractual obligation for the County to provide a certain volume of biosolids as described in Section 2.4.4.5 on page 29 of 446. This may make it infeasible for the Heidelberg plant to serve as a second end user or a backup option. Overall, reliance on Heidelberg appears to be a high risk option with numerous tradeoffs. The suggestion from Biosolids Partnership of a second potential end user late in the analysis process that is a drive of over two hours away and across an international border highlights the limited market for dried biosolids.

The letter of interest from Heidelberg does not alter Consor's fundamental conclusion that the market for dried biosolids is limited.

Item 7:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"No end users of the excess hot water capacity have been identified, which would result in a large amount of heat being wasted after use in the dryer."

Andritz Rebuttal:

75% of the recovered heat will be used by the existing anaerobic digesters and the South Plant buildings. The future digesters will be heated with the additional heat from the hot water recovered so that almost all of the hot water recovered will be utilized.

Consor Response to Andritz, May 2023:

Andritz is incorrect. The potential for heat recovery is discussed in Section 3.2.3.2 on page 23 of 446. As described in this section, Consor obtained operational data for the hot water loop boilers from the County that shows an average heat input of 6.7 MMBtu/h and the Andritz proposal states that the heat recovery is up to 18.7 MMBtu/hr, so only 36% of the heat would be reused. Even on the day of maximum heat usage from the two-year data set (12.8 MMBtu/hr), only 68% of the available heat would be reused. Additional discussion of the challenges of using the excess heat are discussed in Section 2.4.5.1 on page 29 of 446. Consor maintains that if the revised proposal was implemented there would be a large amount of excess heat that is likely to be wasted unless other end users can be identified.

Item 8:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"The biosolids would not be available for community use."

Andritz Rebuttal:

We refer you to the many newspaper articles academic papers, and media reports on PFAS "Forever Chemicals". It is not likely that the community will want to use the compost. The use of the dried biosolids pellets as a source of renewable energy in a cement plant is an important step towards being carbon neutral.

Consor Response to Andritz, May 2023:

Andritz does not contest that if the revised proposal is implemented then the biosolids would not be available for community use. Instead, they are questioning if the community would have the desire to use the compost produced if the baseline alternative is implemented.

Consor does not agree that it is unlikely that community members will want to use a compost product. For the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022), Consor interviewed several composting operations and found that community support was widespread, as noted in Section 2.2.2 of that report, which can be found on page 55 of 446. There is no reason to expect that similar support for a composing program would not occur in King County. Additionally, as noted in Section 2.4.5.4 on page 35 of 446, both the Department of Ecology and the County are still in the early stages of evaluating if PFAS is present in sludge and if so, determining if it is a problem. It is presumptuous to assume that none of the 2.2 million residents of King County will want to use compost because it *might* have a currently undetermined level PFAS in it. Consor discussed PFAS with composting operations and none reported widespread concern regarding PFAS from community members.

Consor maintains the conclusion from the *Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal* (April 2023) that the revised proposal would not have biosolids available for community use and the conclusion from the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022) that the County can expect that the community will want to use the compost produced by the baseline alternative.

Item 9:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Energy use would increase compared to the baseline alternative. This would require additional energy capacity to be obtained through the Green Direct program, which likely does not have sufficient excess capacity available for immediate purchase."

Andritz Rebuttal:

Incorrect. It is proposed that the renewable electricity will be obtained from PSE through a regular supply, which is required by state law to achieve carbon free emissions by 2030. It is reasonable to assume that PSE will succeed in ramping up to that point, rather than relying on the Green Direct program to deliver zero-carbon power. The first year of operation is only three years before the deadline, so the emissions reported as Scope 2 herein on the spreadsheet provided to Consor is reasonable.

Consor Response to Andritz, May 2023:

Energy use is described in Section 2.4.5.1 on page 29 of 446. As Consor noted, the energy demand of the drying system is more than what the entire plant uses, so energy use would more than double.

The Washington Clean Energy Transformation Act (CETA) does not require that utilities achieve carbon free emissions by 2030, it requires carbon neutral emissions by 2030. PSE does not indicate that they will do anything more than meet the CETA requirements. In their 2022 Renewable Energy Report Card, PSE reports that only 15% of the energy they supply is renewable, and in 2020 50% of their supplied energy was either coal or natural gas, so they have significant changes to make in the next several years to meet the CETA requirements. A dramatic increase to the energy demand at the South WWTP would be counterproductive as it would make it more challenging to decarbonize the electrical grid at a time when utilities are already working to make a transition to more renewable sources.

Furthermore, it should be noted that as PSE works towards eliminating their non-renewable energy to meet CETA requirements, they are generally not decommissioning equipment but instead attempting to sell the assets to other energy producers who are not subject to the CETA requirements. This means that fossil fuel derived energy, even if it is not directly owned by PSE, will still be used to power the grid and PSE will buy renewable capacity from other producers. Therefore, buying regular grid supplied electrical energy from PSE, even in 2030, will not guarantee it is from a zero emissions source and will not eliminate the use of fossil fuels feeding the electrical grid.

Consor believes that use of the Green Energy program for direct ownership of renewable energy remains the County's best mechanism to ensure that they are using truly renewable energy and believes that the increase in energy demand as proposed in the revised proposal presents a challenge for the County.

Item 10:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"The process would increase carbon dioxide emissions compared to the baseline alterative."

Andritz Rebuttal:

Incorrect. See attached 5 pages of Biosolids Sludge to Pellet GHG Emissions which is a gate-to-gate greenhouse gases emission analysis of the proposed plant consistent with the WRI and TCR protocols for Scope 1 and Scope 2 emissions. The spreadsheet includes all assumptions and references to data sources. Consor's analysis is flawed. The discussion of the Carbon Footprint analysis begins on page 2-18 (or pg 32) of the Consor document. It is summarized in Table 2-4. Although the table reports in the second column GHG emissions in 2022, it is more correct to report these as 2027.

In the second paragraph the text reports emissions from the diesel trucks that will carry the sludge from Brightwater and West Point. While this is outside the scope of the project, it is a Metro GHG emission needed for comparison to the Baseline case, which also includes hauling emissions. The third paragraph states that PSE's Green Direct program would be used to provide the electric power. However, it is proposed that power will be obtained from PSE through a regular supply, which is required by state law to achieve carbon free emissions by 2030. It is reasonable to assume that PSE will succeed in ramping up to that point, rather than relying on the Green Direct program to deliver zero-carbon power. The first year of operation is only three years before the deadline, so the emissions reported as Scope 2 in the spread provided to Consor is reasonable.

While it is correct that the spreadsheet does not calculate the embedded carbon in the development and construction of the wind and solar farms, the calculation of operating GHG emissions generally does not include embedded carbon, as this is still a developing technique and the results vary widely depending on the availability of reliable data. This is a problem that stretches across the economy and does need further work to standardize so data are comparable where some calculations can be made and where they cannot.

The project to recover heat from the wastewater could be an important step in reducing GHG emissions from the South plant. When this project is successful, it would have the impact suggested in the report. This would significantly reduce the GHG savings from the use of down cycle hot water from the project.

The calculation of carbon emissions from the burning of the pellets in the cement kiln is misplaced. The source of the pellet carbon is entirely biogenic and is not fossil-based. The GHG emissions from their combustion is limited to the N_2O generated in the combustion process and does not include the CO_2. Reducing the carbon emissions from cement plants will most likely involve the use of biogenic fuels. There should be no GHG emissions ascribed to the combustion of the pellets. The elimination of the emissions from coal, tires, natural gas and the other fuels currently used will be credited to the cement kiln and not to the project.

The credits claimed for the land application of Class B biosolids and compost are highly controversial. We submit that a certain fraction of the applied carbon will be released back into the atmosphere by biological processes in the soil, which are highly variable with soil type. With time the continued application of the biosolids will increase the fraction that is released. In addition, N_2O will also be generated by the processes. The CO_2 will be biogenic so it is not a positive emission but it is not correct to claim all of the carbon is sequestered. Nor is it at all clear that sequestering biogenic carbon should be counted in a carbon footprint calculation.

In conclusion, the project would be entirely consistent with the County's GHG emission goals and will also contribute to reductions in emissions in the private sector in the County..

Consor Response to Andritz, May 2023:

Andritz brings up several items in this section which will each be addressed.

Andritz takes issue with the use of the year 2022 as a basis for comparison and use of diesel trucks for hauling. Both items are consistent with the *King County Biosolids Class A Alternatives Analysis Final Report* (June 2022) to maintain a basis of equal comparison between alternatives.

Andritz takes issue with Consor's description of the Green Direct program, which was discussed previously in Item 9. It should be noted that, as it pertains to GHG emissions and as described in the report, Consor made the assumption that it would be feasible to use renewable energy through the Green Direct program for the basis of the calculations, which results in lower carbon footprint for the revised alternative and represents a 'best case' scenario for the revised alternative.

Andritz agrees that embedded carbon in the electrical energy production is outside the scope of this analysis.

Andritz notes that the heat recovered from the dryers would reduce the emissions from the hot water loop boilers. This was included in the analysis, see the line for "GHG Change as Digester Heating (Natural Gas) Replacement" in Table 2-4 on page 33 of 446.

Andritz takes issue with including the GHG emissions from burning the biosolids at the plant since they are biogenic. The process for determining the emission form the biosolids is described in Section 2.4.5.2 on pages 32 and 33 of 446. The biosolids contain carbon, so if they are combusted this carbon will be converted to carbon dioxide and emitted into the atmosphere, therefore it is a GHG emission. It is not a fossil fuel emission, but carbon is still released, so it should be included in the analysis in order to make an equal and holistic comparison of alternatives.

Andritz suggests that because the biosolids offset other fuels that the emissions are net zero. This is not accurate. Consor's analysis did consider the reduction of fuel (assumed to be coal) used at the cement plant, but the emissions and heating value of coal and biosolids vary with biosolids emitting slightly more CO_2 per MMBtu generated. The analysis used only the difference in emissions factor between the coal and the biosolids to calculate the net GHG change. This is described in Section 2.4.5.2 on page 33 of 446. It should be noted that coal has a much higher emissions factor than natural gas, so by assuming the biosolids offsets coal use, this again represents the 'best case' scenario for the revised alternative.

Andritz takes issue with the carbon sequestration for land application and suggests it should be excluded from the calculations. Consor is aware that some of the carbon and nitrogen in Class B or compost biosolids is released via biological processes and has used emissions factors that include these emissions to estimate the sequestration. Although there is some uncertainty associated with the sequestration, the amount of carbon sequestered through land application and composting was calculated to be nearly ten times higher than the amount of carbon emissions saved through natural gas replacement (as shown in Table 2-4 on page 33 of 446) so some error in the calculation will not affect the overall conclusion.

Andritz states that the revised proposal is consistent with the County's GHG emissions goals. This is incorrect. The County's policies and initiatives are discussed in Section 2.4.7.2 on page 37 of 446. As it pertains to the climate footprint, the County has a target of carbon neutral operations by 2025.

Sequestration of carbon through land application and composting has a large net reduction in GHG emissions and helps support this goal. The revised proposal does reduce emissions, but only by approximately 1/20th the amount achievable by land application and composting (as shown in Table 2-4 on page 33 of 446). Andritz is correct that the proposal would reduce (non-renewable) emissions in the private sector, however the *2020 Strategic Climate Action Plan* considers emissions County-wide. The greatest county-wide impact on emissions is from carbon sequestration using land application and composting.

Additional discussion of the *2020 Strategic Climate Action Plan* can be found in the response to Item 14 also.

Item 11:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Additional costs for treatment of nitrogen load from the dryer condensate."

Andritz Rebuttal:

True - we submit this is a small price to pay for the benefits of emission reduction and PFAS destruction afforded to the County by this solution.

Consor Response to Andritz, May 2023:

Andritz is in agreement with the analysis presented in the report, however, it should be noted they are suggesting a false equivalency of two issues. The County is subject to current regulations limiting effluent nitrogen loading, but there are not currently any requirements to test for or destroy PFAS.

Item 12:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Does not conform to Washington Administrative Code requirements for biosolids in Chapter 173-308."

Andritz Rebuttal:

WAC 173-308 does not apply and is irrelevant. This chapter of the WAC applies only to biosolids that are to be applied to land or in municipal landfills (WAC 173-308-020(2)(b). The appropriate reference for this proposal is the Climate Commitment Act, which in RCW 70A.65.010 (11) and (12) clearly states that biosolids from municipal wastewater plants qualify as a biofuel. Although these biosolids are lower in heat content than the currently used coal, they do qualify under this provision. Using biosolids in a cement kiln is not equivalent to biosolids incineration as waste incineration is defined as combustion for the purpose of volume reduction. The purpose here is the use of biogenic fuels in place of fossil carbon fuels to reduce fossil carbon emissions. Using dried biosolids as a fuel in a cement kiln has been approved by the US EPA for the Lehigh Union Bridge Plant in Baltimore, MD, which has been operating successfully since 2010. There are other treatment plants and fuel producers in the US that have been approved for such use of sewage sludge biosolids in combustion units with EPA Comfort Letters. Biosolids pellets are used for fuel in cement plants in Europe, Japan and the Philippines.

Consor Response to Andritz, May 2023:

WAC 173-308 is the applicable legislation. Discussion of the regulations can be found in Section 2.4.7.1 on page 37 of 446 and additional detail will be included here.

Specifically, 173-308-020 says *"(1) These rules apply to all treatment works treating domestic sewage as defined by this chapter. In addition, these rules apply to, but are not limited to the following: (a) a person who prepares biosolids or sewage sludge…"*

RCW 70A.205.205 gives the Department of Ecology the authority to regulate biosolids which is enacted through the *Statewide General Permit for Biosolids Management* (SGPBM). The permit is consistent with WAC 173-308-020 and requires all publicly owned treatment works to obtain a permit. Further, the SGPBM states: *"Ecology will not approve permit applications for disposal or incineration of biosolids except as described in this section."* The section goes on to list five facilities that already have incinerators which are allowed to continue incineration. None of King County's facilities are on the list. Since combustion in a cement kiln is slightly different than incineration, Consor also contacted Ecology to see if use of the biosolids for cement kiln fuel would be considered beneficial reuse and was advised that "*this would not count as beneficial use and would likely not be allowed*." Therefore, Consor concludes that WAC 173-308 is the relevant legal requirement.

Andritz references RCW 70A.65.010 which is the Definitions section of the Greenhouse Gas Emissions – Cap and Invest Program chapter. The section defines Biomass as "*nonfossilized and biodegradable organic material originating from plants, animals, and microorganisms, including products, by-products, residues, and waste from agriculture, forestry, and related industries as well as the nonfossilized and biodegradable organic fractions of municipal wastewater and industrial waste, including gasses and liquids recovered from the decomposition of nonfossilized biodegradable organic material*." This is a very general definition for the purposes of the Cap and Invest Program which is used later in the section to exempt carbon dioxide emissions resulting from combustion of biomass from the carbon cap in regulations. It does not modify or affect regulations of biosolids specifically in any way, so WAC 173-308 remains the governing regulation.

Andritz notes several other instances where biosolids have been or are currently used at cement plants. Consor does not disagree that biosolids can be used for cement kiln fuel and that this has been successfully permitted and implemented in other places, however, based on the regulations and discussion with Ecology, this use is not permitted in Washington as described above and in Section 2.4.7.1 on page 37 of 446.

Item 13:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Does not meet King County biosolids policies found in King County Code Title 28, Chapter 28.86.090."

Andritz Rebuttal:

This project is specifically consistent with the following sections of KCC 28.86.090.

BP-1: King County shall strive to achieve beneficial use of wastewater solids. A beneficial use can be any use that proves to be environmentally safe, economically sound and utilizes the advantageous qualities of the material.

BP-3: King County shall consider new and innovative technologies for wastewater solids processing, energy recovery, and beneficial uses brought forward by public or private interests. King County shall seek to advance the beneficial use of wastewater solids, effluent, and methane gas through research and demonstration projects.

BP-6….The county shall…explore technologies that may enable the county to generate class A biosolids cost-effectively or because they have better marketability. Future decisions about technology, transportation and distribution shall be based on marketability of biosolids products. The dried pellets will be used as a fuel in a local Seattle cement plant's kiln replacing natural gas and other fossil carbon fuels and will produce reduced GHG emissions as required by the Carbon Commitment Act. The temperatures in the kiln will eliminate the PFAS 'dangerous chemicals' in the sludge, which been widely covered in The Seattle Times. There are no fossil GHG emissions to be counted in the combustion of the pellets. Solar Panels will be placed on the proposed facility roof generated 5.7 Megawatt hours per year which will help to reduce the overall greenhouse gas footprint over the facility's life span. Electric trucks will haul the biosolids pellets to a nearby cement plant. By 2030, Puget Sound Energy will be providing fossil-fuel free electricity.

Consor Response to Andritz, May 2023:

Andritz seems to be in agreement with Consor's analysis in Section 2.4.7.2 on page 37 of 446, that the proposal may meet Biosolids Policies 1, 3 and 6 in King County Code 28.86.090, however, they are ignoring several policies, which are not met by Biosolids Partnership's proposal. These policies are:

BP-2: Biosolids-derived products should be used as a soil amendment in landscaping projects funded by King County.

BP-4: King County shall seek to maximize program reliability and minimize risk by one or more of the following:

1. *maintaining reserve capacity to manage approximately one hundred fifty percent of projected volume of biosolids;*
2. *considering diverse technologies, end products, and beneficial uses; or*
3. *pursuing contractual protections including interlocal agreements, where appropriate.*

BP-5: King County shall produce and use biosolids in accordance with federal, state and local regulations.

BP-9: King County shall seek to minimize the noise and odor impact associated with processing, transporting and applying of biosolids, consistent with constraints of economic and environmental considerations and giving due regard to neighboring communities.

Consor maintains that the revised proposal from Biosolids Partnership does not meet these policies.

Item 14:

Biosolids Class A Analysis of the Revised Biosolids Partnership Proposal (Consor, April 2023):

"Does not align with the County's 2020 Strategic Climate Action Plan goals to reduce greenhouse gas emissions and achieve carbon neutral operation."

Andritz Rebuttal:

The County's Strategic Action Plan does not focus on activities that involve external parties, so actions by industry are encouraged but there are no specific action items in the plan. In the discussion of a circular economy, which is strongly endorsed by the plan, the chart on Consor's page 136 does cite "Transition toward renewable energy and away from fossil fuels" as one of the critical elements in building the circular economy. In short, although the plan does not address specific actions by industry to support the plan, the proposal is consistent with the plan in, overall, reducing fossil fuel greenhouse gas emissions in King County and achieving more carbon neutral processes in the private sector.

Consor Response to Andritz, May 2023:

The *2020 Strategic Climate Action Plan* is discussed on Section 2.4.7.2 on page 37 of 446. The overarching goal of the plan is to "reduce countywide sources of GHG emissions, compared to a 2007 baseline, by 25% by 2020, 50% by 2030, and 80% by 2050." The baseline alternative has a much larger net GHG reduction than the revised proposal alternative, as previously discussed in Item 10, which directly contributes to achieving the overarching goal of the plan.

It is accurate that one of the focus areas of the *2020 Strategic Climate Action Plan* is to achieve a circular economy. The revised proposal alternative can contribute to Priority Action 5.7.2 to specify low-embodied carbon building material in King County capital projects, which mentions use of low emissions concrete. Use of alternative fuels to reduce the energy required for cement manufacturing is one of many strategies to reduce embodied carbon. In contrast, there are seven Action Items that involve increasing recycling of organic material and use of compost, so the baseline alternative contributes more broadly to achieving the Action Items.

Overall, Consor does not believe that the revised proposal aligns with the *2020 Strategic Climate Action Plan* since implementation of the plan would result in higher emissions compared to the baseline alternative and contribute towards fewer Priority Action items.

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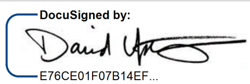
Dave Upthegrove dave.upthegrove@kingcounty.gov Chair Security Level: Email, Account Authentication (None)	 Signature Adoption: Uploaded Signature Image Using IP Address: 67.160.80.216	Sent: 11/30/2023 1:00:07 PM Viewed: 11/30/2023 2:10:43 PM Signed: 11/30/2023 2:11:03 PM
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Envelope Summary Events	Status	Timestamps

Envelope Summary Events	Status	Timestamps
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Certified Delivered	Security Checked	11/30/2023 2:33:17 PM
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Electronic Record and Signature Disclosure

ELECTRONIC RECORD AND SIGNATURE DISCLOSURE

From time to time, King County-Department of 02 (we, us or Company) may be required by law to provide to you certain written notices or disclosures. Described below are the terms and conditions for providing to you such notices and disclosures electronically through the DocuSign system. Please read the information below carefully and thoroughly, and if you can access this information electronically to your satisfaction and agree to this Electronic Record and Signature Disclosure (ERSD), please confirm your agreement by selecting the check-box next to 'I agree to use electronic records and signatures' before clicking 'CONTINUE' within the DocuSign system.

Getting paper copies

At any time, you may request from us a paper copy of any record provided or made available electronically to you by us. You will have the ability to download and print documents we send to you through the DocuSign system during and immediately after the signing session and, if you elect to create a DocuSign account, you may access the documents for a limited period of time (usually 30 days) after such documents are first sent to you. After such time, if you wish for us to send you paper copies of any such documents from our office to you, you will be charged a $0.00 per-page fee. You may request delivery of such paper copies from us by following the procedure described below.

Withdrawing your consent

If you decide to receive notices and disclosures from us electronically, you may at any time change your mind and tell us that thereafter you want to receive required notices and disclosures only in paper format. How you must inform us of your decision to receive future notices and disclosure in paper format and withdraw your consent to receive notices and disclosures electronically is described below.

Consequences of changing your mind

If you elect to receive required notices and disclosures only in paper format, it will slow the speed at which we can complete certain steps in transactions with you and delivering services to you because we will need first to send the required notices or disclosures to you in paper format, and then wait until we receive back from you your acknowledgment of your receipt of such paper notices or disclosures. Further, you will no longer be able to use the DocuSign system to receive required notices and consents electronically from us or to sign electronically documents from us.

All notices and disclosures will be sent to you electronically

Unless you tell us otherwise in accordance with the procedures described herein, we will provide electronically to you through the DocuSign system all required notices, disclosures, authorizations, acknowledgements, and other documents that are required to be provided or made available to you during the course of our relationship with you. To reduce the chance of you inadvertently not receiving any notice or disclosure, we prefer to provide all of the required notices and disclosures to you by the same method and to the same address that you have given us. Thus, you can receive all the disclosures and notices electronically or in paper format through the paper mail delivery system. If you do not agree with this process, please let us know as described below. Please also see the paragraph immediately above that describes the consequences of your electing not to receive delivery of the notices and disclosures electronically from us.

How to contact King County-Department of 02:

You may contact us to let us know of your changes as to how we may contact you electronically, to request paper copies of certain information from us, and to withdraw your prior consent to receive notices and disclosures electronically as follows:
To contact us by email send messages to: cipriano.dacanay@kingcounty.gov

To advise King County-Department of 02 of your new email address

To let us know of a change in your email address where we should send notices and disclosures electronically to you, you must send an email message to us at cipriano.dacanay@kingcounty.gov and in the body of such request you must state: your previous email address, your new email address. We do not require any other information from you to change your email address.

If you created a DocuSign account, you may update it with your new email address through your account preferences.

To request paper copies from King County-Department of 02

To request delivery from us of paper copies of the notices and disclosures previously provided by us to you electronically, you must send us an email to cipriano.dacanay@kingcounty.gov and in the body of such request you must state your email address, full name, mailing address, and telephone number. We will bill you for any fees at that time, if any.

To withdraw your consent with King County-Department of 02

To inform us that you no longer wish to receive future notices and disclosures in electronic format you may:

i. decline to sign a document from within your signing session, and on the subsequent page, select the check-box indicating you wish to withdraw your consent, or you may;

ii. send us an email to cipriano.dacanay@kingcounty.gov and in the body of such request you must state your email, full name, mailing address, and telephone number. We do not need any other information from you to withdraw consent.. The consequences of your withdrawing consent for online documents will be that transactions may take a longer time to process..

Required hardware and software

The minimum system requirements for using the DocuSign system may change over time. The current system requirements are found here: https://support.docusign.com/guides/signer-guide-signing-system-requirements.

Acknowledging your access and consent to receive and sign documents electronically

To confirm to us that you can access this information electronically, which will be similar to other electronic notices and disclosures that we will provide to you, please confirm that you have read this ERSD, and (i) that you are able to print on paper or electronically save this ERSD for your future reference and access; or (ii) that you are able to email this ERSD to an email address where you will be able to print on paper or save it for your future reference and access. Further, if you consent to receiving notices and disclosures exclusively in electronic format as described herein, then select the check-box next to 'I agree to use electronic records and signatures' before clicking 'CONTINUE' within the DocuSign system.

By selecting the check-box next to 'I agree to use electronic records and signatures', you confirm that:

- You can access and read this Electronic Record and Signature Disclosure; and
- You can print on paper this Electronic Record and Signature Disclosure, or save or send this Electronic Record and Disclosure to a location where you can print it, for future reference and access; and
- Until or unless you notify King County-Department of 02 as described above, you consent to receive exclusively through electronic means all notices, disclosures, authorizations, acknowledgements, and other documents that are required to be provided or made available to you by King County-Department of 02 during the course of your relationship with King County-Department of 02.