KING COUNTY

1200 King County Courthouse
516 Third Avenue
Seattle, WA 98104

Signature Report

Motion 16251

Proposed No. 2022-0372.1 **Sponsors** Upthegrove

A MOTION acknowledging receipt of an independent consultant report on a biosolids thermal drying comprehensive study, prepared in accordance with the 2021-2022 Budget Ordinance, Ordinance 19210, Section 112, as amended by Ordinance 19364, Section 83, Expenditure Restriction ER2 and Proviso P5.

WHEREAS, the King County 2021-2022 Budget Ordinance, Ordinance 19210, Section 112, as amended by Ordinance 19364, Section 83, Expenditure Restriction ER2 and Proviso P5, states that $300,000 shall not be expended or encumbered until the executive transmits a biosolids thermal drying comprehensive study, and a motion that acknowledges receipt of the study is passed by the council, and

WHEREAS, the executive has transmitted to the council the requested report entitled biosolids thermal drying along with a motion acknowledging the receipt thereof by August 5, 2022.

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

Receipt of the biosolids thermal drying study, Attachment A to this motion, is hereby acknowledged.

Motion 16251 was introduced on 10/18/2022 and passed by the Metropolitan King County Council on 12/6/2022, 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:
Claudia Balducci
F8830816F1C4427...
Claudia Balducci, Chair

ATTEST:

DocuSigned by:
Melani Pedroza
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Melani Pedroza, Clerk of the Council

Attachments: A. Biosolids Thermal Drying Report, August 2022

Motion 16251

Attachment A

Biosolids Thermal Drying Report

August 2022

King County

Contents

Proviso Text

Ordinance 19364, Section 83, DNRP WTD, Expenditure Restriction ER2 and Proviso P5[1]

ER2 EXPENDITURE RESTRICTION: Of this appropriation, $200,000 shall be expended or encumbered solely for the retention of an independent consultant and the development of the biosolids thermal drying comprehensive study described in Proviso P5 of this section.[2]

P5 PROVIDED FURTHER THAT:
Of this appropriation, $300,000 shall not be expended or encumbered until the executive transmits a biosolids thermal drying comprehensive study and a motion that should acknowledge receipt of the study and a motion acknowledging the receipt of the study 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.

The comprehensive study shall include, but not be limited to, the following:

A. Implementation steps for thermal drying of all digested and dewatered biosolids from the West Point, Brightwater, and South regional wastewater treatment plants for the production of Class A biosolids;

B. Feasibility and approach for utilizing only renewable energy sources in the thermal drying process;

C. Development of a process for making Class A biosolids available for use by the public as a fertilizer for residential or commercial application or for use as an energy product;

D. Analysis of the scalability, cost, environmental and climate footprint, and specifics of implementing the program;

E. Identification of any necessary changes to county policies to implement the program; and

F. Identification of future budget proposals that may be necessary to implement the program.

The executive should file the comprehensive study and motion required by this proviso no later than June 30, 2022, with the clerk of the council, who shall retain an electronic copy and provide an electronic copy to all councilmembers, the council chief of staff and the lead staff for the mobility and environment committee, or its successor.[3]

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[1] Link to Ordinance 19364
[2] The amounts listed in ER2 and P5 are different, per the ordinance approved by the Council.
[3] The due date for this report was extended from June 30, 2022, to August 5, 2022, with consent from the Council sponsor of the proviso, due to barriers the consultant faced in obtaining timely information necessary to complete the report.

Executive Summary

Ordinance 19364, Section 83, Expenditure Restriction ER2 and Proviso P5, required the Department of Natural Resources and Parks (DNRP) to retain an independent consultant to conduct a biosolids thermal drying comprehensive study. The Council sponsor of the Proviso clarified that the intent was to review a specific biosolids thermal drying concept put forth by a private vendor and technology consortium called the King County Biosolids Partnership (Biosolids Partnership).

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 cost and carbon emissions as two major benefits of its proposal (see Appendix A, page 7).

With input from the Council sponsor of the Proviso, DNRP retained the consulting firm Murraysmith, and developed a scope of work, evaluation criteria, and deliverables for the independent study that clarified and expanded the study beyond what was in the original proviso language. Murraysmith compared the Biosolids Partnership's concept with a baseline scenario of the County's current biosolids program direction of continued Class B land application and development of a Class A composting program.[4] The consultant's report also included a review of past King County evaluations of biosolids options, such as the 2020 report *Alternative Options for the Use of Biosolids,* which was prepared by another consultant in response to a 2019 Council budget proviso.[5]

Murraysmith identified several significant considerations should the County choose to pursue implementation of the Biosolids Partnership thermal drying concept:

Significantly higher estimated cost. The Biosolids Partnership concept's estimated 20-year lifecycle cost is almost double the baseline alternative's estimated cost. The Biosolids Partnership concept has a 20-year lifecycle cost of $723.6 million, which includes initial capital cost plus annual operations and maintenance cost for 20 years, as compared to the baseline (compost) alternative's 20-year lifecycle cost of $373.8 million. These costs are preliminary planning level costs, which by definition have an uncertainty range wherein each estimate could increase by as much as 100 percent.[6] The estimated lifecycle cost of $723 million for the Biosolids Partnership concept is due to the complexity of the dryer and gasification systems. Up-front costs are also high, making scalability limited and costly. Funding the cost difference for the Biosolids Partnership's concept would require either a greater increase to the County's annual sewer rate or a deferral of priority capital projects including those for asset management, planned capacity improvements or regulatory compliance. If necessary, deferrals could be made to projects at any of WTD's treatment plants or within the conveyance system.

Unknown market demand. The Biosolids Partnership's concept produces two final products, biochar and pellets. The Partnership's concept proposes to utilize pellets as a fuel for a cement plant, though it is unclear whether the cement plant would purchase the pellets or need to be paid to use them. A known

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[4] Link to King County Biosolids Class A Alternatives Analysis: Final Report. June 10, 2022. Murraysmith, pg. 6.

[5] Link to *Alternative Options for the Use of Biosolids*

[6] 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.

market has not been identified for the biochar product of the partnership proposal. Murraysmith found a lack of market diversification normally required for successful implementation of a biosolids management program. If a market cannot be identified for the biochar or dried pellets, the County may then have to dispose of the products in a landfill at additional high cost as well as bearing the associated risk of non-compliance with Washington State guidance to beneficially reuse biosolids.

Inconsistency with policy. The Murraysmith report identified inconsistencies between the Biosolids Partnership's concept and Washington Administrative Code 173-308, which encourages maximum beneficial use of biosolids. The Partnership concept does not align with the County's Strategic Climate Action Plan goal for King County to be carbon-neutral by 2025, due to the significantly lower carbon footprint of the baseline alternative compared to the Partnership concept. Implementation of the Biosolids Partnership alternative would eliminate the carbon sequestration benefits from land application that are realized in the baseline scenario and result in a net increase of greenhouse gas (GHG) emissions. Therefore, implementing the Biosolids Partnership proposal would also require the County to revisit its climate action goals and likely extend the date for carbon-neutral operations.

Land acquisition, siting/permitting and operations. The facility needed to implement the Partnership's concept would need to be sited outside of the South Treatment Plant because most onsite land has already been allocated to other projects. This siting would require the acquisition of three or more acres of property near the treatment plant. Siting of the facility requires equity and social justice impacts to be assessed with the surrounding community. Implementation also requires construction and environmental permits; an air permit from the Puget Sound Clean Air Agency; and various building permits. Another important consideration for implementation is the need for trained operators who have the specific skill sets to operate the Biosolids Partnership's thermal drying facility. The thermal drying process is mechanically intensive and would necessitates hiring of an estimated 24 additional staff, adding substantial operational costs.

Single supplier risk. In its report, Murraysmith found that using a single supplier of wood biomass, as proposed by the Biosolids Partnership, would add risk. The extraordinarily high demand for biomass wood would have to be met by multiple sources, and sourcing an adequate amount of woody debris may become more difficult as other industries utilizing wood waste energy emerge in the future.[7]

Murraysmith recommended that King County continue implementing the current program direction as planned, and that the Biosolids Partnership's proposal not be further considered. Murraysmith also encouraged King County to continue monitoring any Class A biosolids technologies and operations that will utilize the renewable resource and reduce the carbon footprint, while maximizing program reliability and minimizing risk. The County is nearing design completion for a Class A compost pilot project that will be constructed at South Treatment Plant. This pilot would test the marketability of a Class A compost product that would be sold locally as a soil amendment. DNRP concurs with Murraysmith's findings and recommendations.

The due date for this report was extended from June 30, 2022, to August 5, 2022, with consent from the Council sponsor of the Proviso.

[7] Appendix A, page 14

Background

Department Overview: The Department of Natural Resources and Parks (DNRP) works in support of 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 King County Biosolids Program is housed within the Resource Recovery Section of WTD.

The Resource Recovery Section manages the administration and delivery of products and programs from renewable resources captured from the wastewater treatment process.[8] The Resource Recovery Section is comprised of a strategic support team and five programs: Sustainability, Technology Assessment and Innovation, Energy, Recycled Water, and Biosolids. The Biosolids Program manages the distribution and use of Loop®, a branded biosolids product created by recycling the County's wastewater.[9] Loop® is a natural soil builder and endlessly renewable resource that returns carbon and nutrients to the land.

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.[10] The Biosolids Program has successfully produced and distributed its Loop® brand of biosolids for almost 50 years, with full regulatory compliance and beneficial use.[11]

The Biosolids Program, in conjunction with University of Washington scientists, in response to the Clean Water Act, began researching and developing a program in 1972 for biosolids to be used on forestlands and land that needed to be reclaimed from other uses, such as mining. From 1978-2020, the Biosolids Program entered a long-standing partnership with GroCo, Inc., to compost a portion of its biosolids into a retail garden product. Composting involves mixing biosolids with woody material, such as sawdust, yard clippings, or wood chips, and then microorganisms break down the material into a garden product called compost.[12] After nearly two decades of operations, the Biosolids Program added two agricultural projects in Yakima and Douglas counties.

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[8] A renewable resource is a natural resource that will replenish and replace the portion depleted by usage and consumption. Biogas, biosolids, and recycled water are three byproducts of the wastewater system that are considered renewable resources.

[9] 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.

[10] Market-based approaches use business models and supply and demand market forces to address public interest challenges more sustainably and/or at scale.

[11] Loop® Biosolids [www.loopforyoursoil.com]

[12] Composting is an aerobic biological process that uses microorganisms in the presence of air to decompose organic material and to produce heat to reduce pathogens to Class A requirements. Composting biosolids involves mixing Class B biosolids with woody materials to accelerate decomposition.

In 1993, federal biosolids regulations were added to The Clean Water Act of 1972 (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.[13] Washington State followed suit, developing the biosolids rule, or chapter 173-308 in the Washington Administrative Code (WAC) in 1998.[14] 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. King County produces Class B biosolids, which are treated, but do have detectable levels of pathogens and require a permit for use.

In addition to developing a successful Class B program, the Biosolids Program examined opportunities for Class A options many times over the past several decades. In general, these options have not been undertaken due to prioritization of other operational and infrastructure needs. Completed in 2020, the most recent examination was a comprehensive report and consultant study entitled *Alternative Options for the Use of Biosolids*, which was prepared and transmitted to the Council in response to a 2019 Council budget Proviso.[15,16] The 2020 report compared three alternative scenarios for King County's Biosolids Program on 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.[17] The results of the 2020 report are summarized below:

Table 1. Summary of Results From 2020 l *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.[18]	Very High

[13] Information on the Clean Water Act is here and the section is here.
[14] The biosolids rule in located in Chapter 173-308 of the WAC, which can be found here.
[15] Link to the 2020 report to the Council entitled *Alternative Options for the Use of Biosolids*
[16] Link to Ordinance 18930, Section 72, Proviso P3
[17] The triple bottom line — an analysis method to account for environmental, economic, and social factors — are commonly used in planning or feasibility studies to evaluate King County alternatives, options, and projects. This 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.
[18] 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 United States Environmental Protection Agency standards by operating at a temperature of

Alternative Scenario	Description	Triple Bottom Line Score
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[19]	The creation of a public-private partnership to dry and pyrolyze Class B biosolids at a new offsite pyrolysis facility.	Medium

The report also noted that any development of a Class A biosolids program would require changes to the biosolids policies in the King County Code (KCC), which currently prohibits the production and sale of anything other than Class B Biosolids.[20]

Key Current Conditions: The 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.[21,22,23] In recent years, Loop® biosolids use has provided approximately 20 percent of the carbon offsets for the DNRP's carbon footprint.[24] When biosolids are applied to land, carbon emissions are reduced in three main ways: the biosolids' inherent carbon content is sequestered in soil; the nutrients from biosolids enable plants to grow more robustly and remove more carbon from the atmosphere; and 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 plants to operate in a more energy-efficient manner. At South Treatment Plant, the biogas produced from the biosolids anaerobic digesters is sold to Puget Sound Energy, providing revenue for DNRP's carbon emissions reduction projects, as well as contributing a renewable energy source for use by the community, which helps offset the region's overall carbon emissions. In addition to carbon benefits, biosolids also provide slow-release nutrients and improve soil's ability to hold moisture, thereby reducing soil runoff, erosion, and associated water pollution.

King County currently produces up to a total of 130,000 wet tons of biosolids each year from three regional treatment plants, which is equivalent to filling a stadium 70 feet high or filling 8,000 King County Metro buses. Each of King County's treatment plants is slightly different, but all use a technology called 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

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122˚°F to 140˚°F, called thermophilic temperatures, in order to reduce pathogens to the level required for Class A biosolids. In order 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.

[19] 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.

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

[21] Carbon sequestration refers to the process of removing carbon dioxide from the atmosphere.

[22] The website for Clean Water Healthy Habitat is here.

[23] More information on the Strategic Climate Action Plan is here.

[24] Carbon offsets refer to actions taken to compensate for carbon dioxide emissions. Offsets can be traded as part of environmental programs.

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 became more reliant on agricultural uses, reducing options for the Biosolids Program if biosolids use in agriculture declines.

Washington state farmers in Douglas, Lincoln, Benton, and Yakima counties currently use most (approximately 65 percent) of King County's biosolids. Commercial timberland in the Cascade foothills uses approximately 35 percent. In May 2020, the Biosolids Program's compost partner, GroCo, 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 product 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 with compost donations and by maintaining a robust, widespread outreach and education program.[25] 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 Biosolids Program on a new product. Several past studies of Class A technologies, including the 2020 *Alternative Options for the Use of Biosolids* report mentioned above 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. 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.[26,27]

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 adopted 2021-2022 King County Budget.[28] 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 process to further process Class B biosolids into a marketable Class A product. Once operational, information from the composting pilot 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, to collect data to inform a capital project process for a larger, permanent, off-site facility. The current cost estimate for the pilot project is $5.1 million, with project completion anticipated in 2023.

In 2021, members of the King County Council were briefed by a private vendor and technology consortium called the Biosolids Partnership. 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.

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[25] Link to The Determinants of Equity: Identifying Indicators to Establish a Baseline of Equity in King County, 2015.
[26] Link to the 2020 report to Council entitled *Alternative Options for the Use of Biosolids*
[27] A compost market assessment showed that there is market opportunity for King County biosolids compost representing approximately 20 percent of the total biosolids production.
[28] Link to the 2021-22 King County Budget Book; see pg. 420 for listing of compost pilot (project #1139044)

The Biosolids Partnership concept has many similarities with the pyrolysis alternative discussed and analyzed in the 2020 report to the Council referenced above.[29] 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.[30] In keeping with the Council's direction for an independent consultant, DNRP identified a consultant, 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.

Report Methodology: DNRP contracted with the consulting firm Murraysmith to perform an independent consultant review of the Biosolids Partnership's thermal drying proposal, as compared to the status quo current direction for the Biosolids Program (Class B land application with compost pilot).[31] Murraysmith is a large, established consultant working nationwide to assist communities in all aspects of wastewater system planning and design, including biosolids handling and beneficial use.[32] Murraysmith was contracted with review through King County's competitive procurement process. Before beginning the contract, DNRP shared the consultant scope of work with the Council sponsor of the proviso to confirm direction for the consultant's review. After the consultant was contracted, Murraysmith conducted a participant focus group with the Council sponsor of the proviso to receive direct input on its proposed strategy and deliverables for the independent review.[33] DNRP provided Murraysmith with past King County reports on the Biosolids Program and access to the King County Biosolids Program, as well as access to the King County Biosolids Partnership consortium representatives, so that Murraysmith was able to obtain information it deemed necessary to conduct its evaluation. DNRP is committed to preserving the independence of the consultant evaluation and directs readers to the independent Murraysmith report (Appendix A).

In developing the scope of work for the independent consultant, DNRP identified and proposed expanded criteria for the evaluation to further refine the consultant's work in conducting its independent review. These criteria were developed with input from, and approval of, the Council sponsor of the proviso. The expanded evaluation criteria that were included in the independent consultant's scope of work are as follows:

Scalability
Risk and benefits
Cost
Capital costs, operations and maintenance, and simple payback period.[34]
Social Impacts
Equity and Social Justice
Odor
Air Pollution

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[29] Link to the 2020 report to Council entitled *Alternative Options for the Use of Biosolids*
[30] Link to Ordinance 19364, Section 83, Expenditure Restriction ER2 and Proviso P5
[31] Murraysmith general website [https://www.murraysmith.us]
[32] Murraysmith wastewater expertise website [https://www.murraysmith.us/wastewater/]
[33] Murraysmith conducted a participant focus group with representatives from the Council on February 23, 2022. Councilmember Dave Upthegrove and Council District Five Staff Member Zoe Mullendore attended.
[34] Payback period: the time it takes to recover the cost of an investment.

Trucking impacts to neighborhoods
Ability for communities (in King County or statewide) to utilize biosolids to amend and build their soils for urban or rural agriculture
Environmental impacts
Overall energy use and maximizing use of renewable energy sources
Climate footprint
Air Quality
Contaminants of Emerging Concern (CEC) reduction[35]
Economic impacts
Class A product marketability, either as a fertilizer product for residential/commercial use or an energy product
Diversity of Class A product user portfolio
Policy impacts
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, carbon-related, and greenhouse gas reduction goals
Scope of how King County could implement such a program
Other criteria as identified by King County staff
Consultant to identify other relevant criteria

The deliverables for the independent consultant's scope of work are listed as follows, also developed with input from, and approval of, the Council sponsor of the proviso:

Alternative Analysis Report [shall include]: *a. Ranked table listing each alternative with its relevance to each of the criteria identified in Task 400*[36] *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* *f. Clearly identify the most beneficial future state for WTD* *g. Other deliverables as identified through participant focus group*

The due date for this report was extended from June 30, 2022, to August 5, 2022, with consent from the Council sponsor of the proviso, due to barriers the consultant faced in obtaining timely information necessary to complete the report.

[35] 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.
[36] Task 400 refers to the list of evaluation criteria for the consultant scope of work, as listed on page 10 of this report.

Report Requirements

The Council expenditure restriction requires an independent consultant to develop a biosolids thermal drying comprehensive study. The proviso requires that this evaluation include, but not be limited to, the following:

A. Implementation steps for thermal drying of all digested and dewatered biosolids from the West Point, Brightwater and South regional wastewater treatment plants for the production of Class A biosolids;
B. Feasibility and approach for utilizing only renewable energy sources in the thermal drying process;
C. Development of a process for making Class A biosolids available for use by the public as a fertilizer for residential or commercial application or for use as an energy product;
D. Analysis of the scalability, cost, environmental and climate footprint and specifics of implementing the program;
E. Identification of any necessary changes to county policies to implement the program; and
F. Identification of future budget proposals that may be necessary to implement the program.

A. Implementation steps for thermal drying of all digested and dewatered biosolids from the West Point, Brightwater and South regional wastewater treatment plants for the production of Class A biosolids.

In its report, Murraysmith considered the space, resources, material sourcing, and the marketability of the final product put forward by the Biosolids Partnership in its concept. Murraysmith ultimately found that the Biosolids Partnership's proposal is not feasible for King County to implement.

Murraysmith identified significant factors for implementation of the partnership proposal. Such factors include lack of space at South Treatment Plant and a mechanically intensive process that would require hiring an estimated 24 additional staff. Murraysmith also noted that sources of feedstock and end-user markets would need to be diversified for successful implementation because a single feedstock supplier likely cannot provide enough supply, and a limited number of end-users likely cannot provide enough demand for products. More information on the factors related to implementation identified by Murraysmith, please see section 2.3 of Appendix A.[37]

Establishing and operating a large capital project such as a thermal drying facility is a multi-year process that includes site acquisition, design, permitting, and construction. The initial step to establish the drying facility and associated infrastructure would be acquiring three to three and a half acres of property outside of the South Plant footprint, but proximate enough for the dryer condensate[38] to be conveyed back to South Plant for treatment. More information on the space requirements is provided in section 2.3.1 of Appendix A.

[37] Appendix A, page 10
[38] The Murraysmith report indicates that additional nitrogen load is the primary concern with condensate, however specific concentrations are not estimated. (Sec 3.1; page 24). The proposal from the Biosolids Partnership includes a "Conceptual Project Basis of Design Memorandum" that presumes the condensate will be returned to the treatment plant and that this will be designed in future phases of the project. Additional nitrogen loading into County treatment plants exacerbates a current regulatory issue arising from the nutrient general permit.

Siting of the facility would need to be evaluated for equity impacts. The Murraysmith report notes that, 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 Environmental Justice Screening and Mapping Tool, the community near South Treatment Plant is more vulnerable to a number of social impacts such as air pollution and the presence of potentially hazardous and toxic sites, than those in the neighborhoods surrounding West Point or Brightwater.[39] The area is populated by under-represented groups with lower socio-economic means. Subsection 2.4.4 of the Appendix A provides more information on social impacts.

Implementation would require construction and environmental permitting, an air permit from the Puget Sound Clean Air Agency, and various building and construction permits. The Murraysmith report notes the thermal drying concept is anticipated to be more complicated than the baseline scenario of the County's current biosolids program, making it more difficult to implement. Section 2.4.7.1 of Appendix A provides more information on compliance with local, state, and federal regulations.

Another important consideration for implementation of the thermal drying concept the need for specifically trained operators with distinctive a skill sets to operate the Biosolids Partnership's thermal drying facility. This concept would require an estimated minimum of 24 full-time employees to operate and maintain the facility. Alternatively, the County could consider paying to contract the operations and maintenance to a third-party operator pursuant to potential labor negotiations.

B. Feasibility and approach for utilizing only renewable energy sources in the thermal drying process.

Based on the information provided by the Biosolids Partnership, Murraysmith's analysis found that the Biosolid Partnership's concept of using woody materials as a renewable feedstock for gasification is not feasible. Specifically, the Biosolid Partnership's concept identifies only a single supplier of wood biomass, a product necessary for the gasification process, which is in high demand. Murraysmith found it to be unrealistic to be able to secure the amount of woody material necessary from a single source, noting that sourcing could become even more difficult in the future. Using only renewable energy sources, as proposed by the Biosolids Partnership, would require multiple sources of feedstock because the single supplier identified has not proven able to supply the amount of wood biomass that would be necessary. Murraysmith noted that the County would need to develop relationships with entities such as sawmills, green waste recycling facilities, paper and cardboard recycling facilities, and furniture manufacturers to acquire woody materials needed to meet the facility's energy demand. More information is detailed in subsection 2.3.3 and 2.4.2(3) of Appendix A.[40]

C. Development of a process for making Class A biosolids available for use by the public as a fertilizer for residential or commercial application or for use as an energy product.

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[39] The CDC's Social and Environmental Justice Index is available on their website here.

[40] Appendix A, page 12; pages 13-14

In its report, Murraysmith found that the Biosolids Partnership's concept produces two final products: biochar from biomass gasification and pellets from biosolids drying. The Biosolids Partnership's concept proposes to utilize pellets as a fuel for a cement plant. It did not identify a market for the biochar. Murraysmith found that a greater number of end users for the products would be needed in order for the Partnership's concept to be successfully implemented. More information is detailed in subsection 2.3.4 and 2.4.2of Appendix A.[41]

Notably, should the market for the dried pellets be unreliable, the County would need to consider what it would do with the product should it not be able to sell it. Such considerations would include sending the product to a landfill or potentially giving the product away. If disposal of unpurchased, excess, dried pellets in a landfill is necessary, it would be inconsistent with Washington State's guidance to maximize the beneficial reuse of biosolids. In its report, Murraysmith found that the Biosolids Partnership concept does not align with Washington Administrative Code 173-308 which encourages maximum beneficial use of biosolids. Beneficial use involves application of biosolids to the land for the purposes of improving soil characteristics. The Biosolids Partnership's concept is equivalent to biosolids incineration, which is not considered a way to achieve beneficial use of biosolids. In addition to the regulatory issue, landfilling biosolids would also be additional cost to the County. Other challenges also include a smoldering and fire risk from the product.

The County is nearing design completion for a Class A compost pilot project that will be constructed at South Treatment Plant. This pilot will test the marketability of converting class B biosolids into a Class A compost product that would be sold locally as a soil amendment for residential or commercial application. More information on the County's existing Class B biosolids program and Class A composting facility is provided in subsection 1.3.1 of Appendix A.

D. Analysis of the scalability, cost, environmental and climate footprint and specifics of implementing the program.

In its report, Murraysmith found that the initial capital cost to implement the Biosolids Partnership concept has an estimated 20-year lifecycle cost of $723 million.[42] Due to the complexity of the dryer and gasification systems, it is not economical to manufacture or operate many small units. This means that the increment of scaling is larger than the baseline alternative, and the up-front cost for upscaling the facility would be higher than the baseline alternative. These factors make scalability limited and costly. The County's baseline or current biosolids program has an estimated 20-year lifecycle cost of $373 million. The costs Murraysmith provided for both scenarios are preliminary planning level costs, which by definition have an uncertainty range wherein each estimate could increase by as much as 100 percent.[43] More information on scalability and cost is detailed in subsection 2.4.1 and subsection 2.4.3 of Appendix A, respectively.[44]

[41] Appendix A, pages 12-13; pages 13-14
[42] Includes initial capital cost plus annual operations and maintenance cost for 20 years.
[43] Murraysmith prepared these cost estimates 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.
[44] Appendix A, page 13; page 15

Murraysmith's analysis of environmental and climate footprint included energy use, carbon footprint, air and water quality impacts, and potential for reducing contaminants of emerging concern (CECs) in biosolids.[45] Murraysmith found that the Biosolids Partnership concept would have air quality impacts, while the baseline (composting) alternative could have water quality impacts. Neither the thermal drying technology proposed by the partnership nor the baseline alternative technology is proven and approved by EPA to remove per- and poly-fluorinated alkyl substances (PFAS), a notable CEC.[46] Murraysmith found that while the baseline alternative would use more energy, the baseline alternative provides a significant carbon reduction benefit due to carbon sequestration. The Biosolids Partnership concept results in an additional 452 metric tons of carbon dioxide equivalent emissions annually, whereas the baseline alternative provides a net carbon reduction of -46,558 metric tons of carbon dioxide equivalent annually.[47] More information on environmental and climate footprint is detailed in subsection 2.4.5 of Appendix A.[48]

E. Identification of any necessary changes to county policies to implement the program.

In its report, Murraysmith found that the Biosolids Partnership concept does not align with Washington Administrative Code 173-308 which encourages maximum beneficial use of biosolids. Beneficial use involves application of biosolids to the land for the purposes of improving soil characteristics. The Biosolids Partnership's concept is equivalent to biosolids incineration, which is not considered a way to achieve beneficial use of biosolids.

Murraysmith found that the Biosolids Partnership's concept does not align with the County's SCAP goal to be carbon-neutral by 2025, due to the significantly lower carbon footprint of the baseline alternative. Murraysmith also found that the baseline alternative aligns with King County's Equity and Social Justice Initiative through supporting community gardens in underserved areas with compost donations and maintaining a robust outreach and education program. More information on policy impacts is detailed in subsection 2.4.7 of Appendix A.[49]

King County Code (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". Biosolids Policy 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 either the Biosolids Partnership concept or the County's

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[45] 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.
[46] PFAS = per- and poly-fluorinated alkyl substances. PFAS are known as "forever chemicals" for their resistance to break down in the environment and are linked to human health impacts. As of this writing, PFAS regulations for biosolids from EPA or Ecology are anticipated in the near term (1-3 years) but what the regulations will require is unknown. WTD actively monitors this area and will adapt the biosolids program to emerging regulatory needs.
[47] Carbon dioxide equivalent is a metric measure used to compare emissions from various greenhouse gases on the basis of their global warming potential by converting amounts of other gases to the equivalent amount of carbon dioxide.
[48] Appendix A, page 18
[49] Appendix A, page 21

baseline alternative, which includes a Class A compost pilot, will require these policies to be potentially amended.

In its 2020 Strategic Climate Action Plan, King County committed to meeting a countywide GHG emissions reduction target of 50 percent by 2030 and 80 percent by 2050. DNRP set a target of carbon-neutral operations by 2025, primarily through carbon sequestration from biosolids land application.[50] Because implementation of the Biosolids Partnership alternative would eliminate the carbon sequestration benefits from land application that are realized in the baseline scenario, the Partnership proposal would result in a net increase of GHG emissions. Implementing the Biosolids Partnership proposal would also require the County to revisit its climate action goals and likely extend the date for carbon-neutral operations.[51]

F. Identification of future budget proposals that may be necessary to implement the program.

In its report, Murraysmith found that the Biosolids Partnership's concept has a 20-year lifecycle cost of $723.6 million, which includes initial capital cost plus annual operations and maintenance cost for 20 years. The baseline (compost) alternative's 20-year lifecycle cost is $373.8 million. Comparing the two shows that the Biosolid Partnership concept's 20-year lifecycle cost is $349.8 million greater, or more than double the baseline alternative's cost.

The County would consider the project cost as part of its future annual sewer rate adoption and ten-year rate forecast, adding it to WTD's Capital Improvement Program (CIP). The County would either need to increase the annual sewer rate to fund the approximately $349.8 million in additional costs for the Biosolids Partnership alternative or consider deferral of priority capital projects for asset management, capacity improvements or regulatory compliance, or a mix of rate increases and deferral of other capital projects . More information on costs is detailed in subsection 2.4.3 of Appendix A.[52]

Conclusion

The independent consultant report (Appendix A) provides the following conclusions and recommendations. DNRP concurs with 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 resource and reduce the carbon footprint, while maximizing program reliability and minimizing risk to the County.

Excerpt from independent consultant report (Appendix A):

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[50] Carbon sequestration refers to the process of removing carbon dioxide from the atmosphere.
[51] Appendix A, pages 21-22
[52] Appendix A, page 15

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, the 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: Murraysmith King County Biosolids Class A Alternatives Analysis Final Report, King County WA

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
	Erika Kinno, Research & Policy Project Manager, King County WTD
From:	Miaomiao Zhang, PE, PMP, Murraysmith
Prepared by:	Patrick Davis, PE, Murraysmith
	John Thayer, PE, Murraysmith
Reviewed by:	Miaomiao Zhang, PE, PMP, Murraysmith

Murraysmith

Address: 600 University Street, #300
Seattle, WA 98101

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Table of Contents

List of Figures

List of Tables

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.

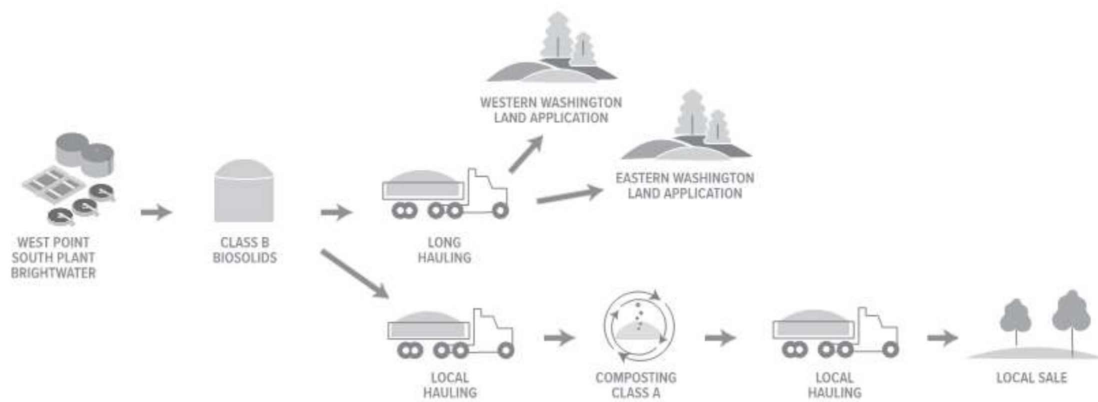
Baseline – WTD Existing Class B Biosolids Program with Class A Composting Facility

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



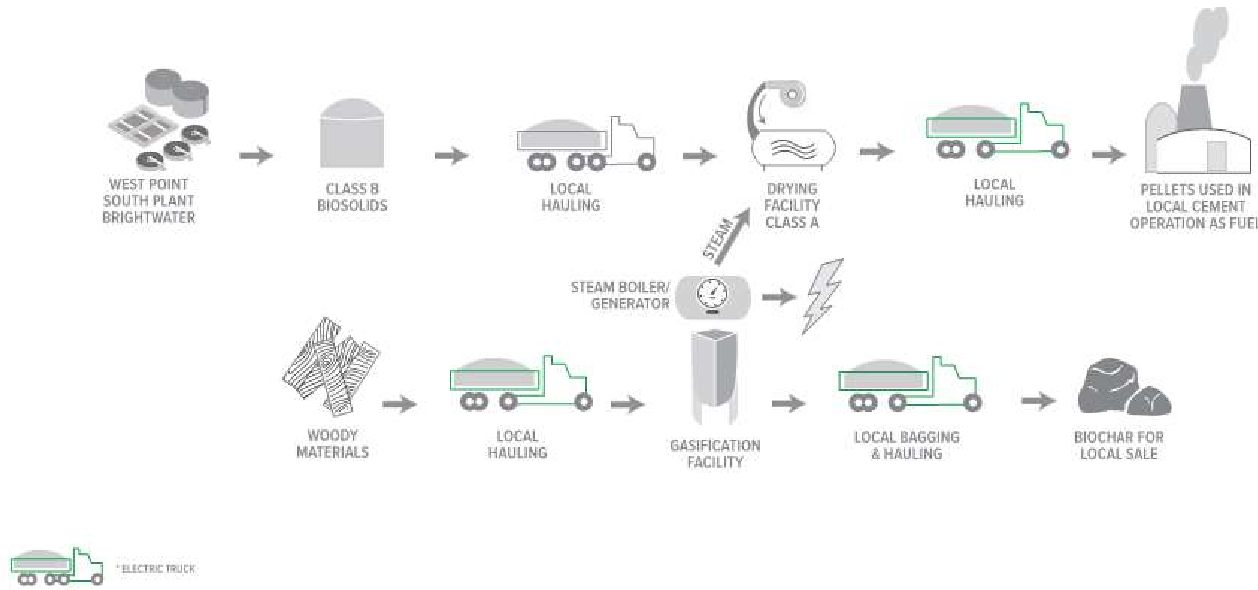
Biosolids Partnership Proposal

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.

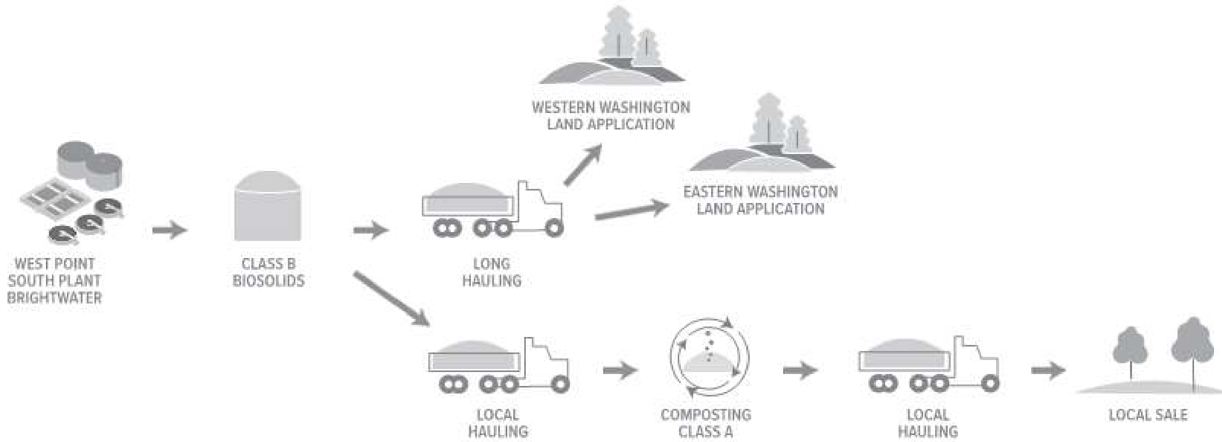
The amount of Class B Loop biosolids is expected to increase to approximately 198,000 wet tons in 2050, based on the Class A Biosolids Technology Evaluation (Brown and Caldwell, 2020). The County has nearly completed the design and will soon start the construction of a compost pilot facility at South 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.

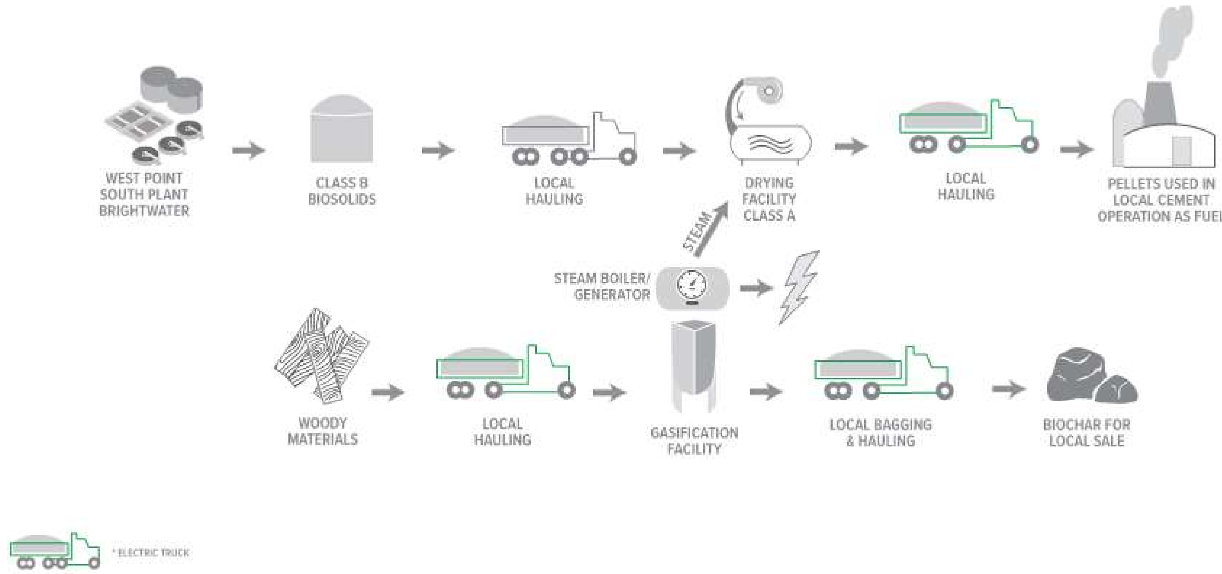
From early February to the end of April 2022, the Biosolids Partnership, primarily under the direction of Bart Lynam, assembled a team and put together a second conceptual design proposal on biosolids drying, biomass gasification, and power generation (Appendix B). The key difference between the September 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

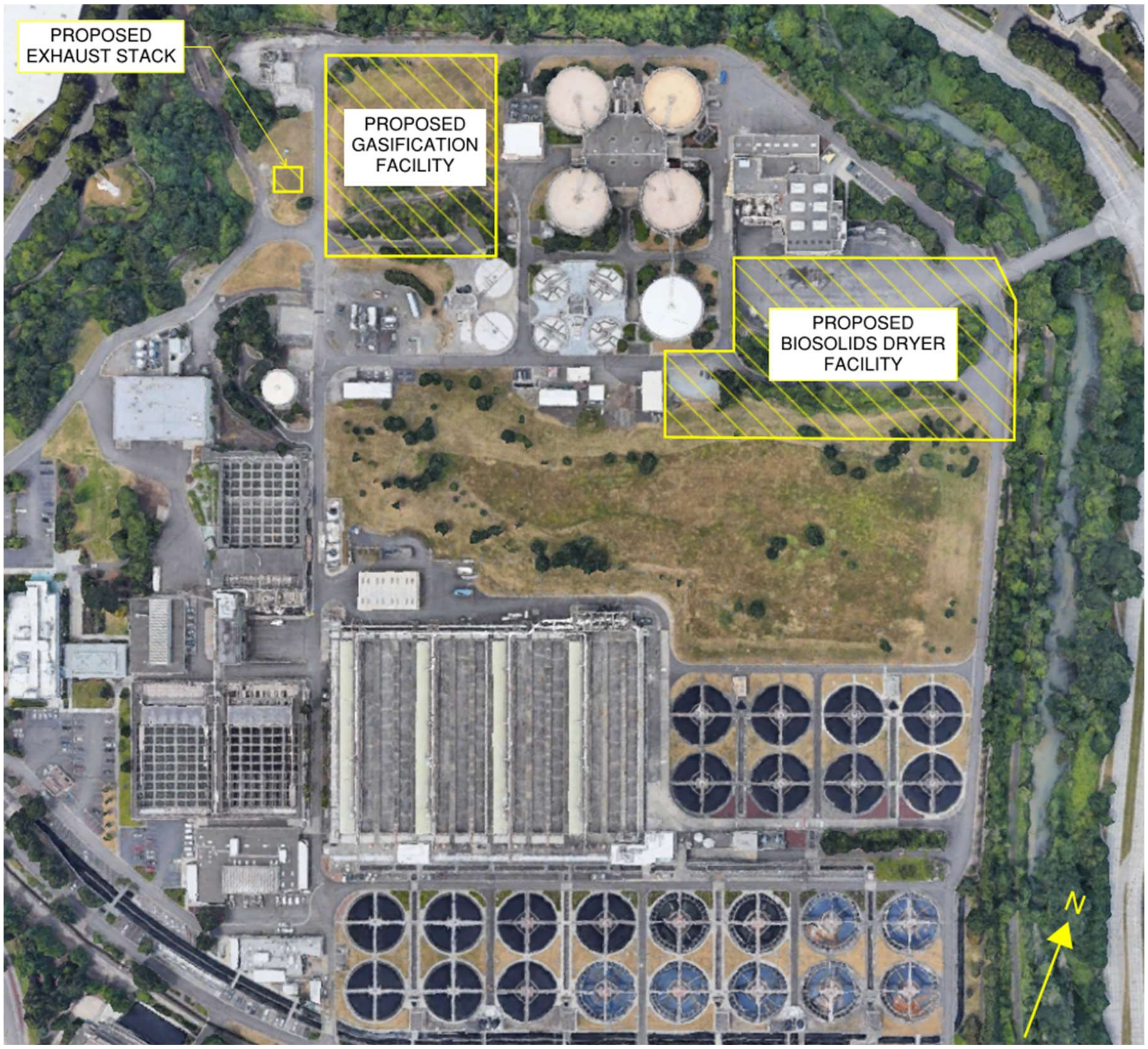
The April 2022 Biosolids Partnership proposal presented a large and comprehensive program involving three, stand alone yet inter-dependent processes–biomass gasification, power generation, and biosolids drying. Key considerations for potential implementation of this proposal are discussed in the sections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

APPENDIX A

Carbon Net Negative
King County's
Enhancement
Wastewater Biosolids Utilization
Meeting

Kamuron Gurol
Director of Wastewater Treatment Division

September 9, 2021

King County Biosolids Meeting Calendar

December 10, 2018: King County Executive Dow Constantine's Office - Biosolids Drying Proposal with No Green Energy

**October 14, 2019: Christie True's Office
Biosolids Drying Proposal with All Green Energy**

February 1, 2021: CM Jeanne Kohl-Welles Zoom Meeting - All Green Energy

February 24, 2021: CM Rod Dembowski Zoom Meeting - All Green Energy

April 13, 2021: Councilmember Kathy Lambert Zoom - All Green Energy

May 23, 2021: CM Dave Upthegrove Zoom - All Green Energy

June 2, 2021: Tyler Pichette, Chief of Staff for Peter von Reichbauer – All Green Energy

July 6, 2021: CM Reagan Dunn– Net Zero Carbon Balance

July 28, 2021: Chair Claudia Balducci – Net Negative Carbon Balance

September 1, 2001: Grant Lahmann, Chief of Staff for CM Joe McDermott and Rhonda Lewis, Chief of Staff for CM Girmay Zahilay

Introduction of King County Biosolids Team

- **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 Illinois Institute of Technology.**

- **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 147 sludge drying plants worldwide and 126 in the United States.**

- **Rick Bender - Former President of the Washington State Labor Council for 17 years; former 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.**

Introduction of King County Biosolids Team (Continued)

- Dr. Jerry Whitfield, President of Whitfield Biochar, LLC, whose education includes a Bachelor and Ph.D. degrees from Southampton and Cambridge Universities, United Kingdom. Jerry is an Aerospace Engineer having worked at Boeing, Rolls Royce Aero Engines, and General Electric on advanced jet engines. Recognizing early on the need for low carbon sources of energy, Dr. Whitfield invented the first wood pellet stove in 1982.
- Bart T. Lynam holds a 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 National Association of Clean Water Agencies (NACWA).

Agenda
A Path to Net Negative Carbon Balance for King County's Biosolids

- **Our project presents a solution to King County's existing Class B land application on farmlands in Eastern Washington and spraying of the biosolids in King County's forests which contain Billions Per Day of pathogens and viruses (cited by Washington State University *Guide To Biosolids Quality).***
- **Our project design is to be Climate Net Negative; that is, with zero fossil carbon emissions, not just Net Zero, balanced by the purchase of external "offsets" with proven odor control with subsequent sequestering of carbon to be net negative balance.**
- **The Andritz dryer uses the conventional and proven drum dryer that produces dried pellets from the biosolids which can be used as a fuel or as a fertilizer.**
- **Renewable energy will be obtained by using renewable biomass such as wood chips to be gasified into a biogas and biochar.**
- **The Andritz Dryer and the gasification unit would be an "Add-On" to the existing South Wastewater Treatment Plant in Renton.**
- **We will use purchased renewable electricity for the plant's electrical load.**
- **We will use electric trucks for transferring wet sludge cake from West Point and Brightwater to the South Plant in Renton and the handling of dried fertilizer pellets and biochar from the plant in Renton.**
- **We will capture waste heat from the operations to provide heat for the digesters and buildings at the South Plant in Renton.**
- **We greatly reduce the overall cost of handling King County's biosolids in a modernized, state-of-the-art, proven technology which will cost substantially less than King County.**

How King County Can Save $1 Million a Year

- The digester gas from the South Plant in Renton is processed into natural gas quality and injected into the natural gas pipeline. This is sold by King County as renewable biogas at a premium of several times the value of natural gas. The problem here is that the King County South Plant is buying back either natural gas or renewable electrical energy to replace the renewable natural gas sold. So in reality, there is an **actual increase in the carbon balance for the South Plant.** Our proposal will generate hot water in sufficient quantities to heat the existing digesters and buildings at the South Plant in Renton. This will allow King County to take credit for the carbon reduction by making available the processed digester gas into natural gas.

Class B Biosolids Only Partially Digested

- **In Class B Biosolids, the digested sludge is only partially digested from the digesters as liquid or as a cake dewatered by centrifuge or other dewatering devices.**
- **The digesters are completely mixed continuously and usually fed each day, so a portion of the sludge is always only partially digested or still digesting.**
- **Class B Biosolids contain each day Billions of pathogenic bacteria and viruses that are applied to farmland or sprayed in King County forests.**
- **In France, sewage sludge produced during the COVID-19 epidemic can only be applied to fields after disinfection (News of 2/04/2020).**

Table 1. Approximate concentrations of selected pathogenic bacteria and viruses in Class B biosolids, manure, and pet feces

Pathogenic organism	Biosolids[a]
Bacteria	
Campylobacter jejuni	2
E. coli O157:H7	< 1
Listeria monocytogenes	20
Salmonella	50
Viruses	
Adenoviruses	20
Enteroviruses	< 1 to 30

- Salmonella 50 organisms per gram
- 100 Dry Tons per day
- = 4,540,000,000 Salmonella per day being trucked to farms in eastern Washington and forests in King County (From Washington State University *"Guide to Biosolids Quality).*

U.S. EPA Restrictions on Use of Class B Biosolids

Class B **biosolids may not be applied** to home lawns and gardens. Additionally, the following restrictions apply:

Harvesting of crops and turf:

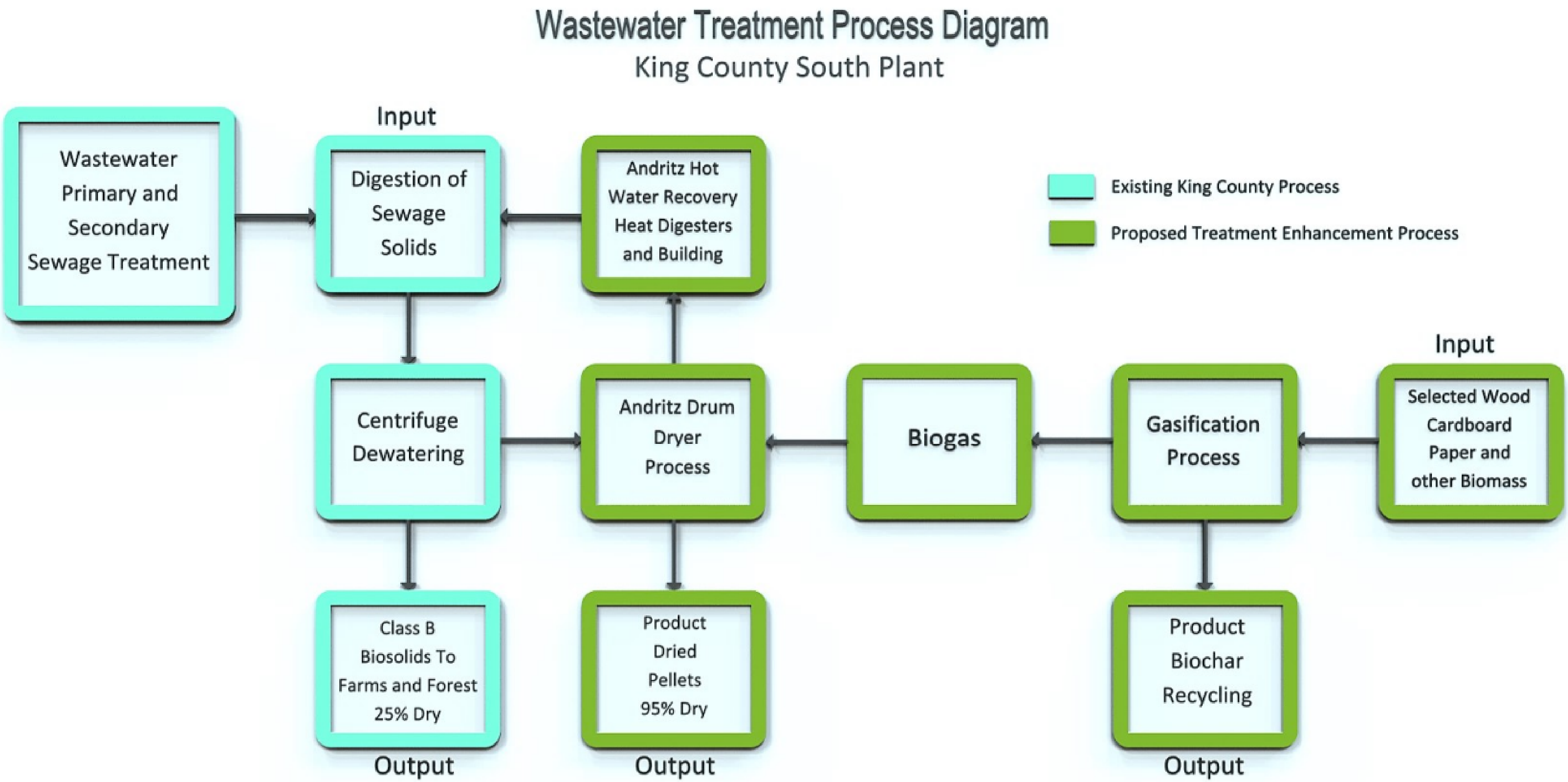
- Food crops, feed crops, and fiber crops, whose edible parts do not touch the surface of the soil, shall not be harvested until **30 days after biosolids application.**
- Food crops with harvested parts that touch the biosolids/soil mixture and are totally above ground shall not be harvested until **14 months after application of biosolids.**
- Food crops with harvested parts below the land surface where biosolids remain on the land surface for **4 months or longer** prior to incorporation into the soil shall not be harvested until 20 months after biosolids application.
- Food crops with harvested parts below the land surface where biosolids remain on the land surface for less than 4 months prior to incorporation shall not be harvested until **38 months after biosolids application**.
- Turf grown on land where biosolids are applied shall not be harvested until **1 year after application** of the biosolids when the harvested turf is placed on either land with a high potential for public exposure or a lawn, unless otherwise specified by the permitting authority.

Grazing land for animals:

- Animals shall not be grazed on land until **30 days after application of biosolids** to the land.

Public contact:

- Access to land with a high potential for public exposure, such as a park or ballfield, is restricted for **1 year after biosolids application**. Examples of restricted access include posting with no trespassing signs, and fencing.
- Access to land with a low potential for public exposure (e.g., private farmland) is restricted for **30 days after biosolids application**. An example of restricted access is remoteness.



Wastewater Treatment Process Diagram
King County South Plant
Wastewater Primary and Secondary Sewage Treatment
Input
Digestion of Sewage Solids
Andritz Hot Water Recovery Heat Digesters and Building
Existing King County Process
Proposed Treatment Enhancement Process
Centrifuge Dewatering
Andritz Drum Dryer Process
Biogas
Gasification Process
Input
Selected Wood Cardboard Paper and other Biomass
Class B Biosolids To Farms and Forest 25% Dry
Output
Product Dried Pellets 95% Dry
Output
Product Biochar Recycling
Output

Proposal Produces Net Negative Climate Change

- **Use renewable source of energy from wood chips.**
- **Andritz Company out of Austria employs 25,000 and has installed 147 sludge drying plants worldwide.**
- **Andritz drying uses the conventional and *proven drum* dryer that produces dried pellets from the biosolids which can be used as a fuel or fertilizer. The dried pellets can be bagged or blended and sold like "Milorganite" as a fertilizer.**
- **Chamber Creek Wastewater Treatment Plant in Pierce County has an Andritz drum dryer that has a history of successful operations.**
- **We either produce renewable electricity or purchase renewable electricity.**
- **We capture waste heat from the operations to provide heat for the digesters and buildings at the South Plant in Renton.**
- **We use electric trucks for transferring wet sludge cake from West Point and Brightwater to the South Plant.**
- **There will be odor control and emissions control for the building's ventilation exhaust and from the drying operation.**

Conversion of Wood Chips into Biogas or Syngas

- **We are proposing to use a proven simple way to extract the energy from wood chips into a biogas or syngas.**
- **Fluid bed gasification uses sand or other media like crushed limestone as the bed material.**
- **The bed is fluidized by recalculating the gases created from the conversion of the biomass into biogas by adding small amounts of oxygen that combines with the biomass into heat energy.**
- **The gases formed are removed from the reactor as biogas or syngas as a fuel to piped to the Andritz Drum dryer and combusted with air to create the heat source for the drying of the prepared sludge pellets.**

Company profile – ANDRITZ worldwide

25,000 employees, >USD 7 billion annual shipments

PULP & PAPER

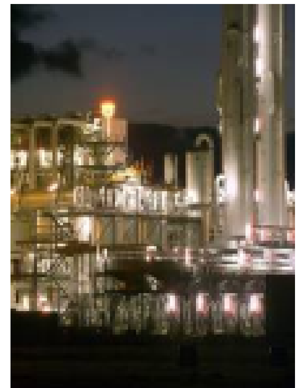
- 40% of Group Sales
- Systems for production of all types of pulp and certain paper grades

HYDRO-POWER

- 30% of Group Sales
- Turnkey electro-mechanical equipment for hydropower plants; pumps

ROLLING MILLS & STRIP PROCESSING

- 10% of Group Sales
- Systems for production and processing of stainless steel and carbon steel strips



SEPARATION

- 10% of Group Sales
- Systems for mechanical and thermal solid/liquid separation

FEED & BIOFUEL

- 5% of Group Sales
- Systems for production of animal feed and wood/biofuel pellets

ANDRITZ Separation

ANDRITZ Drum Drying System (DDS)

- **The ANDRITZ drum drying system (DDS) dries and granulates the sludge. The dewatered sludge is combined in a "back-mixer" with previously dried pellets to a blend of about 68% dry matter. The formed pellet is then dried in the triple-pass rotating drum (three concentric cylinders revolving around a joint axis) in a convective drying process to < 5% residual moisture. The sludge is conveyed pneumatically by the stream of hot gases, ensuring an evenly dried, pasteurized product.**

Drum Dryer Chambers Creek Pierce County

Andritz Biosolids Drying Systems

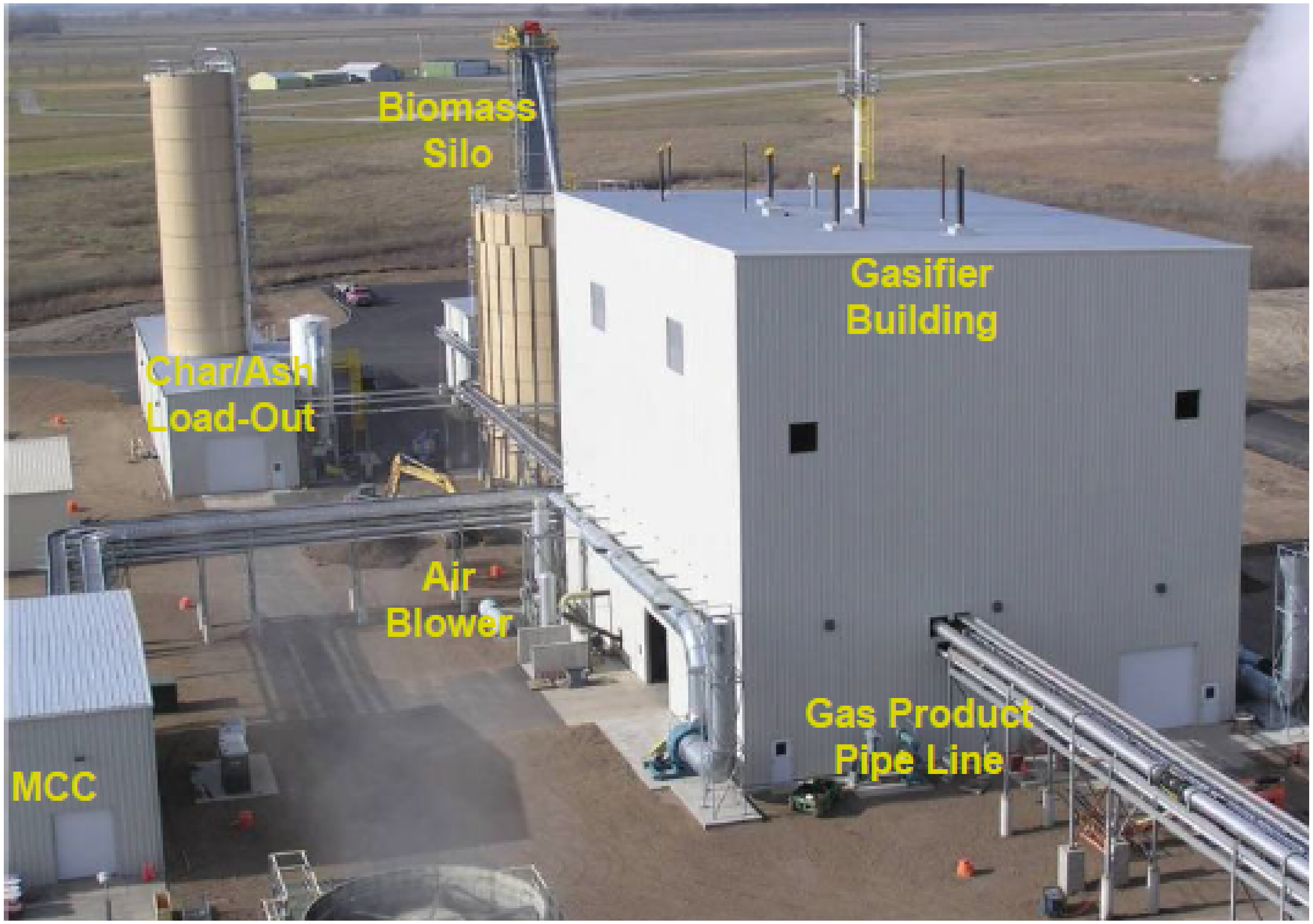

Drum Drying System


Fluid Bed Drying System


Belt Drying System


Paddle Drying System

Gasifier System



Gasifier System Design

- Pressurized (up to 60 psig)
- Bubbling Fluidized Bed
- Scalable – units > 1000 tpd
- Fuel flexible – omnivorous
- Simple, robust, and stable operation
- Minimizes footprint
- Up to 10 : 1 turndown

Job Retraining and Relocation

Rick Bender, former Washington State Labor Council President for 18 years, will work with the unions regarding retraining and relocating the personnel eliminated by consolidation of the biosolids process at the South Plant as a result of the elimination of trucking (20 loads a day) to eastern Washington and the elimination of biosolids land spreading and forest spraying of biosolids.

ALL GREEN ENERGY

- **Purchase or generate on-site Renewable Electrical Energy for the Drying Plant's Operation.**
- **Use Electric Trucks with Renewable Electrical Energy.**
- **Convert wood chips into biogas.**
- **The Andritz Drum Dryer produces dried pellets using biogas as a fuel.**
- **Eliminate the current purchase of natural gas or renewable electricity by King County to heat the South Plant while selling the treated digester gas as Renewable Natural Gas.**

Electrified on the Highway

GHG Greenhouse Gases Emissions

Summary		Scope 1 (MT CO2e)	Scope 2 (MT CO2e)	Scope 3 (MT CO2e)		Net Scope 1 + 2
		direct	purchased	other		
Facility						
	Base case (wood chip boiler)	-1766	1,730	27,627	Biogenic emissions	-36
	BEF RECs		2,200			2200
	with electric boiler	-2398	2,375			-23
	BEF RECs		19,200			19200
	base case with electric trucks	-2628	1,802			-826
	BEF RECs		2,200			2200
Fertilizer						
	Base case	-33	29			-4
	BEF Carbon credits	3,700				3700
	with electric trucks	-198	59			-139
	BEF Carbon credits	3,700				3700
	BEF RECs		120			120
Distribution						
	Base case	7	0			7
	BEF Carbon credits	1,500				1500
	with electric trucks	0	-5			-5
	BEF Carbon credits	0				0
	BEF RECs		350			350
Application						
	Base case			-50,755		
Total	Base case with woodchip boiler	-1792	1759			-33
	BEF RECs		2,200			2200
	BEF Carbon credits	5,200				5200
	Base case with electric boiler	-2424	2404			-20
	BEF RECs		19,200			19200
	BEF Carbon credits	5,200				5200
	with electric trucks	-2826	1856			-970
	BEF RECs		2,670			2670
	BEF Carbon credits	3,700				3700

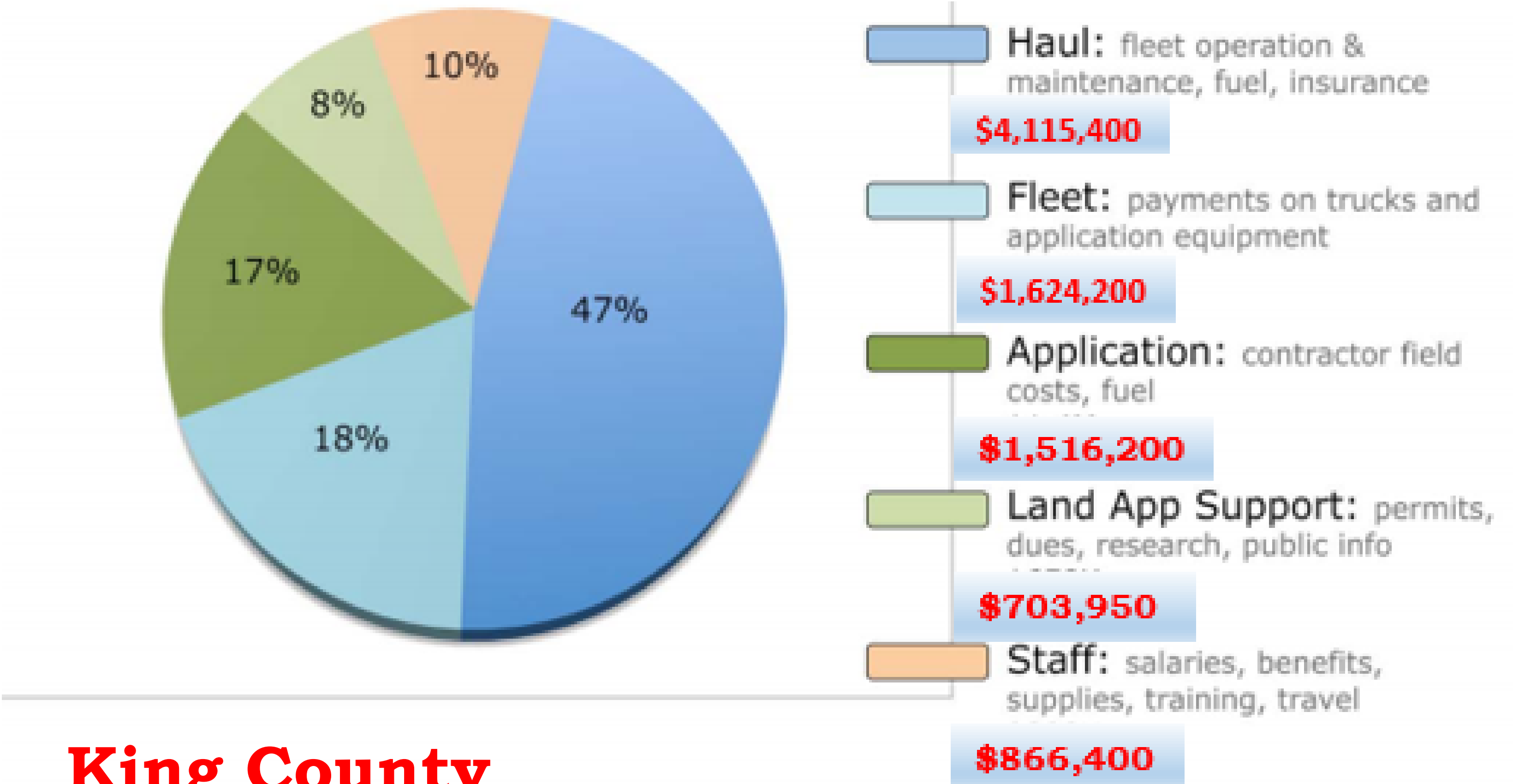
King County's Annual Production of Wet Tons of Biosolids Current and Future

	Total	West Point	South Plant	Brightwater
• 2020	130,000	50,308	60,075	19,617
• 2050	261,430	101,170	120,810	39,450

King County Report
Alternative Options for the Use of Biosolids
Brown and Caldwell
August 1, 2020

Table 1. Total Costs and Scores			
	Baseline: Class B	Alternative Option One: 100 Percent Class A	Alternative Option Two: Pyrolysis
Escalated Capital Costs	$335,000,000	$590,000,000	$1,115,000,000
2050 Operating & Maintenance Costs	$40,500,000	$49,000,000	$39,000,000
2050 Annual Transportation Costs	$6,000,000	$4,000,000	$1,500,000
2050 Annual Revenue	$11,100,000	$19,500,000	$10,500,000
2050 Annual Net Operating & Maintenance Costs and Minus Revenue	$29,400,000	$29,500,000	$28,500,000
Triple Bottom Line Score[9]	High	Very High	Medium

Table 1: Total Costs and Scores



King County

Biosolids Management Costs 2017

$8,826,450 per Year

$315 per Dry Ton

Financial & Net Negative Climate Impact
to
King County Ratepayers

- **This proposal will cost the King County ratepayers substantially less than continuing with the King County Class B Biosolids program, as outlined in the Brown & Caldwell Report.**
- **If adopted, this proposal will result in a Net Negative Climate Impact and will not require the projected cost elements in the Brown & Caldwell report.**
- **This proposal is proven and will be financed and will guarantee its process. The components for the dryer will be manufactured off-site and delivered for assembly at the South Plant in Renton.**
- **If adopted, this proposal will be a Net Negative Carbon Balance for all of the operational steps relating to the handling and processing of the dewatered Biosolids from the South Plant, the West Point Plant, and the Brightwater Plant.**

Aerial View of Proposed Addition

murraysmith

APPENDIX B

Rev	Issued for	Date	Revision Comment
A	Information	April 29, 2022	CONCEPTUAL - DRAFT

KING COUNTY SOUTH PLANT

BIOSOLIDS DRYING, BIOMASS GASIFICATION AND POWER GENERATION

CONCEPTUAL PROJECT BASIS OF DESIGN

Contents

1 BASIS OF DESIGN MEMORANDUM – GENERAL

This CONCEPTUAL project design basis memorandum (DBM) establishes the scope of the project, scope of the work and the basic design parameters for the project going forward and includes:

- A brief description of the project
- Project objectives
- Scope of the Project
- Design criteria for each engineering discipline
- Basic design data and a general scope of work for all disciplines:
    - Process
    - Civil / structural / architectural.
    - Mechanical / piping / HVAC.
    - Electrical / controls.
    - Division of Responsibilities (Scope Matrix)

The DBM will be used to formally define the project to set the scope and price of the project with all major stakeholders aligned and agreed (including sign-off via wet signature by all stakeholders) before full funds authorization and detailed design and construction begins.

ESTIMATE & SCHEDULE PREPARATION

The estimates were prepared from budget pricing from vendors, factoring and benchmarking off comparable projects. Minimal engineering was performed for the preparation of these estimates. No "first principles" buildup was performed, which would be based on proper site information, takeoffs, market specific labor factors and rates, and current materials and utilities pricing. Accordingly, these estimates should be considered as indicative only. Note: no design has been finalized, no site survey obtained, no proper plans and elevations have been developed, and therefore no takeoffs were utilized in the generation of this estimate.

This estimate is a Class 5 estimate, also known as a rough order of magnitude (ROM) estimate. The estimate has an accuracy range of -50% on the low side and +50% on the high side and is used for early-stage capital planning, as total engineering effort expended to date is <1% of the total engineering effort required.

A stochastic cost estimating method was used to provide this Class 5 estimate. Examples of these are cost/capacity curves, rule of six-tenths, Lang factor method, scale of operation factors, high level budget quotes from major equipment suppliers and cost indices. These techniques use parametric cost estimation methods to deduce the total cost of a given project.

This estimate is an approximation and is not guaranteed. The estimate is based on information provided from the client regarding project requirements and our own in-house expertise with similar projects built in the U.S.. Actual cost may change once all project elements are finalized or negotiated, including formal project start date.

A Level 1 schedule has been prepared. This schedule is based on major tasks, high level durations, assumptions regarding permitting and other typically critical path items, and expected overlaps based experience. The schedule has not been developed from detailed engineering documents, which have not been developed. Accordingly, it should be considered as a reasonable approximation but by no means firm.

2 PROCESS ENGINEERING DESIGN CRITERIA

2.1 Scope

This CONCEPTUAL criterion establishes requirements and permitting that shall be used in the design, layout, construction, commissioning, and startup of the project. This project entails the engineering and construction of biosolids fluid bed drying, biomass gasification and combined heat and power generation.

Codes, Standards, and Practices

The layout and design will be in accordance with the laws and regulations of the federal government, State of Washington, local laws, adoptions and modifications, and industry standards. The most current issue or revision of the code or standard applies unless otherwise noted. If there are conflicts between the cited documents, the more conservative requirements shall apply.

The following codes and standards are applicable:

- American Society of Mechanical Engineers (ASME)
- American Society for Testing and Materials (ASTM)
- American National Standards Institute (ANSI)
- American Petroleum Institute (API)[1]
- Environmental Protection Agency (EPA)
- International Building Code (IBC)
- Factory Mutual (FM)
- Washington Department of Environmental Protection Division of Air Pollution Control
- National Electric Code (NEC)
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)

2.2 Project Summary

The Wastewater Treatment Division, King County, Washington (the County) operates three (3) large waste water treatment plants, and two (2) smaller community systems. Biosolids management and disposal is an aspect of this effort.

The County is exploring options for carbon footprint reduction and increasing use of energy from renewable sources. Biosolids management creates opportunities in these areas. As part of its deliberations, the County is contemplating needs out to the year 2050:

(https://kingcounty.gov/services/environment/wastewater/resource-recovery/Energy/renewable.aspx?msclkid=687216efc24f11ecaad9e36427ee2b9d)

Per this effort, Venture conceptually evaluated three (3) options for this project, as follows:

[1] Pumps will be designed to ANSI standards.

Option	Major components	Comments
A	Biosolids fluid bed drying (FBD) Boiler fired by NG or RNG for steam supply to FBD Biofilters, scrubbers and activated carbon for odor control	No pelletizing or post processing of biosolids Bulk shipping No power generation
B	Biosolids fluid bed gasification (FBG) Syngas combustion heat recovery for biosolids drying and thermal fluid heating to Organic Rankin Cycle (ORC) turbine generator Parasitic load power generation via ORC turbine generator Biofilters, scrubbers and activated carbon for odor control	No pelletizing or post processing of biosolids Bulk shipping
C	Biosolids fluid bed drying (FBD) Wood biomass gasification Syngas combustion heat recovery for wood waste drying and heat recovery steam generation to conventional steam turbine generator with extracted process steam Combined process steam generation and parasitic load power generation via conventional steam turbine generator Biofilters, scrubbers and activated carbon for odor control	No pelletizing or post processing of biosolids Bulk shipping

A second consideration with respect to biosolids management is the posture of the state of Washington with respect to Per- and Polyfluoroalkyl Substances (PFAS). As we understand the situation, there is no moratorium contemplated yet for land application of biosolids, as was imposed by the State of Maine on March 22, 2019, relaxed, and essentially re-imposed on April 15, 2022. However, this is subject to change.

In the event of such a moratorium, EPA's Interim Guidance on Destroying and Disposing of Certain PFAS and PFAS-Containing Materials on December 18, 2020 recommends high temperature thermal processing for destruction of PFAS. Gasification, as proposed in Option B is such a tool, and has been proven viable through a facility built by team member Aries in Linden, New Jersey since November, 2021. Another option is incineration, or use as a fuel source in a cement kiln, as contemplated by ReNuFuels in Option A or C.

Following the establishment of the above scenarios, Venture undertook the following:

- Information gathering, such as characteristics and composition of wood waste, and gathering performance data from vendors.
- Initial system modeling using ChemCAD, a process simulation software, and standard mass and energy (M&E) calculations, as part of a conceptual mass and energy balance.
- Preparation of process flow diagrams depicting major equipment.
- Engagement of major equipment and system vendors for budget data and pricing.
- Preparation of Rough Order of Magnitude (ROM) estimate
- Prepare of Level 1 schedule

Based on discussions with the County and the County's consultant Murraysmith, Venture Engineering, in collaboration with ReNuFuels and selected vendors, has prepared this CONCEPTUAL design basis, block flow diagrams, process flow diagrams, mass and energy balance data, and indicative cost estimate for Option C, as a tool to support the County's decision-making process.

Henceforth, Option C will be referred to as the Project and may also be referred to as "King County Biosolids Drying, Wood Gasification & Power Generation". Financing, development, design, build, ownership, and operations of the Project has not yet been determined by the County. Hence, Operations and Maintenance (costs and revenues) will depend on the ultimate ownership and operations structure of the Project.

The Project will be based on two (2) biosolids mass flow cases for drying as follows:

	CASE 1	**CASE 2**
BIOSOLIDS FEED MASS FLOW	85 DRY TON/DAY 425 WET TON/DAY	150 DRY TON/DAY 750 WET TON/DAY
BIOSOLIDS FEED MOISTURE CONTENT	20%	20%
BIOSOLIDS PRODUCT MASS FLOW	85 DRY TON/DAY 89 WET TON/DAY	150 DRY TON/DAY 158 WET TON/DAY
BIOSOLIDS PRODUCT MOISTURE CONTENT	95%	95%

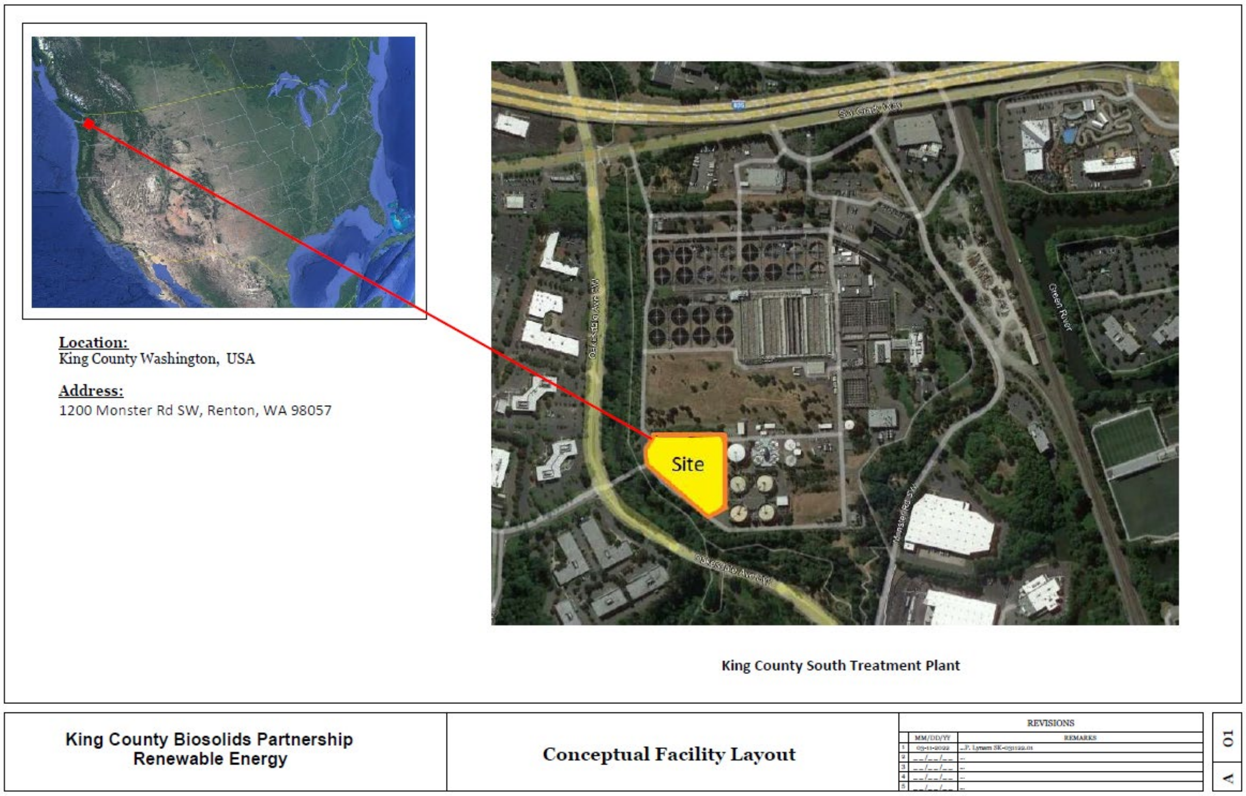
To accomplish the above requirements, the Project will involve the phased installation of sludge unloading via bulk truck trailer, wet sludge storage, interconnected piping from existing site sludge supply, two (2) initial and one (1) future Andritz Fluid Bed Dryer Trains, one (1) Heat Recovery Steam Generator system train, one (1) Steam Turbine Generator system, and three (3) initial and one (1) future Downdraft Wood Gasification trains, as well as an Odor Control system. Biomass wood will be procured and supplied as a raw material feedstock fuel to gasification, initial start-up utilities (natural gas and electrical) will be required, dry pellet biosolids product will be weighed and trucked offsite for sale to cement kiln incineration, and wood biochar product will be weighed and trucked offsite for external sales/use, as well. Bulk material trucking for the wood, biosolids product and biochar will be performed using electric power vehicles with bulk trailers and on-site charging station.

The facilities will process biosolids sludge from the existing site, as well as sludge trucked in from a second site, through fluid bed drying, which will be designed and supplied by Andritz, to produce dry biosolids. The fluid bed drying system will be supplied process steam for indirect heat transfer to dry the biosolids from steam extracted at medium pressure from the turbine generator, which will be designed and supplied by Elliott. The Elliot turbine generator will also condense a portion of high pressure steam feed in order to generator parasitic load power to the new systems in the scope of this upgrade. No power will be exported to the grid or to the rest of the South Plant site as determined by the County. The turbine generator will be fed high pressure steam by a Heat Recovery Steam Generator (HRSG) system, which will be designed and supplied by Babcock & Wilcox. The HRSG will be delivered thermal input for steam generation via combustion of syngas in a Thermal Oxidizer Unit (TOU), which a supplier has not been defined to date. Syngas will be delivered to the TOU from the Downdraft Gasification of woody biomass, which will be designed and supplied by Aries Gasification. All other major supporting equipment and ancillary equipment items in the Balance of Plant (BoP) will be detailed for design and supply upon further engineering in a future phase of the Project. Overall, major equipment systems are anticipated to include, but are not limited to:

Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)
Andritz Fluid Bed Dryers (3rd future train)
Digester Heating Upgrades Equipment (HXs/Pumps)
Drying Building
EV Trucks (qty 3)
Truck Trailers (qty 3)
Charging Station (qty 1)
Truck Scale (qty 2)
HRSG & Turbine-Generator Systems (B&W / Elliott)
Aries Downdraft Gasifiers (3 initial trains)
Aries Downdraft Gasifiers (4th future train)
Wood Processing, Screening and Conveying (3 initial trains)
Wood Processing, Screening and Conveying (1 future trains)
Dryers (2/gasifier x 3 initial trains)
Dryers (2/gasifier x 1 future trains)
Inclined Inlet Conveyors w/ Metals Removal (3 initial)
Inclined Inlet Conveyors w/ Metals Removal (1 future)
Cooling Screw Conveyors (3/train x 3 initial trains)
Cooling Screw Conveyors (3/train x 1 future trains)
Product Conveyors (2/train x 3 initial trains)
Product Conveyors (2/train x 1 future trains)
Product Silos (3 initial)
Product Silos (1 future)
Truck Scale (qty 2)
Thermal Oxidizer (future sized w/ turndown)
Heat Recovery Exchangers (3 initial)
Heat Recovery Exchangers (1 future)
SCR System (TBD)
Stack
Cooling Towers System (COULD BE REDUCED IF EXISTING PLANT CAN SUPPLY EFFLUENT WATER AND UPTAKE HEAT LOADS NEEDED)

Electrical controls/SCADA/Power Dist.

These major systems and equipment will be installed as depicted in the conceptual facility layouts. Below is an overview image of the site for reference:



The following section describes work at each site area for major system installation.

2.3 Biosolids Fluid Bed Drying Location

The Biosolids Fluid Bed Drying location will consist of installation of the following as depicted in conceptual layouts:

WET SLUDGE RECEIVING
WET SLUDGE STORAGE
FLUID BED DRYERS (2 INITIAL TRAINS, 1 FUTURE)
DRY SLUDGE PELLET STORAGE
ODOR CONTROL
ELECTRICAL CONTROLS/SCADA/POWER DIST.

Conceptual Facility 3D Rendering

King County Biosolids Partnership Renewable Energy	**Conceptual Facility Revised Layout**	REVISIONS MM/DD/YY – REMARKS 1 04/27/2022 – SK-042722.03 2 --/--/-- – 3 --/--/-- – 4 --/--/-- – 5 --/--/-- –	A 03

Upgrades will include road work and parking, new drying building and associated infrastructure, truck charging and weigh scale, as well as the major equipment systems as listed.

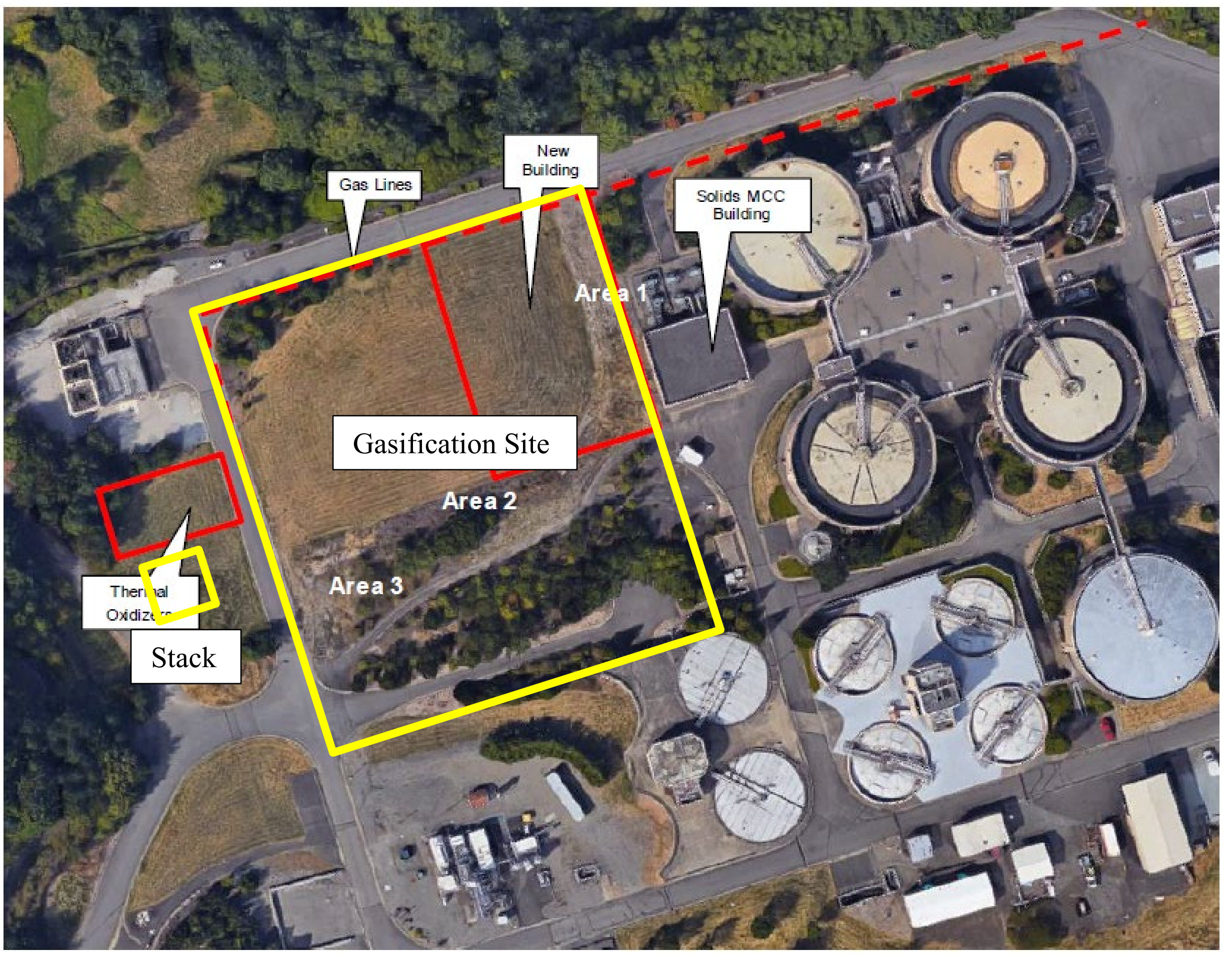
2.4 Wood Biomass Gasification Location

The Wood Biomass Gasification location will consist of installation of the following:

HRSG & Turbine-Generator Systems (B&W / Elliott)
Aries Downdraft Gasifiers (3 initial trains)
Aries Downdraft Gasifiers (4th future train)
Wood Processing, Screening and Conveying (3 initial trains)
Wood Processing, Screening and Conveying (1 future trains)
Dryers (2/gasifier x 3 initial trains)
Dryers (2/gasifier x 1 future trains)
Inclined Inlet Conveyors w/ Metals Removal (3 initial)
Inclined Inlet Conveyors w/ Metals Removal (1 future)
Cooling Screw Conveyors (3/train x 3 initial trains)
Cooling Screw Conveyors (3/train x 1 future trains)
Product Conveyors (2/train x 3 initial trains)
Product Conveyors (2/train x 1 future trains)
Product Silos (3 initial)
Product Silos (1 future)

Truck Scale (qty 2)
Thermal Oxidizer (future sized w/ turndown)
Heat Recovery Exchangers (3 initial)
Heat Recovery Exchangers (1 future)
Selective Catalytic Reduction (SCR) System (TBD)
Stack
Cooling Towers System (COULD BE REDUCED IF EXISTING PLANT CAN SUPPLY EFFLUENT WATER AND UPTAKE HEAT LOADS NEEDED)
Electrical controls/SCADA/Power Dist.

Upgrades will include road work and parking, associated infrastructure, truck weigh scale, as well as the major equipment systems as listed. Conceptually it this is planned for installation in the below yellow encompassed areas as depicted and overlayed on the South Plant Biogas and Heat Systems Improvements Site Plan drawing contained in the County's baseline project plan report.

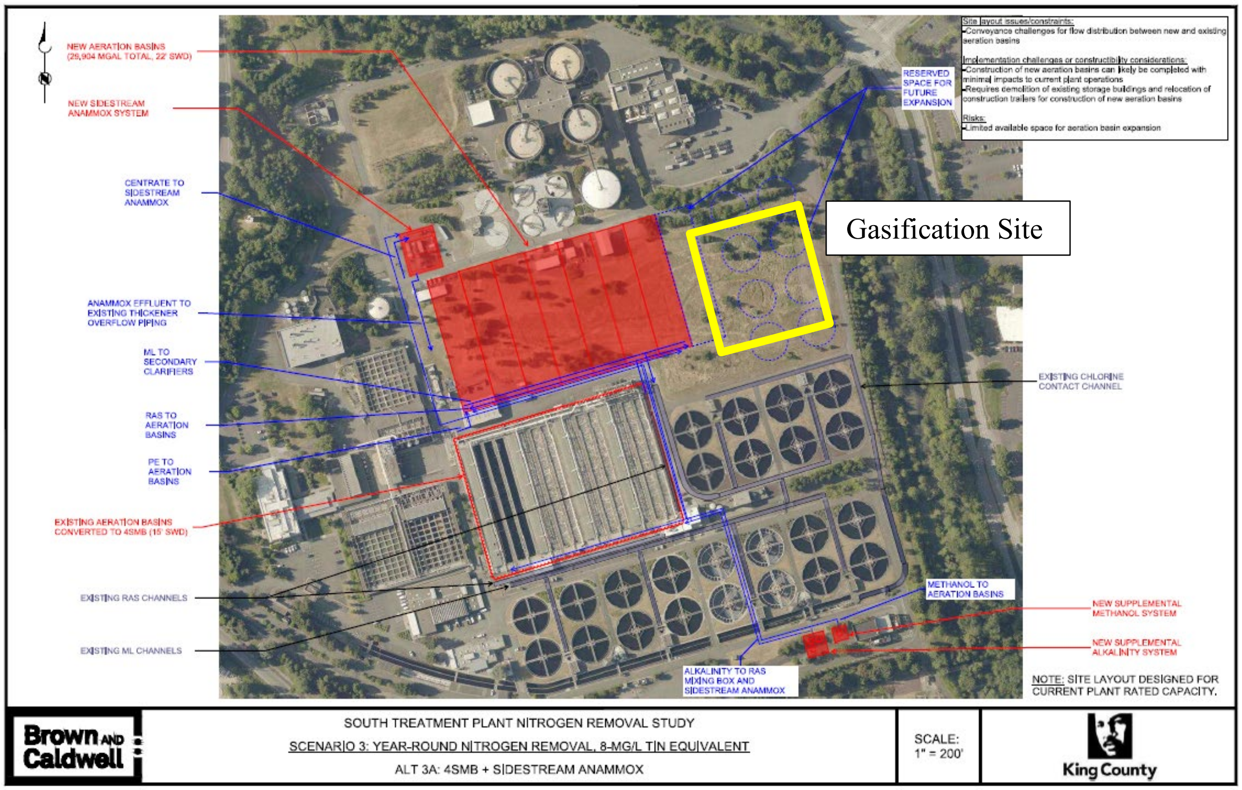


South Plant Biogas and Heat Systems Improvements / D150513.00

Figure 1
Site Plan

Separate location of the gasification site a distance from the biosolids drying site will require a medium pressure steam header and condensate return piping rack from the gasification site to the drying site location. This will be designed in future engineering phases of the Project.

Ideally, to shorten this distance and provide additional space, the gasification site would be co-located across the road from the drying site as shown below; however, this was initially rejected by the County as it is planned for future expansion as shown in the Brown and Caldwell South Treatment Plant Nitrogen Removal Study conceptual drawing:



2.5 Key Design Features

2.5.1 Safety and Security

E-stop pushbuttons located throughout the plant at strategic locations. These are in addition to the vendor stop buttons. Activation of any of these E-stop buttons will cause an immediate shutdown of rotating equipment and closure of plant inlet and product outlet valves. The vendor skid Emergency Stop buttons only stop that particular skid. In addition, there is a soft process stop button available in the BOP control system which initiates a controlled shutdown of the process.

The fire and gas detection and alarm system will be vendor designed, installed, tested and commissioned. This includes auto-dial to local Fire Department. Flame, smoke and heat detection, LEL and CO monitoring will be part of the detection equipment, with a variety of annunciation devices.

Pressure relief venting to a safe area (outside breathing zone and area of occupancy) will be provided if needed. Insulation will be provided for personnel protection on hot surfaces.

The system will be OSHA compliant. Stairs, platforms and ladders will be provided for access to areas requiring service, although some manlift access may be required. Yard lights will be provided.
Plant Integration

2.5.2 Site Development

For purposes of this indicative cost estimate, we assume that the following is available at the designated site:

- Electrical service
- Sewer service
- Water service
- Natural gas
- Tel/data
- Ingress and egress, including weekends
- Laydown area for materials, and an area for a construction trailer and C-Tainer for secure storage.

The site is assumed to be secure. Fencing and a camera system are not included.

Roads will be paved. Tipping floors (if applicable) will be concrete. Prefabricated metal buildings will be used.

2.5.3 Code Compliance

The design will be code compliant as listed herein. County to notify of additional requirements.

2.6 Process Design Criteria

Project Inlet and Outlet Specifications

	CASE 1	CASE 2
BIOSOLIDS FEED MASS FLOW	85 DRY TON/DAY 425 WET TON/DAY	150 DRY TON/DAY 750 WET TON/DAY
BIOSOLIDS FEED MOISTURE CONTENT	20%	20%
BIOSOLIDS FEED ENTHALPY (ESTIMATED)	900 BTU/LB	900 BTU/LB
BIOSOLIDS FEED TEMPERATURE (ESTIMATED)	75F	75F
BIOSOLIDS PRODUCT MASS FLOW	85 DRY TON/DAY 89 WET TON/DAY	150 DRY TON/DAY 158 WET TON/DAY
BIOSOLIDS PRODUCT MOISTURE CONTENT	95%	95%

Ambient Site Conditions

Design Condition	Value
Elevation	~30 ft (9 m)
Coordinates	47.4699929°N, -122.2388527°W
Barometric Pressure	~30.2 in
Heating Dry Bulb Temperature (ASHRAE 99.6%)	23.8 deg F
Cooling Dry Bulb Temperature (ASHRAE 0.4%)	84.9 deg F
Cooling Wet Bulb Temperature (ASHRAE 0.4%)	66.5 deg F
Seismic Design Category	D2
Design Wind Speed	110 mph
Ground Snow Load	20 psf
Noise Limits	TBD
Minimum Metal Design Temperature	TBD

2.7 Design Capacity

	CASE 1	CASE 2	Estimated Efficiencies
Biosolids Drying	85 DRY TON/DAY 425 WET TON/DAY 28k lb/hr Water Evaporation	150 DRY TON/DAY 750 WET TON/DAY 49k lb/hr Water Evaporation	85% Thermal Efficiency
Biomass Gasification	230 DRY TON/DAY 270 WET TON/DAY	306 DRY TON/DAY 361 WET TON/DAY	85% biomass volume reduction

	116 MMBTU/hr Thermal Output	155 MMBTU/hr Thermal Output	85%vol syngas production 5% thermal losses
Heat Recovery Steam Generation	81k lb/hr @ 600psig 97 MMBTU/hr Thermal Output	121k lb/hr @ 600psig 145 MMBTU/hr Thermal Output	TBD
Steam Turbine Generator	5.1 MW Power Generation (6 MW Design) – Designed for full in-rush 49k lb/hr @ 200psig Process Steam 58 MMBTU/hr Thermal Output	5.6 MW Power Generation (6 MW Design) – Designed for full in-rush 86k lb/hr @ 200psig Process Steam 103 MMBTU/hr Thermal Output	65% overall efficiency
Digester Heating	13.1 MMBTU/hr	13.1 MMBTU/hr	TBD
Odor Control	6 Air Changes/hr ~85k scfm	6 Air Changes/hr ~125k scfm	TBD
Thermal Oxidizer	47k lb/hr 13k scfm syngas thermal oxidation ~116 MMBTU/hr Thermal Output	63k lb/hr 17k scfm syngas thermal oxidation ~155 MMBTU/hr Thermal Output	TBD
Cooling Tower	TBD in Detailed Design Subject to change based on existing site ability to supply effluent as cooling water	TBD in Detailed Design Subject to change based on existing site ability to supply effluent as cooling water	TBD
SCR System	47k lb/hr 13k scfm thermally oxidized syngas TBD in Detailed Design	63k lb/hr 17k scfm thermally oxidized syngas TBD in Detailed Design	TBD

2.8 Equipment Redundancy

To maximize the uptime of the Project, built-in redundancy will be incorporated for certain rotating equipment if:

- operating under harsh conditions where more frequent maintenance outages may be required; or,
- when the power requirements of operating two (2) smaller units are more favorable compared to one (1) large unit.

Having at least 50% built-in redundancy for equipment in a difficult service will allow the Plant to operate at partial capacity during maintenance events. The facility will feature redundant rotating equipment as deemed necessary during detailed design in order to maintain continuous operation.

Redundancy of major systems will include multiple trains as described herein, with turndown as applicable. Inherent redundancy exists for the biosolids fluid bed drying and biomass gasification systems based on the initial multiple trains required for the Project.

Certain auxiliary “utility” equipment that supports the main process will be specified with built-in redundancy. This may include redundant pumps, instrument air compressors, etc. as deemed necessary during detailed design.

2.9 Plant Uptime

The overall uptime of the Project is projected at 98%. Meaning once the plant is in commercial production (following successful startup and commissioning), it will be producing dry product in some capacity for 355 days per year. This projection is contingent on Owner and/or O&M Contractor stocking critical spares as recommended.

In the event of an emergency shutdown, the process exhausts gases will continue to be directed to emissions control systems and building odor control will continue to be directed through the odor control system until full safe shutdown is complete.

2.10 Equipment Turndown

Majority of process equipment will be specified to require a minimum 4:1 system turndown capability; where possible VFDs will be implemented on motorized equipment to provide further turndown capability where possible and where necessary. Major systems will require turndown or redundancy for ability to turn down during normal operation. Equipment turndown specifics will be available in detailed design.

2.11 Operating Requirements

The products of the Plant will be dry pellet biosolids and biochar. Raw materials will include:

- Biosolids sludge down to 20%wt moisture content
- Wood biomass waste at ~15%wt moisture content
- Sodium hydroxide, sulfuric acid, sodium hypochlorite, and nutrient chemicals for use in odor control
- Activated carbon for use in odor control and VOC removal/polishing
- Renewable Natural Gas (or Natural Gas), Nitrogen, and Utility Electrical for start-up
- Make up water, boiler water chemicals, etc.
- Lubrication oil for rotating equipment
- Critical spares
- Clean wastewater effluent (if possible) to supplement cooling water needs and reduce Cooling Tower demand

Wastes generated will include thermal waste heat and emissions via emissions control in accordance with regulatory permitting requirements, particulate matter, liquid water condensate blowdown from drying condenser and boiler systems, odor control wastewater blowdown, spent activated carbon, and waste oil from rotating equipment. If acceptable, the wastewater blowdowns could be directed to the wastewater treatment plant for processing.

Operating requirements for the will be established during detailed design.

2.12 Regulatory Requirements

The Department of Energy and Environmental Protection issues permits for sources that are below the emission thresholds and that are not considered exempt or insignificant. A permit application will need to be submitted to cover the proposed scope of work. It is anticipated that the final air permit will include at minimum the following emissions sources: the fluid bed dryer trains exhaust gas, the gasifier thermally oxidized exhaust gas processed through SCR (if required) and exhausted through the stack, the HRSG exhaust gas from natural gas start-up and/or duct firing as applicable, biomass dryer exhaust gas from natural gas start-up, and the odor control system exhaust gas. Key emissions and air quality control systems will include the thermal oxidizer unit, SCR and the odor control system.

Site construction and building permits will be required from the City of Renton and King County, and Air Permit modification from the Puget Sound Clean Air Agency. It is anticipated that separate permits from the Puget Sound Clean Air Agency will be required for the gasification unit and the fluid bed dryers.

Process vessels and storage tanks that vent to atmosphere will be reviewed to determine if they need to be identified as additional emissions sources. Regarding fugitive emissions, the EPA has specifically noted in guidance documents that "vents from continuous emissions monitors and other analyzers" are trivial activities that do not need to be regulated in air permits or even included in a list of insignificant activities. Therefore, any gas quality analyzers will be excluded from permitting requirements.

Specific regulatory requirements will be established during detailed design.

2.13 System Requirements

The general approach to equipment design and fabrication will be major system supplier systems, and modular or skid mounted systems, shop fabricated to the extent possible and feasible. For skid and modular systems, these will be complete with all necessary instrumentation and controls, wiring, and piping where possible. System wiring will be complete and will be in junction box enclosure(s) unless specified otherwise. Skid mounted modules will be designed, fabricated, and delivered as complete working systems that will function as specified once all tie-points are finalized. Each skid will include lifting lugs and all carbon steel structural members that are used for the skid assembly, equipment frame, and piping supports will be coated with an epoxy paint.

An Allen Bradley PLC with Ethernet/IP port and local HMI interface will be provided with each system where possible. The Ethernet connection will be for communicating with the plant balance of plant (BOP) PLC and HMI. Critical safety functions will be hardwired. The setting and changing of parameters, as well as the switching between modes (manual control / stop / automatic control) and acknowledge and reset alarms, will be done using the local operator's panel or plant operator's panel (located in a central control room). Local HMI screens will be furnished in electronic format so the screens and functionality can be integrated into the BOP HMI.

Electrical switchgear, motor starters, VFDs, etc. will be specified and supplied by the EPC Contractor for the Plant (versus individual equipment suppliers) and housed in a centralized electrical room or modular MCCs/PDCs. Exceptions to this approach will be identified during detailed design and final procurement activities. In these cases, all electrical equipment will be vendor-supplied and require a single point power supply only.

2.14 Technology Description & Equipment Summary (Details to be determined during design)

The following descriptions should be used in conjunction with the PFDs. Not all systems described are part of every option.

2.14.1 Cake Receiving

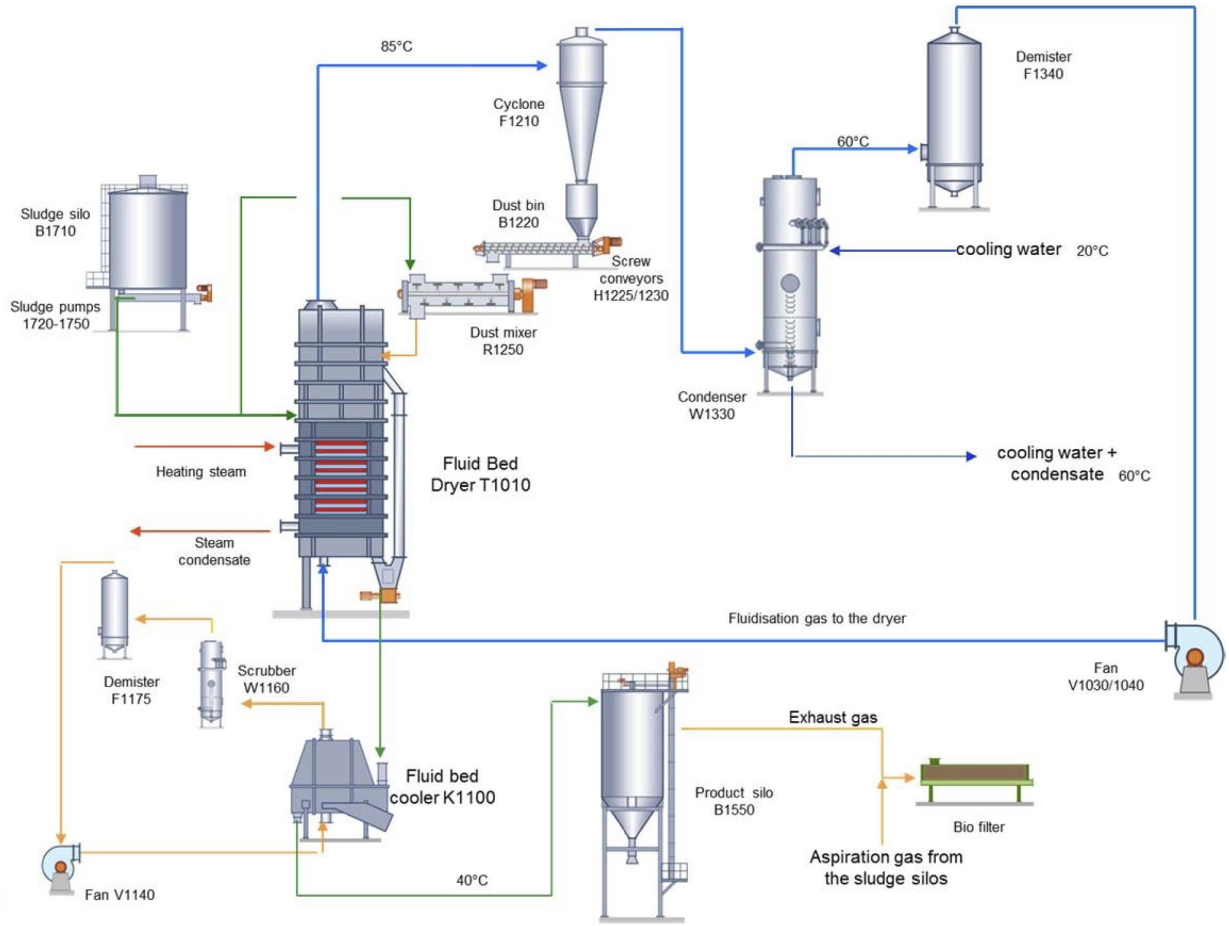
The Dewatered Municipal Solids from the other WWTP (Brightwater and Renton) will arrive via trucks, either in 20 cubic yard bins or in tandem-axle dump trucks. The trucks will offload at an unloading facility. The trucks will dump into a covered hopper and the hopper cover will be motorized to open and close remotely. The below grade hopper will include foul air extraction (12ACH) for odor control. The unloading facility will feature roller shutter doors which will close during truck unloading. Wash stations for truck cleaning prior leaving the facility will be included.

2.14.2 Dryer System

A fluidized bed steam dryer supplied by Andritz is proposed. The drying system consists of

- Steam Supply (per HRSG and Steam Turbine by others)
- Dryer
- Gas (air) recirculation system with cyclone and scrubber/cooler
- Fluidized bed cooler

A conceptual PFD is shown below per Andritz budget proposal:



Typical Flow sheet of the Fluid Bed Drying Plant for dewatered sludge;

The fluidized bed dryer 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 dewatered sludge is blended with 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. The fluidized bed dryer is filled with biosolids granules and the granules float on a vertically rising bed of air. 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%wt TS dry solids (design 95%wt TS). Granulation occurs by water evaporation and the particle movement in the fluidized layer.

The recycle gas which is used for fluidization carries dust and evaporated water from the fluid bed dryer.

Dust is separated from the fluidizing gas in a cyclone. The cyclone is fitted with a dust bin equipped with level measurement. The captured dust is mixed with dewatered feed sludge to form wet granules returning into the dryer.

After the cyclone, the evaporated water is condensed out of the gas stream in the using counter-current direct water spray. The condensed water is removed from the recycle gas and discharged. Effluent from the wastewater treatment plant is used for cooling water. The condensate together with the cooling water is discharged back to the WWTP.

The dry product is discharged from the fluid bed dryer by airlock valves with a minimum dry solids content 90%wt TS (95%wt TS design). The final product is discharged directly from the airlock valves into a vibrated fluid bed cooler and is cooled by a gas stream to a temperature of <104°F (40°C). The heated gas from the fluid bed cooler is cooled in the scrubber with cooling water and recycled to the fluid bed cooler. The cooling gas system is fed by the low oxygen content excess gas from the fluid bed dryer gas recycle system.

Specifically:

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 steam produced by syngas by the and provide 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 100 m^3 (3,532 ft^3) 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 90 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 <104°F (40°C) for subsequent mechanical conveying to the dried product storage silo or directly to a truck loading hopper. Dustrol will be added to the dried pellets to control the dust. 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. This stream is used for inertion of 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.

Operating Facilities:

Andritz has provided a list of operating facilities with this technology for reference.

Specifically:

The ANDRITZ Dryer to be built in Dallas, Texas (to be delivered to the South Plant in Renton) uses the conventional and proven Fluid Bed Dryer that produces dried pellets from the biosolids. The Fluid Bed Drying System can be designed for steam or thermal oil. The design herein employs steam use because we are proposing a steam electric turbine. The North Shore Treatment Plant in Zion, Illinois north of Chicago uses thermal oil in the heat exchanger in its Fluid Bed Drying System. The only difference between the steam and the thermal oil is in the heat exchanger. For a visit to the North Shore Sanitary District in Zion, contact Manager Steve Waters at stwaters@northshorewrd.org. Andritz has delivered the equipment for one of the world's largest wastewater treatment drying plants globally (up to 3,000 wet TPD) in Shanghai, China with operations started in 2020. Shanghai has nine (9) FDS-9.0 and is now commissioned and accepted in successful operation to use an ANDRITZ Fluid Bed Dryer on steam. ANDRITZ delivered the drying equipment of similar scale for Hong Kong in operation for 5 years and operated by Veolia. ANDRITZ has installations with the Fluid Bed Dryer using steam at Bern, Switzerland and Houthalen, Belgium. Visits to these plants can be arranged by contacting Peter Commorford at Peter.Commerford@andritz.com.

There are also ANDRITZ Fluid Bed Drying systems at Pensacola, Florida and Victoria, B.C. operating on thermal oil, as well.

2.14.3 Emissions and Odor Control

Emissions will consist of exhaust gases, fine particulates and odor.

Collection systems will be provided at points of particulate matter and odor generation and particulate matter will be collected in cyclones followed by bag houses on both the dryer and the gasifier (as applicable).

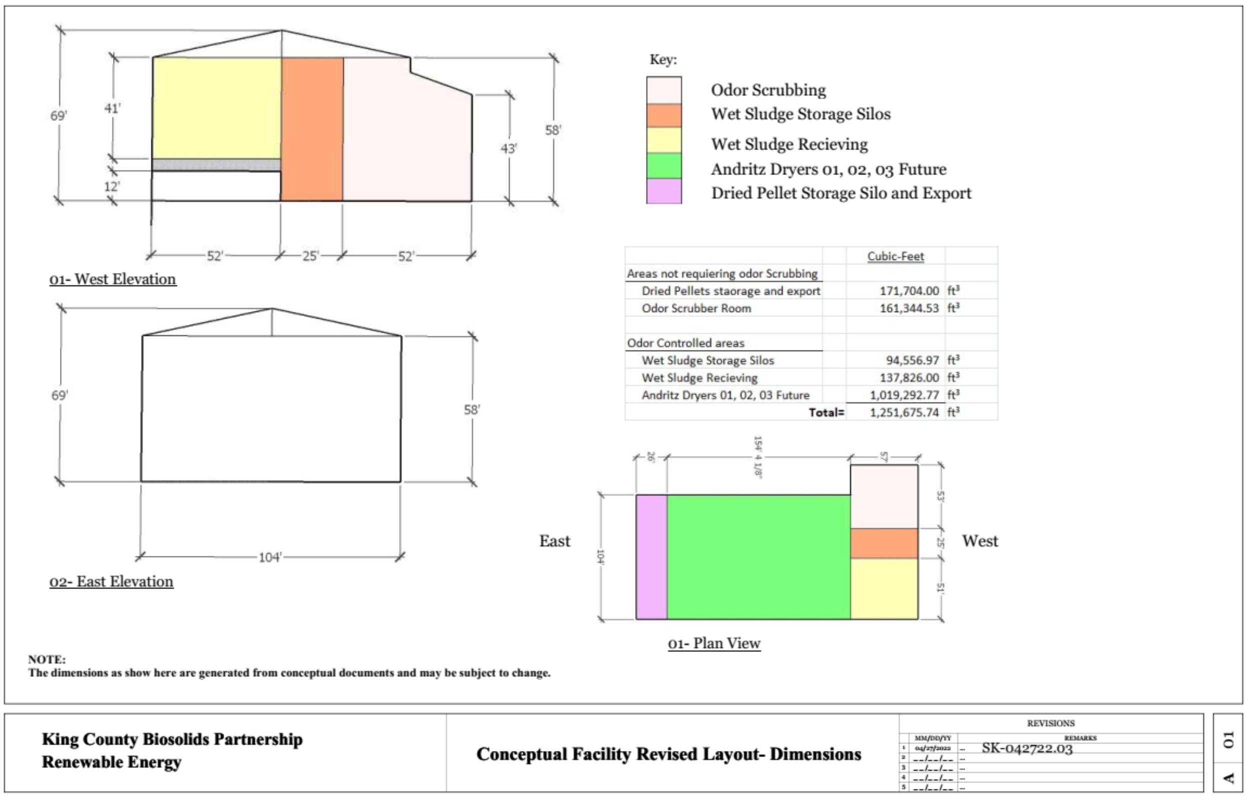
Odors are of concern at the front end (biosolids handling and drying) and will be managed by a three-stage system consisting of biofilters, chemical scrubbers and activated carbon polishing.
The odor collection system layout is based on conveying sources, with various odor characteristics, to a central 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 biotrickling 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 residuals 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

Based on the following building sizing the odor control volumes were estimated as follows:



		Cubic-Feet	
Areas not requiering odor Scrubbing			
Dried Pellets staorage and export		171,704.00	ft³
Odor Scrubber Room		161,344.53	ft³
Odor Controlled areas			
Wet Sludge Storage Silos		94,556.97	ft³
Wet Sludge Recieving		137,826.00	ft³
Andritz Dryers 01, 02, 03 Future		1,019,292.77	ft³
	Total=	1,251,675.74	ft³

Operating facilities:

A similar design is in operation at the North Shore Sanitary District, IL. The North Shore Fluid Bed Drying System incorporates many of the odor control strategies outlined here and the customer is encouraged to visit this plant, with operations exceeding 10 years.

2.14.4 Gasifier System

A downdraft gasifier supplied by Aries Gasification is proposed for gasifying wood biomass. Gasification is a process that converts biomass to gases (syngas) and char. The syngas steam is primarily composed of: nitrogen, carbon monoxide, hydrogen, carbon dioxide and methane, and contains small amounts of tar and water. The char (biochar) is primarily carbon (96% biobased carbon) and minerals and is produced at a 85%vol reduction from the original wood feed volume.

The feedstock material is heated in an environment with controlled levels of oxygen and steam at high temperatures, without combustion, via controlling the amount of oxygen and/or steam present in the reaction. The resulting gas mixture is called syngas or producer gas and is itself a fuel due to the presence of constituent gases such as H_2 and CO. Depending on operating conditions, the gas can have condensable organic liquid content as well.

For a downdraft gasifier, the feedstock must be sized and dried for optimum performance of the gasifier, and to promote a uniform temperature profile without hot spots. After sizing (1/4'' to 4'') and drying (to 10%wt moisture), the feedstock is fed into the reactor at a controlled rate which can be accomplished by various methods.

A desired velocity profile is maintained in the reactor by controlled recirculation of hot syngas, supplemented by limited air which promotes oxidation; i.e., sub-stoichiometric levels of oxygen are introduced, typically oxygen levels of less than 45% of stoichiometric.

The char is discharged onto water cooled jacketed conveyors to reduce the temperature of the char to levels that will not initiate combustion or pose a safety hazard to the operators. Contact with air while the char is above the auto-combustion temperature is prevented by a lockpot, dual knife gate valves, or rotary valve, or similar device.

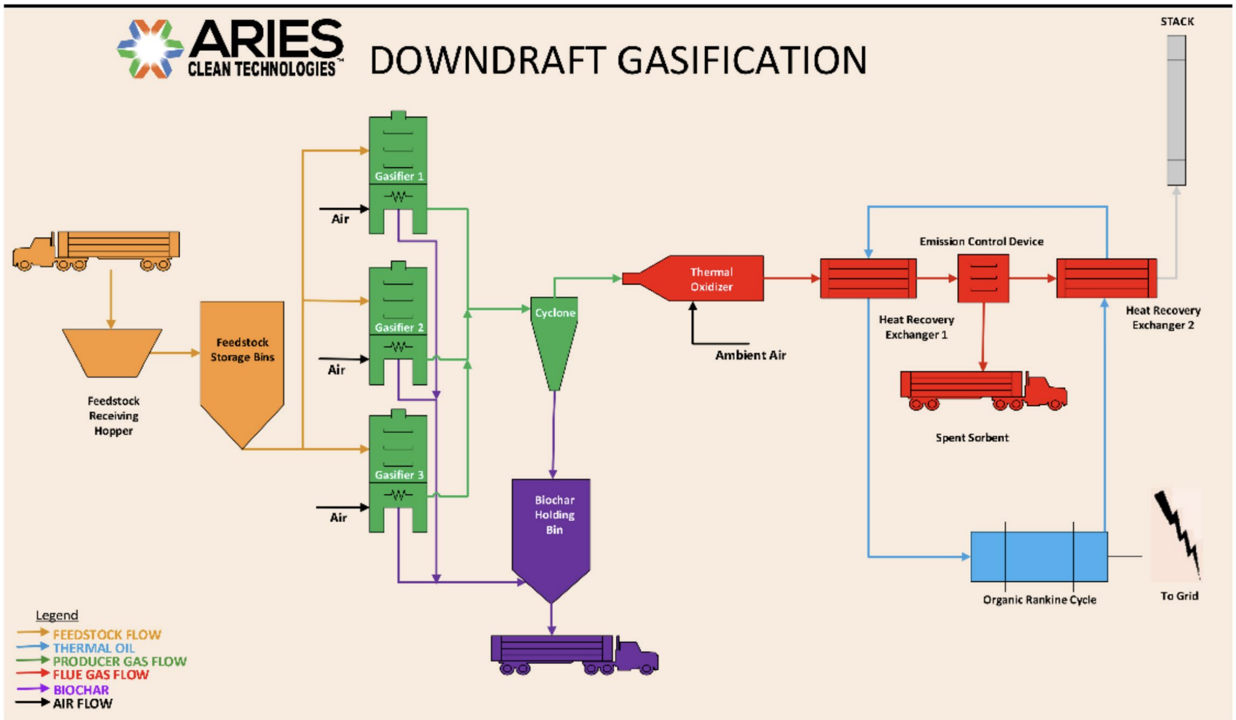
Process control is accomplished through:

- Monitoring of oxygen and/or carbon dioxide in the production gas, oxygen in the recycled flue gas, and adjusting the speed of the gasifier blower
- Modifying the speed of the flue gas recycle blower to achieve the target velocity profile.
- Monitoring temperature at various points.

For this application (King County) syngas is removed and combusted in a thermal oxidizer after which it is processed for heat recovery. Particulates are captured in a bag house.

Expected char and ash volume is 15% of feed.

A conceptual process flow diagram of the Aries system as available on their website is provided below:



Operating facilities:

In 2016, Aries successfully implemented its 8 patented wood gasification technology for the City of Lebanon, Tennessee at its wastewater treatment plant. The successfully operating Aires Wood Downdraft Gasification Plant in Lebanon, Tennessee has received numerous national, state, and local awards for its environmental stewardship, including in 2017 and 2018 the Greater Nashville Regional Council Local Government Award for Public Works and Utility Infrastructure, the Tennessee Governor's Environmental Stewardship Award, and the Top Project of the Year Award from the Tennessee Chapter of the American Public Works Association. A visit to the Lebanon, Tennessee Wood Downdraft Gasification Plant can be arranged by contacting Joe Regnery at joseph.regnery@AriesCleanTech.com.

2.14.5 Thermal Oxidizer

Vendor to be selected.

The Thermal Oxidizer Unit is used for the destruction of organics in production gas after the gasifier.
For this application, we expect to use a direct flame thermal oxidizer. If the concentration of combustible constituents is too low to create a flame front, then additional fuel will be added in the form of RNG or natural gas. When fuel demand increases, air flow increases according to a preset air/fuel ratio.

Elements of the thermal oxidizer include blowers for combustion air and possibly dilution air, an induction fan for the stack, burners and controls, a firebox, soot blower, and various heat recovery measures.

Thermal oxidizers achieve their high efficiency through the intensive mixing of the pollutants with air and fuel, high turbulence, and long residence time. Expected operating temperature will be approximately 1800 F, or higher as applicable.

Controls include temperature sensors (RTDs), flame sensors, and a variety of safeties and interlocks. A minimum residual of oxygen is provided to ensure complete combustion (approximately 3%).

2.14.6 Materials Handling

Standard mobile equipment (front end loader) will be provided for feeding of the wood waste. Piled feedstock will be stored under roof.

Otherwise, standard conveying equipment will be used, belt, cleated belt, drag plate, conventional shafted screw conveyors or shaftless screw conveyors, and bucket elevators or pneumatic conveyance for silo filling. In general, conveyors will be covered and connected to the odor control system where applicable.

Storage silos will be out loaded using a telescopic unloading spout to bulk truck trailer filling.

Trucks will be weighted via weigh scale and bill of ladings will be generated via control system and truck kiosk station.

This project entails the purchase of three (3) electric trucks that will be manufactured locally at Kenworth Truck Company, a subsidiary of PACCAR. The electric trucks will be the Kenworth T680E which is a 82k GCW rated tractor capable of ePTO applications.

It is estimated that one (1) charging station will be required for the electric trucks. It is assumed the station will require 400kw for the power to recharge a T680E completely. Rough average pick-up and delivery economy could be 2.2kwh/mi.

Three (3) trailers to go with the three (3) electric trucks will be needed with trailers covered during transport to keep the cargo dry. These will be end dump trailers as follows: Three (3) TT 39’ Alumatech 3 Axle Half Round Tub Frameless Trailer.

It is anticipated that the electric trucks would be used as follows:

- Haul the wood biomass from Cedar Grove to the South Plant in Renton, a distance of 12 miles.

- On the appropriate return trips, haul the BioChar from the South Plant in Renton to Cedar Grove Bagging Plant, a distance of 12 miles.
- Haul the dried pellets from the Andritz Dryer from the South Plant in Renton to the Ash Grove Plant in Seattle, a distance of 12 miles.

2.14.7 Process Integration

Each system will feature a vendor supplied control system (PLC and HMI). A Balance of Plant (BOP) PLC will be provided, for control of equipment between major systems. The BOP HMI will typically feature system overview screens, and mirror screens on vendor HMIs. The BOP HMI will typically allow adjustment of setpoints as needed, have start-up and shut down capability, and have a system an E-Stop, as well as a soft process stop button which initiates a controlled shutdown of the process.

We assume level of integration of both process systems and the fire alarm system with King County will be required.

For this application, Allen Bradley will be the preferred supplier of both PLCs and HMIs.

2.14.8 Safety Reliefs

The Plant will include several pressure safety valves (PSVs) that will relieve excess pressure to protect equipment. The pressure that is released needs to be properly vented to protect people. Accordingly, the PSVs need to vent to floor level (in the case of air) or vent to some remote and safe area, in the case of process liquids and gases.

The vent caps on outside vents will be kept in good repair and screens maintained to prevent moisture, leaves, birds' nests, etc. from creating blockage.

The PSVs provided will be calibrated valves set to vent at a pressure setting that is protective of equipment, based on nameplate information. The valve will be sized for scenarios such as blocked flow, in which a valve may be suddenly shut, or fire case, in which case gases are created and pressure may be build, or full flow. None of these valve's release to an air pollution control device because of the potential for backpressure.

The PSVs may discharge via a single line or into a properly sized manifold (header). The cross-sectional area of the header is typically equal to or greater than the sum of the cross-sectional areas of the PSV outlets contributing into it. For a complex manifold with multiple branches and long distances that may create potential for backpressure, modeling is used to ensure that the maximum backpressure permitted for the vessel, is not exceeded, which is an additional 10% of the PSV setting (block flow or full flow case) or 21% of the PSV setting (fire case).

2.14.9 Instrument Air

Instrument air will be provided by air compressor package(s) with redundant compressors (if deemed necessary) mounted on a common receiver and a single dryer package. 100% of the air will be dried in a dual regenerative desiccant dryer unit (lead/lag). A surge vessel (receiver) will be provided with automatic condensate removal.

2.14.10 Water Supply

Make-up water to the will be supplied from the city water supply or from the wastewater plant effluent if applicable/acceptable.

Safety shower(s) will be skid-mounted and include a hot water storage tank and blending valve, with integrated shower and alarms. The unit will store hot water in the tank and blend it with supplied cold water to create tempered water for the connected shower.

2.14.11 CHP Plant

The Project will be served by a combined heat and power plant (HRSG and Steam Turbine Generator) to supply heat and electricity for the facility. Thermally oxidized syngas will supply the thermal input to the HRSG for high pressure steam generation at approximately 600psig. A conventional steam turbine generator with extraction steam offtake for fluid bed drying process steam feed, and a condensing section for power generation will be employed for this purpose.

The CHP plant will have utility power and natural gas interconnects for use in plant start-up. It is anticipated all parasitic loads for the project will be powered by the CHP.

3 MECHANICAL ENGINEERING DESIGN CRITERIA

3.1 Scope

This section summarizes the codes, standards, criteria and practices that will be generally used in the design and construction of mechanical engineering systems for the Project. More specific project information will be developed during the detailed design, engineering, material procurement, specification and construction specification development phases and as required by the Owner.

3.2 Codes and Standards

The design of the mechanical systems and components will be in accordance with the laws and regulations of the federal government, State of Washington (King County), and industry standards. The most current issue or revision of the Code or Standard applies unless otherwise noted. If there are conflicts between the cited documents, the more conservative requirements shall apply.

The following codes and standards are applicable to the mechanical aspects of this facility.

- ASME Boiler and Pressure Vessel Code, Section VIII, Division I (ASME VIII)
- ASME/ANSI B31.3 Process Piping Code (ASME B31.3)
- ANSI B16.5, B16.34, and B16.9
- ANSI B73.1
- ANSI B16.11
- American Petroleum Institute (API)
- American Society for Testing and Materials (ASTM)
- American Welding Society (AWS)
- American water Works Association (AWWA)
- Hydraulic Institute (HI)
- Manufacturing Standardization Society (MSS) of the Valve and Fitting Industry
- National Fire Protection Association (NFPA)
- Occupational Safety and Health Administration (OSHA)
- Piping Fabrication Institute (PFI)
- 2012 International Mechanical Code (IMC)
- American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE)
- 2012 International Fuel Gas Code (IFGC)
- 2012 International Energy Code
- 2012 International Plumbing Code
- **County** Additions and Addenda

3.3 General Mechanical Design Criteria

Mechanical systems, equipment, materials, and their installation that will be designed in accordance with the applicable codes; industry standards; and local, state, and federal regulations, as well as the design criteria; manufacturing processes and procedures; and material selection, testing, welding, and finishing procedures are specified in this section.

The equipment vendors, in accordance with the performance and general design requirements specified by the Engineer, will perform detailed equipment design and selection. Equipment vendors will be responsible for using and selecting materials, gaskets and elastomers suitable for the intended use. Gaskets and seals in contact with sour digester gas services prior to the hydrogen sulfide removal process shall be constructed of Viton material. Butyl material shall not be allowed in services prior to the hydrogen sulfide removal process.

Asbestos shall not be used in the equipment, gaskets, coatings or insulation supplied.

3.3.1 HVAC Design Criteria

HVAC engineering details will be completed during the design phase of the project.

3.3.2 HVAC System Description

HVAC engineering details will be completed during the design phase of the project.

3.3.3 Pressure Vessels

Unfired Pressure Vessels shall be designed, fabricated, inspected and tested in accordance with the ASME Pressure Vessel Code, Section VIII, Division I. All vessels shall be protected by an ASME approved pressure relief device and bear the ASME Code certification plate. All pressure vessels shall be registered with the National Board

Pressure vessel corrosion allowance shall be 0.05-inch for carbon steel materials. No corrosion allowance is required for stainless steel materials.

The MAWP for deign purposes shall be as noted on the design data sheets. Full vacuum design shall be incorporated only where required by the process design and specified by the Engineer.

Nozzles 2-inch NPS and larger for pressure vessels will be of raised-face flanged design in conformance with the dimensional requirements of ASME/ANSI B16.5. Threaded or socket welded couplings are permitted for nozzles smaller than 2-inch NPS.

Where applicable, manways for pressure vessels shall be at least 18 inches in diameter and either hinged or davited to facilitate inspection and maintenance. Vessels shall be equipped with ladders and platforms for vessels taller than 14 feet to facilitate access/maintenance. All ladders, cages, platforms, handrails, mid-rails and kickplates shall conform to OSHA standards.

3.3.4 Thermal and Insulating Jackets

Components requiring insulation to reduce heat loss or afford personnel safety will be insulated. Minimum insulation thickness for hot surfaces near personnel will be designed to limit the outside lagging surface temperature to a maximum of 140 degrees F, based on 95 degrees F (to be confirmed) ambient temperature and 1 mph/hr air velocity. Other insulation minimums will be designed to limit the heat loss to approximately 80 Btu/hr-ft2 based on a 0 degrees F (to be confirmed) ambient condition and an air velocity of 20 mph/hr.

Thermal insulation shall be mineral wool, fiberglass, or calcium silicate, and will consist of pre-formed slabs or blankets, where feasible. Asbestos and asbestos bearing materials are prohibited. Aluminum jackets or suitable coating will be provided on the outside surface of the insulation. Where a hard-setting compound is used as an outer coating, it shall be nonabsorbent and non-cracking. Thermal insulation will be chemically inert even when saturated with water. Insulation system materials, including jacketing, will have a flame spread rating of 25 or less when tested in accordance with ASTM E84.

Insulation at valves, pipe joints, steam traps, or other points to which access may be required for maintenance will be specified to be removable with a minimum of disturbance to the pipe insulation. At each flanged joint, the molded material will terminate on the pipe at a distance from the flange equal to the overall length of the flange bolts to permit their removal without damaging the molded insulation.

Design temperature limits for thermal insulation will be based on system operating temperature during normal operation. Outdoor and underground insulation, if required, shall be moisture resistant.
Fouling factors will be specified in accordance with owner's experience or with those contained in TEMA. Corrosion allowance shall be 0.05" for carbon steel materials. No corrosion allowance is required for stainless steel materials.

All testing shall be done in accordance with TEMA and ASME Section VIII Standards.

Hydrostatic testing of tanks and pressure vessels will be specified and performed for pressure boundary components. Records will be transmitted to the owner at the time of equipment shipping.

Hydrostatic testing of piping systems is addressed elsewhere in this document. Where required by the design data sheets, performance testing of rotating equipment will be performed at the manufacture's facility.

3.3.5Welding and Fabrication

Welders and welding procedures will be certified in accordance with AISC, AWS or ASME requirements.

The vendor will maintain indexed records of welder qualifications and weld procedures in accordance with the design codes.

3.3.6Painting and Coatings

Except as otherwise specified, equipment will receive the respective manufacturer's standard shop finish.

- Uninsulated piping located outdoors will be primed and epoxy coated.
- Piping, storage tanks, and pressure vessels to be insulated will not be finish painted but will only be primed.
- Stainless steel piping and vessels will not be painted.
- Buried steel piping is to be factory coated with 40 mils Fusion-Bonded Epoxy Coating 3M ScotchkoteTM 206N or equivalent.

3.3.7 Safety Shower

Safety Shower shall be located in the close proximity to the caustic storage used in the bio-desulfurization process area.

Safety Showers shall be of the freeze protected type, equipped with electric heating tape for outdoor service. The shower station shall be equipped with pull chain, eye and face wash basin. The shower and eye wash flowrates, valving and delivery temperature requirements shall comply with the appropriate ANSI standards.

The shower station shall be firmly anchored to concrete or supporting steelwork. The shower station will comply with all OSHA, ANSI and Owner signage requirements.

Piping to the shower station shall be electrically heat traced. The water source shall be able to supply water for the minimum time of operation as required by the ANSI Standard.

The safety shower shall be fully compliant with ANSI Z ANSI Z358.1-1998 and OSHA 29 CFR 1910.151(C)

The safety shower will be configured to allow periodic testing in accordance with State and national code requirements. The safety shower will be configured to alarm in the control room.

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3.3.8 Mechanical Site Utility Services

Mechanical site utility details will be completed during the design phase of the project.

4 PIPING DESIGN CRITERIA

4.1 Scope

This Specification establishes the criteria, requirements, and procedures that shall be used in the design, layout, and sizing of piping systems.

4.2 Codes and Standards

Current editions and revisions of the following Standards, Codes, and Specifications shall be considered an integral part of this Specification and shall govern the design, fabrication, testing, and inspection of equipment.

- American Society of Mechanical Engineers (ASME)
  - Boiler and Pressure Vessel Code, Section I B 31.1--Code for Power Piping
    - B 31.3--Code for Process Piping
    - American Society for Testing and Materials (ASTM)
- American National Standards Institute (ANSI)
- American Petroleum Institute (API)
- Manufacturers Standardization Society of the Valve & Fittings Industry, Inc. (MSS)
  - MSS-SP-58--Pipe Hangers and Supports - Materials and Design
  - MSS-SP-69--Pipe Hangers and Supports - Selection and Application
  - MSS-SP-89--Pipe Hangers and Supports - Fabrication and Installation Practices
  - MSS-SP-90--Guidelines on Terminology for Pipe Hangers and Supports

4.3 Design and Selection of Piping Components

The pressure rating and materials specified represent minimum acceptable standards for piping design systems. The piping systems shall be suitable for the design conditions, services specified and intended. Each piping system shall be coordinated to function as a unit.

4.3.1 Basis for Line Sizing

The following data are used as a basis for line sizing:

- Preliminary Design
  - Liquid Line Velocities (ft/sec): 4 – 12
  - Gas Line Velocities (ft/sec): 30 – 70

Pipe Sizes	1” - 2”	3” - 4”	6” - 8”	10”	12” & Larger
Water (32°F to 140°F) & Similar Liquids	5	6	8	10	12
Velocities (ft/sec):					
Gas Velocities (ft/sec)	30	30	40	60	70

Final line sizing for pumped water and similar liquids will be based on pressure loss considerations. After determining the total pressure requirements of the system, adjustments in line sizes will be made to provide a balance between installation and operating costs. This evaluation will consider line size, control valve pressure drop, equipment pressure losses, pump size, and horsepower requirements. The operating horsepower requirements will be given priority.

Air and gas systems will be sized for velocities of 1800 to 4800 feet per minute. For system pressure less than 50 psig, pressure loss will be limited to 0.5 psi per 100 feet of pipe maximum. For system pressure above 50 psig, pressure loss will be limited to 1.0 psi per 100 feet of pipe, maximum. Final line sizing of air and gas systems shall limit total line pressure loss to 10 percent of initial pressure.

Pump suction velocities will be 4 feet/seconds or less, if NPSH requirements dictate. Pump suction lines will always be equal to or greater than pump suction size. On reciprocating pumps, suction velocity is taken as twice the average flow velocity to allow for fluctuations in the flow rate in each pump cycle.

Preliminary friction loss calculations will be made using Crane Co. "Technical Paper No.410", "Cameron Hydraulic Data" or "Standards of the Hydraulic Institute." Final calculations will be made and checked by CHEMCAD computer programs.

Pipe wall thickness shall be calculated in accordance with ASME B31.3 for Process Piping, as applicable.

4.3.2 Hangers and Supports

Requirements of ASME/ANSI B31.1, ASME/ANSI 31.3, MSS-SP-9, MSS-SP-89 and MSS-SP-90 shall serve as a design basis for all system components.

Hanger and support types shall be selected to withstand all static and dynamic load conditions and shall take into consideration limitations imposed by the surrounding structure, equipment, adjacent piping, ventilating and heating ductwork, and electrical trays.

4.3.3 Design of Vents and Drains

In general, venting and draining shall be accomplished through vessel and/or equipment connections.

Drains shall be provided at low points in the system to completely drain all equipment and lines after a test or shutdown.

Vent and drain valves shall be provided on liquid systems at the high point and low point of all lines and systems where condensate has potential to form.

Drain and vent valves in water or non-hazardous process or utility service shall not be plugged or blinded unless otherwise specified.

Drain and vent valves in services containing flammable, explosive, toxic, lethal, extremely reactive, or government-regulated fluids shall be plugged or blinded unless otherwise specified.

4.4 Piping System Chart

Piping system details will be completed during the design phase of the project.

Facility Area (s)	Piping System Description	Pipe Spec

5 CIVIL/STRUCTURAL ENGINEERING DESIGN CRITERIA

5.1 Scope

These design criteria are to be used as general guidelines for the civil/structural design, the selection of materials, and the preparation of engineering specifications and drawings for the Project.

5.2 Codes and Standards

The design shall comply with current editions and revisions of the codes, specifications, and standards listed below as noted, supplemented, or modified herein.

5.2.1 General

- IBC, International Building Code.
- OSHA, Occupational Safety and Health Administration.
- ASCE 7, American Society of Civil Engineers, Minimum Design Loads for Buildings and Other Structures.

5.2.2 Structural Steel

- AISC 360, American Institute of Steel Construction, Specifications for Structural Steel Buildings, Current Edition.
- AISC and RCSC, Research Council on Structural Connections, Specifications for Structural Joints Using ASTM A325 or A490 Bolts.
- AWS D1.1, American Welding Society, Structural Welding Code.
- AISC and SJI, Steel Joist Institute, Specifications and Load Tables for Steel Joists.

5.2.3 Structural Reinforced Concrete

- ACI 318, American Concrete Institute, Building Code Requirements for Structural Concrete.
- ACI 315, American Concrete Institute, Manual of Standard Practice for Detailing Reinforced Concrete Structures.

5.3 Design Loads

Buildings and structures for this project shall be designed for the following minimum load requirements listed in the IBC, as modified by state and local codes.

5.3.1 Live Loads

All building live loads shall be 100 psf.

5.3.2 Wind Loads

All buildings and structures shall be designed to withstand the forces of wind pressure, assumed in any horizontal direction, with no allowance for the effect of shielding by other adjacent structures, in accordance with the provisions of ASCE 7.

Wind Pressure
Design wind pressures are based upon the following:

- Risk Category II.
- Exposure category: D.
- Importance Factor: 1.00.

5.3.3Snow Loads

Snow loads shall be applied in accordance with the provisions of ASCE 7 using a basic ground snow load of 30.0 psf and applying all appropriate factors to account for such conditions as drift and snow slide. Design snow loads shall be based on the following:

- Exposure Factor 1.0
- Thermal factor 1.0
- Importance factor 1.0

For King County, WA, the flat roof snow load shall be 25 psf.

5.3.4Earthquake Loads

Every building, structure, foundation, and portion thereof shall be designed to resist the effects of earthquakes in accordance with the requirements of IBC. For King County, WA the Seismic Design Category shall be “B”.

Using a Risk Category II, the seismic design parameters are as follows:

Address: TBD
Coordinates: 47.4699929°N, -122.2388527°W
Elevation: 30 ft (9 m)

Hazard Type: Seismic
Risk Category: II
Site Class: D-default

5.3.5Impact Loads

All structural framing and concrete foundations subject to vibration, impact, impulse, shock, etc., shall be designed to withstand the generated forces within the limits of acceptable stress, deflection, and/or amplitude of vibration.

5.3.5.1 Vibration

All structures including foundations supporting reciprocating equipment or rotating equipment with excessive imbalance shall be analyzed for both strength and response.

5.3.5.2 Impact, Impulse and Shock

All structures supporting moving or stationary equipment shall be designed for static loads plus appropriate impact factors as defined by the equipment manufacturer, AISC, or as listed below:

Table 4.3.5.2 – Equipment Description Impact Factor

Equipment	Impact Factor
Elevator Machinery	100%
Forklift Trucks, Hard Wheels	50%
Forklift Trucks, Pneumatic Wheels	30%
Pneumatic Wheel Trucks	AASHTO
Light Machinery, Rotating (Less than 50 HP)	20%
Heavy Machinery, Rotating (50 HP & Greater)	50%
Reciprocating Machinery	50%
Hangers for Floors, Stairs, and Balconies	33%
Jib Cranes and Monorails (1,000-lb minimum load)	25% Vertical 20% Longitudinal

5.3.6Load Combinations

Each element of a building or structure shall be provided with sufficient strength to resist the most critical effects resulting from the combination of loads as specified in the IBC, with additions and modifications from ASCE 7.

Impact loads shall be included in the design of foundation elements but not in determination of soil pressures or piles loads.

Wind and seismic loads shall not be assumed to act simultaneously.

When designing concrete structures or foundations, the load factors for vibration, impact, and short-term overloads shall be considered the same as live load. The load factor for thermal shall be considered as dead load.

5.4 Allowable Stresses

Concrete design shall be in accordance with ACI 318.

Structural steel members, connections, and connectors shall be selected so that the stresses due to the working loads do not exceed the allowable stresses specified in The Manual of Steel Construction. (14th Edition)

5.5 Deflections

Every building, structure, foundation, and portion thereof shall be designed to have adequate stiffness to limit deflections and lateral drift per industry standards and manufacturer's requirements.

5.6 Materials of Construction

Unless required by specific process or maintenance considerations, the structural materials described below shall be used.

5.6.1 Structural Steel

A. Rolled Shapes and Plates

All Structural Steel Shapes, Flanges and Tees shall be ASTM A992, Grade 50. All other steel and connection material shall be ASTM A-36 or A992, unless approved otherwise.

B. Steel Pipe (Round)

ASTM A53, Grade B, Type E, Fy = 35 ksi (design)

C. Structural Tubing

ASTM A500 (Rectangular, Square) Grade C, Fy = 50 ksi

5.6.2 Floor Plate

Regular quality, carbon steel, checkered with allowable bending stress equal 16,000 psi. Checkered plate for exterior use shall be galvanized.

5.6.3 Grating

W-19-4 (1 1/4 inch by 3/16 inch) steel plain, galvanized. Exterior grating (grating exposed to moisture) shall be serrated.

5.6.4 Stair Treads

A. General Purpose

W-19-4 (1 inch by 3/16 inch) steel plain, galvanized, with checked plate nosing.

B. Closed Treads

Bent plate, minimum 3/16 inch thick, with slip-resistant electric arc spray on horizontal surface.

5.6.5 Railing

Handrail shall be 1 ½" nominal schedule 40 pipe with 1 ½" nominal schedule 80 posts spaced no more than 8'-0" apart. Handrail shall meet all Occupational Safety and Health Administration (OSHA) guidelines for non-public access.

5.6.6 Steel Connections

Beam and girder end reactions unless shown on the design drawings shall be designed to support one-half the total uniform load capacity shown in the Allowable Uniform Load Tables, AISC, Manual of Steel Construction, Part 2. Shop and field high-strength bolts shall be ¾ ", ASTM A-325, type N bolts unless noted on design drawings.

Purlins, girts, treads, doorframes, etc., shall be connected with 3/4 inch, ASTM A307 bolts.

5.6.7 Anchor Rods

Conforming to ASTM F1554-36, with a minimum yield of 36 ksi, with ASTM A563, Grade A, heavy hex steel structural nuts.

5.6.8 Welding Electrodes

Welding electrodes shall conform to American Welding Society (AWS) Structural Welding Code, AWS D1.1, Class E70.

5.6.9 Concrete

Cement shall conform to ASTM C150 Type I. Concrete aggregates shall conform to ASTM C33. Concrete shall conform to ASTM C94 for Ready Mix Concrete with the following minimum 28-day compressive strength:

All structural members f'c = 4,500 psi
All slabs elevated and on-grade f'c = 4,500 psi
Fill concrete f'c = 2,000 psi

5.6.10 Reinforcing

Reinforcing steel shall be deformed billet steel conforming to ASTM A615, Grade 60. Welded wire fabric shall conform to ASTM A185 flat sheets.

5.6.11 Concrete Embeds

All embedded steel shall be ASTM A36 or A992.

All major equipment and structures shall be anchored to concrete with cast-in-place bolts unless otherwise note on design documents.

Minor supports may be anchored with post-installed anchors.

5.6.12 Deck Forms

Steel deck units shall conform to ASTM A611, Grade C, D, E or ASTM A653-94 structural quality, galvanized, with a minimum yield strength of 33 ksi.

5.7 Foundations

5.7.1 General

All foundations shall be designed: to prevent sliding, to prevent undesirable settlements, to resist vibration, for stability against overturning, and in accordance with the Project Geotechnical report.

Buildings, structures, equipment, sumps, floors, etc. shall be supported on foundations of the type specified in Project Geotechnical report.

For design of concrete structures where surcharge is required, a minimum of 300 psf will be used, unless specified otherwise.

Pits, walls, and trenches shall be designed for hydrostatic conditions. The design of retaining wall type structures shall also incorporate the surcharge effects due to adjacent roads, equipment, and construction activities.

The point of support elevation (top of foundation grout) for all equipment shall be in accordance with dimensions and reference lines set by the equipment arrangement drawings.

For the purpose of hydrostatic calculations and calculating the effects of buoyancy, the water table will be considered at the elevation below grade specified in the Project Geotechnical report.

All exterior foundations shall extend to or below frost depth as defined in the project Geotech report.

5.7.2 Spread Foundations (Individual, Combined, Strip Footings and Mats)

Spread foundations shall be designed such that positive bearing will occur over at least 70 percent of the footing area. Additionally, the overturning moment due to wind or seismic loading shall not exceed two-thirds of the dead load stabilizing moment, providing an overall 1.5 safety factor for stability.

Foundations subject to horizontal forces shall be designed such that the resulting safety factor against sliding failure is 2.0 for cohesive soils and 1.5 for non-cohesive soils.

The design net allowable soil bearing pressure shall be defined in the project Geotech report.

5.7.3 Pile/Caisson Foundations

Pile foundations including helical piles shall be implemented and designed based on the recommendations of the project Geotech report.

5.7.4 Soil Properties

Foundations will be designed in accordance with the recommendations provided by the site specific GEOTECH Report and soil boring analysis.

6 ELECTRICAL ENGINEERING DESIGN CRITERIA

6.1 Applicable Codes and Standards

Electrical system will be designed and material will be specified in accordance with applicable sections of the following Codes and Standards:

- ANSI American National Standards Institute
- ICEA Insulated Cable Engineers' Association
- IEEE Institute of Electrical and Electronics Engineers
- NEC National Electrical Code
- IES Illuminating Engineers Association
- NEMA National Electrical Manufacturers Association
- NESC National Electrical Safety Code
- NFPA National Fire Protection Association
- OSHA Occupational Safety and Health Administration
- UL Underwriters' Laboratory
- Applicable local and state codes

6.2 Electrical Systems

The following electrical systems, with attendant characteristics, are anticipated for this facility:

Incoming Power TBD

Low Voltage Power Distribution 480 Volts, 3 phase, 60 hertz, three wire, solidly grounded

Low Voltage Utilization Motors:
Rated ½ HP thru 200 HP 460 Volts, 3 phase, 60 hertz
Motors rated less than ½ HP 115 Volts, single phase, 60 hertz
Rated above 200 HP 460 Volts, 3 phase, 60 hertz (reduce voltage start or VFD control)

Lighting Systems:
Roadway and Perimeter Lighting 120/208 Volts, 3 phase, 60 hertz, four wire, solidly grounded
Plant High Bay 120/208 Volts, 3 phase, 60 hertz, four wire, solidly grounded

Plant Low Bay and Stanchion Mounts 120/208 Volts, 3 phase, 60 hertz, four wire, solidly grounded

Finished Areas 120/208 Volts, 3 phase, 60 hertz, four wire, solidly grounded

Motor and Process Control High Level 120 Volts, single phase, 60 hertz, grounded, two wire

Process Instrumentation/Control Low Level 24 Volts, direct current

Process Instrumentation/Signal Level 4 to 20 milliamperes

6.3 Power supplies

6.3.1 Main Incoming Supply

The main power supply for the plant will have the following characteristics:

Quantity of Incoming Circuits	1
Capacity, Incoming circuit	Later
Voltage	Later
Phases	3
Frequency	60 Hz
Short Circuit three Phase Fault/ x/r	Later MVA/______
Short Circuit Line to Ground Fault/ x/r	Later MVA/______
Take over Point	Line Side terminals of a Pole Mounted Disconnect switch

Feeder cables will be 5 KV, 1/c (single core) Shielded, installed in underground conduits.

6.3.2 Standby Power

For critical functions that cannot tolerate a power interruption an uninterruptible power supply (UPS) will be provided. The UPS will provide power for 30 minutes after loss of normal source power. The size of the UPS and the loads on it will be determined later.

6.4 Low Voltage Distribution

The 480V, three phase, 60 Hertz distribution system will generally consist of the 12 KV - 480V outdoor pad mounted transformers feeding a single ended 480V switchboard assembly with transformers sized as required by the loads. Transformers will be rated as follows:

Winding	Two/Copper
Phases	Three (3)
Frequency	60 Hz
Insulating Medium	Less-flammable
Temperature Rise	65C by resistance over a 30C Ambient.
Cooling	ONAN
Capacity	3750 KVA ONAN
Impedance voltage 3 MVA-base	7.5%

Primary Voltage	Later
Secondary Voltage	480 V Wye solidly grounded
Primary Termination	Dead-Break Connector
Secondary Termination	Spade Connection
Tap Changer	Off Load (2±2.5%)

The transformers will be connected to the 480 V switchboard assemblies by means of 600V, multiple- 1/c cables via underground conduit.

Switchboard assemblies shall be indoor units comprised of one (1) incoming line insulated case air circuit breakers and the necessary feeder breakers and circuit auxiliaries to satisfy the low voltage loading requirements. The switchboard assemblies and circuit breakers shall be rated as follows:

System Operating Voltage	480 Volts
Phase	Three (3)
Frequency	60 Hz
Circuit Breaker Voltage Rating	600 Volts
Incoming Line Continuous Current Frame Rating	5000 Amperes Minimum
Incoming Line Interrupting Current Rating	65 kA (RMS Sym) Feeder Breaker Continuous
Feeder Breaker Continuous Current Frame Rating	1600 A Maximum
Feeder circuit Breaker Interrupting Current Rating	65 kA (RMS Sym)
Enclosure	NEMA 1

Switchboard assemblies shall be provided with the following construction features:

Switchboard shall consist of the required number of vertical sections bolted together to form a rigid assembly. The sides and rear shall be covered with removable bolt-on covers. All edges of front covers or hinged front panels shall be formed. Provide adequate ventilation within the enclosure.

All bus bars shall be silver-plated copper. Main horizontal bus bars shall be mounted with all three phases arranged in the same vertical plane. Bus sizing shall be based on NEMA standard temperature rise criteria of 65°C over a 40°C ambient (outside the enclosure).

Potential transformers shall be molded type fixed unit.

Current transformers shall be of the ring type with five ampere secondaries.

5.4.1 Circuit Breakers

Circuit breakers larger than 1600 Amperes shall be three pole, single throw, fixed mounted, insulated case, manually operated complete with adjustable electronic short circuit and temperature compensated thermal overcurrent devices.

Each insulated case circuit breaker shall be equipped with a solid-state tripping system consisting of three current sensors, microprocessor-based trip device and flux-transfer shunt trip. Current sensors shall provide operation and signal function. The trip unit shall use microprocessor-based technology to provide the basic adjustable time-current protection functions. True rms sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time delay settings are reached. Interchangeable current sensors with their associated rating plug shall establish the continuous trip rating of each circuit breaker.

Circuit breakers 1600 Amperes and smaller shall be three pole, single throw, fixed mounted, molded case manually operated complete with thermal inverse time delay overcurrent and instantaneous magnetic release devices.

Each molded case circuit breaker microprocessor-based tripping system shall consist of three (3) current sensors, a trip unit and a flux-transfer shunt trip. The trip unit shall use microprocessor-based technology to provide the adjustable time-current protection functions. True rms sensing circuit protection shall be achieved by analyzing the secondary current signals received from the circuit breaker current sensors, and initiating trip signals to the circuit breaker trip actuators when predetermined trip levels and time-delay settings are reached.

All breakers shall be UL listed for application in their intended enclosures for 100% of their continuous ampere rating.

Branch circuit distribution will utilize 3/c cable in tray and/or conduit.

6.5 Motor Control Equipment /Accessories/Systems

6.5.1 General

Motor control equipment and motor control circuitry shall be judiciously selected to properly accelerate, control and protect the associated rotating machinery and to impose insignificant disturbances on the plant electrical systems.

Motor control equipment shall be grouped and located within electrical equipment rooms that shall be air conditioned.

6.5.2 Control, Panels, Relay Panels and Accessories

Instrument/control panels, protective relaying/metering panels, and relay panels, if required, shall be self-contained, free standing or wall mounting units, completely assembled and wired. Panels shall be fabricated of non-corroding material (non-plastic) and have sufficient mechanical strength and degree of protection NEMA 12 or higher. All control devices and components shall be mounted and wired to unit terminal boards to facilitate remote circuit extensions.

Control accessories such as pushbutton stations, selector switches, indicating lights, etc. shall be heavy duty, oil tight, industrial type units with function legend plates.

Local control items and pilot devices such as pushbuttons, emergency stop switches, limit switches, etc. shall be heavy duty, industrial type units, with cast, ferrous or aluminum alloy enclosures suitable for the location involved.

6.5.3 Low Voltage Motor Control Centers

Low voltage motor control centers shall be free standing, dead front, metal enclosed assemblies consisting of standard, modular dimensional units, arranged for front and/or rear mounting. Control and feeder tap units of the same size and rating shall be readily interchangeable. Channel sills and lifting angles shall be provided to facilitate installation.

The control centers shall be provided with vertical and horizontal wireways of adequate cross section for all anticipated wiring. The wireways shall be free of all live parts and equipped with cable supports.

The general arrangement of the motor control centers shall be such as to accommodate all required components and shall include a minimum of ten percent (20%) spare space to allow for future starter additions.

The necessary, bare copper main, vertical riser and ground buses shall be provided with the continuous current ratings and fault current stress bracings as required.

The necessary spaces and provisions shall be made at each control center assembly to terminate and connect the incoming feeder cables adequately and properly.

Motor starters shall be draw-out, combination, circuit breaker disconnect type, across the line, non-reversing, multi-speed, etc., as required. Each starter unit shall be equipped with the following:

6.5.4 Circuit Breaker

Contactors and auxiliary relays as required for the function and duties. Over current thermal trip relay or motor protection molded case circuit breakers.

Control Power Transformer with primary and secondary fusing.

Push buttons, indicating lamps as required by the applications. Motor Contactor Auxiliary contacts (2-NO and 1-NC).

For special Consumers (heaters, cranes, etc.) The feeder units shall be equipped with a circuit breaker, motor protection molded case breakers, contactors, and other equipment deemed necessary for such feeders.

The incoming feed cubicle for each MCC shall be equipped with the following:

A suitably rated fixed mounted circuit breaker, which can be locked in the open position or main lugs only (see one line diagrams).

All circuit breakers, bus bars, connections, etc. shall have a minimum of 20% future capacity over the maximum calculated load.

The motor control center assemblies shall be rated as follows:

System Voltage	480 Volts
Frequency	60 Hertz
Number of Phases	Three (3)
Short-circuit rating	65,000 Amperes effective
Main Bus Capacity (continuous)	As required
Enclosure	NEMA 1A Gasketed

The motor control centers shall be assembled and wired with strict adherence to manufacturer's instructions with special attention to bolt torques, frame alignment and shipping split wiring.

6.6 Rotating Apparatus

6.6.1 General

Motor and drive system types, ratings and construction features will be judiciously selected to satisfy the driven mechanical load requirements and to perform without detriment in the installed environment.

Winding RTD's (Platinum, 100-ohm resistance at 0°C), resistance thermostats or thermistors will be supplied on motors rated 200 to 1500 HP and critical duty motor less than 200 HP.

6.6.2Small Squirrel Cage Induction Motors

Motors shall be horizontal, two bearing, squirrel cage induction type, with single shaft extensions suitable for the drive application. Motor enclosure types shall be totally enclosed fan cooled suitable for the application. Space heaters shall be provided for all motors rated above 50 HP. If ambient conditions dictate, motors rated 50 HP and below will be provided with space heaters.

Motor frames and end shields shall be of cast iron or fabricated steel construction, designed to adequately house, support and secure motor components and to provide protection commensurate with the enclosure type employed.

Windings shall be random, or form wound, insulated with Class F materials or higher if the design application warrants, and securely braced to resist failure through electrical stresses and vibrations.

Motor shafts shall be fabricated of high-grade machine or forged steel, of adequate size and design to withstand the loading stresses normally encountered with the ratings employed.

Rotors shall consist of high grade, low loss, silicon steel lamination adequately fastened together and to the shaft. Rotor squirrel cage winding shall be of copper construction with brazed end rings.

Motors shall be equipped with end shield mounted, anti-friction ball bearings. Inverter duty motors will be used when variable frequency controllers are applied. The motors shall be rated as follows:

Output, HP	1/2 thru 600
Utilization Voltage	460 Volts
Phases	Three (3)
Frequency	60 Hertz
Speed	1800RPM (Preferred)
Service Factor	1.15
Duty	Continuous
Temperature Rise (by resistance)	80°C (Class B) Insulation Class F
Torques, Full Voltage	NEMA B, or as required
Load Inertia Capability	Normal, or as required

Locked Rotor Current shall not exceed 6.5 times full load current.

6.7 Lighting

Illumination system will be designed as per following criteria:

Interior and exterior illumination stems shall be designed to provide the average intensity levels listed below required for the particular seeing task and application, through the employment of minimum lamp type and quantities.

In general, LED lamped, industrial type luminaries shall be employed in all areas and shall be pendant, bracket or stanchion mounted as indicated by the application.

Average maintained illumination levels based on a Light Loss Factor of 0.70 will be employed as follows for lighting design purposes.

Location (Avg. Foot-candles)	Intensity Level Work Plan
Outdoor (Walkways, Stairs,	5 Grade Platforms)
Indoor compressor area	20 Grade
Electrical Equipment Rooms	30 Floor
Outside Lighting	2 Grade
Control Room	30" above Floor
Offices	30" above Floor

Emergency lighting shall be provided at stairways, exit passageways, electrical apparatus rooms, operator's control rooms, and other specially designated essential plant equipment areas to permit the safe egress of plant personnel from plant areas which have experienced the loss of normal electrical service and general illumination.

Emergency lighting units shall be individual and portable, battery powered units complete with integral charger, control relays and incandescent, sealed beam type, adjustable lighting fixture heads. Exit signs shall be illuminated (LED); self-powered units, capable of providing 90 minutes of illumination in the emergency (battery operation) mode. Input to exit signs shall be 120V, 1 phase. Exit signs shall be located at each door exit.

Convenience receptacles for installation in plant areas shall be duplex, 20 ampere, 125 volts, two pole, three wire, grounding type, NEMA 5-20R, installed in ferro-alloy cast device boxes with sheet stainless steel covers. Receptacles shall be mounted 2'-6" above finished floors.

Convenience receptacles for installation in architecturally finished areas such as offices, control rooms, laboratories, etc. shall be duplex, 20 amperes, 125 volts, two pole, three wire grounding type, NEMA 5-

20R installed in flush mounted pressed steel outlet boxes with sheet stainless steel covers. Receptacles shall be mounted 1'-6" above finished floors.
Ground fault circuit interrupters shall be employed with convenience receptacles when receptacles are installed in areas subject to potential shock hazards in wet areas.

Toggle switches for installation in all areas shall be 20 amperes, 125 volts, single pole, three way or four-way units as required. Toggle switches shall be mounted 4'-6" above finished floors.

Dimmer switches and fixtures shall be provided in control rooms.

Outdoor lighting systems shall be controlled in groups by lighting contactors with photoelectric and/or time clock control. The contactors shall have a bypass switch for testing and maintenance.

Lighting panel boards shall be indoor, dead front, circuit breaker type, with main circuit breakers and will be suitable for connection to a 120/208 volt, three phase, four wire, 60 hertz service. Panel boards shall be provided with surface mounting type enclosures, complete with flush hinged doors, latch, lock, directory card holder and trim. Quantities and continuous current rating of branch circuit breakers shall be as required. 20% spare breakers will be provided.

6.8 Grounding

A complete coordinated grounding system will be provided for the project.

A grounding system shall be provided at each process area to ensure safety to personnel and equipment in case of electrical equipment failure, provide a low impedance path for ground fault currents and lightning arresters and prevent fires by removing the possibility of static discharge in hazardous areas.

The grounding system shall be of the perimeter loop design with taps and extensions to equipment and structures as required by installation code authority.

Grounding electrodes shall be minimum 3/4" x 10'-0" copper clad, steel rods designed for mandrel driving.

The ground system perimeter loops shall be constructed of No. 4/0 AWG minimum size, soft drawn, stranded bare copper conductor, or as required by Vendor grounding requirements.

Ground taps and above grade cable for electrical equipment and associated supports shall be constructed of No. 2 AWG minimum, copper stranded, green PVC insulation.

Ground taps and above grade cable for non-electrical equipment shall be constructed of No. 2 AWG minimum, copper stranded, green PVC insulation.

Main subsurface grounding loops shall be extended a minimum of 1'-6" beyond the perimeter of all structures and located at a minimum depth of 1'-6".

Electrical equipment enclosures receiving their power from sources in excess of 600 volts shall be positively connected to the grounding system.

Frames of electrical equipment and motors operating at voltages in excess of 600 volts shall be positively connected to the grounding system.

Buried or concealed connections to the grounding system shall be made employing the exothermic welding process. (E.g. Cadweld or equal).

Exposed connections to the grounding system shall be of the mechanical, compression type, in accordance with standard detail drawings.

Each underground duct run shall have a # 4/0 AWG minimum size ground cable and shall be run in the concrete envelope.

Frames of electrical equipment, motors, control devices (minimum voltage rating 120V) shall be grounded through grounding conductors installed integral with branch circuit conductors.

All conduits with grounding type insulated bushing will be grounded to equipment frame and/or cable tray.

6.9 Communications Systems

Phone system TBD.

6.10 Electric Heat Tracing

Electric heat tracing will be provided for freeze and process protection as required. Self-regulating heater cable rated 120 or 208 volts will be utilized for this purpose, and
will be thermostatically controlled.

Heat tracing circuits will be powered from dedicated distribution panelboards through 120 Volt, single phase, ground fault circuit interrupter circuit breakers.

Each Heat Trace Circuit will be provided with End of the Line indication Lights.

6.11 Construction Materials/Installation

6.11.1 Wire and Cable

6.11.1.1 15KV Class, Non-Metallic Sheathed

Cable for 15KV feeder and branch circuits, installed in underground conduit. Consisting of single or multiple Class B stranded, annealed tinned copper conductors, each in an Ethylene Propylene Rubber (EPR) insulation. Class B stranded bare grounding conductor. 5 mil annealed copper tape with 25% overlap shield. Lead free, low friction flame retardant, moisture and sunlight resistant Polyvinyl Chloride (PVC) jacket. 133% level and 105 degrees C rated. Approved for CT use for single conductor cable that is 1/0 AWG and larger. General Cable Spec 6355 or equivalent.

6.11.1.2 600 Volt Class, Single Conductor Non-Metallic Sheathed (Power)

Cable for 480 Volt, feeder wiring installed in conduit and tray. Consisting of single, Class B stranded, annealed, tinned copper conductors in a 600 Volt Class, flame retardant, cross-linked polyethylene (XLPE). Rated 90 degrees C wet or dry. Approved for CT use on 1/0 AWG and larger cable. General Cable Spec 5250 or equivalent.

6.11.1.3 600 Volt Class, Three Conductor Non-Metallic Sheathed (Power)

Cable for 480 Volt, motor branch circuit (fixed speed) and feeder wiring installed in conduit and trays. Consisting of multiple Class B stranded, annealed tinned copper, each conductor contained in flame retardant cross-linked polyethylene (XLPE) insulation. Color coded per ICEA Method 4. Uninsulated bare annealed copper ground. Jacket is lead free, flame retardant, sunlight resistant polyvinyl chloride (PVC). Rated 90 degrees C wet or dry. Approved for CT use. General Cable Spec 4550 or equivalent.

6.11.1.4 600 Volt Class, Three Conductor Shielded VFD (Power)

Cable for 480 Volt, VFD motor circuit installed in conduit and tray. Consisting of multiple Class B stranded, annealed tinned copper conductors, each conductor contained in flame retardant cross-linked polyethylene (XLPE) insulation. Color coded per ICEA Method 4. 3 symmetrically placed annealed bare copper conductors in direct contact with shield. Overall, 5 mil annealed bare copper tape shield with 50% overlap. Jacket is lead free, flame retardant, sunlight resistant polyvinyl chloride (PVC). Rated 90 degrees C wet or dry. Approved for CT Use. General Cable Spec 4580 or equivalent.

6.11.1.5 600 Volts, Non-Metallic Sheathed (Control)

Cable, of multi conductor construction, for control circuit and high-level instrumentation system wiring, 120 Volt and less, installed in cable tray or conduit raceways, shall consist of multiple (as required) Class B stranded, annealed tinned copper, each conductor contained in flame retardant cross-linked polyethylene (XLPE) insulation. Color coded per ICEA Method 1, Table E-2. Jacket is lead free, flame retardant, sunlight resistant polyvinyl chloride (PVC). Rated 90 degrees C wet or dry. General Cable Spec 4500 or equivalent.

6.11.1.6 300 Volts, Non-Metallic Sheathed (Instrumentation)

Wire and cable for low level signal, instrumentation wiring, shall be multiple (as required) stranded, annealed, tin-coated copper conductors, No. 18 AWG size, each contained in lead free cross-linked polyethylene (XLPE), arranged in twisted pairs of eight twists per lineal foot. Each twisted pair shall be shielded with 100% coverage aluminum/polymer tape, in contact with tinned copper drain wire. Color coded per ICEA Method 1: Pairs. Jacket is lead free, sunlight-resistance, polyvinyl chloride (PVC). Cable shall be provided in accordance with ICEA standards. General Cable Spec 1200 or equivalent.

6.11.1.7 600 Volts, Non-Metallic Sheathed (RTD)

Wire and cable for RTD wiring, shall be multiple (as required) stranded, annealed, tin- coated copper conductors, No. 18 AWG size, each contained in lead free cross-linked polyethylene (XLPE), arranged in triads. Each triad shall be shielded with 100% coverage aluminum/polymer tape, in contact with tinned copper drain wire. Color coded per ICEA Method 1: Triads. Jacket is lead free, sunlight-resistance, polyvinyl chloride (PVC). Cable shall be provided in accordance with ICEA standards. General Cable Spec 1200 or equivalent.

6.11.1.8 Ethernet Cable

Per Vendor recommendation, Category 6 preferred.

6.11.2 Connectors

All connectors for wire and cable shall be compression type and shall be made of high conductivity corrosion resistant nonferrous material. Connectors for power cable sizes up to and including #8 AWG shall be Burndy Type YAV or Owner approved equal, and for power cable sizes #6 AWG and larger shall be Burndy Type YAL or Owner approved equal. Wire nuts are only permitted on lighting circuits. Contractor shall furnish all material and tools for terminating cables and wires such as connectors, from the smallest specified size up to larger sizes, except for those furnished with the equipment, insulation, fire proofing and copper tapes, solder, pulling compounds, identification tags, terminal blocks other than provided on fabricated equipment, ground straps, serving and waxed lacing twine, and other material which is required for the complete installation of cable and wire. Cables shall be terminated in accordance with the cable manufacturer's specifications.

All current connectors shall be insulated compression type ring tongue connectors.

All control connectors shall be compression type insulated ring tongue or flanged spade lug type connectors when screw type terminals are used. When terminals are compression plate type a bare conductor under the pressure plate is acceptable.

6.12 Wire and Cable Installation

All wire and cable shall be installed in raceway systems unless otherwise indicated on the drawings. No wire or cable shall be installed until a raceway system is complete. Any wire installed in a raceway before the raceway system is completed shall be replaced.

The use of wire and cable pulling lubricants other than powdered soapstone or compounds approved by the cable manufacturer is not permissible. Use of petroleum greases is prohibited.

It shall be the Contractor's responsibility to assure that the maximum pulling tensions and sidewall pressure values during pulling of cables do not exceed the cable manufacturer's recommendations. If the maximum pulling tensions and sidewall pressure are exceeded, the cables shall be deemed unserviceable and shall be removed, discarded and replaced.

Cable shall be fed straight into the end of the conduit to avoid sharp bends and edges that may cause cable damage.

Lashings shall be removed as cable is pulled into conduit.

At panels, terminal boxes, etc. multiconductor cable jackets shall be stripped back to the panel entry point. Individual conductors shall then be bundled, trained and wrapped with self-locking "TY-RAPS" or approved equal. Any disassembly of bundles to facilitate trouble shooting during the course of construction shall be retrained and wrapped to present a neat and finished appearance. Spare conductors shall be dressed out for future use.

Cables having nicks, tears or any other factory imperfections shall be rejected and replaced at no costs or delay to the project. If nicks, cuts, tears or other imperfections are observed after a cable is installed, the cables will be removed, discarded and repulled without cost or delay to the project. Taping or other field repair to cables is not acceptable.

Power wires and cables shall be spliced in junction boxes where required and approved by Owner. Where it is necessary to tap or splice control circuit conductors, terminals boxes shall be provided for this purpose. Boxes and terminals shall be provided in accordance with this specification.

Wiring installation shall be made so that no undue stress is placed upon the insulation and coverings when they are drawing through conduits or otherwise handled. Slack wire shall be left in all junction boxes, pull boxes and other places so that wire are not drawn tight against conduit and bushings or short radius corners and the insulations eventually damaged by being squeezed between conductors and other objects. Ample slack wire shall be left at all terminal connections so that stress is not placed on terminal studs and other connections.

Maximum allowable pulling tensions (with pulling eye on conductor or with basket weave grip over cable coverings) and maximum allowable sidewall pressures shall not exceed cable manufacturer's recommendations.

Bakelite wedging plugs are to be used to support cable in all conduits running vertically for a distance greater than fifty (50) feet. They are to be installed in pull boxes, in switchgear or vertical runs to overhead indoor feeders.

Cables shall be adequately supported in pull and junction boxes with insulated supports. When installing cables in cable trays, the installation practice such as pulling tension, minimum bending radii, handling, etc. shall be in strict accordance with the cable manufacturer's recommendations.

Exposed cable risers of the same circuit level from trays beneath or above equipment shall be bundled and tied with cable ties for mutual support. Where cables may be subjected to mechanical damage, adequate protection shall be provided.

All wiring inside pull boxes, devices, etc. shall be tagged with its respective wire number and cable number.

Where a grounded (neutral wire) in a multiconductor cable is required, the subcontractor shall permanently identify the conductor at each termination at the time of installation by a distinctive white marking or other equally effective means.

Where an equipment grounding conductor is required in a multiconductor cable, the subcontractor shall permanently identify the conductor at the time of installation at each end and at every point where the conductor is accessible by one of the following means:

- Stripping the insulation from the entire exposed length.
- Coloring the exposed insulation green, or

- Marking the exposed insulation with green tape or green colored adhesive labels.

6.12.1 Conduit, Fittings and Accessories

Conduit, couplings, elbows and nipples for outdoor or wet installation shall be of rigid, heavy wall, galvanized steel fabrication, with an interior coating of lacquer of the nominal trade sizes required. Conduit shall be furnished in nominal ten (10) foot lengths with one coupling attached. Minimum size shall be 1/2". Transition from PVC embedded shall be rigid metal conduit.

Conduits, elbows and nipples shall be threaded on each end per latest ANSI Specifications. The threads shall be tapered for their entire length, and the taper shall be 3/4 inches per foot.

Conduit fittings shall be cast ferrous metal type, threaded for rigid heavy wall conduit and provided with gasketed covers and stainless-steel fasteners.

Conduit hub connections shall be of heavy-duty steel or malleable iron construction with corrosion resistant finish complete with recessed, polychloroprene sealing ring and taper threaded hub for positive watertight seal. Conduit hub connections shall be used for all outdoor installations.

Conduit cable supports for use in supporting wire and cable in vertical conduit risers, shall be installed at fittings or junction boxes and shall consist of bakelite wedging plugs of the proper size for the conduit and cable involved.

Conduit locknuts shall be heavy duty, cast ferrous metal type.

Conduit bushings shall be heavy duty, galvanized or cadmium plated, metal cast ferrous with grounding lug, molded and "locked-in" bakelite insulation.

Flexible conduit shall be employed at all apparatus or devices subject to vibration, movement for belt adjustment, operational inspection, etc. as required, or as shown on the drawings. Flexible conduit shall consist of oil-resistant, liquid tight jacket in combination with flexible metal reinforcing tubing for use with watertight fittings complete with integral grounding conductors.

Conduit for underground installation shall be rigid, Schedule 40, high impact resistant, polyvinylchloride (PVC) designed for direct buried and of the nominal trade sizes required (transition to rigid metal conduit at vertical conduit riser including 90° elbow).

PVC conduit couplings, adapters, etc., shall be rigid, high impact resistant polyvinylchloride, dimensionally and mechanically compatible with PVC conduit straight sections and designed for solvent welded jointing.

Conduit and fittings for corrosive, caustic and continuously damp areas shall be PVC coated. The coating integrity shall be fully maintained at all times.

6.12.2 Conduit and Accessories Installation

Conduit expansion fittings or bends to take expansion shall be provided in every straight conduit run above ground which is more than 200 feet in length. Conduit expansion shall be provided for wherever conduits cross structural or building expansion joints.

Long above ground conduit runs or runs having low points shall have suitable provisions for condensation drainage.

No welding or attachment of conduit hangers, clamps or brackets shall be done on crane girders or on parts of structures that carry tensile stress unless special written authorization is first obtained from the Owner.

Double locknuts and bushings shall be installed at all conduit terminations located in electrical equipment and control rooms.

Where conduit penetrates building roofs or exterior walls the necessary flashing, gasketing and/or caulking required to affect a weathertight installation shall be provided and installed.

The installation of all conduits shall be properly coordinated with the work of other trades.

All conduits shall have brass tags at each end of each conduit run showing the conduit number as shown on the conduit and cable schedules.

6.12.3 Junction/Pull/Terminal Boxes

Field fabricated junction boxes, pull boxes and terminal boxes shall be fabricated of stainless-steel sheet with formed-out flanges, full seam welding and screw-on, polychloroprene gasketed, steel coves. Boxes and covers shall be of the same metal gage, No. 12 minimum. Screws shall be corrosion resistant, stainless steel, machine screws.

Factory fabricated boxes shall be of the design and materials required to satisfy the environmental conditions of the location of the box. All boxes installed outside of environmentally controlled rooms shall be NEMA 4X stainless steel.

Junction, pull and terminal boxes shall be installed at all locations necessary to facilitate the conduit raceway and wiring installation. Boxes shall be set true and plumb and shall be rigidly secured to building or supporting steel or masonry walls per installation standards as shown on drawings. Boxes shall be supported independently of all associated conduit raceway. Openings for necessary conduit and fittings only will be provided in each box. Boxes shall be sized in accordance with the latest edition of the NEC. Each box shall be designed to accommodate installation of a cabinet ground.

6.12.4 Outlet Boxes

Outlet boxes for installation in architecturally finished areas shall be flush mounted galvanized pressed steel units of square, rectangular or octagonal configuration, designed and provided to accommodate the conduit, wiring, devices and fittings encountered at any specific location.

Outlet boxes for installation in plant areas shall be cast, ferrous metal type, of rectangular or round configuration, designed and provided to accommodate the conduit, wiring, devices and fittings encountered at any specific location.

6.12.5 Cable Trays and Accessories

Cable tray straight sections for power and control will be composed of stringers and rungs hot dip galvanized after fabrication steel tray of the widths, depths, and rung spacing's as required. Straight sections will be free of sharp edges or burrs which could be detrimental in the cable pulling effort (Hot-dip galvanized after fabrication steel cable tray maybe used.

Cable tray straight sections for low signal level will be composed of solid bottom hot dip galvanized after fabrication steel tray with a solid hot dip after fabrication steel cover.

Cable tray fittings and accessories, such as horizontal and vertical elbows, tees and splice plates will be dimensionally compatible with tray straight sections. The material will be compatible with straight sections.

NEMA cable tray designations and classifications shall be as required. Cable tray shall be provided with the following features:

- The usable inside depth of each tray shall not be less than four inches.
- Rung spacing shall not exceed nine inches.
- Cable tray hold down clamps as well as all other hardware and accessories shall be of the type and construction material to be compatible with the tray material.

Cable trays to be supported as per the latest NEMA VE-1 standard.

5.17.1 Cable Trays Systems Installation

Cable trays shall be installed either parallel with or perpendicular to structural members and shall be rigidly secured to hangers and supports as required by the NEMA VE-1 standard.

Cable tray supports shall be located per the NEMA VE-1 standard.

Vertical or horizontal cable tray fire stops shall be provided and installed where trays pass through walls or floors and when entering switchgear or other electrical apparatus and at other locations shown on the drawings.

Cables installed in vertical trays and racks shall be adequately supported for stress relief purposes employing drop out fittings or basket type cable supports where the vertical distance exceeds 50'.

The installation of all cable trays shall be properly coordinated with the work of other trades.

6.12.6 Hangers and Supports

Supports for individual exposed conduit raceways shall be galvanized or cadmium plated malleable iron, one-hole conduit clamps.

Supports for exposed conduit raceway groups or cable tray raceways shall be field fabricated racks, composed of structural steel shapes or field assembled, prefabricated galvanized hanging or supporting systems, including channels, hanger, clamps, spacers, etc. Prefabricated systems shall be utilized unless support loadings require field fabricated system.

Supporting steel for raceways and electrical apparatus where attached to structural steel shall be by approved welding attachment methods as shown on installation detail drawings.

Supporting steel where attached to concrete or masonry construction shall be by means of steel expansion anchors, through bolting or power tool driven inserts.

Where supporting steel penetrates building roofing or exterior sidewalls, all necessary flashing, gasketing and/or caulking shall be provided to affect a weathertight installation.

Finished surfaces of hanging and supporting material, whether galvanized or painted, which have been marred or removed through cutting for welding operations, shall be restored to original integrity to preclude the initiation and perpetration of corrosion deterioration.

All hanger rod attachment clamps (to building structural steel) must have J-hook safety beam clamps.

6.12.7 Cabinets and Enclosures

Cabinets and enclosures for electrical apparatus shall be essentially of formed sheet steel or cast aluminum constructions and shall be of the NEMA class design appropriate for the environmental location. Generally, enclosures shall be:

Outdoor or Wet Locations	NEMA 4X Stainless Steel
Corrosive Areas	NEMA 4X Stainless Steel
Indoor environmentally clean areas	NEMA 1
Indoor Areas	NEMA 12

Cabinets and enclosures shall be arranged for surface mounting, set true and plumb, and secured rigidly to supporting steel or building structures in accordance with installation detail drawings. Mounting heights from finished floors to center line of cabinets and enclosures shall be essentially as follows:

Motor Starters	5'-0"
Safety Switches	5'-0"
Control Accessories	4'-6"

Welding Receptacle	3'-6"
Lighting Panel boards	6'-0" (top)
Power Panel boards	7'-0" (top)
Lighting/Small Power Transformers	8'-6" (bottom) (wall mounting type)

6.12.8 Power Receptacles

Receptacles for welding machines or any other such portable apparatus shall be 60 amperes, three wire, three pole, 600 volts rated, units with enclosed circuit breaker disconnect.

6.12.9 Tags and Markers

Conduit tagging shall consist of brass tags embossed with conduit identification number and attached to the conduit with No. 14 AWG minimum, stainless-steel wire.

Cable tags shall consist of a vinyl tag computer printed with the cable identification number in indelible ink.

Markers for wire number identification shall be of the flame retardant, vinyl sleeve type with computer printed indelible markings.

6.12.10 Hardware

All hardware, such as expansion shields, machine screws, toggle bolts, "U" or "J" bolts, machine bolts and nuts, etc. required in conjunction with the electrical installation, shall be of cadmium plated or galvanized steel fabrication.

7 PROCESS CONTROLS ENGINEERING DESIGN CRITERIA

7.1 Engineering Design Criteria

7.1.1 Documentation

P&I Symbols & Identification:	VE Standard/ ISA S5.1-2009
P&I Diagram:	VE Standard/ ISA 5.1 implemented using AutoCAD PID.
Instrument Tag Numbering System:	ISA Style as follows.

AA-BBB-CCDD

Where AA = Area designation (Assigned by Process)
BBB = Standard ISA Functional Designation (PT, LSH, etc.)
CC = Last two digits of PID
DD = Sequential loop number per module (01 – 99)

Loop Sheets:	None
Instrumentation Specification Sheets:	Per ISA Standard S20.
Instrument Index:	Venture Standard (Excel format)
Installation Details:	None

7.1.2 Standards

The following standards will be references for the project:

- ANSI (pipe materials)
- ISA S5.1-2009
- ISA S5.2
- ISA S5.3
- ISA S5.5
- ISA S7.0.1/ ISO 8573-1
- ISA S20
- NEC (NFPA 70/70e)
- NEMA
- NFPA 79
- NFPA 496/497/499
- UL 508A
- UL/IEC 61131 et al

7.1.3 Customer Approval

Customer approval requirements will be per the project deliverables schedule.

7.2 Control System Hardware Selection

6.2.1 Field Instrumentation Criteria

Transmitters, general:

- Electronic 4-20mA DC
- Accuracy: ±0.25% or better

Preference for electronic instruments in Class I Division 2 areas is non-incendive.

Electronic instrumentation shall be factory calibrated and certificate supplied.

7.2.1.1 Flow

In general, orifice plates or other DP measuring devices shall be used for general purpose flow measurement for turndowns of 4:1 or less. Orifice plate design shall be per ASME MFC-3M. Integral/compact orifice shall be used for ½" to 1-1/2" pipe sizes. Flange taps shall be used for 1/2" to 6" pipe size. Radius taps shall be used for 8" and larger pipe size.

Magnetic, vortex, Coriolis, and other types may be used where orifice plates are not suitable, not accurate enough or do not have the required turndown.

Flow switches will be thermal.

Mass flow shall be done using a thermal dispersion style mass flow transmitter, direct mount w/ compression fitting or low DP insertion flow meter (Annubar or similar type) w/ multi-variable transmitter capable of providing an analog mass flow signal.

7.2.1.2 Level

Table 6.2.1.2.1 – Equipment Level Control Design

Application	Point level	Continuous
Tanks <1 psig	Float (internal) Magnetic flag/float	NA
Tanks/ Vessels, general	Float (internal) Magnetic flag/float	NA
Bins, solids	NA	NA
Open sumps	NA	NA

Switches shall be hermetically sealed (Div. 2 rated) or encased in explosion proof housing.

7.2.1.3 Pressure

No process chemical seals are required for any applications on this project.

Local indication shall be by gauge. Standard specification shall be glycerin-filled 4.5” dial, ASME B40.1 2A accuracy (±0.5%), FRP case, ½” bottom connection, black lettering on white face, stainless steel wetted parts unless noted otherwise on data sheets.

Separate ½” block and bleed valve shall be provided with instrument for all pressure gauges and transmitters. Provide snubber where vibration or pulsing is expected.

5-way manifold shall be provided for all DP transmitters.

7.2.1.4 Temperature

From -100°F to 1000°F RTD sensors will be used and shall meet BS 1904 Class A accuracy. Three wire sensors shall be used.

For temperatures above 1000°F, a thermocouple with suitable range/accuracy shall be used. Accuracy per ASTM E 230. Element shall be ungrounded.

All elements contacting process fluid shall be installed in thermowells with 3/4” NPT process connection, rating to suit process. Element length to suit installation. Elements shall be spring- loaded.

Temperature indicators: bi-metallic local gauge with 5” dial, ¼” stem, and ½” element connection.

Temperature transmitters will be mounted direct to elements when access is not an issue, otherwise remote electronics will be provided.

No infrared temperature measurement will be used.
Self-operated filled temperature control systems will not be used for this project. Temperature transmitters shall be used for control variables where higher signal resolution is needed; direct wired elements shall be used for indication only inputs.

7.2.1.5 Control Valves

In general, for modulating control, globe valves shall be used up to 1-1/2” pipe size, V-ball valves for 2” to 4”, and hi-performance butterfly or segmented V-ball for larger services. There will be exceptions for specific processes (plug valves, pinch valves, etc.) which will be identified on the specific valve data sheets.

Pneumatic spring & diaphragm or piston actuators shall be used for both linear valves and quarter turn valves. A heavy-duty scotch yoke style drive is preferred for quarter turn valves.

Actuators shall be designed for 70 psig minimum air supply and be able to withstand 100 psig maximum air pressure.

Current/pneumatic transducers are to be mounted: On the control valve, preferably integral with the positioner, and designed to accept up to 100 psig supply air, either directly or in conjunction with vendor supplied regulator.

Positioners shall be configured such that an increasing signal always opens the valve, regardless of failure position. This requires reverse action for fail open valves. Position feedback signal shall generally not be provided unless specifically noted.

Limit switches are required for critical on-off valves, to be determined by process. Due to area classification concerns, all switch packs shall use contacts suited for Class I Division 2 areas (hermetically sealed).

All tubing shall be 316 SS

On/off valves are to have high visibility position indicator (green = open, red = closed)

24 VDC solenoid coils shall be used.

7.3 Control Signal Criteria

Analog signals shall be:

- isolated 4-20mA DC. Single-ended,
- IO modules shall be used.
- For specific inputs isolators may be required, TBD during design.

Discrete signals (inputs and outputs) shall be 24 VDC. Control relays shall be used to provide 120VAC power when required.

Discrete contacts used for alarming shall OPEN on the alarm condition. Example: A low flow switch contact will open when the flow is below set point.

Discrete contacts indicating status shall close to indicate the desired condition. Example: A position switch will close when the position is reached. A local motor “In Remote” switch will close when the equipment is placed in remote operation.

All discrete outputs shall be individually fused.

In general, local motor control (Hand-Off-Remote) will be evaluated on a case-by-case basis. In general, motor status monitoring is: Running for each motor.

Software latching shall be used for motor run command.

7.4 Miscellaneous Criteria

7.4.1 Instrument Air Supply and Tubing

Instrument air supply pressure: 70 psig nominal

Instrument air quality: shall meet ISO 8573-1 Class 2.2.2 (particulates< 1µ/ particulate concentration <1 mg/m3/ -40°F dew point/ oil < 0.1 mg/m3).

Type by Area: 316 Stainless steel tubing drops, 1/2" minimum. Instrument air headers will be specified per piping system chart (Section 3.4).

7.4.2 Control Panel Construction

Control Panel Type in Control Rooms, MCC Rooms, or Other Environmentally Protected Spaces: NEMA 12, gasketed.

Control Panel Type Outside of Protected Spaces: NEMA 4 (general purpose areas), NEMA 7/9/4-purged (Class I Div 1 & 2). Preference will be Type 4 with area rated components and installation.

When required by ambient conditions, panel cooling will be provided by powered A/C units (120/240/480 VAC depending on load). Design interior temperature is 100°F.

Panel Nameplate Legend: Phenolic, white with black letters.

Freestanding panels are to be provided with 12" legs. Panels are to be designed for bottom or side conduit entry.

7.4.3 Electrical Classification

Class I, Division 2, Group C & D. See area classification maps.
Generally electrical instrumentation and panels in these areas shall comply with the area classification by using appropriate enclosures/construction, purging, or intrinsic safety as listed below. Hermetically sealed switch contacts are preferred for discrete signals.

Using Division 2 ratings in order of preference:

- Area rated components
- Non-incendive
- Z-purge
- Explosion proof construction
- Intrinsic safety

Class I, Division 1, Group C & D. See area classification maps.

Electrical installations in Division 1 areas will be avoided due to the extra cost and risk.

When required electrical instrumentation and panels in these areas shall comply with the area classification by using appropriate enclosures/construction, purging, or intrinsic safety as listed below.

Using Division 1 ratings:

- Explosion proof construction
- Intrinsic safety
- X-purge

7.5 HMI, PLC and I/O

7.5.1 Plant PLC

The Plant PLC will be used for control of any auxiliary instruments not being controlled by one of the packaged skid units. Venture will provide as part of the Plant PLC system, an Allen-Bradley PLC with logic for the Plant control and ties to the Rockwell Site Edition (SE) HMI system. Factory Talk Historian shall be used for collecting data from the plant.

The Digester Gas Pressure Boosting System, Feed Gas Compression Systems, Membrane System, Product Gas Compression System, RNG Plant Flare, and TOU will all contain local PLC panels with on-board I/O prewired.

The Plant PLC will be located in the MCC Room. The VFDs shall contain connectivity for monitoring in the Plant HMI and to allow configuration across the network. VFD control signals shall be hardwired (run/stop/speed reference).

No redundancy is planned for any of the PLCs on this project.

Skid PLCs

For skids being supplied with on-board control, Allen-Bradley PLCs are specified with local HMI. The I/O will reside within the skid PLC and wire to local instruments and starters and VFDs either local or within the MCC room. A minimum of 20% spare will be required of each I/O card type.

Panel mounted E-Stops will be provide as part of the local I/O or PLC panel. This E-Stop will only shut down the equipment associated with the button. Plant E-Stops will be mounted near Exit doors to shut down the entire system. Equipment suppliers will provide a contact into their E-Stop String for the functionality and an auxiliary contact for the equipment in the MCC Room.

7.5.2 HMI System

The Plant HMI system will be set up in a Client/Server basis such that workstations may be set up at strategic areas of the plant and the screens will look consistent throughout.

On-board HMIs will be used for local maintenance functions. Area workstations will be considered as the detail design develops.

The following conventions will be followed on both the plant and local HMIs:

- HMI screens will be designated with Green is Running (Motor), Grey is Stopped and Red is Faulted.
- Valves will be designated as Green is Opened, Grey is Closed and Red is Faulted.
- Alarms will be set up in ALMD and ALMA format, which provides messaging within the PLC logic.
- Equipment suppliers will provide their screens and alarms with tag names for importing into the Control Room HMI Server.
- Hand/Off/Auto selection will be provided on a case-by-case basis as reflected on the PID Diagram.

7.6 Camera Systems

No camera system is planned at this time.

7.7 Auto-dialer System

No Auto-dialer System is planned at this time.

7.8 Area Gas Monitor System with Horns and Beacons

Area gas monitoring will be tied into the fire alarm control panel (FACP) that will be designed by a third party.

Horns and beacons shall be wired from the controllers and be located on the inside and outside of the buildings. High-High alarm points shall be wired to the BOP PLC to initiate a "Process Control Stop".

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Engineering & Construction

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ATTACHMENT 1

Example Biomass Analysis

Conti Testing Laboratories, Inc.
PO Box 174
Bethel Park, PA 15102
412-833-7766 (o), 412-854-0373 (f)
contilab@contitesting.com
PA DEP Reg 02-869,WV DEP 121103608, WDBE 12013,WBENC 2005128964

CTL ID	213040
Received	2/13/2017
Sampled by	client
PO	4500883548

Sample ID **Greenway Alternative Fuel #614 2/06/17 11:30am Load # 111681**

ANALYSIS

	As Received	Dry	MAF	ASTM Method
Moisture	9.91			D2961/ 3173
Ash	1.32	1.47		D 3174
Btu/lb (HHV)	9,469	10,511	10,667	D 5865
Chlorine(wt.%)	0.04	0.04		D4208/ISE
Sulfur (wt.%)	0.04	0.04		D 4239

	Dry Ash	Dry Btu	Dry Cl	Extra Btu	Extra Cl
Run 1	1.53	10,468	0.05		
Run 2	1.38	10,294	0.04		
Run 3	1.50	10,771	0.03		
Avg	1.47	10,511	0.04		

Approved by: *P.Conti Otroba,Chemist*
Laboratory Director

Conti Testing Laboratories, Inc.
PO Box 174
Bethel Park, PA 15102
412-833-7766 (o), 412-854-0373 (f)
contilab@contitesting.com
PA DEP Reg 02-869,WV DEP 121103608, WDBE 12013,WBENC 2005128964

CTL ID	213041
Received	2/13/2017
Sampled by	client
PO	4500883548

Sample ID **Greenway Alternative Fuel #614 2/07/17 7:30am Load # 112010**

ANALYSIS

	As Received	Dry	MAF	ASTM Method
Moisture	16.79			D2961/ 3173
Ash	2.27	2.72		D 3174
Btu/lb (HHV)	8,272	9,941	10,220	D 5865
Chlorine(wt.%)	0.12	0.14		D4208/ISE
Sulfur (wt.%)	0.06	0.08		D 4239

Note: 4th run of btu resulted in heat value over 19K with explosion
something very reactive was present in sample

	Dry Ash	Dry Btu	Dry Cl	Extra Btu	Extra Cl
Run 1	2.73	9,945	0.05		
Run 2		9,466	0.06		
Run 3	2.72	9,594	0.32		
Avg	2.72	9,668	0.14		

Approved by: *P.Conti Otroba,Chemist*
Laboratory Director

Conti Testing Laboratories, Inc.
PO Box 174
Bethel Park, PA 15102
412-833-7766 (o), 412-854-0373 (f)
contilab@contitesting.com
PA DEP Reg 02-869,WV DEP 121103608, WDBE 12013,WBENC 2005128964

CTL ID	213042
Received	2/13/2017
Sampled by	client
PO	4500883548

Sample ID **Greenway Alternative Fuel #614 2/08/17 Load # 112089**

ANALYSIS

	As Received	Dry	MAF	ASTM Method
Moisture	17.14			D2961/ 3173
Ash	1.38	1.67		D 3174
Btu/lb (HHV)	8,682	10,478	10,655	D 5865
Chlorine(wt.%)	0.46	0.55		D4208/ISE
Sulfur (wt.%)	0.07	0.09		D 4239

	Dry Ash	Dry Btu	Dry Cl	Extra Btu	Extra Cl
Run 1	1.61	10,321	0.64		
Run 2	1.72	10,220	0.38		
Run 3		10,891	0.64		
Avg	1.67	10,478	0.55		

Approved by: *P.Conti Otroba,Chemist*
Laboratory Director

Conti Testing Laboratories, Inc.
PO Box 174
Bethel Park, PA 15102
412-833-7766 (o), 412-854-0373 (f)
contilab@contitesting.com
PA DEP Reg 02-869,WV DEP 121103608, WDBE 12013,WBENC 2005128964

CTL ID	213043
Received	2/13/2017
Sampled by	client
PO	4500883548

Sample ID **Greenway Alternative Fuel #624 2/09/17 Load # 112195**

ANALYSIS

	As Received	Dry	MAF	ASTM Method
Moisture	17.19			D2961/ 3173
Ash	2.00	2.41		D 3174
Btu/lb (HHV)	9,340	11,279	11,558	D 5865
Chlorine(wt.%)	0.07	0.08		D4208/ISE
Sulfur (wt.%)	0.06	0.07		D 4239

	Dry Ash	Dry Btu	Dry Cl	Extra Btu	Extra Cl
Run 1	2.48	11,196	0.14		
Run 2	2.39	11,308	0.06		
Run 3	2.37	11,333	0.05		
Avg	2.41	11,279	0.08		

Approved by: P.Conti Otroba,Chemist
Laboratory Director

Conti Testing Laboratories, Inc.
PO Box 174
Bethel Park, PA 15102
412-833-7766 (o), 412-854-0373 (f)
contilab@contitesting.com
PA DEP Reg 02-869,WV DEP 121103608, WDBE 12013,WBENC 2005128964

CTL ID	213084
Received	2/13/2017
Sampled by	client
PO	4500883548

Sample ID **Greenway Alternative Fuel Comp. (2/6,7,8,9/17)**

614	2/6/2017	11:30 AM	111681
614	2/7/2017	7:30 AM	112010
614	2/8/2017		112089
624	2/9/2017		112195

ANALYSIS

	As Received	Dry	MAF	ASTM Method
Moisture	14.69			D2961/ 3173
Ash	1.85	2.16		D 3174
Btu/lb (HHV)	8,972	10,517	10,749	D 5865
Chlorine(wt.%)	0.07	0.09		D4208/ISE
Sulfur (wt.%)	0.06	0.07		D 4239

	Dry Ash	Dry Btu	Dry Cl	Extra Btu	Extra Cl
Run 1	2.16	10,100	0.06	10,364	
Run 2	2.15	10,794	0.07	10,548	
Run 3	2.18	10,778	0.13		
Avg	2.16	10,517	0.09		

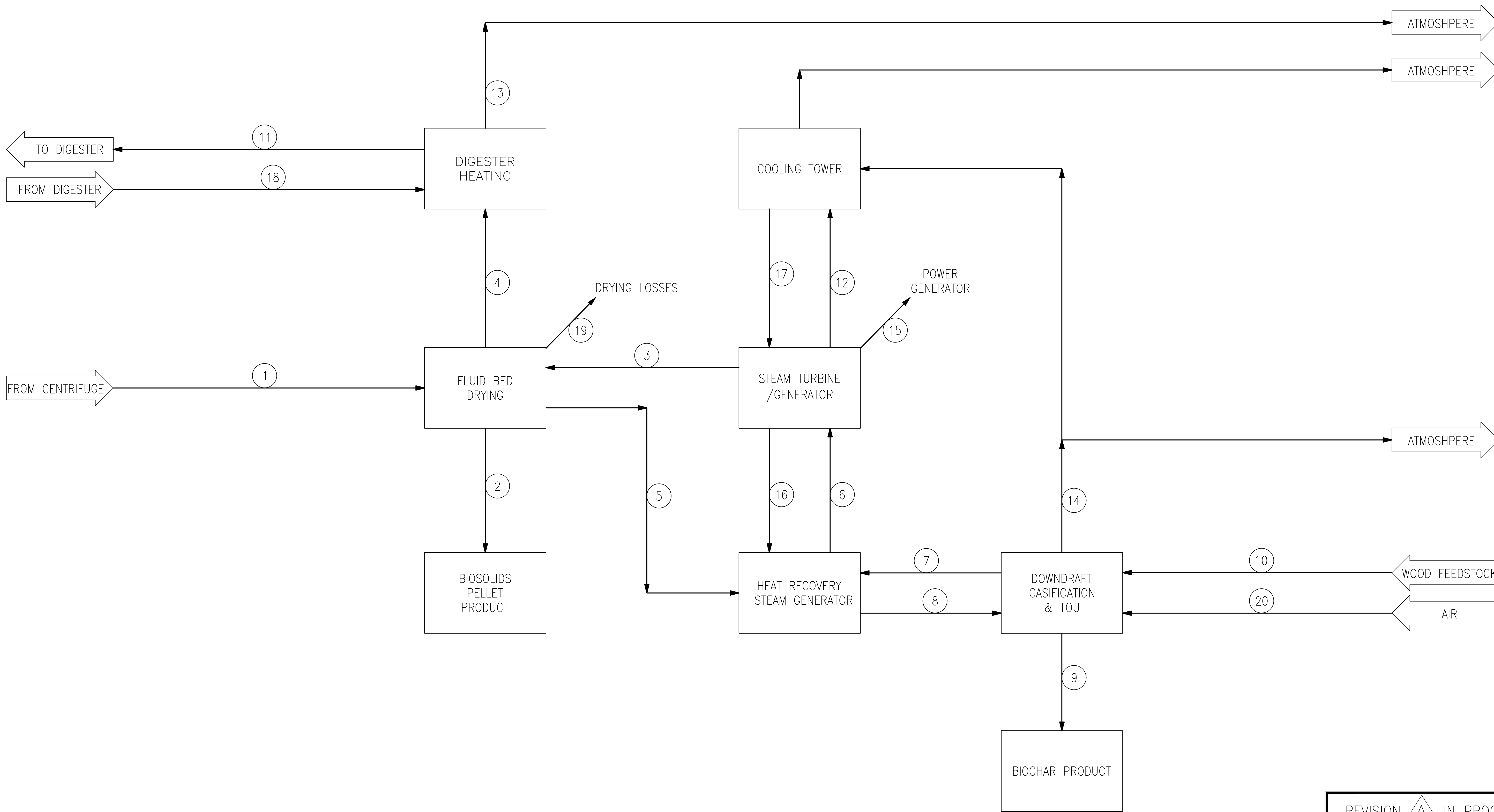
Approved by: *P.Conti Otroba,Chemist*
Laboratory Director

ATTACHMENT 2

Conceptual BFD, PFDs and M&E

BFD-0001

— OPTION C —



REVISION A IN PROGRESS

CONCEPTUAL

— OPTION C —

VENTURE

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE	NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
					A	CONCEPTUAL	WBS PV	PV	

DESIGNED/DWN BY	WBS	DATE	04/26/2022
CHK.D BY	PV	DATE	–
CHKD. BY ENGR	PV	DATE	–
APPRVD. BY PM	–	DATE	–
APPRVD. BY MANAGER OF ENGR.	–	DATE	–
SCALE	–		

Venture Engineering & Construction, Inc.

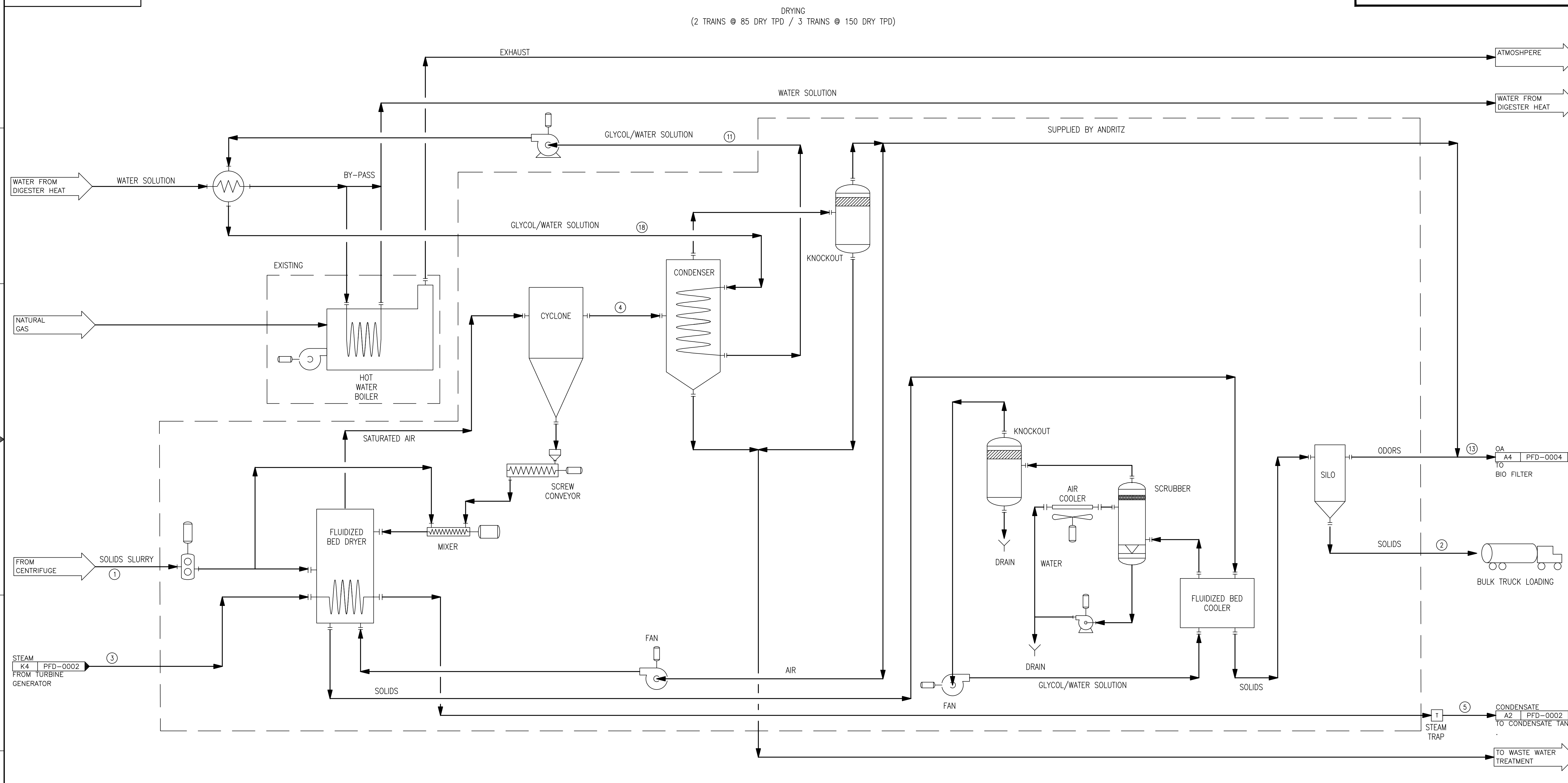
CONTRACT P22-3014-00 Pittsburgh, PA

LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPTION C
BLOCK FLOW DIAGRAM

DRAWING NUMBER BFD-0001 REV. A

— OPTION C —



REVISION A IN PROGRESS

CONCEPTUAL

NOTES:
1. ACTUAL CONFIGURATION OF EQUIPMENT SUBJECT TO CHANGE BASED UPON AGREED PROCESS, ASSOCIATED MODELING AND ENGINEERING ANALYSIS.

— OPTION C —

VENTURE

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE	NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
					A	CONCEPTUAL			

DESIGNED/DWN BY	WBS	DATE	4/18/2022
CHK.D BY	DO/PV	DATE	4/18/2022
CHKD. BY ENGR	DO/PV	DATE	4/18/2022
APPRVD. BY PM	–	DATE	–
APPRVD. BY MANAGER OF ENGR.	–	DATE	–
SCALE	–		

Venture Engineering & Construction, Inc.

CONTRACT P22-3014-00 Pittsburgh, PA

LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPT C – KING CO. BIOSOLIDS DRYING AND NG STEAM PROD.
PROCESS FLOW DIAGRAM

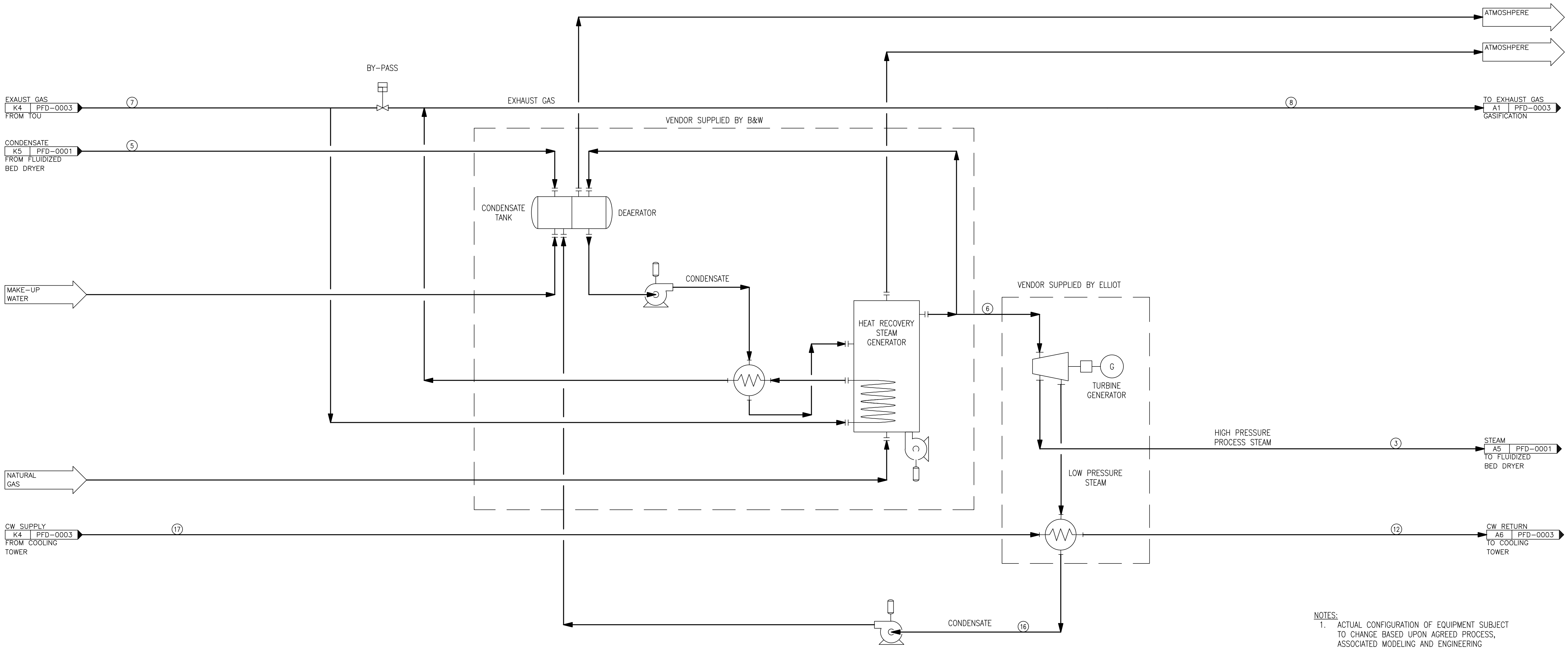
DRAWING NUMBER PFD-0001

REV. A

PFD-0002

— OPTION C —

STEAM/POWER
(1 HRSG TRAIN BOTH CASES)
(1 6MW TURBINE-GENERATOR BOTH CASES)



NOTES:
1. ACTUAL CONFIGURATION OF EQUIPMENT SUBJECT TO CHANGE BASED UPON AGREED PROCESS, ASSOCIATED MODELING AND ENGINEERING ANALYSIS.

REVISION A IN PROGRESS

CONCEPTUAL

— OPTION C —

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE	NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
					A	CONCEPTUAL			

DESIGNED/DWN BY	WBS	DATE	4/18/2022
CHK.D BY	DO/PV	DATE	4/18/2022
CHKD. BY ENGR	DO/PV	DATE	4/18/2022
APPRVD. BY PM	–	DATE	–
APPRVD. BY MANAGER OF ENGR.	–	DATE	–
SCALE	–		

VENTURE

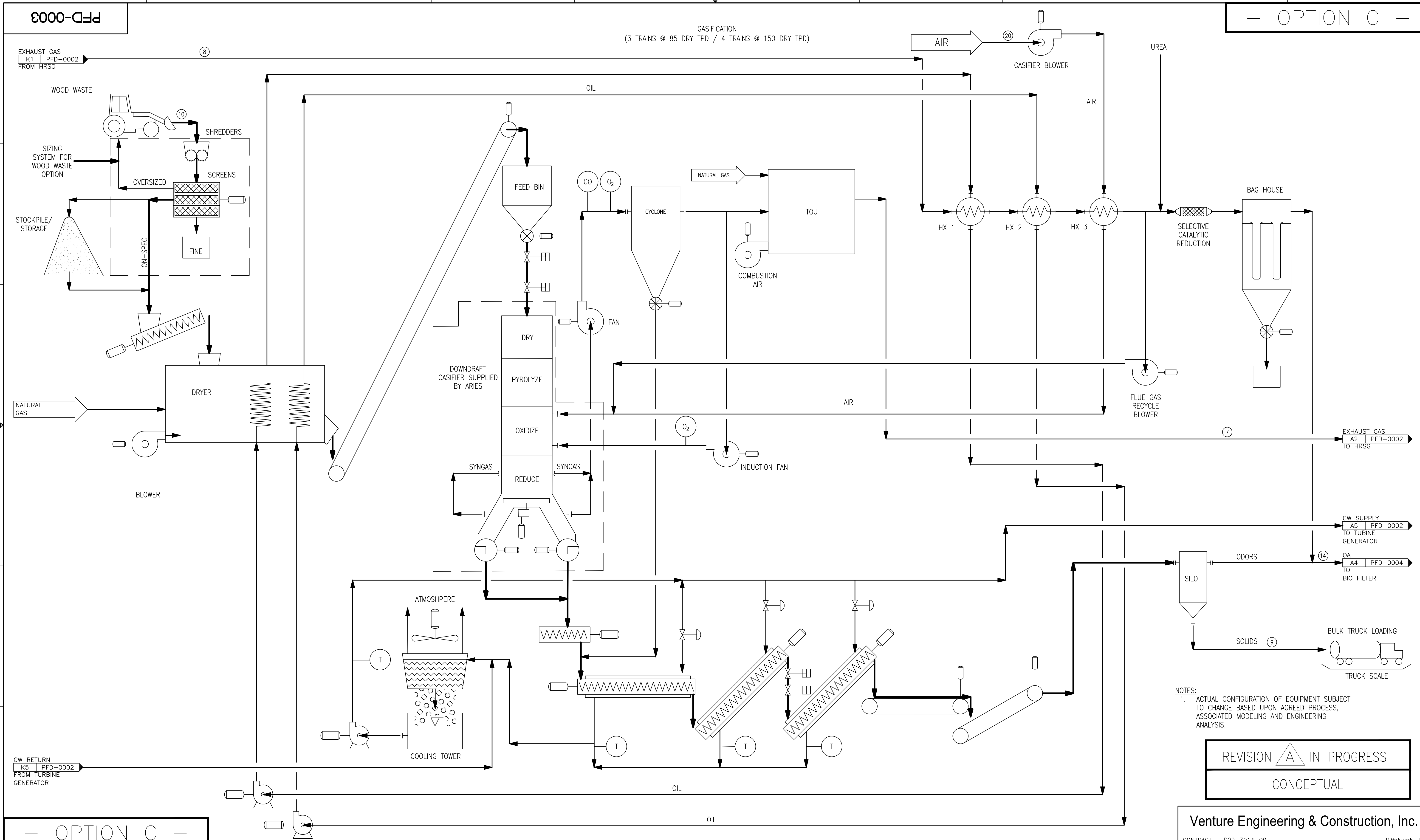
Venture Engineering & Construction, Inc.

CONTRACT P22-3014-00 Pittsburgh, PA

LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPT. C – KING CO. BIOSOLIDS DRYING AND WOOD GASIFICATION
PROCESS FLOW DIAGRAM

DRAWING NUMBER PFD-0002 REV. A



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CONTRACT P22-3014-00 Pittsburgh, PA

VENTURE

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE	NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
					A	CONCEPTUAL			

DESIGNED/DWN BY	WBS	DATE 4/18/2022
CHK.D BY	DO/PV	DATE 4/18/2022
CHKD. BY ENGR	DO/PV	DATE 4/18/2022
APPRVD. BY PM	–	DATE –
APPRVD. BY MANAGER OF ENGR.	–	DATE –
SCALE	–	

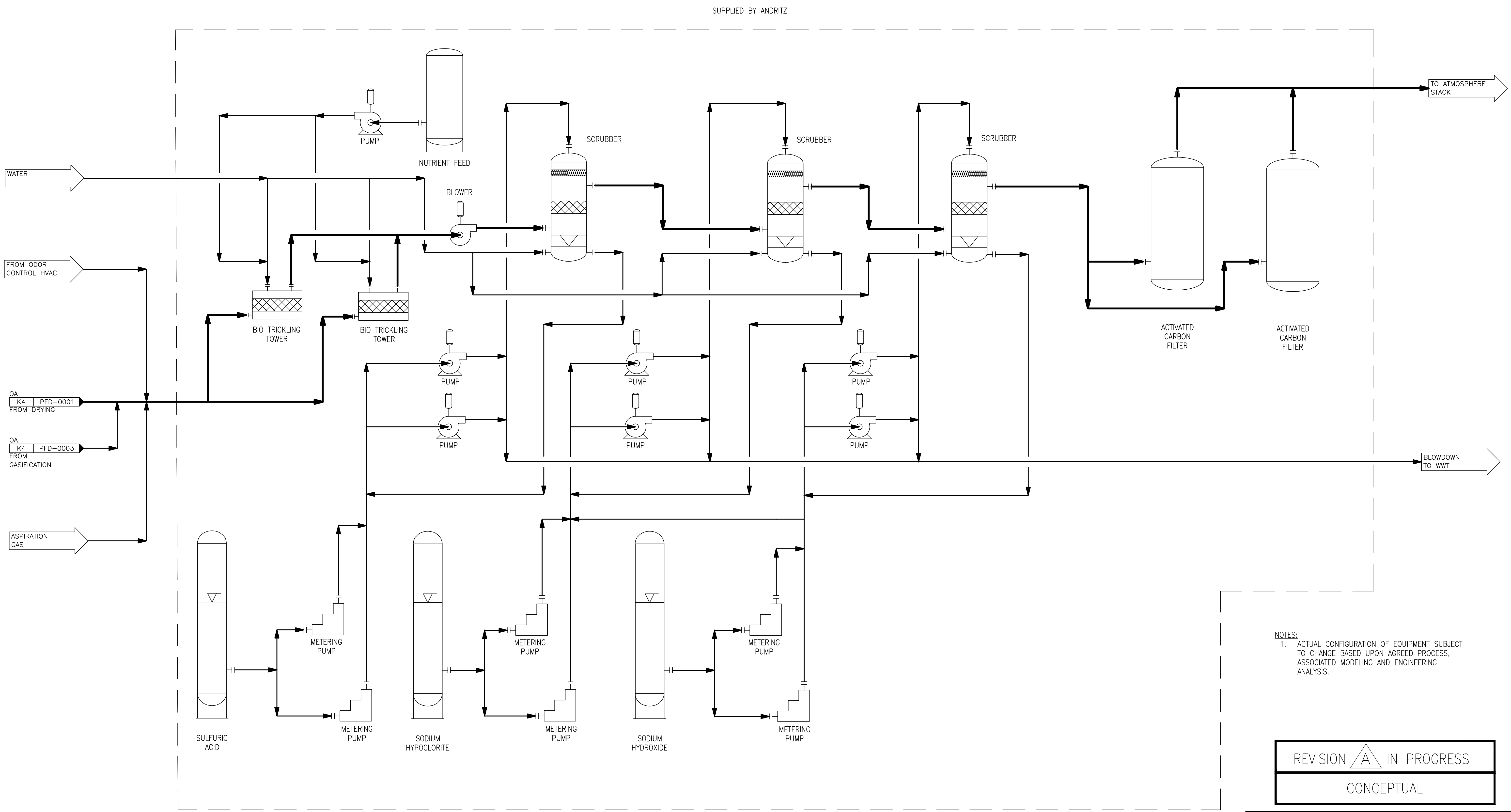
LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPTION C – GASIFICATION SYSTEM
PROCESS FLOW DIAGRAM

DRAWING NUMBER PFD-0003

REV. A

— OPTION C —



NOTES:
1. ACTUAL CONFIGURATION OF EQUIPMENT SUBJECT TO CHANGE BASED UPON AGREED PROCESS, ASSOCIATED MODELING AND ENGINEERING ANALYSIS.

REVISION A IN PROGRESS

CONCEPTUAL

— OPTION C —

Venture Engineering & Construction, Inc.

CONTRACT P22-3014-00 Pittsburgh, PA

VENTURE

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE	NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
					A	PRELIMINARY			

DESIGNED/DWN BY	WBS	DATE	4/18/2022
CHK.D BY	DO/PV	DATE	4/18/2022
CHKD. BY ENGR	DO/PV	DATE	4/18/2022
APPRVD. BY PM	–	DATE	–
APPRVD. BY MANAGER OF ENGR.	–	DATE	–
SCALE	–		

LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPTION C – ODOR CONTROL
PROCESS FLOW DIAGRAM

DRAWING NUMBER PFD-0004 REV. A

PFD-0005

— OPTION C —

Case: 85 dry ton/day @ 20%wt H2O inlet feed; winter conditions; 2 fluid bed dryers, 3 downdraft gasifiers

Stream No.	1	2	3	4	5	6	7	8	9	10
Stream Name	Centrifuge Sludge to Andritz Fluidized Bed Dryer	Product Dried Pellets	Turbine Extraction Steam to Andritz Fluidized Bed Dryer	Andritz FBD Exhaust Heat to Digester Hot Water Heating	Fluid Bed Drying Condensate Return to HRSG	Steam to Turbine/Generator	Thermally Oxidized Biogas (Syngas) to HRSG	Thermally Oxidized Biogas (Syngas) Return to Gasification	Product Biochar (post cooling)	Wood Feed Biomass to Gasification (pre-drying)
Temp F	75	< 104	388	185	388	489	1,800	900	125	Ambient
Pres psia	15	15	215	15	215	615	Undet	Undet	15	15
Pres psig	0	0	200	0.5	200	600	Undet	Undet	0	0
BTU/scf	-	-	560	44	-	1,626	131	62	-	-
BTU/lb	900	4,275	1,199	1,140	362	1,203	2,450	1,021	11,851	8,947
MMBtu/h	31.9	31.9	58.2	31.9	17.6	96.9	116.1	48.4	34.0	201.6
Moisture %wt.	80	5	100	100	100	100	Undet	Undet	0	15
Total Solids %wt.	20	95	0	0	0	0	0	0	100	85
Vapor mole frac.	0	0	1	1	0	1	1	1	0	0
Total lb/h	35,417	7,456	48,555	27,961	48,555	80,540	47,388	47,388	2,869	22,538
Total std L gpm	Undet	-	-	-	97	-	-	-	-	-
Total std V cfm	-	-	1,732	12,116	-	993	12,963	12,963	-	-
Total std W wet tons/day	425	89	-	-	-	-	-	-	34	270
Total std W dry tons/day	85	85	-	-	-	-	-	-	34	230
Particulate Size (in)	< 0.38	-	-	-	-	-	-	-	-	0.25 - 4 (nonuniform)
Power MW	-	-	-	-	-	-	-	-	-	-

Stream No.	11	12	13	14	15	16	17	18	19	20
Stream Name	Hot Water to Digester Heating	Condensing Water to Cooling Tower	Fluid Bed Drying Exhaust & Thermal Losses to Cooling and Odor Control then to ATM	Combined Gasification Exhaust to Cooling and Odor Control then to ATM & Cooling Tower to ATM	Parasitic Load Power Generation	Steam Turbine Condensate Return to HRSG	Cooling Water Supply to Steam Turbine Condenser	Water Return from Digester	Fluid Bed Drying Thermal Losses	Air to Gasification
Temp F	140	110	140	Multiple	-	388	65	70	-	-
Pres psia	Undet	Undet	Undet	Undet	-	215	Undet	Undet	-	-
Pres psig	Undet	Undet	Undet	Undet	-	200	Undet	Undet	-	-
BTU/scf	-	-	571	128	-	-	-	-	-	-
BTU/lb	108	40	763	2,108	-	362	28	38	-	-
MMBtu/h	16.2	1.0	21.3	99.9	26.8	11.6	0.7	5.7	8.7	-
Moisture %wt.	100	100	0	0	-	100	100	100	-	-
Total Solids %wt.	0	0	-	-	-	0	0	0	-	-
Vapor mole frac.	0	0	-	-	-	0	0	0	-	-
Total lb/h	150,000	24,990	27,961	47,388	-	31,985	24,990	150,000	-	27,719
Total std L gpm	300	50	-	-	-	64	50	300	-	-
Total std V cfm	-	-	621	12,963	-	-	-	-	-	604
Total std W wet tons/day	-	-	-	-	-	-	-	-	-	-
Total std W dry tons/day	-	-	-	-	-	-	-	-	-	-
Particulate Size (in)	-	-	-	-	-	-	-	-	-	-
Power MW	-	-	-	-	5.1	-	-	-	-	-

REVISION C IN PROGRESS

CONCEPTUAL

— OPTION C —

Venture Engineering & Construction, Inc.

CONTRACT P22-3014-00 Pittsburgh, PA

VENTURE™

NO.	REVISION	DWN.	CHK.	ENG.	PM.	DATE
C	UPDATED DRAFT PER REVISED WOOD FEEDSTOCK ANALYSIS – REVERT TO DOWNDRAFT GASIFICATION	WBS	DO	PV		4/25/2022
B	UPDATED DRAFT PER REVISED WOOD FEEDSTOCK ANALYSIS – CHANGE TO FLUID BED GASIFICATION	WBS	DO	PV		4/14/2022
A	DRAFT	WBS	DO	PV		4/22/2022

DESIGNED/DWN BY WBS DATE 4/27/2022
CHK.D BY DO DATE –
CHKD. BY ENGR PV DATE –
APPRVD. BY PM – DATE –
APPRVD. BY MANAGER OF ENGR. – DATE –
SCALE –

LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPTION C – MASS AND ENERGY BALANCE
–

DRAWING NUMBER PFD-0005 REV. C

PFD-0006

— OPTION C —

Case: 150 dry ton/day @ 20%wt H2O inlet feed; winter conditions; 3 fluid bed dryers, 4 downdraft gasifiers

Stream No.	1	2	3	4	5	6	7	8	9	10
Stream Name	Centrifuge Sludge to Andritz Fluidized Bed Dryer	Product Dried Pellets	Turbine Extraction Steam to Andritz Fluidized Bed Dryer	Andritz FBD Exhaust Heat to Digester Hot Water Heating	Fluid Bed Drying Condensate Return to HRSG	Steam to Turbine/Generator	Thermally Oxidized Biogas (Syngas) to HRSG	Thermally Oxidized Biogas (Syngas) Return to Gasification	Product Biochar (post cooling)	Wood Biomass to Gasification (pre-drying)
Temp F	75	< 104	388	185	388	489	1,800	900	125	Ambient
Pres psia	15	15	215	15	215	615	Undet	Undet	15	15
Pres psig	0	0	200	0.5	200	600	Undet	Undet	0	0
BTU/cf	-	-	560	44	-	1,626	131	52	-	-
BTU/lb	900	4,275	1,199	1,140	362	1,203	2,450	847	11,851	8,947
MMBtu/h	56.3	56.3	102.7	56.3	31.0	145.0	154.8	53.5	45.3	268.9
Moisture %wt.	80	5	100	100	100	100	Undet	Undet	0	15
Total Solids %wt.	20	95	0	0	0	0	0	0	100	85
Vapor mole frac.	0	0	1	1	0	1	1	1	0	0
Total lb/h	62,500	13,158	85,685	49,342	85,685	120,493	63,184	63,184	3,825	30,051
Total std L gpm	Undet	-	-	-	171	-	-	-	-	-
Total std V cfm	-	-	3,056	21,382	-	1,486	17,284	17,284	-	-
Total std W wet tons/day	750	158	-	-	-	-	-	-	46	361
Total std W dry tons/day	150	150	-	-	-	-	-	-	46	306
Particulate Size (in)	< 0.38	-	-	-	-	-	-	-	-	0.25 - 4 (nonuniform)
Power MW	-	-	-	-	-	-	-	-	-	-

Stream No.	11	12	13	14	15	16	17	18	19	20
Stream Name	Hot Water Boiler System Heating Water	Condensing Water to Cooling Tower	Fluid Bed Drying Exhaust & Thermal Losses to Cooling and Odor Control then to ATM	Combined Gasification Exhaust to Cooling and Odor Control then to ATM & Cooling Tower to ATM	Parasitic Load Power Generation	Steam Turbine Condensate Return to HRSG	Cooling Water Supply to Steam Turbine Condenser	Water Return from Digester	Fluid Bed Drying Thermal Losses	Air to Gasification
Temp F	140	110	140	Multiple	-	388	65	70	-	-
Pres psia	Undet	Undet	Undet	Undet	-	215	Undet	Undet	-	-
Pres psig	Undet	Undet	Undet	Undet	-	200	Undet	Undet	-	-
BTU/cf	-	-	695	118	-	-	-	-	-	-
BTU/lb	108	40	927	1,934	-	362	28	38	-	-
MMBtu/h	16.2	1.0	45.7	122.2	29.1	12.6	0.7	5.7	15.4	-
Moisture %wt.	100	100	0	0	-	100	100	100	-	-
Total Solids %wt.	0	0	-	-	-	0	0	0	-	-
Vapor mole frac.	0	0	-	-	-	0	0	0	-	-
Total lb/h	150,000	24,990	49,342	63,184	-	34,808	24,990	150,000	-	36,958
Total std L gpm	300	50	-	-	-	70	50	300	-	-
Total std V cfm	-	-	1,096	17,284	-	-	-	-	-	805
Total std W wet tons/day	-	-	-	-	-	-	-	-	-	-
Total std W dry tons/day	-	-	-	-	-	-	-	-	-	-
Particulate Size (in)	-	-	-	-	-	-	-	-	-	-
Power MW	-	-	-	-	5.55	-	-	-	-	-

REVISION C IN PROGRESS

CONCEPTUAL

— OPTION C —

VENTURE

NO.	REVISION	DWN. CHK.	ENG. PM.	DATE
C	UPDATED DRAFT PER REVISED WOOD FEEDSTOCK ANALYSIS – REVERT TO DOWNDRAFT GASIFICATION	WBS DO	PV	04/25/2022
B	UPDATED DRAFT PER REVISED WOOD FEEDSTOCK ANALYSIS – CHANGE TO FLUID BED GASIFICATION	WBS DO	PV	04/14/2022
A	DRAFT	WBS DO	PV	04/04/2022

DESIGNED/DWN BY WBS DATE 04/27/2022
CHK.D BY DO DATE
CHKD. BY ENGR PV DATE –
APPRVD. BY PM – DATE –
APPRVD. BY MANAGER OF ENGR. – DATE –
SCALE –

Venture Engineering & Construction, Inc.
CONTRACT P22-3014-00 Pittsburgh, PA

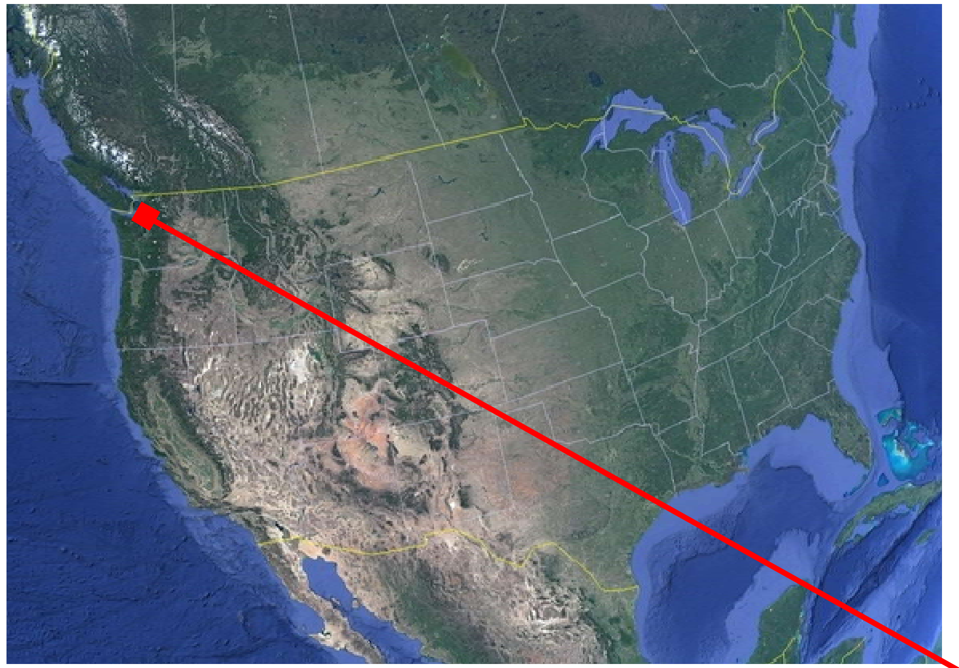
LYNAM
KING COUNTY, WA

LYNAM – KING COUNTY
WASTE WATER TREATMENT PLANT
OPTION C – MASS & ENERGY BALANCE
–

DRAWING NUMBER PFD-0006 REV. C

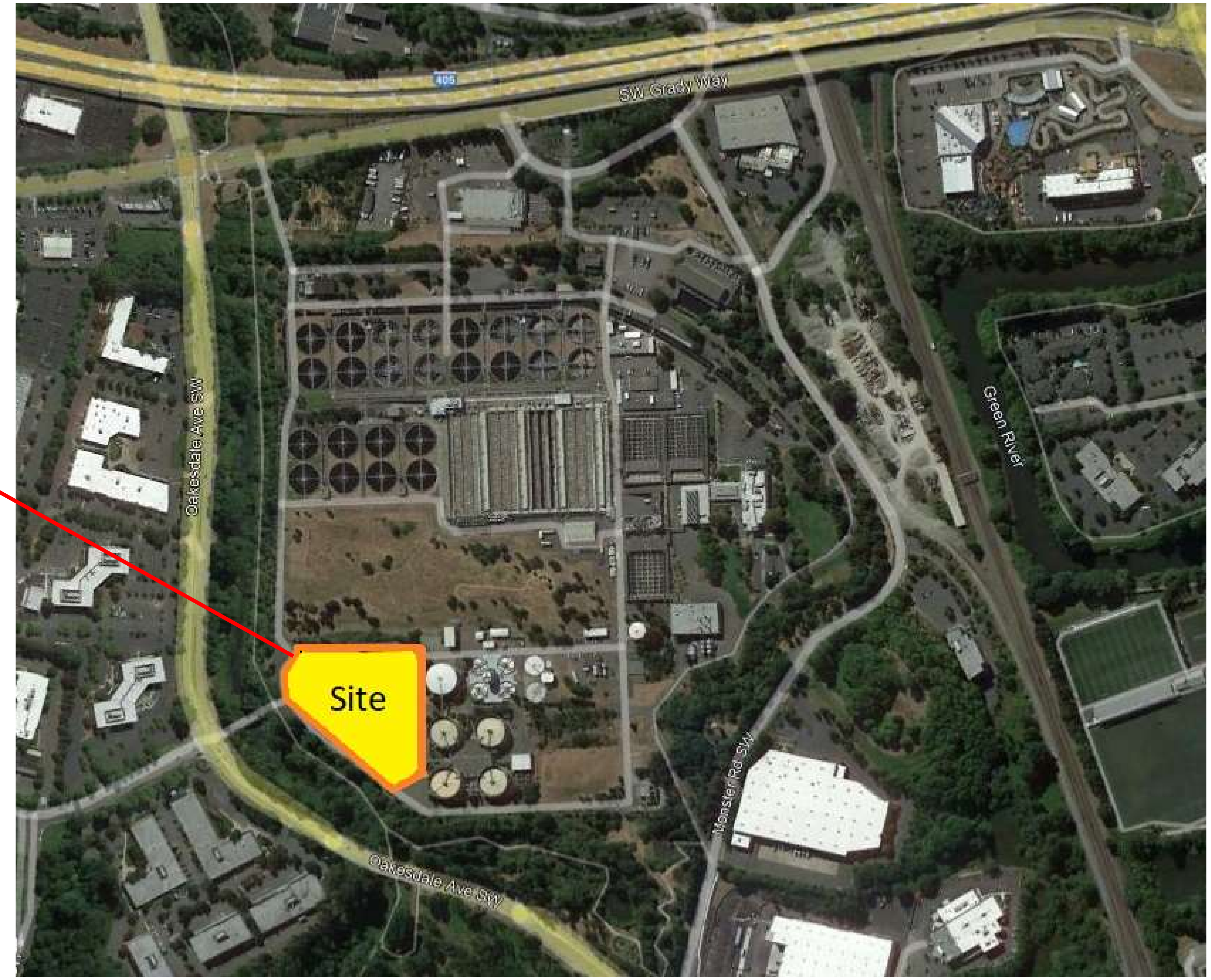
ATTACHMENT 3

Project Conceptual Layouts



Location:
King County Washington, USA

Address:
1200 Monster Rd SW, Renton, WA 98057



King County South Treatment Plant

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

01

A

Existing Condition of Site

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 02

Aerial View of Proposed Site

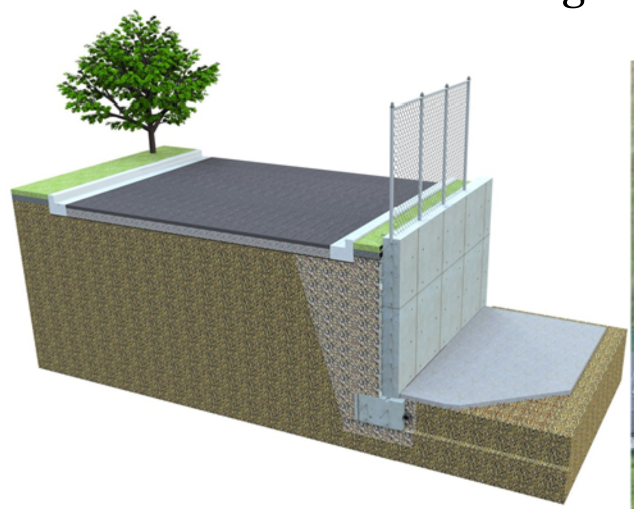
King County Biosolids Partnership Renewable Energy	Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 03

Section view of new retaining wall and road.



Aerial View of Front Elevation

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

04

A

Wet Sludge Receiving Storage and Odor Scrubbing Room

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 05

Dryer Building - Wet Sludge Receiving

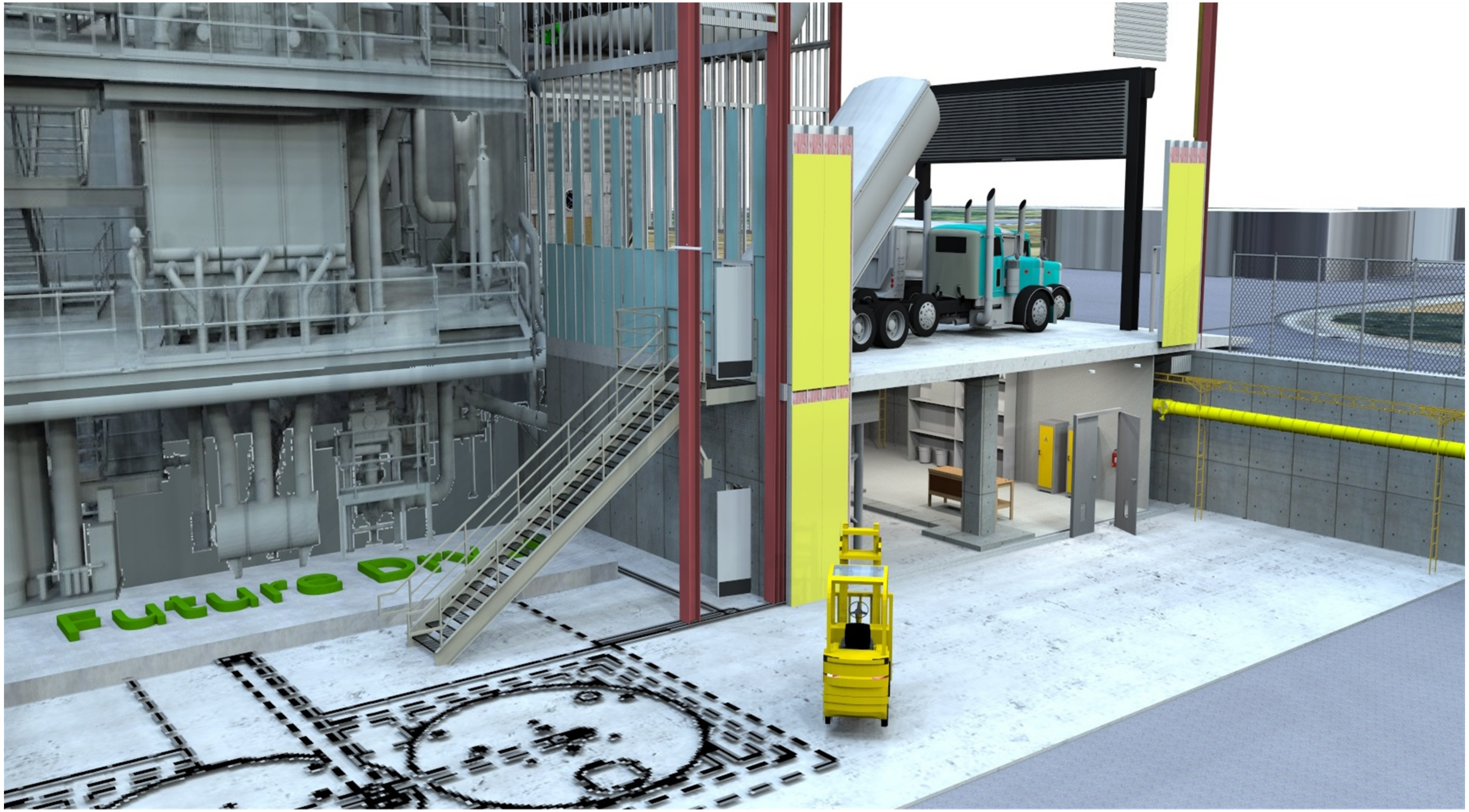
King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 06



Dryer Building - Northeast Corner Layout

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Layout

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	... REV SK-042922.15
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 07

Site Location

King County Biosolids Partnership
Renewable Energy

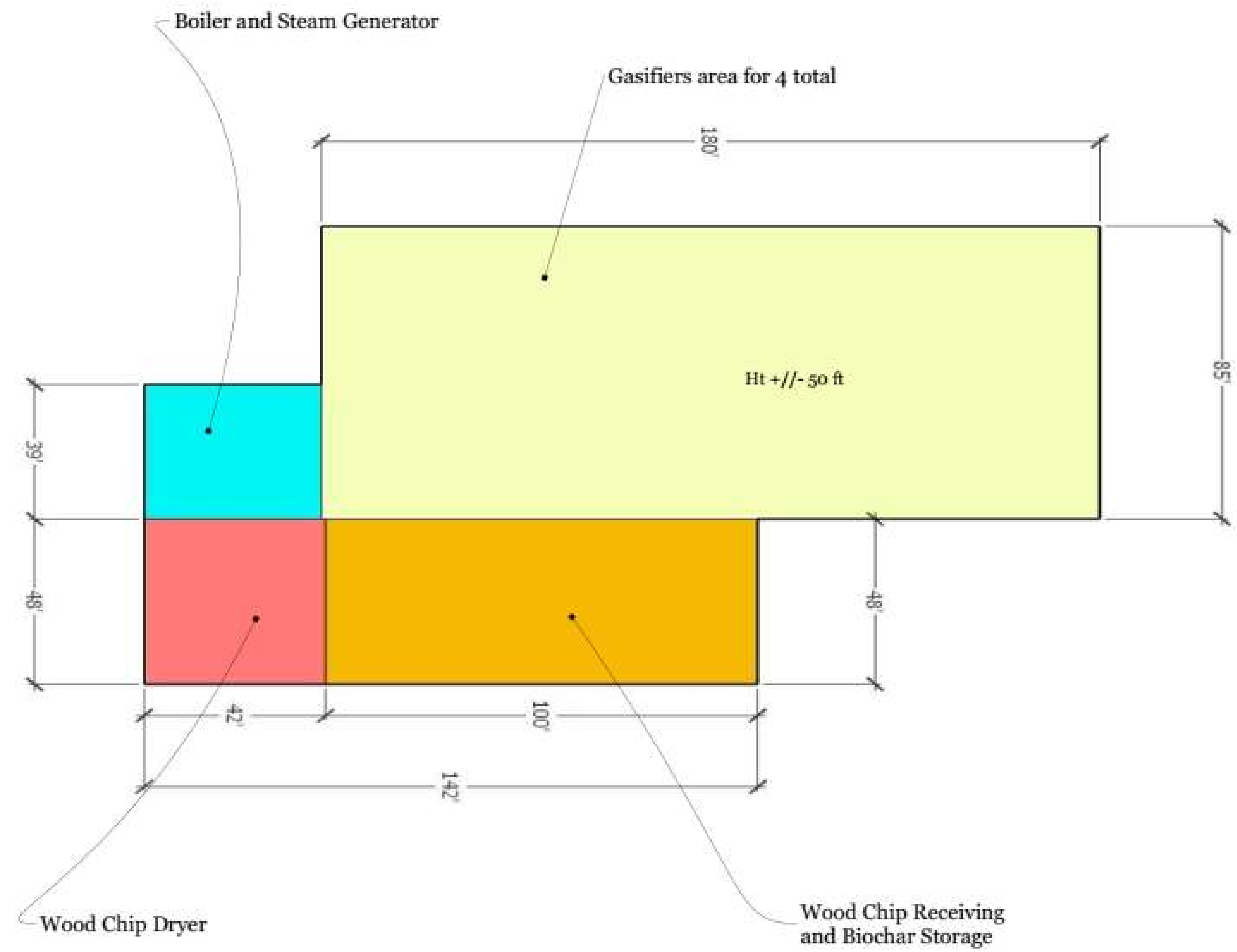
Conceptual Facility Revised Gasification Bld Layout-

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

08

A



Dimension Location

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Revised Gasification Bld Layout-

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 09

Looking East

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Revised Gasification Bld Layout-

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

A 10

Looking West

King County Biosolids Partnership
Renewable Energy

Conceptual Facility Revised Gasification Bld Layout-

REVISIONS

	MM/DD/YY	REMARKS
1	03-11-2022	...P. Lynam SK-031122.01
2	04-29-22	...
3	__/__/__	...
4	__/__/__	...
5	__/__/__	...

11
A

VENTURE™
Engineering & Construction

Venture Engineering & Construction

ATTACHMENT 4

Project ROM Estimates for CapEx, O&M and Schedule

King County - Opt C
4.28.22

Equipment & Installation

Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)	$	37,200,000.00	
Andritz Fluid Bed Dryers (3rd future train)	$	14,880,000.00	
Digester Heating Upgrades Equipment (HXs/Pumps)	$	1,000,000.00	
Drying Building	$	2,500,000.00	
EV Trucks (qty 3)	$	1,200,000.00	
Truck Trailors (qty 3)	$	266,155.74	
Charging Station (qty 1)	$	60,000.00	
Truck Scale (qty 2)	$	500,000.00	
HRSG & Turbine-Generator Systems (B&W / Elliott)	$	3,000,000.00	
Aries Downdraft Gasifiers (3 initial trains)	$	15,000,000.00	
Aries Downdraft Gasifiers (4th future train)	$	5,000,000.00	
Wood Processing, Screening and Conveying (3 initial trains)	$	3,000,000.00	
Wood Processing, Screening and Conveying (1 future trains)	$	1,000,000.00	
Dryers (2/gasifier x 3 initial trains)		3,000,000.00	
Dryers (2/gasifier x 1 future trains)		1,000,000.00	
Inclined Inlet Conveyors w/ Metals Removal (3 initial)	$	750,000.00	
Inclined Inlet Conveyors w/ Metals Removal (1 future)	$	250,000.00	
Cooling Screw Conveyors (3/train x 3 initial trains)	$	4,500,000.00	
Cooling Screw Conveyors (3/train x 1 future trains)	$	1,500,000.00	
Product Conveyors (2/train x 3 initial trains)	$	600,000.00	
Product Conveyors (2/train x 1 future trains)	$	200,000.00	
Product Silos (3 initial)	$	1,500,000.00	
Product Silos (1 future)	$	500,000.00	
Truck Scale (qty 2)	$	500,000.00	
Thermal Oxidizer (future sized w/ turndown)	$	1,500,000.00	
Heat Recovery Exchangers (3 initial)	$	600,000.00	
Heat Recovery Exchangers (1 future)	$	200,000.00	
SCR System (TBD)	$	3,000,000.00	
Stack	$	250,000.00	
Cooling Towers System	$	4,000,000.00	
Electrical controls/SCADA/Power Dist.	$	5,000,000.00	
Fire Detection and Suppression	$	2,500,000.00	
Site Prep	$	2,169,123.11	
Civil/Structural Install	$	4,338,246.23	
Electrical install	$	10,845,615.57	
Mechanical install	$	8,676,492.46	
Total	**$**	**141,985,633.12**	
Overhead on Equipment & Installation (4.5%)	**$**	**6,389,353.49**	**4.5%**
Grand Total	**$**	**148,374,986.61**	

Fixed Price: Engineering & CM

EPC Fee	$	11,869,998.93	8.0%
EPC OH	$	287,520.91	4.5%
Engineering	$	11,869,998.93	8.0%
CM	$	4,451,249.60	3.0%
Commissioning	$	1,483,749.87	1.0%
General Conditions	$	2,967,499.73	2.0%
Total	**$**	**32,930,017.96**	

Project Summary

Equipment & Installation	$	148,374,986.61
Engineering & CM	$	32,930,017.96
Project Total	**$**	**181,305,004.57**

O&M Estimate Annually:	**$**	**7,418,749.33**	5.0%

Project Level 1 Schedule:	**Duration**
LNTP - FEL 2/3	~6 months
FNTP	Month 0
Mechanical Completion	Month 20
Substantial Completion	Month 24
Turnover	Month 25

Disclaimer:

The estimates were prepared from budget pricing from vendors, factoring and benchmarking off comparable projects. Minimal engineering was performed for the preparation of these estimates. No "first principles" buildup was performed, which would be based on proper site information, takeoffs, market specific labor factors and rates, and current materials and utilities pricing. Accordingly, these estimates should be considered as indicative only. Note: no design has been finalized, no site survey obtained, no proper plans and elevations have been developed, and therefore no takeoffs were utilized in the generation of this estimate.

This estimate is a Class 5 estimate, also known as a rough order of magnitude (ROM) estimate. The estimate has an accuracy range of -50% on the low side and +50% on the high side and is used for early-stage capital planning, as total engineering effort expended to date is <1% of the total engineering effort required.

A stochastic cost estimating method was used to provide this Class 5 estimate. Examples of these are cost/capacity curves, rule of six-tenths, Lang factor method, scale of operation factors, high level budget quotes from major equipment suppliers and cost indices. These techniques use parametric cost estimation methods to deduce the total cost of a given project.

This estimate is an approximation and is not guaranteed. The estimate is based on information provided from the client regarding project requirements and our own in-house expertise with similar projects built in the U.S.. Actual cost may change once all project elements are finalized or negotiated, including formal project start date.

King County - Opt C - 85 DRY TON/DAY
4.28.22

Equipment & Installation

Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)	$	37,200,000.00	
Andritz Fluid Bed Dryers (3rd future train)			
Digester Heating Upgrades Equipment (HXs/Pumps)	$	1,000,000.00	
Drying Building	$	2,500,000.00	
EV Trucks (qty 3)	$	1,200,000.00	
Truck Trailors (qty 3)	$	266,155.74	
Charging Station (qty 1)	$	60,000.00	
Truck Scale (qty 2)	$	500,000.00	
HRSG & Turbine-Generator Systems (B&W / Elliott)	$	3,000,000.00	
Aries Downdraft Gasifiers (3 initial trains)	$	15,000,000.00	
Aries Downdraft Gasifiers (4th future train)			
Wood Processing, Screening and Conveying (3 initial trains)	$	3,000,000.00	
Wood Processing, Screening and Conveying (1 future trains)			
Dryers (2/gasifier x 3 initial trains)		3,000,000.00	
Dryers (2/gasifier x 1 future trains)			
Inclined Inlet Conveyors w/ Metals Removal (3 initial)	$	750,000.00	
Inclined Inlet Conveyors w/ Metals Removal (1 future)			
Cooling Screw Conveyors (3/train x 3 initial trains)	$	4,500,000.00	
Cooling Screw Conveyors (3/train x 1 future trains)			
Product Conveyors (2/train x 3 initial trains)	$	600,000.00	
Product Conveyors (2/train x 1 future trains)			
Product Silos (3 initial)	$	1,500,000.00	
Product Silos (1 future)			
Truck Scale (qty 2)	$	500,000.00	
Thermal Oxidizer (future sized w/ turndown)	$	1,500,000.00	
Heat Recovery Exchangers (3 initial)	$	600,000.00	
Heat Recovery Exchangers (1 future)			
SCR System (TBD)	$	3,000,000.00	
Stack	$	250,000.00	
Cooling Towers System	$	4,000,000.00	
Electrical controls/SCADA/Power Dist.	$	4,000,000.00	
Fire Detection and Suppression	$	2,000,000.00	
Site Prep	$	1,678,523.11	
Civil/Structural Install	$	3,357,046.23	
Electrical install	$	8,392,615.57	
Mechanical install	$	6,714,092.46	
Total	**$**	**110,068,433.12**	
Overhead on Equipment & Installation (4.5%)	**$**	**4,953,079.49**	**4.5%**
Grand Total	**$**	**115,021,512.61**	

Fixed Price: Engineering & CM

EPC Fee	$	9,201,721.01	8.0%
EPC OH	$	222,888.58	4.5%
Engineering	$	9,201,721.01	8.0%
CM	$	3,450,645.38	3.0%
Commissioning	$	1,150,215.13	1.0%
General Conditions	$	2,300,430.25	2.0%
Total	**$**	**25,527,621.35**	

Project Summary

Equipment & Installation	$	115,021,512.61
Engineering & CM	$	25,527,621.35
Project Total	**$**	**140,549,133.96**

O&M Estimate Annually:	**$**	**5,751,075.63**	5.0%

Project Level 1 Schedule:	**Duration**
LNTP - FEL 2/3	~6 months
FNTP	Month 0
Mechanical Completion	Month 20
Substantial Completion	Month 24
Turnover	Month 25

Disclaimer:
The estimates were prepared from budget pricing from vendors, factoring and benchmarking off comparable projects. Minimal engineering was performed for the preparation of these estimates. No "first principles" buildup was performed, which would be based on proper site information, takeoffs, market specific labor factors and rates, and current materials and utilities pricing. Accordingly, these estimates should be considered as indicative only. Note: no design has been finalized, no site survey obtained, no proper plans and elevations have been developed, and therefore no takeoffs were utilized in the generation of this estimate.

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A stochastic cost estimating method was used to provide this Class 5 estimate. Examples of these are cost/capacity curves, rule of six-tenths, Lang factor method, scale of operation factors, high level budget quotes from major equipment suppliers and cost indices. These techniques use parametric cost estimation methods to deduce the total cost of a given project.

This estimate is an approximation and is not guaranteed. The estimate is based on information provided from the client regarding project requirements and our own in-house expertise with similar projects built in the U.S.. Actual cost may change once all project elements are finalized or negotiated, including formal project start date.

King County - Opt C 150 DRY TON/DAY
4.28.22

Equipment & Installation			
Andritz Cake Intake, Fluid Bed Dryers, Product Silos & Odor Control System (2 initial trains)			
Andritz Fluid Bed Dryers (3rd future train)	$	14,880,000.00	
Digester Heating Upgrades Equipment (HXs/Pumps)			
Drying Building			
EV Trucks (qty 3)			
Truck Trailors (qty 3)			
Charging Station (qty 1)			
Truck Scale (qty 2)			
HRSG & Turbine-Generator Systems (B&W / Elliott)			
Aries Downdraft Gasifiers (3 initial trains)			
Aries Downdraft Gasifiers (4th future train)	$	5,000,000.00	
Wood Processing, Screening and Conveying (3 initial trains)			
Wood Processing, Screening and Conveying (1 future trains)	$	1,000,000.00	
Dryers (2/gasifier x 3 initial trains)			
Dryers (2/gasifier x 1 future trains)		1,000,000.00	
Inclined Inlet Conveyors w/ Metals Removal (3 initial)			
Inclined Inlet Conveyors w/ Metals Removal (1 future)	$	250,000.00	
Cooling Screw Conveyors (3/train x 3 initial trains)			
Cooling Screw Conveyors (3/train x 1 future trains)	$	1,500,000.00	
Product Conveyors (2/train x 3 initial trains)			
Product Conveyors (2/train x 1 future trains)	$	200,000.00	
Product Silos (3 initial)			
Product Silos (1 future)	$	500,000.00	
Truck Scale (qty 2)			
Thermal Oxidizer (future sized w/ turndown)			
Heat Recovery Exchangers (3 initial)			
Heat Recovery Exchangers (1 future)	$	200,000.00	
SCR System (TBD)			
Stack			
Cooling Towers System			
Electrical controls/SCADA/Power Dist.	$	1,000,000.00	
Fire Detection and Suppression	$	500,000.00	
Site Prep	$	490,600.00	
Civil/Structural Install	$	981,200.00	
Electrical install	$	2,453,000.00	
Mechanical install	$	1,962,400.00	
Total	**$**	**31,917,200.00**	
Overhead on Equipment & Installation (4.5%)	**$**	**1,436,274.00**	**4.5%**
Grand Total	**$**	**33,353,474.00**	

Fixed Price: Engineering & CM			
EPC Fee	$	2,668,277.92	8.0%
EPC OH	$	64,632.33	4.5%
Engineering	$	2,668,277.92	8.0%
CM	$	1,000,604.22	3.0%
Commissioning	$	333,534.74	1.0%
General Conditions	$	667,069.48	2.0%
Total	**$**	**7,402,396.61**	

Project Summary		
Equipment & Installation	$	33,353,474.00
Engineering & CM	$	7,402,396.61
Project Total	**$**	**40,755,870.61**

O&M Estimate Annually: $ 1,667,673.70 5.0%

Project Level 1 Schedule:	**Duration**
LNTP - FEL 2/3	~3 months
FNTP	Month 0
Mechanical Completion	Month 18
Substantial Completion	Month 20
Turnover	Month 21

Disclaimer:
The estimates were prepared from budget pricing from vendors, factoring and benchmarking off comparable projects. Minimal engineering was performed for the preparation of these estimates. No "first principles" buildup was performed, which would be based on proper site information, takeoffs, market specific labor factors and rates, and current materials and utilities pricing. Accordingly, these estimates should be considered as indicative only. Note: no design has been finalized, no site survey obtained, no proper plans and elevations have been developed, and therefore no takeoffs were utilized in the generation of this estimate.

This estimate is a Class 5 estimate, also known as a rough order of magnitude (ROM) estimate. The estimate has an accuracy range of -50% on the low side and +50% on the high side and is used for early-stage capital planning, as total engineering effort expended to date is <1% of the total engineering effort required.

A stochastic cost estimating method was used to provide this Class 5 estimate. Examples of these are cost/capacity curves, rule of six-tenths, Lang factor method, scale of operation factors, high level budget quotes from major equipment suppliers and cost indices. These techniques use parametric cost estimation methods to deduce the total cost of a given project.

This estimate is an approximation and is not guaranteed. The estimate is based on information provided from the client regarding project requirements and our own in-house expertise with similar projects built in the U.S.. Actual cost may change once all project elements are finalized or negotiated, including formal project start date.

ATTACHMENT 5

Supplier Budget Proposals

King County, WA - Biosolids Dryer

ANDRITZ Fluid Bed Dryer System (FDS) for Biosolids

Proposal No.: 3743670-1
Version No.: 00

Inquiry No.: 000-0000-0000
Date: March 8th,, 2022

ENGINEERED SUCCESS

Renufuel LLC
Attention: Bart Lynam

9606 Wharf St
Edmonds WA 98020
PH: (206) 612-5392
bart.lynam@renufuel.com

ANDRITZ
Contact: Peter Commerford
Separation
1010 Commercial Blvd. So.
Arlington, TX 76001
p: 817-271-2855
peter.commerford@andritz.com
andritz.com

TABLE OF CONTENT

March 7th, 2022 Budgetary Info Package # 3242216-1

Renufuel LLC
9606 Wharf St
Edmonds WA 98020

ATTENTION: Bart Lynam
Principle
P 206612 5392
Bart.Lynam@renufuel.com

SUBJECT: Request for Budget Proposal - Biosolids Drying System Supply for
King County Washington
ANDRITZ Budgetary Info Package # 3743670-1
Steam heated fluid bed drying system for biosolids

Dear Bart,

Thank you for your inquiry. Please find attached within, our budgetary information package to supply the Equipment and Services package featuring the ANDRITZ Fluid Bed Drying technologies for your Biosolids Drying System Project at the King County South Plant Biosolids Processing Facility.

We are providing this budgetary concept package to establish a basic concept for the drying system and the preliminary scope of work for this project. The ANDRITZ Biosolids Dryer plant design being proposed is based upon processing at 24 hours per day, 5 day per week operation per table on the next page:

- located at the South Plant, the drying facility will also accept dewatered cake from BrightWater and West Point wastewater treatment plants.
- Steam will be provided via the gasification of woody biomass (by others)
- Final dried product will be conveyed to two truck loadout silos sized for about one week of production.
- Whilst the basic sizing criteria is 85 dry TPD at 24% DS, the fluid bed drying plant offered in this proposal has the capability off drying up to 25% additional flow based on the 5/24 operation, allowing for peaking factor and growth, not accounting for the 2 extra days per week of operations if needed.
- The fluid bed drying system features a heat recovery system capable of heating the existing anaerobic digesters and potentially district heating.
- As at North Shore Water Reclamation District near Chicago, operational since 2006, and serving 3 wastewater treatment palants, a two stage chemical scrubber will provide for odor control of the cake intake end fluid bed drawing system.

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.

Facility Sizing is as per the table below:

Nominal Daily Sludge Production	85 dry tons/day	110 dry tons/day
Cake Dryness	24% DS	24% DS
Nominal Daily Sludge Production	354 wet tons/day	458 wet tons/day
Annual Sludge Produced	129,271 wet tons/annum	167,292 wet tons/annum
Dryer Operations	5 days per week	5 days per week
Dryer Operations	24 hours/day	24 hours/day
Dryer Operations	120 hours/week	120 hours/week
Dryer Capacity Required	119 dry tons/day	154 dry tons/day
Dryer Capacity Required	496 wet tons/day	642 wet tons/day
Final Product	95% DS	95% DS
Final Product	125 tons/hour	162 tons/hour
Evaporation Rate	15.4 tons/hour H2O	20.0 tons/hour H2O
Evaporation Rate	30,881 lb/hour H2O	39,963 lb/hour H2O
Evaporation Rate	14,005 kg/hour H2O	18,124 kg/hour H2O
No. of Drying Trains	2	2
Evaporation Rate/train	7,002 kg/hour H2O	9,062 kg/hour H2O
Dryer Technology	Fluid Bed Dryer	Fluid Bed Dryer
Dryer Model Selrction	FDS-9.0	FDS-9.0
	78%	101%
Max. Evaporation Rate	9,000 kg/hour H2O	9,000 kg/hour H2O
Specific Energy Consumption	1,250 BTU/lb/water	1,250 BTU/lb/water
Heat Energy Requirement	38.60 MM BTU/h	49.95 MM BTU/h
Heat Energy Requirement	11.30 mW (th)	14.63 mW (th)

Two (2) each ANDRITZ FDS 9.0 Fluid Bed Drying systems

The ANDRITZ Fluid Bed Dryer will produce EPA Class A biosolids.

The proposed plant is a dual drying train able to evaporate over up to 18 metric tons per hour of water, inclusive of:

- Nominal 2,825 ft3 Dewatered Cake feed hopper fitted with progressive cavity feed pumps (6).
- ANDRITZ fluid bed Dryer with fluidizing fans, ductwork, dust collection cyclones, condenser wet scrubber and demisting cyclone.
- Fluidized bed dried granule cooler, with integration of fluidizing air into dryer circuit.
- Heat Recovery System incorpoeating duty/standby heat exchangers and cooling towers/
- Mechanical conveyance of granules to two (2) 300 ton dry product storage and truck load-out mass flow storage silo, with nitrogen storage tank, control valve, ambient air vaporizer and dust baghouse.
- Dryer system Automation and Instrumentation Control system with PLC/HMI and software program
- Structural steel work for dryer equipment with access platforms and stairs.
- Start-up and Commissioning Services
- Freight to job site

Taken together with the experience of unattended operations at night, we believe the FDS (fluid bed drying system) approach offers the King County team an exceptional value, and I look forward to discussing this offer with you in detail.

The Drying lines offered are identical in size to those recently commisioned in Sahanghai, China (capable of processing uo to 3,000 wet TPD dewatered cake.

Steam Heated Fluid Bed Drying System, FDS 9.0 Bailonggang China

Thanks again for your interest in Andritz products and services

Sincerely,

Peter Commerford
Manager Drying Systems
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1. EXECUTIVE SUMMARY

The ANDRITZ Fluid Bed Dryer (FDS) technology has been successfully implemented in over 30 installations Worldwide.

The Fluid Bed Dryer has a proven record of safety and reliability. Fluidized Bed Dryers used in sludge applications operate in a closed inert gas loop. The entire heat energy required to evaporate the water is fed to the dryer via heat exchangers without any direct contact between the heat transfer medium and the product.

The Fluid Bed Dryer is capable of transferring large amounts of heat at low temperatures. This design allows for large evaporation capacities in a small footprint as well as being able to utilize many different sources of thermal energy.

Highlights of the ANDRITZ Fluid Bed Dryer include:

- Sludge is directly fed – no back mixing or recycle required
- Low Drying Temperatures – Ability to utilize waste heat
- Indirect heat supply via internal heat exchanger
- Thermal oil or steam can be used as heating medium
- Product is treated in an inert atmosphere (<4% O2), ensuring a high safety standard
- Low off-gas emissions
- No sweep air required

Typical Fluid Bed Dryer Installation

2. FLUID BED DRYER TECHNICAL INFORMATION

2.1 FACILITY DATA

Project Name	King County Biosolids Drying Facility
Project Location	Seattle, WA
Type of WWTP	Domestic Municipal wastewater
• Type	Anaerobically digested
• Expected Cake Dryness	24% TS after dewatering
• Cake Dryness variation	< 1% DS in any one hour (max.)
• Metals Content	< limits imposed by EPA 40CFR Part 503 regulations for Class A biosolids

2.2 DRYING FACILITY DESIGN CRITERIA

Design Basis ....85 dry tons/day @ 24% TS feed

Dried Pellet Moisture Content .... 92% DS minimum Class A

Dryer proposed... ANDRITZ FDS-9.0 operating 24/5

Number of Dryer trains proposed........................... Two (2) lines.

Design Evaporation Rate .... 19,845 lbs / hr H_20 evap / FDS dryer train

Primary Energy for the Dryer .... saturated steam at 200 psig

Non-Potable Filtered Plant Effluent Water .... 68°F, 70 psig (min.)

Electric Power .... 480V, 60 Hz, 3-phase, 3-wire

Estimated Heat Energy Requirement ~ 49.5 MM BTU/Hour (at max capacity)

Estimated Water Consumption .... ~350 USGPM NPW (recirculated condenser liquor)

Estimated Electricity Consumption .... ~ 850 kW/Hour per dryer train

Estimated Other Consumables .... Nitrogen for Start-up inertization

3. FLUID BED DRYER GENERAL DESCRIPTION

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 (30) installations worldwide.

The drying system is designed for treating pumpable dewatered sludge from municipal waste water treatment plants when equipped with:

- Mechanical screening (< 6 mm openings) in order 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

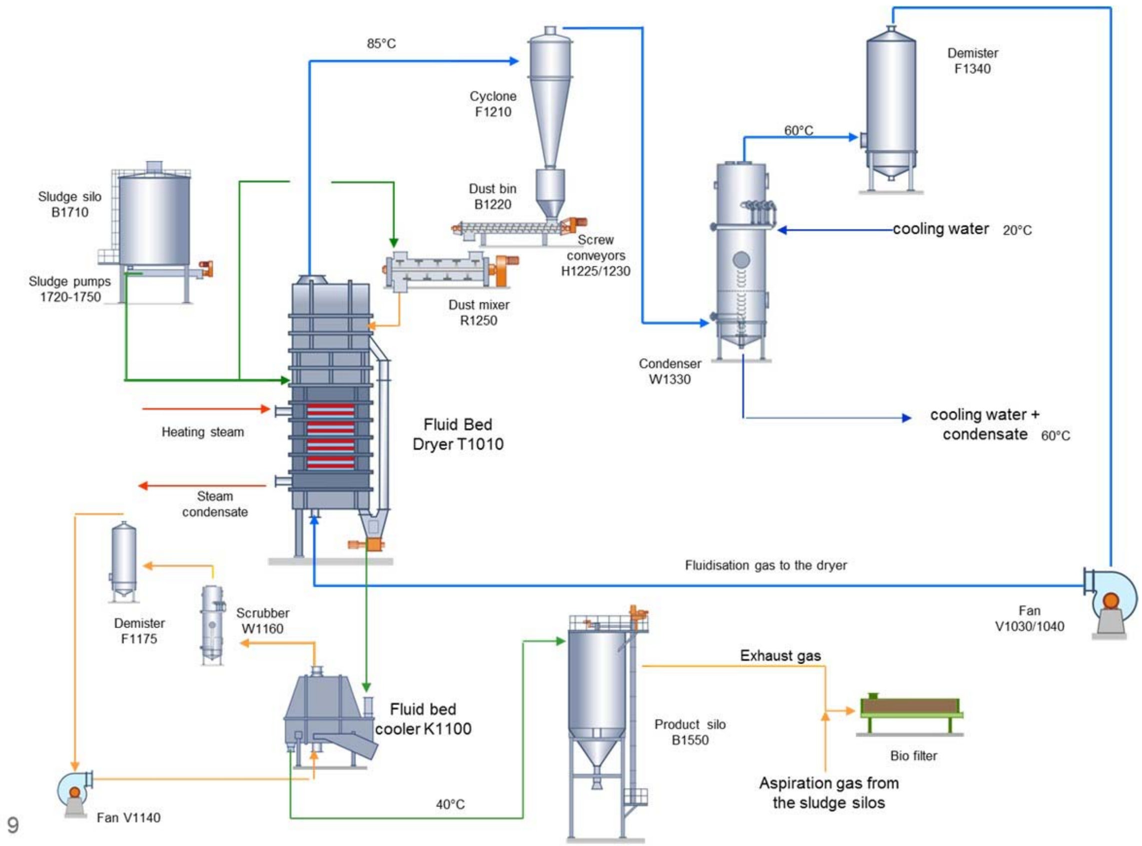
The fluid bed drying process produces a final product with a minimum dried solids content of 92% TS which greatly reduces the overall Biosolids volume and allows for reduced shipping and storage volume.
The dry product generated by this process can be beneficially used:

- 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.

Drying Process

The fluid bed drying plant is designed for 24 hour per day operation, 7 day per week.



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).

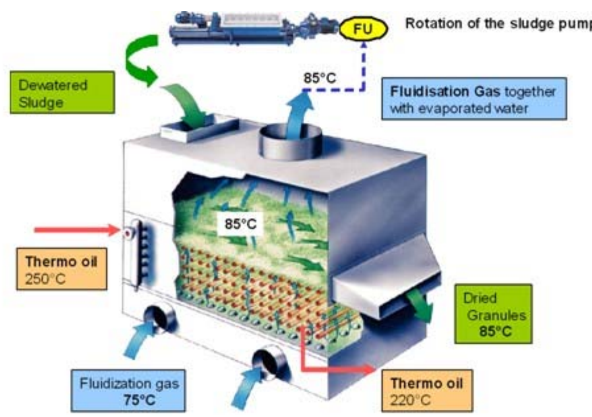
The sludge cake bin is connected to the aspiration system (by others). The ambient air is sucked through the bin to avoid accumulation of explosive gas (mainly methane) inside the bin.

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.

Principle of the fluid bed dryer

Particle in floating motion



The fluid bed dryer (T-1010) consists of three different sections:

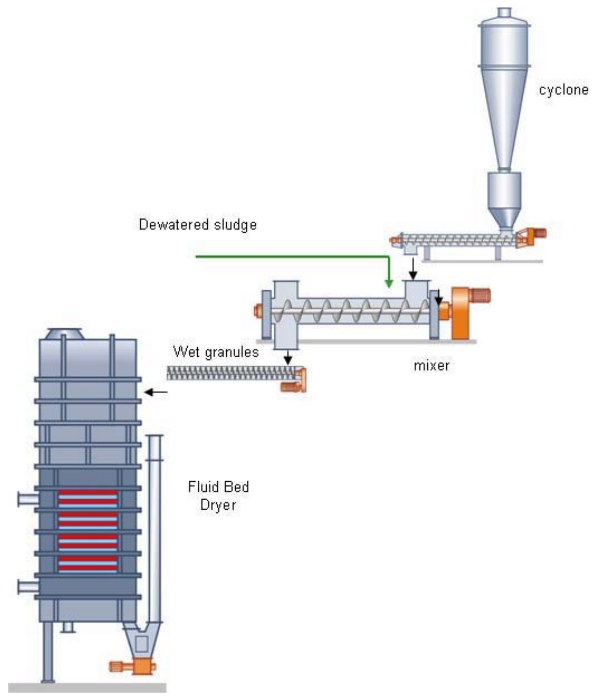
- The wind box with a gas distribution plate which distributes the fluidization gas uniformly across the area of the dryer in order to keep the dry granules in an evenly floating motion.
- The middle section houses the heat exchanger which is immersed in the fluidized layer. This heat exchanger transfers 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.

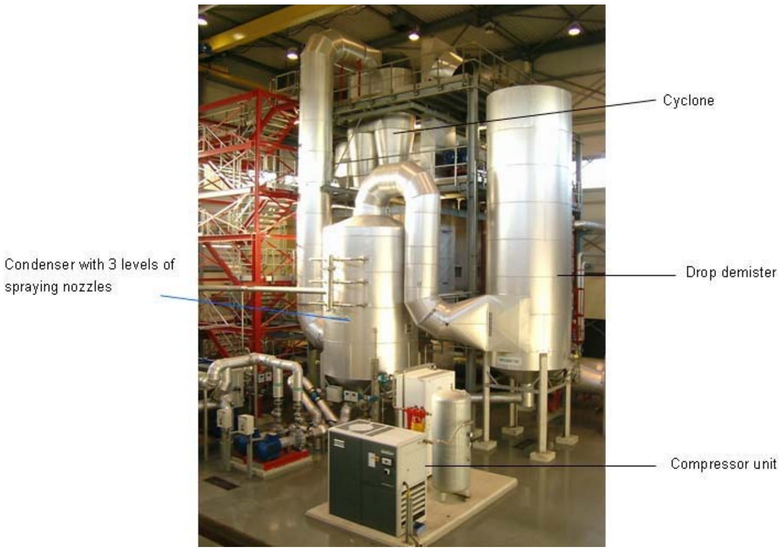
Dust Separation

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).



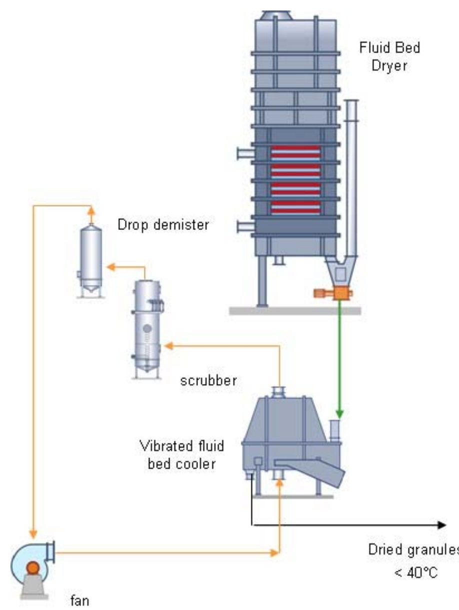
Dryer Gas Recycle System

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 waste water treatment plant is used for cooling water. The condensate together with the cooling water is discharged back to the WWTP.



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 other than 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.

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 shut downs.

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:

- One or 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 - only Qty 1 ea. included

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)].

4. SCOPE OF SUPPLY

4.1 SCOPE OF SUPPLY – FLUID BED DRYER SYSTEM

Item	Description	By ANDRITZ	By Others
General			
	Unloading and proper storage of all equipment supplied by ANDRITZ		X
	Install dryer and ancillary equipment as shown on contract plans		X
	Supply and install all piping and valves (per ANDRITZ supplied P&ID drawing)		X
	Supply and install all electrical wiring including conduit, junction boxes, fittings, seals, cables and wiring to all field instruments and motors supplied by ANDRITZ		X
	Supply and install air duct from condenser exhaust to odor control equipment		X
	Supply of lubricating oil and grease for initial start-up (dryer equip only)	X	
	Supply of all spare parts recommended by the ANDRITZ, and equipment vendors not supplied under the contract		X
	Conducting a Performance Test of the completed biosolids drying system under the supervision of the dryer system supplier and Engineer	X	X
	Determining if structures and surrounding areas have suitable load bearing strength to support ANDRITZ provided equipment		X
	Grounding grid system and lightening protection systems		X
Utilities			
	All utilities including electric, natural gas, potable and non-potable water and sewer to dryer connecting points		X
	All utilities for operation of the plant such as chemicals, electricity, natural gas, process and potable water etc.		X
Consumables			
	Electricity, fuel for heat generation, water, and wear parts during start-up, commissioning, performance tests, and warranty period		X
Infrastructure			
	Training of the dryer plant operators and maintenance staff	X	
	Provision of operating personnel for commissioning and performance testing to assist ANDRITZ		X
	Connections for electricity, water, fuel, thermal oil and drainage systems		X
	Process and utility piping, process ductwork, supports, bridgework, etc.		X
	Discharge and treatment of all effluents produced by the plant as well as their connection to the sewerage or other treatment system		X
Planning, Permits, Approvals			
	Geotechnical surveys		X
	Building permits		X
	Environmental permits and testing		X
	Fees for necessary connections to utilities		X
	Third party or special inspections, performance tests, or measurements		X
Dryer System Wet Cake Feed			
	Dewatering equipment and conveyance to wet material dosing bin		X
B1710	Wet Material Dosing Bin – Minimum 80 m3 capacity (estimated size) w/ live bottom	X	

Item	Description	By ANDRITZ	By Others
P1720-50	Wet Cake Feed Pumps – 4 each for wet material bin (estimated)	X	
	Wet Cake Feed Piping, elbows, fittings, pipe supports, etc. bin-to-dryer		X
	Water Injection Pump, skid & piping	X	
FDS	**Dryer System Components**		
T1010	Fluid Bed Dryer, c/w Wind Box, Intermediate Section, Heat Exchanger and Upper Hood	X	
X1012-15	Sludge Dispersers	X	
X1020-21	Rotary Airlock Valves (2)	X	
V1030-40	Gas Circulating Fans (2)	X	
K1110	Product Cooler	X	
V1140	Cooler fan	X	
W1160	Scrubber	X	
F1175	Demister	X	
F1210	Cyclone	X	
B1220	Dust Bin	X	
H1225	Live Bottom	X	
H1230	Screw Conveyor	X	
H1235	Bucket Elevator	X	
H1240	Screw Conveyor	X	
R1250	Mixer	X	
H1260	Screw Conveyor	X	
W1130	Condenser	X	
F1340	Demister	X	
P1350	Condensate pump	X	
H1410	Bucket Elevator	X	
H1420	Screw Conveyor	X	
H1425	Screw Conveyor	X	
B1430	Start-up Bin	X	
H1440	Screw Conveyor	X	
H1450	Screw Conveyor	X	
H1455	Screw Conveyor	X	
B1550	Storage silo 1	X	
X1551	Bin Activator 1	X	
H1460	Screw Conveyor	X	
H1465	Screw Conveyor	X	
X1561	Dustless loadout spout	X	
F1582	Dust Collector	X	
V1593	Fan	X	

Item	Description	By ANDRITZ	By Others
Heat Generation			
36WM	Steam Generation and condensate return		X
	Back up Boiler	X	X
Flue Gas Exhaust and Vent			
	Exhaust stack, vent line or damper supply, design, and installation to safe discharge location as required by codes		X
Electrical, Instrumentation, and MCC & Control Equipment for Dryer System			
	PLC Software and HMI screen with preprogrammed software	X	
	MCC, VFD's and motor starters	X	
	Instrumentation (per ANDRITZ supplied P&ID drawings)	X	
On-Site Services			
	Installation Guidance (up to 60 Man Days and 6 round trips)	X	
	Start-up, Testing, and Training (up to 10 Man-Days)	X	
	Lab testing of dryer samples; in-feed and output for performance verification		X
Access Platforms			
	Access Platform with stair, handrails and grating	X	
	Installation of Access Platform with stair, handrails and grating		X
Insulation			
	Specification of Insulation Material to be used for Dryer equipment	X	
	Supply & Installation labor of Insulation after dryer erection		X
Site Electrical and Control Installation			
	Installation onsite of Control and Instrumentation wiring and MCC wiring		X
Packaging and Transport			
	Packing and Transport to FL Job Site (for ANDRITZ supplied equipment only)	X	
Plant Water System			
	Facility Plant Water System – assume 50 psig minimum pressure		X
	Screening of plant water for dryer system use (400 mesh)		X
Potable Water System			
	Facility Potable Water Systems		X
Product Load-out and Storage			
41H01,	Conveyors system delivery of final product into storage silo	X	
A&B45B01	Dried Product Storage Silo	X	
A&B45X01	Telescoping load out chute for bulk loading into trucks or sacks	X	
	Nitrogen inertization system equipment & design	X	
	Dust collection baghouse, Biofilter, etc.	X	
	Installation, assembly, and erection of final product handing system		X
Dewatered Cake Truck Unloading and Receival hoppers			
	Two hoppers 35 yd with sliding frame unloading /cake pumps to dryer wet material	X	
Odor Control System			
	Three Stage Chemical Scrubber	X	

PLEASE REFER TO THE ANDRITZ PRELIMINARY PROCESS FLOW DIAGRAM (PFD) AND MECHANICAL GA LAYOUT DRAWINGS ENCLOSED FOR THE ANCILLARY EQUIPMENT TYPICALLY REQUIRED FOR A FLUID BED DRYING SYSTEM OPERATION.

4.2 EXCLUDED FROM DRYER SYSTEM SCOPE OF SUPPLY

Battery Limits / Exclusions to ANDRITZ scope of supply:
The ANDRITZ supplied P&ID Drawing should form the guidelines for ANDRITZ scope of supply.
The following parts and services (not all inclusive) are specifically not included in our supply:

- All civil engineering work, buildings and additional services (high-voltage supply, lighting, lightening protection, fire protection equipment, etc.), grouting work or shim plates
- Installation, assembly, and erection of equipment, including wiring and piping
- Field welding and fit up of duct work
- Electrical system I/O and wiring checks
- System rotation checks
- Heating, cooling, and ventilation systems for building
- Weather and temperature protection consideration or equipment
- Any work and/or material related to touch up painting and repair of paint
- Uninterrupted power supply (emergency supply), power compensation, harmonic factor compensation for VFDs and dryer controls
- Equipment vibration or harmonic analysis
- Cleaning of all water lines, cake lines, process lines and equipment prior to start-up
- Drinking water system for sanitary purposes
- All consumables and process materials for plant operation
- Cleaning services, cleanup of site and waste disposal
- Leak testing, inspections, or approvals of any installation
- Third party testing of samples
- Special designs or submittals required to meet codes beyond federal OSHA requirements for platforms, handrails, and grating
- Cranes, lifting gear, transport equipment for unloading/erection work of the plant parts
- Fees and dues in connection with obtaining permits, and carry out tests and inspections at the plant, including measuring and testing devices, sampling, analyses, and emission monitoring.
- Taxes or fees
- Bonds or Letter of Credit
- Fees and dues in connection with obtaining permits, and carry out tests and inspections at the plant, including measuring and testing devices, sampling, analyses, and emission monitoring.

5. COMMERCIAL SUMMARY

5.1 NON-BINDING BUDGET INFORMATION

Per Scope of Supply parts 3.0 and 4.0 above generally consisting of;

D.1. 2 each ANDRITZ FDS 9.0 Fluidized Bed Dryer System .... Included

D.2. 2 each Wet material bin 2825ft3 with live bottom & (6) cake feed pumps .... Included

D.3. 2 Lots Support steelwork, service platforms, guardrails, and access walkways for Andritz scope ....Included

D.4. 2 Lots Associated process ductworks ....Included

D.5. 2 Lots Insulation and cladding of ANDRITZ equipment only ....Excluded

D.6. 2 Lots All instruments, motors for supplied equipment, PLC's and operator interfacein dryer control panel ....Included

D.7. 2 lots Dried Product Storage silo, 300 Ton mass flow design with Loadout spout, nitrogen s ystem, dust baghouse and exhaust fan. ....Included

D.8. 2 lots Cake Intake System and tranfer ....Included

D.9. I lot Odor Control System ....Included

D.10. 1 lot Andritz Engineering Services including:
(a) Installation supervision 10 days
(b) Field testing after completion of installation 2 days
(c) Start-up 3 days
(d) Performance testing 1 day
(e) Training 1 day
(f) O&M Manuals .... Included

D.6. 1 sets Submittal Data in accordance with attached Drawings and Data Requirements .... Included

D.10. 1 Set Final O&M Manuals (two (2) CD sets)... Included

D.11. 1 Lot Estimated Freight Charges... Included

D.12. 1 Lot Delivery DAP Sioux Falls, SD jobsite (INCOTERMS 2010) ……… Included.

5.2 TOTAL AMOUNT ABOVE SCOPE NON-BINDING PRICE .... $ 37.2 MM

5.3 PRICE BASIS

The budget prices quoted are valid for delivery DAP Seattle, WA jobsite (named destination), according to Incoterms 2010.
All ancillary costs, such as, but not limited to, customs duties, local taxes, fees, stamp duties, insurances, authorizations and certifications are not included in this budget offer.

5.4 ANDRITZ PAYMENT TERMS

This Budget Proposal is offered based on the current ANDRITZ Separation Inc. Standard Terms and Conditions of Sale.
Our offer is based on the assumption of mutually agreed terms of payment, including adequate securities, and a project handling time of approx. 12-14 months.

5.5 DELIVERY

Delivery to site approx. 10 – 12 months from receipt of order confirmation and clarification of all commercial and technical details.

5.6 Special information

- The price quoted in this proposal 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 remain firm for a period of thirty (30) days, except and subject to the following. In the event that the introduction of new tariffs, levies, duties, 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, nor in any of the applicable contractual documentation shall be construed as a waiver of this right.
- The cost of tariffs is not included in our cost estimates at this time.
- All prices are US Dollars.
- Prices do not include any local or federal fees or taxes, permits or other fees. Any taxes or fees that may apply must be added to the quoted price and paid by the Buyer.
- This Budgetary information is based on current commodity prices & currency exchange rates and is subject to adjustment at time of order entry & acceptance by Andritz.
- This Budgetary information is based upon known present safety codes and protection requirements for this type of equipment. Any changes between now and date of an actual order may require adjustments for codes and safety requirements in place at that point in time.
- Bid Bond, Payment Bond nor Performance Bond are not included.

5.7 ANDRITZ SEPARATION TECHNOLOGIES INC. STANDARD TERMS AND CONDITIONS OF SALE

1. 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 15% 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 defense 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 defense 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.

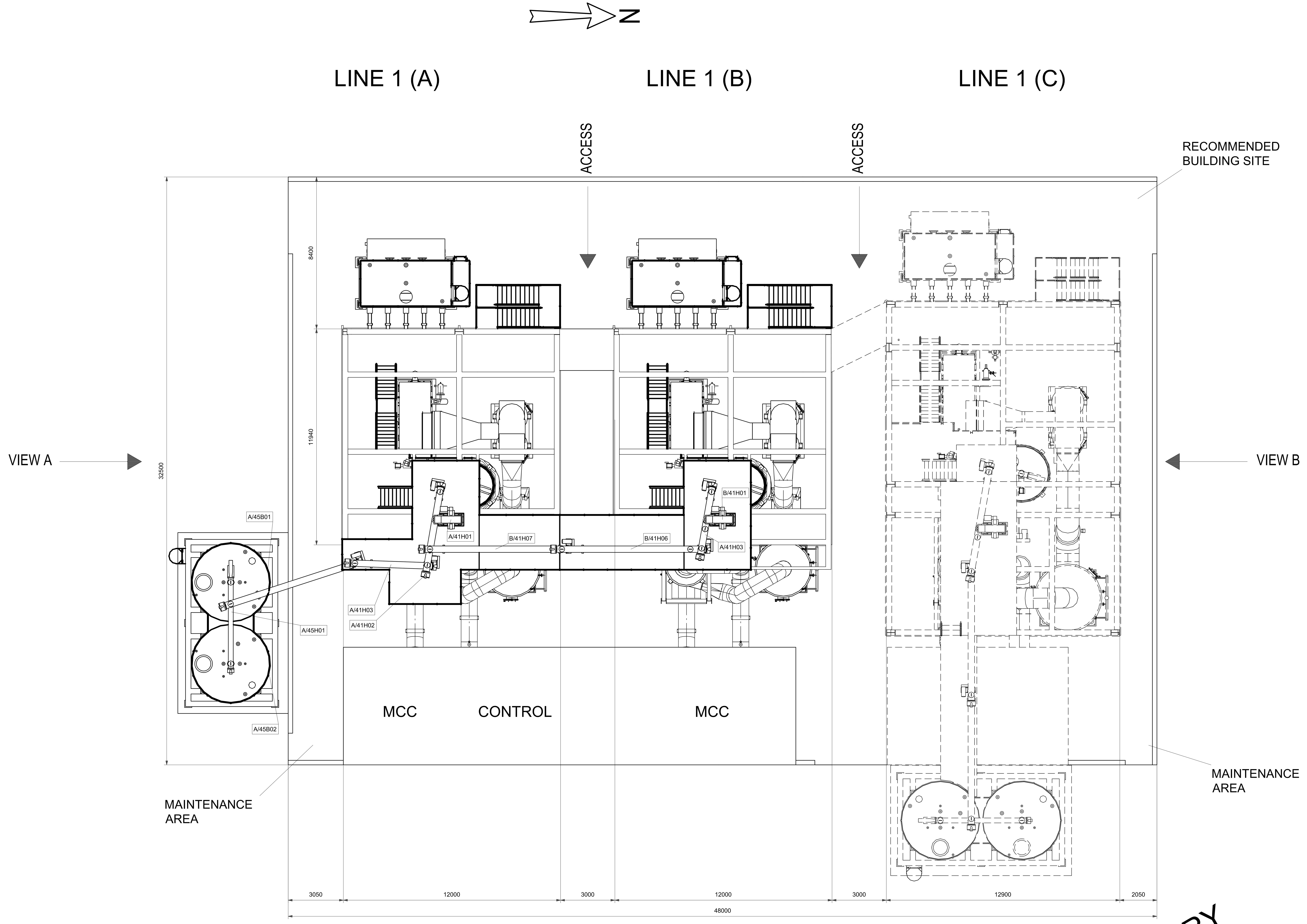
14. FORCE MAJEURE

(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, willful 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 defense 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 defense 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, transshipped, 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. Les parties aux présentes ont exigé que la présente convention soit rédigée en anglais.

Feb. 2019 Rev.

6. GENERAL ARRANGEMENT DRAWINGS

The attached General Arrangement drawings are from a facility recently completed in Istanbul – note that these drawings show three3 lines – two (2) constructed and one (1) drying line future. Note that the cake intake envisaged for the South plant is not represented in these drawings.



PRELIMINARY

Index	Date	Draw.	Chkd.	App.	Beschreibung/Description
4	25.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
3	22.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
2	20.01.2016	ma			LAYOUT UPDATED ON VARIANTE 1
1	21.12.2015	ma			LAYOUT UPDATED

Stand: / Updated: 04.02.2016

185

Masse sind auf getrenntem Messwerterfassungsblatt nachzuweisen.
Note all measurements are recorded on a separate data sheet

Laengen und Winkelmasse nach DIN ISO 2768 Teil 1 Klasse M Length and angle dimensions DIN ISO 2768 part 1 class M	Form und Lage Toleranzen DIN ISO 2768 Teil 2 Klasse K Form and Position DIN ISO 2768 part 2 class K

Schweisskonstruktionen nach EN ISO 13920 Tab. 1-3 Klasse B/F
Welding construction Acc. EN ISO List 1-3 class B/F

Gezeichnet von / Drawn by	Datum / Date	Visum
ma	11 Nov 2015	
Freigabe/approved:		
Abtlg.	Datum	Visum
AFSR 435 Design and Plant Engineering		
AFSR 435 Project Manager Process Automation		
AFSR 425 Project Manager Engineering and Sales		
AFSR 435 Project Manager Order Execution		
Zugehoerige Spezifikation Nr: / Associated specification No.:		

ANDRITZ FLIESSBETT SYSTEME GmbH
Goethestrasse. 36, D 88214 Ravensburg, Tel. +49-751-560580
www.andritz.com

Kunde/Client:

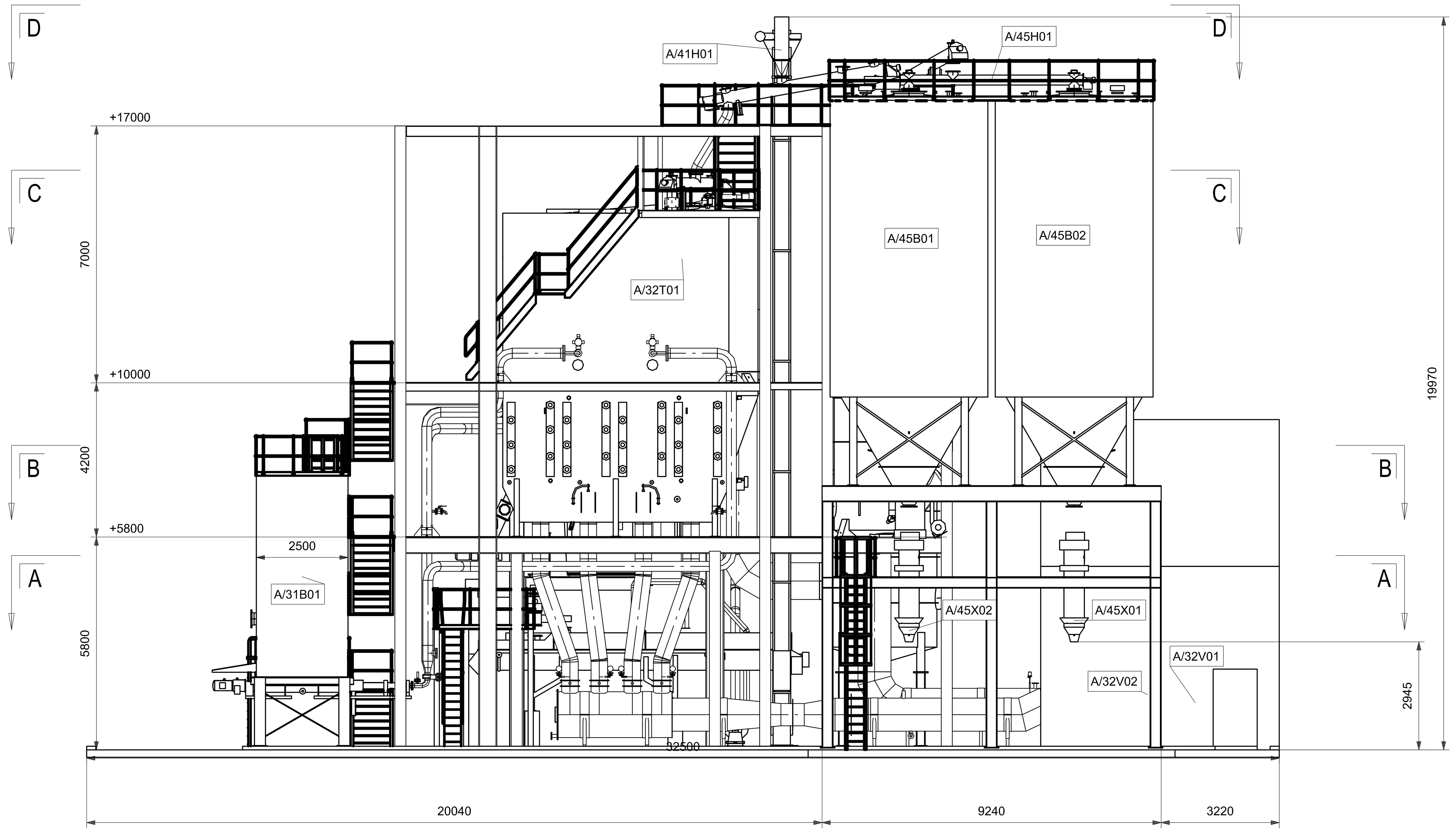
Anlage/Project:
ATAKOEY PHASE 2

LAYOUT DRAWING

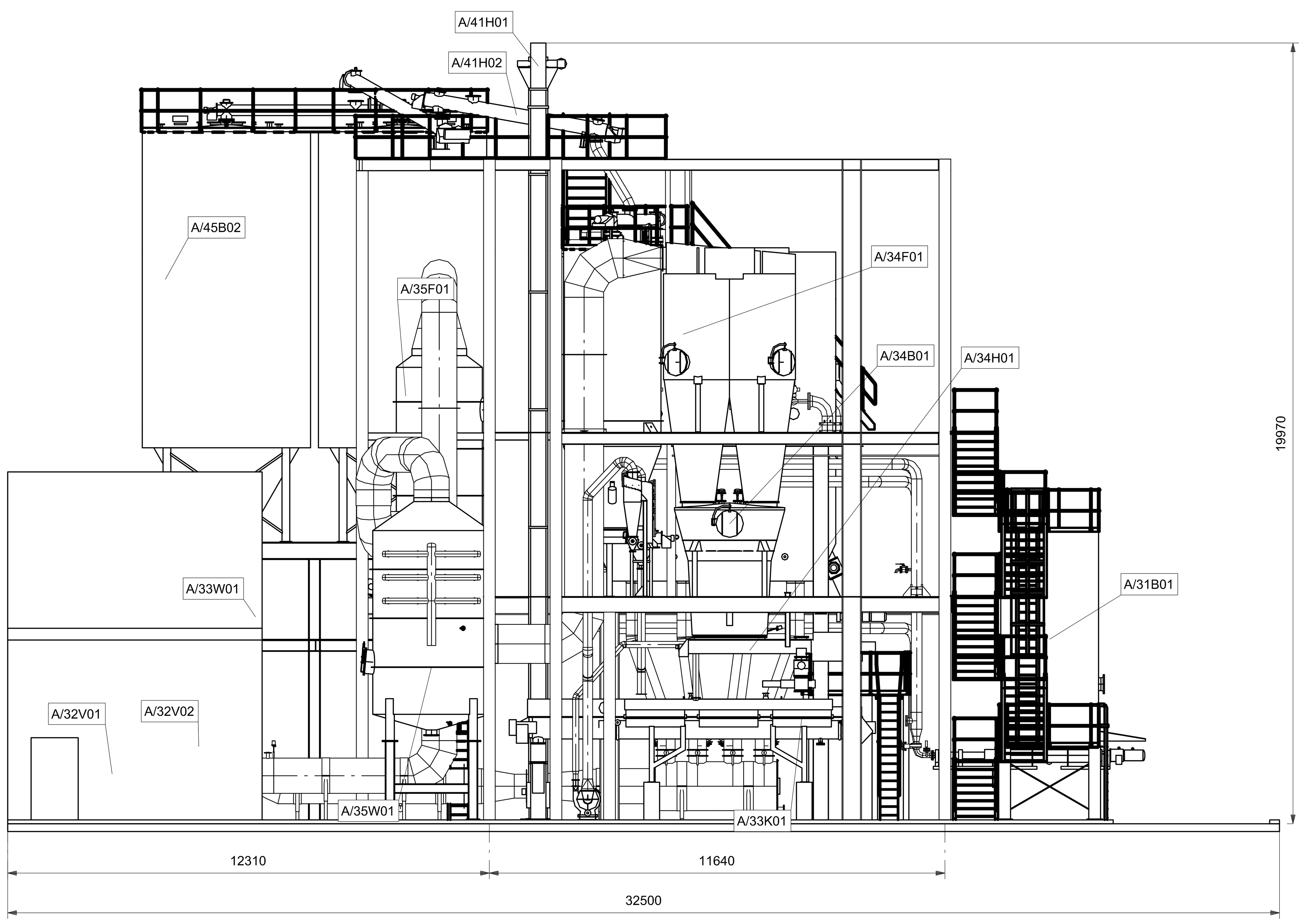
SLUDGE DRYING PLANT
LINE 1 - 2

Auftrag Nr./Order No.	Zeichnungs Nr./Drawing No.	Format	Massstab Scale	Blatt Nr. Sheet No.	Rev.
1802238	506637396V2	A0	1:75	1/5	4

VIEW A



VIEW B



PRELIMINARY

Index	Date	Draw.	Chkd.	App.	Beschreibung/Description
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1	21.12.2015	ma			LAYOUT UPDATED

Stand:
Updated: 04.02.2016

185
Masse sind auf getrenntem Messwerterfassungsblatt nachzuweisen.
Note all measurements are recorded on a separate data sheet

Laengen und Winkelmasse nach DIN ISO 2768 Teil 1 Klasse M
Length and angle dimensions DIN ISO 2768 part 1 class M

Form und Lage Toleranzen DIN ISO 2768 Teil 2 Klasse K
Form and Position DIN ISO 2768 part 2 class K

Schweisskonstruktionen nach EN ISO 13920 Tab. 1-3 Klasse B/F
Welding construction Acc. EN ISO List 1-3 class B/F

Gezeichnet von / Drawn by	Datum / Date	Visum
ma	11 Nov 2015	

Freigabe/approved:

Abtlg.	Datum	Visum
AFSR 435 Design and Plant Engineering		
AFSR 435 Project Manager Process Automation		
AFSR 425 Project Manager Engineering and Sales		
AFSR 435 Project Manager Order Execution		

Zugehoerige Spezifikation Nr:
Associated specification No.:

ANDRITZ FLIESSBETT SYSTEME GmbH
Goethestrasse. 36, D 88214 Ravensburg, Tel. +49-751-560580
www.andritz.com

Kunde/Client:

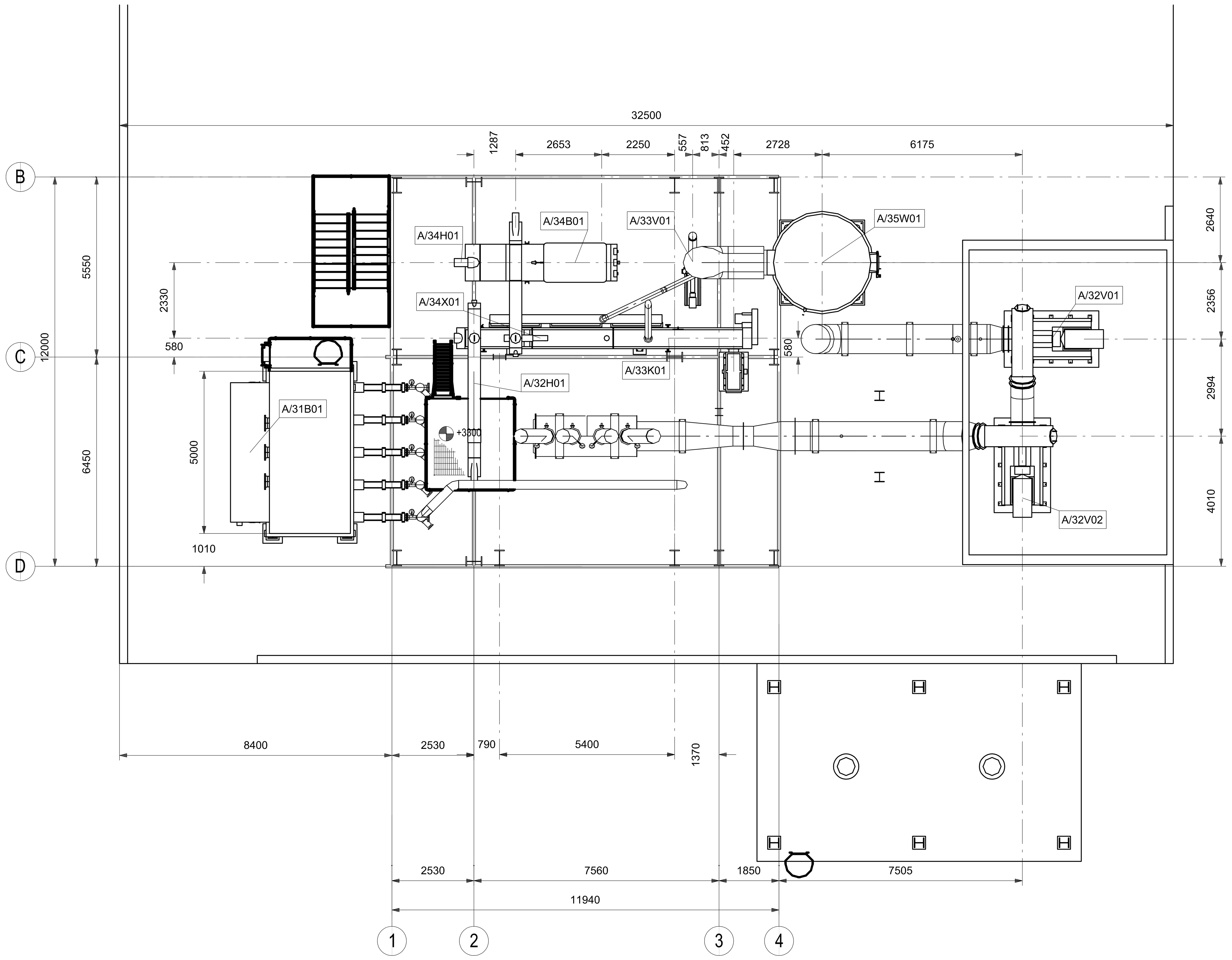
Anlage/Project:
ATAKOEY PHASE 2

LAYOUT DRAWING

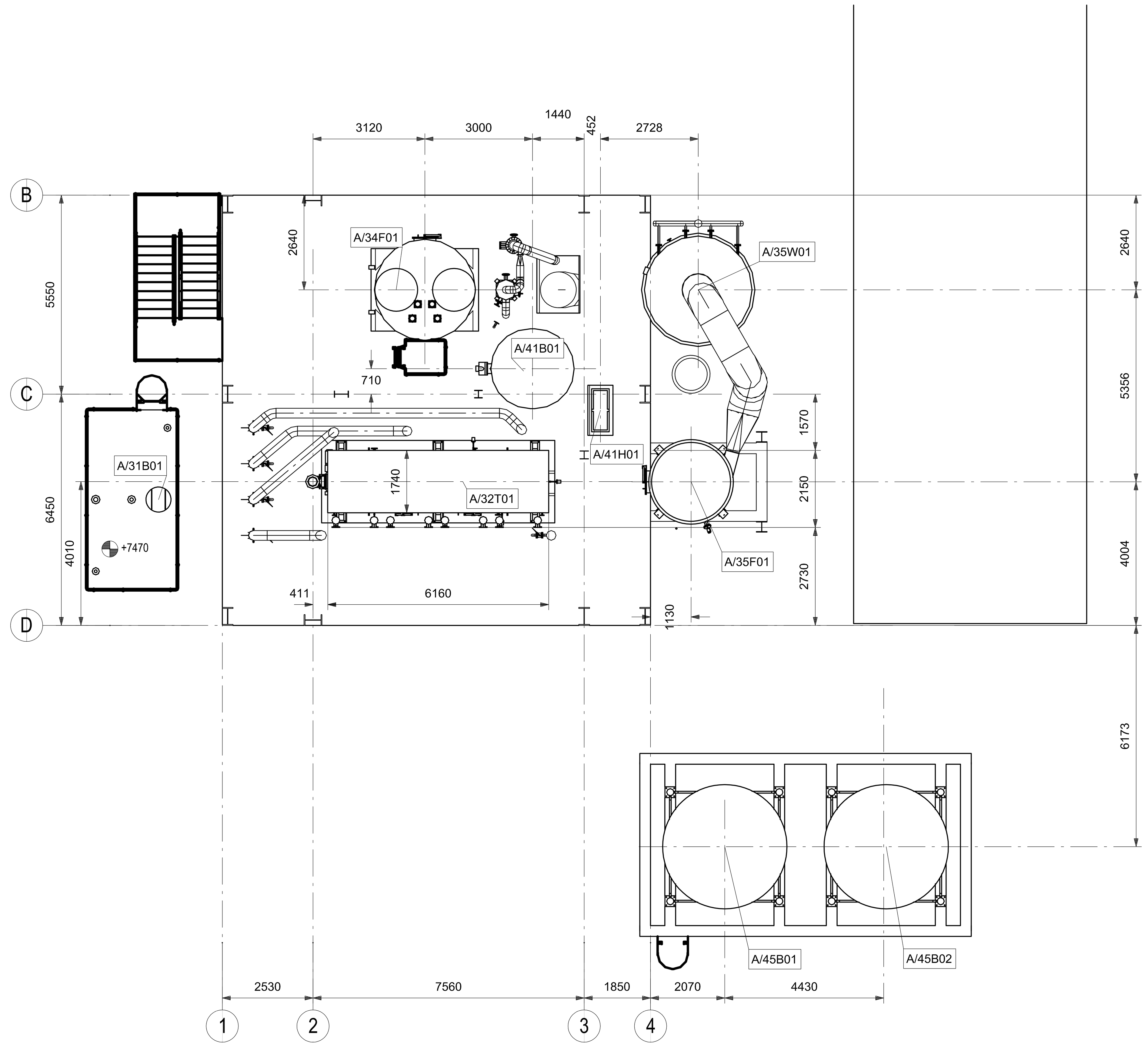
SLUDGE DRYING PLANT
LINE 1 - 2

Auftrag Nr./Order No.	Zeichnungs Nr./Drawing No.	Format	Massstab Scale	Blatt Nr. Sheet No.	Rev.
1802238	506637396V2	A0	1:75	2/5	4

SECTION A - A 0m
LINE 1 (A)
M 1:75



SECTION B - B 5.8m
LINE 1 (A)
M 1:75



PRELIMINARY

Index	Date	Draw.	Chkd.	App.	Beschreibung/Description
4	25.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
3	22.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
2	20.01.2016	ma			LAYOUT UPDATED ON VARIANTE 1
1	21.12.2015	ma			LAYOUT UPDATED

Stand:
Updated: 04.02.2016

185
Masse sind auf getrenntem Messwerterfassungsblatt nachzuweisen.
Note all measurements are recorded on a separate data sheet

Laengen und Winkelmasse nach DIN ISO 2768 Teil 1 Klasse M
Length and angle dimensions DIN ISO 2768 part 1 class M

Form und Lage Toleranzen DIN ISO 2768 Teil 2 Klasse K
Form and Position DIN ISO 2768 part 2 class K

Schweisskonstruktionen nach EN ISO 13920 Tab. 1-3 Klasse B/F
Welding construction Acc. EN ISO List 1-3 class B/F

Gezeichnet von / Drawn by	Datum / Date	Visum
ma	11 Nov 2015	
Freigabe/approved:		
Abtlg.	Datum	Visum
AFSR 435 Design and Plant Engineering		
AFSR 435 Project Manager Process Automation		
AFSR 425 Project Manager Engineering and Sales		
AFSR 435 Project Manager Order Execution		

Zugehoerige Spezifikation Nr:
Associated specification No.:

ANDRITZ

Kunde/Client:

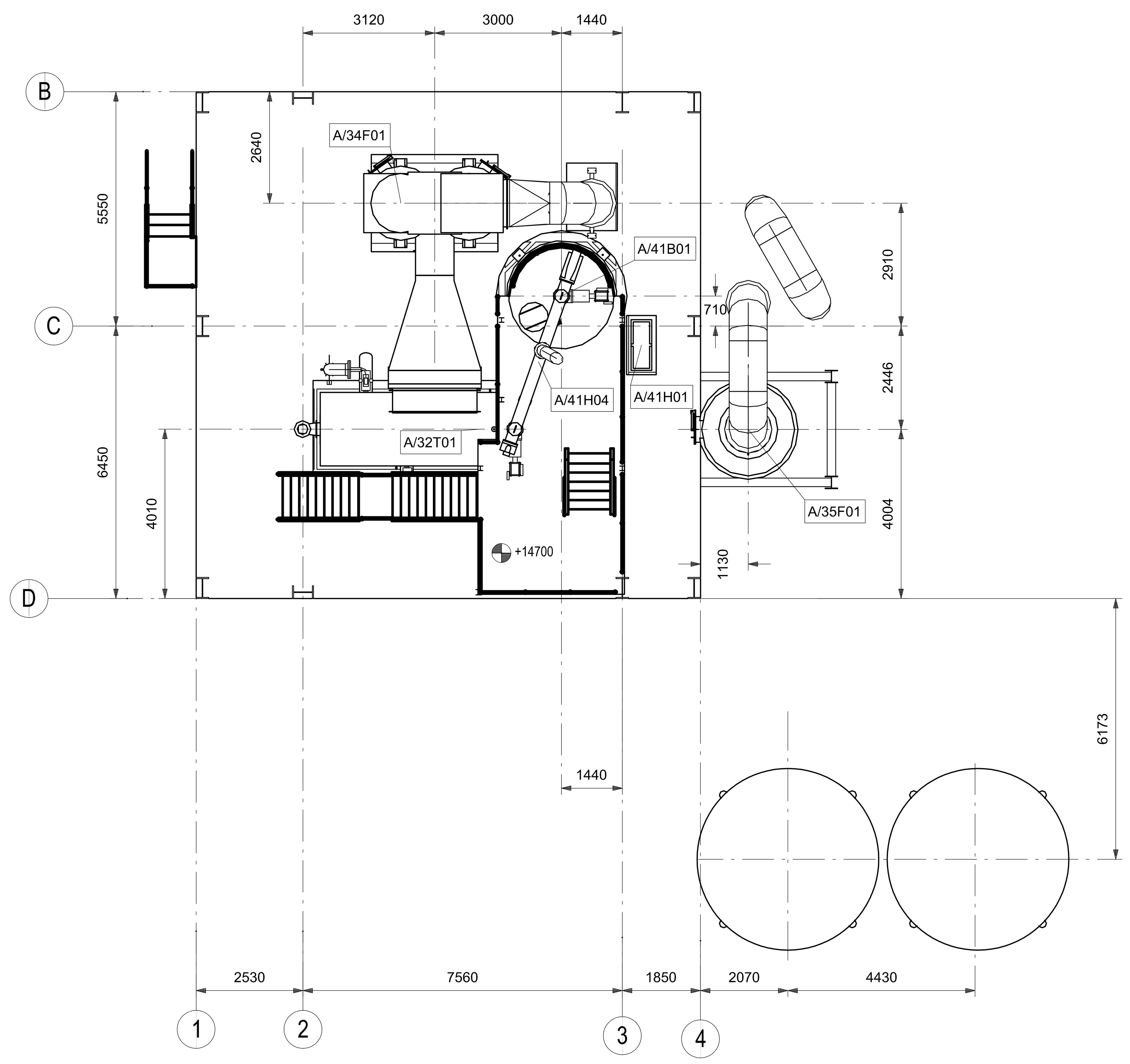
Anlage/Project:

LAYOUT DRAWING

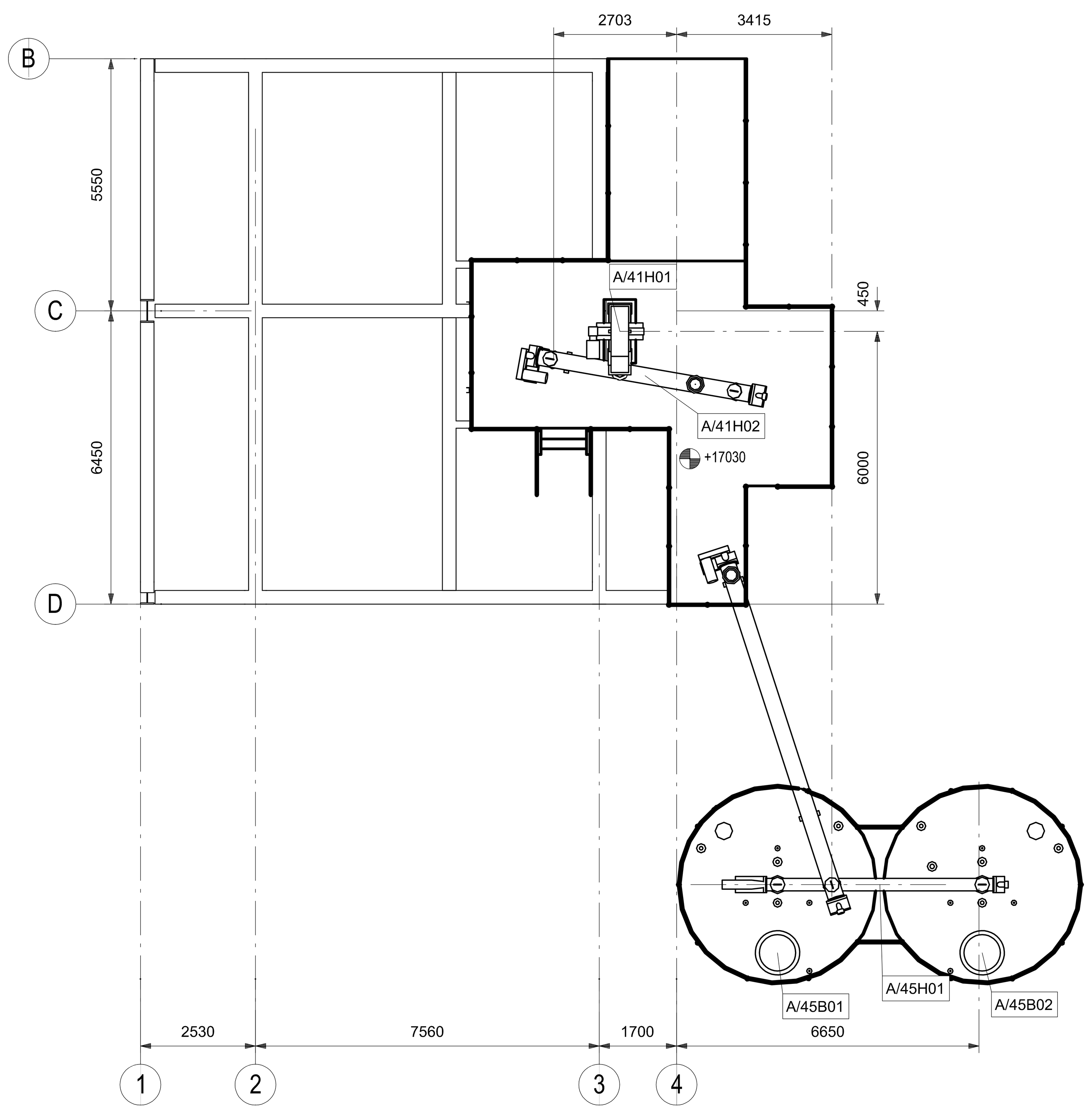
SLUDGE DRYING PLANT
LINE 1 - 2

Auftrag Nr./Order No.	Zeichnungs Nr./Drawing No.	Format	Massstab Scale	Blatt Nr. Sheet No.	Rev.
1802238	506637396V2	A0	1:75	3/5	4

SECTION C - C 10.0m
LINE 1 (A)
M 1:75



SECTION D - D 17.0m
LINE 1 (A)
M 1:75



PRELIMINARY

Index	Date	Draw.	Chkd.	App.	Beschreibung/Description
4	25.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
3	22.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
2	20.01.2016	ma			LAYOUT UPDATED ON VARIANTE 1
1	21.12.2015	ma			LAYOUT UPDATED

Stand: Updated: 04.02.2016

185
Masse sind auf getrenntem Messwerterfassungsblatt nachzuweisen.
Note all measurements are recorded on a separate data sheet

Laengen und Winkelmasse nach DIN ISO 2768 Teil 1 Klasse M
Length and angle dimensions DIN ISO 2768 part 1 class M

Form und Lage Toleranzen DIN ISO 2768 Teil 2 Klasse K
Form and Position DIN ISO 2768 part 2 class K

Schweisskonstruktionen nach EN ISO 13920 Tab. 1-3 Klasse B/F
Welding construction Acc. EN ISO List 1-3 class B/F

Gezeichnet von / Drawn by	Datum / Date	Visum
ma	11 Nov 2015	

Freigabe/approved:

Abtlg.	Datum	Visum
AFSR 435 Design and Plant Engineering		
AFSR 435 Project Manager Process Automation		
AFSR 425 Project Manager Engineering and Sales		
AFSR 435 Project Manager Order Execution		

Zugehoerige Spezifikation Nr: / Associated specification No.:

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www.andritz.com

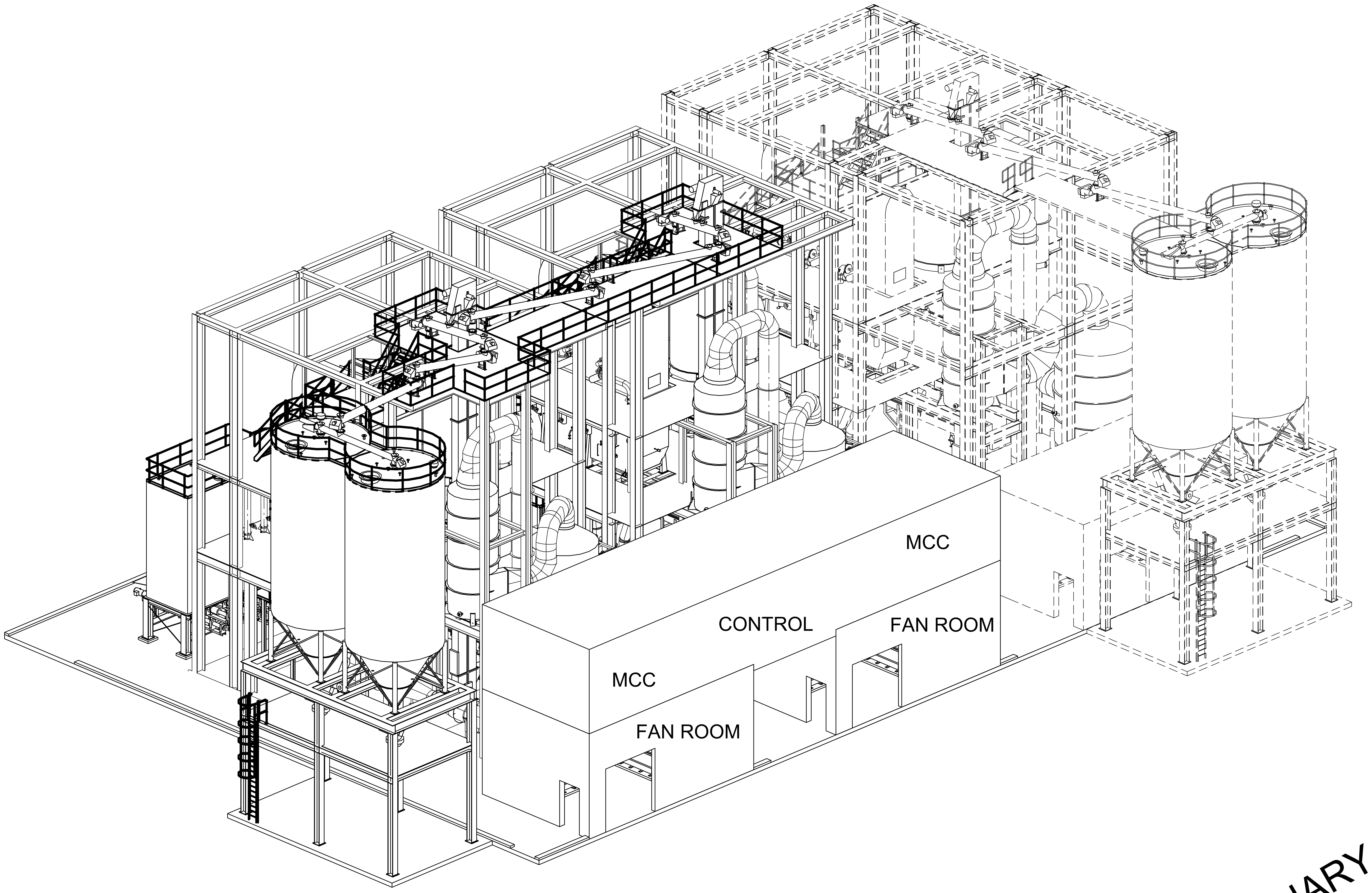
Kunde/Client:

Anlage/Project:

LAYOUT DRAWING
SLUDGE DRYING PLANT
LINE 1 - 2

Auftrag Nr./Order No.	Zeichnungs Nr./Drawing No.	Format	Massstab Scale	Blatt Nr. Sheet No.	Rev.
1802238	506637396V2	A0	1:75	4/5	4

ISO VIEW
M 1:75



PRELIMINARY

Index	Date	Draw.	Chkd.	App.	Beschreibung/Description
4	25.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
3	22.01.2016	ma			LAYOUT UPDATED ON VARIANTE 2
2	20.01.2016	ma			LAYOUT UPDATED ON VARIANTE 1
1	21.12.2015	ma			LAYOUT UPDATED

Stand:
Updated: 04.02.2016

185

Masse sind auf getrenntem Messwerterfassungsblatt nachzuweisen.
Note all measurements are recorded on a separate data sheet

Laengen und Winkelmasse nach DIN ISO 2768 Teil 1 Klasse M Length and angle dimensions DIN ISO 2768 part 1 class M	Form und Lage Toleranzen DIN ISO 2768 Teil 2 Klasse K Form and Position DIN ISO 2768 part 2 class K

Schweisskonstruktionen nach EN ISO 13920 Tab. 1-3 Klasse B/F
Welding construction Acc. EN ISO List 1-3 class B/F

Gezeichnet von / Drawn by	Datum / Date	Visum
ma	11 Nov 2015	
Freigabe/approved:		
Abtlg.	Datum	Visum
AFSR 435 Design and Plant Engineering		
AFSR 435 Project Manager Process Automation		
AFSR 425 Project Manager Engineering and Sales		
AFSR 435 Project Manager Order Execution		
Zugehoerige Spezifikation Nr: / Associated specification No.:		

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Kunde/Client:

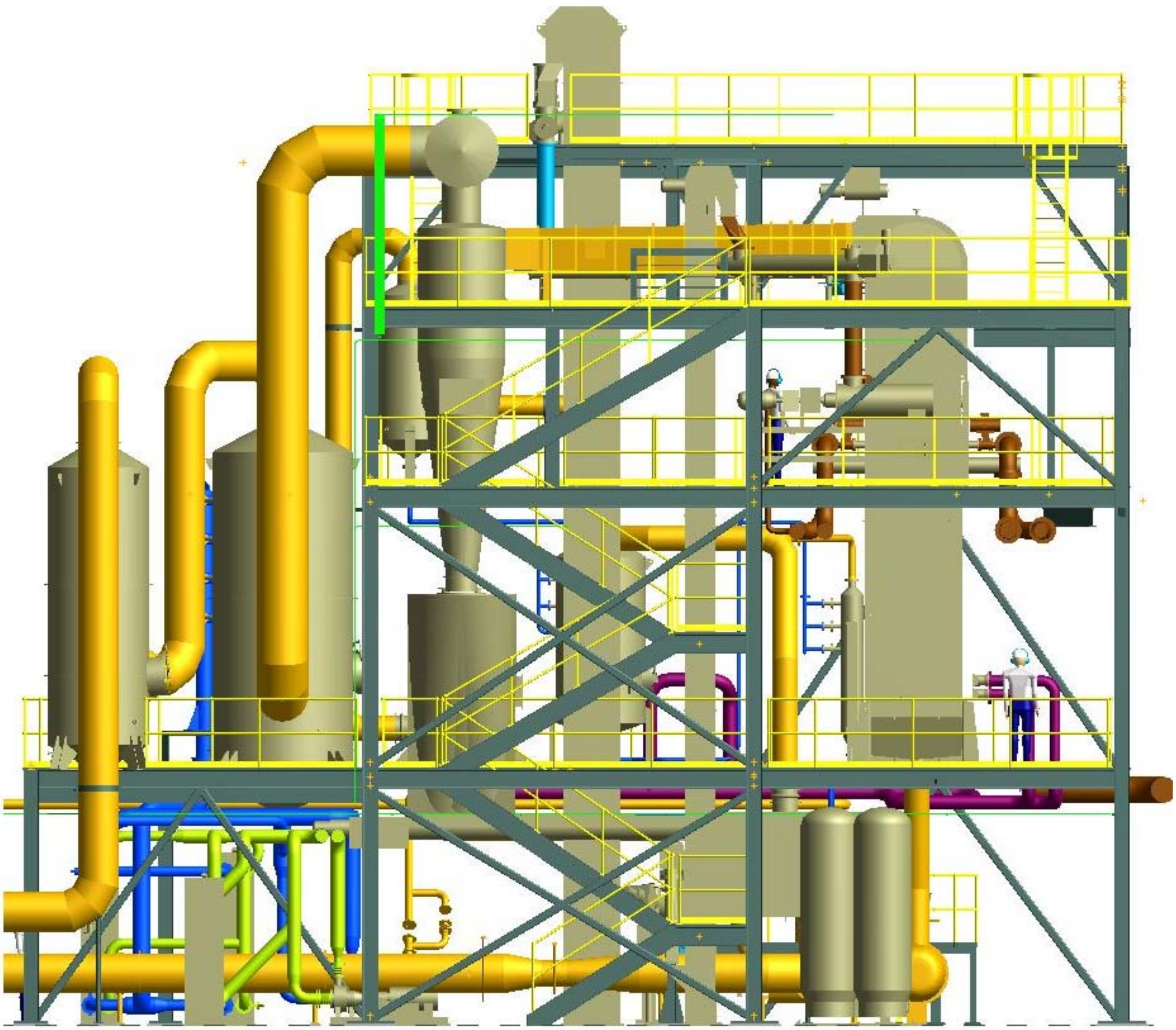
Anlage/Project:

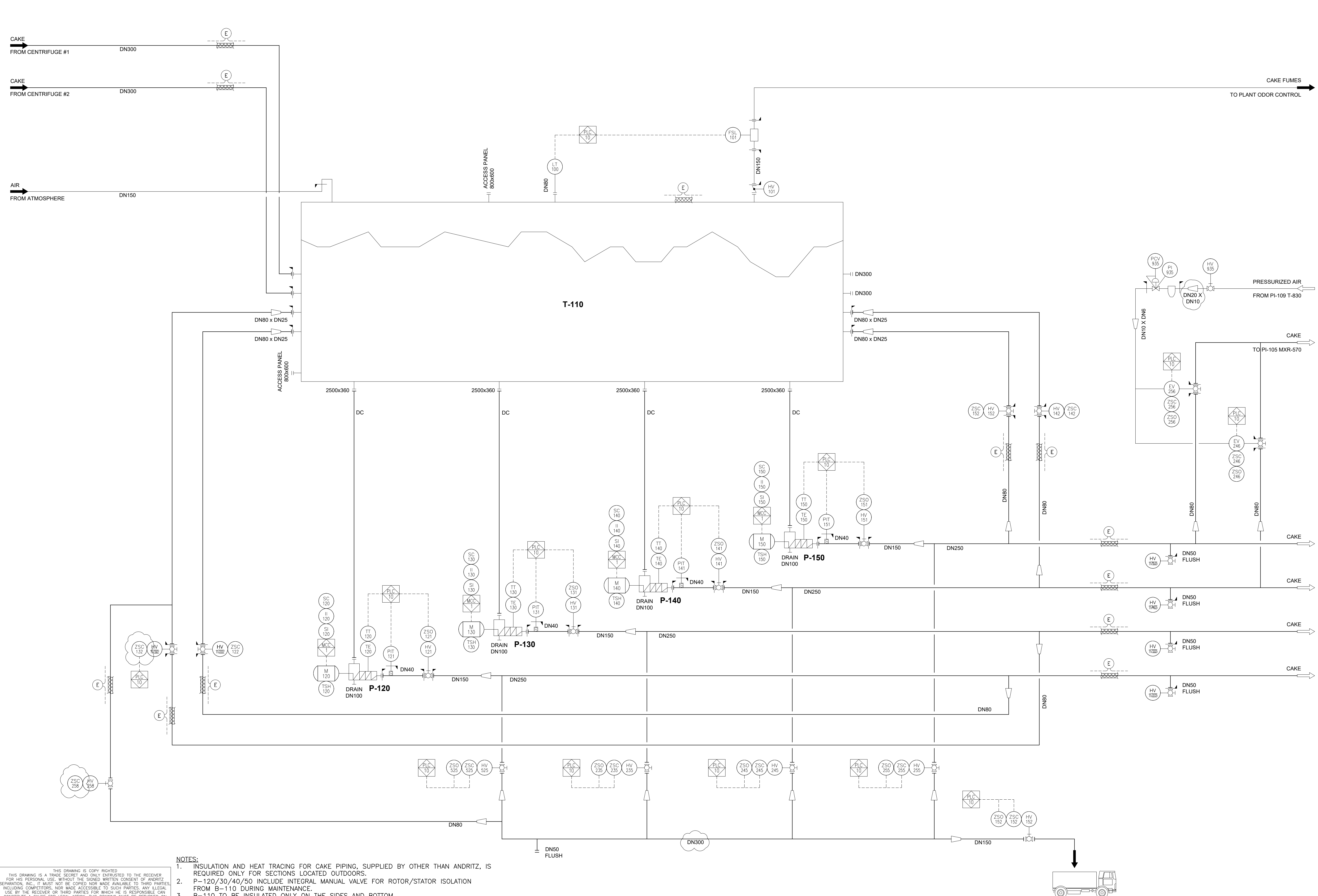
LAYOUT DRAWING
SLUDGE DRYING PLANT
LINE 1 - 2

Auftrag Nr./Order No.	Zeichnungs Nr./Drawing No.	Format	Massstab Scale	Blatt Nr. Sheet No.	Rev.
1802238	506637396V2	A0	1:75	5/5	4

7. PRELIMINARY PROCESS FLOW DIAGRAM (PFD)

The P&I drawings attached are from the Victoria BC facility which is a single FDS-6.0. represented in the drawing below





NOTES:

1. INSULATION AND HEAT TRACING FOR CAKE PIPING, SUPPLIED BY OTHER THAN ANDRITZ, IS REQUIRED ONLY FOR SECTIONS LOCATED OUTDOORS.
2. P–120/30/40/50 INCLUDE INTEGRAL MANUAL VALVE FOR ROTOR/STATOR ISOLATION FROM B–110 DURING MAINTENANCE.
3. B–110 TO BE INSULATED ONLY ON THE SIDES AND BOTTOM.

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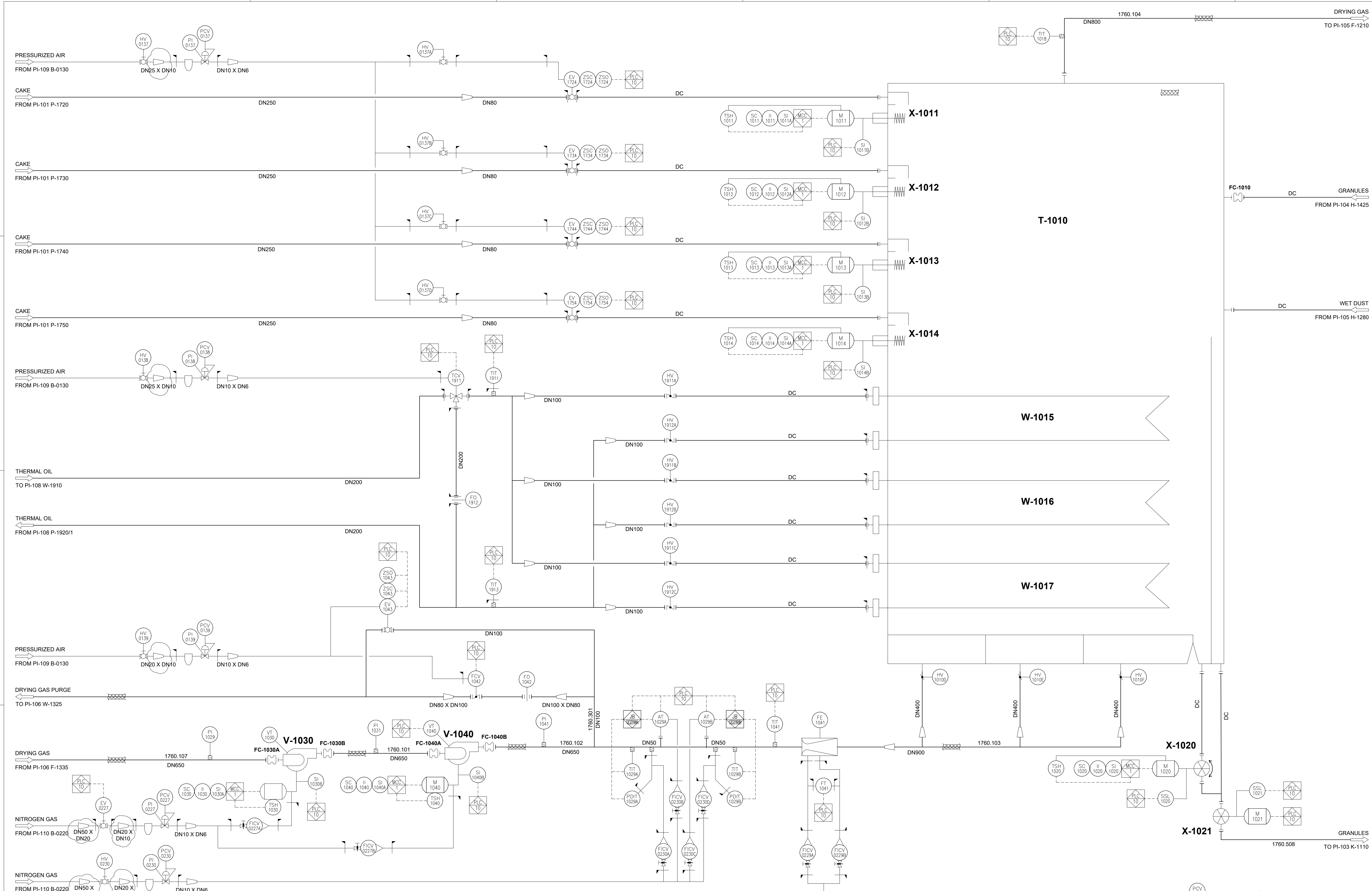
REV	REVISION	DATE
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES; UPDATED TAGGING	08/12/2019
G	DESIGN UPDATES; UPDATED TAGGING	04/24/2019
F	DESIGN UPDATES; UPDATED TAGGING	11/01/2018
E	UPDATED NOTE 1; RELOCATED LINES	09/19/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018

DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE PI–101
SIZE FDS–60

JOB NAME: CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE: P&ID
CAKE TRANSFER

PROJECT NUMBER 831064
DRAWING NUMBER PI–101 REV J
SHEET 1 OF 1



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REV	REVISION	DATE
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES	08/12/2019
G	DESIGN UPDATES	04/16/2019
F	DESIGN UPDATES	11/01/2018
E	DESIGN UPDATES, UPDATED TAGGING	09/19/2018
D	DESIGN UPDATES, UPDATED TAGGING	07/12/2018
C	DESIGN UPDATES	07/02/2018

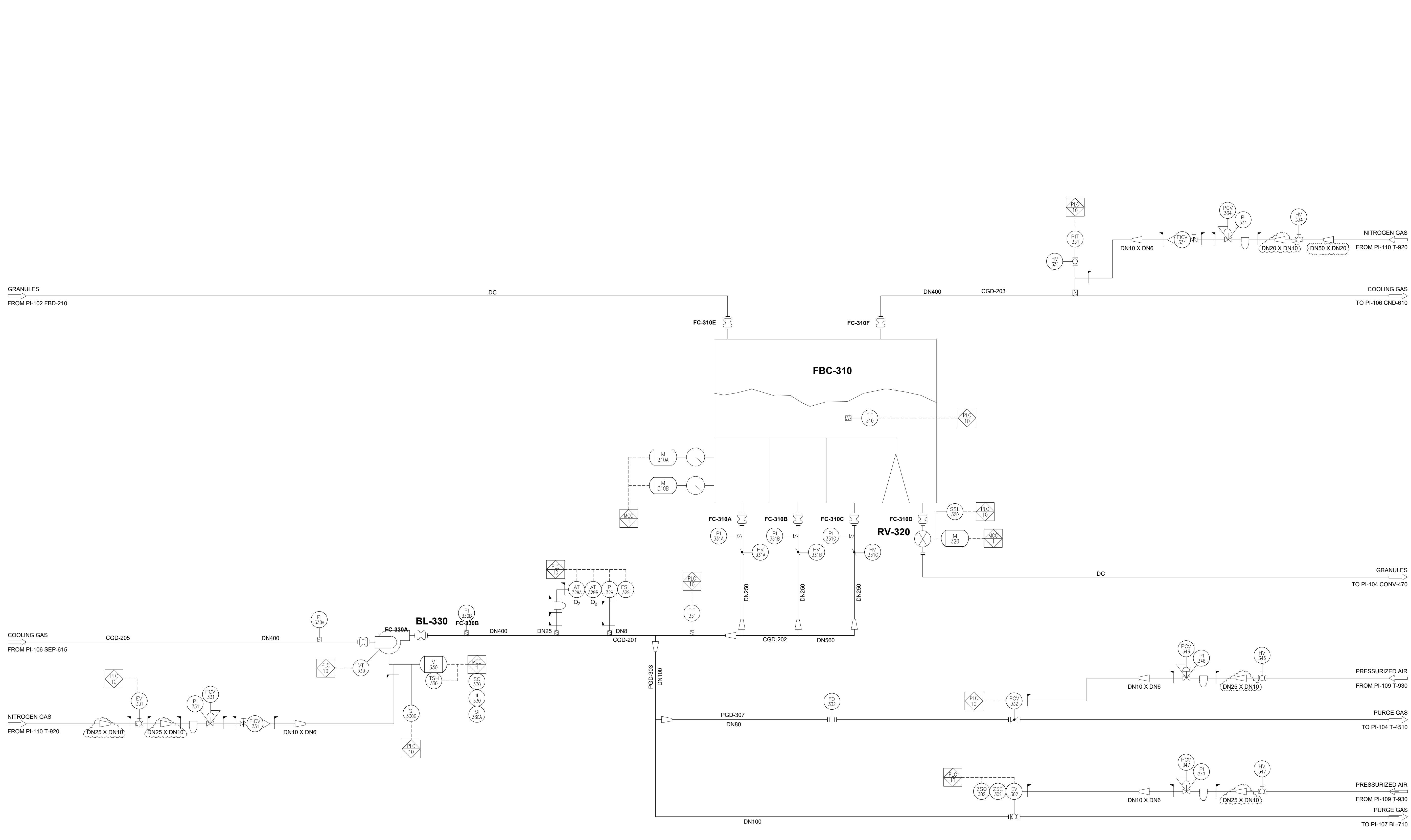
DRAWN BY: RT
DATE: 03/09/18
CHECKED BY:
DATE:
APPROVED BY:
DATE:
SCALE: NTS
FILE PI-102
SIZE FDS-60

JOB NAME
CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE
P&ID
DRYING

PROJECT NUMBER 831064
DRAWING NUMBER PI-102
REV J
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-102.dwg



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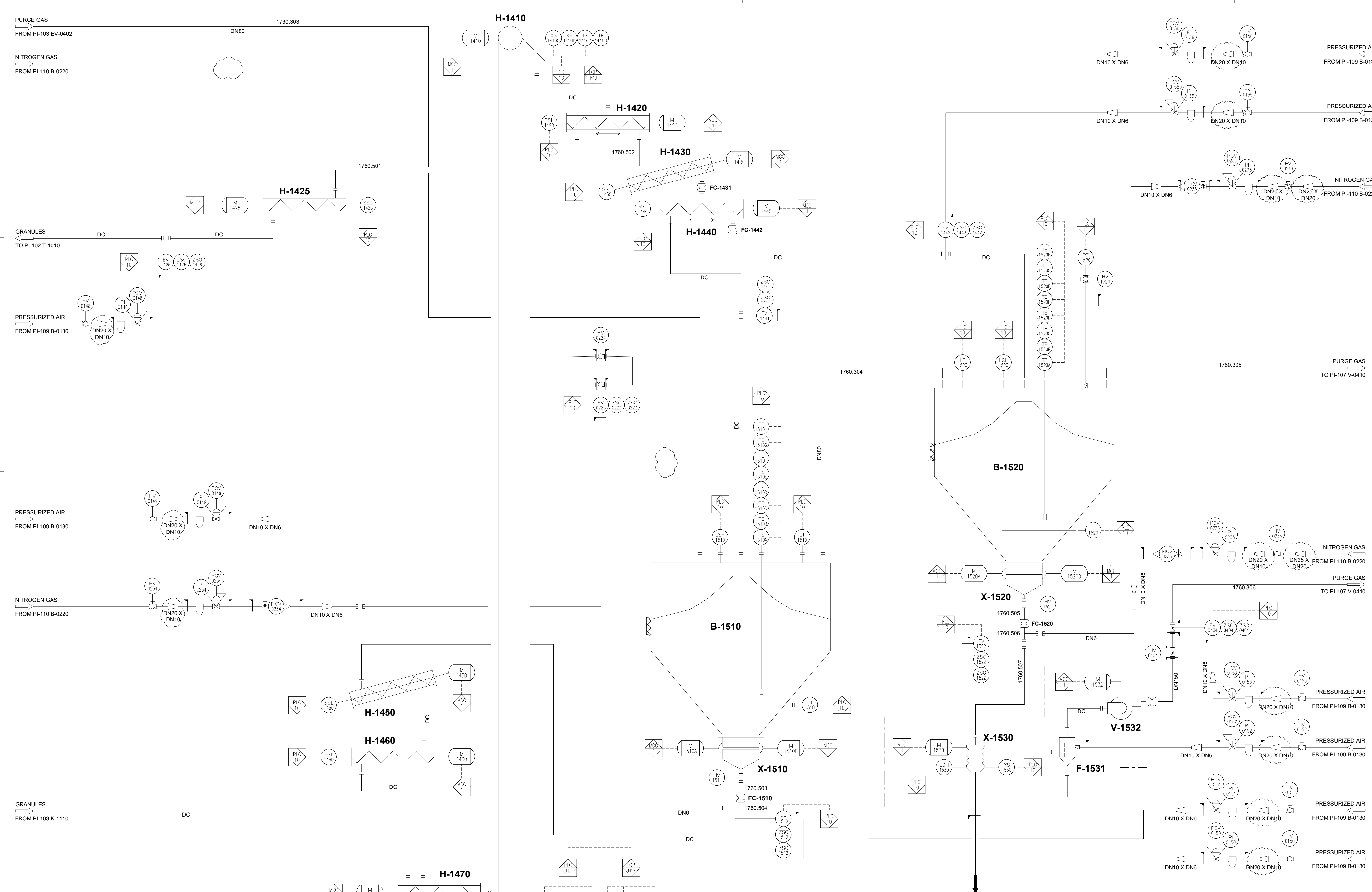
REV	REVISION	DATE
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES	08/12/2019
G	DESIGN UPDATES	04/15/2019
F	DESIGN UPDATES	11/01/2018
E	DESIGN UPDATES	09/19/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018

DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE: PI-103
SIZE: FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT VICTORIA, BC, CANADA
TITLE: P&ID COOLING

PROJECT NUMBER: 831064
DRAWING NUMBER: PI-103 REV: J
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-103.dwg



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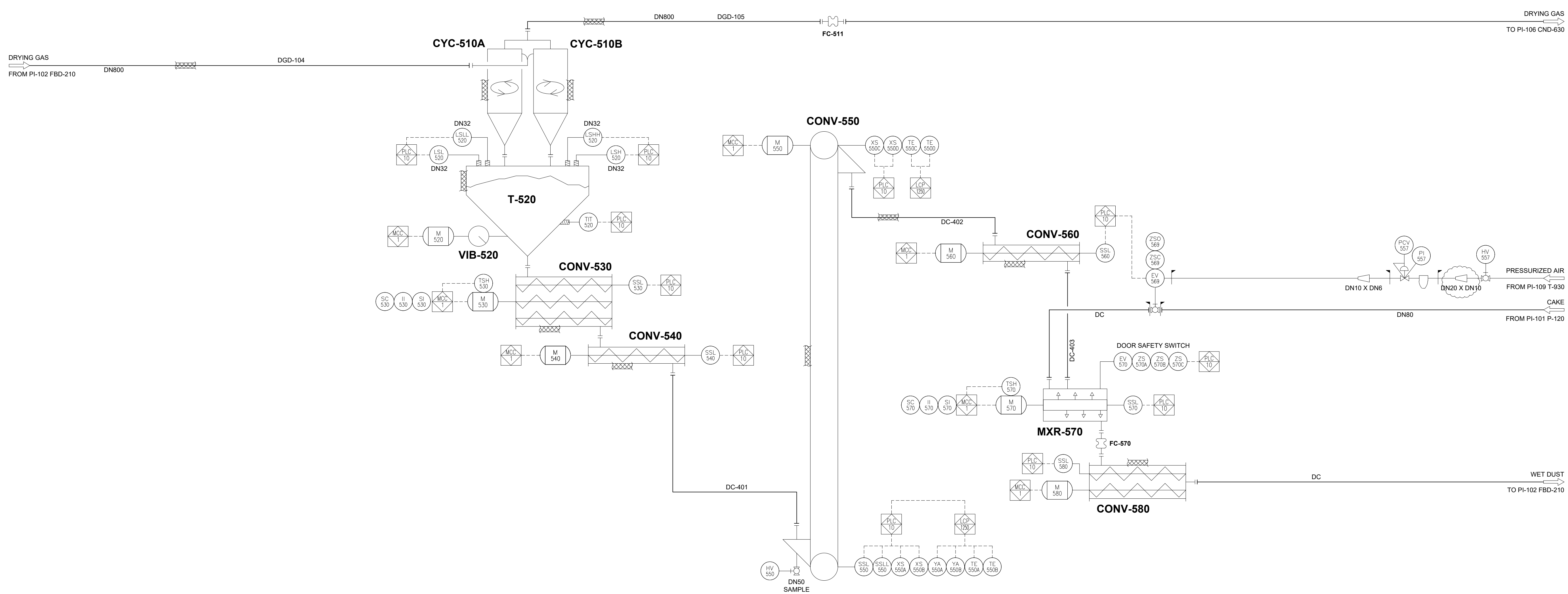
REV	REVISION	DATE
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES	08/12/2019
G	DESIGN UPDATES	04/15/2019
F	DESIGN UPDATES	11/01/2018
E	DESIGN UPDATES	09/18/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018

DRAWN BY: RT
DATE: 03/09/18
CHECKED BY:
DATE:
APPROVED BY:
DATE:
SCALE: NTS
FILE PI-104
SIZE FDS-60

JOB NAME
CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE
P&ID
GRANULE TRANSFER

PROJECT NUMBER 831064
DRAWING NUMBER PI-104 REV J
SHEET 1 OF 1



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REV	REVISION	DATE
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES	08/12/2019
G	DESIGN UPDATES	04/15/2019
F	DESIGN UPDATES	11/01/2018
E	DESIGN UPDATES	09/19/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018

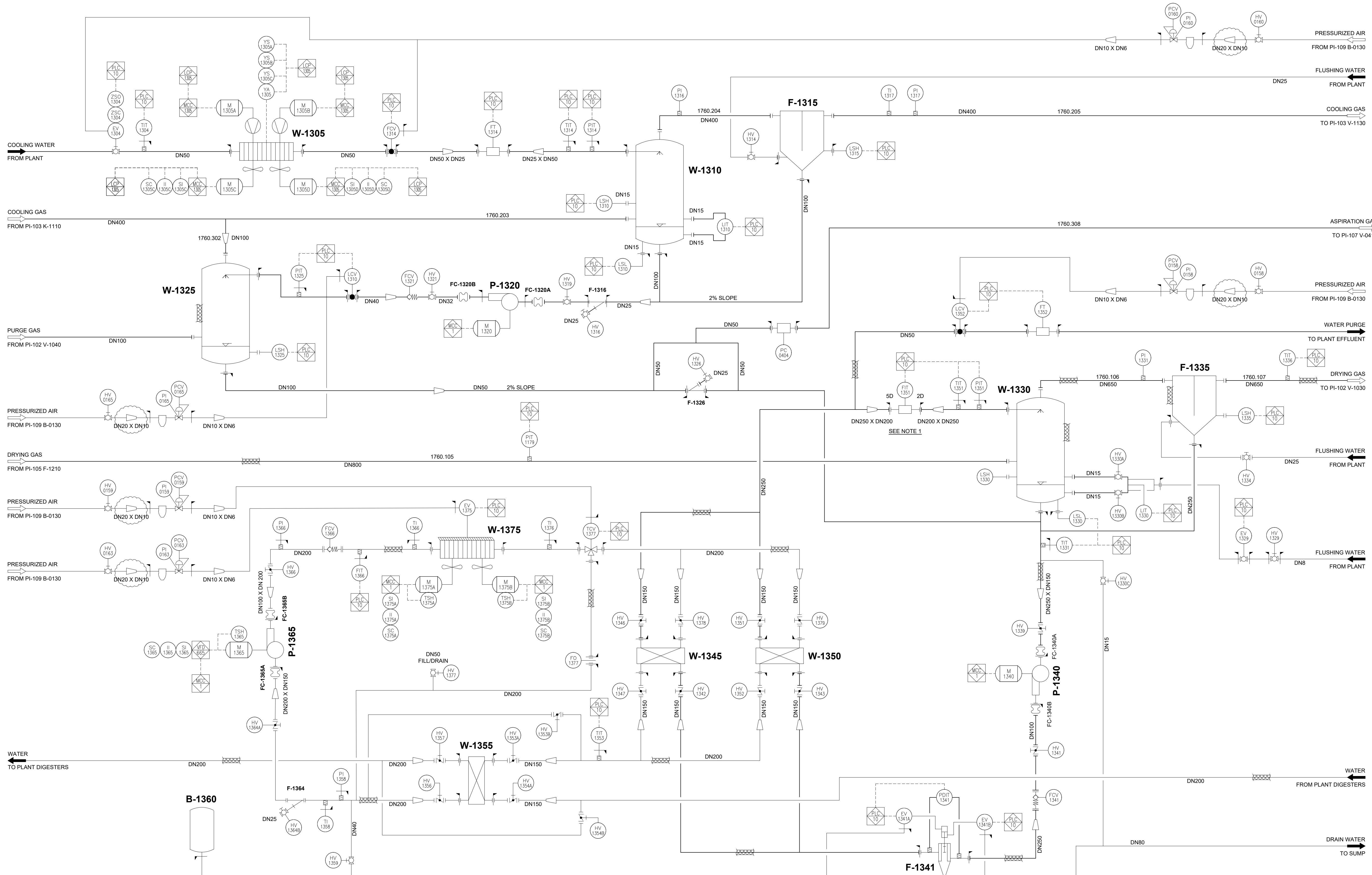
DRAWN BY: RT — DATE: 03/09/18
CHECKED BY: — DATE:
APPROVED BY: — DATE:
SCALE: NTS — FILE: PI-105
SIZE: FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE: P&ID
DUST TRANSFER

PROJECT NUMBER: 831064
DRAWING NUMBER: PI-105 — REV: J
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-105.dwg



NOTES:
1. MINIMUM STRAIGHT LENGTH OF 5 PIPE DIAMETERS UPSTREAM AND 2 PIPE DIAMETERS DOWNSTREAM REQUIRED FOR FIT-1351.

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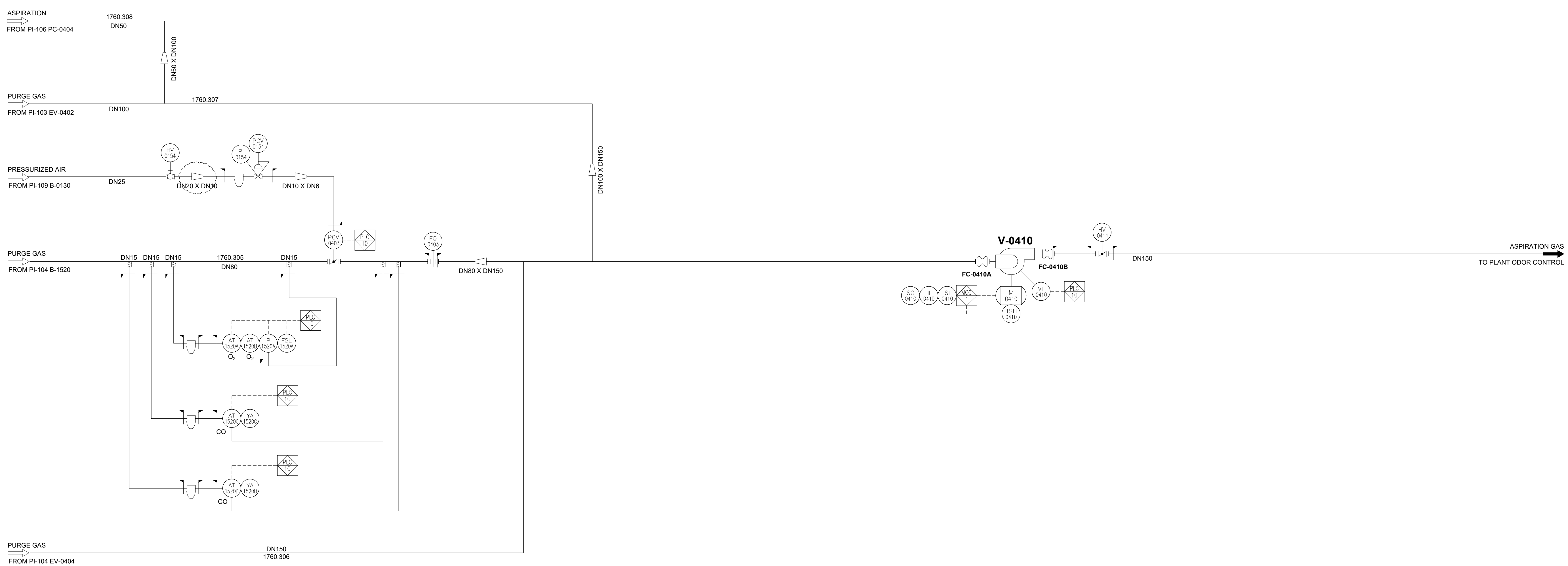
J	DESIGN UPDATES	09/18/2019
H	DESIGN UPDATES	08/12/2019
G	DESIGN UPDATES	04/15/2019
F	DESIGN UPDATES	11/01/2018
E	DESIGN UPDATES	09/18/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018

DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE: PI-106
SIZE
FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT VICTORIA, BC, CANADA
TITLE: P&ID CONDENSATION

PROJECT NUMBER: 831064
DRAWING NUMBER: PI-106 REV: J
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-106.dwg



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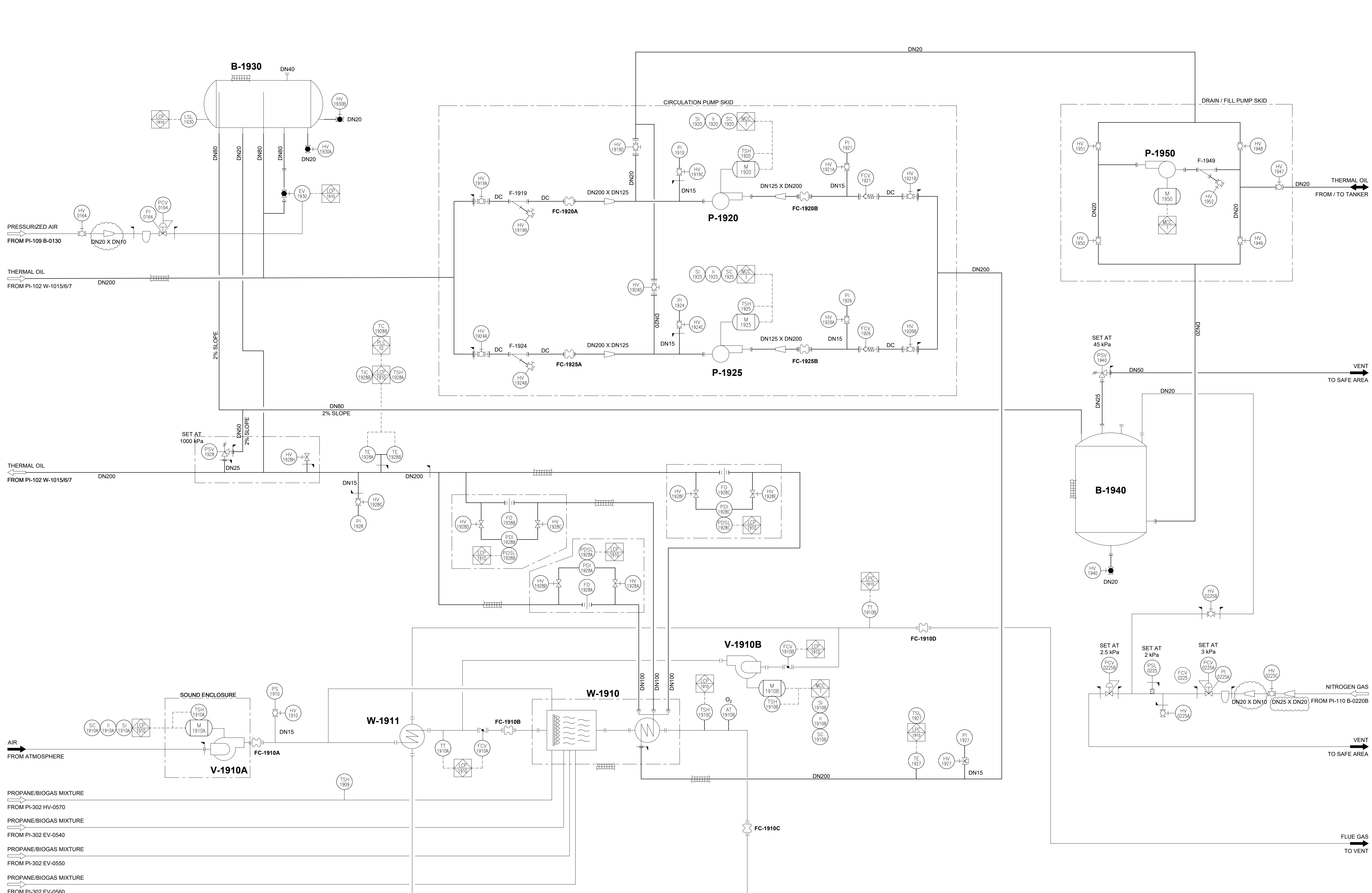
REV	REVISION	DATE
H	DESIGN PDATED	09/18/2019
G	DESIGN PDATED	08/12/2019
F	CORRECTED TAGGING	04/15/2019
E	CORRECTED/ADDED TAGGING	11/01/2018
D	DESIGN UPDATES	07/12/2018
C	DESIGN UPDATES	07/02/2018
B	UPDATED TAGGING	05/11/2018

DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE PI-107
SIZE FDS-60

JOB NAME
CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE
P&ID
ASPIRATION

PROJECT NUMBER 831064
DRAWING NUMBER PI-107 REV H
SHEET 1 OF 1



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REV	REVISION	DATE
H	DESIGN UPDATES	09/18/2019
G	DESIGN UPDATES	08/12/2019
F	DESIGN UPDATES	04/15/2019
E	UPDATED TAGGING	11/01/2018
D	DESIGN UPDATES	09/18/2018
C	DESIGN UPDATES	07/12/2018
B	UPDATED TAGGING; ADDED SCOPE FLAGS	05/11/2018

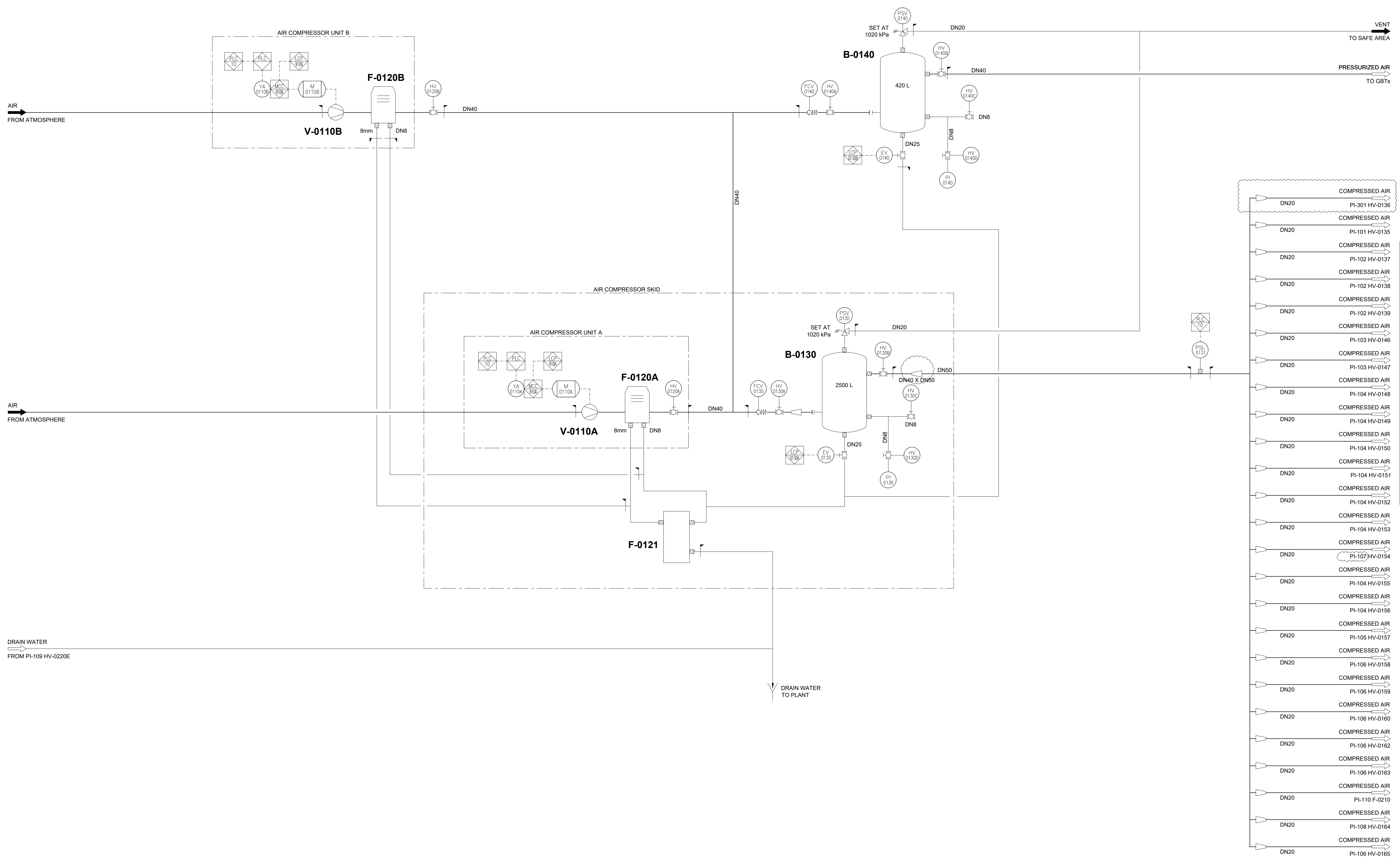
DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE: PI-108
SIZE

FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT VICTORIA, BC, CANADA

TITLE: P&ID THERMAL OIL LOOP

PROJECT NUMBER 831064
DRAWING NUMBER PI-108 REV H
SHEET 1 OF 1



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REV	REVISION	DATE
H	DESIGN UPDATES	09/18/2019
G	DESIGN UPDATES	08/12/2019
F	DESIGN UPDATES; UPDATED TAGGING	04/15/2019
E	DESIGN UPDATES; UPDATED TAGGING	11/01/2018
D	UPDATE CALLOUT	09/19/2018
C	DESIGN UPDATES	07/12/2018
B	ADDED ROUTING; UPDATED TAGGING	05/11/2018

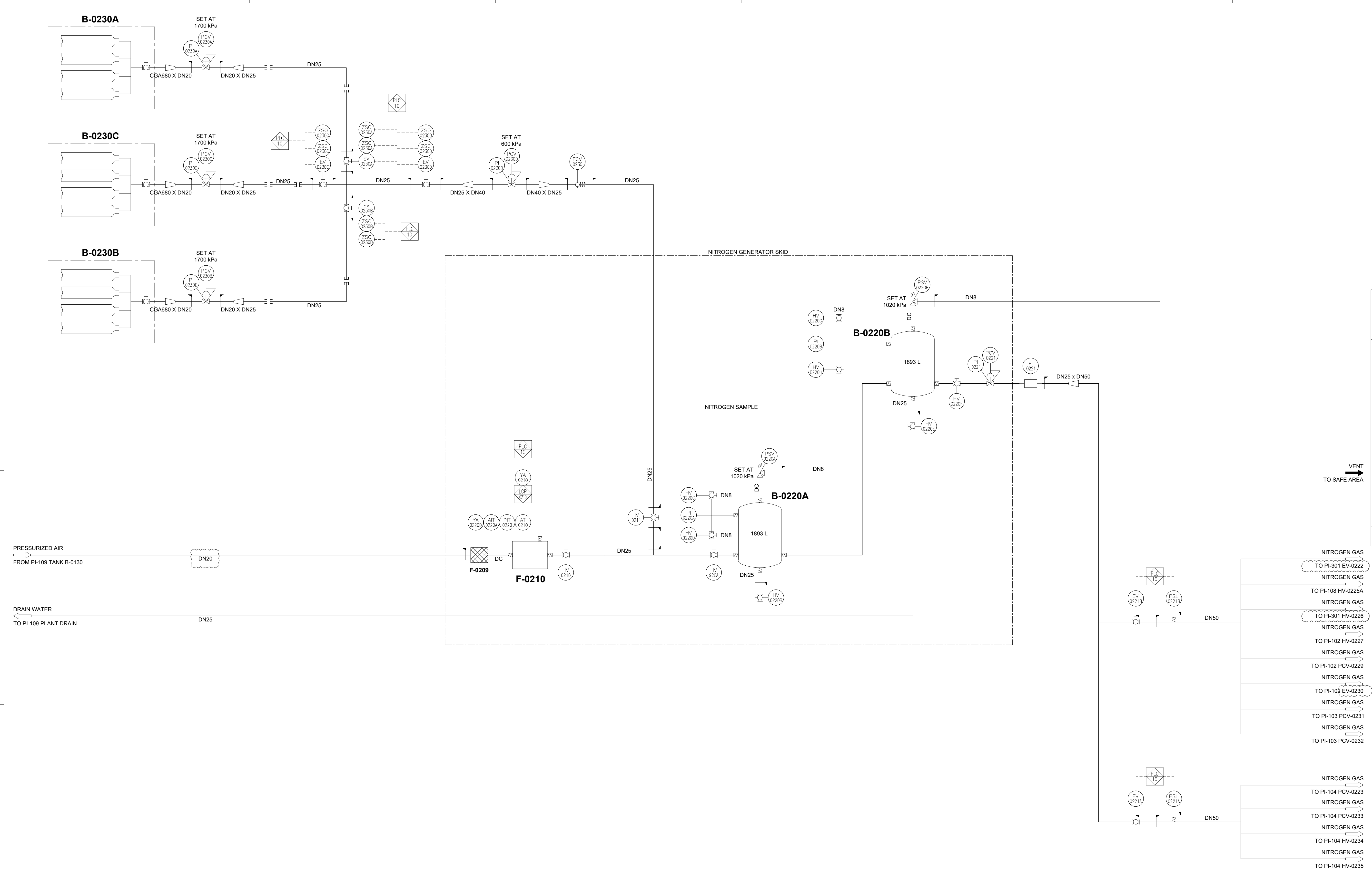
DRAWN BY: RT DATE: 03/09/18
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE PI-109
SIZE FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE: P&ID
COMPRESSED AIR

PROJECT NUMBER 831064
DRAWING NUMBER PI-109 REV H
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-109.dwg



NOTES:
1. B-0230A, B-0230B, AND B-0230C MUST INCLUDE A MINIMUM COMBINED VOLUME OF 300 Nm^3.

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REV	REVISION	DATE
L	DESIGN UPDATES	09/19/2019
K	DESIGN UPDATES	08/27/2019
J	DESIGN UPDATES	08/12/2019
H	DESIGN UPDATES	07/11/2019
G	DESIGN UPDATES	06/17/2019
F	DESIGN UPDATES	04/15/2019
E	TAGGING UPDATES	11/01/2018

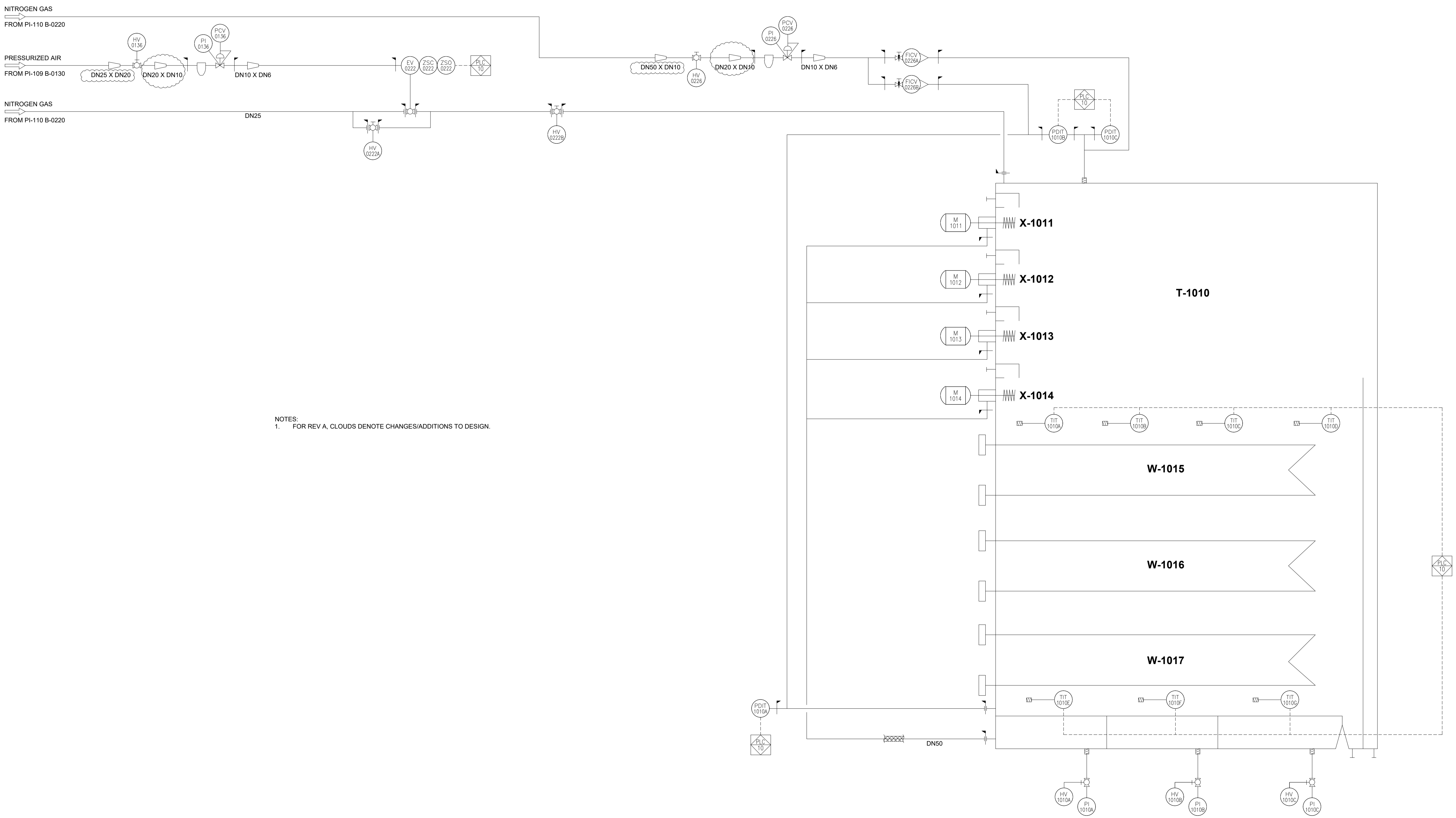
DRAWN BY: RT
DATE: 03/09/18
CHECKED BY:
DATE:
APPROVED BY:
DATE:
SCALE: NTS
FILE: PI-110
SIZE

FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE: P&ID
NITROGEN

PROJECT NUMBER: 831064
DRAWING NUMBER: PI-110
REV: L
SHEET 1 OF 1



NOTES:
1. FOR REV A, CLOUDS DENOTE CHANGES/ADDITIONS TO DESIGN.

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REV	REVISION	DATE
C	UPDATED TAG	09/19/2019
B	UPDATED TAG	08/12/2019
A	INITIAL RELEASE	04/16/2019

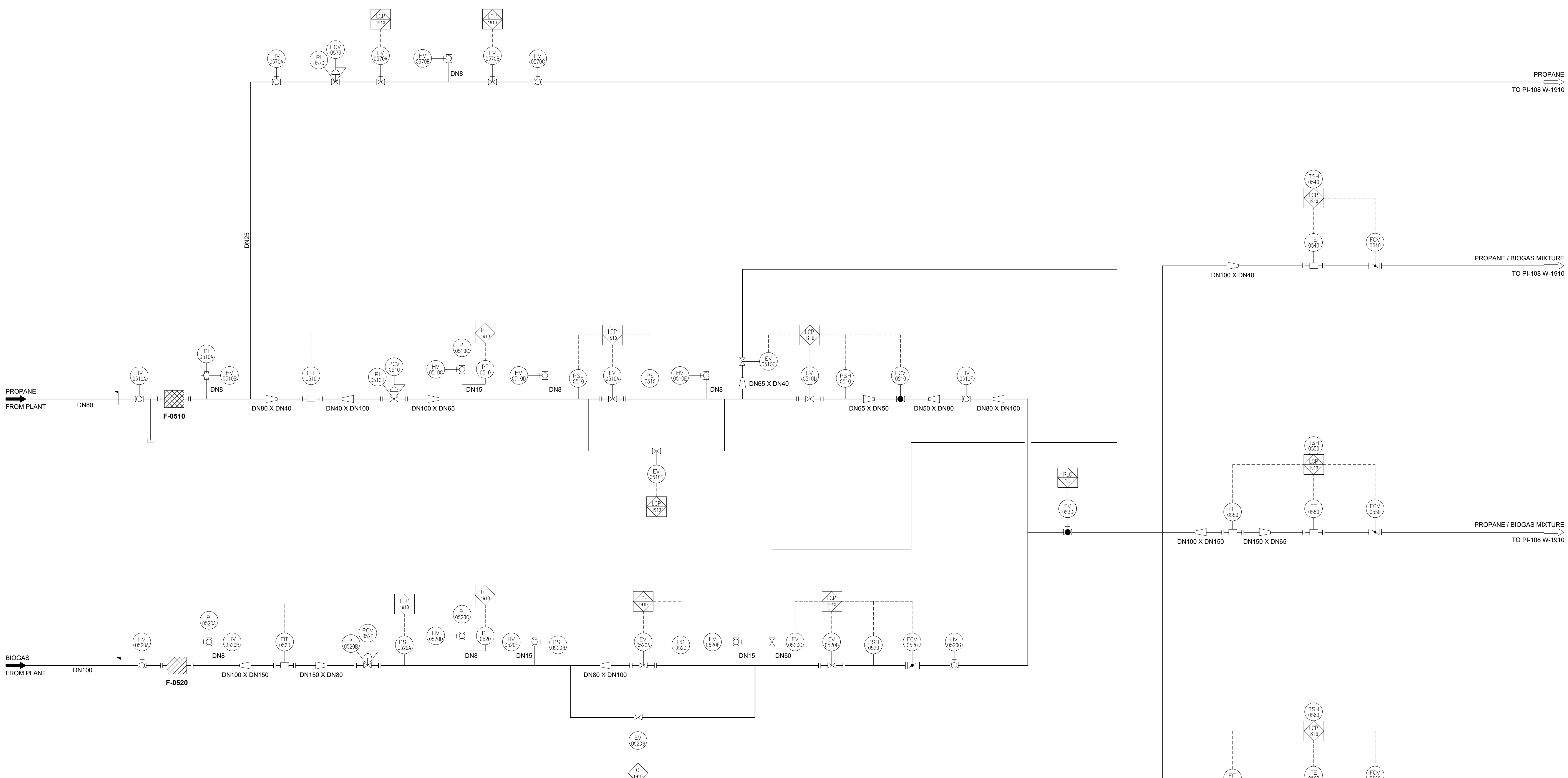
DRAWN BY: RT DATE: 04/16/2019
CHECKED BY: DATE:
APPROVED BY: DATE:
SCALE: NTS FILE PI-301
SIZE FDS-60

JOB NAME CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE P&ID
FLUID BED DRYER DETAIL

PROJECT NUMBER 831064
DRAWING NUMBER PI-301 REV C
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-301.dwg



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REV	REVISION	DATE
A	INITIAL RELEASE	08/14/2019

DRAWN BY: WCH — DATE: 07/15/19
CHECKED BY: — DATE:
APPROVED BY: — DATE:
SCALE: NTS — FILE: PI-108
SIZE: FDS-60

JOB NAME: CAPITAL REGIONAL DISTRICT
VICTORIA, BC, CANADA

TITLE: P&ID
THERMAL OIL HEATER FUEL TRAIN

PROJECT NUMBER: 831064
DRAWING NUMBER: PI-302 — REV: A
SHEET 1 OF 1

\\ARLSMS003\Arlington\Jobs\Active\831064 CRD\CRD FBD\Drawings\PID\PI-302.dwg

8. FLUID BED DRYING SYSTEM REFERENCE LIST

Reference List - ANDRITZ Drying Plants for sludge   FDS Fluid Bed Dryers

Award	Client	Plant Location	Country	Type	Number of drying lines	Evaporation per line Capacity kg H2O/h	Total Evaporation Capacity kg H2O/h	Start up	status of operation
2018	Shanghai Sewage Company	Shanghai	China	FDS	9	9,000	54,000	2020	in operation
2018	Synagro/Maple/Bird JV	Victoria	Canada	FDS	1	6,000	6,000	2020	in execution
2017	Fisia for Istanbul Water and Sewerage Administration	Istanbul	Turkey	FDS	2	6,770	13,540	2018	in operation
2012	ARA Region Bern AG	Bern	Switzerland	FDS	1	3,430	3,430	2015	in operation
2008	Shanghai Sewage Company	Shanghai	China	FDS	3	2,830	8,490	2011	in operation
2006	Beijing Municipal Drainage Group Co	Qinghe WWTP Beijing	China	FDS	2	6,500	13,000	2009	in operation
2005	EDAR Fuengirola	Fuengirola	Spain	FDS	1	2,350	2,350	2008	stopped due to the costs of fuel
2005	Infilco for Canal de Isabel II	Madrid - Loeches	Spain	FDS	2	5,000	10,000	2010	in operation
2002	Shanghai Suzhou Creek Rehabilitation	Shidongkou	China	FDS	1	6,000	6,000	2004	in operation
2002	Stadt Memmingen Gruppenklärwerk	Memmingen	Germany	FDS	1	1,500	1,500	2004	stopped
2002	Aquafin	Leuven	Belgium	FDS	1	3,700	3,700	2003	in operation
2001	VATech Wabag for ARA Region Bern	Bern	Switzerland	FDS	1	3,175	3,175	2002	replaced by Bern 2
2000	VA Tech Wabag for City of Putrajaya	Putrajaya	Malaysia	FDS	1	3,000	3,000		not in operation, no sludge
2000	Northshore Sanitary District NSSD	Waukeegan / IL	USA	FDS	1	5,800	5,800	2006	in operation
2000	Aquafin	Houthalen	Belgium	FDS	1	3,700	3,700	2003	in operation
2000	IDA FOCE TICINO	Locarno	Switzerland	FDS	1	850	850	2003	in operation
2000	Zuiveringschap Limburg	Susteren	Netherland	FDS	1	8,300	8,300	2002	in operation
1999	Black & Veach for Escambia County Utilities Authority	Pensacola / FL	USA	FDS	2	3,450	6,900		stopped
1999	SGT for ARUSA	Rubi	Spain	FDS	1	3,000	3,000	2001	in operation

Award	Client	Plant Location	Country	Type	Number of drying lines	Evaporation per line Capacity kg H2O/h	Total Evaporation Capacity kg H2O/h	Start up	status of operation
1998	ARA Eger	Eger	Hungary	FDS	1	1,200	1,200	2000	out of operation
1998	ARA Chur	Chur	Switzerland	FDS	1	2,000	2,000	1999	in operation
1998	ARA Aalborg	Aalborg	Denmark	FDS	1	3,650	3,650	2000	in operation
1997	Yorkshire Water	Huddersfield	Great Britain	FDS	1	1,400	1,400		stopped
1996	Introtec GmbH for City Rastatt	Rastatt	Germany	FDS	1	1,100	1,100	1997	dismounted
1995	Stadtentwässerung Göppingen	Göppingen	Germany	FDS	1	2,125	2,125	1997	stopped
1995	SPC Shanghai Petro-chemical Complex	Shanghai	China	FDS	1	6,930	6,930		stopped
1995	KSE	Löhne	Germany	FDS	1	2,000	2,000		dismounted
1994	Hoogheemraad-schap	Beverwijk	Netherland	FDS	2	6,000	12,000	1996	in operation
1994	AVA Augsburg	Augsburg	Germany	FDS	1	4,400	4,400		stopped
1994	Introtec GmbH for City Lahr	Lahr	Germany	FDS	1	1,400	1,400	1994	dismounted
1994	Introtec GmbH for City Offenburg	Offenburg	Germany	FDS	1	1,400	1,400	1994	dismounted
1992	Stadt Leutkirch	Leutkirch	Germany	FDS	1	1,200	1,200	1992	stopped
1990	ARA Dornbirn	Dornbirn	Austria	FDS	1	1,600	1,600	1992	in operation
1987	Sonitherm	Nice	France	FDS	1	2,260	2,260		??
1986	MVA Ingolstadt	Ingolstadt	Germany	FDS	1	2,310	2,310		dismounted

ENGINEERED SUCCESS

9. LITERATURE


Andritz high solids centrifuge facility, Dana Point, CA


Integrated dewatering and drying, Ocean County, NJ


Regional Drying Plant Manatee County, Bradenton, FL


Integrated dewatering and drying facility, Sacramento, CA

ANDRITZ designs and builds dewatering and drying facilities around the world, with 35 facilities in North America. ANDRITZ can provide equipment supply only or complete design or build services as required.

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ANDRITZ Fluid Bed Drying System FDS

Tour of North Shore WRD, Zion, IL


Houthalen, Belgium
15 years operations history
Unattended nights, weekends

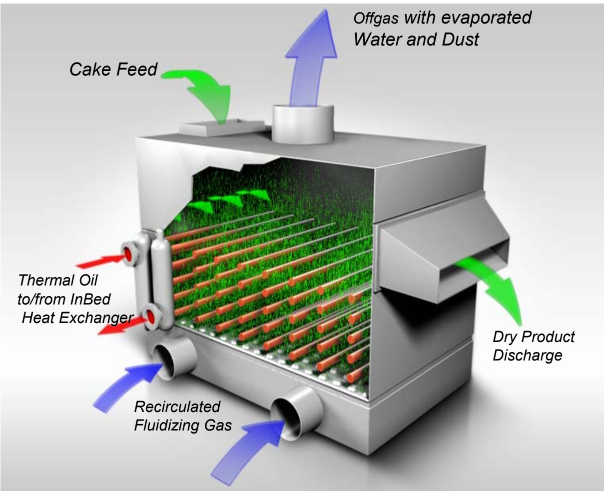
- *20+ Fluid Bed Dryer Facilities worldwide, many with 10-15 years operations history, including landmark projects at:*
  - *Amsterdam*
  - *Beijing*
  - *Shanghai (2 sites)*
  - *Brussels region (3 sites)*
  - *North Shore, Chicago IL*
- *7/24 and >7,500 hours per year operations*
- *Unattended nights and weekends*
- *Class A granules*
- *Ultra-low emissions (<200 ACFM)*
- *Compact footprint*
- *Backed by the most experienced Dewatering & Drying Service group in North America.*


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..

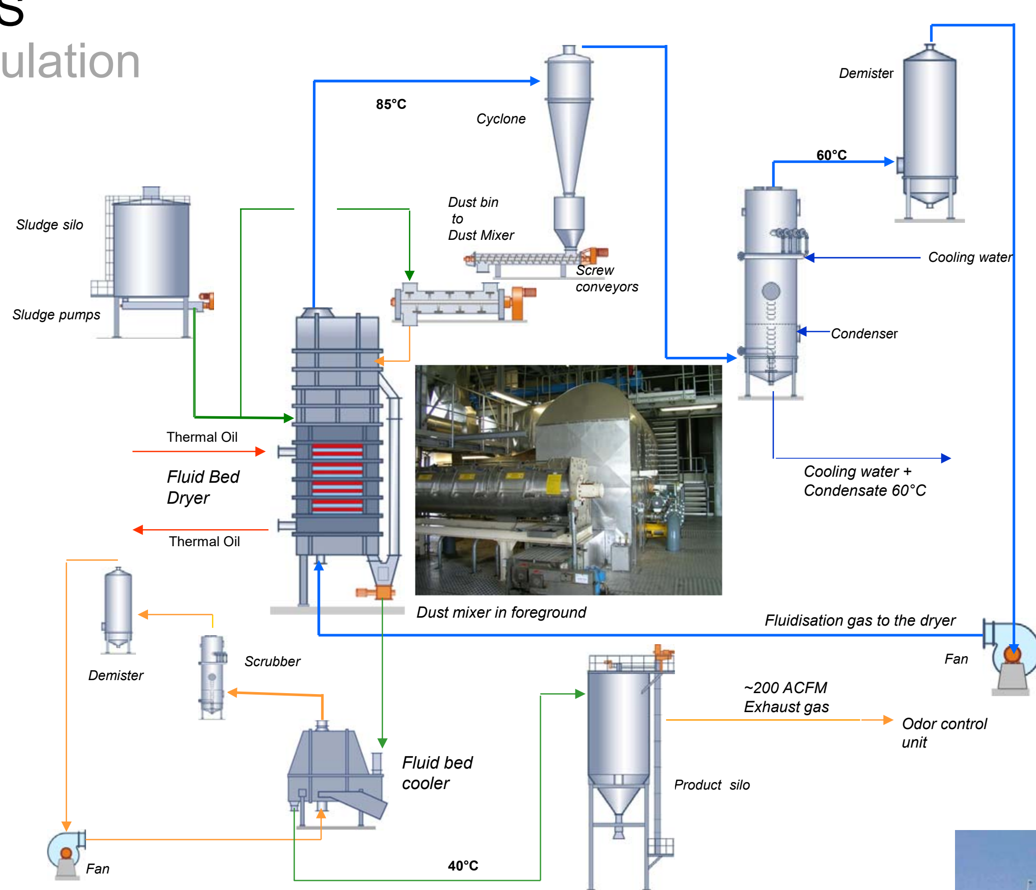
Fluid Bed Drying System FDS

Single Step Drying and Granulation

ANDRITZ Separation



Fluid Bed with direct injection nozzles in foreground



Dust mixer in foreground

Spray Condenser with heat recovery pumps and heat exchangers (up to 75% heat recovery as hot water)

Fluid Bed cooler

Class A granules

Product Silos (foreground)

Sustainable productivity

Creating environmentally friendly energy from municipal sludge

SUCCESS STORY:
FLUIDIZED BED DRYING SYSTEM AT ARA REGION BERN AG, BERNE, SWITZERLAND

▲ Dryer middle section

The challenge: Produce CO_2-neutral energy from waste and wastewater

Already a leader in environmental sustainability, ara region bern ag (arabern) in Switzerland had an ambitious plan to produce renewable energy. Their plant has used digestion gas for heating processes in the wastewater treatment plant. But a new concept would take the plant's energy efficiency and environmental sustainability to the next level.

To accomplish their goals to convert biogas into CO_2-neutral biomethane for direct injection into the gas grid, an entirely new sludge drying plant was required to:

- use 16-bar steam (instead of digestion gas) from the incinerator for sludge drying,
- dry an annual 38,000 tons of sludge with 29% DS to 90% dry solids content,
- use the dried product coming from the dryer as a substitiute fossil fuel for the cement industry.

The client had pre-selected a Fluidized Bed Drying System (FDS) on the basis of excellent experience with their existing ANDRITZ SEPARATION fluidized bed dryer plant over the past 13 years. In addition to its proven reliability, the technology would be ideal in achieving the new plant's goals for high automation, high safety levels guaranteed by inert gas conditions at each stage of operation, and high thermal efficiency using steam condensate.

Our solution: A new Fluidized Bed Drying System (FDS)

Working closely together with arabern, ANDRITZ SEPARATION has helped to develop a new turnkey electromechanical system to facilitate the new CO_2-neutral operations. The compact process design utilizes closed gas loops to ensure energy-efficient and environmentally friendly operation with minimal amounts of exhaust gas.

The new system is highly automated, requiring only one operator during daytime operations and no operator attendance during nights and weekends. Low maintenance and operating costs are also assured due to the small number of moving parts, which contribute to reduced wear and tear.

Along with the upgraded, steam-powered system design, ANDRITZ SEPARATION was able to improve the previous plant design in cooperation with a team of highly experienced operators, particularly in terms of optimized maintenance conditions and wear resistance.

Results: 8.1 million acm of biomethane gas per year

The new steam-heated sludge drying system now makes it possible for more than 8 million acm per year to be upgraded to biomethane and fed directly into the natural gas grid of the city of Berne. The biomethane, which has properties similar to those of natural gas, has made it possible to significantly reduce the combined CO_2 emissions of the waste incineration and wastewater treatment plants. Additionally, all wastewater sludge is now dried and transferred as sludge granulate for use as a fossil-fuel substitute or as a mineral product for the cement industry.

On top of being able to produce 100% renewable energy from sludge for the city's gas grid, arabern has also considerably reduced operation costs for sludge drying and disposal. As the sludge market continues to evolve with new technologies and strategies for hydrothermal carbonization, gasification, phosphorous removal, and more, the arabern plant stands as a major milestone in sustainable wastewater system design.

8.1
MILLION ACM OF CO_2-NEUTRAL BIOMETHANE

100%
RENEWABLE ENERGY PRODUCTION FROM SLUDGE TO ENERGY

"Over the past 13 years, we have experienced excellent operation results with the ANDRITZ SEPARATION fluidized bed technology. Based on this experience, and in order to achieve our own high expectations in terms of energy consumption, cost, and environmental sustainability, we have chosen to integrate this safe and reliable technology into the new energy concept of arabern."

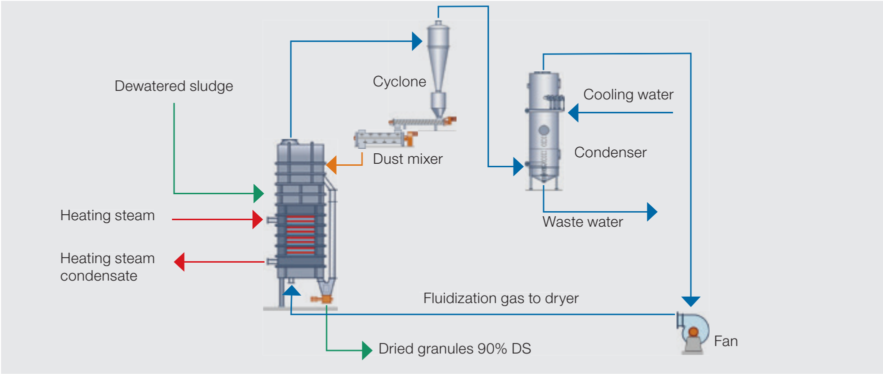
BEAT AMMANN
DIRECTOR, ARABERN
SWITZERLAND

ENVIRONMENT

ANDRITZ Separation

Key equipment

▲ Dryer hood with sludge feed



▲ Flow sheet for fluidized bed drying system (FDS)

Benefits of the fluidized bed drying system

- High reliability and availability
- Compact plant design
- Closed gas loops
- Energy efficient and environmentally friendly
- Very low exhaust gas amounts
- High level of automation combined with a mature plant control concept
- Unmanned plant operation during nights and over weekends
- High safety level due to the inert gas conditions in the drying plant

Product specification	
Dryer type	Fluidized bed dryer, complete electro-mechanical part
Sludge feed capacity	11,000 t DS/a with 29 % DS
Water evaporation	3,430 kg/h
Heat source	Heating steam 16 bar
Operation per week	24 h/day, 7 days/week, no operator attendance during the night and over weekends
Final product	Granules >90 % DS

What's your separation challenge?

ASK YOUR SEPARATION **SPECIALIST**

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SEPARATION

ENHANCING SUSTAINABILITY BY PROVIDING A WIDE RANGE OF RECYCLING OPTIONS

ANDRITZ SLUDGE DRYING SYSTEMS

ANDRITZ

ENGINEERED SUCCESS

Paddle, belt, fluid bed, or drum? ATEX/NFPA, Class A, or low-grade waste heat? Whatever your preferences and requirements, ANDRITZ offers the industry's widest range of safe and efficient drying solutions – all tried and proven in the world's largest and most complex plants.

Comprehensive drying solutions from a single source

Choosing from one of the world's most comprehensive product portfolios in drying technologies grants you the flexibility to select the right single dryer or a complete turnkey solution optimized to your requirements, including all components, services, and electrical and automation systems.

To ensure that you have the driest final product at the lowest cost, we provide a customized solution tailored to nearly any heating source or downstream application. The result is a complete process solution together with any test run optimizations or ancillary technologies you may need, all from a single source. Based on experience from hundreds of installations worldwide, we can help you minimize your disposal costs to profitably produce an equally wide range of dried sludge products. This could mean turning out Class A biosolids for fertilizer products, alternative fuels for power plants or cement plants, or dried sludge for a variety of mono-combustion and co-combustion applications.

OPTIMIZED DRYING SOLUTIONS FOR MULTIPLE RECYCLING OPTIONS

After screening, dewatering, thickening, and dewatering steps, a drying phase is required for valorization. ANDRITZ's industry-leading range of drying solutions makes it possible to tailor the right process technology for any demand. Depending on your local market conditions and desired dried sludge product, we can advise on the most efficient and best value-for-money solution for your needs.

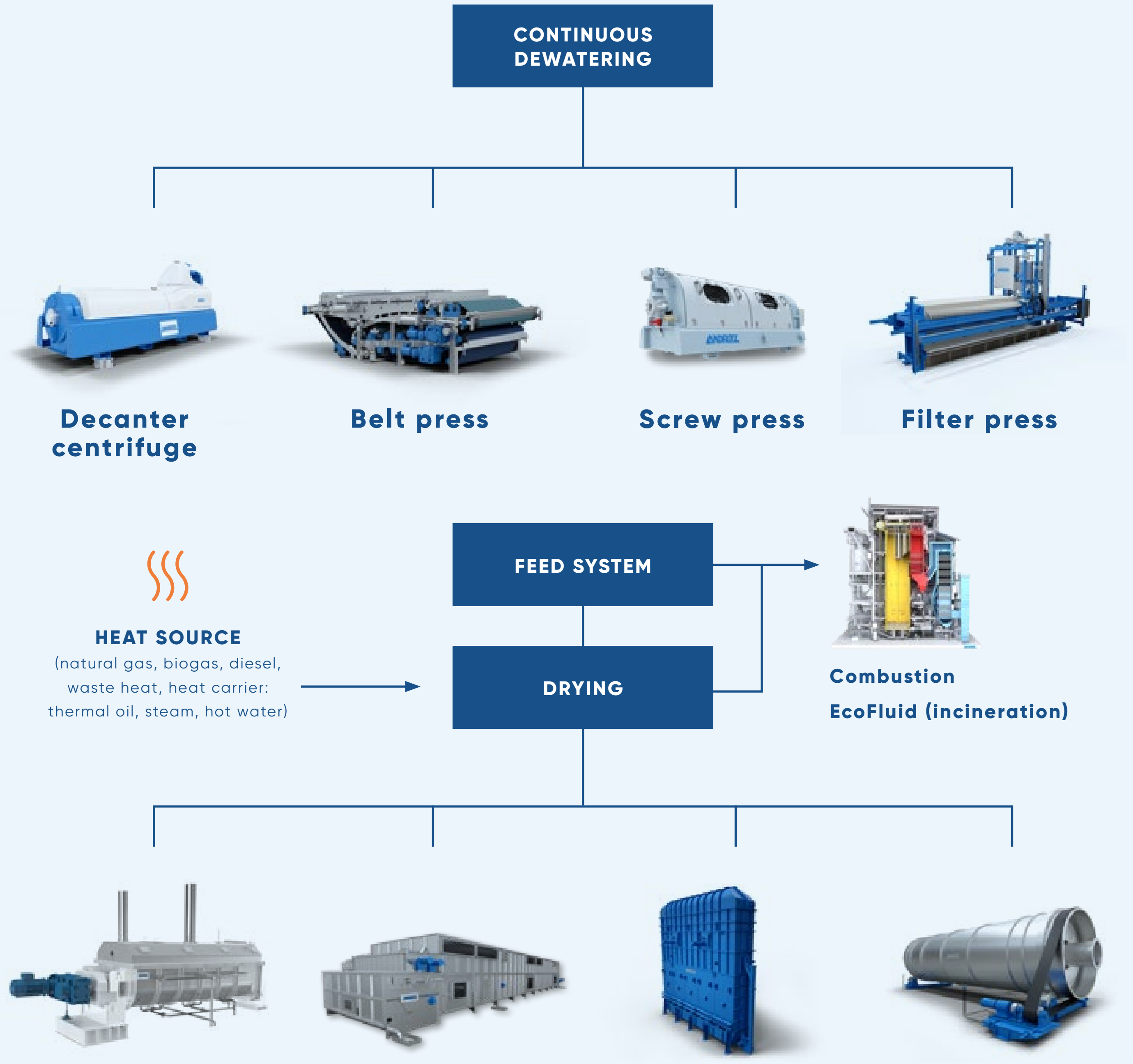
Meeting your needs with our broad range of thermal drying systems

Different methods of utilization require different preparation and treatment. ANDRITZ offers the right solutions for various processes and uses.

ANDRITZ already offers the widest range of dewatering equipment on the market. After this key step in sludge treatment, the drying phase is often recommended to enhance the properties of the sludge. With its four solutions (paddle dryer, belt dryer, fluid bed dryer, and drum dryer), ANDRITZ provides global customers with systems that are 100% compliant with ATEX and NFPA. With such thermal solutions, ANDRITZ also achieves full drying to >90% DS, producing a final product in Class A, suitable for agriculture as a fertilizer.

Type of sludge handled with our dryer systems (reduction of sludge volume)

Specifications	Wet	Dewatered	Dried	Combustion
Weight	1,000 kg	160 kg	44 kg	22 kg
Dry solids	4%	25%	approx. 90%	100%
Organics in dry solids	40-80%	40-80%	40-80%	0%



Paddle dryer

- 200–5,000 kg/h water evaporation per unit
- Smallest footprint and compact plant design
- Low exhaust gas volume
- Optional heat recovery from the dryer with temperature level of approx. 80°C

Belt dryer

- 700–6,000 kg/h water evaporation per unit
- <5% dust content in final product
- Low-grade waste heat as heating medium
- Add-back system offers high operating reliability and product quality

Fluid bed dryer

- 2,000–15,000 kg/h water evaporation per unit
- Fully automated operation
- Operation in oxygen-reduced atmosphere
- High flexibility in dealing with changing sludge qualities

Drum dryer

- 3,000–15,000 kg/h water evaporation per unit
- Exceptional product quality for applications in agriculture
- Add-back system offers high operating reliability

Keeping heat transfer simple with the ANDRITZ Gouda paddle dryer

Paddle dryers are used to dry dewatered sludge in a continuous, indirect heat transfer process.

The ANDRITZ Gouda paddle dryer is built to handle products with the utmost care – a machine with a lot to offer for most materials. The continuous, indirect heat transfer setup within the paddle dryer's state-of-the-art interior produces a quality product with incredible efficiency – and a minimum of maintenance.

Saturated steam or hot oil are perfect for drying or heating. The hollow design of the paddle shafts means that the entire interior surface acts as one large heat exchanger. Controlled agitation by the rotating shafts with paddles delivers superb product-to-surface interaction for optimum heat transfer.

SIMPLE, CONVINCING AND SUCCESSFUL TECHNOLOGY

The ANDRITZ Gouda paddle dryer is designed for a long, continuous life cycle and manufactured with sophisticated welding procedures so that it can withstand high temperatures as well as heavy-duty and corrosive products.

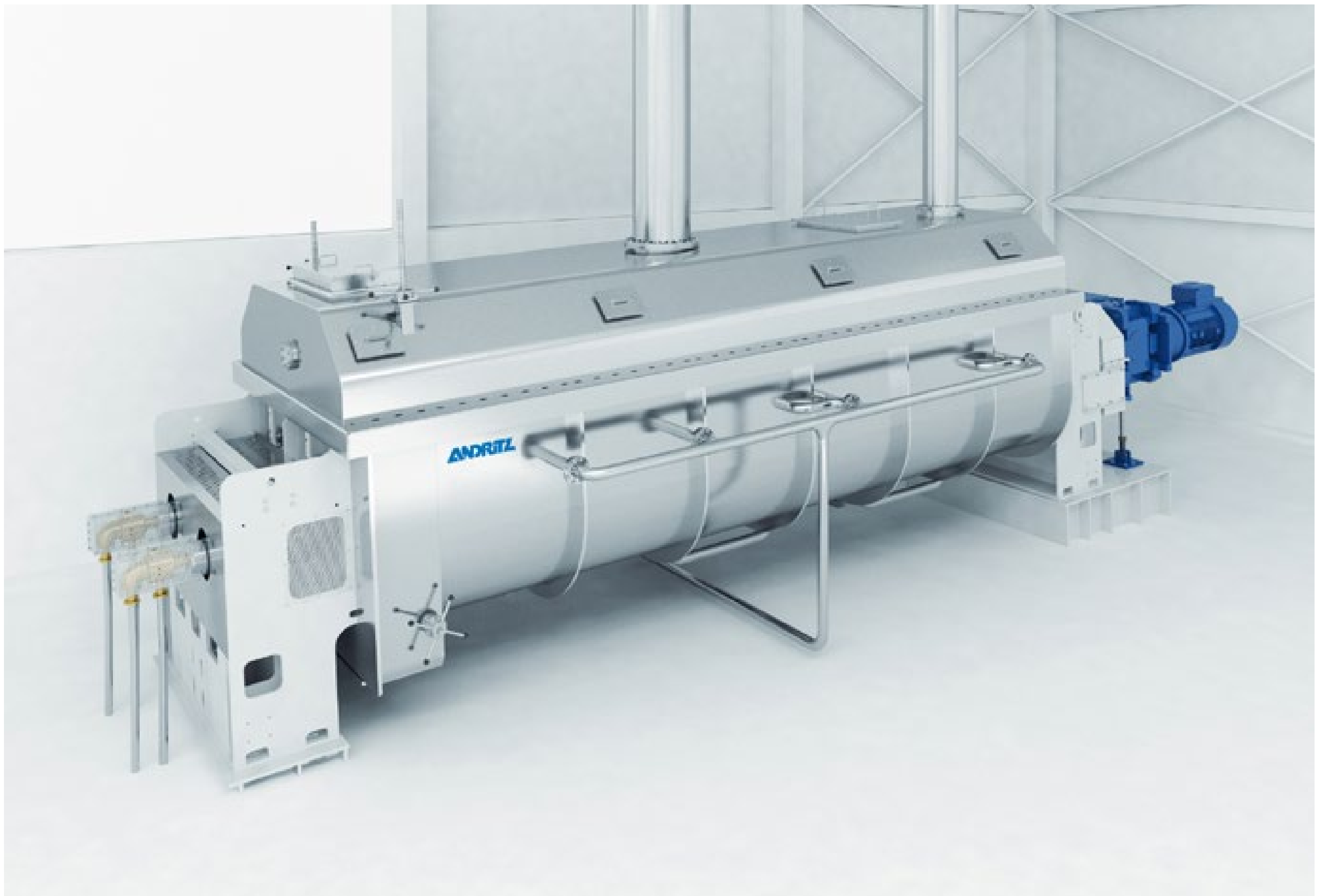
To protect the crucial, heat-exchanging paddle surface against heavily abrasive products, a wear-resistant, hard-face coating can be applied. HVOF is a high-velocity spraying process to create protective, anti-abrasive layers. ANDRITZ Gouda introduced the HVOF technology years ago and still is the only manufacturer of paddle dryers to use this proven, best-in-class coating technique.

THE PROCESS

The dewatered sludge is fed in at one end of the paddle dryer without any pre-treatment and conveyed by gravity to the machine outlet due to the slight downward angle of the trough. During the long residence time of the product in the machine, plug flow is maintained and provides uniform product quality. An overflow weir ensures that the product height is always the same, while the evaporated vapor leaves the dryer through the exhaust outlet in the cover to reach the condenser. The small and compact vapor condenser offers the option of heat recovery at a high temperature level, and the absence of air during the drying process results in safe operation due to the low oxygen content. Finally, the dried material is discharged to a cooling screw conveyor and cooled to a temperature of <50°C.

YOUR BENEFITS

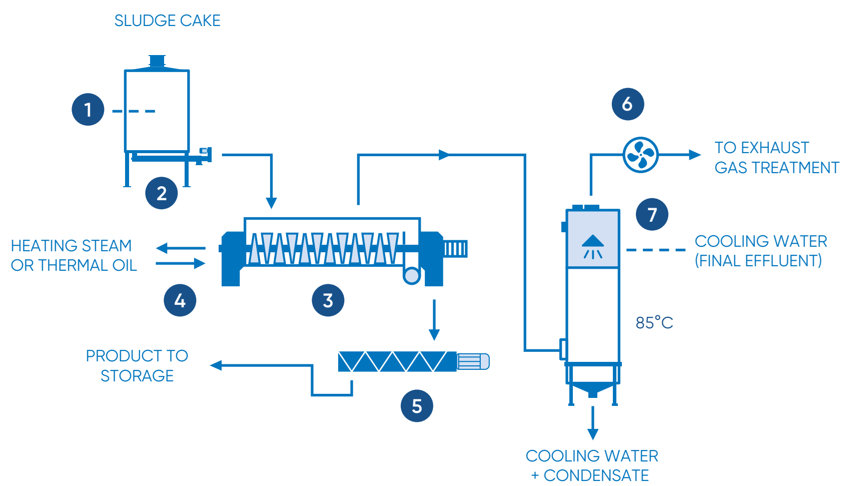
- A once-through drying technology that avoids back-mixing
- No gas loop system is required, resulting in low fan capacity for exhaust gas discharge.
- Small off-gas treatment facility due to the low flow of excess gas
- Waste heat from the condenser at a high temperature level >80°C.
- Compact design



ANDRITZ Gouda paddle dryer

SLUDGE DRYING PROCESS WITH AN ANDRITZ GOUDA PADDLE DRYER

1. Wet sludge silo
2. Wet sludge pump
3. ANDRITZ Gouda paddle dryer
4. Steam or thermal oil supply
5. Product cooler
6. Exhaust gas fan
7. Condenser



ANDRITZ Gouda paddle dryer: Selected references

"The ANDRITZ team and their ANDRITZ Gouda paddle dryer technology have enabled us to design and build a compact, energy-efficient plant that produces dry bio-solids, a sustainable, environmentally friendly material for use as fertilizer and soil improver in the numerous green areas that feature in Dubai and distinguish it from other desert cities."

YVES DE RUE
Project Director, BESIX-LARSEN & TOUBRO Joint Venture

Fertilizer

JEBEL ALI, DUBAI

Model	17W300
Heat source	Thermal oil via biogas/diesel
Water evaporation	3 x 4,300 kg/hr
Operation start	2019

Cement

AMBARLI, TURKEY

Model	6 x 14W190
Heat source	Gas-fired thermal oil boilers
Water evaporation	6 x 3,000 kg/hr
Operation start	2013

SCHWENK, GERMANY

Model	17W300
Heat source	Thermal oil via waste heat
Water evaporation	2 x 5,700 kg/hr
Operation start	2016

Power plant

FIBRIA, BRAZIL

Model	17W300
Heat source	Steam
Water evaporation	1 x 4,000 kg/hr
Operation start	2017

Setting standards in terms of safety and simplicity with the ANDRITZ fluid bed dryer

ANDRITZ fluid bed dryer technology with direct sludge feeding is used to dry dewatered sewage sludge with a wide range of different properties.

Fluid bed dryers for drying dewatered sewage sludge operate with an indirect heat transfer and in a closed inert gas loop, resulting in energy-efficient and environmentally beneficial plant operation with small amounts of exhaust gas from the drying process.

SIMPLE, CONVINCING, AND SUCCESSFUL TECHNOLOGY

The fluid bed dryer is filled with dry granules. The granules then "float" (free floating) and are mixed thoroughly when the gas passes through the product layer. The dewatered sludge is fed into the fluidized bed of dried granules by pumps and cut into small pieces by a special device inside the dryer. These wet granules are mixed immediately with the granules from the fluid bed, which have already been dried.

The entire thermal heat required to evaporate the water is fed to the dryer via heat exchangers immersed in the fluid bed, i.e. without there being any direct contact between the heat transfer medium and the product. Due to the good heat and mass transfer conditions, the water contained in the sludge evaporates immediately and the particles are dried to >90% dry solids (DS). Granulation itself is spontaneous as a result of water evaporation and the particle movement in the dryer.

THE PROCESS

Due to the even temperature distribution at each point of the fluid bed dryer, the drying temperature of 85°C can be maintained easily by the sludge input for temperature adjustment. The mechanically dewatered sewage sludge is pumped directly to the fluidized bed dryer without any pre-mixing, structured by special distributors inside the dryer, mixed with granulate that has already been dried and then held in motion by the fluidizing gas. In the next step, the sewage sludge is dried to >90% dry substance at a temperature of 85°C in a very short time. The fluid bed dryer operates in an oxygen-reduced gas loop (0–3% oxygen by volume). A condenser removes the evaporated water from the system, and the evaporated water provides waste heat at a temperature of 60°C for further use. The final product is mainly granules, and an almost dust-free product can be obtained by adding a dust granulation step.

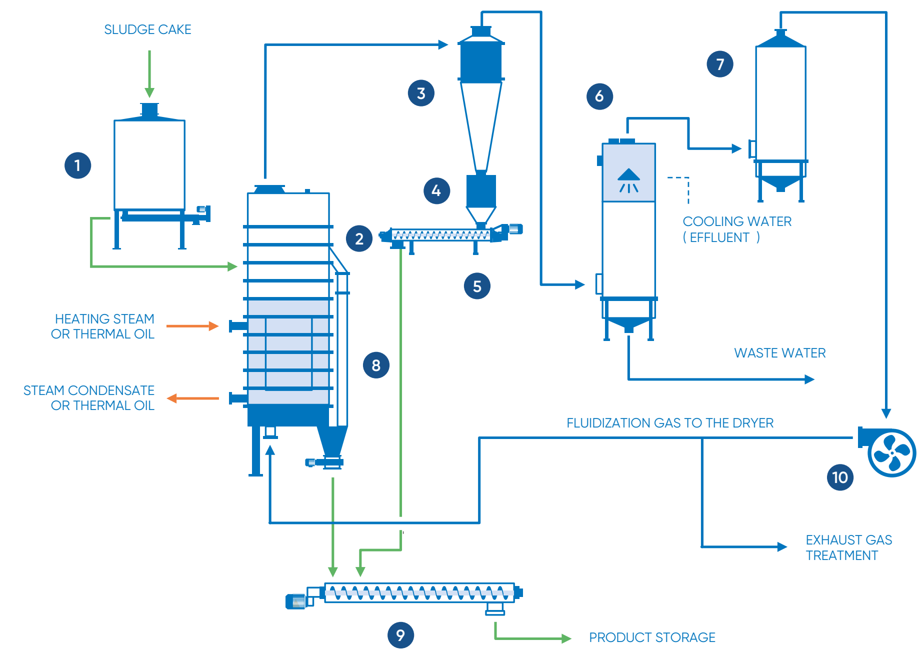
SEWAGE SLUDGE DRYING AT THE HIGHEST LEVEL OF SAFETY ENGINEERING

- Operations in oxygen-reduced gas conditions guaranteeing safe plant operation in all operating modes (start-up, shutdown, stationary, upset)
- These inert gas conditions are maintained from the dryer and product cooling to storage
- Sludge feed without backmixing of dry granulate offers substantial flexibility in adapting to different sludge qualities
- Automatic operation (no personnel present during the night and at weekends) is possible
- Gentle and efficient processing
- Low waste gas volume (<200 m³/h) due to closed design

ANDRITZ fluid bed dryer

SLUDGE DRYING PROCESS WITH AN ANDRITZ FLUID BED DRYER

1. Sludge silo
2. Feed pump
3. Cyclone
4. Dust collector
5. Screw conveyor
6. Condenser
7. Demister
8. Fluid bed dryer
9. Cooling screw conveyor
10. Fan



ANDRITZ fluid bed dryer: Selected references

"The Bailonggang expansion project will have an installed capacity of up to 3,000 tons of sludge per day. The plant is set to be the world's largest sludge incineration plant and will serve as a landmark among Chinese environmental projects.
The complete drying and incineration system features nine fluidized bed drying systems that operate as closed-loop systems, as well as other ANDRITZ technologies. One of the reasons for choosing fluidized bed drying technology was the impressive operational track record of other plants ordered by the same customer."

MRS. XU YAN
Project Manager Engineering and Sales, ANDRITZ Fliessbettsysteme GmbH

Mono sludge incineration

SHIDONGKOU, CHINA

Model	FDS 700
Heat source	Steam
Water evaporation	1 x 4,700 kg/hr
Operation start	2019

BAILONGGANG PHASE 2, CHINA

Model	9 x FDS 960
Heat source	Steam
Water evaporation	9 x 9,600 kg/hr
Operation start	2019

Cement utilization

ATAKÖY, ISTANBUL, TURKEY

Model	FDS 1200
Heat source	Thermal oil
Water evaporation	2 x 6,770 kg/hr
Operation start	2020

BERNE, SWITZERLAND

Model	1 x FDS 570
Heat source	Steam
Water evaporation	1 x 3,430 kg/hr
Operation start	2015

The ANDRITZ belt dryer, ideal for making use of waste heat

The ANDRITZ belt dryer is a low-temperature dryer with a closed circulating air loop that makes efficient use of waste heat.

The ANDRITZ belt drying system (BDS) belongs to a new dryer generation in a special stainless steel construction using a simplified back-mixing system for structuring of dewatered sludge.

SIMPLE, CONVINCING, AND SUCCESSFUL TECHNOLOGY

The main mechanical parts, such as the feed module, belt drive and rolls, the belt support and guiding system as well as the discharge system are integrated into the steel casing structure as pre-assembled modules. The mixer and the conveying screws are mounted on the longitudinal side of the dryer. On the opposite longitudinal side of the dryer, the fans and the heat supply system (heat exchanger or combustion chamber) are situated on the outside of the steel casing. This layout concept offers optimal conditions for easy inspection and maintenance.

THE PROCESS

The ANDRITZ belt drying system granulates the dewatered sludge in a mixer with product that has already been dried. The moist granulate produced here is distributed evenly over the belt in the dryer by a specially designed feed module. This even layer of material on the belt creates optimum conditions for even distribution of the drying air and optimal heat and material transfer conditions during drying. The layer of material on the belt forms a filter medium for the air flowing onto the granulate layer from above and thus prevents entrainment of dust. Waste heat is used to heat the drying air via heat exchanger or the drying air is heated by flue gas coming from the in-duct burner integrated into the drying air loop system. The heated drying air flows at a temperature of <130°C through the product layer from top to bottom and absorbs the moisture it contains. To achieve the best possible thermal efficiency, the dryer has a high circulating air rate, i.e. a large part of the drying air is recycled by fans to the dryer and re-heated to the drying temperature.

An exhaust air fan discharges a part of the drying air to the condenser. After cooling and condensation of the evaporated water, some of the discharged air is recirculated to the dryer. The rest of the extracted air is discharged by an exhaust gas fan, thus keeping the main components of the dryer under vacuum in order to minimize dust and odorous emissions. The dried material is cooled in a separate belt cooler.

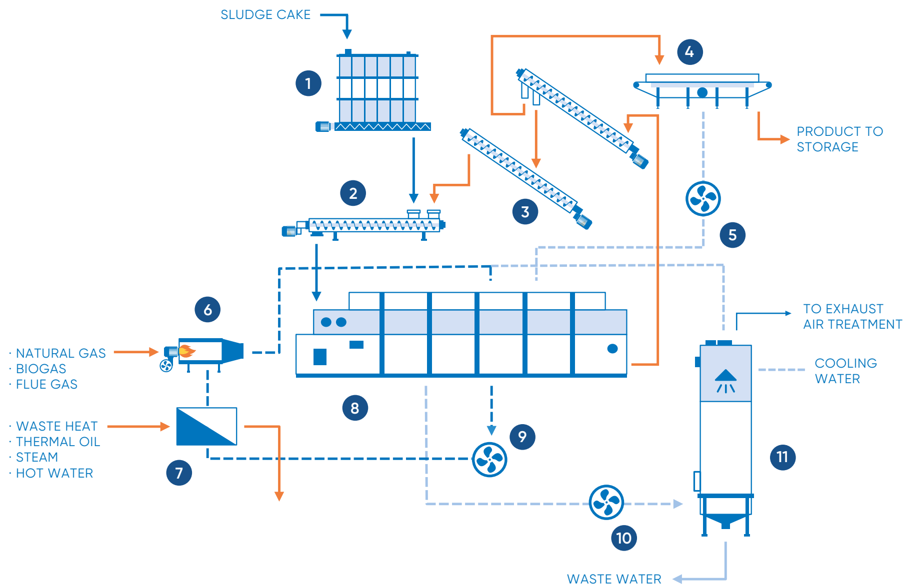
BELT DRYER WITH SIMPLIFIED BACK-MIXING

- Flexible to feed in sludge with different properties
- Even distribution of the pre-granulated mixture across the belt
- Deals easily with impurities in the dewatered sludge
- Low drying temperature ensures careful drying of the product
- Results in high and even dryness of the final product
- High flexibility to integrate thermal energy from different sources, especially low-grade waste energy
- Modular structure and simple design

ANDRITZ belt dryer

SLUDGE DRYING PROCESS WITH AN ANDRITZ BELT DRYER

1 Sludge silo
2 Mixer
3 Conveyor
4 Belt cooler
5 Cooling air fan
6 Burner furnace
7 Heat exchanger
8 Belt dryer
9 Circulation air fan
10 Exhaust air fan
11 Condenser



ANDRITZ belt dryer: Selected references

"We approached ANDRITZ with very strict cost and product quality requirements. We especially appreciate their ability to modify their technology to meet our needs within such a short delivery time."

TADEUSZ KRĘŻELEWSKI
President Krevox Enviromental Center, Warsaw, Poland

Fertilizer

AL MADINAH, BAHRAIN

Model	BDS 25
Heat source	Natural gas/diesel
Water evaporation	1 x 2,400 kg/hr
Operation start	2018

GRESILLONS, FRANCE

Model	BDS RD 40
Heat source	Natural/biogas
Water evaporation	3 x 4,000 kg/hr
Operation start	2013

Cement

SCHWENK, GERMANY

Model	BDS 70
Heat source	Waste heat
Water evaporation	1 x 7,800 kg/hr
Operation start	2005

TORUN, POLAND

Model	BDS 25
Heat source	Natural gas
Water evaporation	2,600 kg/hr
Operation start	2013

Drying and granulating in a single step with the ANDRITZ drum dryer

The ANDRITZ drum dryer provides high water evaporation capacities and high final product quality.

The ANDRITZ drum drying system is the technology with the longest history in sewage sludge drying. Our DDS is the product of more than 40 years' experience. Reference plants located all over the world prove their versatility and reliability.

SIMPLE, CONVINCING, AND SUCCESSFUL TECHNOLOGY

The triple-pass drum consists of three cylinders with a common axis that fit inside one another. As the drum turns slowly, the sludge moves forward in the air stream, from the inner to the middle cylinder and finally into the outer cylinder. During this process, the granulate will also roll, and this movement contributes towards the formation of stable, spherical granulate. As the material passes through the three cylinders, it is lifted by blades positioned along the cylinder's inner walls and then drops downwards through the warm gas stream under the force of gravity.

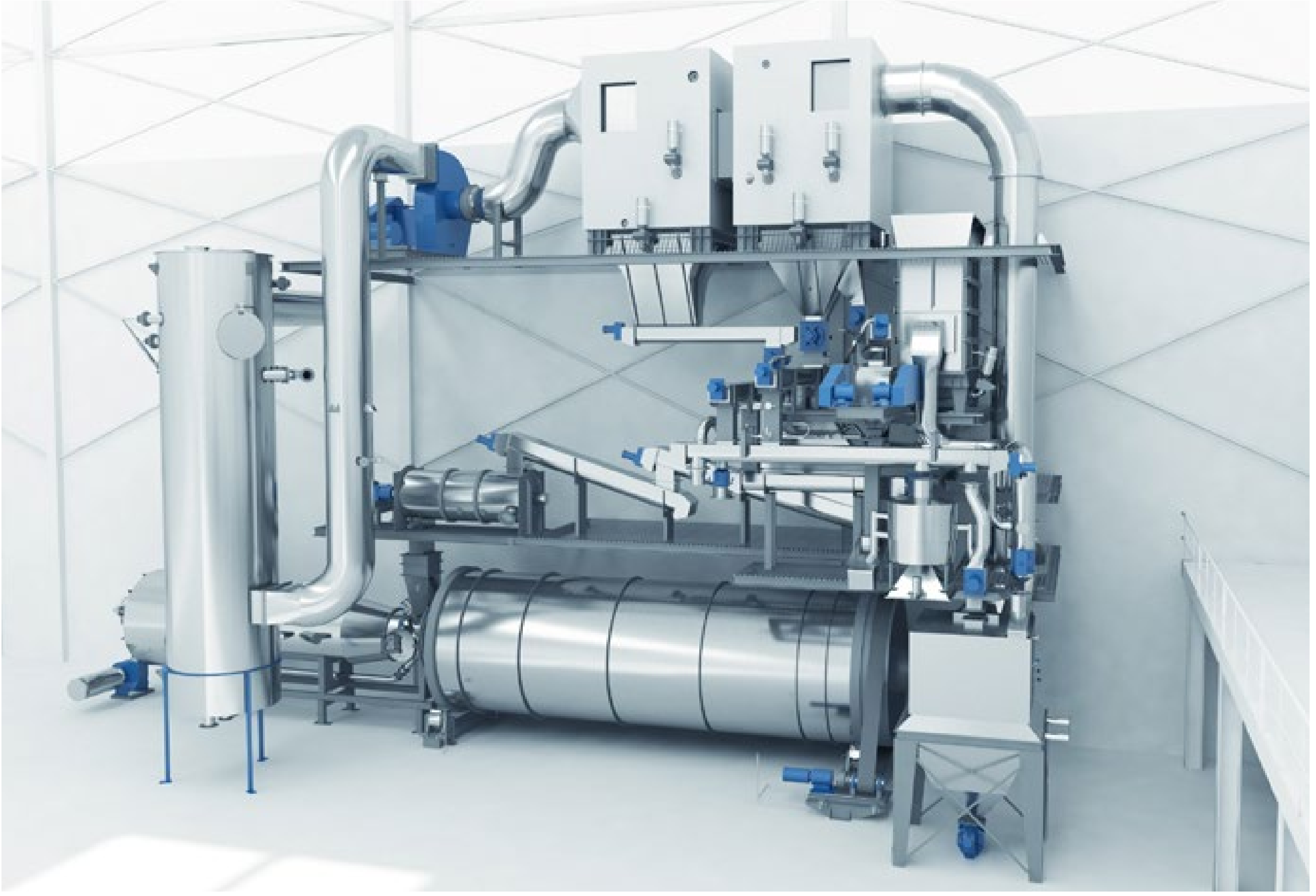
THE PROCESS

Dewatered sewage sludge is mixed together with material that has already been dried (add-back process). The hot gas flowing through the drum carries the pre-granulated sewage sludge along with it, and water contained in the sludge is evaporated at the same time. In the slowly rotating triple-pass drum, which is made up of concentric cylinders, the product is shaped into round granulate due to the constant rolling movement.

The dried material leaves the drum dryer at a temperature of approx. 90°C and is separated from the gas flow in a pre-separator and multi-cyclone.
In order to structure the dewatered sludge, the fines return to the mixer together with part of the granulate. The final product is a largely dust-free, dry granulate with 92–95% DS. It is stable, easy to store and dose and shows excellent handling properties. The drum dryer is integrated into a gas loop that is heated by hot gases coming from the combustion of natural or biogas. A scrubber is used to condense the evaporated water, while the main part of the cooled gas returns to the combustion chamber and is mixed with the hot combustion gases to an inlet temperature of 400–600°C.

DRUM DRYERS ARE STURDY, STABLE AND RELIABLE

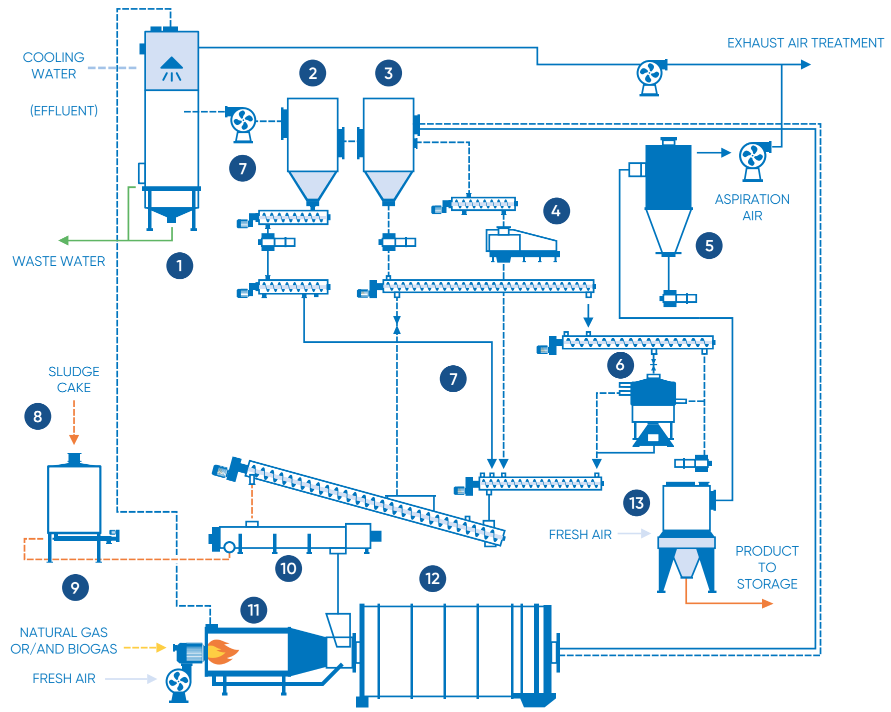
- Low energy consumption due to special drum design and closed gas loop
- Low-odor operations due to partial vacuum in the drying system
- Long plant service life by using sturdy plant components, short conveying routes, and compact design
- The final product is dried evenly right through and hygienized, hence making it particularly suitable for use in agriculture (as fertilizer)



ANDRITZ drum dryer

SLUDGE DRYING PROCESS WITH AN ANDRITZ DRUM DRYER

1. Condenser
2. Multi-cyclone
3. Pre-separator
4. Crusher
5. Aspiration filter
6. Sieve
7. Fan
8. Sludge silo
9. Sludge pump
10. Mixer
11. Furnace
12. Drum dryer
13. Product cooler



ANDRITZ drum dryer: Selected references

"OCUA owes their award-winning, successful history to the expertise of the ANDRITZ team, especially their ability to implement cost-effective solutions and system enhancements while minimizing process downtime. The reliability of the ANDRITZ drying equipment combined with their dedicated personnel provide OCUA with value and confidence year in and year out."

KEITH MARCOON, P.E.
Executive Director, Ocean County Utilities Authority

Fertilizer

PHILADELPHIA, USA

Model	2 x DDS-120
Heat source	Biogas, natural gas
Water evaporation	12,000 kg/hr
Operation start	2012

NASHVILLE, USA

Model	2 x DDS-80
Heat source	Biogas, natural gas
Water evaporation	8,000 kg/hr
Operation start	2008

BRIGHTON, UK

Model	1 x DDS 50
Heat source	Biogas, natural gas
Water evaporation	5,000 kg/hr
Operation start	2011

Mono sludge incineration

VALENTON, FRANCE

Model	3 x DDS 70
Heat source	Biogas, natural gas
Water evaporation	7,000 kg/hr
Operation start	2005

Cement

SCHWENK, GERMANY

Model	1 x DDS 180
Heat source	Waste heat
Water evaporation	14,300 kg/hr
Operation start	2018

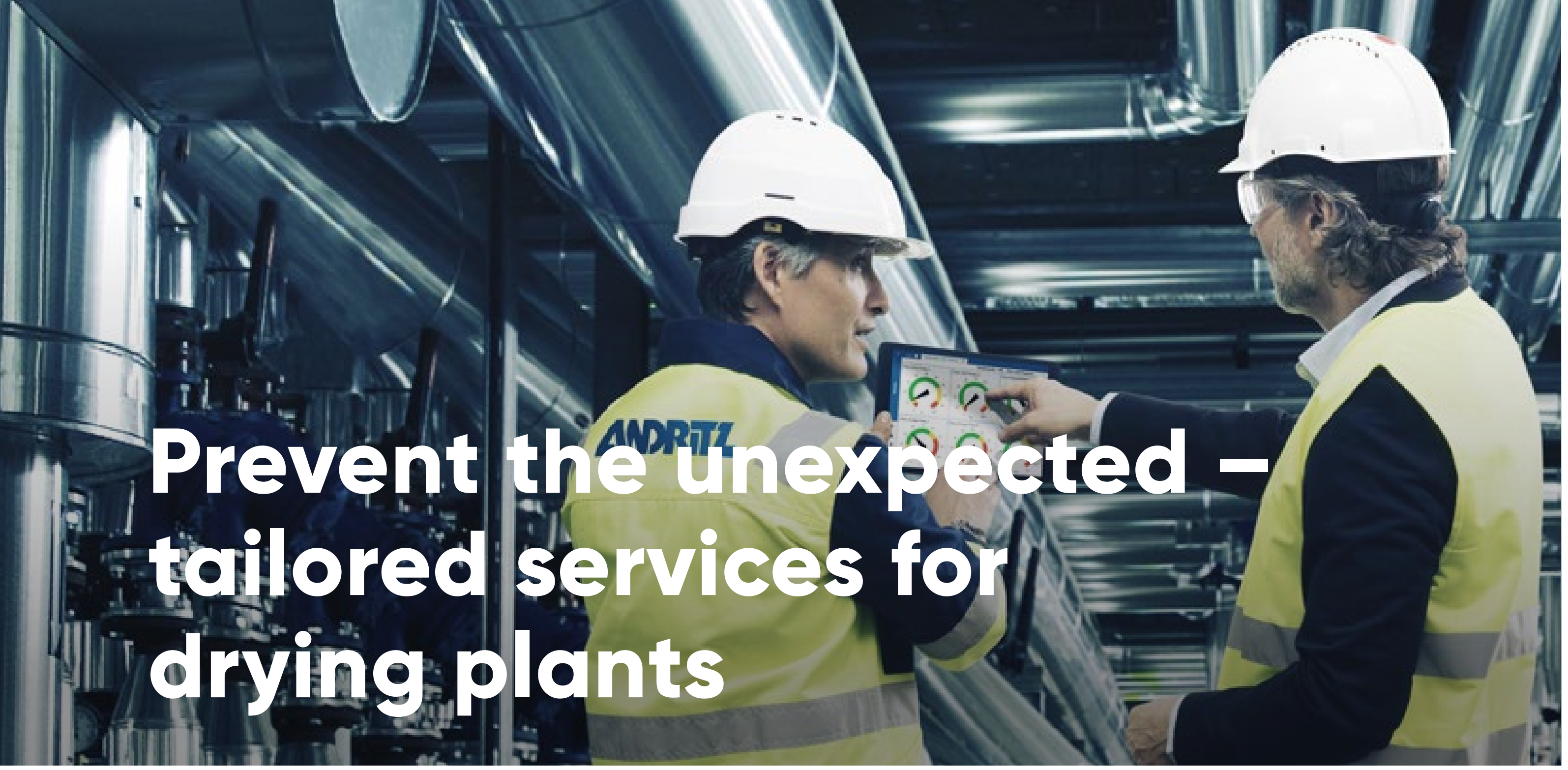
DALDOWIE, UK

Model	6 x DDS 40
Heat source	Natural gas
Water evaporation	4,800 kg/hr
Operation start	2002

Count on our expertise to best support your project!

PLANT DESIGN	**DESIGN SUPPORT:** 3D ENGINEERING, MECHANICAL, CIVIL, ELECTRICAL DRAWINGS, DOCUMENTATION
PLANT CONSTRUCTION	**MECHANICAL SAVINGS, ELECTRICAL SAVINGS:** OPTIMAL NUMBER OF DRYERS, CORRECT SIZING OF INSTALLATION
PLANT OPERATION	**OTHER SAVINGS:** ENERGY SAVING, MAINTENANCE SAVINGS, EXTENDED ASSET LIFE, HIGH RELIABILITY

Sludge drying in Scotland with ANDRITZ drum dryers



Prevent the unexpected – tailored services for drying plants

Whether it's a belt, drum, paddle, or fluid bed drying plant, there's a tailored process or control solution that can reduce operating costs and improve performance, safety, and product quality at your dryer. At ANDRITZ, we have the expertise to appraise your process, support or execute R&D projects, and modernize your automation. 150 years of experience in solid/liquid separation is proof of our exceptional process know-how, which in turn means optimal engineering. Everything you need from a single source, provided by our local specialists!

OPTIMAL EFFICIENCY IN PLANT OPERATIONS

- Process performance studies in order to identify and evaluate potential for optimizing your process: We start by determining all of the existing parameters, such as throughput, consumption figures, feed rates, and product quality, on site or in our labs.
- On-site process performance audits for a thorough inspection of the thermal equipment, including assessment of the dryer's KPIs, such as throughput, evaporation rate, and consumption quality.
- Mechanical audits to evaluate the functioning and condition of mechanical equipment and provide a thorough, written report including recommendations for operation, maintenance, spare parts, and repair work.
- Electrical and automation audits to check the functioning and condition of selected electrical equipment, instrumentation and measuring devices, and also to evaluate the functioning of safety-related instruments and sensors.
- Safety audits to assess all key aspects of the process as well as checking the hardware and software.

CONTROL SYSTEM UPGRADES

The goal of any operator is to maximize availability, capacity, and quality while minimizing costs. By installing automation equipment from ANDRITZ, you can reduce downtime with features like predictive analysis, allowing you to optimize availability and take appropriate preventive action. Capacity and quality are easy to control and enhance with customizable systems – the Metris addIQ control system is based on the latest PLC and HMI technologies and has an integrated fail-safe system.

The upgrade can be carried out in several steps to accommodate your production schedule. It is platform-independent (Siemens, Rockwell, etc.), and existing technology can be incorporated or replaced as needed. Huge delivery scope from a single source: ANDRITZ supplies engineering, hardware, software, and equipment, as well as safety concept evaluation.

SUPERIOR LIFETIME PERFORMANCE

To bring your plant up to date, ANDRITZ can rebuild all models and makes of thermal equipment, from drum to belt, paddle, and fluid bed dryers. ANDRITZ is your full-service provider when it comes to ensuring that your drying plant is fit for future challenges – for decades to come. The services provided include repair work, modernization, supply of spare and wear parts, as well as second-hand equipment and rentals combined with various upgrade products, such as the air humidity control system upgrade for greater process stability and lower operating costs.

KNOW-HOW FOR OPERATING AND MAINTENANCE STAFF

Even with the world's best equipment, there's always room to improve performance, reduce downtime, and enhance safety. With specialized training from the OEM specialists at ANDRITZ, we're here to provide all the know-how you need to get more out of your machines. We offer individual on-site training for operators, as well as classroom training for groups at our service academy in Den Helder, Netherlands, depending on your individual training needs.

RELIABLE AND COST-EFFICIENT PLANT OPERATIONS

Keeping your business profitable can be more than just a full-time job. That's why we at ANDRITZ take care of all your maintenance requirements by offering service and maintenance contracts for all your specific needs: Whether you only want a spare part list with prices, or perhaps a consignment stock for spare and wear parts, or if you want ANDRITZ to operate your entire plant, we have the service and maintenance contract that fits your requirements best.

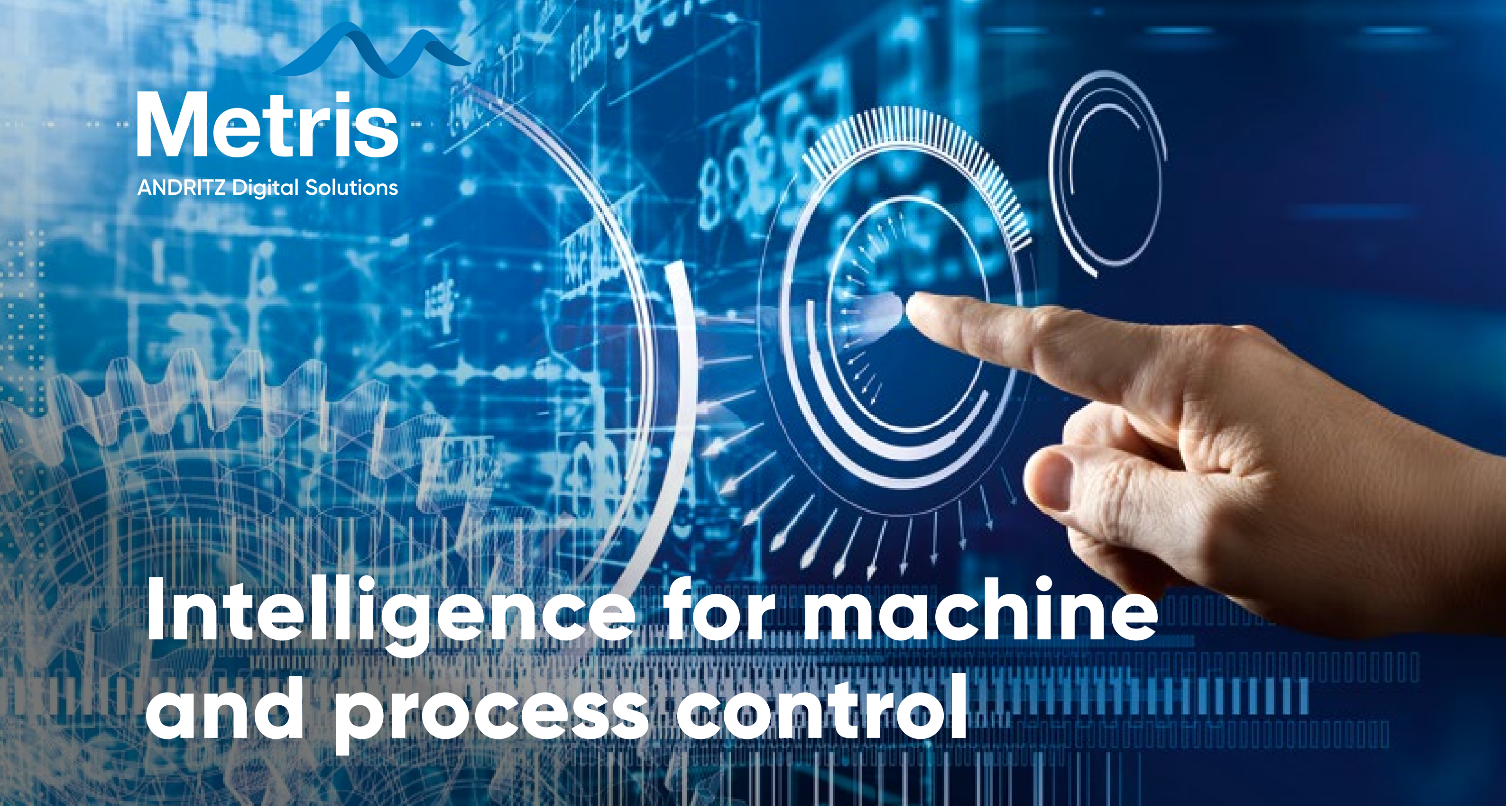
Your full-service provider

With ANDRITZ, you gain access to one of the world's largest OEM manufacturers for solid/liquid separation systems, including such well-known brands as 3Sys Technologies, Bird, Delkor Capital Equipment (Pty) Ltd., Escher Wyss dryers, Frautech, Guinard Centrifugation, KHD Humboldt Wedag, Krauss-Maffei centrifuges, dryers, and filters, Lenser, Netzsch Filtration, Rittershaus & Blecher, Royal GMF Gouda, Sprout Bauer, and Vandenbroek. Whether you need spare parts, rentals, local service, repairs, upgrades, or modernization of your equipment, ANDRITZ is your true full-service provider. From initial consulting through to service agreements, process optimization, and training programs, we are always looking for ways to minimize downtime and increase predictability in operations while raising your overall production efficiency. Wherever you operate, our network of 550 service specialists and global service centers ensures we'll always be there to support you for many life cycles to come. Let's sit down and see how we could take your operations to the next level.

LOCAL SUPPORT | REPAIRS & UPGRADES | SECOND-HAND & RENTALS | TRAINING

OEM SPARE PARTS | SERVICE AGREEMENTS | PROCESS OPTIMIZATION | LAB AND ON-SITE TESTS

UPGRADE YOUR DRYER
Scan this QR code and obtain more detailed information about specific service and upgrade products for your drum, belt, paddle, and fluid bed dryers.



Intelligence for machine and process control

With Metris addIQ control systems, intelligent control for processes and machines is at your disposal. Specialists in automation for solid/liquid separation technologies use their in-depth expertise to provide scalable solutions that are individually tailored to regional and application requirements, regardless of whether it's automation for new equipment or upgrades to extend the lifecycle of existing systems.

POWERFUL PROCESS CONTROL AT YOUR FINGERTIPS

Metris addIQ control systems cover all levels of automation, from basic automation with different Metris addIQ packages through upgrades and process optimization solutions. Optimized systems, reduced maintenance effort, and preventive service for machines and plants are delivered from a single source and always individually tailored to your business demands. Metris addIQ control systems are part of the ANDRITZ brand for digital IIoT (Industrial Internet of Things) solutions.

Whichever drying solution meets your requirements, ANDRITZ is able to provide complete systems for control, instrumentation and integration of your facility. To ensure a seamless operator experience, this often extends into upstream and downstream processes, including digestion, dewatering, and dewatered cake storage as well as interfaces with plant-wide control systems (DCS).

END-TO-END AUTOMATION ON ANY SCALE

One recent project that illustrates the advantages of our wide range of control and automation capabilities is a new biosolids management facility in Hamilton, Ontario. As part of the project, an ANDRITZ drum drying process helps to convert 60,000 wet tons of biosolids annually into biomass pellets for slow-release organic fertilizer or as a renewable fuel substitute for coal-burning plants.
In addition to the fully integrated biosolids drying line, this solution was based on the Metris addIQ Prime system, and the customer has already planned implementation of the next level of automation - Metris addIQ Monitoring.

YOUR BENEFITS

- Tailored turnkey systems to improve plants or machines
- State-of-the-art automation technologies and digitalization for best-in-class performance
- Reduced gaps in many production process steps because machinery is automated
- Reduced downtimes and optimized productivity with predictive analysis

Automation for drying systems - the ANDRITZ scope of supply

ELECTRICAL ENGINEERING

- Power supply and distribution
- Motors and drives, MCC

ENGINEERING

- Basic
- Detailed
- Installation engineering

AUTOMATION

- Machine control system
- Distributed control system
- Industrial network structures
- Digital image processing

SIMULATION

- Machine and process

INSTALLATION

- Installation supervision

START-UP

- Start-up supervision

TRAINING

- Flexible training in a computer-assisted learning environment

OPTIMIZATION (METRIS addIQ OPTIMIZING)

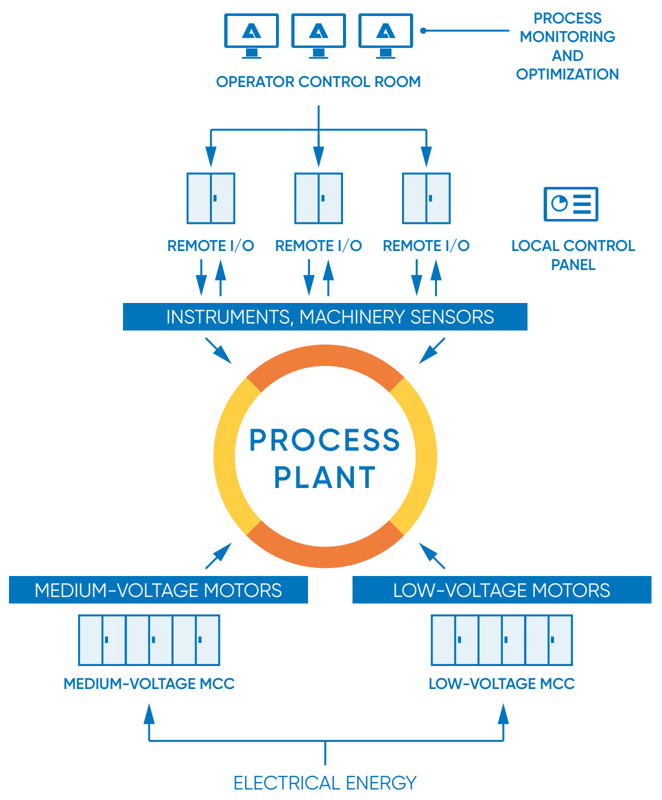
- Seek out ways to save money, and stabilize and increase production by the equipment

TREND ANALYSIS AND DATA COLLECTION (METRIS addIQ MONITORING)

- Monitor the health status of your machine 24/7 from anywhere in the world

REMOTE DIAGNOSTICS (METRIS addIQ CONNECT)

- Your system links up with the ANDRITZ environment
- Remote support for fast interaction



Energy flow from main power inlet to complete process optimization – everything from a single source

TECHNICAL SUPPORT AND PROCESS EXPERTISE CLOSE TO YOU

Thanks to our decades of experience in industry-leading drying solutions, all ANDRITZ customers can confidently rely on the world's strongest network of sludge drying automation specialists. From greenfield consultation and process design to automation upgrades and local service, we continue to tailor our solutions and provide daily support for hundreds of sludge drying facilities worldwide - whether your operations demand electrical engineering, machine or process simulations, personnel training, or ongoing optimization.

Contact our automation specialists today to find out how we can help improve your process performance

WHAT'S YOUR SEPARATION CHALLENGE?

ANDRITZ Separation is the world's leading separation specialist with the broadest technology portfolio and more than 2,000 specialists in 40 countries. For more than 150 years, we have been a driving force in the evolution of separation solutions and services for industries ranging from environment to food, chemicals, and mining & minerals. As the OEM for many of the world's leading brands, we have the solutions and services to transform your business to meet tomorrow's changing demands – wherever you are and whatever your separation challenge. **Ask your separation specialist!**

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ANDRITZ.COM/SEPARATION

VENTURE ENGINEERING – RESPONSE TO REQUEST FOR INDICATIVE PROPOSAL FOR ARIES DOWNDRAFT GASIFIERS

Prepared by

Aries Manufacturing LLC

4037 Rural Plains Circle, Franklin, TN 37064

Phone (720) 548-0580

E-mail jregnery@ariesenergy.com

Mr. Dave Moniot
Venture Engineering & Construction, Inc.
200 Allegheny Drive, Suite 100
Warrendale, PA 15086

Subject: **Indicative Gasifier Supply Proposal to Venture Engineering & Construction Inc.**

Dear Mr. Miniot,

Aries Manufacturing LLC (Aries), the wholly owned manufacturing subsidiary of Aries Clean Technologies LLC, is pleased to submit its indicative proposal for the supply of 2-3 enhanced performance downdraft gasifiers to Venture Engineering.

Our indicative proposal is based on Aries Clean Technologies' proprietary third generation Large Format Downdraft Gasifier technology developed and commercialized in the USA. This technology is highly recommended for sized woody biomass feedstock processing. Aries Clean Technologies has designed, installed and operated 16 downdraft gasifier installations of various capacities in the USA over the last 15 years. Aries second-generation downdraft gasifier is the largest commercial unit operating in the world today. It was commercialized in a facility built for the City of Lebanon in Tennessee and has been in operation since 2017. The operations and maintenance experience and learnings from this unit have been incorporated into the third-generation downdraft large format gasifier technology design to improve conversion efficiency and realize lower life cycle costs.

We are submitting a proposal for only the gasifiers. We believe the third-generation Aries Large Format Downdraft Gasifier technology will offer the best value and performance along with the lowest O&M requirements of any competing gasifiers in a similar service on the market.

Attached to this letter are the following:

Indicative Technical Proposal
Indicative Scope of Supply
Indicative Commercial Proposal

The following summarizes the key benefits Venture receives with a third-generation Aries Large Format Downdraft Gasifier:

Commercial Technology - Aries has installed and operated downdraft gasifier systems since 2005 and is the leading supplier and operator of commercial downdraft gasifiers in the USA. Aries has proven to be leader in the processing of various wood waste streams. We are confident in our ability to deliver a system tailored to your technical needs and stand by our Aspen process calculations and overall design philosophy.

Delivery Schedule Commitment – One of Aries's strengths is staying true to our commitments. We recognize that equipment delivery, installation and commissioning schedules are critical and must be achieved. We will work with you to adjust our schedule as needed to achieve your project schedule objectives.

Robust and Reliable Equipment – Aries strives to meet its Customer's equipment availability needs. In doing so, we design robust, long-lasting and simple to operate gasifiers by selecting high quality reputable equipment fabricators that share this design philosophy. Aries' gasifiers have been field proven for reliability and dependability.

Simple to Operate and Control – Our gasification experience provides you access to valuable operating and control knowledge. Our control system has been rigorously field tested**.** This translates into supporting high up-time for your plant.

Aries is confident that its equipment should be the lowest cost to install and will offer the lowest cost of ownership.

This proposal is indicative only and does not constitute an offer nor represent a basis on which a contractual arrangement can be formed. A formal solicitation and offer utilizing Aries standard equipment supply terms and conditions will need to be issued and a formal supply agreement between the parties will need to be executed to establish such a contractual arrangement.

Should you have any questions or queries, please do not hesitate to contact us.

Yours Sincerely,

Joseph Regnery
Business Development Director,
Aries Clean Technologies LLC
4037 Rural Plains Circle, Suite 290
Franklin, TN 37064

e-mail: joseph.regnery@ariescleantech,com
phone: (720) 548-0580
Website www.ariescleantech.com

TABLE OF CONTENTS

1. INDICATIVE TECHNICAL PROPOSAL

1.1. General equipment specification

The process and mechanical design, fabrication and supply of two (2) Downdraft Gasifier Units designed to convert a total of 55 tons per day per gasifier of specification compliant wood residues.

The Gasifier Package offered by Aries Manufacturing includes the following major equipment:

Vertical Down-Fired Gasifier unit
Refractory Materials & Installation
Gasifier Management Control Narrative
Gasifier feeder chute (Dutchman) and valving
Gasifier feed and residue augers
Bed and plano air manifold and ring header piping connected to the gasifier
Gasifier residue discharge chute and valving
Lot Engineering, Documents & Drawings

The major design objectives of the Gasifier Unit system are as follows:

Safe, stable and reliable operation
Continuous operation, high availability
Adequate residence time and temperature
Ability to process varying wood waste stream flows and composition
Address & Manage impact of specified ash relative to refractory material selection and corrosion
Minimize fuel consumption

1.2. Design basis

Gasifier Unit Design Basis:

Type:	Large Format Downdraft
Orientation:	Vertical down-fired
Nameplate capacity:	55 tons per day chipped wood per gasifier
Bed & Plano Air:	Ambient air @6 psig max
Operating Time:	Continuous operation
Operating Pressure:	2-5 psig

Site Conditions

This proposal is based upon the following site conditions, which have been assumed:

Pressure:	14.53 psia
Location:	Outdoors
Elevation:	328 ft AMSL
Ambient Temperature Range:	38°F-96°F
Design Relative Humidity:	0-100% RH
Electrical Area Classification:	Class 1, Div. 2 Group C&D
Maximum Noise Level:	85 dBA @ 3 feet

Available Utilities

This proposal is based upon the following site utilities, which have been specified or assumed:

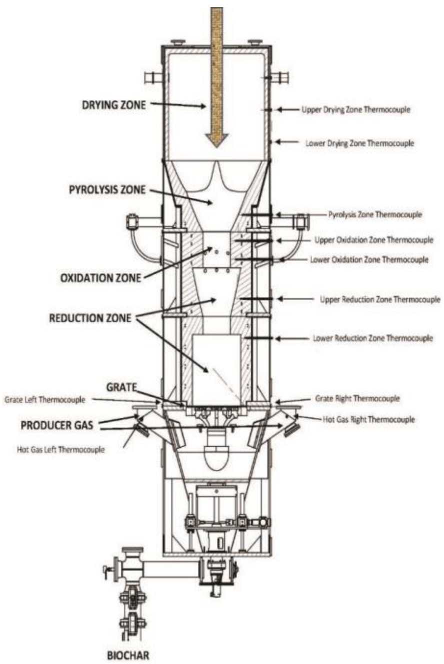
Plant & Instrument air	100 psig (-40°F dewpoint)

Electricity	480VAC
Natural gas	30 psig

1.3. System design description

The Aries Large Format Downdraft Gasifier is a biomass reactor system that converts organic materials into a synthetic fuel gas known as syngas or producer gas. Producer gas is a low BTU fuel gas that can be combusted to provide heat for a variety of industrial processes or co-heat and power production. The converted organic material from the gasification process is discharged from the gasifier as biochar. This biochar can be recycled as a soil amendment, used as a color additive like carbon black or repurposed in a variety of other applications.

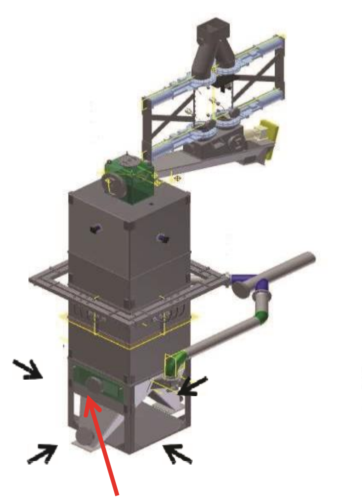
Figure 1 – Aries Gasifier Diagram



The ACE DDLF-3000 Large Format gasifier is capable of consuming up to 55 tons of organic biomass per day and, depending on the calorific value and quality of the feedstock, can produce up to 20 MMBtu/hr of combustible fuel gas. It uses downdraft gasification technology (as opposed to updraft or cross-draft) for the biomass conversion process which minimizes the amount of tars and volatiles produced in the phase change reaction. The Aries Large Format Downdraft Gasifier has undergone extensive testing with a variety of feedstocks in order to ensure safe, reliable, long-term operation. The Aries Large Format Downdraft Gasifier may be operated manually, remotely or be integrated into a facility control system,

The gasifier has four sides. The front side houses the grate door and is designated as the Front of the unit as depicted by the red arrow in Figure 2. The remaining three sides are labeled in relation to the Front of the unit.

Figure 2 – Aries Gasifier Diagram

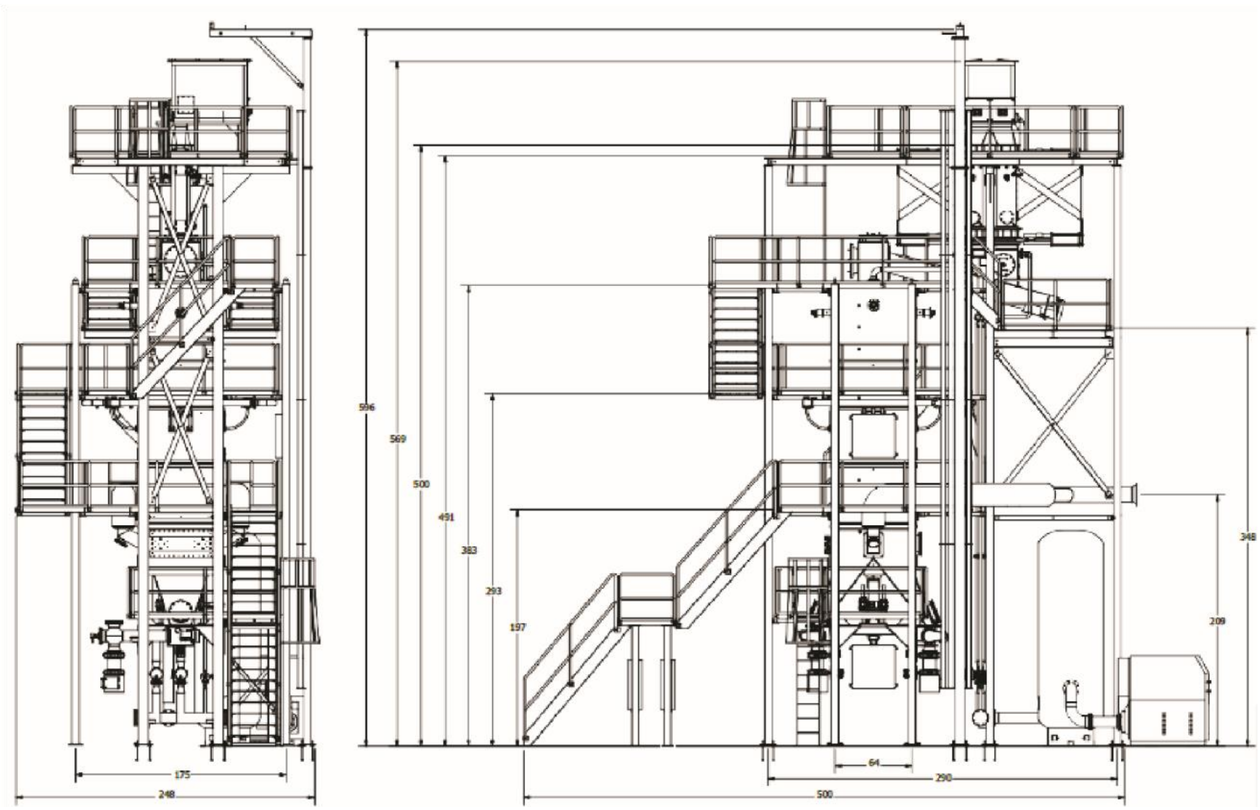


The Aries Large Format Downdraft Gasifier is a stratified unit that has four distinct zones in the process as follows: 1) drying zone; 2) pyrolysis zone; 3) oxidation zone; and 4) a reduction zone. In the first phase, the drying zone, the feedstock moisture is driven out with hot air. As the feedstock flows through the drying zone into the pyrolysis zone, heating of the biomass continues without air to make biochar and begin the first reactions. The pyrolysis zone provides the heat into the next zone, where a partial oxidation reaction takes place. Metered air is added to fuel the reactions and cracking of the tar gases. After cracking, the biomass and gases flow into the reduction zone where additional tar cracking takes place, reforming and the water-gas shift reaction occurs, converting the carbon or biochar into producer gas.

The biomass bed is supported on a vertically adjustable grate which can be slowly rotated to remove the biochar. The gasifier is operated under a slight positive pressure of 2 to 5 pounds per square inch gauge (psig) to facilitate the transport of the producer gas to the downstream equipment. The resulting producer gas typically has a higher heating value (HHV) in the range of 120 to 140 Btu/scf).

The scope of supply in this proposal does not include the structures, staircases, ladders or any of the connecting piping, air tanks, and other auxiliary equipment

Figure 1 – Free standing assembled gasifier unit.



1.4. Process Calculation Summary

Gasification performance estimates for illustrative purposes were prepared based on typical assumed wood chip feedstock per the feedstock specification below. To validate design parameters, analysis of composite samples of the feedstock earmarked for the project and feedstock testing at Aries Lebanon, TN facility will be required.

<u>Feedstock Specification</u>

The feedstock specification at the inlet of the gasification system is shown in table 1. Aries' experience is that consistent compliance with this specification will support meeting performance targets to a high confidence level.

Table 1: Feedstock Specification for Wood Chips

Parameter	Unit	Specification	Typical Value
Composition (as Received basis)			

Moisture Content[1]	%	< 20	5 - 15
Ash Content	%	< 8	1 - 2
Foreign Material	%	Free	<1
Physical Properties[2,3]			
Chip Bulk Density (wet)	lb/ft^3 (kg/m^3)	16 (225) min	10 - 17
Chip Bulk Density (dry)	lb/ft^3 (kg/m^3)	8 (130) min	6 - 15
Chip Size Range[4]			
Chip size (any direction)	in (mm)	¼ (6) min / 3 (75) max	½ (12)/ 2 (50)
Chip Thickness	in (mm)	3 (75) max	2 (50)
Undersize below min	%	< 2	1
Other Parameters			
Proximate Analysis, dry basis			
Volatile Matter	wt%	80	73.0 – 81.4
Fixed Carbon	wt%	19.6	15.2 – 28.6
Ash	wt%	0.4	0.38 – 0.42
Ultimate Analysis, dry, ash free basis			
Carbon	wt%	50.1	48.5 – 51.1
Hydrogen	wt%	6.0	5.9 – 6.1
Oxygen	wt%	43.2	42.1 – 43.6
Nitrogen	wt%	0.08	0.05 – 0.5
Sulfur	wt%	0.01	0.01 – 0.02
Total Halogens (as chlorine)	µg/g	22.0	21.0 – 25.6
Heating Value[5]			
HHV	(btu/lb)	8,200	7,200 - 8,500
LHV	(btu/lb)	7,700	6,700 – 8,000

Notes:

1. Moisture measured by method SS 18 71 70 involving drying the sample for 24 hours at 105° C. Moisture is "as-received" at the receiving bin sample point.
2. Chip bulk density measured by ASTM E873 – 82(2006) Standard Test Method for Bulk Density of Densified Particulate Biomass Fuels.
3. Solid wood density from Wood Handbook: Wood as an Engineering Material, USDA General Technical Report, FPL-GTR-190, 2010.
4. Chip dimensions per industry (American Pulp Wood Association) standards – chips will be accepted for delivery / processing after passing of min/max sieve sizes selected for size specifications. Fines and oversize materials to be returned for recycle to supplier.
5. Chip heating values are gross heating values according to ASTM D5865.

Gasifier Performance Specification

Tables 2 and 3 represent the estimated producer gas (syngas product) composition that will be produced if the feedstock specification is met. A feedstock test run will be required in the Aries facility at Lebanon, TN. A sample of approximately 55 tons of the feedstock to be used for the Project will be required to confirm performance specifications for gasifier process performance guarantee purposes.

Table 2: Expected Syngas Composition from Gasifier (dry basis)

Component (dry)	Typical Value Vol %	Standard Deviation
Nitrogen	50.09	6.32
Carbon Monoxide	16.59	2.25
Carbon Dioxide	15.46	1.64
Hydrogen	14.51	3.88
Methane	3.35	1.33

Table 3: Expected Contaminants in Raw Syngas

Component	Unit	Normal Value	Maximum Value	Minimum Value
Biochar and Particulate Matter	g/N-m3	0.12	0.24	0.08
Tars	g/N-m3	48.39	93.90	30.05
Water	g/N-m3	415.90	878.32	254.00

The physical properties of the syngas produced from the Aries Large Format Downdraft Gasifier are summarized in Table 4 and the Biochar in Table 5. The syngas flowrate calculated below is based on a single downdraft gasifier fed 55 tons pe day @ 15% moisture content.

Table 4: Raw Syngas Physical Properties

Property or Characteristic	Unit	Normal Value	Maximum Value	Minimum Value
Temperature	°F	900	1200	600
Specific Heat	BTU / lb.F	0.37	-	-
Higher Heating Value	BTU/scf (dry)	131	150	90
Molecular Weight	lb/lbmol	27.09	28.8	24.3
Density	lb/ft^3	0.067	-	-

Table 5: Biochar Physical Properties

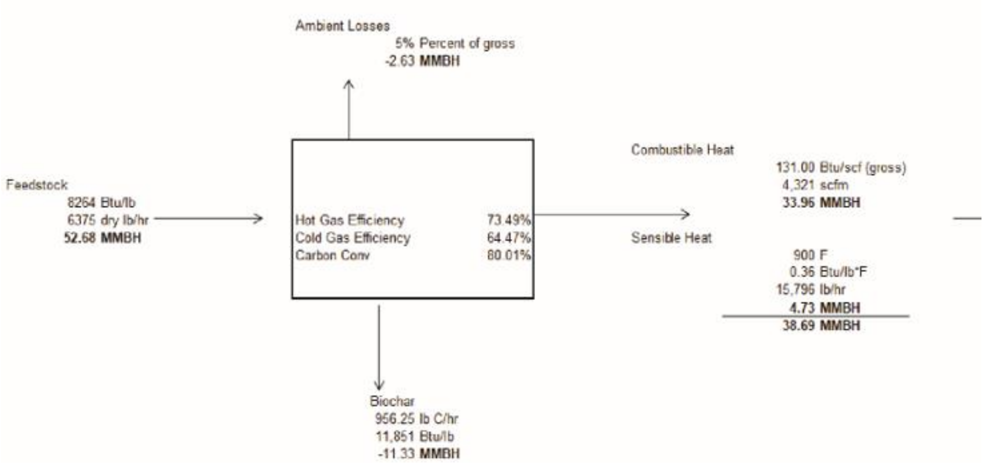
Proximate Analysis, dry basis, % by weight	Normal Value	Maximum Value	Minimum Value
Volatile Matter	5.8	7	4
Fixed Carbon	90.6	93	88

Ash	3.6	7	2
Ultimate Analysis, dry, ash free basis			
Carbon	82.2	84	80
Hydrogen	1.7	3	1
Oxygen	15.2	17	12
Nitrogen	0.9	1.5	0.5
Sulfur	0.02	0.1	0

Aries Large Format Downdraft Gasifier Energy Balance

The numbers of gasifiers recommended in this indicative proposal takes into account the syngas energy conversion efficiency expectations of the syngas clean-up & heat recovery objectives that you communicated to Aries

GASIFIER ENERGY BALANCE			
Feedstock 8264 Btu/lb 6375 dry lb/hr **52.68 MMBH** **Biochar** 956 lb C/hr 11,851 Btu/lb **-11.33 MMBH** **Ambient Losses*** 5% Percent of gross **-2.63 MMBH**		**Gas** **Combustible Heat** 131.00 Btu/scf (gross) 4,321.00 scfm **33.96 MMBH** **Sensible Heat** 900 F 0.36 Btu/lb*F 15,796 lb/hr **4.73 MMBH**	
38.72 MMBH	=	**38.69 MMBH**	=



Operating Costs (per gasifier)

Estimated Utility costs for the Scope of Supply include the following:

Electricity: 10 kW Connected load per gasifier
7.2 kW Operating load per gasifier

Natural Gas: 16scfm (1MMBtu/hr) for start-ups only
Cold Starts required 8-10 hours
Warm Starts require 1-2 hours
Cooling water for augurs: TBD
Blowers for Air to gasifier: 800 scfm max per gasifier

2. INDICATIVE SCOPE OF SUPPLY

This section details ARIES's scope of supply. Our scope of supply is limited to the gasifier unit including only the defined and attached equipment, attached instrumentation, critical air manifolds and defined flanges and drawings, documentation and services listed in this proposal.

During detailed engineering, Aries Manufacturing reserves the right to select materials and equipment other than that itemized herein, in order to produce an installation best design to meet customer's specified requirements.

Any work or services not specifically identified herein as being within the scope of supply and services is ***excluded*** from the scope of supply.

2.1. Equipment

Gasifier Unit:

The gasifier has minimal moving components that makes it easy to operate and maintain. The gasifier is highly suitable for a wide range of feedstock quality characteristics and we engineer and tailor the critical component designs for each gasifier specifically for the intended feedstock application. A summary of the technical specification for the schematic shown in section 1.3 is provided in table 6 below.

Table 6: Gasifier Unit - Technical Specification Summary

Gasifier Unit	Specification	Notes
Type	Downdraft	
Outlet temperature, °F	700 min	
Operating Pressure, psig	2-5	
Design Temperature, °F	1,800 max	
Design Pressure, psig	5 psig	
Turndown	to 25%	
Refractory Lining	50% Alumina castable or gunnite	Subject to review of Feedstock ash properties
Casing material	A36 Carbon Steel	
Shell Temp	200°F minimum (cold shell design)	

Surface Prep & Paint	SSPC-SP6 & prime coat of inorganic zinc	
Physical dimensions	8' X 17' X 50 ft high	
Orientation	Vertical	
Approximate weight, lbs	75,000	Total empty weight, incl components

<u>Gasifier Control:</u>

Aries Manufacturing provides a controls narrative on how to properly program, control and operate the gasifier for Clients' Engineer to integrate with the main plant system.

<u>Instruments & Controls</u>

Aries Manufacturing specifies control instrumentation associated with the Gasifier and will supply Miscellaneous Instrumentation/Controls, Components, and Equipment listed below. We would be glad to include additional instrumentation into our scope upon request with an appropriate cost adjustment. All instruments will be suitable for outdoor installation in a Class 1, Div. 2, Group C&D electrical area classification. The instruments & controls included at this time are as follows:

<u>Miscellaneous Instrumentation/Controls, Components, and Equipment:</u>

Lot (1) miscellaneous instrumentation and controls per gasifier , local to the Gasifier Unit is as follows:

7 – Standard Thermocouple and Thermowells for gasifier (Type K)
2 - High temperature limit switches
1 - Differential pressure indicator across gasifier
3 - Zero speed switches / indication for augurs
8 - High temperature Limit switches
8 - Valve position indicators
5 - weld pad thermo couples and Skin temp indicators
6 – microwave level indicators

<u>Equipment Scope Battery Limits</u>

The diagrams in below depicts the division of responsibility interfaces for the gasifier. The responsibility breaks are at the end flanges shown on the gasifier (figures 3) and bed and plano air manifold piping (figure 4)

<u>Gasifier assembly and flange connections.</u>

The reactor assembly begins with the installation and securing of the 4-leg base on the pre-poured footers and proceeds in a stacking manner with the subsequent sections of the reactor, all done onsite or at the factory shop. The reactor sections may be stacked freestanding as long as all necessary precautions are taken into account, but once fully stacked, each section is seal-welded to its neighboring sections. See figure and table below.

<u>Piping and scope breaks</u>

Piping for each gasifier section is divided into three segments; instrument air, process air, and process gas. Instrument air supplies compressed air needed to operate valve actuators. It is supplied from the plant compressed air system; process air is pumped into the reactor via the main air blower and drives the gasification reactions; process gas piping contains the hot producer gas and transports the gas to downstream processes.

The Plano air inlet header flanges represent the scope break between the gasifier and the process air piping. The connecting piping between the header and the gasifier are in the gasifier scope of supply. The upper drying section flanges represent the scope break between the gasifier and the process air piping. The upper airlock valves (2) represent the scope break between the gasifier and the fuel feed. The design of the residue system after the outlet of the residue valves is outside of the scope of this document and the scope of the gasifier.

2.2. Scope of Supply Matrix

Our scope of supply is limited to the equipment, drawings, documentation and services listed in this proposal. The following Equipment Scope of Supply Matrix specifically details Aries Manufacturing 's included equipment scope of supply. Aries Manufacturing will be happy to adjust our scope of supply to satisfy your project needs and objectives.

Equipment Scope Item	**By ARIES**	**By Customer**	**Comment**
MAJOR EQUIPMENT ITEMS:			
Natural gas start-up burner + BMS		X	
Down-fired Gasifier Unit	X		
Refractory material & installation	X		Assumes all shop installed
Refractory Anchors	X		
Dutchman gasifier feed system	X		
Natural gas valve fuel trains		X	Interconnecting piping and control by customer
Gasifier Feed Auger	X		
Gasifier Residue Augers (2)	X		
Gasifier air blower motor, inlet duct & silencer		X	
Primary air valve train/controls		X	
Secondary air valve train/controls		X	
All equipment/ducting		X	
Exhaust stack		X	
Bed and plano air manifold and ring header piping connected to the gasifier	X		
Biochar cooling, conveyance and storage		X	
CIVIL /STRUCTURAL:			
Platforms, supports, stairway access & ladders		X	
All combustion air duct supports		X	
Foundations & anchor bolts		X	
DUCTING:			
Main combustion air header		X	

Primary combustion air (blower to gasifier)		X	
Secondary combustion air (blower to gasifier)		X	
Tail Gas ducting		X	
PIPING:			
Utility field piping up to Aries fuel valve train		X	(Aux. gas & IA)
Utility field piping from Aries valve train.		X	(Aux gas & IA)
Field piping for aux. gas vent to safe area		X	
Instrument air to valve train header		X	
Instrument air / purge air, sight ports, etc.		X	
ELECTRICAL:			
Supply of all 3PH & 1 PH power		X	
MCC center & motor starters		X	

Blower motors		X	
All interconnecting field wiring, conduit, trays		X	
Pilot ignition transformer	X		
All field routed instrument cable, wiring conduit		X	
Variable frequency drive		X	
EXTERNAL INSULATION:			
External insulation		X	
PERSONNEL PROTECTION:			
Accessible areas of Incinerator shell		X	
HEAT TRACING:			
If any heat tracing is required		X	NA
EXPANSION JOINTS:			
Combustion air blower inlet & outlet		X	
Primary and secondary air connection		X	
Flex hoses on main gas at burner		X	
Tail Gas tie points at Incinerator		X	
All expansion joints within ducting system		X	
MISCELLANEOUS ITEMS:			
Gaskets & bolt kits	X		

Spare parts (if purchased)	X		(not included at this time)
Touch up paint	X		
Grounding lugs	X		
Lifting lugs	X		
Area Lighting		X	
Installation of equipment		X	
INSTRUMENTATION & CONTROLS			
All instruments & controls for Gasifier proper	X		
All Producer Gas instruments & controls		X	
All Biochar instruments & controls		X	

2.3. Drawings / documentation

After receipt of official purchase order and all applicable specifications, orientations, and subject to subvendor drawing availability, Aries Manufacturing will submit the following drawings and documents as indicated.

Please note that this is Aries Manufacturing's "standard" engineering, drawing, and document submittal package**.** If additional engineering, drawings, and documentation are required, these requirements might result in additional charges.

Drawing & Document Description	**E-Copy Qty.**	**Submitted As**				**Wks, After receipt of Order**	**Wks, After receipt of Approval**	**Notes**
		A	**C**	**R**	**I**			
First Submittal:								
Monthly Project Schedule (preliminary)	1				X	1-2		
General Arrangement Plan/Elevation	1	X				6-8		
Preliminary P & I Diagram	1	X				6-8		
Preliminary Equip. Weights & Loading Plan	1	X				6-8		
Customer Approval Cycle						1-2		
Second Submittal:								
Control Narrative	1	X					6-8	
Wiring Diagram (BMS)	1	X					4-6	Subject to vendor
Instrument ISA Data Sheets & Component Parts List	1	X					4-6	

Customer Approval Cycle							1-2	
Third Submittal: Certified for Construction								
1 & 2 submittal Drawings/Doc.	1		X				TBD	
Spare Parts List (start-up & 1 year)	1				X		TBD	
Additional Submittals:								
Installation, Operation, and Maintenance Manuals	1 hard + 1 Ecopy			X				TBD

Submittal Legend: *A = for approval: C = certified: R = for record only: I = for information only*

After Aries Manufacturing receives approval and *as the project schedule dictates*, all other necessary fabrication/shop drawings will be completed. These detail drawings are not issued for approval. 2.4. Services

The following services are available upon request. These services can be purchased with the equipment or under a separate service contract:

HAZOP meeting attendance in person
Installation Supervision
Commissioning/Start-up Supervision Service
Operator Training
Performance Test Witness

Aries Manufacturing will be happy to develop a complete service package proposal after further discussion of need. Service rates of sub-vendors will apply in addition to Aries' standard rates.

As a best practice, Aries Manufacturing offers an Instrumentation and Controls technician from in-house staff to participate in the Aries Manufacturing service team's site activities. Customers can not only reduce commissioning duration and associated field service costs, but also increase its system staff competence for the new equipment by actively participating in the commissioning/startup of the unit.

There are many factors that can impact any service package duration offered. If additional service time is required due to no fault of Aries Manufacturing or our sub-vendor (if applicable), Buyer agrees to reimburse Aries Manufacturing for the additional labor and expenses at applicable standard rates plus per diem.

2.4. Exclusions

Specifically excluded from this proposal are any components or services unless itemized in this quotation. Aries Manufacturing would be willing to consider adding additional scope associated with the gasifier to our supply at your request such as:

- Feedstock conveyance system to the Dutchman
- Site Grading, foundations, anchor bolts, slide plates, and off-loading equipment
- Electrical supply, step down transformers, motor starters, MCC, DCS, electrical grounding, lightning protection, and interconnecting field wiring
- All utility systems, regulated fuel supplies, interconnecting (field) piping and ducting, pipe supports, and duct supports
- Start-up burner test (using a standard proven burner); Aries would be glad to discuss your specific needs as project proceeds and price accordingly
- All external insulation, personnel protection, cladding, tracer heating and waterproofing of equipment
- Any field labor or modification changes on account of work performed on our equipment unless prior approval in writing by an authorized Aries engineer
- Access platforms and ladders
- Area lighting and fire protection
- Syngas gas piping, instruments, controls, safety shut-off valves, seal pots, flash back protection, or other items that might be necessary for the routing and delivery of the syngas gas
- Control PLC Hardware or Programming
- Air supply to gasifier, including connecting piping, surge tanks, and control/instrumentation
- Installation, demolition, commissioning, emission compliance testing, taxes and permits
- Interconnecting piping & supports
- Instrument wiring
- Freight to site location
- Biochar cooling, conveyance and storage

3 INDICATIVE COMMERCIAL SECTION

3.1 Price

The total fixed price Ex Works for two (2) Aries Large Format Downdraft Gasifier Units is estimated at US$ 8,000,000. This proposal is indicative only and does not constitute an offer nor represent a basis on which a contractual arrangement can be formed. A formal solicitation and offer utilizing Aries standard equipment supply terms and conditions will need to be issued and a formal supply agreement between the parties will need to be executed to establish such a contractual arrangement.

Item	Pricing Basis	Qty	Price each (US$)	TOTAL (US$)
Gasification Unit(s)	Fixed Price	2	$4,000,000	$8,000,000

HAZOP Meeting Participation (if required): Not included. Available upon request at then applicable rates
Erection Supervision: Not included. Available upon request at then applicable rates
Start-up Service / Training: Not included. Available upon request at then applicable rates

3.2 Delivery

We estimate the following drawing and equipment delivery timing. When the project nears the purchase order release date, we are willing to review and adjust our schedule to best suit your project objectives.

Engineering Drawing for Approval:	6-8 weeks after receipt of purchase order Approval
Cycle:	2 weeks
Equipment:	Ready to ship - 18 weeks after receipt of approval and release to fabricate. ***If a more accelerated schedule is required, please advise.***
Taxes, Duties, Fees:	Price excludes all taxes, duties, and fees.
Freight:	Ex-Works. Not included. Aries Manufacturing would be willing to prepay and invoice at actual cost +10% for handling.

3.3 Terms of Payment

Terms of Payment: (net 30 days)	40% receipt upon placing of purchase order 40% receipt upon approval of drawings to start fabrication 10% upon completion and ready to ship Ex Works from fabrication shop

murraysmith

APPENDIX C

Miaomiao Zhang

From: Miaomiao Zhang
Sent: Thursday, February 3, 2022 3:24 PM
To: bart.lynam@renufuel.com; btlynam@comcast.net
Cc: Patrick Davis; John Thayer; Kinno, Erika; Thompson, Drew
Subject: Information request on Biosolids Partnership's proposal

Hello Bart,

My name is Miaomiao Zhang. I am a wastewater engineer with Murraysmith, an engineering consulting company. Recently we are contracted with King County to conduct an independent analysis of biosolids thermal drying based on the proposal that Biosolids Partnership presented in a PowerPoint entitled "Carbon Net Negative King County's Enhancement Wastewater Biosolids Utilization Meeting" on September 9, 2021. I am leading this effort and working with my Murraysmith team.

The first step of the analysis is to develop an implementation plan for your proposal. Then we will evaluate the thermal drying option with the other biosolids option identified by the County, from the aspects of scalability, cost, environmental and climate footprint and specifics of implementing the program. To do the work we'd like to get a better understand of your proposal. We'd like to request any additional information you have related to the proposal, specifically, but not limited to,

1. Process Flow Diagram for proposed Class A biosolids facility, including gasification and dryer
2. Design criteria and any calculations for proposed Class A biosolids facility
3. Equipment cutsheets and capacities of major components including gasification and dryer
4. Mass balance of the entire process, including biomass, biochar, biogas, sludge and pellets, etc.
5. Energy balance of the entire process, including biochar, biogas, renewable electricity, hot water, etc.
6. Carbon footprint calculation for the entire process
7. Life cycle, capital, or O&M cost assessments of the proposed Class A biosolids facility
8. Odor control requirement and sizing
9. Any further plan on electric truck or renewable energy utilization for the proposed facility
10. Site plan and layout drawings of the proposed Class A biosolids facility
11. Gasification and Andritz drum dryer installation list for Class A biosolids facilities in Western US, with contact info

I know this is a lot of information to ask, and you may not have all. We'd love to take whatever information you can offer. If a phone conversation is preferred, we'd love to discuss our request with you. Thank you for your attention and look forward to the collaboration with Biosolids Partnership.

Miaomiao

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Saturday, March 26, 2022 1:26 PM
To:	Miaomiao Zhang
Cc:	Commerford Peter; John Sudnick (jjs@pintegration.com); jewing@harriscompany.com; Rick Bender; Mike Ruby; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject:	Update Gasifcation of Woodchips RE: Update ANDRITZ Dryers - -RE: Update March 18, 2022 King County Biosolids Partnership
Attachments:	Email Status Metso-Outotec Gasification 3-18-2022.pdf; Email 3-22-2021 Ototec Business news release.pdf; Outotec has taken a strategic decision to divest three businesses in the Metals, Energy & Water segment.pdf

Hi Miaomiao:
We want to keep you informed regarding the gasification of prepared woodchips into syngas and biochar. We are very confident of our custom design to produce a net-negative carbon balance for King County's biosolids processing and utilization which is based upon proven fundamental elements that result in the net-negative carbon balance.

The purpose of this email is to communicate to you the status of using Metso-Outotec for our gasification of woodchips. The 1st attachment is a copy of an email regarding our communication with Metso-Outotec wherein we proceeded to work with Mike Grimm, Business Development Manager - Energy with Metso on 3-18-2022. Then on 3-22-2022 we received another email (refer to the 2nd attachment) from Mike Grimm informing us that Outotec is in the process of divesting from the energy market which is the 3rd attachment.

We are pursuing alternative companies that provide proven gasification. We will have additional information early next week as we are in conversation with a world-class gasification company that will fulfill our gasification needs. We appreciate your patience with regard to this one element that we need to nail-down and move forward to complete your list of questions for King County.

With appreciation.
Bart T.

From: Bart Lynam
Sent: Wednesday, March 23, 2022 6:41 PM
To: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Cc: Commerford Peter <Peter.Commerford@andritz.com>; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; jewing@harriscompany.com; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: FW: Update ANDRITZ Dryers - -RE: Update March 18, 2022 King County Biosolids Partnership

Hi Miaomiao:
With regard to your Question #1 in your email of 3-22-2022:

1. Your PowerPoint on 9/9/2021 called out the "drum dryer" by Andritz, while this Andritz's proposal proposes the "fluid bed dryers" by Andritz. What is the reason for the switch?

We decided to enhance the carbon balance by using steam to heat the Andritz Fluid Bed Dryer by utilizing the extraction from a steam turbine electrical generator. We originally planned to purchase renewable electrical power but determined it better to make our own renewable electrical power from the gasification of biomass.

2. This proposal sized two dryer trains based on 85 dry tons/day sludge quantity. Unfortunately this is not the correct design criteria for King County's biosolids. After some further review of the previous information, I noticed one of your slides from 9/9/2021 PowerPoint had the wrong biosolids quantity. Please see the attached document and Tables 8 and 9 from 2020 Brown & Caldwell's report below. It appears this Andritz's proposal is based on the "wet ton" sludge quantity in year 2020, while those sludge numbers are actually dry solids in lb/day. Could you please update the Andritz's proposal based on the criteria of year 2050 solids production: 130 dry tons/day annual average; 150 dry tons/day maximum month?

With regard to your question #2 in your email of 3-22-2022, please find the answer from Peter Commerford with Andritz in the email below.

We will respond to your question #3 shortly:

3. I didn't find the price information in the Andritz's proposal. Could you please provide it in the updated proposal?

Thank you for your patience. We are continuing to pursue the answers to your original list of 11 questions.
With appreciation,
Bart

From: Commerford Peter
Sent: Wednesday, March 23, 2022 10:39 AM
To: Bart Lynam <bart.lynam@renufuel.com>
Subject: RE: Update ANDRITZ Dryers - -RE: Update March 18, 2022 King County Biosolids Partnership

Bart,

We can handle this as follows:

King County/MurraySmith	2050 AA	2050 MM
Nominal Daily Sludge Production	130 dry tons/day	150 dry tons/day
Cake Dryness	24% DS	24% DS
Nominal Daily Sludge Production	542 wet tons/day	625 wet tons/day
Annual Sludge Produced	197,708 wet tons/annum	228,125 wet tons/annum
Dryer Operations	7 days per week	7 days per week
Dryer Operations	24 hours/day	24 hours/day
Dryer Operations	168 hours/week	168 hours/week
Dryer Capacity Required	130 dry tons/day	150 dry tons/day
Dryer Capacity Required	542 wet tons/day	625 wet tons/day
Final Product	95% DS	95% DS
Final Product	137 tons/day	158 tons/day
Evaporation Rate	16.9 tons/hour H2O	19.5 tons/hour H2O
Evaporation Rate	33,735 lb/hour H2O	38,925 lb/hour H2O
Evaporation Rate	15,299 kg/hour H2O	17,653 kg/hour H2O
No. of Drying Trains	2	2
Evaporation Rate/train	7,650 kg/hour H2O	8,827 kg/hour H2O
Dryer Technology	Fluid Bed Dryer	Fluid Bed Dryer
Dryer Model Selection	FDS-9.0	FDS-9.0
	85%	98%
Max. Evaporation Rate	9,000 kg/hour H2O	9,000 kg/hour H2O
Specific Energy Consumption	1,250 BTU/lb/water	1,250 BTU/lb/water
Heat Energy Requirement	42.17 MM BTU/h	48.66 MM BTU/h
Heat Energy Requirement	12.35 mW (th)	14.25 mW (th)

Using the same size dryer as already proposed, on an 2050 Annual Average basis, we have 85% utilization/availability of the 2 dryers operating 24/7 – it is a relatively minor change to increase processing capacity by ~10% using an ANDRITZ Fluid Bed Drying System FDS-10.0)
Please advise facility sludge lading at start up – need to ensure the gasification system has sufficient turndown.
Please confer with Ms. Zhang.

As a note to those interested, YouTube & links re the ANDRITZ Fluid Bed Drying system at Victoria BC

- Construction Flyover of the site -ANDRITZ supplied the thickening, dewatering and Fluid Bed Dryer (the tallest structure)
- Capital Regional District's New Residuals Treatment Facility

Note that Victoria's dry product is being used as fuel in the Lafarge Cement plant in Vancouver.

Please confirm Mr. John Thayer's request for information on a drum dryer facility is still required.

Thanks
Peter

Sincerely,

Peter Commerford
SEPARATION
Manager - Drying Systems

ANDRITZ Separation Inc.
1010 Commercial Blvd S
Arlington, TX 76001 USA
Ph: 817-419-1719
Fax: 817-419-1910
Cell: 817-271-2855
peter.commerford@andritz.com
www.andritz.com

From: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Sent: Wednesday, March 23, 2022 12:36 AM
To: Bart Lynam <bart.lynam@renufuel.com>
Cc: Patrick Davis <Patrick.Davis@murraysmith.us>; John Thayer <John.Thayer@murraysmith.us>; Kinno, Erika <Erika.Kinno@kingcounty.gov>; Thompson, Drew <DrThompson@kingcounty.gov>; michael.grimm@mogroup.com; Commerford Peter <Peter.Commerford@andritz.com>; jerry.whitfield@gmail.com; pchapman@harriscompany.com; Teeter Mike <Mike.Teeter@andritz.com>; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: RE: Update ANDRITZ Dryers - -RE: Update March 18, 2022 King County Biosolids Partnership

Thank you Bart for sharing the drying facility proposal. After reviewing the document we have a few questions/requests.

1. Your PowerPoint on 9/9/2021 called out the "drum dryer" by Andritz, while this Andritz's proposal proposes the "fluid bed dryers" by Andritz. What is the reason for the switch?
2. This proposal sized two dryer trains based on **85 dry tons/day** sludge quantity. Unfortunately this is not the correct design criteria for King County's biosolids. After some further review of the previous information, I noticed one of your slides from 9/9/2021 PowerPoint had the wrong biosolids quantity. Please see the attached document and Tables 8 and 9 from 2020 Brown & Caldwell's report below. It appears this Andritz's proposal is based on the "wet ton" sludge quantity in year 2020, while those sludge numbers are actually dry solids in lb/day. Could you please update the Andritz's proposal based on the criteria of year 2050 solids production: **130 dry tons/day annual average; 150 dry tons/day maximum month**?
3. I didn't find the price information in the Andritz's proposal. Could you please provide it in the updated proposal?

4.1 Flows and Loads

The sizing for each of the scenarios was based on flows and loads that were projected t
year. Raw influent flows and loadings for each of the three plants were provided by the (
Flows and Loads Study to evaluate treatment plant capacity limitations. A plant-wide sol
model calibrated during that study was used to calculate digester feed solids loading rat
raw influent flows and loadings. **Tables 8 and 9** list the 2050 annual average and 2050
loadings, respectively. **Table 10** contains details on the peaking factors. The peaking fac
combination of loading projections provided by the County and historical data at each pl

Table 8. 2050 Annual Average Flows and Load

Parameters	West Point	South Plant	Brightwater
Digester feed TS load (lb/d)	225,860	263,760	93,910
Digester feed TVS load (lb/d)	182,890	226,530	84,400
Digester feed %TS	6.1	6.2	5.8
Dewatered solids TS load (lb/d)	101,170	120,810	39,450

Dewatered solids %TS	28.5	22.9

Table 9. 2050 Max Month Flows and Lo

Parameters	West Point	South Pla
Digester feed TS load (lb/d)	255,760	303,520
Digester feed TVS load (lb/d)	207,660	259,700
Digester feed %TS	6.1	6.2

Thank you for your time.
Miaomiao

—

Miaomiao Zhang PE, PMP
Principal Engineer | Licensed in WA
600 University Street, Suite 300, Seattle, WA 98101
P 425.943.9130
Murraysmith | https://hes32-ctp.trendmicro.com:443/wis/clicktime/v1/query?url=www.murraysmith.us&umid=276d38c9-7f1f-4562-9d10-bc46b83ce7f4&auth=144056baf7302d777acad187aac74d4b9ba425e1-bcfd43a6aa42fee9925f356b59944cd5ae147675

From: Bart Lynam <bart.lynam@renufuel.com>
Sent: Friday, March 18, 2022 1:22 PM
To: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Cc: Patrick Davis <Patrick.Davis@murraysmith.us>; John Thayer <John.Thayer@murraysmith.us>; Kinno, Erika <Erika.Kinno@kingcounty.gov>; Thompson, Drew <DrThompson@kingcounty.gov>; michael.grimm@mogroup.com; Commerford Peter <Peter.Commerford@andritz.com>; jerry.whitfield@gmail.com; pchapman@harriscompany.com; mike.teeter@andritz.com; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: Update ANDRITZ Dryers - -RE: Update March 18, 2022 King County Biosolids Partnership

Hi Miaomiao:
Here is additional information regarding your questions pertaining to our proposal. Please find attached a 69-page document regarding the King County ANDRITZ Fluid Bed Dryers. These dryers will use steam as a heat source from the electrical steam turbine extraction. Peter Commerford, Manager - Drying Systems for ANDRITZ Separation Technologies, Inc. U.S. out of Arlington, Texas can be available for any discussion of his proposal, if necessary. Peter Commerford's contact info is cell 817.271.2855 and work is 817.419.1719 with email peter.commerford@andritz.com

We will continue to supply you with additional information as it becomes available.
Regards,
Bart

From: Bart Lynam
Sent: Friday, March 18, 2022 1:13 PM
To: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Cc: Patrick Davis <Patrick.Davis@murraysmith.us>; John Thayer <John.Thayer@murraysmith.us>; Kinno, Erika <Erika.Kinno@kingcounty.gov>; Thompson, Drew <DrThompson@kingcounty.gov>; michael.grimm@mogroup.com; Commerford Peter <Peter.Commerford@andritz.com>; jerry.whitfield@gmail.com; pchapman@harriscompany.com; mike.teeter@andritz.com; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: Update March 18, 2022 King County Biosolids Partnership

Hi Miaomiao:
Since our last email, we were informed by David Novak, VP with Ecoremedy, that they need to withdraw from the project because the electrical power generation portion of our proposal does not fit into their business plan. Subsequently, Team Member John Sudnick, President of Project Integration, Inc., an engineering consulting company out of South Carolina, received an

email from Michael Grimm with Metso yesterday. Here is a snip from that email:

From: Michael Grimm <michael.grimm@mogroup.com>
Sent: Thursday, March 17, 2022 5:46 PM
To: John Sudnick <jjs@pintegration.com>
Subject: Commitment from OEP

Hi John

Mike Grimm
Business Development Manager, Energy with Metso

We are indeed pleased that Metso will join our team as Metso-Outotec is a multi-billion dollar diversified international company with offices in 50 countries and 32,000 employees. The word *Metso* translates to Wood Grouse. In 2011, Metso delivered the world's largest biomass gasification plant in Vaasa, Finland enabling the replacement of coal with domestic wood-based renewable fuels and reduction in carbon dioxide emissions. This was the first time in the world that biomass gasification was adopted on such a large scale. Metso is a global supplier of sustainable technology and wood gasification producing renewable energy.

We will soon be sending you additional information with answers to your questions and hope to have all of your questions answered by the end of next week.
Regards,
Bart

From: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Sent: Friday, March 4, 2022 2:07 PM
To: Bart Lynam <bart.lynam@renufuel.com>
Cc: Patrick Davis <Patrick.Davis@murraysmith.us>; John Thayer <John.Thayer@murraysmith.us>; Kinno, Erika <Erika.Kinno@kingcounty.gov>; Thompson, Drew <DrThompson@kingcounty.gov>; Commerford Peter <Peter.Commerford@andritz.com>; jerry.whitfield@gmail.com; pchapman@harriscompany.com; Brian Novak <bnovak@ecoremedyllc.com>; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: RE: [EXTERNAL] Gasification of Woodchips - FW: Questions to be answered

Thank you for the update Bart.

Miaomiao

Miaomiao Zhang PE, PMP
Principal Engineer | Licensed in WA
600 University Street, Suite 300, Seattle, WA 98101
P 425.943.9130
Murraysmith | www.murraysmith.us

From: Bart Lynam <bart.lynam@renufuel.com>
Sent: Friday, March 4, 2022 1:40 PM
To: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Cc: Patrick Davis <Patrick.Davis@murraysmith.us>; John Thayer <John.Thayer@murraysmith.us>; Kinno, Erika <Erika.Kinno@kingcounty.gov>; Thompson, Drew <DrThompson@kingcounty.gov>; Commerford Peter <Peter.Commerford@andritz.com>; jerry.whitfield@gmail.com; pchapman@harriscompany.com; Brian Novak <bnovak@ecoremedyllc.com>; John Sudnick (jjs@pintegration.com) <jjs@pintegration.com>; Rick Bender <ricksbender@gmail.com>; Mike Ruby <mruby@envirometrics.com>; prakasamtata@gmail.com; jerry.whitfield@gmail.com
Subject: [EXTERNAL] Gasification of Woodchips - FW: Questions to be answered

Hi Miaomiao:
We wanted to bring you up-to-date regarding the gasification of woodchips. Below is an email from Brian Novak, VP with Ecoremedy, who will be supplying the gasification phase of our proposal. We originally listed Frontline Bioenergy who has amicably withdrawn from this project because they are too busy with other work, especially the San Joaquin Renewables Project in California that has been funded for $165 million.

We will continue to work on the answers to your original 11 questions and plan to have this all to you by the end of next week. The addition to Ecoremedy will help to move this process along.

With appreciation,
Bart

From: Brian Novak <bnovak@ecoremedyllc.com>
Sent: Friday, March 4, 2022 8:31 AM
To: Bart Lynam <bart.lynam@renufuel.com>
Cc: Dave Mooney <dmooney@ecoremedyllc.com>; Dion Banks <dbanks@ecoremedyllc.com>; Christopher Holcomb <cholcomb@ecoremedyllc.com>
Subject: Questions to be answered

Hi Bart,
It’s been a long time since Stickney. Small world. I talked with Steve Waters this week as well as Dennis Moran.

Dave Mooney asked me to become involved in getting the answers to the questions highlighted in the MurraySmith attachment.
After reviewing the questions, we can respond early next week.

With respect to the feed stock for the gasifier, can you provide the proximate and ultimate analysis for the wood chips. They have to be clean without lead paint, nails, metals, etc.
Please feel free to include me in communications and questions for this inquiry and others for Ecoremedy.
Also, please say hello to Peter Commerford. We do way back to early days of class A drying.

Thanks,
Brian Novak
Vice President Engineering and Operations
Ecoremedy LLC
978.376.7315
bnovak@ecoremedyllc.com
ecoremedyllc.com

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Wednesday, April 20, 2022 2:48 PM
To:	Miaomiao Zhang
Cc:	DMoniot@ventureengr.com; Vescovi, Patrick; Commerford Peter
Subject:	[EXTERNAL] FW: Odor Control for King County Fluid Bed Drying System
Attachments:	North Shore FDS handout.pdf

Hi Miaomiao:
Information from Peter Commerford at Andritz about odor control and sizing. We hope this will answer your question #8 - Odor control requirement and sizing.
Regards,
Bart T.

From: Commerford Peter <Peter.Commerford@andritz.com>
Sent: Friday, April 15, 2022 8:25 AM
To: Bart Lynam <bart.lynam@renufuel.com>
Subject: Odor Control for King County Fluid Bed Drying System

Bart

Cake Receiving

The Dewatered Municipal Solids from the other WWTP (Brightwater and Renton) will arrive via trucks, either in 20 cubic yard bins or in tandem-axle dump trucks. The trucks will offload at an unloading facility. The trucks will dump into a covered hopper and the hopper cover will be motorized to open and close remotely. The below grade hopper will include foul air extraction (12ACH) for odor control. The unloading facility will feature roller shutter doors which will close during truck unloading. Wash stations for truck cleaning prior leaving the facility will be included.

Fluid Bed Drying 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 steam produced by syngas by the and provide 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 100m_3 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 90 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 silo or directly to a truck loading hopper.

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. 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 biotrickling 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 residuals 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

The North Shore Fluid Bed Drying System incorporates many of the odor control strategies outlined here and the customer is encouraged to visit this plant, with operations exceeding 10 years. (See attached)

Sincerely,

Peter Commerford
SEPARATION
Manager - Drying Systems

ANDRITZ Separation Inc.
1010 Commercial Blvd S
Arlington, TX 76001 USA
Ph: 817-419-1719
Fax: 817-419-1910
Cell: 817-271-2855
peter.commerford@andritz.com
www.andritz.com

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Wednesday, April 27, 2022 12:58 PM
To:	Miaomiao Zhang
Cc:	Mullendore, Zoe; Vescovi, Patrick; DMoniot@ventureengr.com; 'Joseph Regnery'; Rick Bender; Mike Ruby; Commerford Peter; Clue Westmoreland
Subject:	[EXTERNAL] Update on Answer to Miaomiao (Murraysmith) Question #9 - KIng County Biosolids Partnership Proposal
Attachments:	Introduction of King County Biosolids Team 4-27-2022.docx; PACCAR Brett Duarte Email 3-11-2022.pdf; Price of Electric Trucks Erik Casebeer 3-8-2022.pdf; PACCAR Electrical Power Recharge 4-19-2022.pdf; Excel Electric Trucks Routing Miles Woodchips, Biochar and Dried Pellets.xlsx; OSW Equipmnet Trailer Quote 4-25-2022.pdf; Truck Scale Proposal 4-27-2022.pdf

Hello Miaomiao:

First, please refer to the attached introduction of our King County Biosolids Team (Attachment #1).

In answer to your Question #9 regarding any further plan on electric trucks or renewable energy utilization for the proposed facility, we submit the following:

We propose the purchase of 3 electric trucks that will be manufactured locally at Kenworth Truck Company, a subsidiary of PACCAR. Per Brett Duarte, Fleet Sales Manager - Electrification at Kenworth Truck Company (phone: 206.276.3829 Email: Brett.Duarte@PACCAR.com ,the electric trucks will be the Kenworth T680E which is a 82k GCW rated tractor capable of ePTO applications. PACCAR's Renton plant is where the T680E is manufactured which is a zero waste to landfill facility (Attachment #2).

Per Erik Casebeer, Territory Manager of Pape Kenworth (206.735.0107 and email of ecasebeer@papekenworth.com <mailto:ecasebeer@papekenworth.com> , the chassis-only costs (roughly speaking and without a detailed spec) could be anywhere from $360k-$400k, plus applicable taxes which are FET @ 12% and state tax at 10.4% if our SeaTac store is closest to domicile location. (Attachment #3).

Erik Casebeer has estimated that one charging station at a cost of $60,000 plus installation would be needed to be located at the South WWTP in Renton.
Per Brett Duarte, Fleet Sales Manager - For electrification at Kenworth (206.276.3829) at PACCAR, a good assumption is to use 400kw for the power to recharge a T680E completely. Rough average pick-up and delivery economy could be 2.2kwh/mi. (Attachment #4).

Attachment #5 is an Excel analysis of the routing schedule for the electric trucks.

We anticipate the electric trucks will be used as follows:

.....We will haul the wood chips from Cedar Grove to the South Plant in Renton, a distance of 12 miles.
.....On the appropriate return trips, we will haul the BioChar from the South Plant in Renton to the Cedar Grove, a distance of 12 miles.
.....We will haul the dried pellets from the ANDRITZ Dryer from the South Plant in Renton to the Ash Grove Plant in Seattle, a distance of 12 miles.

Three (3) trailers End Dump Trailer to go with the 3 electric trucks will be needed with trailers covered during transport to keep the cargo dry. These will be end dump trailers as follows:

3 TT 39' Alumatech 3 Axle Half Round Tub Frameless Trailer (refer to attached quote from Paul Barrett, Sales Manager OSW Equipment Co. email:
paul@oswequipment.com <mailto:paul@oswequipment.com>) Price is $266,155.74 (Attachment #6)

Commercial Truck Scale to be furnished and installed at the South Plant in Renton to weigh in and out the truck and trailer. This will be a permanent scale that will have a drain and concrete deck and a kiosk to collect data and relay to customer SQK Server. Please refer to attached quote from Meridian Scale Company in Kent, WA. Contact: Todd Thompson at Meridian Scale cell 253.951.3901 and email of Todd@usscale.com (Attachment #7)

Rick Bender, past President of the Washington State Labor Council and member of the AFL-CIO Board, will work with the Teamsters Union to relocate and retrain the truck drivers who will be affected by the elimination of the transporting of the centrifuged dewatered biosolids to eastern Washington farm lands and the King County forests. Mr. Bender's research has resulted in determining the current hourly start rate of the wages for truck drivers in King County to be $31.27/hour and top out at $39.75/hour with the employer paying 100% of Health and Welfare at $1,548/month. Truck driver pensions are based on 2% times the number of years worked based on the employee's 5 highest years.

We propose to supply all of our on-site electricity to be generated from the steam produced from the gasification of the wood chips. We also plan to buy renewable electricity during the times when we are not generating our own electricity. Our plan is to use solar panels on the facility's roof to supplement our electrical power needs. (Additional information will be supplied under Question #5.

Sincerely,
Bart T. Lynam

OSW Equipment & Repair, LLC.

Quote Number:

Customer: Bart Lynam

Date:

Salesperson: Paul Barrett
Cell: 425-417-6768
paul@oswequipment.com

Phone: 206-612-5323
Fax:
E-Mail: bart.lynam@renufuel.com

Quantity	Description	Unit Price	Total
3	TT 39' Alumatech 3 Axle Half Round Tub Framless Trailer per Specification Sheet	$ 93,585.00	280,755.00
	****Estimated Freight**** **Final Freight Cost to be Determined** **When Unit is Ready for Shipment** **Any Modification or Relocation to Frame Components will be Charged Back on a "Time & Material Rate"** All OSW Specifications will go to STANDARD build, unless stated above or NOTED in Received "Printed Specification Sheet"		
Customer Signature:		**Sub Total:**	$280,755.00
Date:		**7.8%**	$21,898.89
PO#:		**F.E.T 12%**	$33,690.60
		Quote Total	$336,344.49
		25% Deposit	$70,188.75
		Balance COD	$266,155.74

Quote is good for 7 DAYS. 25% Deposit Is Required with Order.
Due to the Current Volatility of the Market and the Rising Cost of Materials, Final Price is Subject to Change Without Notice. A Surcharge may be Added to Final Sale Price Prior to Delivery
Payment in Full Upon Completion. F.O.B. Woodinville, WA

P.O. Box 1651 ~ Woodinville, WA 98072 ~ Office (425) 483-9863 ~ Fax (425) 483-4504

Model	39ft. Alumatech	Suspension	INTRAAX
Body Type	Half Round Tub	Aux Suspensio	W&C 9100, 13k Axle
Body Length	39ft. Bridge Length	Chassis Length	Extended Alum. Sub Frame
Frame Length	Frameless	Axles	102in., 25,000lbs.
Hoist Size	8" x 265" Custom	Drums	X-30
Hoist Fitting	Male Screw On	Hubs	Duralite
Side Height	57" (41.4 Cubic Yards)	ABS	4S/2M ABS
Side Gauge	.190 (3/16")	Wheel Type	4/4, A/W, Hub Piloted
Side Boards	None	Wheel Size	22.5 x 8.25
Nose Gauge	.250 Aluminum	Tire Make	Std. Radial Tire
Tailgate Height	To Fit	Tire Size	(10) 11R22.5
Tailgate Gauge	.155	Tarp Rods	None
Tailgate Slope	12 DEGREE	Tarp Hooks	None
Tailgate Control	Air	Spreader Chain	None
Tailgate Hinge	Top Hinge	Rear Apron/Siz	None
Tailgate Seal	Rubber Sealed	Tarp	Travis Lock Style Tarp
Coal Door	None	Tarp Color	Black
Safety Latches	2 on the Sides	Pin Stripe Colc	D.O.T.
Floor Thickness	.250 Aluminum	Steel Parts Col	Black
Crossmember Center	None	Body Color	Shiny Aluminum
Draft Arms	Aluminum	Back Up Lights	None
Landing Gear	Drop Legs	Outboard Light	2 per Side, LED
King Pin Setting	-	Marker Lights	3 per Side, LED
Tire Carrier	None	Side Turn Sign	Yes
Tandem Fenders	Front of Rear Fenders	Steps	Yes
Front Fenders	None	5th Wheel Hei	50in.

NOTES/OTHER OPTIONS/COMMENTS

SHORTER BODY WITH 16" APRON, STANDARD

Axle #1 to #3 is 10ft., 6in.

(2) 8.25 x 22.5 Aluminum Wheels in lieu of steel for the 3rd Axle, Mustbe Dished Inward.

3/8" x 12ft wide HMW Liner, to make the material slide out easier

8" Rise Aluminum Nose Cap is standard with the Lock Tarp.

Vinyl Tail Cap attached to the last bow bolted to the Tailgate.

Bart Lynam

From: Brett Duarte <Brett.Duarte@PACCAR.com>
Sent: Friday, March 11, 2022 9:30 AM
To: Bart Lynam; Erik Casebeer
Subject: RE: Kenworth T680 EV Tractors

Bart, Thanks for the call today. Very exciting project!! From our discussion of the routes and application, the Kenworth T680E sounds like it would be a great fit for King County. The T680E is a 82k GCW rated tractor capable of ePTO applications. Our Renton plant where the T680E is manufactured is a zero waste to landfill facility. This is the ideal project to partner with King County on. Please let me know if you need any additional information.

Erik, Bart was asking for preliminary ball park pricing for a T680E w/ hydraulic power and an end dump trailer. Is that something you can provide to Bart? I'm sure you will have a few more questions. Thank you.

Brett Duarte
Fleet Sales Manager – Electrification

Kenworth Truck Company
A **PACCAR** COMPANY
10630 N.E. 38th Place
Kirkland, WA 98033
Phone: (206) 276-3829
Brett.Duarte@PACCAR.com

From: Bart Lynam <bart.lynam@renufuel.com>
Sent: Tuesday, March 8, 2022 1:57 PM
To: Brett Duarte <Brett.Duarte@PACCAR.com>; Erik Casebeer <ecasebeer@papekenworth.com>
Cc: Clue Westmoreland <cluew@cgcompost.com>; Mike Ruby <mruby@envirometrics.com>; Rick Bender <ricksbender@gmail.com>
Subject: RE: Kenworth T680 EV Tractors

Hi Brett:
That will work.
Thanks,
Bart

From: Brett Duarte <Brett.Duarte@PACCAR.com>
Sent: Tuesday, March 8, 2022 1:54 PM
To: Bart Lynam <bart.lynam@renufuel.com>; Erik Casebeer <ecasebeer@papekenworth.com>
Cc: Clue Westmoreland <cluew@cgcompost.com>; Mike Ruby <mruby@envirometrics.com>; Rick Bender <ricksbender@gmail.com>; jhb1223@aol.com
Subject: Re: Kenworth T680 EV Tractors

Hi Bart. I'm currently at NTEA show in Indianapolis. I'll give you a call tomorrow.

Brett Duarte
Fleet Sales Manager – Electrification
Kenworth Truck Company
Phone: (206) 276-3829

From: Bart Lynam <bart.lynam@renufuel.com>
Sent: Tuesday, March 8, 2022 4:38:59 PM
To: Erik Casebeer <ecasebeer@papekenworth.com>
Cc: Brett Duarte <Brett.Duarte@PACCAR.com>; Clue Westmoreland <cluew@cgcompost.com>; Mike Ruby <mruby@envirometrics.com>; Rick Bender <ricksbender@gmail.com>; jhb1223@aol.com <jhb1223@aol.com>
Subject: RE: Kenworth T680 EV Tractors

[You don't often get email from bart.lynam@renufuel.com. Learn why this is important at http://aka.ms/LearnAboutSenderIdentification.]

Erik Casebeer
Territory Manager
Pape Kenworth
206.735.0107

Hi Erik:
Have Brett Duarte call us anytime (206) 612.5392. We are working on this project here in King County for the South Wastewater Treatment Plant in Renton.

Looking forward to hearing from you.
Bart

-----Original Message-----
From: Erik Casebeer <ecasebeer@papekenworth.com>
Sent: Tuesday, March 8, 2022 1:22 PM
To: Bart Lynam <bart.lynam@renufuel.com>
Cc: Brett Duarte <Brett.Duarte@paccar.com>
Subject: Kenworth T680 EV Tractors

Hi Bart,

Thanks for your time on the phone today.

The chassis-only cost, roughly speaking & without a detailed spec, could be anywhere from $360k-$400k, plus applicable taxes (FET & sales tax). We would also need to wrap our heads around logistics of chargers, domicile locations & get a firm grasp on exactly how much these tractors need to haul and how far they need to go.

Would you be open to a conversation with Brett Duarte? He’s on cc; he’s in charge of electrification / sales for Kenworth, and is a wealth of information on the subject. He can give you a call.

If you only need a rough quote, we can put something more formal together, but the pricing above is in the ballpark.

Let us know if I can have Brett give you a call, and we’ll make that the next step.

Looking forward to working with you and learning more about the project.

Thank you,

Erik Casebeer
Territory Manager
Papé Kenworth
ecasebeer@papekenworth.com

Cell: 206-735-0107

Sent from my iPhone

Bart Lynam

From: Brett Duarte <Brett.Duarte@PACCAR.com>
Sent: Tuesday, April 19, 2022 3:29 PM
To: Bart Lynam; Erik Casebeer
Cc: Rick Bender; DMoniot@ventureengr.com; Vescovi, Patrick
Subject: RE: Energy to Recharge RE: Kenworth T680 EV Tractors

A good assumption is to use 400kw for the power to recharge a T680E completely. Rough average pick up and delivery economy could be 2.2kwh/mi.

Brett Duarte
Fleet Sales Manager – Electrification

Kenworth Truck Company
A PACCAR COMPANY
10630 N.E. 38th Place Phone: (206) 276-3829 Kirkland, WA 98033 Brett.Duarte@PACCAR.com

-----Original Message-----
From: Bart Lynam <bart.lynam@renufuel.com>
Sent: Tuesday, April 19, 2022 3:25 PM
To: Erik Casebeer <ecasebeer@papekenworth.com>
Cc: Brett Duarte <Brett.Duarte@PACCAR.com>; Rick Bender <ricksbender@gmail.com>; DMoniot@ventureengr.com; Vescovi, Patrick <PVescovi@ventureengr.com>
Subject: Energy to Recharge RE: Kenworth T680 EV Tractors

Erik:
We have the "estimate" for the 3 Tractors at about $360k to $400k each with a charging station at $60k. How much electrical power does it take to recharge the batteries? Do you have some formula for the kwh per mile? We are waiting on Paul Barrett to give us a price for the trailers.

Thanks for your help so we can rap this up. I look forward to hearing from you.
Regards,
Bart

-----Original Message-----
From: Bart Lynam

Sent: Thursday, April 14, 2022 12:19 PM
To: 'Erik Casebeer' <ecasebeer@papekenworth.com>
Cc: Brett Duarte <Brett.Duarte@paccar.com>; Rick Bender <ricksbender@gmail.com>
Subject: RE: Kenworth T680 EV Tractors

Hi Erik:
I am not sure where we last emailed about our project. We need to have Electric Tractors with Trailers to transport wood chips from Cedar Grove 's operation in Maple Valley and truck back biochar to Cedar Grove (see attached). In addition, we need to haul dried pellets to Ash Grove Cement in Seattle with an empty return to the South WWTP in Renton.

Attached is a copy of the two routes.

The 3rd attachment is an Excel spreadsheet with the estimated loads per day with route miles included. I would assume that we would charge the tractors at our proposed Renton operation.

Can you look this over and let me know what we need to do next to move this along. We have a Team Zoom meeting with King County's consultant and with representation from the King County Council, in addition to staff from the King County Wastewater Treatment Division and our team members from Venture Engineering & Construction north of Pittsburgh and our gasification company, Aires Clean Energy out of Lebanon, Tennessee and myself this coming Monday at 10:00 am Pacific Time and would appreciate this information by then, if at all possible. If necessary, call me on 206.612.5392.

With appreciation,
Bart T
ReNuFuel

-----Original Message-----
From: Erik Casebeer <ecasebeer@papekenworth.com>
Sent: Tuesday, March 8, 2022 1:22 PM
To: Bart Lynam <bart.lynam@renufuel.com>
Cc: Brett Duarte <Brett.Duarte@paccar.com>
Subject: Kenworth T680 EV Tractors

Hi Bart,

Thanks for your time on the phone today.

The chassis-only cost, roughly speaking & without a detailed spec, could be anywhere from $360k-$400k, plus applicable taxes (FET & sales tax). We would also need to wrap our heads around logistics of chargers, domicile locations & get a firm grasp on exactly how much these tractors need to haul and how far they need to go.

Would you be open to a conversation with Brett Duarte? He's on cc; he's in charge of electrification / sales for Kenworth, and is a wealth of information on the subject. He can give you a call.

If you only need a rough quote, we can put something more formal together, but the pricing above is in the ballpark.

Let us know if I can have Brett give you a call, and we'll make that the next step.

Looking forward to working with you and learning more about the project.

Thank you,

Erik Casebeer
Territory Manager
Papé Kenworth
ecasebeer@papekenworth.com
Cell: 206-735-0107

Sent from my iPhone

Bart Lynam

From: Erik Casebeer <ecasebeer@papekenworth.com>
Sent: Tuesday, March 8, 2022 1:22 PM
To: Bart Lynam
Cc: Brett Duarte
Subject: Kenworth T680 EV Tractors

Hi Bart,

Thanks for your time on the phone today.

The chassis-only cost, roughly speaking & without a detailed spec, could be anywhere from $360k-$400k, plus applicable taxes (FET & sales tax). We would also need to wrap our heads around logistics of chargers, domicile locations & get a firm grasp on exactly how much these tractors need to haul and how far they need to go.

Would you be open to a conversation with Brett Duarte? He's on cc; he's in charge of electrification / sales for Kenworth, and is a wealth of information on the subject. He can give you a call.

If you only need a rough quote, we can put something more formal together, but the pricing above is in the ballpark.

Let us know if I can have Brett give you a call, and we'll make that the next step.

Looking forward to working with you and learning more about the project.

Thank you,

Erik Casebeer
Territory Manager
Papé Kenworth
ecasebeer@papekenworth.com
Cell: 206-735-0107

Sent from my iPhone

MERIDIAN SCALE

TRUCK SCALE PROPOSAL

Concrete Deck / Pit Install

Project Name:

ReNuFuel, Renton, WA

Bart Lynam / P:206-612-5392 / bart.lynam@renufuel.com

Product Overview:

- Rice Lake Survivor Truck Scale "Toughest Truck Scales On Earth"
- 25+ Year Service Life with 250 Trucks Per Day (Low Annual Cost)
- 200,000 lb Overall Capacity / 100,000 lb Concentrated Load Capacity
- 6" Thick Concrete Deck Supported By I-Beams / Top Access Load Cells
- Corrosion Resistant Undercoating / Enhanced Lightning Protection
- Non-Proprietary Parts (Service Available from Multiple Sources)

Scope of Work:

- Provide (1) Rice Lake OTR Concrete Deck Truck Scale (80ft x 11ft).
- Provide (1) Rice Lake 1280 / ATS2 Scale Kiosk (indicator, printer, RFID) and mounting post.
- Provide (1) Western A45SL LED Scoreboard and Mounting Bracket.
- Provide software for ATS2 Scale Kiosk to collect data and relay to Customer SQL server.
- Provide drawing for construction of scale pit.
- Provide cutting, demolition, excavation and disposal of asphalt and soil as necessary.
- Provide construction of scale pit (80' x 11' x 2'), approach slabs, and drainage.
- Provide electrical service (115v) and communications for kiosk and scoreboard.
- Provide back fill, compaction, and asphalt patch as necessary.
- Provide transportation of scale and equipment from factory to job site.
- Provide unloading, assembly, and installation of scale.
- Provide material and labor for concrete deck pour.
- Provide wiring, testing, and calibration of scale, kiosk, and scoreboard.

Exclusions:

- Buildings, lighting, signs, and other activities not part of scale.
- Taxes, permits, materials testing, extra work (relocating utilities, buried objects, etc.).

Literature Links:

- Buyers Guide - https://meridianscale.com/pdf/ric.otr.buyer.pdf
- Scale Literature - https://meridianscale.com/pdf/ric.otr-c.lit.pdf
- Scale Spec - https://meridianscale.com/pdf/ric.otr-c.spc.pdf
- Kiosk Literature - https://meridianscale.com/pdf/uss.ats2.lit.pdf
- Scoreboard Literature - https://meridianscale.com/pdf/wes.a45.lit.pdf
- Example Drawing - https://meridianscale.com/pdf/ric.otr.pit8011.pdf

Payment Terms:

- Signed contract and credit agreement.
- Estimated delivery is 180-days from contract signing.
- Progress payments with balance due 45 days from installation.

Amounts:

- Estimated Amount: $250,000.00

Provided By: Todd Thompson Email: todd@usscale.com

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Wednesday, April 27, 2022 1:56 PM
To:	Miaomiao Zhang
Cc:	Mullendore, Zoe; Vescovi, Patrick; DMoniot@ventureengr.com; 'Joseph Regnery'; Rick Bender; Mike Ruby; Commerford Peter; Clue Westmoreland; stwaters@northshorewrd.org
Subject:	[EXTERNAL] Update on Answer to Miaomiao (Murraysmith) Question #11 - King County Biosolids Partnership Proposal

Hello Miaomiao:

In answer to your Question #11 regarding the Gasification and ANDRITZ Fluid Bed Dryer installations for Class A biosolids facilities with contact information, we submit the following:

Drying Systems ANDRITZ Separation, Graz, Austria: The ANDRITZ Dryer to be built in Dallas, Texas (to be delivered to the South Plant in Renton) uses the conventional and **proven** Fluid Bed Dryer that produces dried pellets from the biosolids. The Fluid Bed Drying System can be designed for steam or thermal oil. We prefer using steam because we are proposing a steam electric turbine. The North Shore Treatment Plant in Zion, Illinois north of Chicago uses thermal oil in the heat exchanger in its Fluid Bed Drying System. The only difference between the steam and the thermal oil is in the heat exchanger. For a visit to the North Shore Sanitary District in Zion, contact Manager Steve Waters at stwaters@northshorewrd.org Andritz has delivered the equipment for one of the world's largest wastewater treatment drying plants globally (up to 3,000 wet TPD) in Shanghai, China with operations started in 2020. Shanghai has nine (9) FDS-9.0 and is now commissioned and accepted in successful operation to use an ANDRITZ Fluid Bed Dryer on steam. ANDRITZ delivered the drying equipment of similar scale for Hong Kong in operation for 5 years and operated by Veolia. ANDRITZ has installations with the Fluid Bed Dryer using steam at Bern, Switzerland and Houthalen, Belgium. Visits to these plants can be arranged by contacting Peter Commorford at Peter.Commerford@andritz.com

We will use all renewable electricity, either purchased or generated on-site. The entire South Plant at Renton will be heated from our process. This will save the Renton Plant from buying renewable energy, thereby eliminating the purchase of fuel or electricity at the South Plant. Strict odor control and air emissions control will be implemented by ANDRITZ so odors will be destroyed. Dustrol will be added to the dried pellets to control the dust.

Dried pellets will be trucked to the Ash Grove Cement Plant south of Seattle. Our team has been in discussions with Ash Grove Cement and with the Washington Aggregates & Concrete Association and both organizations are aware that with Climate Change, fossil fuels in the future will no longer be permitted in their industry. With our *All Green Proposal,* the dried pellets will be trucked via electric trucks to the Ash Grove Company and used as a source of fuel for their cement operations. Ash Grove will heat the dried pellets to 1,900-2,000+ degrees F. in an effort to destroy the PFAS.

Aries Clean Energy, LLC based in Franklin, Tennessee: Our proposal will use the All-Green **Aries Downdraft Wood Gasification Proven Technology** which is designed for wood waste and alternative feedstock. In 2016, Aries successfully implemented its 8 patented wood gasification technology for the City of Lebanon, Tennessee at its wastewater treatment plant. At the Renton South Plant, wood chips will be gasified into syngas which will be piped as a fuel to be used in a conventional boiler to make steam. Steam will be used to generate electricity in a conventional steam turbine generator resulting in clean thermal and electrical energy with a reduction in carbon emissions in comparison to using non-renewable electricity. Therefore, this will *not* be labeled or permitted as incineration. In a 2021 meeting with Puget Sound Clean Air, the Agency agreed that gasification would not be incineration if the off-gas were fed directly into a fuel conversion plant and not to the atmosphere.

The successfully operating Aires Wood Downdraft Gasification Plant in Lebanon, Tennessee has received numerous national, state, and local awards for its environmental stewardship, including in 2017 and 2018 the Greater Nashville Regional Council Local Government Award for Public Works and Utility Infrastructure, the Tennessee Governor's Environmental Stewardship Award, and the Top Project of the Year Award from the Tennessee Chapter of the American Public Works Association. A visit to the Lebanon, Tennessee Wood Downdraft Gasification Plant can be arranged by contacting Joe Regnery at joseph.regnery@AriesCleanTech.com

Sincerely,
Bart T. Lynam, President of ReNuFuel, LLC

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Thursday, April 28, 2022 8:39 PM
To:	Miaomiao Zhang
Cc:	Vescovi, Patrick; Commerford Peter; DMoniot@ventureengr.com; Mike Ruby; Rick Bender; Mullendore, Zoe
Subject:	[EXTERNAL] List - RE: Addendum Submitted to Miaomiao (Murraysmith) Question #11 - King County Biosolids Partnership Proposal
Attachments:	Andritz 2 Page List of Fluid Bed Dryers.pdf

Hi Miaomiao:

For some reason, the list we forwarded to you earlier this evening was of poor quality and difficult to read. Here is a better copy.

Regards,
Bart T.

From: Bart Lynam
Sent: Thursday, April 28, 2022 7:22 PM
To: Miaomiao Zhang <Miaomiao.Zhang@murraysmith.us>
Cc: Vescovi, Patrick <PVescovi@ventureengr.com>; Commerford Peter <Peter.Commerford@andritz.com>; DMoniot@ventureengr.com; Mike Ruby <mruby@envirometrics.com>; Rick Bender <ricksbender@gmail.com>
Subject: Addendum Submitted to Miaomiao (Murraysmith) Question #11 - King County Biosolids Partnership Proposal

Hello Miaomiao:

As an addendum to your Question #11 submitted to you on April 27, 2020, we are submitting the attached ANDRITZ listing of Fluid Bed Drying system installations throughout the world. In addition to the Fluid Bed Drying system in Shanghai, China with Hong Kong in operations for 5 years, ANDRITZ has Fluid Bed Drying plants using steam at Bern, Switzerland and Houthalen, Belgium. There are ANDRITZ Fluid Bed Drying systems at Pensacola, Florida and Victoria, B.C. operating on thermal oil. We prefer the use of steam because we are proposing a steam electric turbine to produce our own electricity making our plant even more directed to renewable energy and Climate Change. The contact for plant visits would be Peter Commerford at Peter.Commerford@andritz.com

Please add the above to your Question #11.

With appreciation,
Bart T. Lynam, President ReNuFuel, LLC

Reference List - ANDRITZ Drying Plants for sludge   FDS Fluid Bed Dryers

Award	Client	Plant Location	Country	Type	Number of drying lines	Evaporation per line Capacity kg H2O/h	Total Evaporation Capacity kg H2O/h	Start up	status of operation
2018	Shanghai Sewage Company	Shanghai	China	FDS	9	9,000	54,000	2020	in operation
2018	Synagro/Maple/Bird JV	Victoria	Canada	FDS	1	6,000	6,000	2020	in execution
2017	Fisia for Istanbul Water and Sewerage Administration	Istanbul	Turkey	FDS	2	6,770	13,540	2018	in operation
2012	ARA Region Bern AG	Bern	Switzerland	FDS	1	3,430	3,430	2015	in operation
2008	Shanghai Sewage Company	Shanghai	China	FDS	3	2,830	8,490	2011	in operation
2006	Beijing Municipal Drainage Group Co	Qinghe WWTP Beijing	China	FDS	2	6,500	13,000	2009	in operation
2005	EDAR Fuengirola	Fuengirola	Spain	FDS	1	2,350	2,350	2008	stopped due to the costs of fuel
2005	Infilco for Canal de Isabel II	Madrid - Loeches	Spain	FDS	2	5,000	10,000	2010	in operation
2002	Shanghai Suzhou Creek Rehabilitation	Shidongkou	China	FDS	1	6,000	6,000	2004	in operation
2002	Stadt Memmingen Gruppenklärwerk	Memmingen	Germany	FDS	1	1,500	1,500	2004	stopped
2002	Aquafin	Leuven	Belgium	FDS	1	3,700	3,700	2003	in operation
2001	VATech Wabag for ARA Region Bern	Bern	Switzerland	FDS	1	3,175	3,175	2002	replaced by Bern 2
2000	VA Tech Wabag for City of Putrajaya	Putrajaya	Malaysia	FDS	1	3,000	3,000		not in operation, no sludge
2000	Northshore Sanitary District NSSD	Waukeegan / IL	USA	FDS	1	5,800	5,800	2006	in operation
2000	Aquafin	Houthalen	Belgium	FDS	1	3,700	3,700	2003	in operation
2000	IDA FOCE TICINO	Locarno	Switzerland	FDS	1	850	850	2003	in operation
2000	Zuiveringschap Limburg	Susteren	Netherland	FDS	1	8,300	8,300	2002	in operation
1999	Black & Veach for Escambia County Utilities Authority	Pensacola / FL	USA	FDS	2	3,450	6,900		stopped
1999	SGT for ARUSA	Rubi	Spain	FDS	1	3,000	3,000	2001	in operation

ENGINEERED SUCCESS

Award	Client	Plant Location	Country	Type	Number of drying lines	Evaporation per line Capacity kg H2O/h	Total Evaporation Capacity kg H2O/h	Start up	status of operation
1998	ARA Eger	Eger	Hungary	FDS	1	1,200	1,200	2000	out of operation
1998	ARA Chur	Chur	Switzerland	FDS	1	2,000	2,000	1999	in operation
1998	ARA Aalborg	Aalborg	Denmark	FDS	1	3,650	3,650	2000	in operation
1997	Yorkshire Water	Huddersfield	Great Britain	FDS	1	1,400	1,400		stopped
1996	Introtec GmbH for City Rastatt	Rastatt	Germany	FDS	1	1,100	1,100	1997	dismounted
1995	Stadtentwässerung Göppingen	Göppingen	Germany	FDS	1	2,125	2,125	1997	stopped
1995	SPC Shanghai Petro-chemical Complex	Shanghai	China	FDS	1	6,930	6,930		stopped
1995	KSE	Löhne	Germany	FDS	1	2,000	2,000		dismounted
1994	Hoogheemraad-schap	Beverwijk	Netherland	FDS	2	6,000	12,000	1996	in operation
1994	AVA Augsburg	Augsburg	Germany	FDS	1	4,400	4,400		stopped
1994	Introtec GmbH for City Lahr	Lahr	Germany	FDS	1	1,400	1,400	1994	dismounted
1994	Introtec GmbH for City Offenburg	Offenburg	Germany	FDS	1	1,400	1,400	1994	dismounted
1992	Stadt Leutkirch	Leutkirch	Germany	FDS	1	1,200	1,200	1992	stopped
1990	ARA Dornbirn	Dornbirn	Austria	FDS	1	1,600	1,600	1992	in operation
1987	Sonitherm	Nice	France	FDS	1	2,260	2,260		??
1986	MVA Ingolstadt	Ingolstadt	Germany	FDS	1	2,310	2,310		dismounted

ENGINEERED SUCCESS

Miaomiao Zhang

From:	Bart Lynam <bart.lynam@renufuel.com>
Sent:	Thursday, April 28, 2022 11:26 PM
To:	Miaomiao Zhang
Cc:	Vescovi, Patrick; DMoniot@ventureengr.com
Subject:	[EXTERNAL] King County Biosolids Partnership - All Green Climate Proposal Producing Net Negative Carbon and Energy Balance
Attachments:	Introduction of King County Biosolids Team 4-27-2022 (002).docx

Miaomiao Zhang, PE, PMP
Principal Engineer
600 University Street, Suite 300, Seattle, WA 98101
Murraysmith Consultants

Dear Miaomiao:

Our Biosolids Team has enjoyed working with your Engineering Consulting firm Murraysmith in response to your questions emailed to us on February 3, 2022 relating to you conducting an independent analysis of our team's proposal which aims to produce a Net Negative Carbon Balance for King County's biosolids. We are pleased to answer your eleven (11) questions and are happy to answer any further questions you may have relating to our team's proposal to address *Climate Change* for King County's biosolids. Our team is composed of world-wide leaders in the fields of environment, permitting, chemical analysis, labor relations, and construction engineering (see attached short bio's of team). Global climate change and the impact of harmful emissions are some of the most serious challenges facing the world today. Our All Green Climate King County Biosolids Partnership Proposal addresses these important issues.

Reducing Carbon Emissions: King County has long been a leader in working to reduce carbon emissions, as evidenced by King County's *Strategic Climate Action Plan.* While we recognize that King County is pursuing a path to reduce emissions from County operations to a net zero, our Team Biosolids Proposal is targeted to achieve a ***carbon and energy net negative balance for King County's biosolids program.*** The King County Strategic Climate Action Plan (SCAP) proposed by Executive Dow Constantine was unanimously adopted by the King County Council in May of 2021. King County's Climate Proposal aims to cut greenhouse gas emissions in half by 2030. Our Team's King County Biosolids Proposal, as submitted by the partnership of Venture Construction & Engineering/ReNuFuel, LLC, reduces GHG emissions with the use of biomass (wood from Cedar Grove, Maple Valley) in our Aries Clean

Energy 8-patented gasification technology which will process the biomass into a syngas and BioChar. Our process will have no odors as the trucked biosolids will be off-loaded inside an enclosed building with odor control to mitigate odor emissions. From the thermal treatment of sustainable biomass, we produce an all-natural BioChar end product which returns carbon and nutrients to the soil (carbon sequestration).

Aries Clean Energy, LLC based in Franklin, Tennessee: Our proposal will use the All-Green **Aries Downdraft Wood Gasification *proven technology*** which is designed for wood waste and alternative feedstock. In 2016, Aries successfully implemented its 8-patented wood gasification technology for the City of Lebanon, Tennessee at its wastewater treatment plant which runs today, taking primarily urban wood waste. Downdraft gasification is by far the least complex and most productive of gasification technologies. It has been used for over 100 years. The Aries patented Downdraft Wood Gasification technology results in a process that is very straightforward with only a few moving parts in the gasifier itself. At the Renton South Plant, wood chips will be gasified into syngas which will be piped as a fuel to be used in a conventional boiler to make steam. Steam will be used to generate electricity in a conventional steam turbine generator resulting in clean thermal and electrical energy with a reduction in carbon emissions in comparison to using non-renewable electricity. Therefore, this will not be labeled or permitted as incineration. In a 2021 meeting with Puget Sound Clean Air, the Agency agreed that gasification would not be incineration if the off-gas were fed directly into a fuel conversion plant and not to the atmosphere. The successfully operating Aries Wood Downdraft Gasification Plant in Lebanon, Tennessee has received numerous national, state, and local awards for its environmental stewardship, including in 2017 and 2018 the Greater Nashville Regional Council Local Government Award for Public Works and Utility Infrastructure; the Tennessee Governor's Environmental Stewardship Award; and the Top Project of the Year Award from the Tennessee Chapter of the American Public Works Association (APWA). A visit to the Lebanon, Tennessee Aries Downdraft Wood Gasification Plant can be arranged by contacting Joe Regnery joseph.regnery@AriesCleanTech.com

Drying Systems ANDRITZ Separation, Graz, Austria: The Andritz Dryer to be built in Dallas, Texas uses the conventional and ***proven*** Fluid Bed Dryer that produces dried pellets from the biosolids. The Fluid Bed Drying System can be designed for steam or thermal oil. Victoria, B.C., the North Shore Treatment Plant in Zion, Illinois north of Chicago, and Pensacola, Florida use thermal oil. Andritz has delivered the equipment for one of the world's largest wastewater treatment drying plants globally (up to 3,000 wet TPD) in Shanghai, China with operations started in 2020. Shanghai, China has nine

(9) FDS-9.0 and is now commissioned and accepted in successful operation to use an ANDRITZ Fluid Bed Dryer on steam. We propose using steam.. ANDRITZ delivered the drying equipment of similar scale for Hong Kong in operation for 5 years and operated by Veolia. ANDRITZ has installations with the Fluid Bed Dryer using steam including Bern, Switzerland and Houthalen, Belgium. Visits can be arranged by contacting Peter Commerford at Peter.Commerford@andritz.com . We will use all renewable electricity, either purchased or generated on-site. The entire South Plant at Renton will be heated from our process. This will save the Renton plant from buying renewable energy, thereby eliminating the purchase of fuel or electricity at the South Plant. Strict odor control and air emissions control will be implemented by ANDRITZ so odors will be destroyed. The ANDRITZ odor control system 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 biotrickling towers, a three-stage chemical scrubber, and GAC 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. Dustrol will be added to the dried pellets to control the dust.

Dried Pellets will be trucked to Ash Grove Cement Plant south of Seattle: Our team has been in discussions with Ash Grove Cement and with the Washington Aggregates & Concrete Association and both organizations are aware that with Climate Change, fossil fuels in the future will no longer be permitted in their industry. With our All Green Proposal, the dried pellets will be trucked via electric trucks to the Ash Grove Company and used as a source of fuel for their cement operations. Ash Grove will heat the dried pellets to 2,900 to 3,000 degrees F. in an effort to destroy the PFAS.

Electric Trucks: We propose the purchase of electric trucks to haul wood chips for the Aries gasification and back haul BioChar to Cedar Grove for bagging, and also truck the dried pellets to Ash Grove to be used as a fuel source. Prices have been obtained for three electric trucks, end dump trailers, weighing scale, and a charging station, furthering our result of a Net Negative Carbon Balance. Electric trucks are critical for protecting our health and achieving our climate goals. By 2035, at least 25% of all heavy trucks in Washington must be clean. Brown & Caldwell states that King County uses 10 trucks per day to haul the biosolids to eastern Washington. This creates a lot of greenhouse gases and use of fuel for trucking. With the present trucking of the Loop biosolids program, odors are present in the trucks with the spreading of these Class B biosolids which contain billions of pathogens.

Cedar Grove Composting: Clue Westmoreland, Executive Vice President of Cedar Grove Composting, will coordinate the supply of the clean urban wood chips for the Aries Gasification. Cedar Grove will also handle the BioChar bagging operation since they have a facility that is currently bagging compost. There is a market for BioChars which are natural, renewable, low-carbon materials that can be used in place of non-renewable peat or minerals like vermiculite, which are mined abroad and processed with fossil fuels (reference *Waste Today dated December 3, 2019).* Also, Aries Clean Energy is selling Biochar on Amazon which is USDA IBI certified.

Rick Bender will work with the Teamsters: Former President of the Washington State Labor Council for 18 years and a member of the National AFL-CIO Board (first ever representative from Washington State), Rick will be working with the Teamster Union to retrain and relocate the personnel eliminated by the consolidation of the biosolids process at the South Plant. This will result in the elimination of the daily 10 truckloads of biosolids to eastern Washington. Trucking biosolids to eastern Washington to be spread on farm lands and in the forests creates a lot of greenhouse gases and the use of conventional truck fuel. Rick Bender will work with these Teamster Union members who will receive jobs with our Green Biosolids Proposal which will reduce CO2 and help benefit our Negative Net Zero Climate Change results. Presently, King County transports its Class B biosolids by semi-trailers where the partially dewatered biosolids are dumped and stored until being spread on farm lands and in the forests. During this interval, the sludge cake continues to produce methane which is **21 times** the negative effect of carbon dioxide or CO2. Victoria, B.C. presently transports its dried pellets to Vancouver, B.C. for use in a cement kiln. Michael B. McSweeney, President & CEO of the Cement Association of Canada, in his March 28, 2011 letter to the Honorable Premier Christy Clark, stated that, "The cement companies have a long term interest in using bio fuels; solid waste; bio waste and biosolids as supplementary fuels to reduce their Lower Mainland Airshed emissions even further, and will continue its efforts in this area…..The Canadian cement industry has earned a world class reputation for innovation, product quality, environmental performance and research. The industry is committed to producing green, sustainable products that benefit all communities."

Many U.S. Companies will not allow their food products to be grown with sludge fertilizer. Del Monte asks its growers to "avoid application of sewage sludge and biosolids (as fertilizers)." H. J. Heinz, in its Global Good Agricultural Practices Manual for Vendors states, "Applications of municipal sewer sludge and/or human sewage sludge are strictly prohibited."

Our goal is to propose an **All Green Energy Proposal** to eliminate greenhouse gas emissions in conformance with the new State and County Climate Standard goals ending up with **Negative Net Zero.**

Biosolids Cost – King County: According to the Brown & Caldwell Report dated August 1, 2020, it is stated that escalated capital costs to maintain King County's Loop program with Class B Biosolids over the next 30 years will cost $335 million. The report estimates that for the Class A program, the escalated capital costs will be an additional $590 million with Pyrolysis costing $1 Billion, 115 million. Our proposal would cost King County substantially less than what Brown & Caldwell estimates.

We Propose to Design, Build, Permit, Construct, Operate, and Maintain the new Biosolids Operation. We refer to our All Green Net Zero Carbon Balance Proposal as the Three E's **(Environment, Energy, and Economics)** as it better for the environment and Climate Change; produces clean renewable energy; and economical as it can be done for millions of dollars less than what King County has projected to spend.

Sincerely,
Bart T. Lynam, President
ReNuFuel, LLC

Attachment: Short Bio's of Team

Introduction of King County Biosolids Team

Peter Commerford - National U.S. Sales Manager, Drying Systems at ANDRITZ Separation, the world's leading separation company headquartered in Graz, Austria with over 150 years of experience and 25,000 employees with 147 sludge drying plants worldwide and 126 in the United States. The ANDRITZ Fluid Bed Dryer has a proven record of safety and reliability. Fluidized Bed Dryers used in sludge applications operate in a closed inert gas loop. The company is one of the technology and global market leaders in the hydropower business, the pulp and paper industry, the metal working and steel industries, and in solid/liquid separation in the municipal and industrial segments.

David Moniot, President & CEO of Venture Engineering & Construction, Inc. Warrendale, Pennsylvania is a full-service process engineering and construction management company founded in 2007 providing consulting, multi-disciplinary engineering, project management and construction management to the world's energy, power, construction, mining, and process industries. David Moniot holds a BS Chemical Engineering from the University of Pittsburgh.

Patrick E. Vescovi - PE, PMP – Vice President – Engineering and Principal of Venture Engineering & Construction, Inc. Warrendale, Pennsylvania.

Joseph Regnery – Director, Business Development West Region for Aries Clean Energy, LLC, based in Nashville, Tennessee. Aries designs and builds innovative bio-based downdraft and fluidized bed gasification systems using its eight patents granted to date. Its projects provide for the sustainable disposal of waste, reduction of carbon emissions, and the production of clean thermal and electrical energy.

Jon Ewing - VP and Harris GM Bellingham Office - Harris is a leading national mechanical contractor specializing in design and engineering, construction, building automation, service, manufacturing, conveyors and end-to-end building systems with 14 offices nationwide with over 2,000 employees. Customers who partner with Harris benefit from our national reach, regional offices, local expertise and more than 70 years of experience. From power plants to stand-alone hospitals, stadiums to concert halls, we bring a spirit of creative problem solving and a commitment to excellence to every project, no matter the size, complexity, or location.

John Sudnick – President of Projects Integration, Inc. Professional Engineer has worked in the combustion, heat transfer, and air pollution control fields for over 35 years. John has designed and managed numerous energy and environmental projects. These include optimization of pulverized coal boiler combustion systems to reduce NOx emissions, preliminary designs of fluidized bed alternate fuel boilers, and waste heat steam and hot water recovery systems. He has experience in the specialty chemicals industry, the pharmaceutical industry, the pulp and paper industry, the glass industry, and the metals industry.

Clue Westmoreland - Executive Vice President of Cedar Grove Composting, Seattle, a family-owned business since 1938 specializing in Compost and Recycling. Since 1989, Cedar Grove Composting currently handles 400,000 tons per year of yard and food waste. Cedar Grove has diverted over 4 million tons of organic material from landfills, preventing 3.72 million metric tons (C02e) of greenhouse gas emissions- the equivalent of removing approximately 670,000 cars from the road. Cedar Grove takes valuable resources and converts them into earth friendly compost used to replenish urban soils, minimize storm water run-off, conserve water and provide all-natural gardening solutions that minimize chemical usage and keep waterways healthy for salmon and other vital habitat communities.

Rick Bender - Rick Bender will work with the Teamsters Union regarding retraining and relocating the personnel eliminated by consolidation of the biosolids process at the South Plant in Renton. Former President of the Washington State Labor Council for 18 years and Member of the National AFL-CIO Board 2007 (first ever representative from Washington State), Rick will be responsible for working with the unions regarding retraining and relocating the personnel eliminated by consolidation of the biosolids process at the South Plant.

Dr. Michael Ruby - Completed his education with a Ph.D. in Civil Engineering at the University of Washington. Mike has served as Director of the International Environmental Engineering Institute for the World Health Organization. Started Envirometrics in Seattle in 1984 and has served as a professor in the Department of Civil and Environmental Engineering at the UW and as the Director of the U.S. EPA's Area Training Center at the University of Cincinnati. Dr. Ruby is a worldwide environmental/climate change consultant and is Board certified in Air Pollution Control.

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 Illinois Institute of Technology.

Dr. Jerry Whitfield - President of Whitfield Biochar, LLC, whose education includes a Bachelor and Ph.D. degrees from Southampton and Cambridge Universities, United Kingdom. Jerry is an Aerospace Engineer having worked at Boeing, Rolls Royce Aero Engines, and General Electric on advanced jet engines. Recognizing early on the need for low carbon sources of energy, Dr. Whitfield invented the first wood pellet stove in 1982.

Bart T. Lynam - holds a 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 National Association of Clean Water Agencies (NACWA).

murraysmith

APPENDIX D

MEETING MINUTES

Client:	King County
Project Name:	Biosolids Alternatives Analysis
Meeting Description:	County Council Focus Group
Date and Time:	February 23, 2022, 12:00 PM-1:00 PM
Location:	Online Zoom meeting

Attendees:

King County:

- Dave Upthegrove
- Zoe Mullendore
- Katherine Taylor
- Sharman Herrin
- Drew Thompson

Murraysmith:

- Miaomiao Zhang
- John Thayer
- Patrick Davis

Minutes:

1. Background – Murraysmith presented an overview of the project, which included the following:

    a. Project Drivers – A review of the Proviso P5. This proviso is intended to provide a comprehensive study of the Biosolids Thermal Drying proposal. It outlines the requirements of the study.

    b. Overview of the Biosolids Partnership – Biosolids Partnership proposes construction of a biosolids drying facility to produce Class A biosolid pellets. The dryers would be powered (in part or in whole) by a gasification unit using wood biomass as feed.

    c. Overview of the baseline to be studied – The baseline concept, as scoped, includes the current Class B process at King County's three regional wastewater treatment plants plus a Class A composting pilot that is currently at the final stage of the design and expected to be in operation in 2023. The baseline concept includes land application of the Class B biosolids.

2. Project Objectives – Murraysmith presented the two primary objectives for the study. Those include developing a Class A implementation plan and an evaluation of the Biosolids

Partnership proposal. The evaluation of the Biosolids Partnership proposal is to be compared to the current baseline. In discussing the project objectives some clarifications were discussed.

a. Confirming the alternatives – Councilmember Upthegrove commented that the request in the scope of work is to compare the baseline alternative to the Biosolids Partnership proposal. However, the main intent is to "pursue this until it doesn't work". In other words, the primary need for the project is to validate the claims made in the Biosolids Partnership proposal.

b. Expanding Class A composting as the base case – Councilmember Upthegrove is amenable to the idea of assuming an expanded composting facility as the baseline during comparison. This would allow for a fair comparison of alternatives, especially on criteria related to final product marketability and diversity. The County is interested in the possibility of diversifying their biosolids market and increasing Class A production, regardless of the alternative chosen.

3. Analysis Approach – Murraysmith presented the approach to the analysis including a review of the existing literature, communication with stakeholders, facility visits, and agency surveys. The primary claims to be verified include:

   a. "Net negative carbon balance" – How is this achieved? Under what conditions is this possible?

   b. "Use purchased renewable electricity for the plant's electrical load" – What is the feasibility of this proposal, and what are the realities of purchased renewable energy?

   c. "King County can save $1M per year" – Is that true? How can that happen?

4. Alternatives Analysis – Murraysmith presented on two different approaches for the analysis.

   a. The first approach is a quantitative analysis following the typical "triple bottom line" methodology.

   b. The second approach is a more qualitative method. Distilling the information down into positives, negatives, and neutrals.

   c. Councilmember Upthegrove suggested focusing on the qualitative approach as it would be better received by the Council. Broad details of the rating system can be included in the text of the report, and more granular details can be added as an appendix.

   d. When going through the analysis, the focus should be on *Cost* and *Carbon*. These are the two main drivers that will determine the path forward for the County. Additionally, looking into unintended consequences is important.

   e. Regarding costs, Murraysmith is to break out the capital costs from the O&M costs.

5. Overview – Councilmember Upthegrove suggested that the primary goal of this report is to vet the claims made in the Biosolids Partnership proposal, as opposed to making a discrete recommendation. The report can also be used to put previous reports into context.
6. Of Note – Councilmember Upthegrove suggested finding a way to ensure that proprietary information from Biosolids Partnership is protected. The fact that their data could become public may make the Biosolids Partnership wary to provide the data that Murraysmith needs to move forward. The Office of Councilmember is working with Prosecuting Attorney's Office (PAO) to find a way to protect Biosolids Partnership's proprietary information.

murraysmith

APPENDIX E

Tacoma Central Plant TARGO Site Visit Notes

Date: February 22, 2022

Project: King County Biosolids Class A Alternatives Analysis

Notes By: Patrick Davis, PE; Miaomiao Zhang, PE, PMP; Jeff Moss, PE, Murraysmith

Re: Tacoma Central Plant TAGRO

Interviewed with: Dan Eberhardt, Biosolids Supervisor, TAGRO
Dan Thompson, Division Manager, City of Tacoma

Production Overview

- Approximate Amount of Biosolids Produced: 7,000 to 8,000 dry tons per year out of the plant. Approximately 90% is used to produce TAGRO. The plant can still truck Class B biosolids for land application if needed in order to control TAGRO inventory.
- Among all the TAGRO produced, 90 percent has been sold to the local home growers/gardeners, landscapers, and nurseries. The remaining 10% is given away to local residents for free. TAGRO has provided delivery as far as Lake Chelan. No long-term contract with customers. They just call or order online. Especially busy in March/April.
- Biosolids Treatment Process: Tacoma Central Plant utilizes a two-stage thermophilic/mesophilic aerobic and anaerobic digestion process to produce Class A biosolids. The first stage is aerobic digestion using high purity oxygen at 64 deg C and a SRT of 12 to 24 hours to meet the pathogen inactivation requirement. The second stage is temperature-phased anaerobic digestion (TPAD) that consists of thermophilic, mesophilic and low mesophilic digestion. The total TPAD SRT is about 21 days (7+14 days) to meet the EPA Part 503 regulation Class A requirement. This Class A digestion process is a continuous operation instead of a batch process, which has been approved by EPA since the beginning of the operation. The liquid biosolids are run through a screw press to 25% solids content then trucked a short distance to the TAGRO (which is directly adjacent to the WWTP) to be directly mixed with bulking material. Currently using roll-off boxes for hauling.
- Bulking Agent Used: Sand, clean sawdust, aged bark, and, to a limited degree, biochar (experiential, obtained from green waste facility)
    - Sawdust sourcing has become more difficult over time as mills close and/or get better as using all of their byproducts. Currently getting from Hardwood Northwest

- Sand is easy, from any bulk sand and gravel supplier. Occasionally they are able to get paid to receive sand from a foundry, which was previously landfilling the spent sand from the casting process.
- Bark – did not specifically comment on difficulty or ease. They are paying for this product.

- How it is created: Two medium sized earth movers are used to spread a layer of Class A biosolids within a covered staging area. The equipment then adds layers of sand and sawdust to the mixture. The mixture is turned over repeatedly until homogenous (or close to). It is then sent through a Royer soil shredder to break up large clumps and mix further.
- Required Labor: Approximately 12 people are employed to manage and produce the TAGRO products. They are responsible for the material procurement, new product development, marketing, sales, production, packaging, delivery in the program.
- End Products:
  - Tagro Mix – 50% biosolids, 25% sawdust, 25% sand (by volume or weight?)
  - Tagro Potting Soil – Tagro mix plus aged black bark
  - Tagro Topsoil – Similar to potting soil, but meets WSDOT spec. Adjusted to meet spec changes as needed (can be challenging)
  - Aged Bark – bark only, obtained from supplier and sold at markup due to customer demand

Associated Cost Benefits

- TAGRO is typically given away for free at the plant if shoveled and hauled by the residents. Otherwise, it can be loaded into a personal vehicle/trailer at the plant or delivered for a small fee (approx. $10/yd at the plant, delivery costs vary). The product is also bagged and sent to local gardening shops for sale.
- Overall Costs and Income: TAGRO does not produce any income for the plant; however, it reduces the costs associated with biosolids management. Approximately 50% of the costs to treat the solids is recouped by TAGRO sales/giveaways. Approximate cost to operate is $30/wet ton

Marketability

- TAGRO is a popular product that has been "selling" out for the past 3 years. Customers range from mid-scale landscapers to small scale gardeners. They have thousands (approx. 5,000) of smaller customers. Occasionally they have large scale projects, for example they were specified on a big UW project and had some logistical issues coordinating the delivery volume and timing with the contractor.
- The product began in 1992. There has been 30 years of building up to the current demand

- Additional marketing stems from obtaining booths at local gardening conventions, home & garden shows, communicating with local gardening community groups, (i.e. Garden Clubs and Masters of Garden), partnering with universities (i.e. Sally Brown from UW, and WSU) and obtaining endorsement from the credible end users. The general marketing advice revolved around the idea that local community members would be the best spokespeople for the product.
- Tagro is considering internet sales though amazon. Some similar vendors are doing this already in other places.

Additional Items

- Sourcing bulking material: The plant has relationships with multiple local wholesalers and businesses. This provides them with the sawdust and sand needed for bulking material. There have been issues in the past with suppliers drying up or going out of business. It seems like there is a constant need to reach out to new people in order to retain a redundant supply.
- Operational Challenges: The soil shredder goes down from time to time. They have a backup unit. Otherwise, the equipment is fairly modest needing only standard preventative maintenance.
- Site Requirements: The TAGRO facility sits on approximately 2.5-3 acres of land. This provides enough space to build up and store three different TAGRO products over the winter months. It seemed that there was adequate space for the heavy equipment to maneuver and operate without issue. Tagro has constructed roofs over the main areas where material is stored. For many years, they had open piles and had to cover with large tarps, which was difficult and often not effective (tarps blown off pile). The roofs are much nicer, safer, and effective.
- Public Pushback: When the product was first introduced, there was some public pushback; however, TAGRO has numerous customers who are willing to attest to its benefit. The overall issues coming from the public have been muted. Having a wide customer base means that if one decides to do something else, it is not a huge loss.
- Plant staff mentioned they generally approach the operation with a business mindset and try to operate to keep the customers happy and coming back for more. Said several times that the customer spreading the word is the best marketing tool. Staff is also creative about thinking of new mixes, alternative sources, etc.
- PFAS: Meso and thermophilic digestion process does not remove PFAS from biosolids. TAGRO staff has been closely following the national and local research and regulatory trend regarding biosolids PFAS. A testing regimen is in process to determine the levels of PFAS within the TAGRO. Fate and transport models are in the works, which will be used by EPA. The main concern involves the producers of PFAS and source control.

Pierce County Chambers Creek WWTP Fertilizer Manufacturing Facility SoundGRO Site Visit Notes

Date:	February 22, 2022
Project:	King County Biosolids Class A Alternatives Analysis
Notes By:	Patrick Davis, PE; Miaomiao Zhang, PE, PMP; Jeff Moss, PE, Murraysmith
Re:	Chambers Creek WWTP SoundGRO, Pierce County WA
Interviewed with:	Karla Guevarra, Wastewater Operations Program Manager, Pierce County Jon Kercher, Wastewater Operations Supervisor, Pierce County Jeremy Carnahan, Wastewater Operations Supervisor, Pierce County

Production Overview

- History: The Fertilizer Manufacturing Facility (FMF) at Pierce County's Chambers Creek wastewater treatment plant started in 2006. Before 2018, the facility dried almost 100 percent of biosolids produced at the plant and sold them to several large fertilizer manufacturers and soil blenders, such as Marion Ag, Simplot and Wilbur-Ellis. One of manufacturers' facilities caught a fire in 2017 and attributed the cause to SoundGRO product, therefore stopped SoundGRO purchase for several years. The demand for SoundGRO in recent years has been dropping.
- Approximate Amount of Biosolids Produced: 2,500 dry tons per year out of the plant. Approximately 40% is used to produce SoundGRO. The remaining Class B biosolids is hauled to Boulder Park for land application. The production is based on the demand for the year. Some years it is higher. Some years it is lower.
- Class of Solids Used: Pierce County Chambers Creek plant has mesophilic anaerobic digestion process to produce Class B biosolids. The digested biosolids is dewatered in one of two Andritz centrifuges. A portion of dewatered Class B biosolids is converted to the dried pellets through an Andritz thermo drying system. The dried pellets are Class A biosolids with exceptional quality per EPA Part 503 regulation and Pierce County markets this product as a fertilizer using a trade name of SoundGRO.
- Bulking Agent Used: None/ The SoundGRO is often sold to other manufacturers to produce a mixed product, but the plant does not mix any product itself
- How it is created: The biosolids are digested in a typical mesothermic anaerobic digestion process creating Class B solids. The solids are then dewatered using a centrifuge. This takes

the sludge to approximately 18%-20% TS. The cake is then sent through a drying process to produce the Class A pellets. The pellets are then sent to a silo for storage prior to bagging and distribution.

- Required Labor: The maintenance and operation of the SoundGRO facility is integrated into the rest of the plant operations. It is difficult to extract the FTEs of SoundGRO from the rest of the plant. The minimum assumption is the 2 FTEs are required; however, this is likely not all encompassing of the true needs of the facility.
- Operation of Dryer: Due to the limited demand for SoundGRO, the dryer is only operated for about six months in a year, usually in the winter/spring to match the high demand fertilizer season. During the operating season, it runs about 4 days a week depending on the storage of final product silos and the wastewater treatment plant operation. Although the burner in the drying system is designed to use up to 80 percent of biogas and 20 percent of natural gas, in reality, approximately 50 percent of each type of gas is used to meet the heating BTU requirements.

Associated Cost Benefits

- SoundGRO is sold for $300/ton when sold in 50lb individual bags, or it is sold for $88/ton when sold in one-ton totes. The 50 lb bags are sold in bulk (40 bags per pallet). There is no small-scale sale of SoundGRO. Most consumers are mid to large scale soil blenders with some sale to mid-scale nurseries.
- Overall Costs and Income: SoundGRO does not produce any income for the plant; however, it reduces the costs associated with biosolids management. Minimal information is available regarding discrete numbers as the amount of production changes year over year.
- Class B biosolids Boulder Park hauling and tipping cost is approximately $66/WT or approximately $2,000 per truck.

Marketability

- SoundGRO is a lesser known product. It is integrated directly into the plant and there is minimal marketing. The plant has never "sold out" of the product due to lack of biosolids feedstock. There have been instances where supply (and production rate) has been temporarily outpaced by demand.
- SoundGRO has not done much marketing. No budget for it.
- When SoundGRO was first getting started, they did some marketing and distribution to the public, however, this strategy was abandoned in favor of distributing to large scale users due to the lower overhead required. Marketing effort was also affected by retirement of key personnel and the decision to not hire to replace the role.
- SoundGRO is a registered fertilizer in 3 states with N-P-K (Nitrogen-Phosphate-Potassium) ratio of 5-5-0. Due to some historical legal issue around the design of the bags, SoundGRO bagged product cannot be sold in the large hardware and garden stores like the Home Depot.

- The County has used the Facebook posts and the giveaways events as ways to market the product. They gave away about 70 tons last year, which was an increase from about 42 tons the year before. There is some interest in increasing efforts to distribute to the public, however, the County is hesitant to make marketing or capital improvements a priority.

Additional Items

- Operations and Maintenance: The drying equipment has a full preventative maintenance schedule, and an Andritz representative visits the plant every year to perform checks of the equipment. The bagging system allows 2 people to bag about 2-3 tons/day.
- Operational Challenges: The facility runs the dryer on a schedule of 4 days on 2 days off starting in mid-winter through mid-summer – depending on demand. If the dryer is off for too long, it requires a lot of additional maintenance to bring it back on-line. During off season, the dryer is brought online periodically to prevent these excessive maintenance issues from cropping up. Plant staff mentioned several times the importance of diversity of treatment/disposal methods, and flexibility and redundancy with operations.
- Site Requirements: The SoundGRO facility sits within Peirce County's WWTP. It requires a three-story building at approximately 11,000 square feet. Pallets of SoundGRO are stored in equipment bays nearby until they are picked up by end users.
- Public Pushback: None to speak of, yet the product is not heavily marketed – little exposure
- PFAS: The dryer does not operate at temperatures required to degrade PFAS
- Of Note: When writing the report it is important to consider the human cost of hauling the biosolids. Approximately 1 truck driver dies each year during the Class B biosolids hauling over the pass during wintertime.
- Large scale blenders use SoundGRO as a component of their own fertilizer mixes. Each of the three main users are located in Oregon, so the process is only reducing the hauling required for disposal because the dry material is lighter so more solids can be moved in each load.
- The fire at Simplot and the reduction in ability to dispose when they halted operations caused considerable problems with storage of finished SoundGRO at the plant. They were storing pallets everywhere they could.
- Permitting: When the dryer was first installed there were less stringent air permitting requirements. This is likely changed.
- Haven't needed to land apply dried pellets. The spreading equipment for Class B biosolids cannot be used to spread dried pellets.
- The plant has boilers that can use both natural gas and biogas. However, it stopped feeding biogas to the boilers since last winter because the biogas contains very high level of H_2S which will cause corrosion to the boilers. Except being used for the dryer burner for half a year, the rest of biogas is flared. The County is trying digester micro-aeration with an attempt to reduce H_2S in biogas.

- The driers burners can be designed to use natural gas and/or alternative fuel sources, including digester gas, hog fuel, the pellets themselves, or other materials that can be burned to generate the required BTUs. The plant uses a combination natural gas and digester gas burner, which operates at about 50% of each by volume, and about 70% of the BTUs from natural gas.
- The Andritz centrifuges posed lots of challenges to the plant. After a recent rebuilt, those two units can still only produce 18-19% cake. The County staff is not very pleased with Andritz's service related to the centrifuges. Andritz provides annual inspection of the dryer system and staff does like the inspector who does that work. Not that happy with the company overall.
- Fire hazard related to the equipment and the dried pellets is something needs attention. Equipment at several drying facilities caught on fire in the past, i.e. Snoqualmie WWTP, WA and Sand Island WWTP, HI. The County staff also mentioned pellets need to be stored with caution to prevent fire. A pallet of SoundGRO caught on fire a few years ago during hauling, the plant got a call from the police department responding to determine if it was hazardous.
- Milwaukee has a similar product – Morganite – but they have invested more in marketing and public distribution.

Irvine Ranch Water District Michelson Water Recycling Plant Site Visit Notes

Date of Site Visit:	March 9, 2022
Project:	King County Biosolids Class A Alternatives Analysis
Notes By:	John Thayer, PE, Murraysmith
Re:	Irvine Ranch Water District, Michelson Water Recycling Plant Site Visit, Irvine, California
Interviewed with:	Scott Toland, PE Senior Engineer, Irvine Ranch Water District

Key Process Parameters:

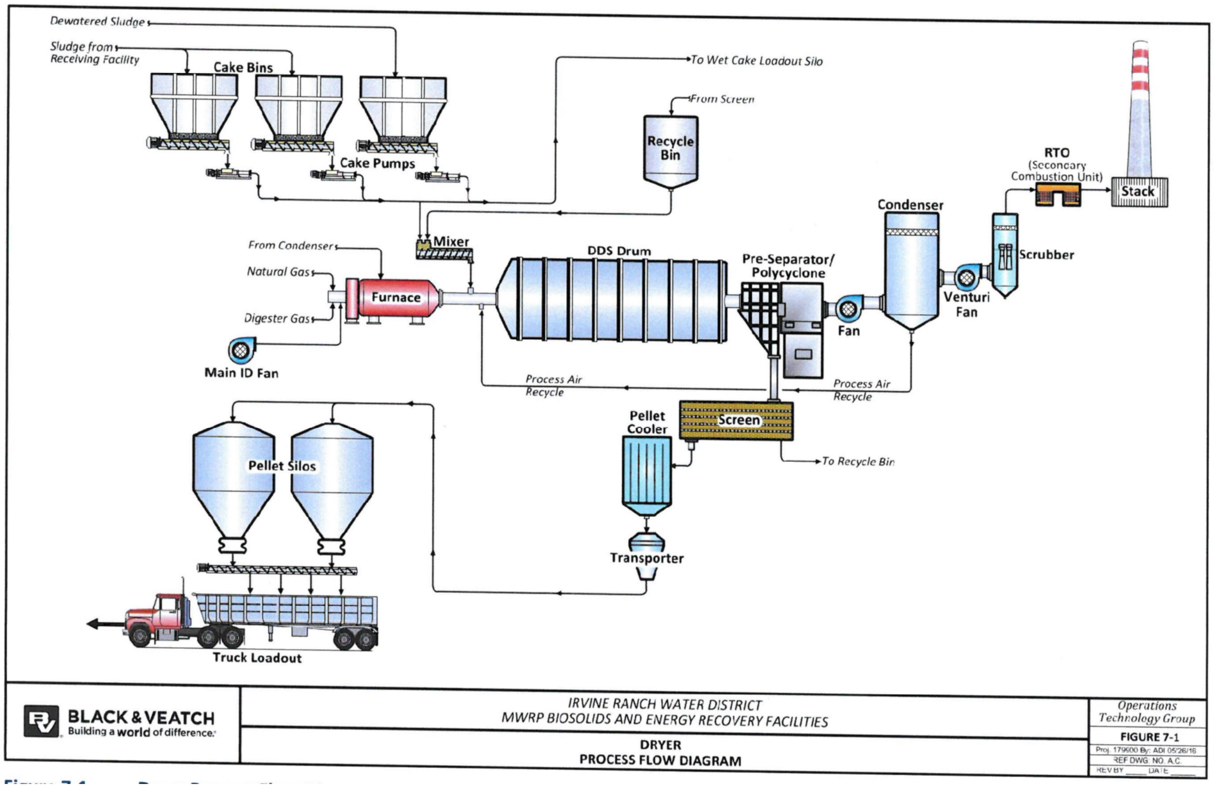
- Michelson Water Recycling Plant (WRP) is a 28 MGD-capacity tertiary wastewater treatment plant which produces recycled water. The anticipated ultimate build-out capacity is 33 MGD.
- The biosolids thermal drying equipment is sized to handle up to 57.5 dry tons per day of dewatered cake feed. However, the estimated build-out maximum-month digested sludge production at Michelson is 67,000 lbs/day of dry solids, which equates to 33.5 dry tons/day at the projected build-out plant flow of 33 MGD.
- The biosolids process train includes:
    - Centrifuge thickening of combined primary + waste-activated sludge
    - Acid-phase digestion in circular digesters, followed by methane-phase digestion in egg-shaped digesters.
    - Centrifuge dewatering, followed by trucking of Class B biosolids to Cynagro in Bakersfield, California.
    - When the thermal dryer is operational, Class B biosolids are converted to Class A pellets and then blended on-site with Class B biosolids being trucked to Cynagro. Currently, the plant has no beneficial local use of the Class A biosolids, with the only tangible benefit of thermal drying being volumetric reduction of sludge and thus reduction in the number of truck loads. IRWD has an interest in local sale and distribution of the Class A biosolids, but currently there is no developed market for this.
- The thermal drying system is designed for the following parameters:

- Dewatered sludge cake solids content: 20 to 26% TS
- Dried pellet solids content: 92% TS
- Dried pellet mass flow: 5,147 lb/hr
- Water evaporation rate: 13,320 lb/hr
- Dry Cake Feed Rate to Thermal Dryer (from Equipment Specification): 40.6 to 57.5 dry tons/day

Project Timeframes:

- It took 9 years to construct the new Sludge Thickening, Digestion, Dewatering, Thermal Drying, and Energy Recovery Facilities. The facilities allow the Michelson Plant to process its own biosolids instead of relying on the old method of sending unprocessed primary and secondary sludge to Orange County Sanitation District, a neighboring agency. The thickening, dewatering, and thermal drying facilities at the Michelson Plant are housed in a large, new, high-bay masonry building. The energy recovery microturbines and odor control facilities are located outside the building at grade. The digesters were constructed on a separate footprint adjacent to the building. The facilities were designed by Black and Veatch. The construction contract amount including change orders was approximately $185 Million. The thermal drying facilities were a pre-negotiated portion of the construction contract, with Andritz as the system supplier. IRWD attributes the long construction duration to delays caused by the Contractor. There was litigation on the project. Nevertheless, the biosolids facilities started up about one year ago.
- In the last year since start-up, Andritz operated the thermal drying facility for the first 7-8 months, followed by IRWD operation for 2 months, followed by the most recent 2-month period of non-operation. The thickening centrifuges, digesters, and dewatering centrifuges remain in continuous service. At the time of the March 9 site visit, the thermal dryer was not operating. During periods of non-operation, IRWD evacuates the drying drum and other system components of dried or partially dried solids. Reasons for non-operation are detailed below.

Process Flow Diagram of Thermal Drying Facilities:



Key Issues and Challenges Experienced by IRWD with New Facility Operation:

- Since start-up about one year ago, the facility has had 7 to 8 smoldering events. The smoldering events occur when the dried pellets are allowed to sit too long and heat up over time. During the most recent smoldering event, the heat from the pellets caused the seals to fail in the pellet cooler outlet valve. As IRWD did not have a spare outlet valve, the system had to be shut down while a new outlet valve was ordered. IRWD attributes smoldering to high iron content, with the possibility that ferric chloride addition on the liquid side contributes to the iron content. Air leaking into the system and the presence of human hair are also potential contributing factors to smoldering, according to IRWD.
- Excessive dust build-up became an issue during the 2-month period that IRWD operated the thermal drying facility. IRWD reports that smoldering is the main cause of dust. Operators report that accessing dust laden surfaces was difficult, as the thermal drying equipment is very tall and inaccessible in places. Operators had to go up on a scissor-lift to vacuum difficult-to-reach surfaces. The facility was built with a common, hard-piped vacuum piping network that operators can tap into with vacuum hoses.
- Build-up of human hair fibers within the thermal drying system is a recurring issue.
- The foul air piping for the entire biosolids building is linked together. Solids from the thickening centrifuges have leaked into the centrifuge vent pipes and have migrated to the foul air piping in the entire building. IRWD has initiated recent contracts to add new access ports to the foul air piping, CCTV the piping, and clean the piping.

- To aid in start-up, the facility was designed and outfitted with a cake bypass line which allows dewatered sludge received at the inlet cake bins in the thermal drying area to be bypassed to a Class B loadout silo when the thermal dryer is not operational. This cake offload line is “too long” according to IRWD and has become plugged with biosolids.
- During start-up, the Thermal Oxidizer (a device which burns the exhaust air from the dryer) had issues with lining bricks delaminating from the inside wall of the oxidizer unit. IRWD said that Gulf Coast Environmental, the subcontractor to Andritz responsible for supplying the thermal oxidizer, was responsive in terms of coming to the site multiple times to fix the issue.
- The gas microturbines (manufacturer: Capstone), which generate electricity from digester gas, are currently non-operational due to condensate migration from the chillers. Currently, all of the digester gas is being flared with a single flare. IRWD plans to re-start the microturbines in the coming weeks.
- When the thermal dryer is operational, it can only operate at 50% capacity. The reason is that cooling water from the Venturi air scrubber system is dust-laden and for water quality reasons cannot be discharged to the on-site stormwater retention pond. As a result, IRWD has to divert this waste stream to the headworks, but the piping for the diversion to headworks is not adequately sized. The dryer can only run at 50% volumetric capacity, to limit the flowrate of spent cooling water discharge from the air scrubber system back to the headworks.

Energy:

- The thermal dryer is fueled by natural gas, and the unit is also designed to operate with a fuel mix containing up to 30% biogas. The 30% maximum biogas threshold is based on the need to maintain a minimum required BTU content in the fuel feed.
- The microturbines, when operational, are capable of supplying electricity for between 50% and 80% of the electrical demand for the entire biosolids facility. The microturbines are sized to consume most of the digester gas currently produced. Each microturbine has a heat exchanger for heat recovery. As a secondary use for biogas, IRWD has the ability to fuel hot water boilers, although the preferred mode of operation is to send digester gas to the microturbines.

DC Water's Bloom Program Meeting Notes

Date:	March 22, 2022
Project:	King County Biosolids Class A Alternatives Analysis
Notes By:	Patrick Davis, PE; Miaomiao Zhang, PE, PMP; Kim Marshall, Murraysmith
Re:	DC Water's Blue Drop Bloom Program
Interviewed with:	Chris Peot, PE, Director of Resource Recovery, DC Water April Thompson, Director of Bloom Marketing, Blue Drop, DC Water

Production Overview

- Approximate Amount of Biosolids Produced: DC Water produces about 160,000 wet tons of Class A biosolids per year. In 2021 about one third of it, 48,000 tons, was sold as Bloom to farmers, landscapers, soil blenders, and homeowners. The remaining two third of it was hauled away by paid contractors for land application.
- Biosolids Process: The Class A biosolids are produced through the batch thermal hydrolysis process (THP) and mesophilic anaerobic digestion. The biosolids are then dewatered to approximately 32% total solids (TS). A small percentage of Bloom (~ 15 percent) is blended with bulking agent for sale to landscapers.
- Bulking Agent Used: Sand, woodfines, hardwood fines.

Associated Cost Benefits

- The pre-blended Class A biosolids, Bloom, sell for $10/ yd plus a hauling fee. The blends are sold for $20/ton and a minimum delivery fee of $200. During winter the Bloom hauling is subsidized to $1/ton.
- Overall Costs and Income: Bloom does not produce any income for the plant; however, it reduces the costs associated with biosolids management. Approximately 75% of the costs to treat the solids is recouped by Bloom sales. The old solids program costs the plant $20 M/yr. The current program costs the plant $5M/yr.

Marketability

- Bloom is a popular and consistent product that is able to meet DOT specifications for landscaping, as well as, the needs of individual buyers and soil blending facilities.

- The plant began its Class A program approximately 7 years ago. There was a 2-year startup period when the facility needed to prove that the biosolids were meeting vector and pathogen reduction. The Bloom product has been on the market for approximately five years.
- Bloom's original marketing approach involved sending people out to contact various user groups. These groups included mid to large-scale farmers, individual households, and soil blenders. Much of the initial marketing effort was "cold calling". Additional marketing involved tabling events at conferences. In general, the marketing approach was similar to TAGRO's approach. In the last four years Bloom has hired dedicated sales people with connections in the landscaping and farming communities to market and sell the product.
- One key to success was the development of cool hats and logos (tongue-in-cheek remark, but it does have validity).

Additional Items

- Distribution: Bloom is distributed in three ways. Customers can pick it up themselves; Bloom has in-house delivery service for smaller, local customers; or they utilize third-party delivery services for larger deliveries.
- Regulations: There are some county and state regulations that restrict how the Bloom/ Class A biosolids are distributed.
- Long Term Contracts: The nature of the Bloom product is such that long term contracts are not typical. Demand rises and falls with the season, so there is little incentive for large scale soil blenders, farmers, and contractors, to take on a long term delivery contract. The Bloom program is also still in its early years and the marketing team does not believe long-term contracts would benefit the program at this stage. They fear "leaving money on the table" if they sign long-term contracts now and prices rise in the future. Bloom did previously have one long-term contract with a whole-sale garden supplier, but the garden supplier did not follow through on the terms of the contract and the contract was severed.
- Future Plans: The main goal for the future is to have a better handle on the inventory of the Bloom / Class A biosolids. This involves increasing the storage capabilities for the solids. Blue Drop is currently in the process of purchasing a farm in Maryland to store the solids during winter months. Additionally, there are plans to purchase specialty loading pads to allow deliveries onto farmland during the wet, winter season. These pads prevent damage to the farm fields making the customers more amenable to receiving deliveries during wetter months.
- Odors: The product has some odors, but they tend to be caused by ammonia, which is not as offensive as odor caused by sulfide.

City of Missoula Garden City Compost Site Visit Notes

Date: April 6, 2022

Project: King County Biosolids Class A Alternatives Analysis

Notes By: Jeff Moss, PE, Murraysmith

Re: City of Missoula Composting Site Visit

Production Overview

- Approximate Amount of Biosolids: 2,100 dry tons/yr
- Approximate Amount of Compost: 18,000 wet tons/yr or 26,000 cy-yds/yr
  - Also incorporates (estimate only, not actually weighed):
    - ~1,900 tons of organics/municipal compost collection
    - ~12,000 tons of leaves
    - ~6,700 tons of brush
- City currently distributes over 100% of annual compost production as they purchased the facility in 2016 with huge stockpiles on site and have been working to reduce the backlog of excess compost.
- Class of Solids Used: Missoula WWTP uses anaerobic digestion followed by dewatering with either a belt press (preferred) or centrifuge. The dewatered sludge is conveyed over the fence to the composting site, approximately 13-15% total solids
- Bulking Agent Used: Chipped brush, sawdust, lumber
  - Accept woody brush, dimensional lumber (untreated, unpainted, <6ft long) and chips in their own chipper to generate woody bulking agent. Cost is $7/10 cu-yd to dump. Fee basically just pays for inspection – people will try to dump all kinds of stuff.
  - Also accepts clean sawdust from mills at no cost.
  - Accept brewery waste and food waste, not for bulking agent but provides a public service. Not 100% sure about cost but believe it is the same as for woody materials.
- How it is created: Bulking agents are accepted and dumped near the entrance, where they are chipped in a 'tub grinder' and stockpiled. Organic food waste and brewery waste is accepted and 'chipped' here also to blend it in. Sawdust and biosolids are stockpiled

separately near the mixer. Biosolids are mixed at a 3:1 ratio with bulking products in the mixer, which creates a homogenous product ready for composting. Composting is aerated statice pile, done in bays constructed of ecology blocks with above ground aeration pipework. Entire operation is 'bare ground' on dirt without concrete or gravel base. They are working to change that but grandfathered in with DEQ. Raw compost pile is topped with finished compost to help contain odors (pretty effective). The site only gets a few odor complaints on hottest days of summer. Usually the WWTP smell is worse. Compost for about 4 weeks, then screened in a trommel screen. Screened compost is 'cured' for 1-3 months before it is sold. Trommel screens remove large debris which is reused as bulking agent. All material movement after acceptance on site is done with several large front loaders.

- Required Labor: 10 people are employed, full time. They are responsible everything, from marketing to accepting incoming wood debris to loading products into totes.
- End Products:
  - Compost ($26/cy-yd, discount for large volumes)
  - Enriched Topsoil – topsoil + 25% compost ($40/cu-yd)
  - Topdressing – fine screened compost, good for direct placement into grass and golf courses ($35/cu-yd)
  - Potting Soil – Compost mixed with mulch, peat moss, and pearlite ($65/cy-yd)

Associated Cost Benefits

- Products are available to the public, private resellers, and landscapers/contractors. Can be picked up from the plant in bulk or totes. Distribute widely to nurseries and landscaping suppliers regionally within a couple hour drive. Occasionally used for large restoration projects even further. There is not much local competition so they can set the price. Working to see if agricultural operations are interested, but location is a challenge.
- Overall Costs and Income: Garden City Compost is a recent acquisition by the City, before that it was operated as a private company that was paid to accept the biosolids. The Composting operation is 'revenue neutral' when considering previous cost to dispose biosolids. They make roughly $600k in revenue and provide $450k in 'biosolids disposal service' value (which is roughly $32/wet ton of biosolids). Additionally divert a lot of compostable material from the landfill, which is viewed as a benefit and service to the public. City wastewater rates are the lowest in the state (did not verify this).

Marketability

- Garden City Compost products are pretty popular, and they are working into the stockpile.
- Eko Compost began in the 1985 and the City bought the facility in 2016. People are very familiar with the product but since the City purchased they have been working to expand

the market to address the stockpile. There are occasional minor concerns over 'non-organic' nature of the compost and metals/chemical concentrations.

Additional Items

- Sourcing bulking material: Accepting and processing woody debris from the public presents some operational challenges but alleviates sourcing issues.
- Organic composting: Garden City Compost also accepts food waste from local municipal composters (Missoula Compost Collection) and businesses (primarily Walmart). This is a relatively small % of the total but provides an additional service. BPI certified compostable materials has been a huge help to make sure these materials can be processed.
- Operational Challenges: Nothing too bad. The stockpile is a concern but they are working on reducing it. Equipment needs maintenance and repair regularly, but that is expected and accounted for. Inspection of public drop off is key, people will try to dump crazy things (for example, a transmission hidden in grass clippings). Also hoping to improve SCADA integration so pile temp can be monitored remotely.
- Site Requirements: The entire lot is about 35 acres, but they only use probably 12-15 actively, the rest is stockpiled compost or not used. As mentioned previously, they are working on getting funding to add concrete pads to the site to help reduce rocks and make the operation cleaner.
- PFAS: Staff is closely following PFAS regulations but has not done any testing yet. Planning to begin once an EPA method is finalized because they don't want varying methods to affect results.
- Site is also used for a couple other things – glass recycling transfer station (since Republic Services will not do this at landfill) and hosting an experimental fungi degradation of particle board with local group.
- Generally got the feeling that the operators have a lot of passion for the operation and take pride in providing valuable services for the community. Flexibility to try new things and seem well supported by WWTP management and City.
- Hamilton has a good small-scale operation. Coeur d'Alene also has a nice operation.

North Shore Water Reclamation District Biosolids Recycling Facility Phone Interview Notes

Date:	May 11, 2022
Project:	King County Biosolids Class A Alternatives Analysis
Notes By:	Patrick Davis, PE; Miaomiao Zhang, PE, PMP, Murraysmith
Re:	North Shore Water Reclamation District Biosolids Drying
Interviewed with:	Steve Waters, Director of Engineering NSWRD Dave Swarthout, Project Manager, Veolia Peter Dorn, Operations Supervisor

Production Overview

- Biosolids Treatment Process: This stand-alone Biosolids Recycling Facility receives and treats solids from three treatment plants owned and operated by NSWRD. Two of the plants do not have digestion process. The raw sludge is dewatered to ~ 18% solids content before being trucked to the Biosolids Recycling Facility. These undigested sludges are approximately 80% of the total solids loading to the facility. The third plant has mesophilic anaerobic digestion. The digested and dewatered sludge (at ~ 20%) is trucked to the Biosolids Recycling Facility. Enhanced biological phosphorous removal (EBPR) is done at all plants. There are two receiving bins and a 3-day-storage on-site storage silo at the Biosolids Recycling Facility. There is one Andritz fluid bed dryer system that is normally running continuously except during the downtime for maintenance. The final product is ~ 92 to 93% solids content. The facility has been operating for approx. 15 years. NSWRD contracts Veolia to operate the facility.
- Approximate Amount of Biosolids Processed: ~9,000 dry tones per year from three plants.
- Product Market: Veolia contracts with a hauling company to haul away and land apply the dried pellets to the farm field. Veolia pays the land application and hauling fee. No revenue. The dried pellets are used solely for mid to large-scale agriculture. There is enough farmland in the Midwest with sufficient demand for the Class A biosolids. The odor of the pellets is strong, which limits the public acceptance for use in the small-scale farm or gardens.
- Bulking Agent Used: No Bulking agent is used. Mineral oil is applied to the solids after bulk loading. This is intended for dust control. Dried pellets are applied directly to the fields

- Issues With the Product: There have been several smoldering incidents. Rarely the product has caught fire. This is due to the nature of the dried pellet as well as the feedstock. The WAS has a lot of volatile organics within it, which tends to be more reactive. Additionally, the pellets have an odor associated with them due to the undigested nature of the feedstock. Plant staff has noticed that more stringent screening of the upstream wastewater flows reduced smoldering incidents.
- Required Labor: The facility is operated by Veolia under a contract operation. Veolia has 8 full time equivalents staff at the facility. This includes four operators with one “floating” operator, one dedicated maintenance person, one project manager, and one assistant project manager. The facility began with 12 people, but they found ways to drop the number of operations personnel without sacrificing operability and maintenance.
- End Products: 92%-94% Class A pellet at approximately 4:5:1 NPK (nutrient value)

Associated Cost Benefits

- The process has had the result of reducing the costs associated with biosolids management; however, they are not making any direct revenue from the process.
- Veolia has a contract with biosolids distributors. The costs associated with these contracts are confidential, and we were unable to obtain a range of values.

Marketability

- The dried pellets are not available to the public. No marketing on that front has been made.
- Due to the contract with Veolia, minimal information on the marketing strategies were made available to us.

Additional Items

- Sludge Characteristics: The sludge that they are running through the dryer tends to be sticky. The sticky sludge tends to stick to and plug the heat exchanger tubes reducing efficiency through the dryer. Plant staff have found that aging the sludge (or using aged sludge) improves operational efficiency.
- Extensive Maintenance: Due to the plugging of the heat exchanger tubes, the dryer requires shutdown and cleaning about once per week during the winter months. During summer, cleaning occurs about once per month. The cleaning cycle takes approximately 17 to 36 hours including shut down, cool down, cleaning and startup. The actual cleaning takes about 10 hours each. They typically clean it on Thursday and run it through the weekend. This level of maintenance is considered preventative.
- Runtimes: The dryer runs constantly except during cleaning. They do not operate it solely remotely. They are always staffed while it runs
- Redundancy: The plant has one dryer – no redundant dryer. During cleaning operations solids are stockpiled and mixed in their storage silo

- Fuel and Ancillaries: The dryer utilizes natural gas for its thermal energy. Thermal fluid is oil. The plant does not have heat recovery, but they are intending to install heat recovery – not by Andritz.
- Permitting: They do have an air permit, but it is not Title V. It is a state operating permit. All the air for the drying process is closed loop. The only emissions are associated with the burning of natural gas.
- Odor Control: The building operates a wet scrubbing odor control unit.
- Andritz Customer Service: The operations staff seemed reasonably pleased with Andritz's customer service. They mentioned that the folks working there genuinely want to find a solution to their problems, but they are a bit closed with their information. The facility tends to do their own modifications and maintenance. They have not recently needed Andritz.
- General Feeling About the Equipment: Operation staff report that the equipment feels safe and reliable. Critical equipment has redundancy and spare parts. Beyond normal wear and tear, the facility has run well. The main issues with the equipment have been with the dust collection system and the dryer solids mixing system. Both systems have caused problems requiring facility staff to make changes. The routine cleaning of the equipment is a very labor-intensive process.

Composter Survey Summary
Class A Biosolids Technology Analysis
King County
20-2900.07

Facility	**Product**	**Location**	What is the approximate weight of biosolids you treat annually (dry, or, if wet at what % solids)?	What type of process do you use (ex. Aerated piles, windrows, etc.) and are you producing a Class A product?	What types of bulking agent (wood chips, hog fuel, yard waste, etc) do you use and where do you obtain it?	How do you dispose or reuse the product? What are the costs or incomes you generate from this?	What is the approximate level of labor that the composting process requires?	What major operational challenges have you encountered?	Have you encountered concerns from the public about use of the compost?	Are there other considerations or advice you would give to another utility considering Class A reuse?
Centralia WWTP	Compost	Centralia, WA	70 dry tn/yr	Aerated static piles	Ground woody debris. The local land fill has a yard debris program (not grass clippings) that they grind and use.	Sell to the public at our WWTP plant for $10/ yard loaded. Also have a bin at a local park that is stocked for people to self-load free of charge. If they run out of room at the plant, the department owns a 400 acre farm that they can land apply. However recent history of selling out of material. Last year sold 1068 yards at $10/yard for a total of $10,680.	1 FTE	No real major operational challenges. There has been a few occasions where feed stocks (woody debris) have been hard to come by.	Initially there were concerns by the public. Public education played a big part of easing the concerns. Created flyers, did presentations at city council meetings and the local newspaper wrote an article on the benefits of composting biosolids. Also had a garden at the treatment plant where we grew vegetables. Then had them tested alongside store bought vegetables and made the results available. The vegetable grown in our compost in many cases had lower levels of pharmaceuticals and metals compared to store bought.	Do your research. Tour other municipal facilities. Send staff to the Compost Facility Operator Training through the Washington Organic Recycling Council. Build your facility/purchase equipment the best your budget will allow. Future upgrades can be challenging both logistically and financially.
Cheney WWTP	Compost	Cheney, WA	212 dry tn/yr	Aerated static piles	1,000 yards Hog Fuel, 13,977 yards yard waste. The current hog fuel supplier is Idaho Forest Group, LLC. Yard waste is collected at a drop off site from our residents free of charge.	Resale to the public at $14.00 per yard. Approx. 2900 yards @ $41,000 per year revenue.	3,500 man-hours were dedicated to the composting operation for hauling, monitoring, mixing, grinding, screening, loading, and equipment maintenance.	Biggest challenge is the ongoing degradation of equipment in the composting building, the maintenance to the mixers and compost screen and rolling stock.	Initially in 1995 when they started producing the biosolids compost it was a challenge to over come the negative attitude from the biosolids human source. Within a couple years, word of mouth got out as to how good the compost was and quickly turned the compost into a hot commodity. They sell all our production each year just by word of mouth and repeat customers.	Individual municipal operation can be expensive to set up and operate initially. Investigate the possibility of joining other entities in a shared facility if possible. Return on sales offsets some costs of operation. Overall annual debt service and operational costs are less than the anticipated annual combined disposal costs of the biosolids and the yard waste that the citizens would occur.
Lynden WWTP	Compost	Lynden, WA	63 dry tn/yr	Aerated static piles	Hog fuel	Sell to the public and provide a "free" loading day to citizens. Calculating compost-only costs have been a challenge and they are making efforts to improve this. Our cost estimation for 2020 was $55,000, revenue was $16,500	Approx. 1 FTE	Labor, equipment O&M	Minimal concerns today. There may have been more questions and concerns 20 years ago. Most customers know what they are getting and understand that it is safe.	Very resource and labor intensive. Boulder Park is a simple, cost effective solution. That being said we appreciate having multiple options for disposal and find value in producing a value-added product to our community.
Port Townsend WWTP	Compost	Port Townsend, W	213 dry tn/yr	Aerated static piles	Use ground yard waste for our bulking agent. We get it from the public bringing it to us. Also we have yard waste collection inside the City of Port Townsend through D.M. Disposal as part of the garbage contract.	Sell all of the compost in bulk to the public, @ $12.00 per yard unless you buy 10 yards or more at a time then it is $9.00 per yard. Usually make between 3500 and 4000 yards a year.	3 FTE	Problems come up, but nothing major	Occasional resistance but generally well accepted.	"My opinion is this is the best thing we can be doing with the bio-solids we all create."
Richland WWTP	Compost	Richland, WA	4,940 wet tons/yr	Aerated static piles	Yard waste from self-haul and curbside collection	Sell some @ $15/tn. Charge to accept greenwaste so process is revenue neutral.	1 FTE	Maintaining appropriate moisture content, fire during certain times of year, marketing product.	Only occasional questions.	Dust and odor may cause concerns in more heavily developed areas.
Westport WWTP	Compost	Westport, WA	6 wet tons/week @14% solids	4x12,000 lb in-vessel containers, but also spread on ground to reduce moisture. Yes it is class A. Designed by Engineered Compost Systems	Wood chips and sawdust to dry out. Woodchips are dropped off by local wood chippers. Sometimes the plant staff go to nearby forest to chip standing deadfall wood if they run out	Sell to public, also used by parks department and maintenance. Will load public container or truck, or deliver whole dump truck load if requested. Generates about $6-8k/yr.	Minimal labor. Total staff is 4 people, 1-2 people responsible for the whole plant. Roughly 25-50% of one person time on compost. Have augers to convey solids	Solids from screw press are too wet. Major challenge to dry out. Otherwise not too bad.	Only concern from public is that there is not enough compost to meet demand.	Be careful with machinery selection. Screw press is really a headache. Mixer is from Luck in Canada and has been great

murraysmith

APPENDIX F

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**

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**

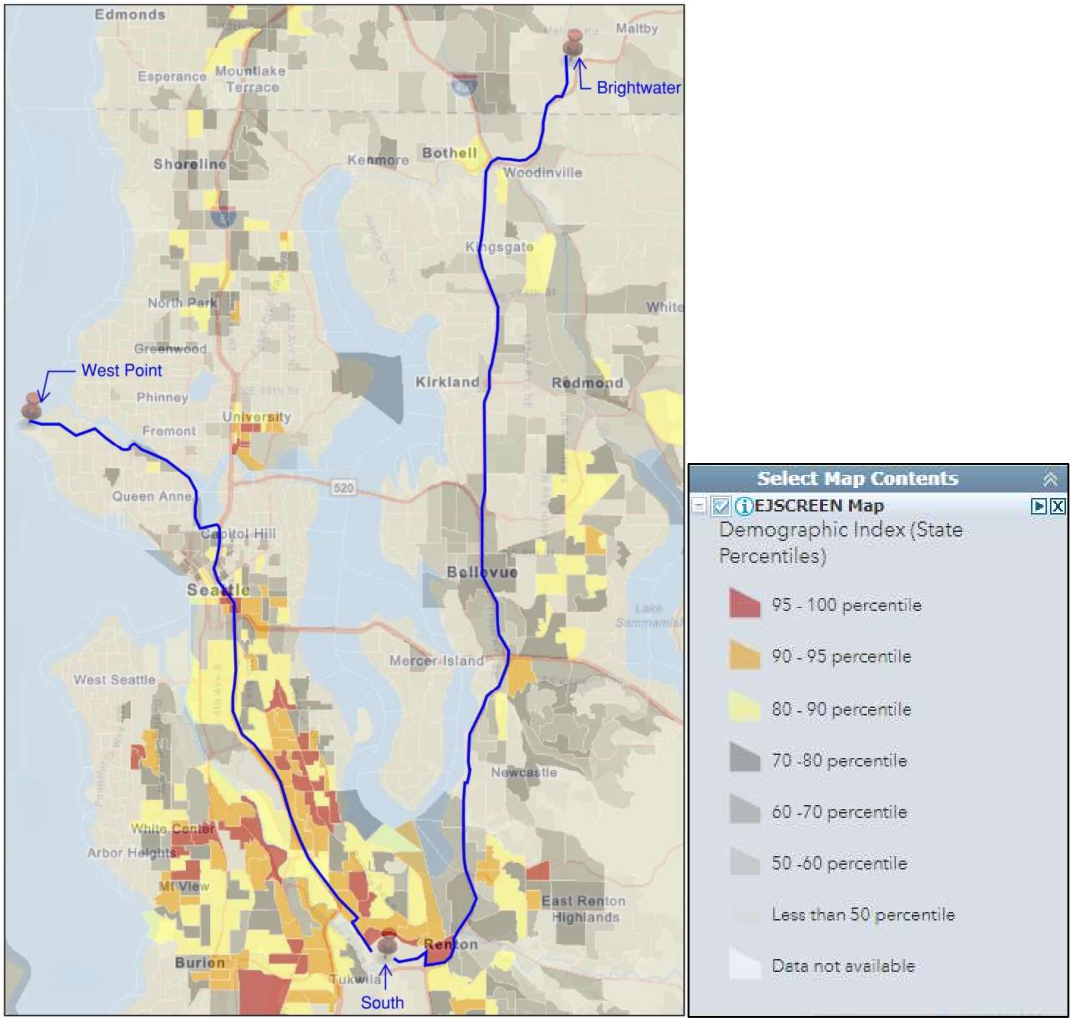
Notes:
1. Assumes the loads are carried by an electric vehicle fleet operates out of, and recharges at, the South Plant which uses 100% renewable energy for power. GHG emissions from vehicle production were not considered for this analysis.

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

2050 Biosolids Partnership Trucking				
Hauled Solids				
T1	**Hauling from SP**	**Average Hauled, wet tons/yr**		**96,279.0**
	Hauling from SP	**Dry Solids, %**		**22.9%**
	Hauling from SP	**Trucks per Day, approximate**		**8.5**
	Hauling from SP	**Trucks per Year**		**3106**
T2	**Hauling from WP**	**Average Hauled, wet tons/yr**		**64,784.0**
	Hauling from WP	**Dry Solids, %**		**28.5%**
	Hauling from WP	**Trucks per Day, approximate**		**5.7**
	Hauling from WP	**Trucks per Year**		**2090**
T2	**Hauling from BW**	**Average Hauled, wet tons/yr**		**35,998.0**
	Hauling from BW	**Dry Solids, %**		**20.0%**
	Hauling from BW	**Trucks per Day, approximate**		**3.2**
	Hauling from BW	**Trucks per Year**		**1162**
		Total Trucks/yr		**6358**
		Total wet tons/yr		**197,061.0**
Woody Debris		**wet tons/yr**		**131,765.0**
		trucks/yr		4251
BioChar		**wet tons/yr**		**16790**
		trucks/yr		542
Class A Biosolids		**wet tons/yr**		**57,670.0**
		solids %		**95%**
		trucks/yr Class A		1861

Total Miles Diesel:		Contents
Brightwater -> Dryer Facility	62,748	CL B Biosolids
West -> Dryer Facility	83,600	CL B Biosolids
South -> Dryer Facility	31,060	CL B Biosolids
Total	**177,408**	
Gallons Diesel:		
Brightwater -> Dryer Facility	11,427	CL B Biosolids
West -> Dryer Facility	15,225	CL B Biosolids
South -> Dryer Facility	5,657	CL B Biosolids
Total	**32,309**	
kg Co2:		
Brightwater -> Dryer Facility	135,815	CL B Biosolids
West -> Dryer Facility	180,948	CL B Biosolids
South -> Dryer Facility	67,228	CL B Biosolids
Total	**316,762**	
Weekly Trucking hours:		
Brightwater -> Dryer Facility	56	CL B Biosolids
West -> Dryer Facility	100	CL B Biosolids
South -> Dryer Facility	89	CL B Biosolids
Cedar Grove <-> Dryer Facility	122	Woody Debris
Drying Facility <-> Cedar Grove	16	BioChar
Drying Facility <-> Ash Grove	54	Dry Pellets
Total Miles Electric:		
Cedar Grove <-> Drying Facility	85,020	Woody Debris
Drying Facility <-> Cedar Grove	10,840	BioChar
Drying Facility <-> Ash Grove	37,220	Dry Pellets
Total	**133,080**	
kWh Electric:		
Cedar Grove <-> Dryer Facility	31,883	Woody Debris
Drying Facility <-> Cedar Grove	4065	BioChar
Drying Facility <-> Ash Grove	13957.5	Dry Pellets
Total	**49905**	
GHG emissions electric:		
Cedar Grove <-> Dryer Facility	0	Woody Debris
Drying Facility <-> Cedar Grove	0	BioChar
Drying Facility <-> Ash Grove	0	Dry Pellets
Total	**0**	

variables	
Miles, Bright->South (one way):	27
Miles, West->South (one way):	20
Miles, South -> Cedar Grove (one way)	10
Miles, South -> Ash Grove (one way)	10
Miles, South -> Dryer Facility	5
miles/gallon, full	4.18
miles/gallon, empty	8
kg CO2/L diesel	3.14
L to gal	3.785
large truck capacity, wet tons	31
miles/kWh electric, full	0.25
miles/kWh electric, empty	0.5
Electric Truck Charging	
Average distance per charge (km):	250
kilometer - small battery	130
miles - large battery	150
miles - small battery	105
Hours, Brightwater -> South round trip	2.5
Hours, West -> South round trip	2.5
Hours, Cedar Grove round trip	1.5
Hours, Ash Grove round trip	1.5

2050 Base Case Trucking				
Hauled Solids				
T1	**Hauling from SP**	**Average Hauled, wet tons/yr**		96,279.0
	Hauling from SP	**Dry Solids, %**		22.9%
	Hauling from SP	**Trucks per Day, approximate**		8.5
	Hauling from SP	**Trucks per Year**		3106
T2	**Hauling from WP**	**Average Hauled, wet tons/yr**		64,784.0
	Hauling from WP	**Dry Solids, %**		28.5%
	Hauling from WP	**Trucks per Day, approximate**		5.7
	Hauling from WP	**Trucks per Year**		2090
T2	**Hauling from BW**	**Average Hauled, wet tons/yr**		35,998.0
	Hauling from BW	**Dry Solids, %**		20.0%
	Hauling from BW	**Trucks per Day, approximate**		3.2
	Hauling from BW	**Trucks per Year**		1162
		Total Trucks/yr - Class B Hauling to East/West WA		**5196**
		Total Trucks/yr - Class B Brightwater to Compost		**1162**

Total Miles:		Contents
East	1,745,856	CL B Biosolids
West	72,744	CL B Biosolids
Compost	103,920	CL B Biosolids
Total	**1,818,600**	
Gallons Diesel:		
East	317,950	CL B Biosolids
West	13,248	CL B Biosolids
Compost	18,926	CL B Biosolids
Total	**331,198**	
kg Co2:		
East	3,778,809	CL B Biosolids
West	157,450	CL B Biosolids
Compost	224,929	CL B Biosolids
Total	**3,936,260**	
Weekly Hours:		
East	638	CL B Biosolids
West	80	CL B Biosolids
Compost	199	CL B Biosolids
Total	**717**	

variables	
Miles, East (one way):	210
Miles, West (one way):	35
Miles, South -> Cedar Grove (one way)	10
miles/gallon, full	4.18
miles/gallon, empty	8
kg CO2/L diesel	3.14
L to gal	3.785
large truck capacity, wet tons	31
Hours, East, round trip	8
Hours, West, round trip	4
Hours, Compost, round trip	2

% Distribution 2018	
East	80.0%
West	20.0%
Brightwater Compost	100.0%

murraysmith

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%.

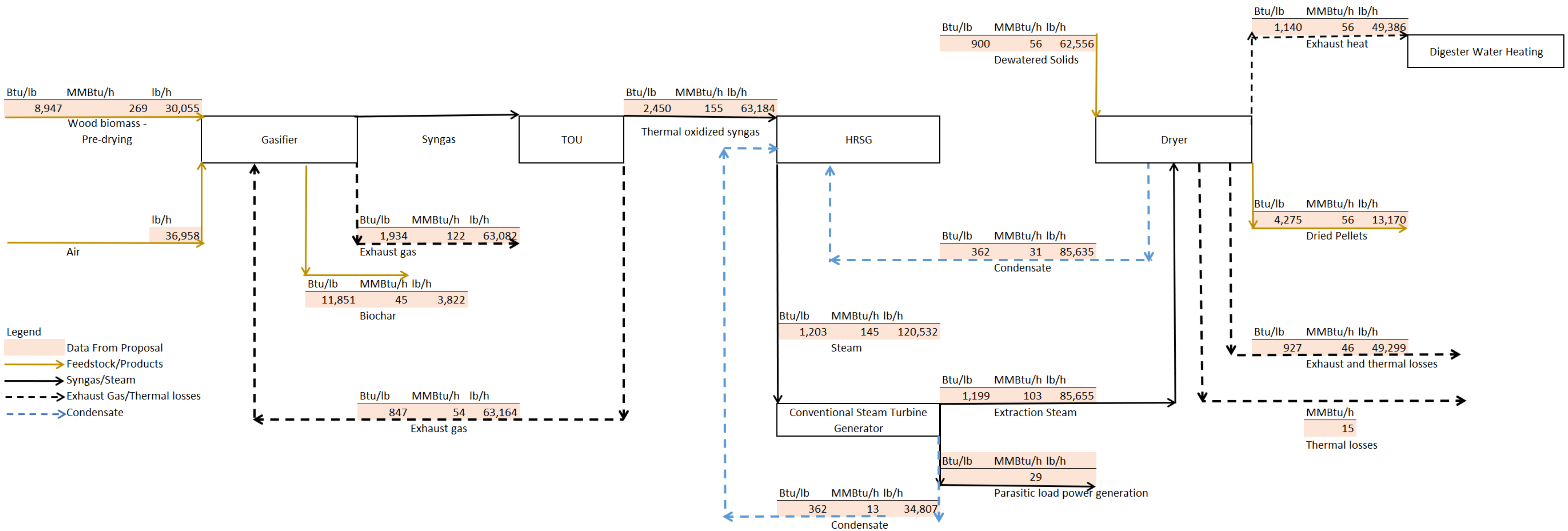
Under the maximum month flow conditions, the projected total dewatered solids produced will be 152 dry ton/d, with a solids content of 24%.

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

GHG Emissions Inventory				1	2
GHG Emissions Inventory				Base-case	Biosolids Partnership Gassification and Drying w/ Soil Blending
Element				Scenario 1	Scenario 2
West Point Treatment plant					
	Hauling and Transportation				
		Hauling	Average Hauled, wet tons/yr	64,784	64,784
		Hauling	Dry Solids, %	28.5%	28.5%
		Hauling	Trucks per year	2,090	2,090
		Hauling	Off-site Processing, Total Miles	0	83,600
		Hauling	Fuel Usage Round Trip, gal/yr	0	15,225
		Hauling	Emissions, kg CO2e/yr	0	180,948
		Hauling	Eastern Washington, Total Miles	702,240	To Dryer Facility
		Hauling	Fuel Usage Round Trip, gal/yr	127,890	
		Hauling	Emissions, kg CO2e/yr	1,519,960	
		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
	Land Application				
		Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	18,519	To Dryer Facility
		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	
			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
		Emissions from Land App	CO2 Emissions, mt CO2e/yr	606	
		Carbon Sequestration	CO2 Emissions, mt CO2e/yr	-20,341	0
		Solids Total	CO2 Emissions, mt CO2e/yr	-18,152	181
South Treatment plant					
	Hauling and Transportation				
		Hauling	Average Hauled, wet tons/yr	96,696	96,696
		Hauling	Dry Solids, %	22.9%	22.9%
		Hauling	Trucks per year	3,285	3,285
		Hauling	Off-site Processing, Total Miles	0	31,060
		Hauling	Fuel Usage Round Trip, gal/yr	0	5,657
		Hauling	Emissions, kg CO2e/yr	0	67,233
		Hauling	Eastern Washington, Total Miles	1,043,616	To Dryer Facility
		Hauling	Fuel Usage Round Trip, gal/yr	190,060	
		Hauling	Emissions, kg CO2e/yr	2,258,844	
		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
	Land Application				
		Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	27,882	To Dryer Facility
		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	
			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

	Emissions from Land App	CO2 Emissions, mt CO2e/yr	808	0
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	-24,608	0
	Solids Total	CO2 Emissions, mt CO2e/yr	-21,447	67
Brightwater Treatment Plant				
Hauling and Transportation				
	Hauling	Average Hauled, wet tons/yr	35,998	35,998
	Hauling	Dry Solids, %	20.0%	20.0%
	Hauling	Trucks per year	1,162	1,162
	Hauling	Off-site Processing, Total Miles	62,748	62,748
	Hauling	Fuel Usage Round Trip, gal/yr	11,427	11,427
	Hauling	Emissions, kg CO2e/yr	135,809	135,809
	Hauling	Eastern Washington, Total Miles	To Off-site Composting	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
Land Application				
	Agriculture	KC Fuel for Agriculture (Eastern) Application, gal/yr	To Off-site Composting	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
	Emissions from Land App	CO2 Emissions, mt CO2e/yr	0	0
	Carbon Sequestration	CO2 Emissions, mt CO2e/yr	0	0
	SolidsTotal	CO2 Emissions, mt CO2e/yr	136	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

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Carbon Copy Events	Status	Timestamp

Witness Events	Signature	Timestamp

Notary Events	Signature	Timestamp

Envelope Summary Events	Status	Timestamps

Envelope Summary Events	Status	Timestamps
Envelope Sent	Hashed/Encrypted	12/15/2022 2:11:15 PM
Certified Delivered	Security Checked	12/16/2022 10:35:42 AM
Signing Complete	Security Checked	12/16/2022 10:35:49 AM
Completed	Security Checked	12/16/2022 10:35:49 AM

Payment Events	Status	Timestamps

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.

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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.

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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.

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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..

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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.

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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
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- 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.