CONFIDENTIAL

APPENDIX L

Advanced Integrated Resource Management

Detailed Analysis of Responses to RFEOI No. 16-1894

Capital Regional District

June 16, 2017

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Glossary of Key Terms

The following glossary is not intended to be a comprehensive overview of all descriptive terms used in this report. However, in order to provide clarity of purpose to this detailed analysis of the RFEOI, key terms essential for understanding of the overall Integrated Resource Management (IRM) project are defined as follows.

Beneficial Use / Beneficial Reuse: Beneficial use and beneficial reuse are used interchangeably and for the purpose of this report and the Integrated Resource Management Project, are assumed to have the same meaning. Beneficial use is applied in the context of this project as a concept for the management of residual solid and liquid waste as a means to save landfill disposal capacity by avoiding disposal of materials and directing them to alternative uses. To be considered a beneficial use, the materials/products recovered from the solid or liquid waste stream must not be stored in anticipation of speculative future markets, the recovered materials must be an effective substitute for an analogous material or a necessary input to generate a new product, the use of the material should not adversely impact human health or the environment, and the material should be used in accordance with applicable standards, requirements, guidelines and best management practices. In accordance with CCME guidelines, Beneficial Use is the use of municipal biosolids, municipal sludge and treated septage according to the *Canada-wide Approach for Management of Wastewater Biosolids*.

Biosolids: For the purpose of this report and in further IRM documents, the term biosolids is used interchangeably and synonymously with Class A Biosolids.

Class A Biosolids: Class A Biosolids are as defined under the BC Organic Matter Recycling Regulation, that meet the requirements of section 6 of the regulation (Schedule 1, Pathogen Reduction Processes; Schedule 2, Vector Attraction Reduction; Schedule 3, Pathogen Reduction Limits; Section 3 of Schedule 4, Quality Criteria; Schedule 5, Sampling and Analysis; Schedule 6, Record Keeping).

Compost: Means a solid mature product resulting from composting but does not include compost to which the Fertilizer Act (Canada) applies. This would include materials defined as “compost” under the BC Organic Matter Recycling Regulation.

Disposal: Is used in this report to refer to the disposition of solids, in a manner that does not result in the recovery of the resources (materials or energy) from those solids, including incineration (without energy recovery) and landfill disposal.

Fertilizer: Means any substance of mixture of substances, containing nitrogen, phosphorus, potassium or other plant food, manufactured, sold or represented for use as a plant nutrient that meets the requirements of the Fertilizer Act (Canada) and includes materials such as Compost where this material is sold as a fertilizer and thus must meet the requirements of the Fertilizer Act. This would include materials defined as “fertilizer” under the BC Organic Matter Recycling Regulation.

Integrated Resource Management (IRM): IRM is defined by the Capital Regional District as the integration of solid and liquid wastes, using currently landfilled or diverted materials along with biosolids, to maximize resource recovery through combined processing or some, or all, of these materials. Combined processing could be accomplished through the application of a single technology or a combination of technologies, from one or more technology providers, which recover resources in the form of materials and/or energy for beneficial use.

Municipal Solid Waste (MSW): Municipal Solid Waste includes solid waste material streams generated by the residential sector, institutional, commercial and light industrial sources as well as waste from construction, demolition and renovation activities. It does not include hazardous, biomedical or agricultural waste, motor vehicles or components, heavy industry waste or contaminated soil.

Pathogen: Means an organism including some bacteria, viruses, fungi and parasites that are capable of producing an infection or disease in a susceptible human, animal or plant host.

Resource Recovery: Resource recovery is identified as the 4th R in the waste hierarchy, and involves the reclaiming of recyclable components and/or energy from the solid waste stream by various methods. To be considered a resource recovery facility, waste to energy facilities will achieve an energy efficiency criteria of obtaining at least 60% of the potential energy from the MSW used as fuel. The energy efficiency criteria is modelled after Annex II of the European Commission Waste Framework Directive model.

Sewage Sludge: Means the semi-liquid material that is removed from a wastewater treatment system as an end product of the treatment process.

Scientific Evidence: Is evidence which serves to support or counter a scientific theory or hypothesis. Such evidence is expected to be empirical evidence and interpreted in accordance with the scientific method.

Table of Key Acronyms and Abbreviations

AD	Anaerobic Digestion
CHP	Combined Heat & Power
CNG	Compressed Natural Gas
CRD	Capital Regional District
DB	Design, Build
DBFO	Design, Build, Finance, Operate
DBFOM	Design, Build, Finance, Operate, Maintain
DBO	Design, Build, Operate
DBOM	Design, Build, Operate, Maintain
DBOO	Design, Build, Own, Operate
DBOOM	Design, Build, Own, Operate, Maintain
DBOOT	Design, Build, Own, Operate, Transfer
EPC	Engineering, Procurement and Construction
FICFB	Fast Internally Circulating Fluidized Bed
FOG	Fats, Oils and Grease
GHG	Greenhouse Gas
Ha	Hectares
ICI	Industrial, Commercial and Institutional
IRM	Integrated Resource Management
kWh	kilowatt hours
LYW	Lead and Yard Waste
m	Meters
MBT	Mechanical Biological Treatment
MSW	Municipal Solid Waste
MW	MegaWatt
Nm^3	Normal Cubic Meter
P3	Public Private Partnership
RDF	Refuse Derived Fuel
RFEOI	Request for Expression of Interest
SRF	Solid Recovered Fuel
SSO	Source Separated Organics
tpd	Tonnes per day
tpy	Tonnes per year
VOC	Volatile Organic Compound
WWTP	Waste Water Treatment Plant

1 Introduction

The Capital Regional District (CRD) issued RFEOI No. 16-1894 as a part of the CRD's exploration of waste management options. Specifically, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing and future solid and liquid waste management facilities.

Further the CRD wishes to explore the possibility of integrating solid and liquid waste management interests and maximizing resource recovery through integrated processing of some or all of these materials and generate energy/revenue. Completion of the Integrated Resource Management (IRM) RFEOI analysis is a critical step in the development of a more detailed IRM plan.

2 Background

At the February 8, 2017 meeting, the CRD Board approved the Advanced Integrated Resource Management (IRM) Project - Request for Expressions of Interest (RFEOI) and directed staff to proceed with the RFEOI. The RFEOI was intended to explore the market interest in beneficially using locally available solid waste and liquid waste residual materials as feedstock for an IRM facility and initiate the process for assessing IRM options as stipulated in Amendment No. 11 of the Core Area Liquid Waste Management Plan.

The RFEOI results provide a key component to support the assessment of the full spectrum of biosolids beneficial uses. This assessment will be documented in the IRM Project Plan.

Subsequent steps in the IRM Work Plan in 2017 could include development of a future IRM procurement process, and review and finalization of the IRM Project Plan.

3 Overview of RFEOI No. 16-1894

The purpose of the RFEOI was to gather as much information as possible ensuring that the CRD is well informed and that the eventual IRM procurement process and evaluation criteria consider all key aspects in a procurement of this nature.

The RFEOI identified that the CRD is seeking a solution or solutions to manage some or all of the following materials:

1. 35,000 tonnes per year of Class A biosolids;
2. 120,000 to 135,000 tonnes per year of general municipal refuse;
3. 8,000 to 12,500 tonnes per year of controlled waste (including screenings and sludge from existing wastewater plants);

4. 15,000 to 20,000 tonnes per year of source separated household organics (kitchen scraps and compostable paper, not including yard and garden wastes); and,
5. 15,000 to 18,000 tonnes per year of yard and garden wastes.

The potential outcome of the RFEOI process could include undertaking a pilot project or directly proceeding to development of a full-scale IRM facility capable at minimum of providing a beneficial reuse solution for the material streams as identified above. The RFEOI clearly indicated CRD is interested in identifying integrated options that present region-wide and/or sub-regional solutions.

Information requested in the RFEOI included:

1. General corporate information;
2. A technical overview of the processing technology;
3. Information regarding reference facilities;
4. Information regarding the future procurement plan, including preferred contract terms, contract structure and allocation of responsibilities;
5. Information regarding the need for and interest in undertaking a pilot;
6. Comments regarding suitable feedstock types and quantities providing insight to the CRD's lack of feedstock control;
7. Comments regarding the site size requirements and site attributes that would be necessary to support their technology, to provide insight regarding the CRD's limitations related to identifying a suitable site;
8. Information regarding the exposure of risks to the CRD and the respondent due to technology and performance; and,
9. Assistance in defining the scope of the project for the individual respondent.

Respondents were requested to indicate their interest and approach to exploring and implementing solutions for managing CRD materials, and to provide an overview of the elements that they have found in their experience to result in successful implementation of a project.

The outcome of the RFEOI process was not intended to qualify technologies or respondents, nor was it intended to validate partners. Information was requested regarding reference facilities in order to understand where similar technologies are being used, and to better understand the operational history of existing facilities. Information regarding preferred contract terms, contract structure and allocation of responsibilities was requested to inform the CRD regarding the market's interest in undertaking an IRM project and to better understand the approaches that would be suitable for this undertaking.

Qualifications of technologies and respondents would be undertaken as part of any future IRM procurement process.

4 Integration of IRM and CALWMP

On November 18, 2016 the BC Minister of the Environment issued a letter regarding its revised conditional approval of Amendment No. 11 to the Core Area Liquid Waste Management Plan (CALWMP). Amendment No. 11 includes the conveyance of sewage sludge from the McLoughlin Point WWTP to the Hartland landfill for processing into Class A Biosolids as defined under the BC Organic Matter Recycling Regulation, for beneficial use and optimization for potential opportunities for integrated resource management (IRM).

As a condition of approval, the Minister requires that the CRD develop a definitive plan for the beneficial reuse of biosolids that does not incorporate multi-year storage of biosolids within a biocell. The CRD has submitted a plan that outlines procedural steps and the schedule it will implement to achieve the definitive plan. The definitive plan must be submitted as of June 30, 2019.

The definitive plan for beneficial reuse of biosolids:

- is to be supported by an assessment of the full spectrum of beneficial uses and integrated resource management (IRM) options available for the Class A biosolids produced at the Hartland landfill;
- incorporates a jurisdictional review of how similar-sized and larger municipalities within BC, North America and abroad successfully and beneficially reuse biosolids;
- must select a beneficial reuse option for treated biosolids that meets the requirements for beneficial use specified in the Canadian Council of Ministers of the Environment *Canada-wide Approach for the Management of Wastewater Biosolids* (October 11, 2012) and be based on scientific evidence.

The CRD has taken a proactive approach to examining IRM options over the past year, and retained HDR as its IRM technical advisor to prepare a Request for Expressions of Interest (RFEOI).

5 Overview of RFEOI Responses

The RFEOI was issued on February 16, 2017 and closed on March 20th, 2017. Ten submissions were received, as noted in the table below.

Table 5-1: List of RFEOI Respondents

Corporate/Team Name	Respondent Name(s)	Location	Website
Anaergia	Anaergia	Burlington, Ontario	http://www.anaergia.com/
APD	Ark Power Dynamics Inc.	Vero Beach, Florida	http://arkpowerdynamics.info/

Corporate/Team Name	Respondent Name(s)	Location	Website
ECS	Engineered Compost Systems	Seattle, WA	http://www.compostsystems.com/
ICC Group	International Composting Corporation	Sidney, BC	http://www.iccgroup.ca/
Ostara	Ostara Nutrient Recovery Technologies Inc.	Vancouver, BC	http://ostara.com/
Pivotal	Pivotal IRM Inc. and West Biofuels LLC	Victoria, BC	http://www.pivotalirm.com/
Redwave	Team led by Redwave, a division of BT-Wolfgang Binder GmbH (Austria), Canadian agent is HBHE Consulting. Anaerobic Digestion (AD) technology provider is Eisenmann.	Gleisdorf, Austria HBHE Consulting located in Duncan, BC	http://redwave.com/en/
Veolia	Veolia Water Technologies Canada Inc.	Saint-Laurent, QC	http://www.veoliawatertechnologies.ca/en/
Walker	Walker Environmental Group, Net Zero Waste	Thorold, ON	http://www.walkerind.com/walker-environmental-group/
Waste Treatment Technologies	Team consisting of Waste Treatment Technologies BV 21(1) [redacted]	Netherlands	http:/www.wtt.nl/

The initial review and assessment of these submissions indicates that:

1. Overall there was a good response to the RFEOI. A reasonable number of submissions were made. Submissions were generally complete and addressed the specific information that was requested.
2. The majority of the respondents are represented in Canada and/or have team members in Canada. This should be helpful during future procurement stages.
3. The majority of respondents proposed approaches are capable of integrated resource management to varying degrees including most if not all of the identified CRD solid and liquid waste streams.
4. All of the respondents indicated that their technology was capable of managing the biosolids stream identified in the RFEOI although in some cases there was a lack of clarity as to how exactly it would be managed. In some cases the submissions indicated that they could manage biosolids or sewage sludge.

5. The diverse feedstock sources tend to attract different treatment technologies. Respondents generally focused on organic processes (aerobic/anaerobic) to process organic wastes (biosolids, food waste, yard/garden wastes, the organic fraction recovered from mixed solid waste) and mechanical/thermal processes (RDF, gasification) for mixed waste sources.
6. Reference projects of singular technologies tended to be relevant in terms of similar feedstock, while reference projects from multi-technology proposals tended to reflect only individual component technologies and not the combined systems, as proposed.
7. The majority of respondents prefer that the CRD provide the site for the IRM facility. Many prefer that the CRD owns the IRM facility.
8. The type of business offerings in the submissions were quite varied. Many respondents are open to a variety of development models (DB, DBOM, DBOOT, etc.).
9. The majority of respondents reported their technology as being proven (operating at a commercial level) and do not recommend that the CRD undertake a pilot project. Those respondents that did not put forward a proven technology, were more interested in, or recommended that the CRD undertake a pilot.

Following the initial review, there were a number of items that required clarification for each submission. Letters were developed and issued to all respondents, seeking additional clarification of the submissions. The letters, responses and additional information provided by the Respondents is provided in Appendix A.

The detailed analysis provided in the following sections reflects the RFEOI submissions and additional information, providing more detail regarding the responses and their applicability in the CRD as part of an IRM solution.

6 Detailed Analysis of Responses

The following sections provided a detailed analysis of the responses from proponents for each category of the RFEOI.

6.1 Processing Technologies

Table 6-1 provides an overview of the proposed processing technologies from each respondent, for each material stream which was indicated in their submission as being an acceptable feedstock for their processing approach.

Table 6-1: Overview of Proposed Technologies Per Solid or Liquid Waste Stream

Corporate/Team Name	Biosolids (and/or Sewage Sludge)	Municipal Solid Waste (MSW)	Source Separated Organics (SSO)	Leaf and Yard Waste (LYW)	Controlled Waste
Anaergia	Blend Class A Biosolids into compost or digesting biosolids by anaerobic digestion. Can process sewage sludge and generate Class A biosolids in combination with organics extracted from MSW or SSO.	Mechanical Pre-processing (OREX press), wet Organic Fraction to CleanREX and then high-solids Anaerobic Digestion (AD), dry fraction directed to RDF Generation, RDF to solid Fuel applications (e.g. Cement Kiln)	Mechanical Pre-processing (Bio-OREX press), wet Organic Fraction to CleanREX and then high-solids Anaerobic Digestion (AD)	NA	Mechanical Pre-processing (Bio-OREX press), wet Organic Fraction to CleanREX and then high-solids Anaerobic Digestion (AD)
APD	Dewatered Sewage Sludge blended with other carbon sources, blend directed to ARK Reformer (electro-thermo-chemical reaction)	NA	Used as other carbon source to blend with dewatered sewage sludge, blend directed to ARK Reformer (electro-thermo-chemical reaction)	Used as other carbon source to blend with dewatered sewage sludge, blend directed to ARK Reformer (electro-thermo-chemical reaction)	NA
ECS	Blend Biosolids 50/50 with bulking agent (wood chips), direct to in-vessel and aerated pile composting	Clarified that they do not recommend composting MSW with their technology unless the CRD is interested in use of the material as alternative daily cover.	Preprocessing, direct to in-vessel and aerated pile composting	Preprocessing, direct to in-vessel and aerated pile composting	NA
ICC Group	Blend Biosolids with LYW and SSO, dry materials and process into fuel briquettes for gasification	Pre-processed to remove inerts and PVC, converted to RDF fuel briquettes for gasification	Blend Biosolids with LYW and SSO, dry materials and process into fuel briquettes for gasification	Blend Biosolids with LYW and SSO, dry materials and process into fuel briquettes for gasification	NA, controlled waste directed to landfill
Ostara	Nutrient Recovery from Biosolids dewatering liquor stream	NA	NA	NA	NA

Corporate/Team Name	Biosolids (and/or Sewage Sludge)	Municipal Solid Waste (MSW)	Source Separated Organics (SSO)	Leaf and Yard Waste (LYW)	Controlled Waste
Pivotal	21(1) [redacted]				
Redwave	Pre-treatment, followed by AD, in-vessel composting and generation of compost (depending on metals/impurities in the material). Applicable to Biosolids or Sewage Sludge.	Mechanical pre-treatment to recover recyclables, biodrying of residual, residual mechanically processed to generate RDF	Pre-treatment, followed by AD, in-vessel composting and generation of compost. LYW used as bulking material for composting.		Mechanical pre-treatment to recover recyclables, biodrying of residual, residual mechanically processed to generate RDF
Veolia	Dedicated Biosolids Train, Wet AD followed by hydro-thermal oxidation of remaining sludge. Indicates system is suitable for all types of thickened sludge.	Mechanical pre-treatment to recover recyclables, dry or batch AD, followed by composting	Dry or batch AD, followed by composting	Composting	Composting
Walker	Blend with residuals/treated painted wood. Biodrying, followed by composting and generation of alternative daily cover. Indicates system is suitable for biosolids and sludge.	Mechanical preprocessing including recovery of recyclables, shredding of inorganic residuals to optimize landfilling, AD of organic fraction, blend digestate with LYW and wood for composting.		Blend with digestate from AD for composting	Processing approach is unclear
Waste Treatment Technologies	Processed separately with organic material (SSO and LYW)	Mechanical preprocessing including recovery of recyclables, organic fraction directed to AD and/or composting, residuals directed to Solid Recovered Fuels (SRF)	Dry or wet AD and/or composting	Dry or wet AD and/or composting	Processing approach is unclear

Table 6-2 below, provides a more detailed overview of the specific processing technologies identified by each respondent.

Table 6-2: Description of Processing Technologies

Corporate/Team Name	Processing Technology
Anaergia	The focus of the Anaergia submission is their mechanical pre-processing technologies used to separate the 'wet fraction' consisting largely of organics from the 'dry faction' (paper fibre, plastics etc.) of mixed material streams. The OREX press separates the wet from the dry fraction from MSW streams. While not discussed in the submission, observations of operating facilities indicate that recyclables can be recovered from the dry stream, which can be further processed to generate refuse derived fuel (RDF) should there be a market for this material. The BioREX press is designed to separate the wet organics stream from material streams with lower levels of contamination such as SSO. The wet organic fraction would then be cleaned through a second pre-processing stage using the CleanREX technology to remove light (plastic film) and heavy (glass, grit) inorganic contaminants, and to produce a mixture suitable for high-solids anaerobic digestion (AD). The Anaergia processing train could include an array of technologies, which can be used to process sewage sludge, producing Class A Biosolids, blended biosolids/compost, or a pyro-oil and biochar through pyrolysis. Applicability in the CRD: There are 13 facilities using varying capacities (sizes) of Anaergia' s OREX and/or BioREX units for processing MSW or SSO. In some cases, this technology was retrofitted to improve the operations of an existing facility. While the submission does not offer a complete IRM solution it does identify component technologies that could be applicable to the CRD particularly for recovery and AD of organics.
APD	The primary technology identified is the ARK Reformer which uses an electro-thermo-chemical reaction to transform carbon-based waste materials (50 to 60% moisture content) into liquid hydrocarbons and synthesis gas. The system includes a feedstock preparation and mixing process used to develop a homogenous feedstock with a particle size of 3 cm or less, and systems to separate/process the recovered synthetic oil and gas streams. The system also generates an ash stream that the respondent indicates is suitable for use as a fertilizer. Feedstock preparation involves mechanical breakdown of the material to particulate of 3 cm or less with commercial grinders or shredders. The system operates best with feedstock of approx. 50% moisture content resulting in a need to remove or add water as appropriate. The submission notes that materials that are either non-conductive (glass) or highly conductive (metals) will not react in the ARK Reformer and will end up in the ash. They can be sifted out from the ash or removed through pre-sorting. Feedstock is introduced to the ARK Reformer 'reaction chamber' via an airlock at the top of the chamber, the process is initiated inside the chamber by heating the feedstock through a propane burner which heats the incoming material to 65 degrees Celsius to initiate the process which is self-sustaining thereafter. Within the low pressure, low temperature chamber, electro-chemical reactions take place resulting in generation of a liquid/gas fraction that rises to the top of the reaction chamber and a heavier ash fraction that falls to the bottom. The liquid/gas fraction flows through a series of separation tanks to separate the gas and liquids. The liquids are then processed to separate the oil and water fractions. The submission indicates that water is recirculated, however, if the incoming feedstock has high water content, it is possible that a wastewater stream would be produced. Applicability in the CRD: There is currently only one operating ARK Reformer, using chicken litter as feedstock. The respondent has indicated that a pilot based on using CRD-like materials would be appropriate. It is unclear if the technology would be suitable for processing Class A Biosolids which has lower energy content than sewage sludge.

Corporate/Team Name	Processing Technology
ECS	The primary technology provided by ECS is an in-vessel and aerated pile composting system. Typically the acceptable feedstock materials for composting include green waste, yard waste food waste and biosolids. The ECS submission also listed MSW as an acceptable feedstock however, ECS clarified they are not envisioning processing (or composting) MSW. Aerated composing involves the use of employing air flows into a compost pile to maintain high quantities air in the material to ensure that the system remains aerobic without physical manipulation during primary composting. The forced aeration can be either positive: blowing air up through the material, or negative: drawing air down into the material. Forced aeration systems can be comprised of windrows, piles, bunkers or in-vessel systems, and can range in size depending on site configuration and equipment. The aerated static pile (ASP) process is a type of forced aeration. The blended feedstock mixture is usually placed over an air conveyance system that provides air circulation for controlled aeration. The piles can be either covered or non-covered/open. Forced aeration systems have historically been used to compost biosolids, but are also being used for other odorous feedstock like food waste. This technology is also well suited for processing large amounts of material. However, proper management of the material and process air is still needed in order to prevent pockets of anaerobic activity. As in open windrow methods, process control parameters include carbon to nitrogen ratio, pile size, temperature, moisture content and porosity. Applicability in the CRD: There are numerous ASP composting systems in the US and Canada. ECS lists five reference facilities that use their system processing similar types of organic materials. They also list six facilities where they have provided services ranging from permitting, design, construction support and operations support.
ICC Group	MSW would be pre-processed to remove recyclables (metals, glass and PVC) and then shredded into a Refuse Derived Fuel (RDF) which would then be combined with a dried biosolids/LYW/SSO blend and briquetted to produce a high energy, consistent material for gasification. The briquettes are gasified to produce a syngas which is used in a steam cycle to produce electricity. Solids (ash) from the gasification process can be blended with flue solids and made into a light-weight concrete or alternatively could be combined with residues from MSW processing (e.g. glass) and used to produce mineral wool. ICC proposes to use landfill gas to fire a rotary drying drum to decrease the moisture content of the blended biosolids, SSO and LYW stream prior to briquetting. Alternatively, the system could be used to dry and blend dewatered sewage sludge into the RDF. ICC also notes an option to direct landfill gas to a system capable of processing the gas to generate diesel fuel and wax. Applicability in the CRD: The ICC Group offers two references where specific components of their system are operational: 1. The Dry AD process in 21(1) [redacted] and 2. The Village Farm composting project in Delta BC. The ICC Group does not offer references where the RDF, briquetting, gasification and light weight concrete systems are in operation.

Corporate/Team Name	Processing Technology
Ostara	The primary technology provided by Ostara is a nutrient recovery process using a precipitating technology to produce a fertilizer from post digestion of biosolids. Although the digestion process converts the volatile solids portion of the biosolids to a gas, the nutrients contained in the biosolids remain in the discharge. Consequently, nutrient recovery from biosolids consisting of the recovery of phosphorus from post-digestion liquor resulting from dewatering biosolids, through a controlled precipitation of struvite is one way to chemically harvest the nutrients from biosolids. Phosphorous recovery from post-digestion liquor is a chemical precipitation process that recovers nutrients (phosphorus and nitrogen) from CRD's dewatering liquor stream before they accumulate as struvite in pipes and on equipment. Struvite is a crystalline formation of minerals that occurs in alkaline conditions which is common in post digestion liquor (biosolids that have been digested). Phosphorous recovery is a controlled chemical precipitation process that facilitates the generation and growth of struvite "seeds" (crystalline pellets). This process occurs in an up-flow container that keeps the struvite seeds in suspension until they accumulate mineral crystals to a desired size for commercial fertilizer markets. The crystals are allowed to settle, extracted and dried for commercial horticulture and agriculture markets. Applicability in the CRD: The Ostara process focuses on processing the liquor from post-digestion biosolids. Ostara provides fourteen (14) operating reference facilities including some in North America, all of which were installed after 2009. This technology could provide an additional contribution to an IRM system.
Pivotal	21(1) [redacted]

Corporate/Team Name	Processing Technology
Redwave	The primary technology provided by Redwave is a Mechanical Biological Treatment (MBT) process for the MSW stream. MBT is a broad term that refers to multiple sub-processes including pre-treatment, biodrying, recyclables recovery, recovery of solid recovered fuel (SRF), end of line anaerobic digestion (AD) followed by aerobic composting of the digestate. Each sub-process can be customized to the specifics of the feedstock. The equipment for each sub-process is based on a series of conventional equipment installations similar to those used in operating MBT plants elsewhere in the world. Pre-digested sludge or Class A biosolids would be directed to AD or to RDF production depending on trace metals/impurity content. SSO would be directed to AD followed by composting, LYW would be used as a bulking material for the composting process. Mechanical Biological Treatment (MBT) is a variation on composting and materials recovery that incorporates a two-stage process of mechanical and biological treatments. During the mechanical stage the entire feedstock is sorted to remove recyclables and contaminants and then shredding or grinding takes place for size reduction of the materials prior to the biological stage. The biological stage includes a digestion step in an enclosed vessel which produces a bio-gas that is used to produce energy in addition to heat to dry the feedstock thereby making it ready for processing into a refuse-derived fuel (RDF) product or SRF as described below. If no fuel markets are available, the product could be further composted to render the material inert for landfilling. This technology is designed to process a fully mixed MSW stream and can handle the CRD waste stream. Materials usually derived from the process include marketable metals, glass, and other recyclables. Limited composting is used to break the MSW down and dry the fuel. The order of mechanical separating, shredding, and composting can vary. It is an effective waste-management method and can be built in various sizes. The RDF produced by an MBT process is intended to be converted into energy in some way: fired directly in a boiler; converted to energy via some thermal process (e.g., combustion, gasification, etc.); or selling it to a third party (e.g. Cement Kiln). Consequently, similar to RDF, the MBT process produces a fuel product that depends on the sale of the product for economic viability. The high-solids AD component used to process organic materials including biosolids, could be operated under mesophilic or thermophilic conditions, processing feedstock in the range of 25% solids. Moisture is added or removed to keep feed in the range of 24 to 28% solids, to keep it mixable and pumpable. Presorting process is required to remove inorganic contaminants as well as post-composting refining to generate a marketable compost product. Applicability in the CRD: Redwave offers a range of technologies currently in operation in other jurisdictions including proposed and operating MBT facilities, processing materials similar to those identified by CRD.

<table>
<tr><th>Corporate/Team Name</th><th>Processing Technology</th></tr>
<tr><td>Veolia</td><td> The primary technologies Veolia propose include a wet anaerobic digestion process for the biosolids (wet material), a mechanical biological treatment (MBT) process that combines mechanical pre-processing with a dry AD system for MSW and SSO and a composting technology for yard and controlled wastes.
Veolia offers a series of dedicated lines for each of the feedstock sources: biosolids train (35,000 tpy) using wet mesophilic Anaerobic Digestion (AD) technology followed by hydro-thermal oxidation (Athos system) to reduce the remaining sludge to an inert sand-like substance. A separate MSW/SSO processing train (158,000 to 185,500 tpy) using mechanical and biological treatment (MBT) and dry or batch AD followed by aerobic composting.
The Anaerobic Digestion process occurs when organic matter is decomposed using bacteria in the absence of oxygen. By consuming the organic materials, the bacteria produce a biogas (primarily methane and carbon dioxide). Veolia offers a wet (low solids) Anaerobic Digestion system for the more liquid wastes and a separate dry (high solids) AD system for the organic fraction of MSW and Source Separated Organics. The latter, dry AD system is a part of a Mechanical Biological Treatment (MBT) as described above and consists of a variation on composting and materials recovery that incorporates a two-stage process of mechanical and biological treatments. During the mechanical stage the entire feedstock is sorted to remove recyclables and contaminants and then shredding or grinding takes place for size reduction of the materials prior to the biological stage. The biological stage includes a digestion step in an enclosed vessel which produces a bio-gas that is used to produce energy. Veolia anticipates landfilling the residue materials from the mechanical process.
Veolia also offers the Athos™ process which consists of a hydro-thermal oxidation reaction followed by a mineralization process to produce a mineral-based inter solid referred to as Technosand; a non-leaching, inert material that can be used in concrete manufacturing. Veolia also offers a phosphorous recovery process for liquid produced through dewatering, described in more detail in the section describing the Ostara technology which is similar.
Applicability in the CRD: Veolia offers nineteen (19) references indicating how a variety of feedstock sources (substrates) are processed using a variety of technologies (six listed) and producing the specified outputs (five types). The Veolia approach offers a full integrated solution for the CRD solid and liquid material streams. Veolia identifies extensive operating experience in creating value from biosolids/sludge streams. </td></tr>
</table>

Corporate/Team Name	Processing Technology
Walker	The primary technologies Walker proposes include: 1. Mechanical preprocessing of MSW and/or SSO to produce an organic fraction for digestion, recyclable product for sale and residual material for landfilling; 2. Anaerobic digestion (AD) of the organic fraction and controlled wastes (fats, oils and grease (FOG) and selected organic ICI wastes); 3. Covered aerated static pile composting (Gore®) of digestate solids, yard and garden wastes; 4. Bio-drying of biosolids and blending of dried biosolids into a suitable landfill cover material. As discussed in the Redwave text above, Mechanical Biological Treatment (MBT) is a variation on composting and materials recovery that incorporates a two-stage process of mechanical and biological treatments. During the mechanical stage the entire feedstock is sorted to remove recyclables and contaminants and then shredding or grinding takes place for size reduction of the materials prior to the biological stage. The biological stage includes a digestion step in an enclosed vessel which produces a bio-gas that is used to produce energy. Walker anticipates landfilling the residue materials from the mechanical process. Walker offers a wet AD process to treat organics in a liquid form. The AD process is designed to accept food wastes, fat oils and grease (FOG), and organics from the MBT process. Digestate from the AD process will be blended with wood and yard wastes and placed into a covered ASP composting process. Other materials blended into the compost include biosolids, sludge, residuals from the MBT system and woody materials. Walker offers an aerated static pile (ASP) process with a patented cover system by GORE®. The system uses a forced aeration process that provides air circulation for controlled aeration. Applicability in the CRD: Walker offers one AD reference (Delta BC), and three GORE® cover compost systems in operation (Abbotsford BC, Whistler BC and Thorold ON). There are no reference facilities for the MBT processes. There are no references provided for the bio-drying process although the process is a relatively common practice in the waste water industry.

Corporate/Team Name	Processing Technology
Waste Treatment Technologies	The primary technologies WTT offers includes the Mechanical Biological Treatment (MBT) process including recyclables recovery, end of line organic processing (anaerobic and/or aerobic) and Solid Recovered Fuel (SRF) production. The proposed equipment to recover recyclables and generate SRF is a series of conventional equipment installations similar to those used in operating MBT plants elsewhere. Organic material processing options include: dry AD followed by composting; wet AD followed by composting; and composting alone. Propose selection of technology based on approach that best meets CRD's needs. Compost refining process is applied to remove inorganic contaminants and generate marketable product. As discussed in the Redwave text above, Mechanical Biological Treatment (MBT) is a variation on composting and materials recovery that incorporates a two-stage process of mechanical and biological treatments. During the mechanical stage the entire feedstock is sorted to remove recyclables and contaminants and then shredding or grinding takes place for size reduction of the materials prior to the biological stage. The biological stage includes a digestion step in an enclosed vessel which produces a bio-gas that is used to produce energy in addition to heat to dry the feedstock thereby making it ready for processing into a refuse-derived fuel (RDF) product or SRF as described below. If no fuel markets are available, the product could be further composted to render the material inert for landfilling. Applicability in the CRD: WTT provides seven reference facilities identified, including: • Dry AD facility in Alytus Lithuania processing 21,000 tpy of MSW • MBT facility in Cambridgeshire, UK processing 170,000 tpy of MSW. • MBT facility in Kaunas, Lithuania processing 220,000 tpy of MSW. • MBT facility in Leeds, UK processing 214,000 tpy of MSW. • Composting facility in Mondragon, France processing 33,000 tpy of sewage sludge. • MBT facility in Southwark, London UK processing 87,500 tpy of MSW. • Dry AD facility in Surrey BC, processing 115,000 tpy of organics material. The list does not appear to include the production and use of RDF, however, the remainder of the processes appear to be included in the WTT submittal.

6.2 Inputs

The majority (6/10) respondents indicated that all of the solid and liquid waste streams identified by the CRD as potential feedstock for an IRM solution, could be processed by their proposed technologies. Some materials would enter the processing stream at different points depending on the technologies being proposed, for instance, in some cases biosolids would be processed along with organic material and in others it was proposed to be processed entirely separately.

Some processes would require additional feedstock including process chemicals, bulking agent (woody biomass) for composting, supplemental fuel sources (wood chips) for thermal processes. In the most part, it is not possible to quantify additional input material requirements and potential cost implications at this time. This would be an item that would be addressed in future procurement stages of the IRM project plan.

Table 6-3: Description of Acceptable Feedstock

Corporate/Team Name	Biosolids	Sewage Sludge	MSW	SSO	LYW	Controlled Waste	Inputs (acceptable feedstock composition and quantity)
Anaergia	✓	✓	✓	✓		✓	Accepted quantities would vary to suit CRD needs. Offers a range of solutions for biosolids or sewage sludge.
APD		✓		✓	✓		Dewatered Sludge mixed with carbon sources such as wood, paper products, source separated organics, yard waste.
ECS	✓			✓	✓		Biosolids, SSO, yard waste.
ICC Group	✓	✓	✓	✓	✓	✓	All solid and liquid waste streams and quantities as identified by the CRD could be accepted including 35,000 tpy biosolids, 18,000 tpy yard/garden waste, 20,000 tpy SSO, 135,000 tpy MSW and 12,500 tpy controlled waste (direct to landfill) annually. Could accept dewatered sewage sludge.
Ostara	✓						Post-digestion liquor from dewatered biosolids. Additional inputs include magnesium and sodium hydroxide for the phosphorus recovery process.
Pivotal	21(1) [redacted]						
Redwave	✓	✓	✓	✓	✓	✓	All solid and liquid waste streams and quantities as identified by the CRD could be accepted. Exact quantities not identified. Indicate economy of scale for MBT with input of approx. 50,000 tpy and AD/Compost component inputs of 20,000 tpy SSO, 18,000 tpy LYW, 12,000 tpy of Controlled waste and 35,000 tpy of dewatered biosolids. Biosolids (and/or sewage sludge) would be directed to the AD and composting components of the system or to RDF processes, depending on trace metals content. LYW is required as a bulking material for the aerobic composting process.
Veolia	✓	✓	✓	✓	✓	✓	Proposed processing sub-systems capable of handling all CRD solid and liquid waste streams including 35,000 tpy biosolids, 18,000 tpy yard/garden waste, 20,000 tpy SSO, 135,000 tpy MSW and 12,500 tpy controlled waste. Separate processing train for biosolids. Submission indicates technology is suitable for all types of thickened sludge (primary, biological, mixed or digested).

Corporate/Team Name	Biosolids	Sewage Sludge	MSW	SSO	LYW	Controlled Waste	Inputs (acceptable feedstock composition and quantity)
Walker	✓		✓	✓	✓	✓	8,000 to 12,500 tpy controlled waste, 20,000 tpy yard and garden wastes, 120,000 to 135,000 tpy MSW, SSO (no quantity stated), biosolids (no quantity stated). Additional feedstock noted included: ICI & liquid food waste, Agricultural waste, FOG, wood, sludge, treated painted wood.
Waste Treatment Technologies	✓		✓	✓	✓	✓	All solid and liquid waste streams identified by CRD including 35,000 tpy biosolids, 18,000 tpy yard/garden waste, 20,000 tpy SSO, 135,000 tpy MSW and 12,500 tpy controlled waste. Propose to process biosolids separately in the organic material processing portion of the facility. Additional wood chip materials may be required to blend with outputs from AD for the aerobic composting process.

6.3 Capacity/Scalability

All respondents indicated that their proposed technologies are capable of being scaled to a capacity to meet CRD's needs and the majority can be scaled up or down as required, within reason. Some processing facilities can be designed to match CRD's processing requirements with a set capacity and others are more modular in nature and can be scaled up or down to meet CRDs needs by adding or removing modules.

It appears that the processing technologies identified by the respondents would be able to manage the tonnes of each material type identified by CRD in the RFEOI. In most cases, the technologies appear to be capable of being scaled down, should less material be available from the CRD.

Table 6-4: Capacity and Scalability of Technology

Corporate/Team Name	Capacity / Scalability
Anaergia	Anaergia states the pre-processing/AD systems are scalable from 20,000 tpy to 100,000 tpy.
APD	APD states that their reformer capacity is 12 tpd (approx. 4,400 tpy). Facility is scalable by adding additional units, and sizing the feedstock receiving and pre-processing area. Indicates that for processing CRD biosolids, SSO and LYW a 20-unit facility would be required.
ECS	ECS states the ASP composting systems are scalable to process 5,000 to 50,000 tpy of yard/green, food waste, biosolids or similar forms of organics.
ICC Group	ICC Group states that all of the technologies identified are modular and additional modules can be added or subtracted when needed. From general knowledge of the industry, each of the components can be scaled up/down within reason.

Corporate/Team Name	Capacity / Scalability
Ostara	Indicates a single Pearl 2K reactor would be suitable to process the dewatering liquor, recovering up to 252 kg of PO_4-P per day. Ostara states their phosphorus recovery system is scalable to recover from 65 kg/day to 1,260 kg/day of PO_4-P.
Pivotal	21(1) [redacted]
Redwave	Redwave indicates minimum capacity for MBT of 50,000 tpy in order to achieve some economies of scale. Range of AD/composting capacity from 8,000 to 80,000 tpy identified with submittal indicating that all CRD organic streams could be accepted. Equipment proposed is modular and can be scaled up or down to meet capacity needs.
Veolia	The submission indicates a dedicated biosolids train for 35,000 tpy (20% solids) and a MSW/SSO/LYW train for 158,000 to 185,500 tpy. The technologies proposed are generally scalable, and reference facility size varied from 20,000 to 195,000 tpy. Veolia indicates that scaling of the biosolids processing train can be accomplished through overdesign, and for the MSW/SSO/LYW train through extending operating hours. A phased approach could be used to allow incremental capacity increases.
Walker	Walker did not identify overall facility capacity assumptions. Noted in order to provide an IRM solution provisions would have to be made to accommodate the 35,000 tpy of dewatered biosolids, 20,000 tpy of LYW and some of the 120,000 to 135,000 tpy of MSW. From general knowledge the individual components of their proposed approach are scalable.
Waste Treatment Technologies	Proposed capacity to address all CRD material streams including 135,000 tpy of MSW, 18,000 tpy of LYW and 20,000 tpy of SSO. Equipment proposed is modular and can be scaled up or down to meet capacity needs.

6.4 Site Size and Siting Requirements

The majority (7/10) of respondents did not indicate site size requirements in their initial submission. Site size requirements would depend on the feedstock being processed (number of streams and technology utilized), therefore it is difficult to compare site size requirements amongst respondents. In general, facilities utilizing composting require more land than AD facilities as composting technologies generally require a larger footprint. Clarification was sought from the majority of respondents in the questionnaires to supplement the initial information provided regarding site size, in order to undertake an initial assessment of the viability of the proposed location for the IRM facility at the Hartland landfill.

Table 6-5: Processing Technology Site Size Requirements

Corporate/Team Name	Site Size Requirements	Siting Requirements
Anaergia	For full installation including access roads etc. 3.2 to 4 ha.	Typical utilities (electrical, natural gas, water). Market approach for biogas unclear, as is requirement for electrical grid connection for sale of power or connection to the gas grid for sale of pipeline quality natural gas or other requirements for sale of recovered energy.
APD	Not provided for full scale development. Minimum of 1 hectare for pilot facility.	Typical utilities (electrical, natural gas, water). Market approach for syngas is unclear. Could require electrical grid connection for the sale of power.
ECS	Site size would vary per feedstock quantity and the technologies used, which individually vary from 2.2 ha to 7.7 ha and collectively equates to 14 ha.	Typical utilities (electrical, natural gas, water).
ICC Group	Total site area for all technologies, outdoor storage, yard, roads, scale and other utilities of approx. 4 ha.	Typical utilities (electrical, natural gas, water). Power generation (maximum electrical power export of 12.5 MW) requires electrical grid connection.
Ostara	Approx. 250 square meters (0.025 ha).	Typical utilities (electrical, natural gas).
Pivotal	21(1) [redacted]	
Redwave	10,000 m^2 (1 ha) for the MBT facility and 20,000 m^2 (2 ha) for the AD plant.	Typical utilities (electrical, natural gas, water). Energy generation from the AD plant requires electrical grid connection and possibly gas pipeline connection.
Veolia	0.3 ha required for Biosolids Processing component. 4.5 to 6 ha required for the full solid waste proven technologies train for capacity from 158,000t o 185,000 tpy	Typical utilities (electrical, natural gas, water). Biogas generated would be directed to CHP or RNG. Could require electrical grid connection or gas pipeline connection.
Walker	Not stated.	Typical utilities (electrical, natural gas, water). Energy generation from the AD plant requires electrical grid connection and possibly gas pipeline connection.

Corporate/Team Name	Site Size Requirements	Siting Requirements
Waste Treatment Technologies	The potential size of site for mechanical separation and of 135,000 tpy MSW and composting of 20,000 tpy SSO, 18,000 tpy Leaf & Yard waste, the organic fraction from MSW and 35.000 tpy biosolids will be approx. 1.8 ha. The potential size of site for mechanical separation and of 135,000 tpy MSW, anaerobic digestion of 20,000 tpy SSO and the organic fraction from MSW and composting of the digestate, 18,000 tpy Leaf & Yard waste, and 35.000 tpy biosolids* will be approx. 2.2 ha. * If also the anaerobic digestion of the liquid biosolids is required an additional wet AD tank of app. 3,000 cubic meters is needed. The additional needed space for tank and auxiliary equipment will be less than 0.2 ha.	Typical utilities (electrical, natural gas, water). Energy generation from AD requires electrical grid connection and possibly gas pipeline connection.

In general, the information provided by the respondents indicates that the potential location for the IRM facility at the Hartland Landfill site as identified in the RFEOI, of approximately 2.17 ha, is likely inadequate for a full IRM solution managing all of the CRD liquid and solid waste streams.

Respondents indicated very clearly that provision of a site by the CRD was preferred, which is not unexpected given the difficulties often associated with siting similar processing facilities. Further effort will be required to identify the area of land that the CRD could make available at the Hartland Landfill, for example determining if some or all of the area indicated for future aggregate stockpiles, could be made available for the IRM facility. Details regarding the available site will be required to support future procurement phases of the IRM Project Plan.

The requirements for utilities to support operations, would be no different from the requirements for the adjacent RTF facility at the Hartland site, and could be potentially be addressed concurrently with the RTF site development.

Further investigations are required to assess the available electrical grid and/or gas pipeline connections that would be required to market energy products generated by AD and/or thermal processing identified by respondents. Alternative CNG use for vehicle fuel, would require development of CNG infrastructure.

6.5 Environmental Implications

The majority of respondents provided information regarding how various emissions from their technologies would be addressed, as well as some discussion or acknowledgement of greenhouse gas emission implications. It should be noted that the respondents were requested to provide general information regarding the environmental implications for the application of their technology, and were not requested to provide specific tests results or evidence regarding the fate of all emissions or contaminants in the CRD solid or liquid waste stream based on the application of their technology. This would be addressed in any subsequent competitive procurement process that may be undertaken by the CRD.

Table 6-6 identifies the direct environmental implications associated with the technologies, indicating how emissions to air, noise and water would be addressed. It also identifies the potential indirect environmental implications associated with the technologies related to GHG, based on the application of standard GHG analysis tools such as the US EPA WARM model as well as information provided by respondents. In addition, given that a primary focus of the IRM is the beneficial reuse of biosolids, the potential fate of trace contaminants and pathogens in the biosolids is noted, based on the technologies proposed and/or biosolids research.

Overall, the respondents identified a reasonable range of approaches to address the potential for direct effects to the environment in response to the RFEOI. Additional information would be requested in response to any future IRM procurement process.

Information in the RFEOI submissions coupled with knowledge of existing GHG models and research indicate potential for GHG emission reduction in many cases, particularly for systems including biological (composting, AD) processes. The approaches noted also offer potential to address concerns regarding the effects of biosolids management on the environment.

Table 6-6: Environmental Implications

Corporate/Team Name	Direct Environmental Implications (emissions to air, noise, water)	Indirect Environmental Implications (GHG Emissions, Biosolids Management)
Anaergia	Control of air, odour and noise emissions through enclosing equipment in building equipped with air management system. Air treatment/odour removal via wet scrubbers. Other air emissions controlled through flares as required. Process water treatment required prior to disposal (including ammonia removal and/or biological treatment).	GHG emission reduction potential is assumed to be comparable with other AD technologies. In general GHG reductions for AD will be comparable to composting based on the WARM model. The result of other GHG models may differ. Composting has the capability to further reduce pathogens in biosolids[1]. Research indicates that biological treatment has potential to degrade trace organic contaminants in biosolids including emerging substances of concern, and can reduce bioavailability of heavy metals.[2] .

[1] US EPA, Biosolids Technology Fact Sheet, Use of Composting for Biosolids Management

[2] LRCS Land Resource Consulting Services, Prepared for the BCMOE, Literature Review of Risks Relevant to the use of Biosolids and Compost from Biosolids with Relevance to the Nicola Valley, BC

Corporate/Team Name	Direct Environmental Implications (emissions to air, noise, water)	Indirect Environmental Implications (GHG Emissions, Biosolids Management)
APD	Submission indicates that under normal operating conditions there are no emissions from the core technology as the reformation takes place within a sealed reaction chamber. Indicates that the technology is carbon negative and that no solid or liquid waste is generated. Unclear in regards to emissions from the process as a whole.	GHG emission reduction potential is assumed to be comparable with other thermal/gasification technologies. In general GHG from thermal processes are not reduced compared to landfilling when estimated using WARM due to how the WARM model treats carbon storage (sequestration) of biogenic carbon. If carbon storage in landfills is not considered, GHG reductions from thermal process will be less than composting/AD but greater than landfilling. The result of other GHG models may differ. Trace organic contaminants and pathogens in the biosolids stream would be consumed during thermal processing. Trace inorganic contaminants would be contained in solid residuals from the process.
ECS	ECS process technology is designed to capture and control air emissions including odour and create process conditions within the Best Management Practices of the US Composting Council guidelines. Operations must maintain BMP conditions in the pile and biofilter. Properly constructed and maintained biofilters can reduce VOC emissions by over 90%.	GHG emission reduction potential is assumed to be comparable with other biological/composting technologies. In general GHG reductions for AD will be comparable to composting based on the WARM model. The result of other GHG models may differ Composting has the capability to further reduce pathogens in biosolids[3]. Research indicates that biological treatment has potential to degrade trace organic contaminants in biosolids including emerging substances of concern, and can reduce bioavailability of heavy metals.[4] Approach/technology does not include management of MSW or controlled waste.

[3] US EPA, Biosolids Technology Fact Sheet, Use of Composting for Biosolids Management

[4] LRCS Land Resource Consulting Services, Prepared for the BCMOE, Literature Review of Risks Relevant to the use of Biosolids and Compost from Biosolids with Relevance to the Nicola Valley, BC

Corporate/Team Name	Direct Environmental Implications (emissions to air, noise, water)	Indirect Environmental Implications (GHG Emissions, Biosolids Management)
ICC Group	Submission states the facility would provide a negative carbon footprint, reducing the CO_2 emissions by 25,684 tpy. Flue gas treatment system (multi-cyclone, baghouse, NOx reduction system) noted for air emissions control from the gasifier. Odour control provided by using air with higher odour content (from tip floor) as process air for the gasifier.	GHG emission reduction potential is assumed to be comparable with other thermal/gasification technologies. In general GHG from thermal processes are not reduced compared to landfilling when estimated using WARM due to how the WARM model treats carbon storage (sequestration) of biogenic carbon. If carbon storage in landfills is not considered, GHG reductions from thermal process will be less than composting/AD but greater than landfilling. The result of other GHG models may differ. Trace organic contaminants and pathogens in the biosolids stream would be consumed during gasification. Trace inorganic contaminants would be contained in solid residuals from the process.
Ostara	Respondent reports recovery of phosphorus through struvite precipitation is the most carbon-efficient means of phosphate and nitrogen based fertilizer production. No other environmental implications are provided. Crystal Green™ has been used as a made in BC solution for spawning stream enrichment, as it is a clean slow-release fertilizer.	GHG emission reduction from this type of process cannot be modeled by WARM. Ostara is currently undertaking GHG emission reduction analysis associated with use of locally produced fertilizer compared to imported materials using the Carnegie model. Have estimated GHG emission reductions in the order of 10 to 14 tonnes of CO2 per tonne of Crystal Green™ Approach/technology does not include management of Biosolids, MSW, green waste, food waste or controlled waste.
Pivotal	21(1) [redacted]	

Corporate/Team Name	Direct Environmental Implications (emissions to air, noise, water)	Indirect Environmental Implications (GHG Emissions, Biosolids Management)
Redwave	Air management systems include dust filters, scrubbers, biofilters and potentially other technologies to control air/odour emissions. Most process water would be re-used following treatment (MBR), excess would be sent to treatment. Plant would be indoors, minimizing noise emissions.	GHG emission reduction potential is assumed to be comparable with recovery of recyclables from the mechanical process and comparable with AD technologies for the AD process. In general GHG reductions for AD will be comparable to composting based on the WARM model. The result of other GHG models may differ. Composting has the capability to further reduce pathogens in biosolids[5]. Research indicates that biological treatment has potential to degrade trace organic contaminants in biosolids including emerging substances of concern, and can reduce bioavailability of heavy metals.[6]
Veolia	Submission indicates Athos stack gases are released to the atmosphere after treatment (clean gas emission), liquid fraction is processed. Overall mechanical processing, AD and composting system would be enclosed, however minimal details provided regarding air/noise/water emission control for overall system.	GHG emission reduction potential appears comparable with other AD and MBT technologies. In general GHG reductions for AD will be comparable to composting based on the WARM model. The result of other GHG models may differ. Composting has the capability to further reduce pathogens in biosolids[7]. Research indicates that biological treatment has potential to degrade trace organic contaminants in biosolids including emerging substances of concern, and can reduce bioavailability of heavy metals.[8]

[5] US EPA, Biosolids Technology Fact Sheet, Use of Composting for Biosolids Management

[6] LRCS Land Resource Consulting Services, Prepared for the BCMOE, Literature Review of Risks Relevant to the use of Biosolids and Compost from Biosolids with Relevance to the Nicola Valley, BC

[7] US EPA, Biosolids Technology Fact Sheet, Use of Composting for Biosolids Management

[8] LRCS Land Resource Consulting Services, Prepared for the BCMOE, Literature Review of Risks Relevant to the use of Biosolids and Compost from Biosolids with Relevance to the Nicola Valley, BC

Corporate/Team Name	Direct Environmental Implications (emissions to air, noise, water)	Indirect Environmental Implications (GHG Emissions, Biosolids Management)
Walker	Indoor pre-processing and AD system includes air, noise, odour emissions control. Covered aerated windrow composting controls VOC and odour emissions through performance of Gore® cover and use of biofilters. Submission indicates that leachate and condensate would be collected and re-circulated as process water.	GHG emission reduction potential is assumed to be comparable with other biological composting and AD technologies. In general GHG reductions for AD will be comparable to composting based on the WARM model. Walker has supported or undertaken analysis of broader GHG emission reductions associated with their process. Composting has the capability to further reduce pathogens in biosolids[9]. Research indicates that biological treatment has potential to degrade trace organic contaminants in biosolids including emerging substances of concern, and can reduce bioavailability of heavy metals.[10]
Waste Treatment Technologies	Air management system with wet scrubber and biofiltration unit proposed to control air/odour emissions. Most process water would be re-used, excess would be sent to treatment. Plant would be indoors, minimizing noise emissions.	GHG emission reduction potential is assumed to be comparable with other AD technologies. In general GHG reductions for AD will be comparable to composting based on the WARM model. The result of other GHG models may differ. Trace organic contaminants and pathogens would be consumed during combustion of the biosolids compost in biomass boilers and/or cement kilns.

6.6 Products/Materials Recovered

Table 6-7 below, provides information regarding the range of products and materials that respondents indicated could be recovered through their technology (ies) for some form of beneficial use. Potential markets for these materials are noted, where respondents provided that information.

Overall, the submissions indicate that a number of products could be recovered and marketed and/or directed to beneficial use, from the CRD liquid and solid waste streams as indicated in the RFEOI.

The market value of these materials has yet to be determined, and is an important consideration in determining the overall cost of an IRM solution. Initial feedback through the RFEOI process indicates that additional research regarding markets and market risks would be appropriate as part of the development of the IRM Project Plan. The viability of

[9] US EPA, Biosolids Technology Fact Sheet, Use of Composting for Biosolids Management

[10] LRCS Land Resource Consulting Services, Prepared for the BCMOE, Literature Review of Risks Relevant to the use of Biosolids and Compost from Biosolids with Relevance to the Nicola Valley, BC

technologies that recover energy such as AD or gasification, may be contingent upon identifying a higher value market for that energy such as vehicle fuel.

In regards to other products, in some cases more limited markets were identified (e.g. cement kilns as an RDF market) while in others the respondents had identified potential for a broader market (Class A compost).

Table 6-7: Products and/or Materials Recovered

Corporate/Team Name	Products / Materials Recovered (including energy balance where applicable)
Anaergia	Products/energy balance depends on feedstock. The organic fraction of MSW and SSO could produce 1 MW of thermal energy per 10,000 tpy. Estimate processing 130,000 tpy of MSW will yield 23,600 tpy of putrescible organics, capable of producing biogas with a gross energy value of 2.36 MW on top of 1.5 to 2 MW from digestion of SSO. Information provided regarding reference projects (Dagenham England) includes performance metrics for AD indicating biogas recovery of 974Nm^3/ton of dry organic matter. Products include renewable energy (e.g. electricity, CHP, pipeline quality gas) from biogas. Solid materials recovered from the input feedstock prior to AD include recovery of recyclable materials (e.g. metals, HDPE, PET, Cardboard and possibly paper), potential recovery of RDF from the dry fraction and nutrient-rich products following AD of the wet organic fraction which range from compost to materials suitable for direct agricultural land application. Dewatered biosolids could be dried using a thermal dryer and sold as a soil amendment or further processed via low temperature pyrolysis. Should it not be possible to market RDF for thermal applications/gasification, a larger residual/reject fraction from the MSW stream would have to be disposed (approx. 110,000 tpy).
APD	Products derived from syngas output could include: electricity, synthetic crude oil, ethanol and methanol. Remnant ash potentially used for soil amendment/fertilizer (ARK SOIL) although the quality of this ash based on CRD feedstock is unclear.
ECS	Product is compost, the quality (grade) of compost is conditional based on level of contamination in the incoming feedstock. Pre-processing and product refinement processes were identified in order to remove contaminants and generate marketable product. Although not stated, this is an aerobic process so recovery of biogas/production of energy/fuel is not possible.
ICC Group	Products include recovered recyclables (metals, glass, PVC), Electrical power (maximum 12.5 MW to the grid, indicated for the quantity of CRD feedstock), diesel fuel and wax, light weight concrete blocks, mineral wool, CO_2 incentives. ICC notes that more than 95% of the marketable and non-combustible material in the MSW stream could be recovered for market. ICC notes that market research would be necessary for the North American market for a number of the potential products noted (e.g. mineral wool).
Ostara	Product is Crystal Green ™ fertilizer. This product is marketed for a variety of uses (salmon stream rehabilitation, agricultural fertilizer etc.). Ostara also noted potential for carbon credit revenues. Ostara would assume responsibility for the certification, management, storage and distribution of the produced fertilizer [redacted] share to the CRD under a fertilizer offtake agreement 21(1) [redacted]

Corporate/Team Name	Products / Materials Recovered (including energy balance where applicable)
Pivotal	21(1) [redacted]
Redwave	MBT process can recover 80% or more of recyclable metals in the MSW, 70% or more of recyclable plastics (HDPE, PET) and 30 to 50% of recyclable paper fibre. RDF/SRF can be produced from the remaining dry fraction of the MSW stream, depending on available markets. AD is expected to generate sufficient biogas to recover 13.4 to 18.2 million kWh per annum of power from the AD plant (based on processing 85,000 tpy of biowaste and biosolids combined). Finished high-quality compost and solid residues are generated by the in-vessel compost process. Details regarding the quality and market for finished compost was not discussed in the submission.
Veolia	Products from the biosolids treatment process include generation of heat and electricity from biogas or alternatively RNG, nutrient recovery (phosphorus recovery) and techno-sand. The techno-sand could be recycled into: expanded clay material, expanded schist, road and sewer building materials, agro-chemical uses or landfill cover. Nutrients would be marketed as fertilizer. Different qualities of compost could be produced in accordance with CAN 0413-200/2016 including Class AA (achievable with LYW), Class A (achievable with SSO) or Class B (achievable with MSW). The MSW/SSO train can recover recyclables, compost, refuse derived fuel (RDF) and biogas (suitable for CHP or upgrade to RNG). Submission indicates that either a compost that meets provincial standards could be produced or a biostabllized material could be generated.
Walker	Products from MSW pre-processing include recyclable materials (metals, plastic). Liquid fertilizer would be recovered from dewatering the AD digestate. Products generated from the co-composting of solid digestate with wood and LYW would be a marketable compost product meeting CCME unrestricted use standards. Energy products from the AD component, include renewable electrical power (from Biogas), heat, and potentially refined biogas to compressed natural gas.
Waste Treatment Technologies (WTT)	Recovers recyclables (paper fibre, ferrous and non-ferrous metals, PET, HDPE), Solid Recovered Fuel (similar to RDF) and two streams of compost, one with biosolids feedstock and the other with SSO, LYW and other organic feedstock. A compost refining process would be used to remove inorganic contaminants to meet OMRR standards. Market research undertaken by the respondent indicates that a market for high quality (Class A) compost meeting OMRR guidelines exists on Vancouver Island. WTT notes that a 'closed loop' approach may be of interest to the CRD wherein the focus would be on local use of compost products. Biosolids compost could be marketed as biomass for biomass boilers. Market research indicates the primary SRF market would be to cement kilns on the mainland. Potentially a range of energy products could be generated if AD is applied (power, heat, gas to grid or CNG applications). System would be a net energy user if no AD is applied. Would be a net energy generator with wet or dry AD. WTT notes that the power or biogas from AD is more expensive to produce than natural gas or current electricity produced in BC. A higher value market (e.g. CNG vehicle application) may be more appropriate.

6.7 Reference Facilities

Table 6-8 below, identifies the range of reference facilities identified by respondents and discusses the relevance of the identified reference facilities to the CRD. In the majority of cases, respondents were able to identify applicable reference facilities, processing similar material streams and at similar capacity to that required by the CRD in an IRM solution.

This indicates that there are a number of representative facilities from which data/information can be sourced in subsequent investigations and that would potentially be available for facility tours to allow for first hand observation of their operations. Members of the HDR team have visited a number of the listed facilities.

In some cases, there were few or no operating facilities utilizing the full suite of identified technologies at a single facility. In some cases these technologies were noted as being in operation at multiple different sites. In the case of all of the thermal technologies, there are operating facilities at some scale, but not currently processing the same material streams as those identified by the CRD. As discussed in Section 5.9, this is linked to the respondent recommendations regarding undertaking a pilot.

Table 6-8: Number, Type and Location of Reference Facilities

Corporate/Team Name	Number, Type and Location of Reference Facilities
Anaergia	• Kaiserslautern, Germany (85,000 tpy facility processing mixed MSW), extruding the dry fraction (which is transported as RDF to a different facility) and digests the wet faction using a vertical Dranco high solids digester. • Vereco, Latvia (50,000 tpy of mixed MSW) producing a wet fraction but it is unclear if further processing occurs on this site or elsewhere. The dry fraction is used a local cement kiln. • Degenham, England (50,000 tpy facility processing food waste), including a hammer mill pre-treatment system, two-stage AD process, biogas to electricity (CHP) with pasteurizers followed by in-vessel composting equipped with air scrubbers. Overall, 13 reference facilities listed. Feedstock varies from mixed MSW, bio-waste, food waste processing and biogreen material. In operation processing similar quantities of material and for a number of years.
APD	• Demonstration & testing pilot site, Arkansas. Operating since 2012, 3 tpd (approx. 1,000 tpy) of chicken litter and woody waste. Technology is currently in the demonstration/pilot phase and has not operated at the scale required for CRD, or with similar feedstock.
ECS	Five compost facilities were identified ranging in size from 30,000 to 110,000 tpy. Details were provided for two of the five reference facilities: • Lenz Enterprises, WA: 60,000 tpy, curbside and commercial food waste, yard waste, slaughter house paunch and manure. The facility includes odour control system to reduce VOCs. • Kelowna/Vernon, BC: a 120,000 tpy biosolids and yard waste facility with a robust odour control system. The facility produces USEPA Exceptional Quality Biosolids Compost. 29 other client facilities were also identified.

Corporate/Team Name	Number, Type and Location of Reference Facilities
ICC Group	None provided for the entire system. Individual component references include: • The ZWE dry fermentation AD facility in 21(1) [redacted] • Village Farm project in Delta, BC Other components are described as being sourced from well-known companies in the industry (Siemens steam power turbines, Machinex mechanized preprocessing systems).
Ostara	14 facilities listed, 3 in the EU, 2 in Canada and the remaining 9 in the U.S. All facilities are located at, or near existing waste water treatment plants (WWTP) and range in capacity from 30 to 4,450 ML/day (input dewatering liquor stream). All facilities are owned by the municipality/water board/ sewerage district, in which the waste water treatment facility is located. Some were greenfield and others were retrofit installations. Ostara provided client contact information for all noted facilities.
Pivotal	21(1) [redacted]
Redwave	• MBT facility in Westerwald, Germany processing 100,000 tpy of MSW since 2000 (includes MBT but not AD component) • MBT facility in Nuthe Spree, Germany processing 135,000 tpy of MSW and 15,000 tpy of bulky waste since 2006 • MBT plant at Ekokem facility in Riihimaki, Finland processing 100,000 tpy of MSW (in commissioning phase) • MBT at Lianyungang, China MSW Incineration site processing 274,000 tpy MSW (under construction) • AD Biomass Plant in Stausebach, Germany processing 30,000 tpy of source separated organics since 2014 Overall, over 50 facilities were identified around the world (including North America) wherein one or more components or aspects of the proposed facility have been or are being implemented. The range of reference facilities identified covers the range of proposed technologies (MBT and organics processing) and types of solid and liquid feedstock identified by the CRD including biosolids. Demonstrate large scale operation over the past 17 years.
Veolia	• Five WWTP facilities in Europe identified that have used the Athos process for 5 to 15 years. • Nineteen reference facilities primarily located in Europe, processing some materials similar to the CRD solid and liquid waste streams, using some of the proposed technologies were noted. Range of capacity from 20,000 to 195,000 tpy. The proposed technologies for both the biosolids and other streams have been used for five years or more, for similar materials.

Corporate/Team Name	Number, Type and Location of Reference Facilities
Walker	Four reference facilities identified: • Digester in Delta, BC processing 20,000 tpy of food waste and commercial organics with 20,000 tpy on-farm dairy waste. • Gore® composting facility in Abbotsford, BC processing 15,000 tpy of curbside SSO and commercial organics • Gore® composting facility in Pemberton / Whistler, BC processing 5,000 tpy of food waste from Whistler and Pemberton restaurants • Gore® composting facility in Thorold, ON, processing 35,000 tpy of SSO, 40,000 tpy of leaf and yard waste. Biodrying of biosolids was not noted for any of the reference facilities, however, Gore® is a known biosolids composting technology. None of the reference facilities appear to include the pre-processing components offered for the MSW stream, however the technologies noted are relatively conventional.
Waste Treatment Technologies	Seven reference facilities identified: • Dry AD facility in Alytus Lithuania processing 21,000 tpy of MSW. • MBT facility in Cambridgeshire, UK processing 170,000 tpy of MSW. • MBT facility in Kaunas, Lithuania processing 220,000 tpy of MSW. • MBT facility in Leeds, UK processing 214,000 tpy of MSW. • Composting facility in Mondragon, France processing 33,000 tpy of sewage sludge. • MBT facility in Southwark, London UK processing 87,500 tpy of MSW. • Dry AD facility in Surrey BC, processing 115,000 tpy of organics material. The range of reference facilities identified covers the range of proposed technologies (MBT and organics processing) and types of solid and liquid feedstock identified by the CRD including biosolids. These are newer facilities with the oldest operational as of 2010 and the most recent being the Surrey facility intended to begin operating in early 2017.

6.8 Preferred Project Arrangements

The following sections provide a discussion on the term and structure of project agreements.

6.8.1 Term of Agreements

In general, about half (5/10) of respondents indicated a longer term agreement would be preferred (e.g. 20+ years), particularly as some form of Design Build Operate (DBO) deal structure was proposed or preferred. Four of 10 respondents did not provide any preferred term, or indicated that it would vary based on the type of deal structure/agreement. Generally, those respondents with a history of facility operations and experience in developing facilities under DBO agreements, preferred longer term agreements. Longer term agreements tend to be favored when the contractor is being held to rigorous performance guarantees for the facility and/or where there is more operational risk given the complexity of the facility.

During development of the Draft IRM Project Plan, assessment of the appropriate deal structure will include development of recommendations related to the appropriate term of agreement.

Table 6-9: Preferred Term of Agreements

Corporate/Team Name	Term of Agreements
Anaergia	20 to 25 years if DBOM with a 5 year minimum. If DB; no apparent term.
APD	5 year renewable agreement.
ECS	Not stated.
ICC Group	Estimate design/construction of 2.5 years. No operating term provided.
Ostara	Contract terms would vary, Prefer 20 years if performance contract.
Pivotal	21(1) [redacted]
Redwave	No term noted.
Veolia	20 years.
Walker	Varies based on type of arrangement selected.
Waste Treatment Technologies	20-25 years.

6.8.2 Type of Deal Structure and Allocation of Responsibility (and risk)

Most respondents were flexible in the potential design, engineering, build, operate and maintain and ownership model that they would typically seek for a project similar to the IRM. Table 6-10 summarizes the responses regarding the type of deal structure preferred by the respondents, and the respondent's thoughts regarding allocation of responsibility (and risk) between the CRD and the respondent.

There was wide variation in the type of preferred deal structure identified by respondents. In general, the majority of respondents identified approaches/technologies that were capable of managing a range of feedstock, and were generally open to a range of deal structures which would reflect the types of feedstock that would be managed. The one respondent (Ostara) with a technology that focuses on recovery of fertilizer from dewatering liquor, indicated a more limited range of deal structures reflecting their experience in the market. Determination of the appropriate type(s) of deal structure to meet CRD's IRM needs, will be addressed in the Draft IRM Project Plan.

The Draft IRM Project Plan will address the allocation of project risks, and the connection of risk allocation to the form of deal structure appropriate for the CRD and how this should be reflected in the procurement approach used to select an IRM solution(s).

As indicated in Table 6-11, Respondents to the RFEOI indicated a wide variation in approach to allocation of responsibility, which reflects allocation of risk. Some indicated preferences that were balanced between the parties, and others indicated preferences that would place more responsibility on the CRD or vice-versa on the respondent. In most cases, respondents clearly stated that their preferences related to allocation of responsibility either reflects their preferred type of deal structure or would vary based on the type of deal structure appropriate for the project. This will be considered in the Draft IRM Project Plan development.

Table 6-10: Preferred Type of Deal Structure and Allocation of Responsibility

Corporate/Team Name	Type of Deal Structure	Allocation of Responsibility
Anaergia	Design Build (public ownership due to the lower cost of financing). They also offer a DBOM delivery approach and request a 20 to 25 year contract if DBOM. Under the DB option, prefer public provide a site, financing, and arrange for offtake agreements.	CRD: Provide Site, Financing, Facility Ownership, Provide Feedstock, Changes in Law, Geotechnical Risk Respondent: Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations, Sourcing Merchant Risk Shared: Obtaining Permits/Licences, Site Utilities, Stakeholder Outreach, Energy/Commodity Price Risk Responsibility for offtake agreements and management of residuals could be allocated to either party
APD	Prefer DBOM, 5 year term is the minimum reasonable contract term.	CRD: Provide Site, Ownership, Provide Feedstock, Obtain Permits/Licences, Site Utilities, Geotechnical Risk, Stakeholder Outreach, Compliance with Emission Standards/Regulations, Sourcing Merchant Waste, Energy/Commodity Price Risk Shared: Arrange Offtake Agreements, Manage Residuals/Provide Disposal Site, Performance Guarantees, Construction Schedule, Construction Deficiencies
ECS	Not stated but operations is not mentioned so the assumption is that Design/Build is implied.	Not Provided
ICC Group	Provide EPC services (essentially Design Build) but also open to other commercial arrangements. Prefer CRD ownership.	CRD: Provide Site, Geotechnical Risk Respondent: Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations Shared: Sourcing Merchant Waste Varies based on Deal Structure: Financing, Arrange Offtake Agreements, Manage Residuals/Provide Disposal Site, Ownership, Provide Feedstock, Obtain Permits/Licences, Site Utilities, Stakeholder Outreach, Energy/Commodity Price Risk

Corporate/Team Name	Type of Deal Structure	Allocation of Responsibility
Ostara	Generally offer arrangements to provide Equipment and Services, but offer a wide variety of other structures including: technology supply only, DB/turnkey, Performance contract (treatment fee). The facility owner/operator is assumed to enter into an offtake agreement for Crystal Green™ fertilizer 21(1) [redacted]	CRD: Provide Site, Financing, Facility Ownership, Provide Feedstock, Obtain Permits/Licences, Site Utilities, Geotechnical Risk Respondent: Energy/Commodity Risk Shared: Arrange Offtake Agreements, Manage Residuals/Provide Disposal Site, Changes in Law, Stakeholder Outreach, Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations
Pivotal	21(1) [redacted]	21(1) [redacted]
Redwave	Prefer a procurement process that includes pre-selection of the technology. No preference for a specific deal structure.	CRD: Provide Site, Changes in Law, Stakeholder Outreach Respondent: Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations Shared: Arrange Offtake Agreements for Output, Manage Residuals/Provide Disposal Site, Obtain Permits/Licences No preference for: Financing, Ownership of facility, Provision of Feedstock, Site Utilities, Geotechnical Risk, Sourcing Merchant Waste, Energy/Commodity Price Risk
Veolia	Prefer progressive DBO where capital pricing is determined in phases as the design progresses. Fall-back or alternatives would be DBOM in which the capital is a fixed price up-front or DBFOM which is doable, however the cost of private sector capital financing is noted as traditionally being more expensive.	CRD: Provide Site, Financing, Manage residuals/Provide Disposal site, Facility Ownership, Provide Feedstock, Changes in Law, Site Utilities, Geotechnical Risk, Energy/Commodity Price Risk Respondent: Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations Shared: Offtake agreement for outputs, Obtaining Permits/Licences, Stakeholder Outreach, Performance Guarantees, Sourcing Merchant Waste

Corporate/Team Name	Type of Deal Structure	Allocation of Responsibility
Walker	Walker is open to a wide range of business arrangements including DBO, DBFO, DBOO and DBOOT.	CRD: Provide Site, Changes in Law Respondent: Facility Ownership, Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations Shared: Financing, Offtake Agreements for Output, Manage Residuals/Provide Disposal Site, Provide Feedstock, Obtain Permits/Licences, Site Utilities, Geotechnical Risk, Stakeholder Outreach, Sourcing Merchant Waste, Energy/Commodity Price Risk
Waste Treatment Technologies	Interested in either P3 DBFOM arrangements, or DBOOM.	CRD: Provide Site, Manage residuals/Provide Disposal site, Facility Ownership, Provide Feedstock, Changes in Law, Site Utilities Respondent: Financing, Arrange Offtake Agreements, Performance Guarantees, Construction Schedule, Construction Deficiencies, Compliance with Standards/Regulations, Sourcing Merchant Waste, Energy/Commodity Risk Shared: Obtaining Permits/Licenses, Geotechnical Risk Indicate that Ownership and Stakeholder Outreach would depend on deal structure.

6.9 Pilot Program Recommendations

The RFEOI specifically sought to understand the potential interest in or perceived necessity to undertake a pilot program in order to demonstrate the applicability of a technology or technologies to process the CRD liquid and/or solid waste materials. Respondents were requested to identify the feedstock of interest to them, the technology solution proposed, whether that technology was demonstrated at a commercial scale and whether they would recommend a pilot be undertaken.

Of the 10 RFEOI respondents, half (5) indicated a pilot would not be necessary as their technology is proven. Two (2) respondents indicated their technology was proven and a pilot would not be required, however, stated that a pilot may provide CRD with some learning experiences and would partner as necessary. Three (3) respondents indicated a pilot would be required. These respondents have either proposed emerging technologies or technologies that are not currently in use with materials similar to the CRD solid and liquid waste streams. The focus of the proposed pilots would be to conduct testing to ensure compatibility with CRD's feedstock.

Table 6-11: Pilot Program Recommendations

Corporate/Team Name	Pilot Recommended	Rationale for Pilot Program Recommendations
Anaergia	No	States their technologies are proven at a commercial scale and do not recommend a pilot for any material stream.
APD	Yes	Indicates a pilot would be needed for all material streams, given that their existing reference facilities process a substantially different feedstock (chicken manure/litter). Propose that a pilot be developed at a CRD site (suggest Hartland landfill). Once the facility has been developed and commissioned, they recommend undertaking three testing phases each lasting 2 months. They encourage third party data collection and reporting of results.
ECS	No, but would partner as necessary	Indicates the technology is proven but that clients will benefit and learn from implementing a well thought out pilot system. All of the feedstock proposed to be managed by ECS are currently being composted at ECS client facilities and are available for tours.
ICC Group	Yes	ICC installed the gasification pilot in Nanaimo previously, later dismantling and moving it to Sidney. ICC suggests a pilot demonstration for RDF gasification of RDF derived from MSW. There would be a cost to install and operate the pilot, with some potential research grant available to evaluate the best RDF formulations. They also suggest that the landfill gas/biogas fuel production system would require a pilot to demonstrate generation of diesel fuel and wax from the input feedstock.
Ostara	No	States that with 14 plants operating throughout North America and Europe, the technology is mature and proven, so no pilot program is necessary. They also state they have the means to conduct a pilot program at either a bench scale or with a Pearl 5 pilot reactor system. Ostara notes that as long as the potential feed sources can be properly quantified and characterized, they are comfortable with the design and implementation of a system without piloting. They also note the lack of a suitable stream for treatment currently to undertake a pilot.
Pivotal	Yes	21(1) [redacted]
Redwave	No	Indicates a pilot would not be needed. Their proposed technologies have been demonstrated at a commercial scale for more than 10 years. They indicate that a pilot project would not provide additional information to support decision making by the CRD, and instead propose that site visits be undertaken to operating facilities.
Veolia	No, but would partner as necessary	Proposed technologies are in operation at full scale. Veolia would be pleased to organize visits to their reference facilities. If CRD determines to develop a pilot program, Veolia would partner. Veolia noted their research program for the Athos technology, beginning in 1993 with bench scale tests to full scale industrial pilot in 2000.
Walker	No	States the technologies are proven and have been tried and tested by Walker Environmental-NZW and therefore do not recommend a pilot project. They do note that integrating their technologies and having them function in an effective system with its own unique design will be a challenge that they would willingly accept.

Corporate/Team Name	Pilot Recommended	Rationale for Pilot Program Recommendations
Waste Treatment Technologies	No	Indicates a pilot would not be needed. Their proposed technologies are demonstrated at a commercial scale for each major material stream at one or more of their reference facilities. Do indicate the necessity for additional feedstock composition and volume information including annual/seasonal variations in quality and quantity to support facility design.

6.9.1 Key Findings Regarding Pilot Program Recommendations

There are a few key findings in the responses regarding undertaking a pilot program as part of the IRM process:

- A number of respondents indicated the need to provide additional information regarding feedstock elemental composition and volume, including annual/seasonal variations in quality and quantity to support facility design. In some cases, such as the post-digestion dewatering liquor that would result from dewatering the CRD Class A Biosolids at the yet-to-be-developed Residual Treatment Facility (RTF), there are no current sources of material to characterize. A number of the solid waste streams identified by CRD as potentially available for a future IRM solution such as MSW and SSO have the potential to shift over time in regards to material composition and quantities. The Draft IRM Project Plan will need to address the potential for longer-term solid waste management system impacts and would identify the potential shifts in material types and tonnages over the planning period for the IRM facility. Prior to undertaking any future IRM procurement process, additional waste stream characterization may be recommended (e.g. compositional and elemental analysis of the SSO stream).
- Two of the respondents indicated their approach to undertaking a pilot would be an installation of a pilot scale facility at Hartland, while a third proposed to undertake a pilot using an existing facility in the US using material streams similar to CRD sources. The cost to undertake these pilots is unclear, however it is reasonable to assume that the cost of an off-site pilot at an existing installation would be lower than developing a pilot-scale facility at Hartland. All pilot approaches would be faced with the same challenge, which is to replicate actual full-scale facility operations, particularly in regards to the physical preparation of the feedstock and resulting feedstock quality/consistency. This is a critical issue for the three technologies for which pilots have been recommended, as all three focus on application of more complex systems to extract energy from organic/carbon materials that have not been demonstrated in full-sale operations elsewhere. This will be considered carefully in the development of the Draft IRM Project Plan, in the assessment of pilot feasibility.

The value of undertaking a pilot as part of the IRM process is unclear. While pilot projects can result in the generation of data that can be used to assess the applicability of a technology to various waste streams, as noted above, it is difficult to replicate actual full-scale facility operations.

In general, it appears that there are a range of technologies/approaches that could be applied to result in beneficial reuse of some or all of the CRD solid and liquid waste streams, without the requirement to undertake a pilot program, and with no direct cost to the CRD to undertake a pilot program. Other companies and technology providers have themselves secured the necessary investment and undertaken the required due diligence in order to market their technology for full scale application for similar waste streams. It should also be noted that the RFEOI results do not represent all current technology providers in the marketplace, which is of relevance when making a decision regarding undertaking a pilot program. It would be reasonable to consider deferring making a final decision regarding the necessity of a pilot program pending the completion of the IRM Project Plan and determining any future IRM procurement process. Within any future IRM procurement process, it would be reasonable to conduct additional market sounding regarding the applicability of a pilot, based on the understanding that the procurement process is likely to engage with additional respondents beyond those that responded to the RFEOI.

6.9.2 Importance of Facility Tours

A number of respondents indicated the potential benefit of and suggested tours of their operating reference facilities, in lieu of undertaking a pilot. Facility tours offer the option to see operations first hand, and to gather information directly from operating staff, facility owners and the local community and/or regulators. Facility tours of each of the primary technology groupings (thermal, mechanical, biological and combinations) can be particularly helpful in appreciating the uniqueness of these facilities. In particular, observing first hand issues such as the feedstock, necessary pre-processing, by-product development, neighborhoods, etc. provide unique insight when considering these systems. HDR has facilitated facility tours for clients undertaking similar investigations regarding suitable processing technologies, and generally these tours have added to the knowledge and understanding of the various technologies under consideration. The IRM Project Plan would identify the rationale and timing for undertaking facility tours in support of the IRM project.

7 Potential Range of IRM Technology Costs

In this section we will discuss the potential range in costs for each ‘group’ of technologies based on the submissions and supplemental information drawn from HDR experience. Although some responses included indicative cost information, many of the responses did not. In subsequent telephone conversations and communications indicative cost information was requested. Given the constraints of time, indicative cost ranges by technology categories based on HDR’s prior experiences will be provided as an overview of potential future IRM cost expectations.

The cost of a solid waste management facility is typically expressed in terms of its cost per tonne or similar unit cost. However, the cost of a solid waste facility includes a wide variety of components, such as:

- Land, site development, permitting, offsite infrastructure, utilities, etc.

- Capital cost (buildings, fixed equipment, on-site utilities, environmental control systems, etc.)
- Operations and Maintenance cost (labor, rolling equipment, fuel, power, parts, chemicals, utilities, environmental compliance, routine maintenance and equipment replacement/refurbishment funds)
- Residue management and disposal costs (post treatment processing, effluent discharge and/or solids transfer, disposal and long term care)

These costs can be partially offset by revenues of byproducts from the system, such as:

- Power sales (electricity, steam or other energy utility)
- Fuels (typically transportation fuels such as renewable compressed natural gas or liquid fuel replacement such as biodiesel)
- Recyclables (metals, plastic, glass, aggregates, etc.)
- Compost or fertilizers (marketable soil enhancement products, chemicals, etc.)
- Emission credits, Carbon credit or other environmental offset attributes

The cost of a solid waste management system needs to be viewed as an overall system cost that includes amortized cost of capital based on durations appropriate for the improvement or equipment's useable lifetime, operations cost, residue costs and offsetting revenues.

The technologies offered in the RFEOI responses reflect a wide range of approaches in terms of costs and potential revenues. These technologies can treat the CRDs liquid and/or solid waste material in different ways, resulting in different recovery amounts, potential energy generation amounts, by-product types, environmental benefits and local economic benefits. These technologies vary in type, characteristics and quantity of the waste stream they can accommodate. The technologies also vary with respect to their current stage of development, capacity and costs.

As a general overview, the lower technologically complex systems such as composting reflect lower capital cost. However, lower technologically complex projects sometimes rely on labor/equipment to process the material and can have somewhat higher operations cost than those using automated equipment such as Mechanical Biological Treatment. Adding complications to the analysis, the cost of equipment, its maintenance and the volatile nature of commodities (recyclables, by-products) can also influence the cost of these systems. We offer the following overall summary table as a general guide to the potential costs of systems by technology type. Actual costs can and will vary depending on a number of factors, including technology, quantity of waste delivered, type of business structure, allocation of risk, source of funding, products generated, general economic conditions and market appetite.

For comparative purposes, CRD staff have indicated that the current capital and operating costs at the Hartland landfill are in the range of $75/tonne. The current tipping fees for disposal of materials at Hartland landfill would reflect other cost considerations such as provisions to address future capital development and/or long-term closure as well as market conditions.

Table 7-1: Overall Range of Cost per Technology Type

Technology	Capital Cost	O & M Cost	Offsetting Revenues	Net System Costs
Thermal (Gasification, pyrolysis, combustion)	High	High	High	High
Mechanical Biological Treatment, Refuse Derived Fuel, etc.	High	Medium	Medium	Medium to medium high
Anaerobic Digestion	Medium	Medium	Medium to Low	Medium
Composting	Low	Medium	Low	Medium to Low

Table 7-2 below, indicates the general cost ranges noted by RFEOI respondents, either in their submissions or during follow-up discussions. As it is very difficult at this stage of an information gathering process, for any party to determine actual costs, it was made clear to the respondents that information on indicative cost ranges was being sought. Determination of costs would also require further progress by CRD towards identifying a the tonnes of material that could be committed to a facility and decisions by the respondents related to facility capacity, which would not be possible until later in the potential IRM procurement process.

It is clearly understood from the review of the submissions, and HDR experience in other projects that these indicative costs do not necessarily include all elements/components associated with the capital costs to develop a facility, or all operating cost and revenue components. The information provided does not allow for ease of comparison, as the numbers are provided in differing units and may or may not include all applicable costs. The trend however, in the reported cost information does generally align with the ranges in cost per technology type as discussed above in Table 7-1.

Table 7-2: General Cost Ranges Noted by RFEOI Respondents

Corporate/Team Name	Range of Capital Costs	Range of Operating Costs
Anaergia	MSW Facility, 135,000 tpy, \$55 to \$75 M CAD SSO Facility, 20,000 tpy, \$12 to \$18 M CAD Biosolids Facility, 30,000 tpy, TBD (will range and would be lower in combination with MSW and SSO components	MSW Facility, 135,000 tpy, \$12 to \$15 M/y CAD SSO Facility, 20,000 tpy, \$2 to \$3.5 M/y CAD Biosolids Facility, 30,000 tpy, TBD (will range and would be lower in combination with MSW and SSO components
APD	\$3 M USD over 5 years for pilot	Not available/applicable based on demonstration/development unit

Corporate/Team Name	Range of Capital Costs	Range of Operating Costs
ECS	$135 to $400 per tonne per annum CAD (the period over which these costs would be capitalized is unclear)	$30 to $40 per tonne per annum CAD
ICC Group	In the order of $200 M CAD, suggest FEED study to confirm costs	Annual operating cost approx. $15 M CAD Assumes revenues in the order of $110/tonne in gate fees, and $100 /MWh for electricity as well as other revenue sources.
Ostara	21(1) [redacted]	Fertilizer offtake agreement would cover portion of operating costs. Generally, would not get full ROI for facility just based on fertilizer revenues, however, other benefits/savings are possible. E.g. Potential savings in pipeline operations by preventing formation of struvite in the line
Pivotal	21(1) [redacted]	
Redwave	MBT Plant costs in the order of $45 to $60 M CAD (without anaerobic digestion). AD Plant costs in the order of $18 to $24 M CAD.	MBT plant operating cost in the order of $30 to $50 per tonne CAD, depending on the project details and the materials processed. Organic processing train (AD, Compost) operating cost in the order of $30 to $40 per tonne CAD.
Veolia	Biosolids Processing Train: $50 to $70 M CAD (7,000 tDS/y) Solid Waste Technology Train: $200 to $280 M CAD (185,500 tpy)	Biosolids Processing Train: $2.8 M/y to $3.5 M/y (7,000 tDS/y) Solid Waste Technology Train: $9 M/y to $12 M/y (185,000 tpy)
Walker	$60 to $300 per annual input tonne, compost facility (the period over which these costs would be capitalized is unclear)	$65 to $110 per tonne for composting, varies based on quality of input material to composing process
Waste Treatment Technologies	$55 to 80 M CAD, for a facility including mechanical treatment and composting $70 to $100 M CAD, for a facility including mechanical treatment, AD and composting	Not Available

8 Input to the Draft IRM Project Plan

The outcome of the detailed analysis of the responses to RFEOI No. 16-1894 will be used as supporting information to complete an evaluation of technology options and feedstock combinations in the Draft IRM Project Plan which will set out a systematic process to find an IRM solution.

It will be combined with additional desktop research regarding the full spectrum of IRM approaches, capable of managing the CRD's liquid and solid waste streams.

Based on the detailed analysis of the RFEOI submissions, the following topics/items have been identified as requiring further assessment in the development of the plan:

1. Generally the outcome of the RFEOI identified a broad spectrum of technologies and approaches that combined could offer the CRD an IRM solution, and in particular offer a range of options to beneficially use some or all of the CRD biosolids stream. However, this did not necessarily cover the full range of vendors that are capable of offering these solutions, nor did the responses to the RFEOI address all options applicable to manage the other CRD material streams. Additional research will be required to complete the evaluation of the broader array of technologies and feedstock combinations.
2. As part of this research, consideration should be given to undertaking facility tours of a representative same of technologies and vendors. Facility tours have the potential to flesh out understanding of a technology, over a shorter timeline and for a lower overall cost compared to undertaking a pilot study. Facility tours should not be undertaken on an ad-hoc basis, but in an organized fashion with specific information targets in mind. The IRM Project Plan would identify the rationale and timing for undertaking facility tours in support of the IRM project.
3. The option to integrate additional market sounding processes within any future procurement process for an IRM facility, and to integrate a proponent review process for draft procurement and/or contract documents, offer the option to fully inform the IRM procurement process and to address uncertainty and concerns regarding risk management approaches.
4. A number of RFEOI respondents, noted the difficulty in identifying IRM solutions for feedstock that is not wholly controlled by the CRD, and where there is significant potential for the materials to vary in quantity and quality over time (e.g. the CRD MSW stream). The assessment of longer-term solid waste management system impacts and determination of potential shifts in material types and tonnages is an essential component of the IRM Project Plan.
5. Further understanding of the need for supplemental feedstock materials is required. Additional research will be undertaken as part of developing the IRM Project Plan, to identify the potential availability of materials such as woody biomass and commercial material streams, which may be required as supplemental materials for some processes (e.g. composting, gasification). This will assist in determining the viability of some approaches.
6. The assessment of economic implications (or preliminary business case) for the IRM project, should assess the cost of continuing under the status quo for the management of the range of CRD solid waste streams, compared to the range of potential IRM system costs. Full economic implications, including the effect on existing infrastructure (e.g. the availability of landfill disposal infrastructure) as well as the potential range of revenues associated with recovery of beneficial use products and GHG emission credits should be addressed.

7. Development of the IRM project plan will include the identification of project risks. Some of the risks identified in the evaluation of the RFEOI submissions, include the adequacy of the location identified at the Hartland landfill site for the development of a full IRM solution. Facility siting is an exercise that has presented obstacles and delays in other similar projects. In addition, there are some IRM solutions that require access to infrastructure (e.g. suitable access to the electrical grid or gas grid) for them to provide a viable option to the CRD. The project risk assessment exercise undertaken as part of the IRM Project Plan development should address these items.
8. The majority of respondents provided information regarding how various emissions from their technologies would be addressed, as well as some discussion or acknowledgement of greenhouse gas emission implications. In addition, given that a primary focus of the IRM is the beneficial reuse of biosolids, the potential fate of trace contaminants and pathogens in the biosolids was reviewed, based on the technologies proposed and/or biosolids research. This information will support the identification of the regulatory and environmental considerations in the project plan.
9. Overall, the RFEOI submissions indicate that a number of products could be recovered and marketed and/or directed to beneficial use, from the CRD liquid and solid waste streams as indicated in the RFEOI. The market value of these materials has yet to be determined, and is an important consideration in determining the overall cost of an IRM solution. Initial feedback through the RFEOI process indicates that additional research regarding markets and market risks would be appropriate as part of the development of the IRM Project Plan. The viability of technologies that recover energy such as AD or gasification, may be contingent upon identifying a higher value market for that energy such as vehicle fuel. In regards to other products, in some cases more limited markets were identified (e.g. cement kilns as an RDF market) while in others the respondents had identified potential for a broader market (Class A compost).
10. In general, about half of the RFEOI respondents indicated a longer term agreement would be preferred (e.g. 20+ years), particularly as some form of Design Build Operate (DBO) deal structure was proposed or preferred. Some respondents did not provide any preferred term, or indicated that it would vary based on the type of deal structure/agreement. Longer term agreements tend to be favored when the contractor is being held to rigorous performance guarantees for the facility and/or where there is more operational risk given the complexity of the facility. During development of the Draft IRM Project Plan, assessment of the appropriate deal structure will include development of recommendations related to the appropriate term of agreement.
11. There was wide variation in the type of preferred deal structure identified by the RFEOI respondents. Respondents to the RFEOI indicated a wide variation in approach to allocation of responsibility, which reflects allocation of risk. Some indicated preferences that were balanced between the parties, and others indicated preferences that would place more responsibility on the CRD or vice-versa on the respondent. In most cases, respondents clearly stated that their preferences related to allocation of responsibility either reflects their preferred

type of deal structure or would vary based on the type of deal structure appropriate for the project. The Draft IRM Project Plan will identify the range of potential project risks, and will discuss the implications of risk allocation in making a decision on ownership, the preferred procurement approach (es) and business/deal structure.

12. The RFEOI specifically sought to understand the potential interest in or perceived necessity to undertake a pilot program in order to demonstrate the applicability of a technology or technologies to process the CRD liquid and/or solid waste materials. Respondents were requested to identify the feedstock of interest to them, the technology solution proposed, whether that technology was demonstrated at a commercial scale and whether they would recommend a pilot be undertaken. The majority of respondents indicated that a pilot would not be required, but did identify the need for the CRD to provide greater understanding of the quantity and composition of the CRD solid and liquid waste streams and/or noted that undertaking facility tours would supplement CRD's understanding of the applicability of their technologies. Prior to undertaking any future procurement process for an IRM facility, additional waste stream characterization is recommended (e.g. compositional analysis of the SSO stream). In addition, the feedback from those respondents that recommended a pilot program, will be considered carefully in the development of the Draft IRM Project Plan. Further, additional market sounding within any future IRM procurement process regarding a pilot program would be reasonable.

APPENDIX A

QUESTIONS TO PROPONENTS
AND
PROPONENT RESPONSES

QUESTIONS
AND
RESPONSES –

PIVOTAL IRM INC

Making a difference...together

Parks & Environmental Services
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Victoria, BC, Canada V8W 2S6

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www.crd.bc.ca

May 8, 2017

Pivotal IRM Inc.
4464 Markham St.
Victoria, BC V8Z 7X8

Delivered via email to: gbethell@pivotalirm.com and matt.summers@westbiofuels.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Pivotal IRM Inc., with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 10th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 11 a.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. At the bottom of Page 11 in the submission, there is some missing text that is not provided on the following page. Please provide the missing text.
2. We would be interesting in reviewing the information collected by Pivotal regarding the initial tests and secondary testing of materials similar to the CRD feedstock. In particular we request information specific to testing related to processing materials similar to CRD's biosolids and MSW materials. As noted below, please indicate what information should be identified as being commercially confidential.
3. In regards to the laboratory and secondary testing of materials, over what timeframe (e.g. number of operating hours and/or days) is the testing undertaken to determine the capability of the technology to manage the subject feedstock?

4. 21(1) [redacted]

5. [redacted]

6. [redacted]

7. [redacted]

8. [redacted]

9. [redacted]

10 [redacted]

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22 [redacted]

fo/ Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

Joshua Frederick MASc, PEng
Manager, Project Engineering
Capital Regional District
625 Fisgard Street
Victoria BC V8W 2S6

10 May 2017
CONFIDENTIAL

Dear Sir

RFEOI 16-1894 QUESTIONS

We are in receipt of your letter dated May 8th, 2017 requesting responses to your questions regarding our submission to the above RFEOI, submitted by us on March 20th, 2017. As your request arrived allowing under two working days to respond we have burned a little midnight oil to comply.

We have responded using the numbering system corresponding to each question in your letter, for ease of reference.

21(1)

1. [redacted]

2. [redacted]

3. [redacted]

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Victoria,
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Canada
V8Z 7X8

t: (250) 478 8820
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21(1)

[redacted]

4. [redacted]

5. [redacted]

21(1)

[redacted]

6. [redacted]

7. [redacted]

8. [redacted]

9. [redacted]

21(1)
[redacted]

Figure 12: Revised CRD Process Schematic

21(1)
10 [redacted]

Please note that the above answers should be considered commercial in confidence.

Yours truly,

Section 22
[redacted]

Graeme Bethell
President
Pivotal IRM Inc.

cc West Biofuels

Appendix 1 Mass/Energy Balance Summary

WEST BIOFUELS

FICFB Gasifier Input-Output Model 15/03/2017

Gasifier Inputs

21(1)

[redacted]

21(1)

[redacted]

Gasifier Outputs

21(1)

[redacted]

CD Gasifier Input-Output Model 15/03/2017

21(1)

[redacted]

21(1)

[redacted]

QUESTIONS
AND
RESPONSES –

VEOLIA WATER TECHNOLOGIES CANADA INC.

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May 8, 2017

Veolia Water Technologies Canada Inc.
4105 Sartelon St.
Saint-Laurent QC, H4S 2B3

Delivered via email to: chris.howorth@veolia.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Veolia Water Technologies Canada Inc, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 1 p.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify the potential market and/or beneficial use for the inert sand-like substance remaining from the dedicated biosolids processing train. Can you provide an example of this use from an existing operating facility?
2. Identify the size of the site required for a facility capable of processing CRD Biosolids.
3. Identify the size of the site required for the solid waste proven technologies train/facility capable of processing CRD MSW, SSO, Controlled Waste and Green Waste. Please confirm that the Green Waste stream discussed in your submission is the yard and garden waste identified in the CRD residual materials summary.

4. Identify the scalability of the proposed technologies for the dedicated biosolids processing train and the solid waste proven technologies train.
5. The submission identifies the approach used to address air and water emissions from the HTO ATHOS technology. Please identify the approach(es) that would be used to address air, noise and water emissions for the overall facility.
6. Indicate in your experience, the GHG emission implications of your proposed approach.
7. Identify the potential range in capital and annual operating costs (in millions CAD) associated with the dedicated biosolids processing train and the solid waste proven technologies train.
8. In regards to the MBT portion of the process, what is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams (cardboard) that would be recovered?
9. Clarify the quantity of rejects/residuals (refusals) from the MBT and composting process. Also please clarify your intentions for the management of rejects/residuals from the MBT and composting process.
10. Insomuch the biostabilized compost is derived from a combination of sources including mixed waste, please clarify your expectations as to the quality and marketability of the compost.
11. Provide an estimated Mass Flow Diagram of your proposed technologies for the CRD material quantities.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22
[redacted]

for / Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

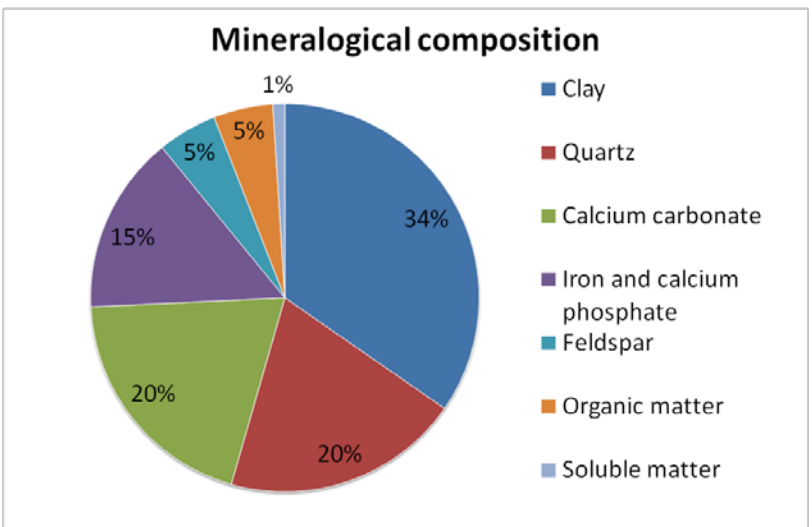
CRD RFEOI – Responses to the May 8th communication on Veolia's submittal

1. Identify the potential market and/or beneficial use for the inert sand-like substance remaining from the dedicated biosolids processing train. Can you provide an example of this use from an existing operation facility?

   The solid material recovered from wastewater using Veolia's ATHOS™ treatment system is called "Technosand". The value of Technosand derives largely on its qualitative composition (see below) and its granulometry, which make it suitable for various possible applications.

   Characteristics:
   - Dryness: >60% on plate-filter without any chemicals (>85% on dryer plate-filter)
   - <3% TOC & <8% VM
   - Average size: 3µm
   - Heavy metals fixed (non leachable)

   Mineralogical composition:



   Possible Re-Use:
   - Landfill cover (done in Brussels)
   - Expanded clay material (done in Brussels)
   - Expanded schist (used in deodorisation & construction)
   - Road and sewers construction (done in Truccazzano and Epernay)
   - Earthenware tiles (for walls)

   Another alternate is:

- The agro-chemical and fertilizer sector, where it can be used as a raw material or stabilization product based on clay. In this application the technosand has a beneficial clay content with a higher percentage of P_2O_5, which is a desired parameter.

An analysis of the minerals in the existing sludge could lead to select the best option for the CRD.

2. Identify the size of the site required for a facility capable of processing CRD Biosolids.

   The size of the site required for a facility capable of processing CRD Biosolids is 3,000 m^2. Only one train is needed including the following ancillaries (if a fully redundant train in standby is required, only 500 m^2 would need to be added):

   - Thickening after digestion
   - Heating system
   - Heat recovery system
   - Athos™ reactor
   - Oxygen storage and expansion
   - Settling and dewatering
   - Technosand storage
   - Odor Control system
   - Sidestream treatment for liquid effluent (alternatively this could be returned to the WWTP)
   - Regeants storage and dosing

3. Identify the size of the site required for the solid waste proven technologies train/facility capable of processing CRD MSW, SO, Controlled Waste and Green Waste. Please confirm that Green Waste Stream discussed in your submission is the yard and garden waste identified in the CRD residual materials summary.

The size of the site required for the solid waste proven technologies facility capable of processing CRD MSW, SSO, Controlled Waste and Green Waste depends on the amount of waste to treat. Based on your RFEOI the solid waste tonnage is from 158,000 to 185,500 tonnes/y. Based on this the size of the site required is between 4.5 ha and 6 ha.

The Green Waste Stream discussed in the submission is the yard and garden waste identified in the CRD residual materials summary.

4. Identify the scalability of the proposed technologies for the dedicated biosolids processing train and the solid waste proven technologies train.

For the biosolids processing train, there are 2 different ways to accommodate increased capacity:

- Overdesign the processing train to be able to handle an increase of the feedstock,
- Overdesign the ancillary equipment (listed in answer n°2) and allow space for an additional Athos™ reactor and the associated heat recovery system.

For the solid waste proven technologies train, given the significant tonnage of waste to deal with, multiple treatment lines would be proposed (for flexibility and redundancy).

For the MBT pre-treatment and sorting, the plant should be operated 2 shifts per day and 5 days per week. A possibility is to add an additional shift and to extend the operation hours to adjust the plant capacity with the new amount of waste.

For the anaerobic digestion and the composting, additional space could be considered to allow process expansion if the amount of waste increases.

In all cases a phasing approach can be taken to allow incremental capacity increases as the quantity of biosolids and solid waste increase.

5. The submission identifies the approach used to address air and water emissions from the HTO ATHOS technology. Please identify the approach(es) that would be used to address air, noise and water emissions for the overall facility.

Air emission

The gases from the reactor are directed first to a separator and then, after expansion of the gases, to a condensation column and finally to the heat treatment station. In the heat treatment station the gases are directed to the combustion chamber where a make-up burner maintains a temperature of at least 800°C. The oxidation reaction converts VOCs to CO_2 and H2O. This reaction is exothermic. When the gases leave the combustion chamber, they pass through a heat recovery exchanger and transfer their thermal energy to the inlet streams to minimize fuel consumption. The treated gases leave through the stack.

Water emission

The effluents collected from the Athos™ system are treated biologically (e.g. using a MBBR process). The treatment can act as a pre-treatment step, before discharge to a WWTP, or full treatment can be provided to meet environmental discharge criteria. If using the pre-treatment approach the design can be adjusted to meet the WWTP's inlet quality requirement in terms of loads and concentrations.

The liquid discharge consists essentially of biodegradable soluble COD (fatty acid and acetic acid) and contain very little hard COD. It also contains significant quantities of ammonia and phosphate. The discharges to be treated are diluted with non-potable water to reduce the ammonia concentration to avoid the potential for it's toxicity to restrict biological treatment.

Noise

All noisy equipment is installed inside buildings (such as blowers and fans). If necessary, additional soundproof enclosures, or walls treatments, can be used.

6. Indicate in your experience, the GHG emission implications for your proposed approach.

Athos™

The GHG emissions for our ATHOS™ installations is approximately 0.2 t CO_2 eq/t DS. For more accurate information, a project specific study should be performed including electricity, reagents, transport, consumables, direct emissions, avoided emissions etc. We are able to undertake this study if required.

MBT

The main advantage of MBT over landfilling of untreated MSW lies in the much lower amount of methane emitted from the stabilised waste, along with avoided emissions due to recycling metals and energy recovery from incineration of rejects. On the other hand, incineration of plastic rejects contributes to process-derived emissions. Overall, MBT results in a lower greenhouse gas flux than standard landfilling when the composted residue is landfilled to maximise carbon sequestration, but is comparable with fluxes from the highest standards of landfill. The relative performance of specific MBT schemes will depend on flows of various waste streams and so these examples provide only a guide. Non-greenhouse gas benefits of MBT over landfilling of raw waste include more effective use of landfill void space, greater stabilisation of the waste, reducing the threat from leachate escape and the consequent reduction in environmental management costs at the landfill. Benefits also accrue from the recycling of materials recovered. MBT is less sensitive than incineration to assumptions about the sources of replaced energy.

Also, if the MBT includes an Anaerobic Digestion stage to produce biogas from the Organic Fraction of the MSW, the solution offers the lowest greenhouse gas fluxes of the waste management options analysed, under base case assumptions on landfill gas management and the source of replaced energy. The performance is relatively insensitive to assumptions concerning the inclusion of carbon sequestration, replaced energy and landfill site management.

7. Identify the potential range in capital and annual operating cost (in millions CAD) associated with the dedicated biosolids processing train and the solid waste proven technologies train.

   For the biosolids processing train, the potential range in capital cost is between 50 M$ to 75 M$ (based on a capacity of 7,000 tDS/y). The annual operating cost range is between 2.8 M$/y to 3.5 M$/y, based on processing 7,000 tDS/y (excluding depreciation & Technosand handling/transport costs).

   For the solid waste proven technologies train, the potential range in capital is between 200 M$ to 280 M$ (for 185,500 t/y capacity) depending on your specific requirements. The annual operating cost range is between 9 M$/y to 12 M$/y, for processing 185,500 t/y (excluding depreciation & output-handling costs).

8. In regards to the MBT portion of the process, what is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams (cardboard) that would be recovered?

   The recovery rate depends on the type of collection: Blue Box, General Municipal refuse, Source Separated Organics.

   The more the Blue Box is developed, the lower is the recovery rate for Paper & Board, Glass, Plastic in the MBT portion because all the clean material is already separated and only the contaminated material is treated on the MBT installation.

   The table below presents the recovery rate for different materials on a specific MBT installation where a selective household collection (Blue Box) is managed, % of material recovered in the incoming stream:

Material	Recovery rate
Paper & Board	1.4%
Glass	0.7%
Ferrous metals	1.7%
Non-Ferrous metals	0.2%
HDPE	0.2%
Mixed plastic	0.7%
PET	0.7%
Film	1.1%
Brick	0.35%
Organic Matter	40%

Each area has its own market for recovered materials, with specific acceptability criteria. Analyses of this market will shortlist the type of materials to recover.

9. Clarify the quantity of rejects/residuals (refusals) from the MBT and composting process. Also please clarify your intentions for the management of rejects/residuals from the MBT and composting process.

   The amount of rejects/residuals (refusals) from the MBT and composting depends on the waste characterization and seasonality, and the selected technology train (typical values are 30 to 50 % of the feedstock for MSW and 10 % of the feedstock for SSO).

   The rejects/residuals from the MBT can be managed in landfilling or in incineration or in a Refuse-Derived Fuel plant.

   The rejects/residuals from the composting process are stabilized and can be sent to a landfill.

   We would develop a more precise rejects/residuals management strategy based on the specific opportunities and constraints in the CRD area.

10. Insomuch the biostabilized compost is derived from a combination of sources including mixed waste, please clarify your expectations as to the quality and marketability of the compost.

   Due to the amount of waste, the facility will include different lines in parallel for pre-treatment, anaerobic digestion and composting. The facility arrangement can avoid the mixing of the different feedstocks (dedicated pre-treatment, dedicated anaerobic digestion (MSW vs SSO) and dedicated composting. Veolia has developed specific tools for the traceability and management of different batches of compost.

   Also, different qualities of compost can be produced depending on your requirements and the market conditions in the CRD area and further afield.

   The CAN 0413-200/2016 Organic Soil Conditioners – Composts refers to 3 categories:

   - Class AA: High Organics content, achievable with Yard and Garden Waste
   - Class A: Low contaminants content, achievable with SSO
   - Class B: Moderate contaminants content, achievable with MSW

   The 3 categories give stabilized and sanitized compost.

   An alternate is to produce “compost like” material which is stabilized and sanitized like the compost but with contaminants. This product isn’t an Organic Soil Conditioner and it is disposed directly to landfilling after volume reduction and biogas production to reduce GHG emission.

The best option will be to target an equilibrium between installation flexibility and market conditions/opportunities. Nevertheless, it is likely that 4,000 to 5,000 t/y of Class A compost could be produced using SSO, which could be applied to public green spaces and horticulture applications.

11. Provide an estimated Mass Flow Diagram of your proposed technologies for the CRD material quantities.

At this stage, it's difficult to provide an estimated Mass Flow Diagram. In order to produce this, further information would be needed, including:

- a characterization of the various inputs, as well as their seasonality;
- a market study and business case for recovered products in the CRD area;
- a study of regulatory constraints;
- a more detailed understanding of your objectives and constraints.

QUESTIONS
AND
RESPONSES –

ANAERGIA

CRD
Making a difference...together

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May 8, 2017

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Delivered via email to: deo.phagoo@anaergia.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Anaergia, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 2 p.m. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify if your processing technology would be capable of managing sewage sludge or Class A biosolids. If so, please identify the approach(es) that would be applied to manage this material.
2. Identify the size of the site required for a facility capable of processing CRD MSW and SSO.
3. Can you provide a typical mass balance for the CRD material sources including the processing technologies identified, including the mechanical pre-processing and high solids anaerobic digestion components as part of an integrated facility?
4. Provide further details regarding control of air, noise and water emissions from your proposed facility.

5. Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.
6. Identify how the liquid and solid outputs from the high solids anaerobic digestion process would be managed? What form of marketable product/beneficial use product would result from the system? What would be the most analogous reference project to the proposed CRD facility?
7. Identify the range of materials that could be recovered and marketed from the mechanical pre-processing of the MSW stream. Would your proposed facility undertake separate or combined mechanical pre-processing of the CRD MSW and SSO material streams?
8. In regards to the mechanical pre-processing, what is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams (cardboard) that would be recovered?
9. Clarify the quantity of rejects/residuals from the mechanical pre-processing and anaerobic digestion processes. Also please clarify your intentions for the management of rejects/residuals.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22

[redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

Anaergia
Breaking Barriers to Sustainability

May 17, 2017

Capital Reginal District
625 Fisgard Street, PO Box 1000
Victoria, BC, Canada V8W 2S6

Attn: Joshua Frederick, Project Engineering Manager, Parks & Environmental Services Department

RE: RESPONSES TO CRD RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

Dear Mr. Frederick,

Thanks for your letter dated May 8, 2017 with follow-up questions related to our submission to CRD RFEOI No. 16-1894. Please find below our responses to your questions.

1. *Identify if your processing technology would be capable of managing sewage sludge or Class A biosolids. If so, please identify the approach(es) that would be applied to manage this material.*

   With respect to the management of sewage sludge we found the RFEOI slightly confusing insofar as in Appendix 1: Project Background it states that the CRD Board does not support the land application of biosolids on any CRD land (parks or agricultural) and in the same section it is noted that existing wastewater facilities will be upgraded to allow for the production of Class A Biosolids. From our perspective there little need to producing Class A Biosolids unless the intent is to land apply them and, that being the case, it is not clear whether the CRD Board's decision to disallow the land application of biosolids is because biosolids do not currently meet Class A requirements or because they do not want biosolids land applied irrespective of whether they are Class A or not.

   Anaergia processing technology can be used to process sewage sludge and generate a Class A biosolids either in combination with clean organics extracted from MSW or SSO (co-digestion) or separately from clean organics extracted from MSW or SSO (dedicated digestion). With respect to biosolids management, Anaergia can provide the following solutions based on increasing level of treatment, reduce volume of material and increasing capital and operating costs.

   a. Produce Class A Biosolids and have the CRD Board amend its policy to allow for the land application of Class A Biosolids. The lowest cost approach to produce Class A

Biosolids is a combination of digestion and pasteurization or chemical/thermal hydrolysis followed by digestion or thermophilic digestion.

b. Produce Class A Biosolids by method 1.a and transport the solids outside the CRD for land application.

c. Produce Class A Biosolids by method 1.a and blend with compost (if permitted) and land applied.

d. Produce Class A Biosolids by mesophilic digestion followed by sludge drying (which will produce Class A Biosolids due to the drying temperature and moisture content). This will significantly reduce the weight and volume of solids to be disposed of, but whether land application of these solids on CRD lands will be possible will depend on the CRD.

e. Add low temperature pyrolysis after item 1.d. to produce digestible Pyro-oil and Biochar as a soil amendment product.

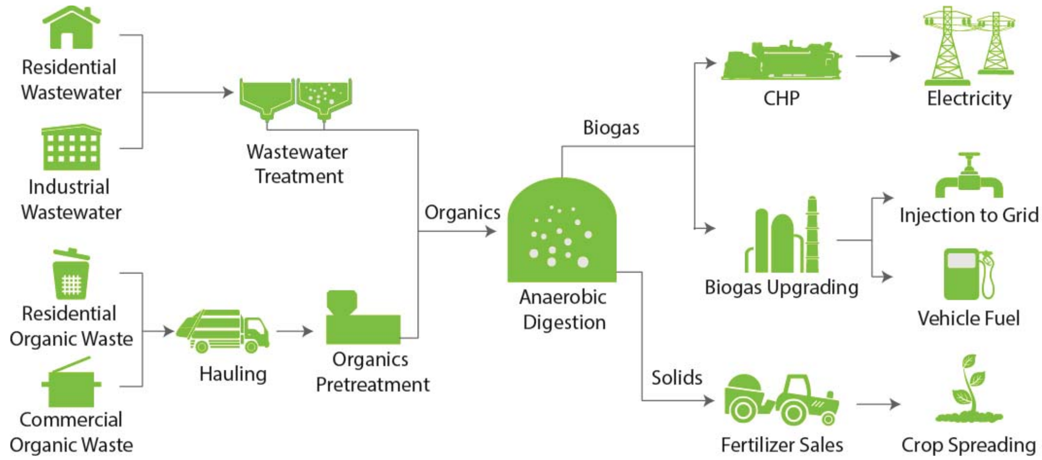
Anaergia can provide all these technologies as part of an integrated waste management solution. Anaergia manufactures/owns high solids digestion technology, as well as the necessary associated process equipment, and has designed and operated pyrolyzer systems. Sludge dryers would be purchased from a third party supplier but there is nothing especially unique about drying technology.

2. *Identify the size of the site required for a facility capable of processing CRD MSW and SSO.*

The site size required to accommodate all the works for processing biosolids, MSW and SSO including all access roads, truck turning and administration would be 8 – 10 acres. This could be reduced if shared with other facilities so common access roads etc. could be used.

3. *Can you provide a typical mass balance for the CRD material sources including the processing technologies identified, including the mechanical pre-processing and high solids anaerobic digestion components as part of an integrated facility?*

Organics extracted from MSW and SSO will produce enough biogas to generate approximately 1.0 MW of thermal energy per 10,000 MTPY. Based on a thermal to electrical conversion efficiency of 40% (typical of biogas driven CHP units), that would generate about 400 kW_e of renewable power. We estimate that processing an average of 130,000 MTPY of MSW will yield 23,600 MTPY of putrescible organics that will produce biogas with a gross energy value of 2.36 MW. On top of this there will be 15,000 – 20,000 MTPY of SSO that will produce biogas with another 1.5-2.0 MW_{th} gross energy.



The biogas can be burned in a CHP unit to generate electricity and heat. Heat can be recovered from the CHP to heat digesters and dry sludge depending on the best solution to the biosolids issue addressed in the answer to question 1 above).

Alternatively the biogas can be upgraded to biomethane for vehicle use or injection into the natural gas pipeline.

4. *Provide further details regarding control of air, noise and water emissions from your proposed facility.*

Ideally the equipment should be sited well away from residential areas to mitigate impacts to the local population. Sources of air emissions from this type of facility and mitigation measures include:

a. Odours from the processing of SSO and MSW are controlled by enclosing all equipment within a building equipped with an HVAC system that keeps the building under a slight negative pressure and exhausts the air to an odour control system. In addition, equipment processing odourous material is typically equipped with local air takes-offs directly to odour control. This includes some pre-processing equipment, sludge dewatering, and sludge drying systems. The latter systems are usually equipped with additional condensers and scrubbers to control odours.

b. Odour control systems typically use either wet scrubbers (acid/alkali/oxidizing agents) to scrub ammonia, H_2S and mercaptans or biological systems such as BIOREM or photoionization technology.

c. The processing equipment building will employ fast acting roll-up doors for truck access to minimize egress of odour as vehicles move in and out of the main facility.

d. Additional air emissions are controlled through the use of high temperature oxidizing type flares that ensure the destruction of contaminants while CHP emissions are controlled through the use of SCR technology.

Noise is similarly controlled by having equipment housed within buildings that are suitably acoustically insulated. Site noise can be mitigated by the use of sound barriers and trees etc. and limiting hours of operation.

Water Emissions are controlled by having all processing operations within buildings equipped with suitable catchment trenches and drains that direct waste liquids to sumps where they can be pumped to treatment systems. The digestion system will produce digestate which will contain high residual levels of COD, BOD, TKN and NH_3. If direct land application of digestate is permissible then this is usually the lowest cost method of disposal, but usually the waste will require some type of treatment before disposal. Treatment of the digestate usually consists of dewatering followed by either ammonia removal prior to biological treatment or simply biological treatment.

Digestates can contain ammonia levels of 3,500-4,000 mg/L which results in a high oxygen demand. Anaergia manufactures ammonia stripping/recovery equipment which produces liquid ammonium sulphate that can be used as a fertilizer. This equipment can be used directly with dewatered digestate and has no problem operating with high BOD/TSS filtrate streams. The second option is to simply treat the wastewater directly by a biological activated sludge treatment process, such as a membrane bioreactor. Anaergia has the membrane bioreactor technology and expertise for this application. Generally, a more detailed feedstock evaluation will need to be undertaken to determine whether to use a combination of ammonia recovery and biological treatment or simply biological treatment on its own.

5. *Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.*

MSW Facility	135,000 MTPY	CAPEX OPEX	CAD 55-75 MM CAD 12-15 MM/yr
SSO Facility	20,000 MTPY	CAD OPEX[Note 1]	CAD 12-18 MM CAD 2.0-3.5 MM/yr
Biosolids[Note 2]	30,000 MTPY	CAPEX OPEX	CAD TBD CAD TBD/yr

Note 1: This would be the estimated OPEX for a stand-alone facility. If the MSW and SSO facilities were combined the overall total OPEX could be reduced due to use of common facilities, shared equipment etc.

Breaking Barriers to Sustainability

Note 2: The extent of bio-solids processing required is undefined and therefore at this time costs cannot be assigned to it

6. *Identify how the liquid and solid outputs from the high solids anaerobic digestion process would be managed? What form of marketable product/beneficial use product would result from the system? What would be the most analogous reference project to the proposed CRD facility?*

   Refer to our answer to question 4 above. Digestate Solids will be separated using Anaergia's Screw Solids Dewatering (SSD) equipment. The residual filtrate can be treated using either a combination of ammonia recovery followed by biological treatment or directly by biological treatment. Anaergia manufactures its own ammonia recovery systems and has membrane bioreactor technology also. As for the dewatered biosolids, it can be dried using a thermal dryer and sold as a soil amendment product or it can be further processed using low temperature pyrolysis to produce a biochar for market for a number of uses (see response to Question #1 above).

7. *Identify the range of materials that could be recovered and marketed from the mechanical pre-processing of the MSW stream. Would you proposed facility undertake separate or combined mechanical pre-processing of the CRD MSW and SSO material streams?*

   Materials that can be recovered and marketed from the mechanical pre-processing of the MSW stream include;

   a. Paper & Cardboard
   b. Ferrous Metals
   c. Non-Ferrous Metals
   d. Plastics
   e. Glass

   Note that while recovery of these materials is possible an economic analysis needs to be undertaken to properly evaluate whether the revenues from the sale of these materials will offset the costs of recovering them.

   In terms of processing the MSW and SSO streams this would be achieved by processing the materials using separate lines. SSO is lower in totals solids and typically contains fewer contaminants than MSW, therefore, it requires very little in the way of pre-processing. The residuals from the SSO stream could be added to the MSW stream in order to recover any additional recyclable materials (usually metals).

   The extracted organics from the MSW and SSO streams can be combined and digested depending on what will be done with the digestate. Digestate from SSO is usually readily acceptable as a soil amendment product for addition to compost. Digestate from MSW organics is also a suitable soil amendment additive although there is sometimes a perception that it may be ‘contaminated’. This perception can be disproven by analysis of the chemical composition of the cake.

8. *In regards to the mechanical pre-processing, what is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other materials streams (cardboard) that would be recovered?*

The typical expected recovery of various materials is tabulated below:

Material	**Typical Recovery**
Ferrous Metals	75% to 85%
Non-Ferrous Metals	75% to 85% of aluminum cans
HDPE	Up to 70%
PET	Up to 70%
Glass	Not much…. If it’s all broken then it will be too expensive to separate using a lot of machinery. Not knowing what’s the glass or aggregate market we can’t estimate at this stage
Cardboard	Up to 50% although not knowing the intended market (paper mills) it is hard to estimate since OCC can be very dirty. Maybe recovery can go up in % if the material can be use with wood in biomass fuel and if so then maybe up 75% is recoverable.
Paper	Up to 50% although not knowing the intended market (paper mills) it is hard to estimate since OCC can be very dirty. Maybe recovery can go up in % if the material can be use with wood in biomass fuel and if so then maybe up 75% is recoverable.
Wood (to be used as biomass fuel)	Maybe up to 75% depending on whether or not treated wood can be re-sued or simply used as biomass fuel. If mainly from C & D source than it will need a C & D Line. That line can be more manual or automated with sizing, air classification, magnet and optical sorter.
Organics	Typical Extraction MSW: 20-35% of MSW can be organics of which 90% can be recovered SSO: Typically contains 10-15% contaminants so organics recovery can be 85-90% depending on the level of contaminants in the SSO.

9. *Clarify the quantity of rejects/residuals from the mechanical pre-processing and anaerobic digestion processes. Also please clarify you intentions for the management of rejects/residuals.*

The quantities of residuals expected from the system are as follows:

Material	Quantity (MTPY)
MSW Input	135,000
MSW Rejects	110,815
MSW Digestate Cake	5,550
MSW Filtrate	40,720
SSO Input	20,000
SSO Rejects	3,115
SSO Digestate Cake	3,625
SSO Filtrate	28,900

The strategy with respect to management of residuals has not been determined at this stage however it will broadly be as follows:

Rejects: Will be sent to landfill. The proposed process scheme does not consider any additional use of the reject material such as RDF for a gasification system. Anaergia's OREX technology typically extracts 90% of organics from the MSW material which reduces the moisture in the residual and results in a much higher thermal value for the material when used in gasification.

In preparing our response to the RFEOI Anaergia simply wanted to demonstrate the breadth of its technology portfolio and in-house process engineering integration expertise. The actual solution that works best for the CRD will need to be determined based on a more detailed analysis of various options, costs and revenue streams than we have undertaken at this stage in the process.

Yours very truly,

ANAERGIA DB INC.

Section 22

[redacted]

Deo Phagoo, P.Eng.
Managing Director, Canada & Eastern US

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QUESTIONS
AND
RESPONSES –

OSTARA NUTRIENT RECOVERY TECHNOLOGIES INC.

Making a difference...together

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May 8, 2017

Ostara Nutrient Recovery Technologies Inc.
Unit 690-1199 West Pender St.
Vancouver BC, V6E 2R1

Delivered via email to: dlycke@ostara.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Ostara Nutrient Recovery Technologies Inc, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 10th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the morning of May 11th at 10 a.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Provide an example of the current agreements with existing facilities for the offtake of the Crystal Green™ fertilizer.
2. What is the current range of fixed and index prices for the Crystal Green™ fertilizer?
3. Identify the potential range of annual operating costs (in millions CAD) for the scale of facility as discussed in your submission.
4. Provide an overview of the mass and energy balance associated with your technology.
5. Clarify if there are residues from the Crystal Green™ process and if so, clarify your assumptions as to the responsibility, management, and cost of these residues.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22 [redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

May 10, 2017

Joshua Frederick, MASc, P.Eng.
Project Manager
Capital Regional District
625 Fisgard Street
Victoria, BC, V8W 1R7

Subject: **Request for Clarification Dated 8 May 2017**
RFEOI No. 16-1894 Advanced Integrated Resource Management
Ostara Reference Number S1046

Dear Mr. Frederick:

Thank you for considering Ostara's response to the Capital Regional District of Victoria's (CRD) Request for Expression of Interest for the Biosolids Energy Centre.

Further to your letter dated May 8, 2017, we are pleased to provide the following response to questions:

Q1: Provide an example of current agreements with existing facilities for the offtake of Crystal Green® fertilizer.

A1: An example of our offtake agreement is provided in Attachment 1. Details can be adjusted to your specific situation.

Q2: What is the current range of fixed and indexed prices for Crystal Green® fertilizer?

A2: Ostara's offtake agreements include ongoing operational support for the Pearl® nutrient recovery facility and fertilizer purchase prices are, in part, dependent on the level of operational support agreed upon.

21(1)

[redacted]

Ostara Nutrient Recovery Technologies Inc.
690 – 1199 West Pender Street, Vancouver BC V6E 2R1 Canada
TEL +1 604.408.6697 | URL www.ostara.com

Q3: *Identify the potential range of annual operating costs (in millions CAD) for the scale of facility discussed in your submission.*

A3: The Pearl® 2K reactor facility discussed in Ostara's submission has the capacity to treat up to 250 kg/d of PO4-P. Under the conditions identified, it is expected that the reactor would be 50% to 100% utilized.

Annual operating costs include:

- Equipment maintenance
- Operating labour
- Power
- Chemicals (magnesium chloride and sodium hydroxide)
- Consumables such as fertilizer bags and pallets

21(1) [redacted] It should be noted that, revenue from the Crystal Green offtake agreement can offset or exceed the operating costs.

Q4: *Provide an overview of the mass and energy balance associated with your technology.*

A4: On average, the Pearl 2K reactor will use a nominal 200 – 250 kWh/day of electricity to run system motors and another 100-200 kWh/day in heat energy to dry the fertilizer product. **Waste heat or biogas from digestion processes can be used as the heat energy source.**

The process will remove 100 to 200 kg PO4-P/d and 50 to 100 kg of NH3-N/d from the dewatering liquor of the anaerobic digester, converting it to 200 to 500 tonnes per year of revenue generating Crystal Green fertilizer.

Q5: *Clarify if there are residues from the Crystal Green® process and if so, clarify your assumptions as to the responsibility, management, and cost of these residues.*

A5: **The Pearl process produces only one product which is Crystal Green. The process does not produce other byproducts or residues that need to be processed or disposed of.**

Please do not hesitate to contact me if you have any questions. I can be reached anytime at **dlycke@ostara.com** or on my mobile at **778-388-4193.**

Sincerely,

Derek Lycke, P.Eng.
Technical Director, Ostara Nutrient Recovery Technologies Inc.

cc. F.P. Abrary, Ostara

Attachment 1: Example offtake agreement

Attachment 1: Example Offtake Agreement

FERTILIZER OFFTAKE AGREEMENT

THIS AGREEMENT is made as of ________________________________

BETWEEN:

OSTARA USA, LLC, a Delaware limited liability company with an address at Suite 690 – 1199 West Pender Street, Vancouver, BC, V6E 2R1, Canada

(“**Ostara**”);

AND

[INSERT CUSTOMER DETAILS]

(“**Customer**”)

WHEREAS:

21(1)

[redacted]

1. 21(1)

1.1 [redacted]

21(1) [redacted]

1.2 [redacted]

1.3 [redacted]

1.4 [redacted]

1.5 [redacted]

2. [redacted]

2.1 [redacted]

21(1)

2.2 [redacted]

2.3 [redacted]

2.4 [redacted]

2.5 [redacted]

3. [redacted]

3.1 [redacted]

3.2 [redacted]

21(1)

[redacted]

3.3 [redacted]

3.4 [redacted]

3.5 [redacted]

21(1)

[redacted]

21(1)

3.6 [redacted]

3.7 [redacted]

21(1)

4. [redacted]

4.1 [redacted]

4.2 [redacted]

4.3 [redacted]

4.4 [redacted]

4.5 [redacted]

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21(1)

6. [redacted]

6.1 [redacted]

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6.4 [redacted]

6.5 [redacted]

6.6 [redacted]

6.7 [redacted]

7. [redacted]

7.1 [redacted]

21(1)

8. [redacted]

8.1 [redacted]

8.2 [redacted]

9. [redacted]

9.1 [redacted]

9.2 [redacted]

9.3 [redacted]

9.4 [redacted]

10. [redacted]

10.1 [redacted]

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21(1)

10.3 [redacted]

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11. [redacted]

11.1 [redacted]

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12. [redacted]

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21(1)

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13.4 [redacted]

13.5 [redacted]

13.6 [redacted]

13.7 [redacted]

13.8 [redacted]

21(1)

13.9 [redacted]

13.10 [redacted]

IN WITNESS WHEREOF, the parties hereto have, through duly authorized officials, executed this Agreement effective as of the Effective Date.

OSTARA USA, LLC	**CUSTOMER**
______________________	______________________
(Signature)	(Signature)
______________________	______________________
(Name)	(Name)
______________________	______________________
(Title)	(Title)
______________________	______________________
(Date)	(Date)

Schedule "A"

21(1)

[redacted]

21(1)

[redacted]

QUESTIONS
AND
RESPONSES –

REDWAVE

CRD
Making a difference...together

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May 8, 2017

REDWAVE
A division of BT-Wolfgang Binder GmbH
Muelwaldstasse 21
8200 Gleisdorf, Austria

Delivered via email to: andreas.puchelt@redwave-de.com and helmut@hbheconsulting.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by REDWAVE, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 10th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the morning of May 12th, at 9 a.m PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify to what component of the Anaerobic Digestion and In-Vessel Composting portion of your proposed process, the following CRD material streams could be directed:
    a. Pre-digested Waste Water Treatment Sludge
    b. Class A Biosolids
    c. Source Separated Organics
    d. Yard and garden wastes
2. Provide typical mass balance information for the MBT portion of your process.
3. For the In-Vessel Composting portion of your process, please clarify the quantity and other specifics of any supplementary material sources such as bulking agent, would be required?

4. In regards to the MBT portion of the process, what is the typical material recovery rate (% of material in incoming material stream that is recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams (cardboard) that would be recovered?
5. In the event that there is no market for SRF, what modifications/adjustments to your approach would be proposed?
6. Clarify the range of operating costs identified in Section 5.2 of your submission. Does the range from $8 to $10 CAD reflect inclusion of all system components (e.g. Anaerobic Digestion and In-Vessel Composting portion)?
7. Provide a range for capital costs (in millions CAD), including both the Anaerobic Digestion and In-Vessel Composting portion of your system.
8. In regards to the mechanical pre-treatment system for the IV Composting, what is the tolerance for presence of non-compostable materials (e.g. plastic) in the incoming material stream?
9. In regards to the mechanical pre-treatment system for the Anaerobic Digestion portion of the system, what is the tolerance for presence of inorganic materials (e.g. plastic) in the incoming material stream?
10. Provide further details regarding the Anaerobic Digester portion of the system. We understand that the proposed approach is high-solids digestion. We are looking for information regarding the temperature range, percent solids and other technical details. Please clarify your assumptions regarding the management of digestate and effluent from the digestion process.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22 [redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

1. Identify to what component of the Anaerobic Digestion and In-Vessel Composting portion of your proposed process, the following CRD material streams could be directed:
   a. Pre-digested Waste Water Treatment Sludge
      The pre-digested waste water treatment sludge after mechanical dewatering to approx. 25% DS can be used as feedstock for the composting facility or if an agricultural use as fertilizer is not possible due to the heavy metal/impurity content of the pre-digested sludge, the pre-digested sludge can be used as feedstock for the mechanical-biological treatment.
   b. Class A Biosolids
      see a above. Due to its low content of heavy metals the likelihood of class A biosolids to be used as feedstock for the anaerobic digestion and/or composting is given.
   c. Source Separated Organics
      Source separated organics can be used as feedstock either for the anaerobic digestion and/or composting.
   d. Yard and garden wastes
      Yard and garden wastes are to be used as bulking material for the composting.

2. Provide typical mass balance information for the MBT portion of your process.
   Waste input: 100% (for example 40% moisture content)
   mass loss: 30% (during biological drying)
   Recycling rate (recovery of ferrous, non-ferrous, paper, card and plastics): 20 – 25%
   Solid Recovered Fuel (SRF): approx. 30 – 35%
   Inerts (glass, sand and aggregates): approx. 10%

   The values given above are depending on the waste composition and the marketability of the output materials.

3. For the In-Vessel Composting portion of your process, please clarify the quantity and other specifics of any supplementary material sources such as bulking agent, would be required?

   To enable a sufficient aeration of the material to be composted the feedstock bulk density should be in the range of 0.6 to 0.7 tons/m³. The material to be composted can be mixed with bulking materials (green waste and yard waste) to achieve the bulk density range mentioned before.

4. In regards to the MBT portion of the process, what is the typical material recovery rate (% of material in incoming material stream that is recovered for market) for Ferrous metals, Nonferrous metals, HDPE, PET and other material streams (cardboard) that would be recovered?
   Typical recovery achievable in a MBT process are:
   Ferrous approx.: 85 - 90%
   Non-ferrous approx.: 80 – 85%
   HDPE approx.: 70 - 80%
   PET approx.: 70 – 80%
   Paper and card approx.: 30 – 50%
   The recovery rates depend on the complexity of the MBT process to be used and are subject to the market value of the corresponding material.

5. In the event that there is no market for SRF, what modifications/adjustments to your approach would be proposed?
   In the event that there is no market for a good, quality SRF for the use in an industrial process (e.g. cement kiln) the MBT process can be modified to meet the requirements of other thermal processes in terms of their fuel specification (e.g. waste incineration).

6. Clarify the range of operating costs identified in Section 5.2 of your submission. Does the range from $8 to $10 CAD reflect inclusion of all system components (e.g. Anaerobic Digestion and lnVessel Composting portion)?

   The range mentioned in section 5.2 does not reflect the costs for all system components. In total taking all system components into account the operating costs for an anaerobic digestion and in-vessel composting facility for a throughput capacity of 20.000 tpa are in the range of $30 to $40 CAD. Revenue generated from the marketing of the gas (electrical power, heat, etc.) is not included in the operating costs.

7. Provide a range for capital costs (in millions CAD), including both the Anaerobic Digestion and lnVessel Composting portion of your system.

   Based on European experience the capital costs for an anaerobic digestion and in-vessel composting facility for a throughput capacity of 20.000 tpa are approx. $800,000 - $1,000,000. The $800,000 – $1,000,000 CAD include the costs for the technology and the civil construction.

8. In regards to the mechanical pre-treatment system for the IV Composting, what is the tolerance for presence of non-compostable materials (e.g. plastic) in the incoming material stream?

The tolerance for the presence of non-compostable material in the incoming material stream should be looked at from different views. Under the view of the technical feasibility the amount of non-compostable material can be quite high because in a mechanical pre-treatment most of the non-compostable material can be removed. However, trying to produce a quality compost with an acceptable effort requires a limitation of non-compostable material in the incoming material to max. 3%. This threshold is based on operational experience from different composting facilities over decades.

9. In regards to the mechanical pre-treatment system for the Anaerobic Digestion portion of the system, what is the tolerance for presence of inorganic materials (e.g. plastic) in the incoming material stream?

The tolerance for the presence of non-compostable material in the incoming material stream should be looked at from different views. Under the view of the technical feasibility the amount of non-compostable material can be quite high but looking from a view of the required composting quality to be achieved after the anaerobic digestion the presence of inorganic material in the incoming material should be max. 3%.

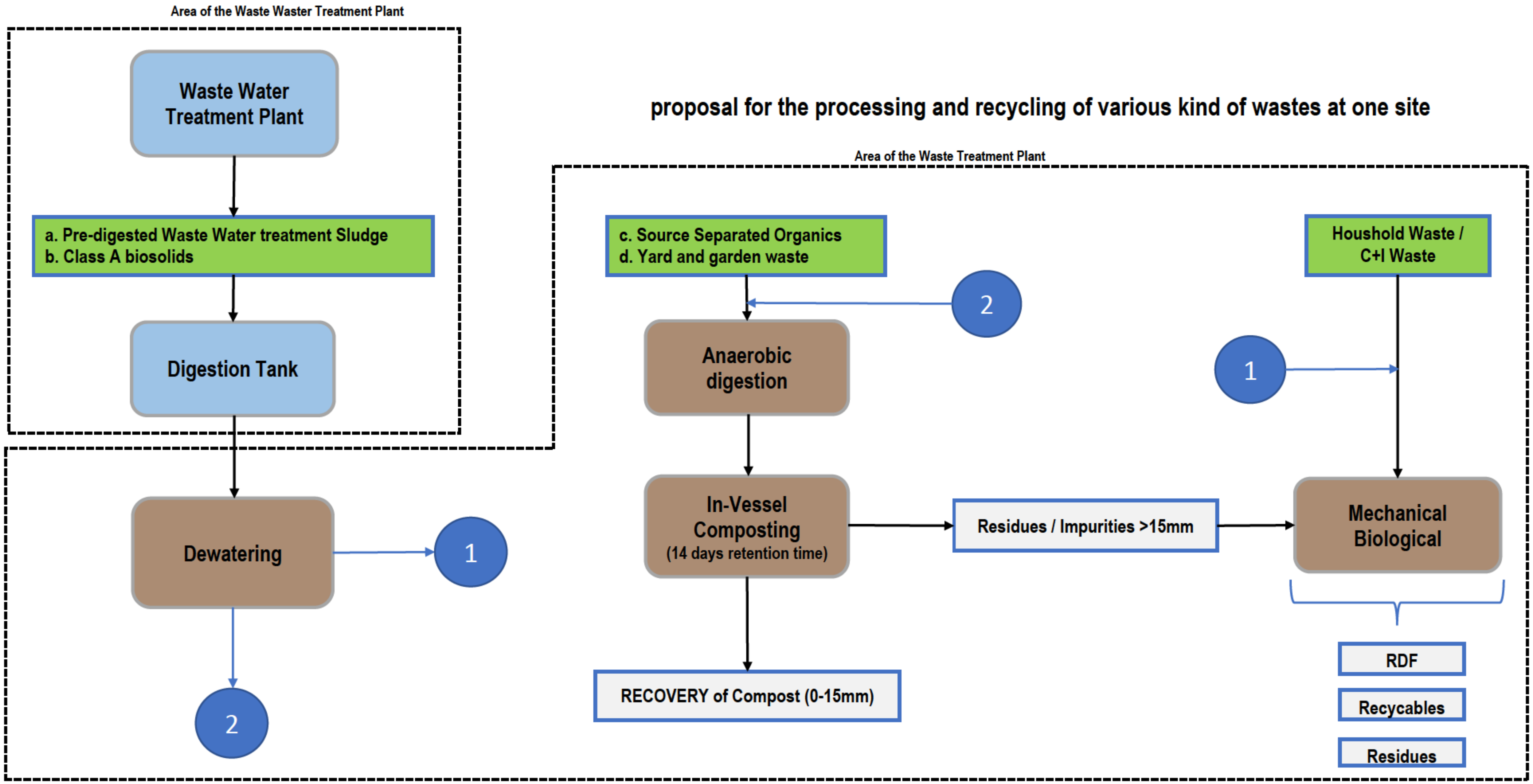
10. Provide further details regarding the Anaerobic Digester portion of the system. We understand that the proposed approach is high-solids digestion. We are looking for information regarding the temperature range, percent solids and other technical details. Please clarify your assumptions regarding the management of digestate and effluent from the digestion process.

- The digestion process can either be operated mesophilic (38°C) or thermophilic (52°C).
- The percent of dry solids in the feedstock to the anaerobic digestion plant should be in the range of 25%. If the feedstock to the digester is to dry (>25%) the required moisture content will be adjusted by adding water in the digester. Adding of water is an automated process.
- The range of DS in the source separated organics varies between 34 and 28% DS depending on the gas yield with dilution of recirculation.
- The process has to be adjusted to 24- 28% DS in the output of the digester to keep it mixable and pumpable.
- If the feedstock to the digester is to dry (>25%) the required moisture content will be adjusted by adding water in the digester. To adjust the amount of water to be added a weekly sampling on the DS content is sufficient and if needed a manual adjusting of additional liquid (condensate, process water, press water) is required.

CRD - Capital Regional District - RFEOI No. 16-1894 - Advanced Integrated Resource Management

Victoria - Vancouver Island, Canada

17.05.2017



1 heavy metal / impurity content to high for agricultural use

2 heavy metal / impurity content acceptable for agricultural use

QUESTIONS
AND
RESPONSES –

WASTE TREATMENT TECHNOLOGIES (WTT)

Making a difference...together

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Victoria, BC, Canada V8W 2S6

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www.crd.bc.ca

May 8, 2017

Waste Treatment Technologies (WTT)
Bedrijvenpark Twente 412
7602KM Almelo, The Netherlands

Delivered via email to: po@wtt.nl

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Waste Treatment Technologies, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the morning of May 12th at 10 a.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify the range of materials that could be recovered and marketed from the feedstock pre-processing recyclables recovery facility. What is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams that could be recovered?
2. The description of the Organic Material Processing (dry AD followed by composting, wet AD followed by composting and composting alone) does not clearly identify how the inorganic (non-compostable) contaminants in the incoming SSO would be managed. Clarify how the removal

of contaminants in incoming material streams (other than MSW that is directed to the pre-processing recyclables recovery facility) would be managed.

3. Clarify the quantity of rejects/residuals from the MBT and composing process. Also please clarify your intentions for the management of rejects/residuals from the MBT and composting process.
4. Insomuch as the compost produced from the facility is derived from a combination of sources including mixed waste, please clarify your expectations as to the quality and marketability of the compost product.
5. Provide an estimate of the potential size of the site that would be required for a facility that would house the technologies required to process the CRD materials as stated in your submission.
6. Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.
7. In the event that there is no market for SRF, what modifications/adjustments to your approach would be proposed?
8. Provide an estimated Mass Flow Diagram of your proposed technologies for the CRD material quantities.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22
[redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

WASTE TREATMENT TECHNOLOGIES

RFEOI N0. 16-1894 Advanced Integrated Resource Management (IRM)
Responses to your Requests for Clarification of May 8, 2017

1. ***Identify the range of materials that could be recovered and marketed from the feedstock reprocessing recyclables recovery facility. What is the typical material recovery rate {% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HOPE, PET and other material streams that could be recovered?***

The range of materials that could be recovered is large, as for most materials there is a technology available. It depends mainly on the available offset market for the different recovered products. The revenues of the recovered products need to be sufficient high to cover the separation costs (e.g. in Europe there is an existing and good paying market for waste plastics, even for LDPE film, so it makes sense to also separate LDPE film.) These markets need to be developed in North America, so there will be started with the production of relatively much Solid Recovered Fuel (SRF) and relatively little recovered products:

- Paper/Card Board
- Ferrous Materials
- Non-ferrous materials
- PET
- HDPE

See mass balance/flow scheme for INDICATIVE figures of recovery rates. Recovery rates of metals up to 80% percent may be expected. Actual recovery rates are depending on waste specifications and final combination of equipment. Alternative equipment and setups are possible. PVC may need to be removed in relation to the necessary SRF quality with low Chlorine content.

2. ***The description of the Organic Material Processing (dry AD followed by composting, wet AD followed by composting and composting alone) does not clearly identify how the inorganic (non-compostable) contaminants in the incoming SSO would be managed. Clarify how the removal of contaminants in incoming material streams (other than MSW that is directed to the preprocessing recyclables recovery facility) would be managed.***

Our tunnel composting system is a very robust process. Contamination is not a significant issue for our technology. It is eminently suited to process a wide variety of organic waste; SSO as well as IC&I waste, even in plastic bags, can be easily managed. If required also diapers and pet manure can be processed.

The preprocessing of the incoming organic waste is usually limited to bag and 'material' opening by a slow speed shredder. Contaminants will be removed at the end of the process when the material is dry and can easily be processed. Large pieces of contamination will however be removed by front end loader and/or hand picking before processing commences. The contamination will be stored in the residual storage bay/container.

The compost refining line
After a minimum of 14 days composting (BC Organic Matter Recycling Regulation - OMRR) the material will be transported by front end loader to the compost refining line. Separation of compost from the light residuals and larger organic fraction will be achieved with two drum screens, operating in series. The first drum will separate the compost (still containing heavy residuals) from the larger fraction (> 15 mm). The fraction that is larger than 15 mm will be transported by a belt conveyor to a second drum with 80 mm screen size. The overflow of the second drum (> 80 mm) will be the fraction mostly containing light residual plastics. This material will either be landfilled or sold to a cement kiln as solid refuse fuel (SRF). The 15- 80 mm fraction will be transported back to the mixing bay to be used as inoculum for subsequent composting, or it can be shredded and screened for a second time.
The purpose of having the second drum screen will be to ensure the amount of residual contamination remains at a minimum, thus achieving at least > 90% landfill diversion, while achieving quality compost that complies with the most stringent Class A compost standards according to the OMRR.
Compost from the first drum screen (< 15 mm) will pass over magnetic belt where ferrous metals are removed. The compost will then be refined further by passing through a ballistic separator which will remove heavy contaminants such as glass and stones due to the difference in density between the light organic material and heavier contaminants. After the multi-stage separation steps the compost will be transported to the finished compost storage bunkers.

3. ***Clarify the quantity of rejects/residuals from the MBT and composting process. Also please clarify your intentions for the management of rejects/residuals from the MBT and composting process.***

See attached 21(1) [redacted] **commercially confidential information**)

*: The implementation of Anaerobic Digestion will be decision of the CRD and/or CRD member municipalities. Biogas and consequently electricity generated from biogas is much more expensive than natural gas respectively traditionally generated electricity. The production of biogas and the conversion by CHP's into electricity and heat may be useful when no or insufficient power is available at the projected sight. An interesting alternative may be the upgrade of the produced biogas to natural gas quality to be used as (waste collection) truck fuel; cheap truck fuel and optimization of the carbon dioxide emission reduction resulting in carbon credits. This may be of particular interest of CRD member municipalities.

Rejects/Residuals Management
The philosophy of our project approach is to separate waste in to an organic fraction, a recyclables and/or an Solid Recovered Fuel fraction and a residuals fraction, which consists mainly of mineral grid. The residual fraction will be landfilled. The mineral grid fraction may be up to 20% in mass, but will probably be less than 10% in volume because of the relatively high density of the material. It's a relatively 'clean' material (low organic content), that can be landfilled more or less nuisance free.

4. ***insomuch as the compost produced from the facility is derived from a combination of sources including mixed waste, please clarify your expectations as to the quality and marketability of the compost product.***

The SSO, Leaf and Yard, IC&I waste and probably the organic fraction from MSW will be processed separately from the biosolids. However, if the organic fraction from MSW is too polluted to be able to produce A grade compost according to the OMRR, it may be processed together with the biosolids.

A marketable end use product is a compost suitable for unrestricted use in accordance with applicable federal (CCME) and provincial (OMRR) regulations and guidelines. The SSO compost will comply with the OMRR requirements:

- schedule 1: temperature in the composting tunnel will be >55°C for 3 days
- schedule 2: temperature in the composting tunnel will be >45°C for 14 days

Regular sampling of the incoming feedstock and outgoing compost will be in accordance with the regulatory requirements, in particular CCME guidelines for compost quality. Analytical results related to compost quality monitoring will be inspected and reviewed as soon as they are received in order to determine appropriate procedures regarding the stored material. Where compost quality criteria are not met, the appropriate response will be triggered.

Market research has been undertaken in cooperation with BC experts, as well as a compost SWOT analysis has been executed: a solid market for high quality compost that meets OMRR guidelines exists on Vancouver Island. Compost would be made available in bulk, pick-up or delivery as well as pre-arranged spreading.

Proposed market segmentation:

- Top Soil Production*
- Gardens*
- Crop/vegetable growing fertilizer*

* Closed Loop Approach may be of particular interest for CRD member municipalities. We would even encourage a 'closed the loop' program in order to provide benefits to the residents of the Capital Regional District and to compensate farmers for storage and spreading costs when they replace synthetic fertilizer. Some possibilities

- "Close the loop" in the CRD and supply CRD member municipalities' compost and top soil needs;
- Specify CRD SSO compost and topsoil products in CRD member municipalities' projects;
- Make compost available to the residents, businesses and farmers in the CRD through a home delivery program ("A Yard to a Yard") and educate residential clients in the benefits of compost use and investigate a delivery/blower service;
- Increase the familiarity with the compost product and its quality in local targeted agricultural sectors;

Biosolids composting is no technological issue. Sufficient volumes of structure material will be needed. It however could be a regulatory issue; Class A compost cannot produced out of biosolids according to the B.C. Organic Matter Recycling Regulation, but only the categories ‘growing medium’ and ‘Class B compost’. Biosolids will therefore be processed separately from SSO, Leaf and Yard waste and IC&I waste. The biosolids compost will have a higher organic content and consequently higher heat value than SSO compost. The preferred application would be as biomass for biomass boilers (and/or cement kilns). If required, the biosolids compost may be pelletized resulting in higher density and better logistical and processing performance.

5. ***Provide an estimate of the potential size of the site that would be required for a facility that would house the technologies required to process the CRD materials as stated in your submission.***

The potential size of site for mechanical separation and of 135,000 tpy MWS and composting of 20,000 tpy SSO, 18,000 tpy Leaf & Yard waste, the organic fraction from MSW and 35.000 tpy biosolids will be app. 4.5 acres.

The potential size of site for mechanical separation and of 135,000 tpy MWS, anaerobic digestion of 20,000 tpy SSO and the organic fraction from MSW and composting of the digestate, 18,000 tpy Leaf & Yard waste, and 35.000 tpy biosolids* will be app. 5.5 acres.

* If also the anaerobic digestion of the liquid biosolids is required an additional wet AD tank of app. 3,000 cubic meters is needed. The additional needed space for tank and auxiliary equipment will be less than 0.5 acres.

6. ***Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.***

<u>Capital costs</u>
The level of overall capital costs will be determined by the ultimate solution chosen and the Specification and Services required by the Capital Regional District.

The base level of costs required to develop and complete the contractual negotiations required for such a large scale complex project tends to remain relatively constant when compared to the overall duration of the project and capital investment associated with such a contract. Costs will also be dependent upon any external funder due diligence requirements and significant technical (design), legal and financial support (and depending on the complexity of the Project agreement).

The cost per ton of capital infrastructure will very much depend on the ultimate objectives of the Capital Regional District and the nature of the outputs it wishes to deliver.

Capital cost affected by:	▪ exact volumes ▪ types and quality of feedstock ▪ final process configuration* ▪ volume of tunnels/reactors/tanks ▪ local construction, environmental, compost regulations ▪ geotechnical aspects (esp. at a landfill) ▪ climate circumstances ▪ methods of financing

*: with or without AD/more respectively less separation technology implementation resulting in less or more handpicking/more separation technology results in higher capita costs.

The investment cost of a facility for mechanical separation and of 135,000 tpy MWS and composting of 20,000 tpy SSO, 18,000 tpy Leaf & Yard waste, the organic fraction from MSW and 35.000 tpy biosolids will be in range of 55m – 80m $

The investment cost of a facility for mechanical separation and of 135,000 tpy MWS, anaerobic digestion of 20,000 tpy SSO and the organic fraction from MSW and composting of the digestate, 18,000 tpy Leaf & Yard waste, and 35.000 tpy biosolids* will be in the range of 70m – 100m $

<u>Operating Costs</u>
There is a similar correlation with operating costs per ton as there are with capital costs in that there is usually a fixed operating cost element associated with each facility type and a variable cost element.

Although there is a reasonably consistent variable cost per ton irrespective of the capacity of the facility, there is often a fixed labour, maintenance and utility cost associated with the base running of the facility.

The overall cost base will very much depend on the level of processing required to transform or reduce the feedstock waste into materials which can be recovered/recycled. The level of processing costs is therefore determined by the level of transformation or mass reduction required to satisfy the requirements of the end markets.

Our solutions vary in size and design based on the drivers underpinned by client specification and objectives. We would seek to discuss the various opportunities with the Regional District in order to design a bespoke solution based on the ultimate environmental and economic objectives of the client.

Operational costs affected by:	▪ the size of the facility (economies of scale) ▪ final configuration* ▪ the amount of non-recyclables ▪ market and market prices for recyclates/recovered products ▪ contract term ▪ indexation

*: with or without AD/more respectively less separation technology implementation resulting in less or more handpicking/more handpicking results in more labour + higher operational costs

7. ***In the event that there is no market for SRF, what modifications/adjustments to your approach would be proposed?***

Market research has been undertaken in cooperation with BC experts, as well as a Solid Recovered Fuel analysis has been executed. The two mayor SRF customers in BC are Lehigh Cement plant in Delta and the Holcim Lafarge plant in Richmond. Both facilities have the necessary (environmental) permits to use SRF and a SRF demand much higher than the proposed facility ever will produce.

Both cement kilns need stable volumes of a high quality SRF (high caloric value combined with a low contamination rate. The SRF produced at the proposed facility will comply with these requirements and can be perfectly used as 'baseload fuel'. No other party within BC is currently able to produce and/or provide this 'baseload fuel'. Both cement kilns are open to negotiate a long term SRF delivery agreement.

8. ***Provide an estimated Mass Flow Diagram of your proposed technologies for the CRD material quantities***.

See attached 21(1) [redacted] **commercially confidential information**)

*: The implementation of Anaerobic Digestion will be decision of the CRD and/or CRD member municipalities. Biogas and consequently electricity generated from biogas us much more expensive than natural gas respectively traditionally generated electricity. The production of biogas and the conversion by CHP's into electricity and heat may be useful when no or insufficient power is available at the projected sight. An interesting alternative may be the upgrade of the produced biogas to natural gas quality to be used as (waste collection) truck fuel; cheap truck fuel and optimization of the carbon dioxide emission reduction resulting in carbon credits. This may be of particular interest of CRD member municipalities.

21(1)

QUESTIONS
AND
RESPONSES –

ENGINEERED COMPOST SYSTEMS (ECS)

Making a difference...together

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www.crd.bc.ca

May 8, 2017

Engineered Compost Systems (ECS)
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Seattle, WA 98199

Delivered via email to: steve@compostsystems.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Engineered Compost Systems, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 3 p.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify the pre or post processing sorting or other technologies that would be applied to separate the non-compostable (non-biological) fraction of the MSW stream from the processed material.
2. Identify if any portion of the non-compostable (non-biological) material would be recovered in a marketable form, and what types/material streams which would be recovered.
3. Identify whether all CRD input material streams (Biosolids, MSW, SSO, yard waste) would be blended/combined as feedstock for the composting process, or if some or all of these materials would be processed separately.

4. Identify the range of compost product quality and potential markets for this material.
5. Provide further details regarding control of air, noise and water emissions from your proposed facility.
6. Identify if any of the reference facilities noted, manage MSW and/or an organic fraction recovered from MSW.
7. For those reference facilities that manage biosolids as a feedstock, please identify the type of product generated and the current markets for this material.
8. Can you provide a typical mass balance for the processing technologies identified, including the pre-processing and all composting components?
9. Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards,

Section 22
[redacted]

Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

Joshua Frederick, P. Eng. May 15, 2017
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Subject: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

Joshua,
It appears that the questions below focus on processing a co-mingled MSW waste stream. ECS does not recommend composting MSW unless the process and product goals are to create an alternative daily cover for landfills. That is…making a viable/marketable compost product from mixed MSW is just not possible. And although ECS has two (2) clients that have composted MSW for alternate daily cover, both of those facilities have shifted their priorities and are now composting SSO in order to make a viable and marketable compost product.

It is possible to make good quality compost from SSO feedstocks that contain <3-5% contamination. And it is possible to make compost from feedstocks that contain as much as 15% contaminants (by weight), however at a high operational cost. Above 15% contamination and the compost produced will likely be landfilled.

Responses are requested for the following:

1. Identify the pre or post processing sorting or other technologies that would be applied to separate the non-compostable (non-biological) fraction of the MSW stream from the processed material.

   No Answer

2. Identify if any portion of the non-compostable (non-biological) material would be recovered in a marketable form, and what types/material streams which would be recovered.

   No Answer

3. Identify whether all CRD input material streams (Biosolids, MSW, SSO, yard waste) would be blended/combined as feedstock for the composting process, or if some or all of these materials would be processed separately.

   With the exception of MSW (unless the goal is to create ADC) any of the other feedstocks can be blended together or composted separately (exception: biosolids needs a bulking agent like YW) depending on product markets and process goals.

4. Identify the range of compost product quality and potential markets for this material.

   Depending on the feedstocks, the possible range of product quality is from ADC to exceptional quality.

5. Provide further details regarding control of air, noise and water emissions from your proposed facility.

   Odour Control – The control of air emissions at a facility depends on the competency of both the process technology and the operations. ECS process technology is designed and constructed to provide uniform and controllable process conditions (Oxygen, temperature, moisture) and the ability to capture and control air emissions. ECS systems are designed to create process conditions that are within Best Management Practices per the US Composting Council guidelines (BMP).

   When the compost process achieves BMP conditions it will produce fewer VOC's and odours that require capture and control. Reduced loading of the capture and control mechanism increases its efficiency. Further, a compost process that enjoys BMP conditions during primary composting will result in compost product that produces lower air emissions during secondary composting, curing and storage; and result in a highly marketable product.

   Operations must maintain BMP conditions in the pile and the biofilter to prevent creating undue air emissions and a biofilter that functions poorly. Properly constructed and maintained biofilters can reduce VOC by +90%

6. Identify if any of the reference facilities noted, manage MSW and/or an organic fraction recovered from MSW.

   West Yellowstone, MT and Mariposa County, CA

7. For those reference facilities that manage biosolids as a feedstock, please identify the type of product generated and the current markets for this material.

   https://www.nwbiosolids.org/kelowna-british-columbia-ogogrow
   Product type: USEPA Exceptional Quality Biosolids Compost
   Markets: Unlimited distribution in most cases

8. Can you provide a typical mass balance for the processing technologies identified, including the pre-processing and all composting components?

   No Answer – to provide a meaningful mass-balance would require detailed data on the incoming feedstocks.

9. Identify the potential range of capital and annual operating costs (in millions CAD) associated with your proposed approach, based on the CRD feedstock you have identified as potential inputs to the process.

   Capex: $135-400 CDN/tonne/year
   Opex: $30-40 CDN/tonne/year

Sincerely,

Steve Diddy
Business Development Director
Cell: 360-280-8985

QUESTIONS
AND
RESPONSES –

INTERNATIONAL COMPOSTING CORPORATION (ICC GROUP)

Making a difference...together

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May 8, 2017

International Composting Corporation (ICC Group)
108-9800 McDonald Park Road
Sidney, BC V8L 5W5

Delivered via email to: byran.imber@iccgroup.ca

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by ICC Group, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 4 p.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Can you provide a reference for a facility or system implemented by a single municipal jurisdiction or the private sector that incorporates all of the technologies that you have identified in your submission, to process the CRD materials (biosolids, yard and garden waste, SSO, MSW and Controlled waste) as identified in your submission?
2. Identify the range of materials that could be recovered and marketed from the mechanical pre-processing (MRF) of the MSW stream. What is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams that could be recovered?

3. Given that you have identified a Design Build approach as your preferred type of deal structure, how would you propose that the facility be operated and maintained over the long-term?
4. Identify a reference facility or example where MSW derived RDF converted to briquettes have been gasified.
5. Identify a reference facility or example where the proposed plasma reforming and the bio-fuel production technology, has been applied to biogas and landfill gas.
6. Can you provide an example of the use of the ash from the RDF gasifier in the production of concrete aggregate?
7. Provide an estimate of the potential size of the site that would be required for a facility that would house the technologies required to process the CRD materials as stated in your submission.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Best regards

Section 22

[redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
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May 15, 2017

Mrs. Margaret Reilly,
Administrative Coordinator
Capital Regional District
625 Fisgard St

P.O. Box 1000
Victoria, BC V8W 2S6|

RE: RFEOI NO. 16-1994 – Responses to CRD questions

Dear Mrs. Reilly,

ICC Group is please to submit a response to the questions raised in your correspondence of May 8, 2017, and following up with the conference call of May the 11th, 2017.

Per the note in your correspondence of May 8, 2017, ICC Group wishes the information attached to be confidential.

The information exchanged during the conference call was sufficient to consider a revision of our original process train to better answer the needs of the Capital Regional District, notably with the understanding that the CRD will supply an anaerobic digestion system.

Please find attached the revised proposal Rev-B with the answers to the questions located at the end of the document.

From the recent Times Colonist article, we note that almost $200,000,000 is the proposed expenditure on the AD plant to treat the biosolids.

For a price of less than one tenth of this 21(1) [redacted] we could take untreated but pressed biosolids into our process stream.

These untreated, but pressed, biosolids would contribute to the overall power production. They would make a contribution to the production of green power.

The savings of providing pressed biosolids would substantially pay for our proposed integrated plant.

We look forward to work with the CRD to offer an integrated solution. Needless to say, we are available to answer questions.

Sincerely,

Section 22 [redacted]

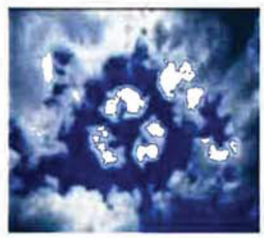
Bryan Imber

ICC GROUP
President and CEO

ICC GROUP

Generating Sustainable Energy






CRD

Advanced Integrated Resource Management

Request for Expressions of Intent

RFEOI No. 16-1894

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August 3, 2017

Purpose

In this document ICC Group and our associates have provided the first stage of a concept design that together can do the following.

- Divert of most of the waste from the land fill so giving the Hartland land fill a further 200 years of life.
- Provide Energy Self-sufficiency – All the power required for the operation is generated on site
- Proven technology – Most of the core technologies proposed are proven technologies and have been practiced around the world for a long time.
- Modular design – Each system are of modular design and can be built as demand increases.
- Financial feasibility – The project will double the income produced by the site and could be a major revenue source for the CRD in the future. The pay back of the CAPEX is less than 7 years.

The following technologies are proposed to be integrated: waste material recover facilities (MRF), refuse derived fuel (RDF) production, advanced gasification, steam cycle, biogas/landfill gas cleaning, plasma gas reforming, upgrading system with Quadrogen Technology and pressure swing absorption (PSA), liquid bio fuel production by Fischer-Tropsch technology, Autoclaved Aerated Concrete (AAC) production, mineral wool production and water treatment.

The integration of all above technologies will divert most of the waste from the landfill and converts them to useful products and electrical power in addition of supplying all internal electrical consumption.

This is the first revision to the preliminary proposal submitted on March 17, 2017. The updates were made to the proposal pursuant to the teleconference with CRD on May 11,2017. During the meeting we realized that biosolids will be digested in sewage treatment system and will be delivered at 75% moisture content. Consequently following changes were made to our preliminary proposal:

1- Dry AD plant is removed. All the solid and semi-solid waste material will be gasified.

2- A rotary drying drum fired with landfill gas is added to decrease the moisture content of the bio-solids, organic material, yard and garden wastes, and fine material from MRF plant.
3- Capacity of F-T unit is reduced because less gas is available for processing.
4- CO2 sequestration unit is removed, because we visited supplier's office and lab and realized the technology is not ready enough to be utilized at the moment.
5- Since more material is available foe gasification, number of gasifiers are increased to 6 and the power generation is increased to 12.5 MW.
6- An optional add-on technology is proposed which is able to convert the residual ash into mineral wool insulation material.

At Hartland, the sludge is to be processed into 35,000 TPY Class A bio-solids using micro-organisms to break down organic matter through anaerobic digestion, which is a soil supplement. If the above bio-solid material can't be applied on land as a fertilizer, it will be useless to produce it. The sewage can be dewatered using different technics such as rotary dryer or belt filter. The thickened sludge can be mixed with shredded wood and other organics and then dried in a landfill gas fired rotary dryer to make a dry feedstock which can be mixed with shredded RDF and make a perfect fuel for gasification. Anaerobic digestion of the sewage will extract most of the valuable calorific value of the biosolids in the form of biogas and the left over sludge/digestate is very lean in energy content. The cost of construction of a wet AD plant capable of processing all the biosoilds is higher than integrated waste to energy solution proposed here. Furthermore, if the class A biosolid is not land applicable, the AD plant will have almost no revenue (except for the biogas). At the same time the integrated waste to energy plant will convert all the waste stream to energy and useful products (Revenue) and diverts the waste from the landfill at lower cost.
"This revision of the proposal is technically similar to revision B, submitted on May 15, 2017. Some names have been removed to make the proposal disclosable to third party reviewers."

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1. Background:

ICC has recently conducted a Front End Engineering and Design (FEED) study for a similar power plant project located in Corby United Kingdom. We have collaborated with Air Clean Technology as the supplier of the steam cycle, Dustex as the supplier of flue gas cleaning system and Ameresco-UK as the EPC contractor. During the FEED study, the plant conceptual design was reviewed and a package of basic design and project planning was developed. The cost of the project was estimated with acceptable accuracy, and a middle stage project execution plan was prepared. In addition to the above activities, a 3D model of the plant was prepared. Finally, a three day in-depth HAZID meeting was held in London to examine and challenge the possible hazards and operability of the plant.

ICC joined the Fischer-Tropsch Consortium at Brigham Young University in 2007 and participated in the development of a new and more efficient Iron and Cobalt catalyst for F-T process; therefore, ICC has access to documentations, simulation model and also the catalyst which is substantial component in the F-T process. In 2014 we held discussions with Fuel Cell Energy ("FCE") and with the assistance of British Columbia Bioenergy Network (BCBN), devised a plan in conjunction with Quadrogen Power Systems ("QPS") for turning the anode exhaust of the fuel cells produced by Fuel Cell Energy to liquid fuels for the Village Farm project on landfill gas in Delta, BC. The idea of using a fuel cell as reformer, brought up another option to use conventional reformers for converting natural gas or landfill gas to syngas instead of fuel cell and make the project more economically viable. Plasma reforming by Ceramatec as the most competitive available technology was selected. ICC is now working on the development of the pilot plant F-T to be installed in Village Farms near Vancouver.

The proposed gasification system has the capacity to generate up to 6x11.6 MW thermal energy from waste fuel. Net electric export from the plant depends on: the operating pressures and temperatures; the efficiency of heat recovery; the efficiency of steam turbine-generators; and the parasitic load of the system. The maximum possible electrical power export with the selected equipment is 12.5 MW, in addition to providing the electrical demand of the proposed facility.

Autoclaved aerated concrete technology can utilize the ash residue of the gasification together with mineral and chemical additives and low pressure steam for production of low weight concrete blocks. This will decrease the ash disposal cost of the plant significantly and contribute to additional revenue by marketing the concrete bricks.

The other complimentary technology uses ash as the raw material for production of mineral wool by air blowing the melted ash in a separate furnace.

The process concept is described in figure 1 below:

2. System description

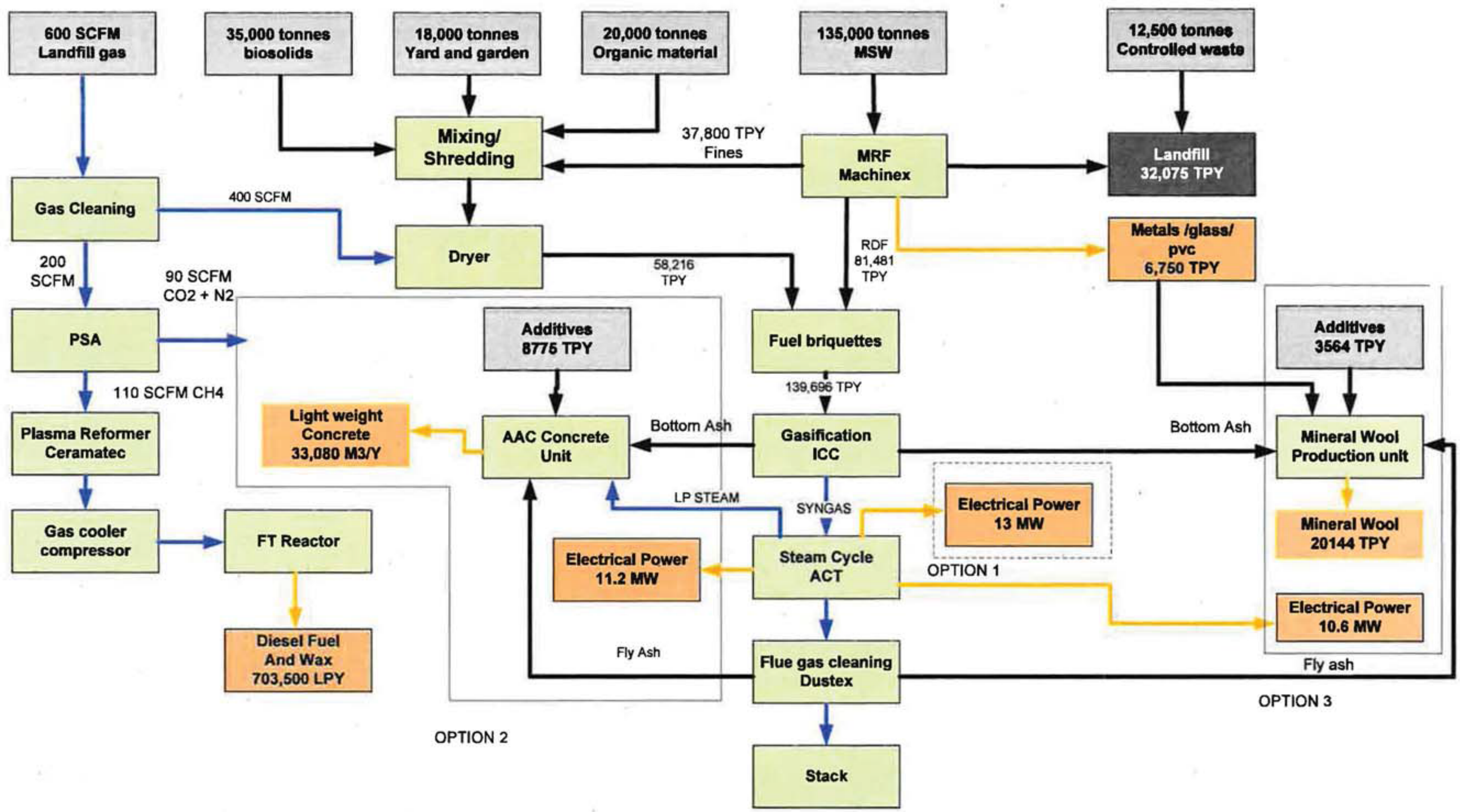

Figure 1: Process Concept

Organics, yard & garden waste and biosolids are mixed together with the fine material separated in MRF unit and loaded into a rotary drum dryer at the rate 12.6 tonnes/hr. The rotary dryer is fired with the landfill gas at 400 SCFM flow rate.

The rest of the landfill gas is first cleaned in the Quadrogen Power Systems (QPS) package and then upgraded by a Pressure Swing Absorption (PSA) to remove excess CO_2 and Nitrogen. 110 SCFM of renewable natural gas is available downstream of the PSA. The renewable natural gas is utilized in a Plasma gas reformer by Ceramatec and converted to syngas. Syngas is composed of CO_2, CO, H_2, H_2O and N_2 with H_2:CO ratio of 2. The Hydrogen and Carbon monoxide can be combined together at high pressure and temperature over catalytic bed and form longer chain hydrocarbons such as Diesel fuel and Wax. Total fuel production by ICC fixed bed reactor will be 2346 liters/day.

The reforming process takes place at 850°C, consequently, one third of the gas is consumed to maintain the remaining portion of the gas at high temperature. The reforming process is followed by a reverse gas shift reaction and heat exchanger for pre-heating the inlet air and fuel. The syngas temperature at heat exchanger outlet is about 500°C and needs to be cooled to 30°C to remove the water content. The heat in the syngas is used for drying the digestate coming out of the AD system from 66% water to 25%. The moisture extracted from the digestate contains odour from the wastes. The stream is combined with the exhaust from the gasification plant prior to release in the stack, hence eliminating the odour at high temperature.

The general municipal solid waste (MSW) is sorted for size distribution and specific gravity to select the portion with high calorific value. The ferrous metals are removed by over band magnets while non-ferrous metals are removed by eddy current equipment. The glass content and other heavy components are removed by a wind sifter machine. Two optic remover lines have been foreseen for removal of PVC to prevent chlorine gases emission. As the result of material recovery facility (MRF), 81,481 TPY of the MSW is converted to RDF. The RDF is mixed with dried digestate and some chemical additives and pressed into 138,698 TPY of briquettes of 3"x2.5"x2" in size.

The moisture content of the briquettes will be less than 15% and can be stored for an extended time without degradation and/or odour issues.

The RDF briquettes are gasified in 6 fixed bed gasifier. The syngas of the gasification is burned in 3 separate combustion chambers at 1150°C. The thermal energy is recovered by three heat recovery boilers to produce steam at 42 barg. The steam is used in 2 steam turbines (Siemens SST-110) to generate electricity. The electricity produced will provide the electrical demand of the whole facility proposed by ICC with an extra 6.9 MW of electrical power exportable to the grid.

At least 12% of the fuel is converted to ash in the gasification process. The ash together with cement, limestone powder, aluminum powder and other chemical additives are the raw material for making light weight concrete in an Autoclave Aerated Concrete (AAC) technology. 30,800 m3 of AAC can be produced using the ash. Using the ash for making concrete will divert 22,000 tonnes of waste from the landfill annually.

Another alternative for the ash utilization is the production of mineral wool. The ash is melted in a furnace together with some other additives such as ground glass and some chemicals goes to an air blown fiber making machine. The mineral fibers are used for making insulation in the form of blanket, slab and pipe sections.

More information is needed about the controlled waste composition. At the moment it has been considered to be landfilled. Depending on the nature of the waste, it can possibly be treated as MSW or organic waste.

The following technology providers will participate in the project:

Table 1: List of technology providers

	Description	Contractor
1	EPC contractor	TBD. We are negotiating with potential candidates
2	Gas cleaning and upgrading	Quadrogen Power Systems
3	Plasma reformer	Ceramatec or engine reformer by ICC
4	Fischer Tropsch Reactor	ICC
5	Material recovery facility	Machinex Quebec or equivalent

6	Briquetting machines	Kahl Germany or equivalent
7	Gasification	ICC
8	Combustion	ICC
9	Steam Cycle integrator	Air Clean Technologies
10	Steam boiler	Hurst boiler or equivalent
11	Steam turbine	Siemens
12	Control system	Siemens
13	Flue gas treatment system	Dustex
14	AAC Concrete	ICC + TBD
15	Mineral wool	GlaFiTech Glass and Fiber Technology GmbH
16	Balance of Plant	EPC Contractor - TBD
17	Environmental consultant	TBD

3. Power plant

3.1 Material Recovery Facility and fuel preparation

Machinex Industries Inc. in Quebec has provided us with a preliminary proposal and estimate for the process and equipment required for recovering valuable metals and glass from the waste and converting the rest of the waste into RDF suitable to be gasified. The concept of the process is to shred and screen the material in several stages with different screening methods for recovering metals, glass and PVC and re-shred the material to the side required. The list of equipment required for a 50 tonnes per hour facility is presented in the appendix 3.

81,481 tonnes of RDF will be produces annually. The RDF is mixed with 58,216 tonnes of dried material together with other additives for abatement of SO2 in the ash, cracking of tar and for higher durability of the briquettes. The briquettes will be 2.5"x2.5"x2" in dimension and will have a heating value around 13.3 MJ/kg at the density of 600 kg/m3.

3.2 Power plant

The thermal power plant will process around 140,000 tonnes of Refuse Derived Fuel (RDF) annually and use ICC Group's gasification technology coupled with a steam cycle and turbine to generate 12.5MW of renewable electricity and the steam/hot water required for the other processes in the facility.

Gasification is the thermal decomposition of waste material at elevated temperatures in an oxygen restricted environment. The process, which requires an initial heat supply to get underway, converts the RDF to a mixture of combustible gases. The process is self-sustaining and fully automated and needs no operator attention once the steady state operation is reached. Compared to the traditional direct incineration, gasification offers a much cleaner combustion at a higher thermal efficiency. Finally, the process retains pollutants (Sulphur, heavy metals etc.) in the ash instead of these being moved to the gas phase and discharged to the atmosphere.

The product of the gasification, called syngas, is then burned in a separate combustion chamber producing hot, clean flue gas that is then forced through the boiler, transferring the heat to the water and producing high pressure steam. The steam leaves the boiler and expands in the turbine which in turn drives the electric generator. The low pressure steam is then condensed under vacuum condition and the water is returned to the boiler thus completing the cycle.

To meet and exceed environmental requirements for power plants emissions, multi cyclones and bag house have been foreseen for cleaning the flue gas prior to release in the atmosphere.

Table 2 and Fig 2 describe the major equipment in the power plant, with the exception of the front-end preparation equipment.

Table 2: Power plant major equipment list

	Description	QTY	Note
1	Walking Floor	6	2 day storage
2	Gasifier	6	Each 11.63 MWth (80 MBTU/Hr)
3	Secondary Chamber	3	2 Seconds residence time
4	Forced Draft (FD) fan	6	Supply of air to gasifiers and burners
5	Screw auger	6	4 tonnes per hour
6	Radiation Chamber	3	To protect the boiler system
7	Heat recovery boiler	3	28.9 t/h, 43 barg, 400°C
8	Steam turbine-generator	3	Siemens ST-110 or equivalent
9	Multi-cyclone	3	To meet environmental mandates
10	Bag house	3	To exceed environmental mandates
11	Induced Draft (ID) fan	3	To Maintain -1" WG through the system
12	De-aerator-Feed water tank	1	20 Minutes storage
13	Vacuum condenser / Cooling tower	3	4.7 PSI
14	Stack	1	Per local requirements

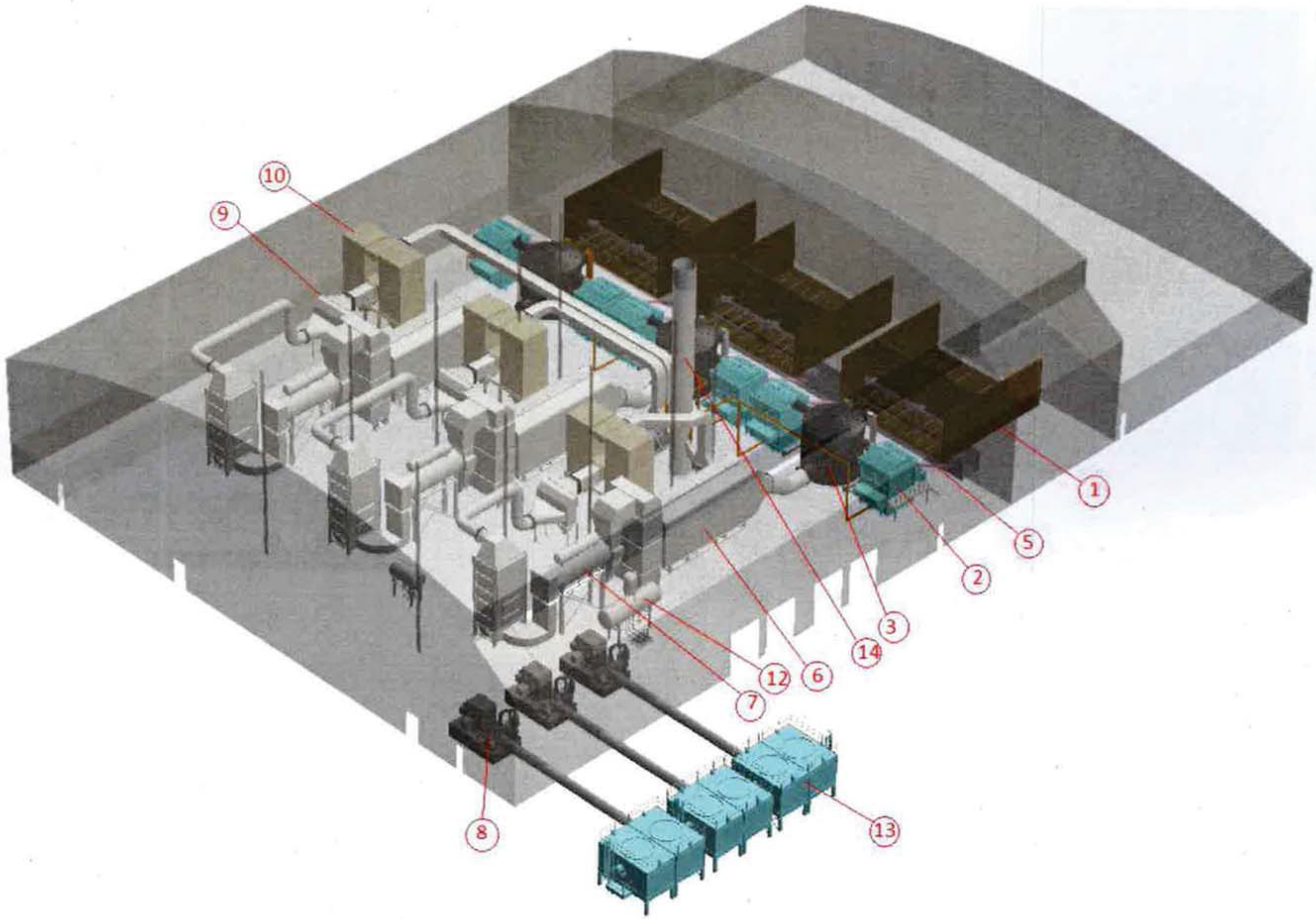

Figure 2: Power plant general layout

3.3 Fuel handling

3.3.1.1 Fuel storage and walking floor

One week supply of fuel will be stored at site. Equivalent to three days of supply will always be ready to use in walking floor storage bin. Five days of supply will be stored under a shelter ready to be loaded to walking floor.

The material is received from the briquetting machines in the feedstock area via the Chain Conveyor. The scraper chain conveyor elevates the material to a high level where it can discharge into one of four sliding gate valves to walking floors.

The stockpile walking floor machines are each suitable to hold 786 m^3 of material. The stockpile is maintained to a maximum height of 4m. The material is pulled towards the hydraulic cylinders and the bunker discharge opening by the reciprocating action of the Walking Floor and falls into a discharge screw conveyor.

The bin is used for receiving, storing and metering the feedstock materials (the fuel) for the gasifier. This system is commonly referred to as "walking floor" storage. The arms move in a reciprocating motion and push the fuel forward. The fuel is continuously moved from the rear to the front and falls into the feed conveyor trough. The bin is supplied with a vertically adjustable opening at the fuel discharge. Each arm is actuated by a separate hydraulic cylinder. The cylinders are powered by a hydraulic power unit which includes: hydraulic pump, oil tank, directional control valves and electric motor, sized to feed the burner continuously at maximum load. The hydraulic unit is equipped with instrumentation and pressure adjustments.

Figure 3: Walking floor hydraulic units

The sub-frame of the walking floor is manufactured from steel sections and fitted with footplates and packing suitable for levelling purposes. Stopper Bars are welded between the steel sections and slightly above the finished floor level to suit the Push Floor machine and to promote material flow. Some small cast-in features will be supplied along with the main frame, these include edge angles and mounting frames for a Levelling Screw and Gate Bars. The Sub-Frame will be installed and levelled prior to being back filled with concrete to form the finished floor. The Push Floor machine will be installed onto the Sub-Frame after the final floor has been cast. Final floor is a pre-cast drying floor which lets hot air pass through the pile.

Figure 4: Walking floor sub-frame

The walking floor discharge machine will be fitted into the flat floor of the sub-frame described above. Each walking floor machine is comprised of: 4 Pusher Ladders with special profiles in carbon steel with moving plates and ladder guides, and 4 double acting hydraulic cylinders. 2 inductive proximity switches per cylinder mounted to the external beams control the walking floor travel across the bunker floor.

The cylinders are powered by a hydraulic power pack complete with motor, pump, oil tank with all necessary valves, fittings and filters. Instrumentation includes pressure sensors & switches, oil level/temperature and an oil heater & cooler, all pre-wired to a terminal box.

Figure 5: Front & rear view of walking floors (rear view shown with steel walls; front shows the levelling screw)

3.3.1.2 Chain conveyor

The chain conveyor, located in the feed conveyor trough, transfers the fuel from the walking floor bin to the gasifier fuel stoker. The conveyor consists of chains running in parallel and a number of arms connected to the chains. As the chain moves, the arms push the fuel forward on the bottom of the trough. The conveyor speed is controlled according to the gasifier fuel demand.

3.3.1.3 Fuel stoker

The proposed fuel stoker comprises of a hydraulic ram (400mm x 400mm pushing face) actuated by a hydraulic cylinder and a dedicated hydraulic power unit. The fuel feed stroke consists of the reciprocation movement of the ram. Once the chain conveyor fills the hopper located upstream of the stoker, the ram moves forward forcing the fuel into the gasifier chamber. When the forward stroke is completed the ram retracts, the hopper fills up again thus completing the cycle.

3.3.2 Gasification

3.3.2.1 Introduction

Four fixed bed, updraft design gasifiers will be installed in the power plant. Gasifiers are designed by Krann Engineering. The heart of the process is a fixed bed updraft gasifier incorporating the following elements:

- Gasification chamber
- Grate for supporting the gasification bed
- Plenum below the bed to supply gasification air
- Syngas exit duct
- Ash removal apparatus for semi continuous removal of ash

Gasification is the thermal decomposition of organic material at elevated temperatures in an oxygen restricted environment. Fuel is introduced in the gasification bed and passes through the following zones:

Char zone: where carbon (char) and oxygen are converted to carbon monoxide of relatively high temperature, and ash. This reaction delivers the heat to the remaining reactions in the fuel pile. The gas leaving the carbon zone is referred as char gas.

Pyrolysis zone: dry, solid particles in absence of oxygen are de-volatized through heat transfer between them and the char gas, yielding carbon particles and pyrolysis gas.

Drying zone: the pyrolysis gases leaving the de-volatization zone dry up the particles. All water contained in the fuel vaporizes and consequently the humidity of gases leaving the fuel pile depends on the raw fuel moisture content. This process allows the gasification of fuels at high moisture content even up to 50% as the water does not enter the combustion zones.

The entire process is exothermic although requires an initial heat source to facilitate reaction. As the fuel passes down the bed a calorific value rich syngas is released and ascends the chamber to pass into the secondary combustion chamber.

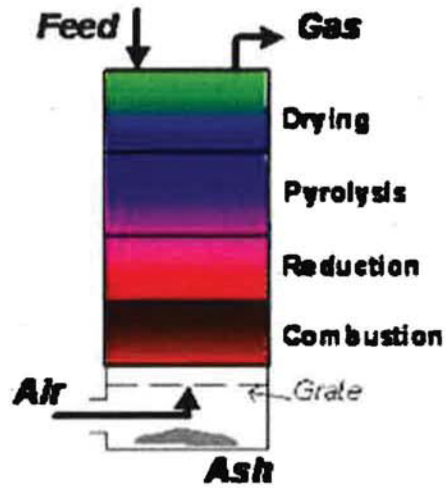

Figure 6: Principles of Updraft gasification

In order to operate efficiently the gasifier requires feedstock to be in a particle form with a specific size distribution. Compared to standard combustion, the process is cleaner with lower emissions and with a high proportion of the contaminants remaining in the ash, depending on the temperature of operation.

The process is capable of dealing with moist feedstocks although as with any thermal process, moisture has a detrimental impact on the thermodynamics of the process.

3.3.2.2 Gasification chamber

The primary combustion chamber is fabricated from steel plates and steel tubes and lined with high temperature refractory material. The fuel is fed into the chamber at the rate proportional to the required unit output, as determined by the PLC program. In the integrated process the gasifier will be slave to the energy utilization process and it will be a signal from the boiler that controls the feed flow to the gasifier.

The function of the primary chamber is to convert the fuel into the combustible syngas. The syngas is partially oxidized in the primary combustion chamber by adding a small proportion of combustion air before entering the secondary combustion chamber. The syngas exit temperature is measured and controlled in the primary chamber. The primary chamber is sized to deliver 11.6 MW (net) syngas flow while burning fuel at 15% moisture content, wet basis.

The gasification process can be observed by operators through the viewport(s). The gasifier is supplied with a side access/maintenance door. The door is secured with nuts, bricked and blanket insulated during the operation. An additional door to the under-grate chamber is also supplied.

3.3.2.3 Syngas exit duct

The Syngas exit duct connects the primary chamber to the secondary chamber. The syngas duct is lined with the refractory material.

3.3.2.4 Secondary chamber

Two gasification chambers are connected to a common secondary chamber where the syngas is burned completely with excess air. The secondary chamber is a vertical chamber insulated from outside and protected against flame from inside. Two forced draft fans (fitted with a variable speed drive) provide measured flow of the combustion air that is fed into the chamber by a series of openings in the refractory.

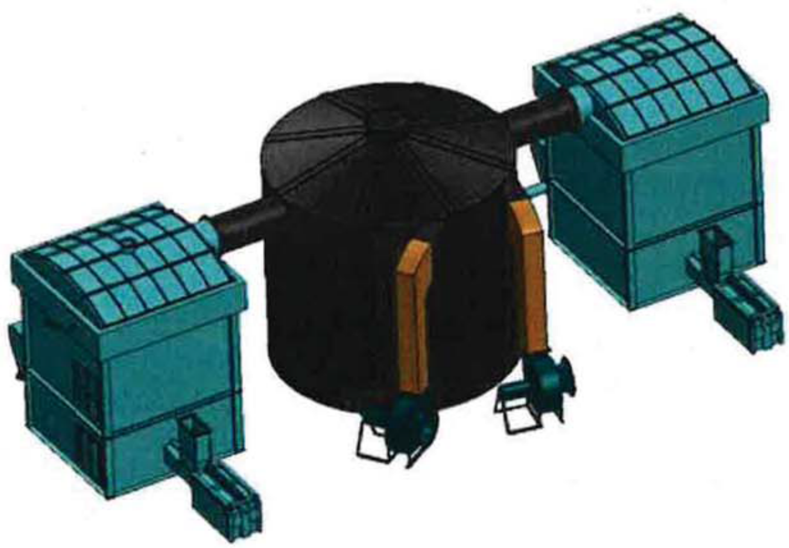

Figure 7: Gasification chambers connected to a common Secondary Chamber

The diameter of the secondary chamber is 6.4 m with a height of6.5 m. The chamber is designed to maintain combustion at 850o C for a minimum of at least 2 seconds.

The combustion temperature and the excess O2 percentage, immediately after the syngas combustion, are monitored. The combustion process can be observed by the operators through the viewports.

3.3.2.5 Ash removal

The ash is continuously accumulated on the grate of the primary chamber. The ash discharge system periodically transfers the ash to the hopper located on the combustor discharge wall. Two screw conveyors (Ash Screw A and B) transfer the ash to the ash container. The Ash Screw B is supplied with a motorized slide gate at its discharge end. The ash operation up to the ash container inlet is fully automatic.

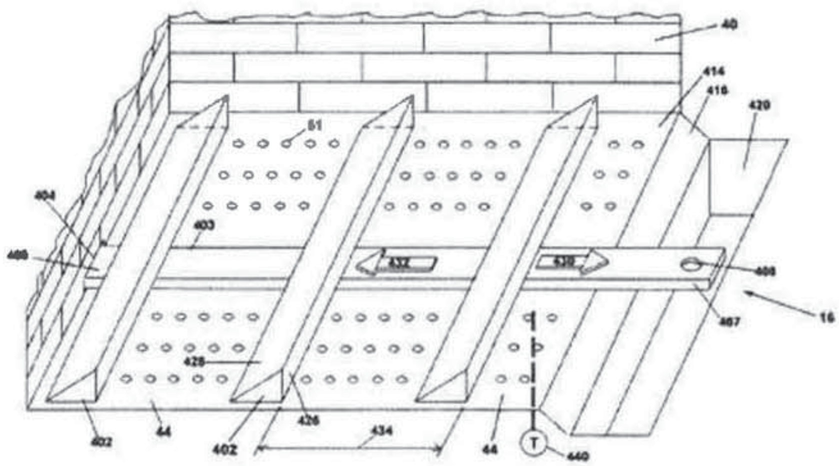

Figure 8: Ash removal arm

3.3.2.6 Forced and induced draft fans

Forced draft fans supply combustion air at 2 levels. The under-fire fan supplies all gasification air to the primary gasifier from exhaust flue gas. Two secondary fans supply remaining air for full combustion of the syngas in the second chamber. The fans are sized to fully complete the fuel combustion.

Each train of 2 gasifiers is equipped with one induced draft fan to maintain the negative pressure of 1" Hg all through the system ensuring that the complete process is maintained under negative pressure at all time

3.3.3 Steam and power generation cycle

Air Clean Technologies (ACT) is the main supplier of small Siemens Steam turbines in North America. ACT worked with ICC on optimization of the design for the last 3 years. Different types of boiler (Fire tube, Water tube, Hybrid) and different models of Siemens Turbines (SST-60 to

SST-111) with various operating temperatures from secondary chamber were investigated to find the best solution with lowest capital and operating cost. 3 boiler manufacturers were contacted during the concept design and design data were communicated. The present integrated arrangement is the result of more than 2 years of iterations with suppliers of steam cycle components and gasifier technology supplier.

2 trains of steam generation and steam turbines are considered in this project with common feed water and cooling system. Heat from combustion products is recovered in a "Piggy back", fire tube steam generator. Superheated steam is utilized in a high efficiency condensing steam turbine to generate power. Condensates from turbines are collected by a common header and treated physically and chemically in deaerator and feed water tank. Hot water is pumped back to boilers at high pressure to close the loop. Cooling cycle rejects the heat from condensate to environment by an open or closed cooling tower. Other auxiliary equipment required for steam cycle are: RO make-up water treatment, chemical injection tank and pumps, blowdown tank and control system.

Boiler will be supplied with safety relief valves, feed water control valve, and steam outlet non-return valve.

The main steam headers will include crossover piping and isolation valves to supply steam to either of the all steam turbine generators

A process schematic of steam cycle is presented blow:

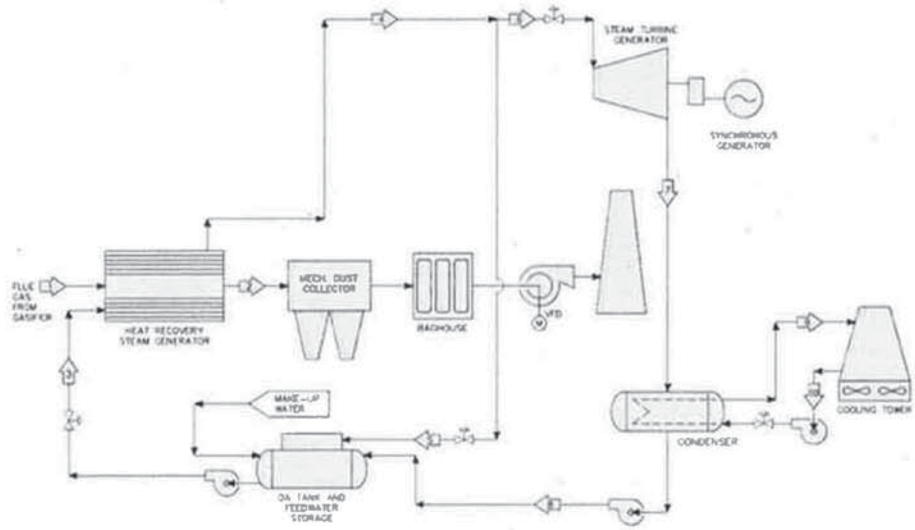

Figure 9: Process Schematic of Steam Cycle supplied through Air Clean Technologies

3.3.3.1 Steam production and utilisation

The heat recovery steam generator (HRSG) will be a single pass piggy back horizontal fire tube boiler. The boiler includes low and high water cut-off switches which cycle the boiler feed water pumps to maintain the boiler water level. Boiler is also equipped with inlet water cooled screen, economizer and super heater.

An integrated control panel will control the feed water pumps and provide alarms for water level and pressure. The present boiler design is based on an operating pressure of 40 barg and a maximum allowable working pressure of 44 barg psig. Outlet steam will be superheated at 400°C.

The boiler package includes the following components:

- Deaerator tank with feed water storage and feed water pump.
- Continuous blowdown tank
- Boiler drains and isolation valves.
- Steam outlet stop and check valves.
- Steam drum safety relief valve with drip pan elbow and vent stack.
- Boiler water level indicator with high and low water level cut-off switches.
- Pressure controller with high and low pressure switch
- Water tube finned economizer
- Water tube plain super heater
- Chemical injection package

Figure 10: Piggy back heat recovery boiler supplied through Air Clean Technologies

3.3.3.2 Steam turbine-generator

The condensing steam turbine will be a Siemens SST-110 and will be fabricated in their shop in Frankenthal, Germany. The steam turbine includes the following features:

- Independent trip and throttle valves for turbine speed control and automatic turbine trip.
- Separate PLC based turbine control system with HMI screen and Modbus and Ethernet communications for integration with other system components.
- Low voltage circuit breaker for connection with plant BUS. Circuit breaker includes current transformers and potential transformers required for metering, power factor correction, and paralleling with the plant's power supply.
- Miscellaneous temperature, pressure, and vibration instrumentation for the steam and lube oil systems. Instruments will be monitored and displayed by the turbine PLC control system and will include appropriate alarm and trip points.
- Miscellaneous drain and leak off piping, moisture separators, and steam traps.

Generator will be a medium voltage synchronous generator with voltage regulator that will operate at 1,500 rpm. Generator includes temperature RTDs for the generator bearings and two winding RTDs for each of the three voltage phases. The bearing and winding RTDs will be monitored and displayed on the turbine PLC control system with appropriate alarm and trip set points.

The generator will be mounted to a base frame to allow easy installation and connection to the Siemens turbine. The base frame will be fabricated by Air Clean Technologies.

Steam turbine Calculation using HRSG steam characteristics is shown below:

Each turbine-gen set will generate 5.9 MW electrical power, 11.8 MW total. Parasitic load of the power plant is estimated to be 0.9 MW which will be consumed internally by electrical motors in fans, conveyors, pumps, RO, lighting and control system. 10.8 MW can be exported to grid.

Table 3: Steam Turbine Calculation by DOE software

Solve for:	
Outlet Properties ▼	
Inlet Steam	
Pressure*	588 psig
Temperature ▼ *	752 °F
Turbine Properties	
Selected Turbine Property	Mass Flow ▼
Mass Flow *	49.5 klb/hr
Isentropic Efficiency *	80 %
Generator Efficiency *	92 %
Outlet Steam	
Pressure*	-13 psig
* Required	Enter [reset]

Inlet Steam		Mass Flow	49.5 klb/hr
Pressure	588.0 psig	Sp. Enthalpy	1,380.8 btu/lbm
Temperature	752.0 °F	Sp. Entropy	1.612 btu/lbm/R
Phase	Gas	Energy Flow	68.3 MMBtu/hr

Isentropic Efficiency	80.0 %
Energy Out	18.0 MMBtu/hr
Generator Efficiency	92.0 %
Power Out	4,842.7 kW

Outlet Steam		Mass Flow	49.5 klb/hr
Pressure	-13.0 psig	Sp. Enthalpy	1,017.9 btu/lbm
Temperature	120.0 °F	Sp. Entropy	1.769 btu/lbm/R
Saturated	0.91	Energy Flow	50.4 MMBtu/hr

3.3.4 Flue gas treatment

The boiler exhaust flue gas emissions will be treated by a multi-cyclone and a baghouse. A NOx reduction system is foreseen to control the NOx emission below permitted level. The multi-cyclone collector configuration offered is a side inlet / side outlet (SISO). It is specifically sized for wood/Biomass fired boiler application to minimize incendiary particulate carryover downstream of the Multiclone. A reagent injection system is foreseen to allow introduction of lime, sodium bicarbonate and/or activated carbon into the flue gas in the event that processing of the feedstock gives rise to higher than anticipated levels of pollutants.

The multi-clone will include the following:

- 9" cast iron tubes
- System differential pressure indicator
- Hopper discharge poke holes and strike plates for hopper discharges
- Rotary valves

The baghouse will use a fabric filter media and an intermediate pressure pulse jet cleaning system. The baghouse will be designed specifically for boiler flue gases. The baghouse design will include:

- Pulse-Jet fabric filter
- Top-removal snap-band filter bags with 20wire A-36 carbon steel cage with integral venture
- Solid State cleaning controls in NEMA 4 enclosures
- Inlet manifolds/Outlet manifolds
- Quick acting inlet isolation damper
- Baghouse system differential pressure transmitter
- Hopper vibrators with capacitance type hopper level switches
- Hopper discharge screw conveyors/ Discharge Rotary Valve
- Structural steel for collector support
- PLC based control system for automation of baghouse equipment and annunciating system conditions. Control system will include a modem link for remote system diagnosis of system problems when required.
- Broken bag detector

NOx reduction will be done by SNCR injection method supplied by Dustex.

3.3.5 Residue handling and disposal

Solid residues produced by the process technologies utilized in the process will include bottom ash from the biomass boiler unit and residues collected from the bag filter and muticlones.
The disposal route/saleable value/disposal cost will determine the ash management strategy and handling equipment/storage requirements for the energy centre.
Landfill is one potential option for the outputs; based on anticipated composition both streams would be expected to be classified as non-hazardous, non-active waste.
The other option is to use the ash in making concrete block and landfill only small portion of the disposal.

4. Autoclaved Aerated Concrete

Autoclaved aerated concrete (AAC), also known as autoclaved lightweight concrete (ALC), is a lightweight, precast, foam concrete building material that simultaneously provides structure, insulation, and fire- and mold-resistance. AAC is so light that it can float on water. AAC products include blocks, wall panels, floor and roof panels, cladding (facade) panels and lintels. AAC is produced using fine aggregate, Quartz sand, calcined gypsum, lime (mineral) and/or cement and water are used as a binding agent. Aluminum powder is used at a rate of 0.05%–0.08% by volume (depending on the pre-specified density). Ash generated from the gasification process (Depending on silica content) can be used as an aggregate.

When AAC is mixed and cast in forms, several chemical reactions take place that give AAC its light weight (20% of the weight of concrete) and thermal properties. Aluminum powder reacts with calcium hydroxide and water to form hydrogen. The hydrogen gas foams and doubles the volume of the raw mix creating gas bubbles up to 3mm (⅛ inch) in diameter. At the end of the foaming process, the hydrogen escapes into the atmosphere and is replaced by air.

Figure 11: AAC autoclave unloading

When the forms are removed from the material, it is solid but still soft. It is then cut into either blocks or panels, and placed in an autoclave chamber for 12 hours. During this steam pressure hardening process, when the temperature reaches 190° Celsius and the pressure reaches 8, quartz sand reacts with calcium hydroxide to form calcium silicate hydrate, which gives AAC its high strength and other unique properties. Because of the relatively low temperature used AAC blocks are not considered fired brick but a lightweight concrete masonry unit. After the autoclaving process, the material is ready for immediate use on the construction site.

Depending on the quality of the RDF, 10% to 25% of the fuel is ash. Some additional bonding agents are added in briquetting stage which increases the ash volume.

The steam required for curing the blocks in the autoclave can be extracted from a middle stage in the steam turbine. AAC blocks can be sold for $120 per cubic meter as the whole sale price. Energy requirement for manufacturing AAC blocks increases the fuel demand and revenue from gate fee consequently. If the ash is not converted to a useful product, then it should be transported to landfill and become a cost centre because of high gate fee at landfills for ash. Detail calculation for concrete block production is described in attached financial model.

5. Mineral wool

Raw materials (Ash + additives) crushed in proper size, are stored into storage silos and, fed to the electric melter in the correct sequence and ratio by means of the weighing and feeding system of the so called batch plant.

A high efficient spinning machine provided with 4 spinning wheels transforms melt into thin fibres by the action of centrifugal power and air speed.

While blowing the fibres away from the spinner, the heaviest parts (shots) are separated. Once separated, they are sprayed with binding agent and then deposited, on a drum-collecting system as a light wool mat.

The binding agent is prepared into the binder plant. From the forming drum the mat, called primary mat, is deposited on the line receiving conveyor. In order to reach the right density and area weight, several layers are deposited one on each other by means of a special system called "pendulum".

The felt is now transported to the processing line. A weighing unit in combination with a line speed and binder control system gives uniform density and binder content quantity is properly controlled.

The wastes (shots & fibres) generated by the fiberizing process can be recycled into the electric melter by using the shots recycling.

Via a 4-stages crimping machine for products with requirements for high compression strength the felt enters into a curing oven, where binder is cured and the required thickness and density is given to the final product.

The product, coming out from curing oven, is cooled trimmed on both sides, cut in width and to a pre-set length. If required the product can be faced with aluminium or kraft paper into the facing section .The panels are then stacked in a full automatic stacker and sent to the packaging section .

Chopper rollup and shrinking will be needed to manufacture mattress in rolls and to manufacture stitched product .

The fibre recycling system allows to handle and recycle all clean fiber waste to the collection chamber and gives high economic benefit.

The whole line is controlled and supervised by a full automatic control system based on PLC and SCADA supervision system.

6. Gas cleaning and upgrading

ICC is working with QPS on Village farm Project for cleaning and upgrading the quality of the landfill gas to be used in fuel cell for power generation and in plasma reformer for syngas production. Village farm project involves cleaning of 400 SCFM of gas which is slightly twice the project in Hartland. Quadrogen Power systems is a Canadian clean technology company that builds customized biogas clean-up systems that allow waste water treatment plants, landfills, agricultural digesters and power generation facilities to turn waste biogas into clean energy. Quadrogen's unique C3P process cleans biogas and other gases and makes them usable as heat/electricity, bio-methane, CO2 for greenhouses/hydroponics, and/or hydrogen.

Quadrogen's core proprietary technology — the C3P process — is comprised of up to 4 steps and allows Quadrogen to remove biogas contaminants to unmatched parts-per-billion (ppbv) levels. The Quadrogen C3P Process includes:

$\boxed{1}$ Condensation

Feed is cooled to condense water and other contaminants such as siloxanes and volatile organic compounds. Condensed liquids are then separated from the gas stream to remove a large proportion of the contaminants without using any adsorbent media.

$\boxed{2}$ Conversion

Dry feed gas is treated with a hydrogen-assisted catalytic process that converts the broad spectrum of problematic organic contaminants into a known and easily captured set of species.

$\boxed{3}$ Capture

Specially-formulated sorbent media beds, specifically tailored to the known species produced by the conversion stage, capture the remaining contaminants.

$\boxed{4}$ Polishing

Biogas is further polished of trace-level contaminants to the parts-per-billion level in a final chemisorption step. This unique polishing step provides reliable protection of downstream equipment, even in the event of spikes in the input gas contaminant levels. When the biogas is clean, excess CO2 can be removed using PSA or membrane systems. QPS provides both technologies.

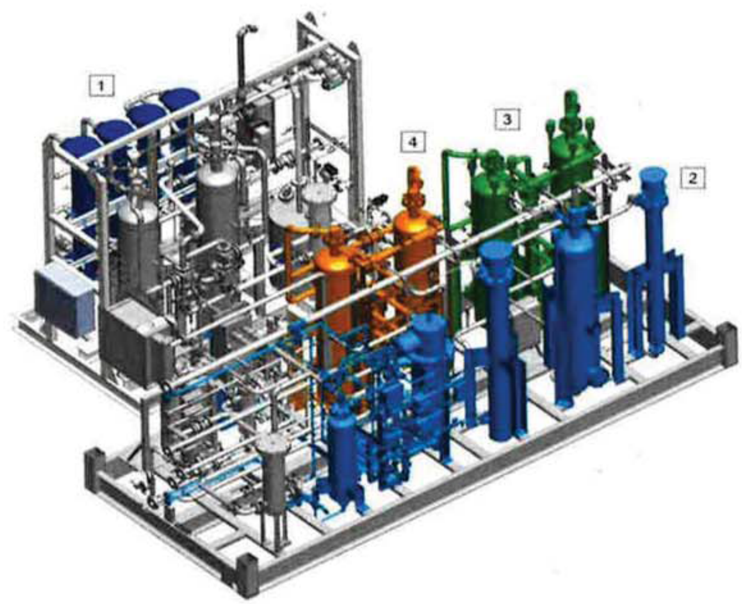

Figure 12: QPS Gas Cleaning system

7. Liquid fuel production

7.1 Plasma reforming

The clean and CO2 removed biogas and landfill gas is converted to syngas using a cold plasma reformer. The syngas leaving the reformer is hot and is used for drying the digestate coming out of AD system and then compressed to high pressure to be converted to liquid fuel in F-T reactor.

The Ceramatec non-thermal plasma system uses a novel patented process that utilizes a gliding plasma arc to create radicals, ions, and excited states (translational, vibrational and electronic) within the vaporized fuel stream to promote breaking of chemical bonds. In effect, the plasma acts in the same manner as a solid catalyst to catalyze the reforming of input hydrocarbons. Overall, the system acts as a plasma-catalyzed, autothermal reformer. Since the plasma is constantly renewed, it is not sensitive to sulfur or halogen compounds and these elements can be eliminated in post processing in the gaseous state. This unique approach processes a wide variety of fuels and provides for saturation of aromatics (i.e. hydrogenation), liberation of deeply bound sulfur (if present), and hydrolysis (hydrocracking) of large hydrocarbons.

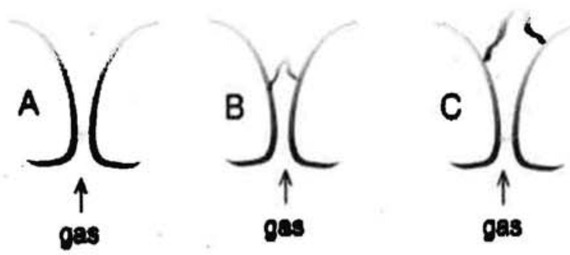

Figure 14:Generation of Plasma

The significant advantages the Ceramatec plasma fuel reformer has over conventional methods for reforming are fuel flexibility, sulfur tolerance, low power usage, low cost, and compact size. The Ceramatec plasma technology is an innovative, integrated process that exploits the thermodynamic advantages of steam reforming and combines it with the robust, highly energetic reaction zone characteristics of partial oxidation.

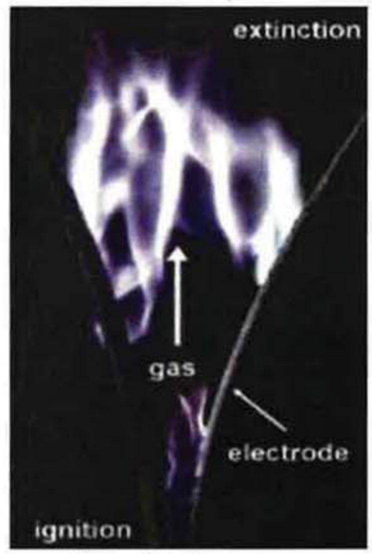

Figure 13: Plasma zone

The plasma is generated at the narrowest point between two or more electrodes (A). A fuel is expanded between the electrodes driving the electric arc along the diverging electrodes (B). As the arc reaches a point.

where the dielectric is too high to maintain the arc, the arc extinguishes, and a new arc forms at the narrowest point (C). This all happens in milliseconds. Thus, the arc is never stationary at any point long enough to cause any damage to the electrodes. The rapid renewal of the catalytic action prevents the problems of poisoning experienced by solid catalysts. Figure 17 is a picture of the plasma formation from a three electrode system.

Figure 15: Reformers for Ammonia Plant

The reformer uses a high voltage, low amperage input to generate the plasma. The transformers used are basically identical to those used for neon signs. This arrangement means that the power requirements are very low.

The reformer is flexible in size. Small laboratory units have been built for laboratory applications but units that can process 1 MMSCFD of high-BTU (contain NGL) natural gas were built for an ammonia plant in Peru. The five units pictured below were sold for US$1.25 million and are mounted on a common manifold to process 5 MMSCFD. Each reformer is ~15' high and 5' in diameter at its widest point. It operates at 50 psi.

Each reformer only takes about 4 kW to operate or a total of ~ 20 kW for processing the 5 MMSCF of natural gas.

7.2 Bio-fuel Production

ICC has patented a method for production of liquid fuel and wax from the syngas using Fischer-Tropsch process in small to medium scale plants.

Production of liquid hydrocarbons over a cobalt catalyst was first reported in 1913 in a patent granted to BASF. In the subsequent one century, catalyst technology has advanced from a simple cobalt oxide supported on asbestos to sophisticated, high-activity, highly-optimized cobalt and Iron catalysts.

The Fischer-Tropsch (FT) synthesis is a well-known process for synthesizing liquid hydrocarbons. This process converts synthesis gas (syngas) composed of H2 and CO at modest temperatures and pressures (e.g., 200-260° C., 15-40 atm) via hydrogenation and chain propagation to form hydrocarbons such as naphtha, diesel and paraffin wax, ranging in carbon number from C1 to about C100 with an equal amount of water and a small amount (1%) of alcohols in the presence of Catalyst. **Syngas can be produced by "reforming" natural gas (mainly methane) or biogas** (methane and carbon dioxide) obtained by anaerobic digestion of biomass or by gasifying biomass or coal. Typically, the raw syngas must be purified of contaminants which include H_2S, chlorine, ammonia, tars, and particulate matter.

The general chemistry of the Tropsch reaction is as follows:

$$nCO+(2n+1)H_2 \rightarrow C_nH_{2n+2} + nH_2O \quad (1)$$

F-T process consumes 2 moles of Hydrogen per 1 mole of Carbon monoxide to form CH_2+ blocks and connect the blocks in longer chains to form liquid fuel and wax; therefore, H_2/CO ratio of 2 is called stoichiometric ratio. Different sources of hydrocarbon produce syngas with different H_2/CO ratios and different CO_2 levels. H_2/CO ratio can be adjusted by water gas shift reaction where Carbon monoxide is combined with Steam in an exothermic reaction to release Hydrogen or reverse water gas shift reaction:

$$CO+H_2O \rightleftharpoons CO_2+H_2 \quad (2)$$

H_2/CO adjustment to 2 in a large plant is feasible due to economy of scale, but in small to medium applications H_2/CO ratio adjustment requires a bigger share of the project budget.

This invention utilizes gas stream at sub-stoichiometric condition $H_2/CO<2$ over a highly activated trilobe Cobalt catalyst in a fixed bed multi tubular reactor to produce F-T products such as liquid fuel and wax. This method will eliminate the need to water gas shift reactor, therefore small and medium syngas sources can be converted to fuel economically.

For the case of CRD project, 200 SCFM of landfill gas is cleaned and upgraded in PSA by removing CO_2. The outlet gas from the PSA will be 110 SCFMwith Methane concentration of 96% which can be considered renewable natural gas.

The renewable natural gas is reformed in plasma reformer. The syngas is utilized in a fixed bed multi tubular reactor over cobalt catalyst at 30 barg. The fuel production with 80% conversion rate will be 2343 liters per day or 855,290 liter per year of total product. 470,410 liter per year of the product will be bio-diesel which reduces 1261 tonnes of CO_2 emission annually. The wax shall be cracked in a refinery to lighter products. Each liter of wax will be converted to 1.9 liter of liquid fuel eventually. The CO2 reduction from the fuel originated from bio-wax will be 1960 tonnes per year.

The ICC bio-fuel system is shown in following figures. The outlet of the reactor is cooled in two steps. In the first steps, called hot trap, wax is removed from the gas. The second trap removes diesel and water from the gas by cooling the gas to ambient temperature. Fuel and water are separated from each other by gravity separators.

The tail gas after the cold trap contains considerable amount of CO2 which can sequestrated in Blue planet system and turned into light aggregate.

The typical arrangement of the ICC system and the data sheet for CRD project are shown below.

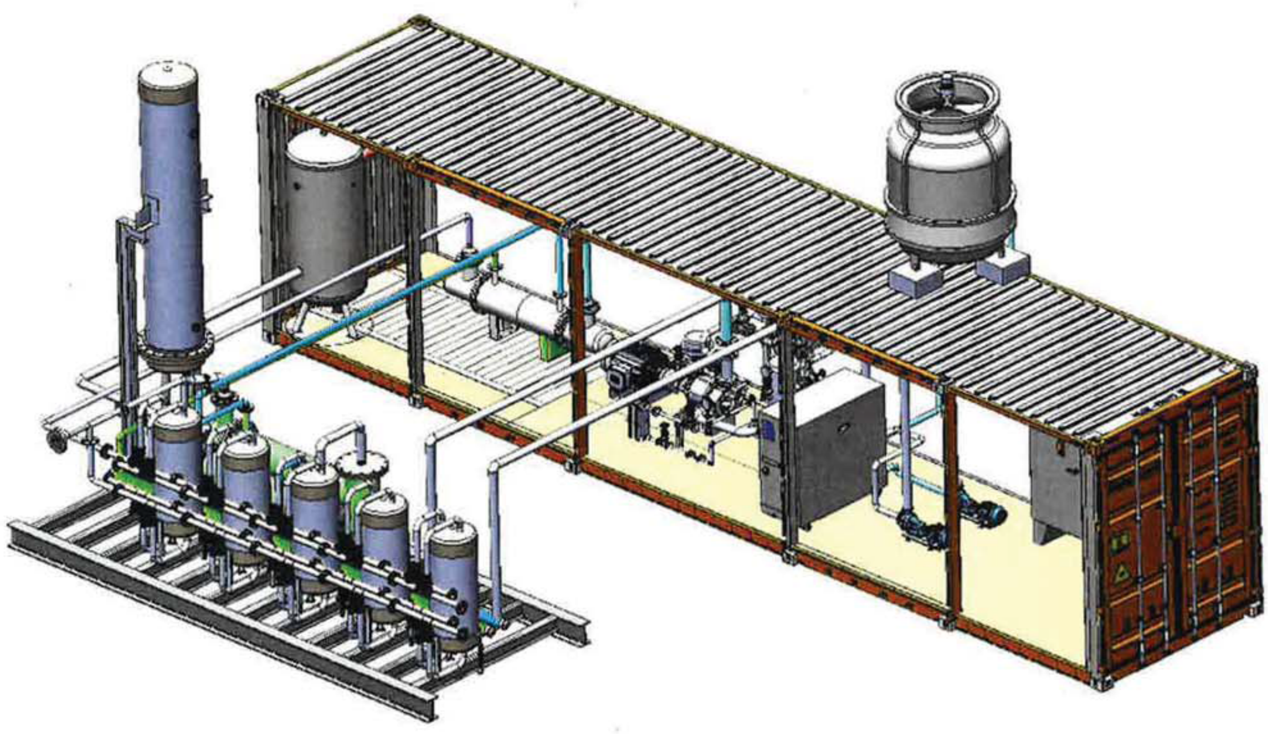

Figure 16: Typical Arrangement of ICC bio-fuel system

	1	2	3	4	5	6	7	8	9	10
Gas Flow rate (SLPS)	94.39	94.39	94.39	65.20	0.94	28.25	65.20	65.20	19.65	153.62
Gas Flow rate (SCFM)	200.00	200.00	200.00	138.15	2.00	59.85	138.15	138.15	41.63	325.49
Molar Flow rate (mol/s)	4.21	4.21	4.21	2.91	0.04	1.26	2.91	2.91	0.88	6.86
Gas Flow rate (L/s)	103.09	4.72	3.88	2.34	1.05	31.37	11.20	33.44	4.82	37.70
Liquid Flow rate (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liquid Flow rate (L/D)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wax Flow rate (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wax Flow rate (L/D)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pressure (barg)	0	30	30	30	0	0	3.45	3.45	3.45	3.45
T ©	25	150	75	30	30	30	-64.39	350	25	25
Composition (%)										
CO	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
H2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
CO2	35%	35%	35%	7%	0%	100%	7%	7%	0%	0%
H2O	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%
CH4	53%	53%	53%	77%	0%	0%	77%	77%	0%	0%
C2-C4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
C5+	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
N2	11%	11%	11%	16%	0%	0%	16%	16%	0%	79%
O2	0%	0%	0%	0%	0%	0%	0%	0%	0%	21%
Other	1%	1%	1%	0%	100%	0%	0%	0%	0%	0%

	11	12	13	14	15	16	17	18	19	20
Gas Flow rate (SLPS)	303.25	303.25	303.25	274.81	274.81	274.81	207.09	0.00	207.09	173.67
Gas Flow rate (SCFM)	642.56	642.56	642.56	582.29	582.29	582.29	438.79	0.00	438.79	367.99
Molar Flow rate (mol/s)	13.54	13.54	13.54	12.27	12.27	12.27	9.77	0.03	9.24	9.24
Gas Flow rate (L/s)	193.00	165.07	129.44	69.71	11.74	15.17	11.77	0.00	11.58	36.50
Liquid Flow rate (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	36.36
Liquid Flow rate (L/D)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3291.39
Wax Flow rate (g/s)	0.00	0.00	0.00	0.00	0.00	0.00	9.91	9.91	0.00	0.00
Wax Flow rate (L/D)	0.00	0.00	0.00	0.00	0.00	0.00	930.47	930.47	0.00	0.00
Pressure (barg)	3.45	3.45	3.45	3.45	30	30	30	30	30	5.33
T ©	500	388.1	245.4	35	150	194	208	200	200	90
Composition (%)										
CO	14%	14%	14%	15%	15%	15%	4.1%	0%	4.1%	4%
H2	29%	29%	29%	32%	32%	32%	9.8%	0%	9.8%	10%
CO2	4%	4%	4%	4%	4%	4%	5.8%	0%	5.8%	6%
H2O	9%	9%	9%	0%	0%	0%	15.6%	0%	15.7%	16%
CH4	0%	0%	0%	1%	1%	1%	0.5%	0%	0.5%	0%
C2-C4	0%	0%	0%	0%	0%	0%	0.1%	0%	0.1%	0%
C5+	0%	0%	0%	0%	0%	0%	0.6%	100%	0.3%	0%
N2	43%	43%	43%	48%	48%	48%	63.4%	0%	63.6%	64%
O2	0%	0%	0%	0%	0%	0%	0.0%	0%	0.0%	0%
Other	0%	0%	0%	0%	0%	0%	0.2%	0%	0.2%	0%

	21	22	23	24	W1	W2	W3	W4	H1	H2
Gas Flow rate (SLPS)	173.67	173.67	0.00	0.00	0	0	0	0	0.00	0.00
Gas Flow rate (SCFM)	367.99	367.99	0.00	0.00	0	0	0	0	0.00	0.00
Molar Flow rate (mol/s)	9.24	7.75	0.03	1.46	154.321	154.321	154.321	154.321	1.27	1.27
Gas Flow rate (L/s)	30.97	30.97	0.00	0.00	0	0	0	0	0.00	0.00
Liquid Flow rate (g/s)	36.36	0.00	9.81	26.56	2777.778	2777.778	2777.778	2777.778	22.86	22.86
Liquid Flow rate (L/D)	3291.39	0.00	996.97	2294.47	240000	240000	240000	240000	1974.93	1974.93
Wax Flow rate (g/s)	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00	0.00
Wax Flow rate (L/D)	0.00	0.00	0.00	0.00	0.00	0	0	0	0.00	0.00
Pressure (barg)	5.33	5.33	5.33	5.33	4	4	4	4	3.45	3.45
T ©	35	35	35	35	5	9.2	10.8	18.9	40	147.6
Composition (%)										
CO	4%	5%	0%	0%	0%	0%	0%	0%	0%	0%
H2	10%	12%	0%	0%	0%	0%	0%	0%	0%	0%
CO2	6%	7%	0%	0%	0%	0%	0%	0%	0%	0%
H2O	16%	0%	0%	0%	100%	100%	100%	100%	100%	100%
CH4	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%
C2-C4	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
C5+	0%	0%	100%	99%	0%	0%	0%	0%	0%	0%
N2	64%	76%	0%	0%	0%	0%	0%	0%	0%	0%
O2	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%

566336%
283.17344

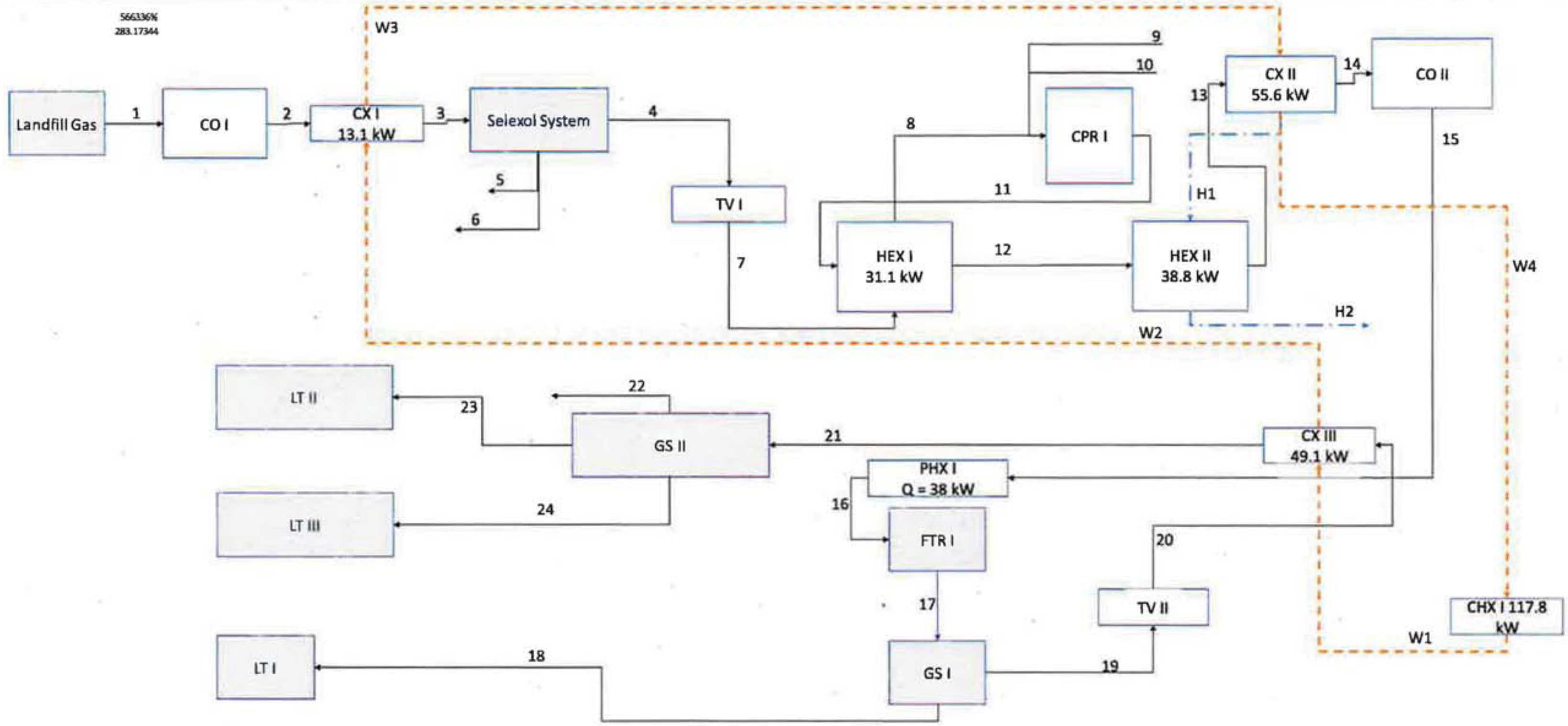

Figure 17: Fischer Tropcsh PFD for CRD Project

8. Financial Analysis

Please see attached Excel sheet for detailed technical and financial calculation of each technology. 3 cases are analysed hereafter.

8.1 Assumptions:

- The unit price for revenue streams of the facility have been assumed to be:

Table 4: Income unit price assumptions

Revenue	Unit	Fee
Gate Fees	$/tonne	110
Electricity	$/MWh	100
AAC concrete	$/m3	120
Lightweight Aggregate	$/Tonne	100
Fuel and wax	$/Liter	1
Mineral wool	$/Kg	1
Revenue from metal/glass recovery	$/tonne	250

- The operation and maintenance costs are detailed in attached Excel file. It includes following elements:

- Maintenance Parts
- Labour – Salaries
- Performance guarantee
- Management
- Insurance
- Sundries, fuel
- Waste disposal
- Operating Contract (Cost +10%)
- Raw material for AAC production
- Raw Material for aggregate Production
- Royalty

- Consumer Price Index (CPI) of 1% annually is applied to all revenue and cost streams.
- Tax has not been considered.
- It has been assumed that 30% of the budget will be provided by equity holders and 70% will be financed by bank or other financial institutions
- The interest rate of the debt portion of the budget has been assumed to be 6% over 20 years of payback.

- A life cycle fund has been considered equal to 4% of the equipment budget for the first year and increase equal to CPI for complete replacement of the equipment over 25 years of facility operation.
- Tax has been considered to be 22%.

8.2 Case 1- Power generation:

13 MW of electrical power is exported to the grid.

Item	First Year	Over 25 years
Project Budget	$ 123,589,074	$ 123,589,074
Equity investment	$ 37,076,722	$ 37,076,722
Annual operating cost	$ (4,746,415)	$ (5,911,040)
Annual income	$ 33,401,963	$ 37,246,269
EBIDTA	$ 28,655,548	$ 31,335,229
Life cycle fund	$ (3,475,982)	$ (3,926,915)
Loan cost	$ (7,456,784)	$ (5,965,428)
Tax	$ (3,899,012)	$ (4,717,435)
Cash flow	$ 17,299,752	$ 20,652,366
Distributeted dividend	$ 13,823,770	$ 16,725,452
Return of investment based on EBIDTA(Years)	4.3	3.9
Return on investment	37%	45%
Distributed dividend / Cash flow	80%	81%

8.3 Case 2- Power generation and concrete production:

Item	First Year	Over 25 years
Project Budget	$ 141,352,943	$ 141,352,943
Equity investment	$ 42,405,883	$ 42,405,883
Annual operating cost	$ (7,137,486)	$ (8,699,628)
Annual income	$ 35,949,535	$ 39,647,348
EBIDTA	$ 28,812,049	$ 30,947,720
Life cycle fund	$ (3,838,779)	$ (4,336,776)
Loan cost	$ (8,528,573)	$ (6,822,858)
Tax	$ (3,617,833)	$ (4,353,379)
Cash flow	$ 16,665,643	$ 19,771,483
Distributeted dividend	$ 12,826,864	$ 15,434,707
Return of investment based on EBIDTA(Years)	4.9	4.6
Return on investment	30%	36%
Distributed dividend / Cash flow	77%	78%

8.4 Case 3- Power generation and mineral wool production:

Item	First Year	Over 25 years
Project Budget	$ 160,122,095	$ 160,122,095
Equity investment	$ 48,036,629	$ 48,036,629
Annual operating cost	$ (8,954,577)	$ (10,681,061)
Annual income	$ 51,649,417	$ 55,440,966
EBIDTA	$ 42,694,841	$ 44,759,904
Life cycle fund	$ (4,538,779)	$ (5,127,586)
Loan cost	$ (9,661,015)	$ (7,728,812)
Tax	$ (6,268,910)	$ (7,018,771)
Cash flow	$ 26,764,915	$ 30,012,321
Distributeted dividend	$ 22,226,136	$ 24,884,735
Return of investment based on EBIDTA(Years)	3.8	3.6
Return on investment	46%	52%
Distributed dividend / Cash flow	83%	83%

9. Time schedule

The project can be divided into two parts:

- Front End Engineering and Design (FEED Study), Feasibility study, Environmental study and permits – one year
- Project Execution at site – 2 years

The project execution time depends on the result of feasibility study and the extent of project decided to be executed.

10. Results:

Please see "Summary-total" and "cash flow-total" tabs in attached excel file for details. The numbers in summary tab are average numbers for 25 years of operation. The main income source is the tipping fee.

The proposed facility can increase the income from the waste by 250%. It also increases the useful life of the Hartland landfill from 30 years to 200 years with current rate of waste disposal.

The proposed integrated solution will divert almost all of the waste from the landfill and convert it useful products and energy. The highlights of the proposed solution are:

- Diverting of most of the waste from the land fill so Hartland can be used for 200 years with current rate of waste production.
- Energy Self-sufficiency – All the power required for the operation is generated on site
- Negative Carbon footprint – The solution reduces the CO2 emission 25,684 tonnes annually which is equal to 5,514 passenger cars.
- Proven technology – Most of the core technologies proposed are proven technologies and have been practiced around the world for a long time.
- Modular design – The system can be extended gradually by adding modules and sub-systems.
- Financial feasibility – The project is profitable with fast return of investment

A preliminary budget estimation has been prepared for the CRD project and presented in attached Excel Spreadsheet *(see Appendix 1)*. The budget estimation for such a project requires deep feasibility study and a FEED study. Since ICC has been involved in all fields of technologies proposed and has access to valid and updated data in addition to good relation with suppliers, we have been able to put together an estimation that we believe is almost accurate. For an accurate project estimate a FEED study and feasibility study shall be performed. For the planning purpose 25% margin shall be considered. ICC suggests $200,000,000 to be considered as the planning budget.

The summary of the budget estimation is as following table. Land cost has not been considered in the budget.

11. CRD Approach

Although the technologies proposed in this document are integrated, the CRD may decide to install them in phases and in expandable modules. ICC recommends that CRD hires an engineering group with expertise in the waste to energy technologies. ICC can suggest engineering companies with expertise and experience in the field. The first stage would then be a Front end engineering study to be directed by the EPC contractor with input from the technology providers and the CRD internal engineer.

All of the technology suggested in the document are modular and the systems can be sized to meet the expected volumes of material to be handled.
From a funding point of view it is probable that two or three phases may be appropriate.
The options for funding and operation will depend on CRD's requirements.
We are open to any commercial arrangements that make sense.
We have filled in the forms required and these are appended, however the best financial model will be the subject of negotiation.

Gasification Pilot plant:

ICC has a 1 MW (thermal) gasification pilot plant available in Sidney. It was originally fabricated for R&D purposes and was installed in ICC's composting facility in Nanaimo. It was dismantled last year and moved to Sidney by the office of the ICC.
One of the unknowns is the best formulation for the bricketed feed source to the gasifier.
ICC has applied for an IRAP grant to evaluate the best RDF formulations.
Our gasifier cost $750,000 to manufacture. We would be pleased to install the gasifier at Hartland to evaluate the best fuel mix for a gasification plant in the project execution. At the moment, the gasifier only generates heat, but electricity generation module can be added if required. 1 MW high quality heat can be used in later phases of the project for drying purpose or the syngas produced can be added to power plant.

Appendix 1- Questions and Answers

CRD
Making a difference...together

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May 8, 2017

International Composting Corporation (ICC Group)
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Sidney, BC V8L 5W5

Delivered via email to: byran.imber@iccgroup.ca

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by ICC Group, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, the CRD IRM Review Team would be available for an hour-long teleconference the afternoon of May 11th at 4 p.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Can you provide a reference for a facility or system implemented by a single municipal jurisdiction or the private sector that incorporates all of the technologies that you have identified in your submission, to process the CRD materials (biosolids, yard and garden waste, SSO, MSW and Controlled waste) as identified in your submission?
2. Identify the range of materials that could be recovered and marketed from the mechanical pre-processing (MRF) of the MSW stream. What is the typical material recovery rate (% of material in incoming material stream that could be recovered for market) for Ferrous metals, Non-ferrous metals, HDPE, PET and other material streams that could be recovered?

3. Given that you have identified a Design Build approach as your preferred type of deal structure, how would you propose that the facility be operated and maintained over the long-term?
4. Identify a reference facility or example where MSW derived RDF converted to briquettes have been gasified.
5. Identify a reference facility or example where the proposed plasma reforming and the bio-fuel production technology, has been applied to biogas and landfill gas.
6. Can you provide an example of the use of the ash from the RDF gasifier in the production of concrete aggregate?
7. Provide an estimate of the potential size of the site that would be required for a facility that would house the technologies required to process the CRD materials as stated in your submission.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information

Best s,

J shua e ng
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

1- The proposed system is a combination of several technologies for processing waste streams. Each technology is feasible in certain technical and financial circumstances. As mentioned in section 4 of our proposal, a feasibility and front end engineering design study should be done as the first step of the project to identify the appropriate technologies for CRD's advanced integrated resource management. The final solution will be the outcome of the feasibility study endorsed by an engineering company.
   The proposed system is not necessarily the best solution. It is a combination of the most advanced technologies available in the market. As the result of the feasibility study, CRD may decide to perform the project in sequential phases to address the waste management issues in the order of importance and according to market value of the products.
   As we know, the combination of all the technologies as presented in the proposal has never been implemented in a single municipal jurisdiction or private sector. However, the combination of subsystems has been implemented successfully.
   Since we are working on a waste to energy project in the UK, we are investigating the potential technologies that can be integrated with the core technology and increase the added value of the products. We have identified a potential technology for using the ash for making mineral wool insulation which is much more profitable than other concrete or asphalt production in UK and European market. We haven't done any market research for North American market.

2- The materials which are recovered in the MRF are: Metals (Ferrous and non-ferrous), glass, heavy non-combustibles (Stone, concrete, and other construction wastes), and PVC. More than 95% of marketable and non-combustible material will be recovered.
   Almost all of the metal is recovered in the MRF. The ferrous metal is recovered by two stages of the over band magnets. Non-ferrous metal is recovered using eddy current separator. The metal removers are located downstream of the waste shredder, so the metals will be in small light weight pieces and can be removed efficiently. Small nails or clips trapped in the wood may pass through the MRF which will end in the ash of gasifier. If the ash is going to be used in value added products such as light weight concrete to mineral wool, then another stage of metal removing shall be added on ash stream.
   Glass and heavy non-combustible material are removed from the water using two stages of air separation with wind sifter followed by two stages of ballistic separators. Glass can be used as the raw material for production of mineral wool together with ash. Small amount of tiny particles of glass and non-combustibles may end the RDF which has no effect on the operation and efficiency of the gasifier.
   It is possible to recover PET, HDPE and rigid plastic from the waste using Optical units or manually handpicked by workers on two sets of conveyors. Since the plastics have high

calorific value and are mostly composed of volatile material with very low ash content, we prefer not to remove the plastics from the waste stream. The plastic is converted into the syngas ($CO+H_2+CH_4$) and burns in a separate combustion chamber to make steam and generate power. Only PVC shall be removed from the waste because of the chlorine content (PVC is the abbreviation for Polyvinyl chloride). The market value for recovered plastic is less than its value as a clean fuel in conjunction with organic waste.

3- We think that the facility shall be run by the CRD or a maintenance company owned or contracted by the CRD. ICC will provide all the required training, manuals, schedules and two year spare parts at the time of project hand over. ICC will also support the operation during the guarantee period after the project hand over. ICC is open to discuss the issue with CRD to find the best solution.

4- We are doing a similar project in the Corby, UK for generation of 10.8 MW of power from gasified, briquetted RDF. Our EPC contractor, Ameresco UK, led a 6 month engineering project for defining the project concept design, major equipment suppliers/specification and layout. Other parties involved in the FEED study were: ICC group (material handling and gasification), Air clean technology (steam cycle integrator), Cochran boiler (heat recover system), Siemens (Steam turbine/generator), Dustex (Flue gas cleaning system) and local construction/architecture companies. The project is now in detail design phase and power generation will start in late 2018.

In parallel we have been awarded a fund by National Research Council Canada (NRC) under the Industrial Research Assistance Program (IRAP) to do research on production of RDF suitable for gasification from MSW. In this research program, we are going to develop the formulation for additives that can enhance the quality of the syngas and decrease the contaminant emission.

There are many RDF gasification plants operating or under development. The biggest operating plant is Lahti Energia in Finland which generates 160 MW of electrical power. The biggest problem which operating RDF gasification facilities are facing, is the amount of particulate carried over into heat recovery boiler. Loose RDF is a fluffy material which is carried over very easily by the syngas to the combustion chamber. The high concentration of particulate in high temperature over heat transfer surface will cause deposition of the ash and decrease the efficiency significantly. High particulate concentration will also increase the cost of cleaning the flue gas.

Briquetting the RDF for other purposes such as combustion together with other fuel such as coal or biomass or using in cement kilns has been practiced for a long time. Other suppliers of gasification technology such as Nexterra are also considering this option and have the plants under development.

You can find attached the list of gasification plants under development as published by U.S department of energy.

5- We have been working with BC Bionetwork Network (BCBN) on development of a pilot landfill to liquid fuel pilot plant to be installed in village farms, Delta, BC. The FEED study was submitted to Epiphany energy in March 2017. Our unique small scale Fischer Tropsch conversion is patented. We are going to use Ceramatec's patented plasma reformer for converting the methane content of the landfill gas into a mixture of Hydrogen and Carbone monoxide. Ceramatec has done similar pilot plant project using their own catalyst and reactor design. Brigham Young University has been involved in development of the catalyst to be used in the project.

The Gas To Liquid (GTL) process for converting methane to liquid fuel is the same for natural gas, biogas, landfill gas or any other source of methane. A mixture of H_2, CO and other inert gases at high pressure and temperature react at the presence of Cobalt (or Iron) catalyst, so the H_2 and CO are combined together and form longer chain hydrocarbons. Fischer Tropsch process has been used over a century and there are many examples of operating plants in the world. In the case of landfill gas as the feedstock of the F-T process, extra gas cleaning systems and CO_2 removal systems are required upstream of the reformer to make sure sulfur and Siloxane compounds are removed from the landfill gas. Sulfur and Siloxanes can damage the Cobalt catalyst. About 35% to 45% of landfill gas and biogas is CO_2. High concentration of CO_2 can result in high methanation in the reactor, so the excess CO_2 shall be removed upstream of the reactor. The core of the F-T system (Reformer + reactor) is the same for all sources of methane. You can see a commercial scale landfill gas to F-T products in following link: https://www.enviaenergy.com/

6- Composition of ash from RDF gasification is similar to the ash achieved by incineration of the waste. The RDF ash has higher CaO and SiO_2 concentration and lower Fe_2O_3 concentration because of the separation of non-combustibles and metals in MRF stage and also because of bonding agent added for briquetting. MSW ash has been used as a raw material for making concrete blocks together with other additives.

RDF ash composition is ideal for making light weight Aerated Autoclaved Concrete (AAC) if some Silicon Oxide in the form of sand or crushed glass is added. Aluminium powder is also added to the mix together with cement, gypsum and lime powder. The slurry is moulded and then cured with medium pressure steam for 6 hours. The Aluminium powder acts as a catalyst and Hydrogen bubbles are released inside the concrete. When the concrete is cured and pressure/temperature is relieved, the porosity caused by small

hydrogen bubbles, makes the concrete very light (Floats on water). The amount of additives to be added to the ash is formulated according to the ash composition and is flexible. The medium steam is available in the facility by inter-stage steam extraction from the steam turbine.

7- **Total building area required for all the technologies proposed is 20,550 m^2. The site total area including the yard, outdoor storages, roads, bridge scale, and other utilities should be around 4 hectares. Details to be specified during the FEED study.**

QUESTIONS
AND
RESPONSES –

NET ZERO WASTE – WALKER ENVIRONMENTAL GROUP

CRD
Making a difference...together

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May 8, 2017

Net Zero Waste - Walker Environmental Group
P.O. Box 100
Thorold, ON L2V 3Y8

Delivered via email to: contactweg@walkerind.com and mateo@netzerowaste.com

Re: RESPONSES TO RFEOI NO. 16-1894 ADVANCED INTEGRATED RESOURCE MANAGEMENT (IRM)

We were pleased to receive your response to the Capital Regional District (CRD) issued RFEOI No. 16-1894. As noted in the RFEOI, the CRD desires to better understand the current market capabilities for an integrated waste management solution to manage residues from the Region's existing solid and future liquid waste management facilities.

We have completed an initial review of the submission presented by Net Zero Waste-Walker Environmental Group, with consultation from our IRM Consulting Specialist, Janine Ralph of HDR.

At this time, we have identified a few questions of clarification related to your submission. We ask that you provide a response in writing as of May 15th, 2017. In addition, should there be some benefit in discussing your responses, members of the CRD IRM Review Team would be available for an hour-long teleconference the morning of May 11th, at 9 a.m. PST. Please notify Margaret Reilly, Administrative Coordinator via email at mreilly@crd.bc.ca by noon on May 10th, 2017 regarding your interest in participating in this teleconference.

Responses are requested for the following:

1. Identify a reference facility(ies) which use the same technology and approach identified in your submission for the mechanical preprocessing of MSW to produce an organic fraction for digestion, a recyclable product for sale and residual materials for landfilling.
2. Can you provide an example of the preprocessing system and clarification of the feedstock material in terms of composition before and after preprocessing as a demonstration of its ability to perform?
3. Are you proposing to use the same equipment/process to sort MSW and SSO material? What would be the tolerance (percent contamination) of the SSO acceptable for your process?

4. The co-digestion schematic provided in your submission, indicates the use of manure and food grade waste as inputs to the AD component of your proposed facility. Will supplementary material sources outside of the control of the CRD, being agricultural and IC&I sourced food wastes, be required for effective operation of your proposed AD component?
5. Can you provide an example of the use of the slurry or digestate that remains after digestion as an organic fertilizer that can be land-applied as is? Can you provide an example of use of the solids from the slurry component which are separated out, as animal bedding?
6. Identify a reference facility(ies) which use the same technology (Gore Bio-dry) and approach identified in your submission for the management of biosolids.
7. Your submission provides a typical mass balance for the Gore composting component of your proposed facility. Can you provide a typical mass balance for other components, including the biosolids bio-drying component? Please identify the potential range of volume/quantity of bulking material that would be required for the Gore composting component of your proposed facility as well as the biosolids bio-drying component.
8. Similarly, the energy balance of one of your reference facilities is provided for the Gore composting component of your proposed facility. Can you provide any typical/reference energy balance information for other facility components? The same applies to discussion of GHG implications.
9. Your submission discusses the scalability of the Gore composting system. Clarify the ability of all of your proposed technologies to be scaled up or down to address the availability of CRD materials.
10. Your submission discusses the control of emissions related to the Gore composting system. Clarify the emissions controls related to all of your proposed technologies.
11. Provide further details regarding the quality/properties of the biosolids product indicated in your submission and its potential suitability for use as landfill cover material. Is your proposal that this material be used as daily, interim or long-term cover material?
12. Identify the potential range in capital and operating facility costs (in millions CAD) for the scale of facility as discussed in your submission.

Note: in your response to the above, please indicate which responses include commercially confidential information.

Your response should be provided via email to Margaret Reilly, Administrative Coordinator at mreilly@crd.bc.ca.

In the event that you have questions regarding the above, please contact our Administrative Coordinator, Margaret Reilly, at the above e-mail address. Responses will be provided in the next couple of days.

We look forward to receiving your information.

Section 22
[redacted]

for Joshua Frederick, P. Eng.
Manager, Project Engineering
Parks & Environmental Services Department, CRD

Cc: Larisa Hutcheson, General Manager, Parks and Environmental Services, CRD
Russ Smith, Senior Manager, Environmental Resource Management, CRD

Shari McCreesh

From:	Mateo Ocejo <mateo@netzerowaste.com>
Sent:	Thursday, June 08, 2017 1:06 PM
To:	Margaret Reilly; contactweg@walkerind.com; 'Mike Deprez'; Mike Watt; Brian Fuchs
Cc:	Joshua Frederick; Larisa Hutcheson; Russ Smith; Shari McCreesh
Subject:	RE: Responses to RFEOI No. 16-1894 Advanced Integrated Resource Management (IRM) - Response 2 of 2
Attachments:	Athens Dispoal DW SM Feb 22 2016.pdf; SWANA Presentation Minnesota Landfill Oct 2011.xps; Clean Soil Amender off Digestor1.JPG

....Email 2 of 2

The pre- processing of materials destined for the landfill can be completed using a shredder and screen in series with the contaminated organic fraction composted separately and used as ADC. This front end solution can also be used to pre-process other items ranging from mattresses to construction / demolition wastes to improve landfill operations and efficiencies.

Also attached is the previously discussed photo of the Clean Soil Amender which is an output from the local Sea-breeze Digester in Delta. While this is not the same material as a compost (from the Gore Cover System) it does have demonstrated agricultural applications and benefits.

Thank you,

Mateo

From: Mateo Ocejo [mailto:mateo@netzerowaste.com]
Sent: Thursday, June 08, 2017 12:55 PM
To: 'Margaret Reilly'; 'contactweg@walkerind.com'; 'Mike Deprez'; Mike Watt (mwatt@walkerind.com); Brian Fuchs (bfuchs@wlgore.com)
Cc: 'Joshua Frederick'; 'Larisa Hutcheson'; 'Russ Smith'; 'Shari McCreesh'
Subject: RE: Responses to RFEOI No. 16-1894 Advanced Integrated Resource Management (IRM) - Response 1 of 2

Margaret,

Please find below the response for the Net Zero Waste / Walker Team RFEOI clarifications requested. I spoke with Josh yesterday and he informed me that the consultants had already taken some of their questions & answers back to the board to present their high level findings. He informed me that the attached response could still be added to our package and may be of interest to staff or the future review committee for any upcoming RFP. Attached please find:

1) "MSW MBT Deyerling Fuchs" – This 16 page report outlines how the Gore Cover System can be used in MSW Mass Reduction and Stabilization, Drying and even Increase of Net Calorific Value (for residual use as a Waste Derived Fuel). A number of reference facilities are included in this report.
2) "Greenhouse…." – This file responds to the GHG emission reduction possible through the use of our solution
3) "SG Biosolids Albany Summary" - City of Albany Biosolids Composting Demonstration Project – Reference Information
4) "MSW Gore Description" – This file is 4 pages and further outlines the Gore Cover Application for pre-treatment of MSW
5) "Gore Cover Clean Compost…." – This file is much of what was already submitted in our original Walker / NZW EOI Response

6) "BIFA ECO....." -This file shows the cost competitiveness of the Encapsulated Solution when Compared to other options – The Mechanical "Pre-Treatment" we have discussed in our proposal and as is shown in various locations throughout the attachments including this one involves the use of a slow speed shredder along with a coarse screen and a picking line. We are proposing to use some of the same equipment for the MSW and SSO Material for this pre-processing area. Following pre-processing materials will be kept separated so that each batch is under its own cover and biosolids / food waste / msw-organics can each be tracked separately and kept free from cross contamination.
7) "SC Gore NA References" – Burtec California Reference along with expanded reference list showing multiple N.American Facilities
8) Pre-Processing References and a Photo of the Clean Soil Amender off the local Sea-breeze Digester (Delta) will follow in a subsequent email due to size constraints

It should be noted that supplementary sources of organic material such as Agricultural and ICI organics are not *required* but could provide additional benefit if included in a program such as we have proposed. An example of the use of digestate on land application at a farm along with solid use as animal bedding can be seen in the Sea-breeze Digestion Facility located at the Sea-breeze Dairy Farm in Delta, BC. We would be happy to arrange for a tour of CRD staff should there be an interest.

The scalability of the Gore System surpasses all other solutions in that Gore Covers can be pre-fabricated to any size or configuration. This allows the CRD to start small and to grow the operation as need demands and as the budget can afford. A small solution could be up and running within 4 months of contract signing so as to process the easiest curbside SSO materials locally. This would provide immediate cost savings when compared to the status quo of exportation of organics by ferry to the mainland for processing. As a reference for the potential range of capital costs we can reference the NZW – Abbotsford Facility where approximately **$5.5MM** was invested in the site equipment and infrastructure allowing for a total processing capacity of 20,000 TPA (similar to what would be expected for the CRD). The Digestor for the liquid fraction would cost **around $6.5MM** and could process 3,300 tonnes/month of liquid organics (based on data from Delta, BC). More information is needed before accurate operating costs can be provided for each solution however a range for between $70-$90/T for the solid waste stream would be realistic for the sizes we are discussing. The higher side of the range would be if the proponent had to cover the capital costs and the lower side would be if the CRD was able to cover some of the infrastructure spending on their land. The Digestor operating costs would be significantly lower and would largely depend on the contracts achieved for the gas/power produced.

Best regards,

NET ZERO WASTE
Mateo Ocejo, P.Eng
604.868.6075
Net Zero Waste

From: Margaret Reilly [mailto:mreilly@crd.bc.ca]
Sent: Monday, May 08, 2017 1:26 PM
To: contactweg@walkerind.com; mateo@netzerowaste.com
Cc: Joshua Frederick; Larisa Hutcheson; Russ Smith; Shari McCreesh
Subject: Responses to RFEOI No. 16-1894 Advanced Ingegrated Resource Management (IRM)

Please find attached our letter in response to your submission for RFEOI No. 16-1894.

Regards,

Margaret

Margaret Reilly | Administrative Coordinator
Facilities Management & Engineering Services | Parks & Environmental Services
Capital Regional District | T: 250.360.3046
mreilly@crd.bc.ca

Mechanical-Biological Treatment – Solid Recovered Fuels

Mechanical-Biological Waste Treatment – an International Overview –

Lothar A. Deyerling and Brian E. Fuchs

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For more than 20 years, W. L. GORE & Associates has been in the waste treatment business. Our first experience started right after the reunification of Germany supplying the first GORE Cover into a Soil Remediation[1] project. Within a short time period thereafter, the first demonstration projects were implemented for the category of Separate Organic Waste (SOW) treatment, leading to the many successful full scale operating plants seen today. From there, the cover technology was expanded into the category stabilizing the organic fraction of Municipal Solid Waste (MSW) and at the same time input material from waste water sludge (biosolids) and various other organic wastes. The cover is supplied directly or by an authorized supplier network of global sustainable partners to the end user. Today, the cover technology is used for the purpose of organic treatment in more than 15,000 tons per day including stabilization, mass reduction and drying before energetic use throughout Europe, Asia Pacific and North and South America. The cover technology provides the operator a high performing technology that meets the regulation at a low investment cost utilizing a flexible design from the standard heap version to fully encapsulated plants and capable of CO_2 equivalents of 12 kg/t input material [8].

The following will discuss how the GORE Cover technology is capable to successfully optimize the process of treating organic waste for meeting strict stabilization and emission regulations, while producing a high quality output finished product (RDF, CLO or stabilized material).

The Solid Waste Treatment business unit began at the companies Munich location during the same time period with the reunification in Germany. The first large on-site remediation plants where built in Germany, Italy, USA and France using the ePTFE membrane due to the solid capabilities of the waterproof yet breathable membrane – even in adverse climate regions:

[1] > 5 Mio tons of contaminated soils have been biologically remediated using GORE Cover

- air permeable (aeration) to maintain aerobic conditions
- external water tightness (up to a water column of 5 m) and internal moisture retention
- mechanically robust and long lasting of the covers (up to eight years)

It was becoming very clear that the similar features and benefits observed using the ePTFE membrane in soil remediation projects would also be used for composting of organic waste. However, the obstacles to become a certified technology according to the TA Luft[2] and BimSchV[3] took at first some references in place and the proof on meeting European Requirements. The reference plants proved that the ePTFE membrane cover is capable of being biologically inert, chemically resistant, temperature resistance (-200 - +260 °C), and UV resistant in order to withstand the very aggressive biological environment in the biological processing of organic waste from MSW. In addition, by combining the cover with positively aerated control process to conduct the biological treatment of Municipal Solid Waste (MSW) delivered a high level of control and produced a quality end use product:

- reliable hygenization of the organic matter
- measurable and consistent mass reduction
- primary step to the stabilized material process
- secondary step in the drying process of MSW
- increase in the Net Calorific Value of RDF (NCV)[4]

Stabilization and Biodrying the MSW waste before mechanical post treatment and the creation of Refuse Derived Fuels (RDF) were an obvious treatment application for the cover. Extended trials and research on existing installations in Germany (Oldenburg, Bremen, Uckermark) and Italy (Tuscany, Campanula, Sicily) became very active and with regards to meeting new regulations. These reference plants, along with Hungary and new European Countries joining European Community, were selected due to the representative and new infrastructure to support the path forward for MSW treatment, as well as proving the need to fulfil the European Landfill Directive (1999/31/EC) on the landfill of waste [2].

The first approaches in the treatment of MSW with plants sized between 5 – 10,000 tons per annum (tpy) using the high performing ePTFE membrane solution. The technology was selected due to the proven background of having a simple handling solution, flexible and expandable design, high level of performance, and a realistic investment cost structure with regards to a sustainable waste treatment approach; all the while operating in compliance with the Waste Framework Directive (2008/98/EC) in the MSW treatment [7]. Today, the technology is being used in Recycling Parks (MBT plants) that offer a daily treatment capacity of 2,000 tons (> 600,000 tons per year of MSW) which meet the stabilization parameters, including, and not limited to, the reduced treatment times in order to achieve DRI[5] or AT4[6] [11].

[2] Air (Technical Instructions on Air Quality Control

[3] Federal Immission Control Ordinance

[4] CEN Draft Standard …*solid fuels prepared form non-hazardous waste intended to be recovered as energy in incineration or co-incineration installation according to … CEN / TS 15359…* Reference: SUEZ Environnement 2007

[5] Dynamic Respiration Index, DRI = 500 mg O_2 kf DM-1 h-1, Italy

[6] Example AT4 < 10 mg O_2/kg/DM, Poland

1. Germany

One of the first approaches of the treatment with the membranes in Germany were carried out by stabilizing MSW before applying to an incineration plant. The result showed:

- observed success to emission reduction during the treatment phase
- significant mass reduction of the different prepared MSW streams
- reduced treatment time

However, there is continued work being performed to evaluate the impact of uncontrolled increase of the NCV[7] of the material.

Table 1: Changes of waste characteristics due to treatment

	Calorific Value	Ash content	Glowing loss	DS-content	Water content
	%				
MSW	+53,6	+11,5	-4,4	+37,9	-50,4
MSW likewise Industrial waste	+20,9	-12,6	+3,0	+8,2	-22,6

Source: Horn, A.: Trockenstabilat – Versuch '97, Blockland Deponie Bremen, Ingenieurbüro Horn & Müller, Berlin, 1997

Taking these experiences into consideration, the first larger facilities on a continuously processed MSW stream were implemented in Italy in the early 1990's. The plant sizes averaging 35,000 tpy of MSW provided a fair and solid foundation to the collection of data and experience using the technology. Several case studies were developed to study the impact on air quality, water quality and finished product quality. These studies include odour measurements confirming an odour reduction of > 90 % atop of the membrane [3]. A study to show a clear separation of storm/rainwater from process/leachate water can be achieved. And the monitoring of the final product as a finished stabilized waste that can put onto the nearby landfill as daily cover.

Figure 1: MBT and landfill, one of the first plants in Italy using side walls and GORE Cover starting operation with 35,000 tpy; Handling Cover: manually

Figure 2: Stabilized organic fraction on the landfill meeting DRI

Source: BioE s.r.l., Milano, Italy

[7] Net Calorific Value

Table 2: Test Results on DRI

Analyzed material after 21 days treatment	Volatile Matters	Index of the breathability of the compost (statically index – method IPLA)
	% p/p s.s	mg O_2/kg SV • h
Biostabilized organic fraction (1A)	46.7	498
Shredded and biostabilised residual waste (1B)	43.3	431

Resulting from these experiences in the years 2001 – 2008 a large landfill remediation project took place in the north of Italy. The landfill was closed 30 years prior and was now polluting the ground water and required to be remediated meeting European Landfill Requirements. The excavated 110,000 ton per year of MSW was grinded, put onto the positive aeration under cover, stabilized, screened, and compost like output (CLO) that met stabilization criteria DRI put back on the new landfill as a daily landfill cover. The remaining over sized material with a high calorific fraction was bundled and used for energetic use.

Figure 3: Handling Cover : First generation Mobile Winder

2. Hungary

Large visitor tours form Hungary went to Italy to seek solutions for the adoption of a national strategy on MSW. The group visited reference plants in Tuscany and Naples area. With the experienced gained from the visits and the support with ISPA and SAPARD funds from the European Union, the Hungarians developed a strategy and new standards as a new member to European Union for the treatment of MSW.

The leading University carried out case studies also with regards to the potential use of Refuse Derived Fuel (RDF) from the MSW [4]. Based on these studies, the Hungarian strategy for the treatment of MSW were founded which included the stabilization and mass reduction of the organic matter plus energetic use of the valuable fraction. What followed next were first coordinated efforts of getting a more than 110 municipalities (reflecting 250,000 + inhabitants in a decentralised area) to work together to create the first Recycling Plants. The recycling plant concept is a cooperative agreement to develop a single serving processing canter; for sorting and reuse recycling and stabilization of the MSW, and separate organic waste stream for composting.

The National Waste Management Plan[8] will implement a landfill tax starting Jan 2013 with a significant fee and, according to the preparation of the new National Waste Management Plan, the AT4 is the guiding landfill criteria, will be implemented not later than 2015.

Figure 4: 160,000 tpy, Recycling Park, MSW, Started operation in 2009, Production of high quality compost from separate collection, RDF for the cement industry, Stabilized organic towards landfill; Handling Cover: Winder on the push wall

Figure 5: 150,000 tpy, 2 Recycling Parks, MSW, Started operation in 2010, Serving 107 municipalties (330,000 inhabitants); Handling Cover: Winder on the push wall

Figure 6:

Biodrying of the MSW fraction for further treatment (mechanical) before used as RDF in the cement industry; Fine fraction stabilized according to Hungarian waste legislation; Handling Cover: Winder on the push wall

A high value outcome of the MSW treatment strategy is the production of RDF from MSW. The potential destinations for the high calorific fractions from MBT plants and the specific requirements were recently presented during the ASA Recycling Days 2012 [10]. The following examples show the final material after biological treatment with a high NCV (> 18 MJ/kg):

[8] Ministry for the Environment and Country Development (KvVm)

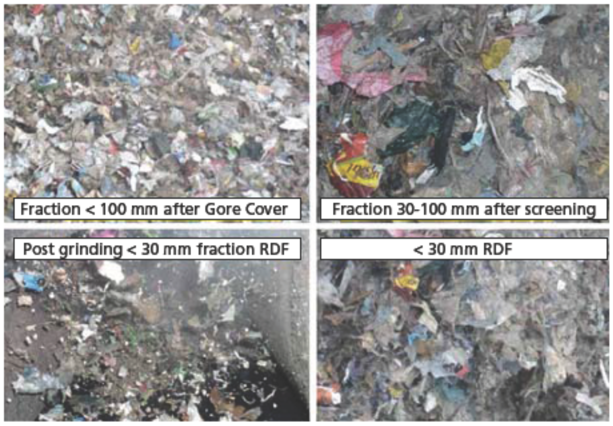

Figure 7:

Top left – the fraction < 100 mm after the biodrying, Top right – the screened material 30-100 mm and Bottom left and right – after the post grinding before supply to the Cement Industry

Source: Alexa, L.: Mixed Waste Treatment Technology – MBT, Szent Istvan University, Gödöllö, Hungary, 2011

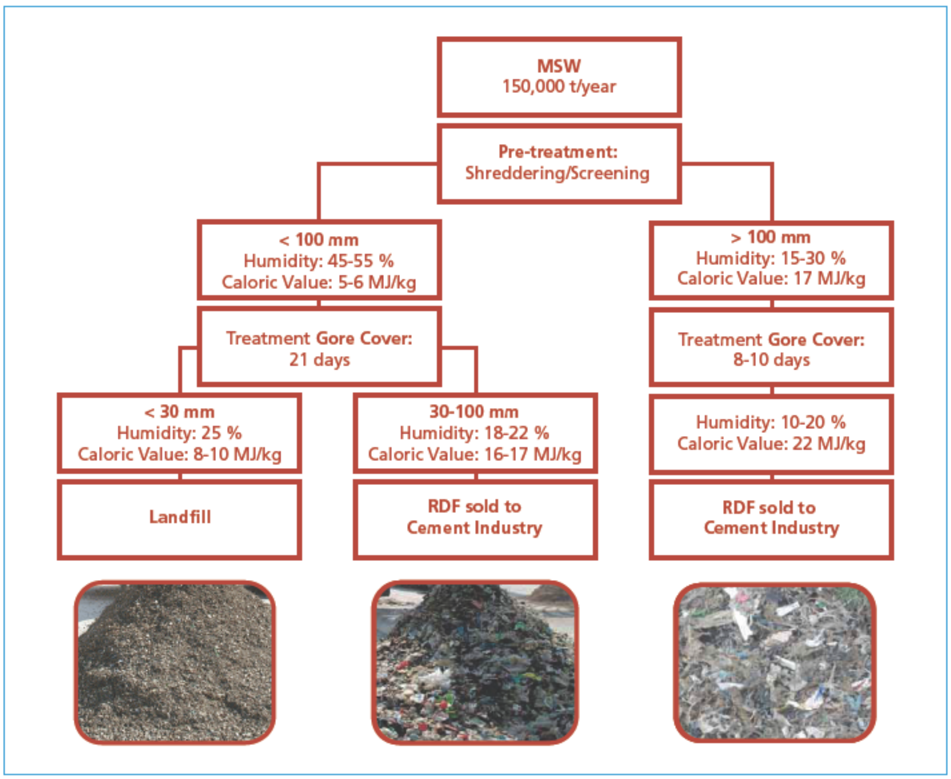

Figure 8: Low and high calorific value material depending on size and treatment time

3. Austria

Existing plants using sophisticated encapsulated mechanical technologies can also experience emission problems and poor finished product quality can also benefit from the technology as retrofit or expansion of the existing technology. A plant in Austria employing a highly mechanized tunnel technology required an upgrade on emission control suffering from high odour complaints from the neighbours and poor final product quality due to inefficient treatment process. The plant processed on average 30,000 tpy with an ongoing treatment time of six to nine weeks.

The objective of the plant was to solve the emission (odour) situation in the maturation area and to enhance the final stabilization of the organic fraction before landfill meeting AT4 < 7 mg O_2/g DS. It was decided to add the technology as a secondary treatment process post tunnel processing, which after the GORE Cover has been installed; no more odour complaints were notified for more than five years of daily use and producing a higher quality finished product.

Figure 9: MSW post treatment facility

4. Poland

Schäfer presents information on the latest developments with regards to the Municipal Waste Act in Poland starting 1st January 2012 of the waste disposal obligation [13] and with enforcement starting 1st July 2013.

The obligation to reduce the large amount of biodegradable MSW put on the landfill has allowed for a high amount of sorting stations/ transfer plants to be established in a short time period. Using a phased in approach, the sorting stations/ transfer plants are using state of the art sorting lines and is a significant portion of the treatment goal which can be achieved right away. Following those sorting plants and meeting the treatment goal for the landfill disposal criteria [2] a number of MBT plants have been already been built and set in operation with great results using the cover approved by the Polish Ministry of Environment.

With the following examples we want to demonstrate an efficient and sustainable approach using unique designs, both heap model and a box design (Biodgma).

The Biodegma Butterfly technology offers the sustainable and solid track record throughout the treatment of MSW in the past 15 years and is utilized whenever a building or tunnel solution are demanded. Both the GORE Cover heap and Biodegma box design are accepted designs currently in use in Poland.

At one reference the client is using both designs to cost optimize the treatment process for meeting standards utilizing a flexible design and being profitable on one location for the production of RDF.

Figure 10:

Organic fraction from MSW, first plant in Poland in Spring 2009 starting operation with 12,000 tpy, Fraction 0/80 mm, AT_4 < 10 mg O_2/kg/DM; Handling Cover: Biodegma Butterfly

Source: SUTCO Polska; Biodegma GmbH, Germany

Figure 11:

Additional capacity in Poland in Spring with 28,000 tpy using both, the butterfly version in the intensive phase and the heap model in the maturation in order to achieve Landfill criteria, AT_4 < 10 mg O_2/kg/DM; Waste code: 19 05 99 code of fraction after bio stabilization of fraction < 80 mm; Handling Cover: Biodegma Butterfly

Source: SUTCO Polska; Biodegma GmbH, Germany

Example:

Total input at the front gate:	~ 170,000 tpy
Input:	MSW
Pre treatment:	Grinding, < 300 mm, screening
Input Biological treatment 0/65 mm:	~ 95,000 tpy[9,10] – stabilization[11]
Input Biodrying treatment 65/300 mm	~ 65,000 tpy biodrying RDF[12]

Biodegma GmbH, located in Ludwigsburg, Germany provides reliable, high performing services in consulting, engineering and training in all categories of organic waste treatment, specializing in MSW stabilizing and production of RDF material. Biodegma has key competence in order to support and meet the requirements set in Municipal Waste Act in Poland. Biodegma has key references with regards to MSW treatment in Germany, Poland, Spain, Slovenia, Turkey and Middle East.

9 Started of first treatment capacity in Dec 2011; final capacity already at site; construction in progress

10 The change with regards to the size of the material from < 65 mm to < 80 mm will become effective starting 01.09.2012.

11 landfill AT4 < 10 mg O_2/kg/DM, Waste code: 19 05 99

12 Drying < 20 % Humidity, post grinding > 30 mm, cement industry, 19-21 MJ/kg

Figure 12:

Installation of first treatment capacity fraction 0/65 mm stabilisation before landfill AT_4 < 10 mg O_2/kg/DM, 2^{nd} phase for 100,000 tpy in start up phase adding 26 heaps; Handling Cover: small mobile winder

Figure 13:

Biodrying Plant Poland; Fraction 65/300 mm, End user: Cement industry, 30 mm < 20 % humidity; Handling Cover: winder on the wall

Source: EQUIPO, Ksawerów, Poland and Biodegma GmbH, Stuttgart, Germany

5. Italy after the early beginnings

Italy, currently has the largest plant using GORE Cover which started operation in autumn last year with a daily input stream of 2,000 + tons of MSW.

This plant concept dates back to 1994 offering the longest history in respect to using the cover as the treatment technology for fulfilling the MSW treatment strategy. Up until this plant was built, the largest significant plants were treating up to 1,700 tons per day of MSW. The next step into a large MBT plant and using the cover as the key in the biological treatment was not only based on the trials that have been carried out but also on the requirement of Best Available Technique (BAT[13]) meeting both, technical and economical sustainable requirements. The site utilizes a state of the art Mechanical Pre-treatment equipment and utilizes a very thought through logistic stream with a high level of performance for both, the pre treatment and biological process at the site.

[13] The term *best available techniques* is defined in Article 2(11) of the Directive as *the most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in principle the basis for emission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and the impact on the environment as a whole*.

Figure 14: Intensive rot – stabilization, drying of < 65 mm fraction

Mass data on the example site:

Total input at the front gate:	620,000 tpy
Input:	MSW (no separate collection)
Pre treatment:	Separation of PET, Plastic, Glass, Paper/Cardboard, FE/NE in total > 50 % of the input material
Input towards Biological treatment:	~ 310,000 tpy
Mass reduction fraction <65 mm:	~ 90,000 tpy (biological process)
RDF (Refuse Derived Fuel):	~ 70,000 tpy
Landfill material at the end	~ 150,000 tpy (< 25 mm fraction)

Surface/dimensions:

(Reception, Mechanical pre treatment)	- 10,000 m²
Biological treatment area	- 14,400 m²
Post treatment	- 1,000 m²

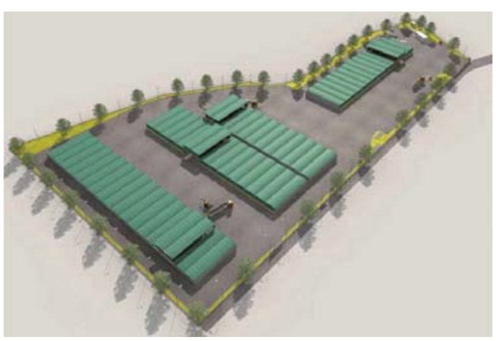

Figure 15: The biological plant from a sketch to reality – 2,000 tons per day MSW

Source: BioE s.r.l., Milano, Italy

Figure 16: Biological Treatment GORE Cover showing 45 out of 60 modules during construction; Handling Cover: Hydraulic frame

Source: BioE s.r.l., Milano, Italy

Figure 17:

Fraction < 65 mm after mechanical pre-treatment in the biological process for 21 days; During ongoing emission testing

Source: BioE s.r.l., Milano, Italy

Odour measurements are continuously monitored to prove validity of the performance of the plant – a very necessary part of the sustainable waste treatment on the site.

After the total treatment on the site, less than 30 % of the total received MSW in a fraction < 25 mm have been put as a stabilized material on the landfill meeting DRI criteria and fulfilling the emission requirements.

In this application, the cover is also fixed on a frame and sealed onto the side walls with strong forces – air tight and the only way to release the humidity is through the membrane. A key characteristic of the membrane is moisture control, which performing under such conditions reduces emissions, enhances drying and stabilizing of the organic fraction. This tunnel design delivers a total encapsulated plant solution, and if needed can be combined with adjacent supporting structures for pre-treatment (receiving, sorting, mixing/ grinding in a solid building, requiring air treatment due to fully encapsulated), while MBT or composting process supplied into the technology, reducing the infrastructure costs. This cover encapsulated design has been successfully in use for more than three years now.

Our Italian partner lately installed the first large facility (MBT plant) in South America with a treatment capacity of 130,000 tpy in the first phase using the comprehensive know-how gained throughout the learning and development during the past years. The plant technology after pre treatment is again using heaps with side walls and handling of the GORE Cover with a mechanized winding machine.

Figure 18:

Handling Cover: Big Winding Machine, mobile

6. Summary

The performance zone of the cover application in some numbers:

Sizes of plants	2,000 tpy	→	200,000 tpy	→	630,000 tpy	→	1,000,000 tpy[14]
Ton per week	39 tpw		4,000 tpw		12,000 tpw		20,000 tpw
Ton per day	~ 7 tpd		~ 670 tpd		~ 2,000 tpd		~ 3,200 tpd

References	MSM, SOW, BS, Landfill Remedation 250 + plants
Treatment experience	15,000 tons per day + (min. 12 months in operation)
Staff	80,000 tpy MSW plant = 2 workers
Buffer zone	from 50 m (example: UK, London, 35,000 tpy) onwards
Energy consumption	MSW 1.0 kw/t input → 4.5 kw/t

The article demonstrated a solid background and a great performance in affordable waste treatment technology. Achieving the strict stabilization criteria's with the technology in various countries, the know-how of the partner and fit for use GORE Cover made its way from the early days. At the given experience, not only in Germany, a cost effective and sustainable approach by choosing treatment technologies is key in the future MSW treatment to our point of view. However, even if a fully encapsulated plant is desired to what ever reason – reference plants even on this specific request are available.

Figure 19: Active Plants using GORE Cover

[14] Plant under construction

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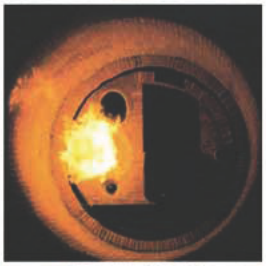
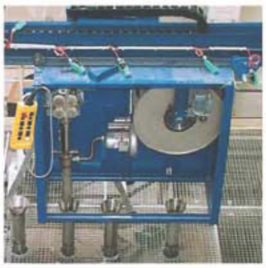


Composting and Fermentation of Biowaste
– Contribution to reduce Greenhouse Gases –

Carsten Cuhls

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1. Introduction

Utilization of bio waste is very popular from the view of resource recovery and regenerative energy production as well. Composting and anaerobic digestion (AD) have become a common treatment option for bio and garden waste in the European Union. Garden waste composting in windrows is state-of-the-art in all the EU countries and covers about half of the treatment capacity in Germany. Other half of the facilities is turned and aerated in-vessel composting. Some plants are combined with an AD step for producing biogas. In future the amount of organic waste treated by composting is expected to increase in order to recycle the carbon and the nutrients in the waste material. Microbial degradation of organic substrate entails the production of various gases such as carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3). Some of this gases are classified as greenhouse gases (GHG), thus contributing to climate change. Currently only few GHG emission data from composting facilities are available. The dynamic and diffuse nature of GHG production and emission from different composting systems challenge the quantification of these.

2. GHG measuring project, Definitions

Between 2006 and 2011 GHG emissions of about thirty different composting plants were analyzed in a research project founded by the German Federal Environmental Agency (Umweltbundesamt). All plants were continuously measured several times in different seasons and over a period of at least one week; parameters: TOC (Total Organic Carbon, continuous FID method), CH_4 and N_2O (continuous NDIR method), NH_3 (discontinuous absorption in H_2SO_4). The representative sampling was complex and laborious because of different types of emission sources: active point (stack), active area (biofilter) and passive area (windrow surface). Large compartments of biofilters were temporary capsulated by thin foil, open windrows were capsulated by large wind tunnel of 10 meters length (Figure 1), samplings in pipes or from stacks were done easily like a typical point source method (Figure 2).

Goals of the research project carried out:

- Identification of relevant emission sources,
- Quantification the GHG emissions,

- Summarize all emission sources with respect to the plant throughput (= emission factor),
- Emission control and mitigation of GHG,
- Guideline and recommendations into the process management for operators.

Figure 1: Sampling method: active open Source (left: biofilter), passive fugitive source (right: windrow)

Figure 2: Sampling method: active point source (pipe)

3. Emission factors and discussion

First of all it is obvious that most emissions various in a very wide range. The emissions depend on input material: substrate (bio, garden, yard, kitchen, sludge) and season, C:N ratio, water content, structure and porosity. And the emissions depend on process conditions seriously: oxygen saturation, temperature, pH-value. So it is very important to regulate the right process by mixture and homogenization of input materials, dimensions of rotting piles, anaerobic potential in case of digester output, active aeration for aerobic milieu, turning and watering.

Table 1: Steps and Types of composting plants, considered in figures

Plant No.	Abbreviation	Steps and Types of composting plants
[1]	Anl+Aufb	material delivery + pre-processing
[2]	KOA g (FrischK)	In-vessel composting (fresh compost)
[3]	KOA g (FertigK)	In-vessel composting (finished compost)
[4]	KOA tg (FertigK)	In-vessel + open composting (finished compost)
[5]	KOA sM	membrane cover composting, aerated
[6]	KOA o (Bio+Grün)	open windrow (bio+garden)
[7]	KOA o (Grün)	open windrow (garden)
[8]	VA	anaerobic digestion
[9]	VA + NR g	anaerobic digestion + in-vessel curing
[10]	VA + NR o	anaerobic digestion + open curing

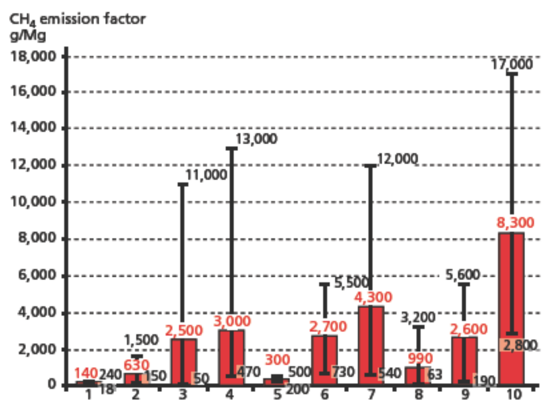


Figure 3:

Methane (CH_4) emission factors – means and ranges

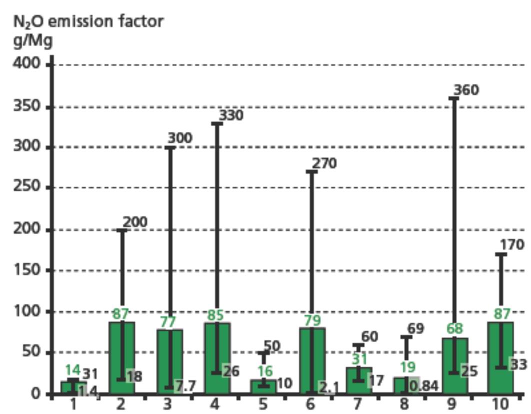


Figure 4:

Nitrous oxide (N_2O) emission factors – means and ranges

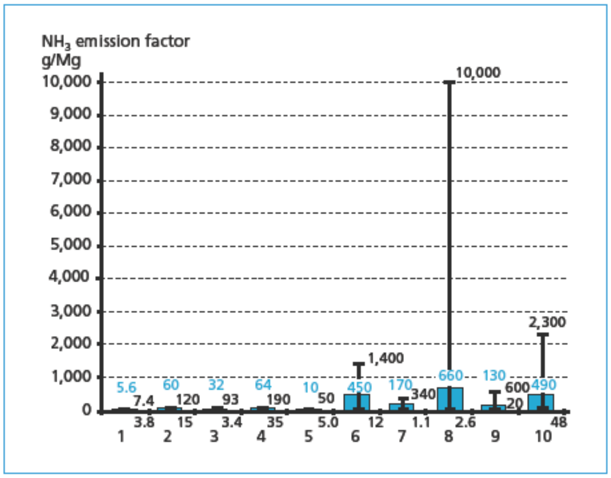


Figure 5:

Ammonia (NH_3) emission factors – means and ranges

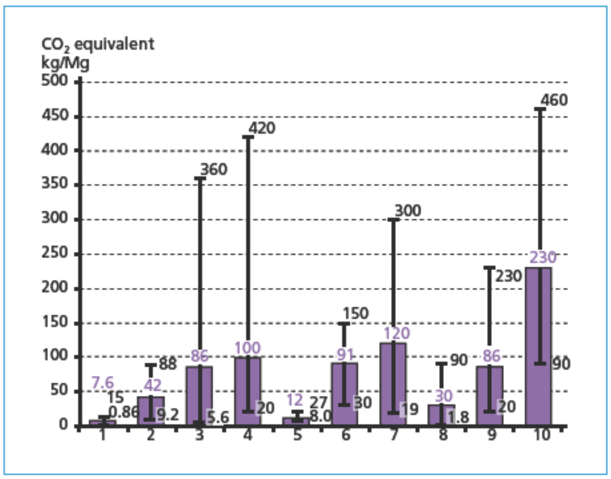


Figure 6:

Carbon dioxide equivalents (CO_2eq.) – means and ranges

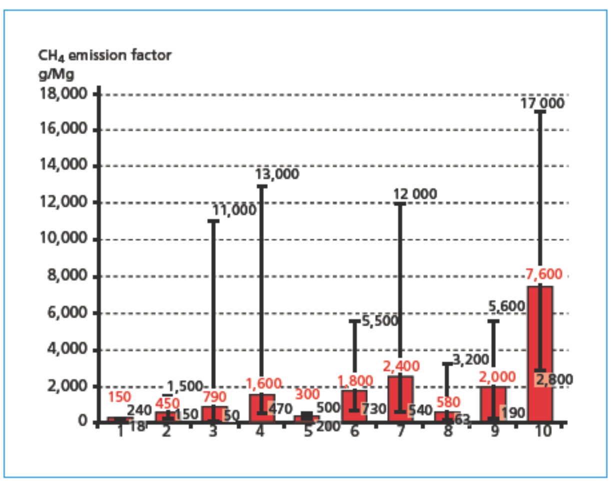


Figure 7:

Methane (CH_4) emission factors – medians and ranges

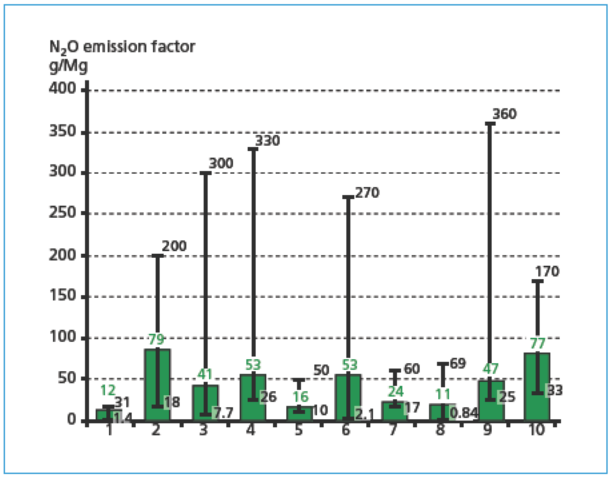


Figure 8:

Nitrous oxide (N_2O) emission factors – medians and ranges

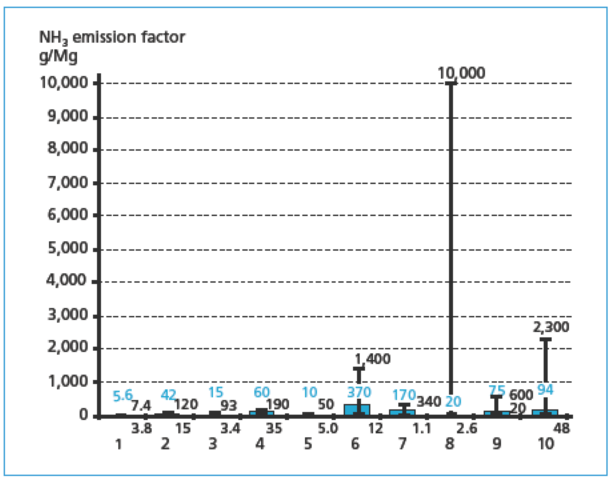


Figure 9:

Ammonia (NH_3) emission factors – medians and ranges

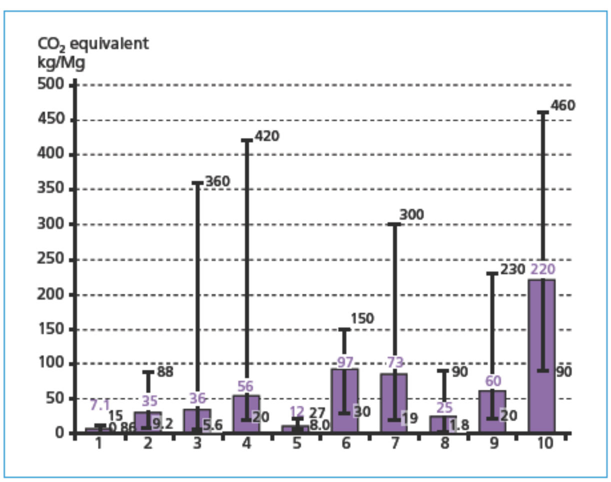


Figure 10:

Carbon dioxide equivalents (CO_2eq.) – medians and ranges

The emission of GHG like methane and nitrous oxide could be minimized only in the biological process of degradation. Methane occurs under anaerobic conditions (high temperature, no oxygen, high water content). Nitrous oxide is produced by nitrification ($NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$) especially in the curing phase under temperature < 45 °C.

In all biological systems methane is minimized by sufficient aeration, best done with positive aeration and smart geometric dimensions, e.g. easily performed by cover systems.

In all biological systems nitrous oxide is reduced by high C:N value > 25 and temperature > 45 °C in the curing phase.

In all biological systems ammonia emissions are reduced by high C:N value < 25, low pH-value < 7 and low temperature < 60 °C. Plant [8] is equipped with a thermal drying for the digestate, therefore ammonia emissions are on that high level of 10 kg/Mg input. In biofilters NH_3 is absorbed and mineralized around 60 %, but formation of secondary N_2O is negative

For AD systems aerobization and in-vessel curing with active aeration is recommended. All storage tanks with anaerobic liquid and reactive prozess water should not be open but connected to the biogas system. To reduce high ammonia emissions it is necessary to have acid scrubber before biofilter.

Additional exhaust treatment cannot reduce GHG methane and nitrous oxide. High pH-level > 7 and high temperature > 45 °C lead to rising ammonia emissions. Low C:N ratio < 17 supports both, decreasing ammonia and nitrous oxide emissions. Acid scrubbers are useful and sometimes – in case of composting after AD – necessary to absorb ammonia before biofilter. It helps to reduce disturbing the accumulation of N-compounds and the new formation of nitrous oxide in biofilters. Normally sulfur acid is used and the product is ammonia sulfate that could be used as fertilizer.

Deficiencies in dimensioning and missing maintenance cause major problems in biofilter operation. Efficiency of degradation is different depending on the organic substances in the waste gas, so it may be reasonable to differ emission control of VOC (Volatile Organic Compounds) into nonmethane VOC + methane. The biodegradability of methane is very low (mean value 10 %) compared to the mixture of various NMVOC from biological waste

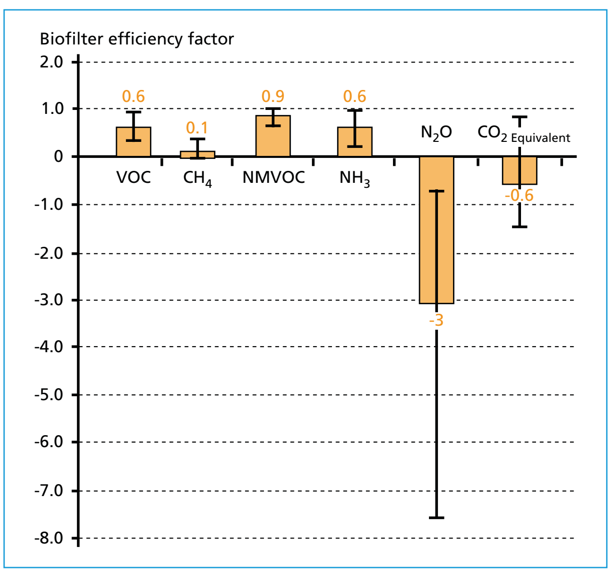


Figure 11:

Biofilter efficiency factors for VOC, CH_4, NonMethaneVOC, NH_3, N_2O, CO_2eq.

treatment with a high rate (mean value 90 %). The degradation of ammonia in biofilter results in high increase rate of nitrous oxide in the clean gas. This is the reason for negative GHG efficiency (CO_2eq.) of biofilters with high ammonia load (Figure 11).

4. Conclusions and summary

Gewitra company carried out R&D project of the German federal environmental agency (UBA) on determining gaseous emissions from different types of large scale treatment plants for bio waste in Germany: open windrow, in-vessel systems and composting plants with integrated anaerobic digestion step. Measurement data of emission control are VOC (FID), CH_4, NH_3 and N_2O; emission factors and CO_2-Equivalents (CH_4 factor GWP 25, N_2O factor GWP 298) will be calculated as well.

Arrangements to optimise/minimise process emissions to air are Guidelines: *Good practice of composting*. They are well known by operators but sometimes superior necessities swing a decision. On principle for a well done process the material characteristics should have structure (high porosity) and water content of max. 65 – 70 %, the C/N ratio should be 25 – 35 to avoid ammonia and nitrous oxide emissions. Important process parameters are water content: 50 – 60 %, O_2-supply, turning cycles (intensive phase 1 – 2 times per week, phase of declining activity 0.5 times per week). Windrow profile: height max. 2.50 m (positive aeration), height max. 1.50 m (passive aeration), best available technology must be decided case-by-case.

Depending on the rotting milieu there is an opposed formation of CH_4 (anaerobic) and N_2O (aerobic) within the biological process. It is a principle that minimisation of the CH_4 and N_2O emissions to air is the result of the right material characteristics and the right process parameters for the entire time of aerobic treatment. Because there is no end-of-pipe technology to reduce CH_4 and N_2O in exhaust gas treatment, like scrubber and biofilter.

Arrangements for the emission control with acid scrubber and biofilter are shown to the components. For methane (CH_4) there is only very less < 10 % in biofilters at suitable air loads > 50 $m^3/m^3 \cdot h$. For N_2O there is no reduction, but rather new generation due to NH_3 degradation in biofilter. For nonmethane Volatile Organic Compounds (NMVOC) there are normally good reductions of easily degradable compounds (~ 90 %) at well operating biofilters and suitable air loads < 100 $m^3/m^3 \cdot h$. Ammonia (NH_3) has deposition rate 60 % in biofilters, accordingly to new generation of N_2O and NO, declining pH value -as a result of nitrification-reinforces accumulating NH_4. Acid scrubber (H_2SO_4) precipitates NH_3 > 90 %, mostly necessary after anaerobic step. Ammonium sulfate from acid scrubbers could be used as fertilizer in agriculture.

Emission factors from composting in practice:

CH_4	low: 100 – 200 g/Mg	average: 250 – 1,000 g/Mg	high: 1,200 – 1,800 g/Mg
N_2O	before biofilter: ~50 g/Mg	clean gas after biofilter: ~100 g/Mg	
NH_3	before biofilter: ~200 g/Mg	clean gas after biofilter: ~20 g/Mg	

Emissions of CH_4, N_2O and NH_3 from anaerobic digestion could be higher than from composting.

CO_2-Equivalent (data from CH_4, N_2O) from biological treatment of bio waste is in the waste gas ~ 30 – 40 kg/Mg and in the clean gas after biofilter ~ 70 – 80 kg/Mg. The estimated specific contingent for CH_4, N_2O and NH_3 from composting/digestion is rather low (< 0.5 % of total national emission).

City of Albany Biosolids Composting Demonstration Project

SG Mobile™ System using GORE® Cover

Summary from the full report: Albany Biosolids Compost Demonstration Project, prepared by Kennedy Jenks Consultants March 8, 2016

The City of Albany, OR, W.L. Gore & Associates and Sustainable Generation collaborated to conduct a Biosolids Compost Demonstration Study utilizing a Covered Aerated Static Pile (CASP) composting process. The City is interested in assessing technologies and processes for improving its current sludge treatment and handling program at its Albany-Millersburg Water Reclamation Facility.

The objectives of this Study included the following:

- Evaluate the optimal mix ratio by weight and by volume of sludge to the bulking material;
- Confirm the finished product will qualify as Class A Exceptional Quality biosolids compost;
- Assess the effectiveness of odor and emission control from the CASP process;
- Identify design, operational, and environmental considerations for the CASP process for the City;
- Confirm treatment time for system sizing, construction and design considerations

<u>Project Team:</u>

City of Albany
Sustainable Generation LLC
W. L Gore & Associates
Kennedy Jenks Consultants

Composting Batch Process Summary

On 5 November 2014, Batch 1 underwent Phase 1, active composting, for approximately four weeks. During this time, the heap reduced in size due to compaction and a reduction in solids quantity through decomposition. On 3 December 2014, the cover was removed and the heap was "flipped" by moving it to the side with a front end loader and then reassembling it back in the same location with the goal of ample mixing and incorporation of the toes of the heap. The heap was re-covered and underwent Phase II, maturation or curing composting, for two more weeks. On 15 December 2015, the pile transitioned from Phase II (curing phase) to Phase III (finishing phase). During finishing, the cover was removed and set aside. Phase III normally occurs for 14 days but in this case, it was 20 days to accommodate the Christmas holiday. Once Phase III was complete, the compost was set aside and stored unscreened for at least four weeks.

Batches 2 through 5 underwent similar processing from January 2015 through August 2015. Batches 1 and 2 were screened using rented equipment to ½-inch minus and the larger screened-out "overs" were used as part of the bulking material in Batches 4 and 5. The same sludge feedstock of WAS was used in each batch except for Batch 4, where solids directly from the Cannibal Interchange Reactors were used as this variable. The demonstration was extended through the summer to check for differences in composting due to varying environmental conditions. A detailed description of all five batches, with photos of the composting process, is provided in the full report Albany Biosolids Compost Demonstration Project, and prepared by Kennedy Jenks Consultants March 8, 2016. A summary of all five batches is presented in the Table 1 below.

Table 1: Comparison of Batch Composition and Process Duration

Parameters	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
Duration (Days)	56	56	55	50	56
Sludge Type	WAS	WAS	WAS	IR	WAS
Carbon Type	Wood waste/ Hog Fuel	Wood waste/ Hog Fuel/ Green waste	Wood waste/ Hog Fuel	Wood waste/ Hog Fuel/ Overs	Overs/ Wood waste/Hog Fuel/ Overs
Sludge:Carbon Ratio (By Weight)	1:2	1:2	1:2	1:2	1:2
Total Weight (Wet Tons)	202	203	202	195	191

Abbreviations:

WAS = Waste Activated Sludge
IR = Interchange Reactor Sludge

Summary of Desired Compost Characteristics

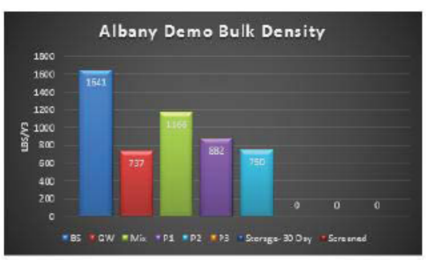
Sampling data comparing the initial mix (prior to Phase I) and final product (following Phase III) after screening for each batch are summarized in Table 2.

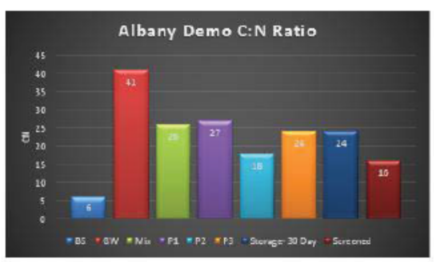
The initial mix is targeted to meet the following:
• A beginning carbon to nitrogen ratio (C:N) of approximately 25-30:1,
• A moisture content of approximately 55-65%, and
• Adequate structure material (bulking agent) to optimize the mixed material porosity, approximately 3 inch minus shredded wood waste, hog fuel or wood chips.

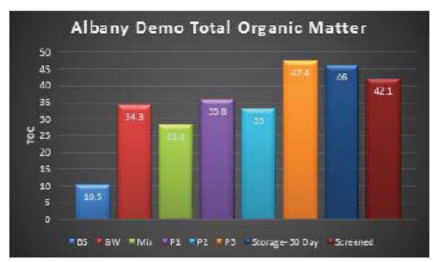
The final compost product is targeted to meet the following:
• An ending carbon to nitrogen ratio (C:N) of approximately 20-15:1,
• A moisture content of below 50%, and
• Carbon Dioxide (CO_2) respiration below 1.0.

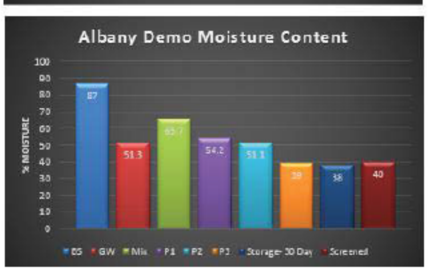
As the demonstration project moved from Batch 1 to Batch 5, the early batches were used to gain an understanding of the following:
• Train the operations team to run the technology,
• Understand the feedstock components and identify the optimal mix ratio of dewatered sludge to bulking materials,
• Understand how the mix ratio influences the system control settings, and
• Monitor and record, time and temperature requirements for meeting Class A biosolids requirements.

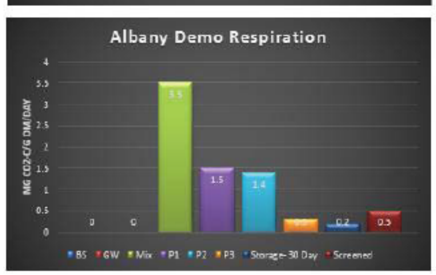
Results from Batch 5:

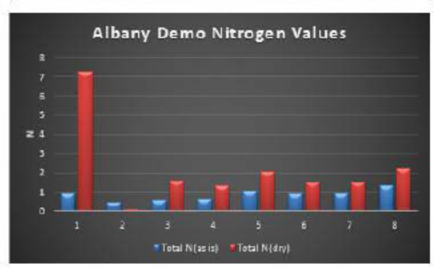












As the demonstration project moved to later batches, it was apparent the City gained confidence in running the demonstration equipment independently from the SG team. Batch 5 was clearly the best batch in terms of demonstrating a proper mix ratio, control settings, temperature profile and the lab reports indicate an ideal initial mix and the screened compost produced a high quality and fully stabilized finished Class A biosolids compost.

Table 2: Summary of Compost Characteristics in Batches 1 Through 5

Parameters	Batch 1		Batch 2		Batch 3		Batch 4		Batch 5	
	Time of Sampling									
Time of Sampling	Initial Mix	Screened	Initial Mix	Screened	Initial Mix	Screened	Initial Mix	Screened	Initial Mix	Screened
Bulk Density (g/cm^3)	0.58	*	0.66	*	0.52	*	0.54	*	0.69	*
Moisture Content (%)	57	58	63	58	66	43	60	33	66	40
pH	6.4	5.8	6.4	6.5	6.2	6.5	7.0	6.0	7.4	6.1
Organic Matter (%)	28.3	30.7	31.2	30.7	27.7	47.9	32.3	43	28.4	42.1
C:N Ratio	24	25	30	25	29	19	36	17	26	16
Respiration ($mgCO_2$/ g/day)	**	0.6	7.1	0.6	**	0.8	4.9	1.0	3.5	0.5
Total N (dry) (%)	1.4	1.6	1.4	1.56	2.2	1.6	1.1	1.9	1.6	2.2
Total P (%)	*	0.51	*	0.45	*	0.69	*	0.50	*	0.58
Total K (%)	*	0.51	*	0.48	*	0.55	*	0.45	*	0.47

Abbreviations:

* = Not sampled because data was not of value

** = Inadvertently not tested

Summary of Results

The data in Table 3 shows the compliance of all five batches with the 40 CFR Part 503 regulations for Class A biosolids compost

Table 3: Summary of Compliance with 40 CFR Part 503 Regulations

	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
EPA 503 PFRP Requirements Met[a]	YES	YES	YES	YES	YES
EPA 503 VAR Requirements Met[b]	YES	YES	YES	YES	YES
EPA 503 Pathogens[c][d]	PASS	PASS	PASS	PASS	PASS
EPA 503 Pollutants	PASS	PASS	PASS	PASS	PASS

Notes:

(a) Requires the sludge is maintained at 131°F or higher for 3 days

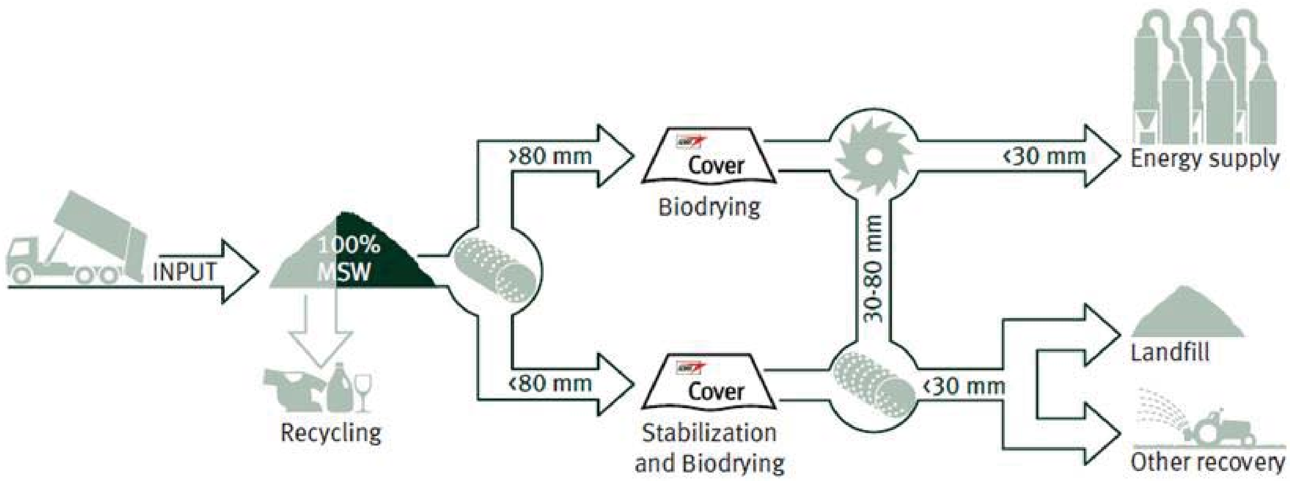
(b) Requires biosolids to be kept under aerobic conditions at temperatures over 104°F for at least 14 days with an average temperature greater than 113°F

(c) Passed for Salmonella *Spp.*

(d) Also passed Class B biosolids limits and thus could be used directly for land application

GORE® Cover for MSW

GORE® Cover technology provides an ecological and economical solution for the treatment of Municipal Solid Waste (MSW). MSW is no longer just a waste product to be placed into a landfill. Rather, MSW is a valuable resource which can be converted for energetic use into Refuse Derived Fuel (RDF), Waste-to-Energy (WTE), and biomass or as a bio-fuel source to power industry. By substituting fossil fuels with MSW, many benefits can be achieved; such as the reduction in landfill usage and reduction in green house gases, the organic component in MSW can also be converted into stabilized compost. Use of GORE® Cover technology for stabilization and drying of MSW is a cost effective solution and is supporting a clean environment strategy.



__Typical Process Description__

Receiving and Sorting: MSW is received and sorted to remove all recoverable materials, such as plastic, glass, metal paper products, electronics, and hazardous materials…other. The remaining MSW is screened and divided into fractions.

Bio-drying: Separated MSW with little organic material and greater than 80mm are processed through the GORE® Cover technology for the purpose to achieve <20% moisture content and a caloric value >20Mj/kg. The dry MSW is reduced to <30mm and sold as feed stock for energetic use; for example, as fuel to a cement kiln.

Stabilization and Bio-drying: Separated MSW with little to high amounts of organic material and less than 80mm are processed through GORE® Cover technology. First the material is to be stabilized according to the regulation, such as the EU Council Directive 99/31/EC, or for that specific country or local regulation, such as AT4 or IR1000. The dry and stabilized product can be further separated to produce a compost or can be used a daily cover at the landfill. While other dry and stabilized material is then sold to the energy intensive industries, such RDF or WTE.

Experience in MSW Stabilization and Bio-drying

Approximately 1.5 million tons of MSW are currently being treated through GORE® Cover technology. The primary use of the GORE® Cover technology had been for stabilization of the organic material according to the regulations, or Mechanical Biological Treatment (MBT). However, as demands for alternative fuels and technological advances in waste to energy infrastructure has developed; Gore has seen an increase demand to dry MSW after, or in lieu of, stabilization.

There are several factors that influence the design, process control and treatment time to achieve the desired results for stabilization and drying of the MSW. These include the following:

- Waste Profile: the types and quantities of differing materials in the collected waste stream
  - Organic Materials (Food and Green Waste)
  - Paper Products
  - Glass
  - Metal
  - Textiles
  - Wood (C & D)
  - Electronics
  - Other…
- Separation Infrastructure: the type and level of pre-sorting to remove recoverable materials
  - Single Stream Collection
  - Curb Side Separation
- Pre-treatment Process: grinding, mixing and sizing (screening) of materials for treatment
- Stabilization and Drying Technology: technology of choice
- Weather: climatic conditions for operations
- Regulations and Permitting Requirements: influences design and operations
  - Emission Reduction
- Location: sensitivity to neighbors for traffic, noise and odors

It is our experience that these factors, along with the size of prepared material and the input moisture (humidity) dictate the treatment process. There are many facilities processing MSW in as little as 2-3 weeks and as long as 10-12 weeks depending on the end use requirements and influencing variables. On average, the majority of the MSW plants have an average treatment time of 4 weeks.

Screen Size	Input Moisture	Output Moisture	Process Time[1]
Greater than 80mm	55%+	25% or below	2 weeks
Less than 80mm	55%+	25% or below	4 weeks
Less than 80mm	45%+	25% or below	3 weeks
Less than 80mm	35%+	25% or below	2 weeks

[1] Minimum process time experienced to achieve desired results.

Typical Operating Process Description for Composting, MSW Stabilization and Bio-drying

The process begins by mixing the organic waste and bulking (wood waste, yard waste and screened overs) materials received. The moisture content, particle size, porosity and carbon/nitrogen ratio are adjusted to optimal conditions for processing. Processing then begins utilizing proprietary technology by Gore. The total process can take from 2 to 10 weeks depending on the local regulations and end user requirements. The compost pad can be divided into multiple sections accordingly for the purpose of moving, remixing and alternative process control scenarios. As the process proceeds, the volume of material and mass of material is reduced through compaction and moisture losses.

The GORE® Cover technology utilizes forced aeration coupled with a semi permeable membrane cover. A standard heap is 26 feet (8m) wide at the base, 165 feet (50m) long and 10 feet (3m) in height, each heap contains approximately 1,000 cubic yards of composting material. The number of heaps is determined based on the total capacity of the project. The heaps are the same size in multiple Phase design. Each heap may have a concrete head wall to retain the material in each heap on the pad. Aeration trenches are built under each heap. These trenches serve as ducts to provide air to the heap and also to collect leachate coming from the heap. Each heap has a blower to provide air to the material via the aeration trenches. The trenches are cast in concrete to provide a solid impervious surface. The entire compost pad consists of a concrete slab or asphalt, which allows for the collection of all storm water and leachate. Gore has additional alternative designs which includes bunker, fixed frame and lifting system designs.

The GORE® Cover system is widely approved as an in vessel composting system. The cover membrane has a pore structure sized to selectively influence the treatment process. The system allows carbon dioxide to pass through the membrane but prevents odors and emissions from escaping. The membrane will not allow rain water to pass through to the organic material.

After a heap is built, the GORE® Cover is placed over the entire heap. Various winding machines for installation and removal of the cover is available. Once the cover is installed and secured in place, temperature and oxygen probes are installed through the cover into the material. The blowers are controlled by a Programmable Logic Controller (PLC) to optimize the process using readings from temperature and oxygen sensors under the cover.

GORE® Cover is recognized or approved as an “in vessel” organic waste treatment system for composting and stabilization of MSW in various countries worldwide. The GORE® Cover in conjunction with the air distribution system optimizes the composting process. Moisture control is granted by providing protection from rain and sun as well and at the same time controlling the amount of moisture loss through the cover. The blower system maintains pressure under the cover insuring homogeneous air distribution through the material.

MSW Stabilization and Bio-drying Facility Example:
Pictured below is a 150,000 ton per year MSW recycling park in Gyor, Hungary using the bunker wall design in a 3 week process for stabilizing and drying of MSW and a heap design in a 8 week process for composting.

Sustainable Generation and GORE® Cover
Membrane Covered Positive ASP Composting Technology

W. L. Gore & Associates

The company began in 1958, when Bill and Vieve Gore set out to explore opportunities for Fluorocarbon polymers, especially Polytetrafluoroethylene (PTFE). Within the first twelve years, Gore had wire and cables on the moon and operations worldwide.

Today, the Gore enterprise is comprised of approximately 10,000 associates in 45 locations around the world. Annual revenues top $3.0 billion USD. Gore fluoropolymer products provide innovative solutions throughout industry, in next-generation electronics, for medical products, and with high-performance fabrics. Gore has repeatedly been named among the '100 Best Companies to Work for in America,' and the culture is a model for contemporary organizations seeking growth by unleashing creativity and fostering team-work.

While Gore may be best known for their GORE-TEX® fabrics, all Gore products are distinguished in their markets. Gore technologies and fluoropolymer expertise are unsurpassed.

GORE® Cover Introduction

The GORE® Cover technology is the most widely distributed composting system in the world with over 200 facilities located in more than 20 countries treating more than 3.5 million tons of organic waste annually. The system has proven to provide a low risk, cost effective solution which can sustainably process a wide range of organic waste in the most varied climate conditions while controlling odors and emissions. More importantly, its simplicity in both construction and operation ensures that a facility can be maintained many years into the future without escalating operating costs which is not often the case with other technologies. Facilities can be built to any size and can also be easily expanded after construction which provides the most flexibility to the end user during the development of its organics processing facility. Composting is the most logical component in any organics management program and we hope to add your project to the growing list of commercially and publically operated facilities across the globe that have chosen the GORE® Cover system as the best choice for composting their organic waste.

The GORE® Cover has been proven in facilities processing quantities from 2,000 to over 200,000 ton/year, in a variety of feed stocks including and not limited to; green waste, food waste, biosolids, animal manures, fish and animal waste and MSW.

It has been implemented as a pre-treatment system for Waste-to-Energy facilities and existing Gore facilities have added “front end” anaerobic digesters (AD) to further optimize the process through the production of bio-gas.

Source Separated Organics, WA USA 2004

Sustainable Generation LLC – Authorized supplier of GORE® Cover for North America

Sustainable Generation brings to the North American market the experience and know-how from more than 200 installations for the design, build, own, and operation of organic recycling facilities based on GORE® Cover technology.

The SG Team is comprised of a deeply experienced and diverse group of dedicated industry leaders with track record of success in composting Source Separated Organics (SSO), Green Waste, Biosolids, Animal Waste, Sludges, and MSW. Our team expertise includes professionals with over 20 years composting experience using GORE® Cover technology. Combined, our team has over 100 years of know-how and hands-on experience with GORE® Cover system.

- Design and construction engineers – have built a combined 200 GORE® Cover composting facilities worldwide.
- Business development associates – have 20+ years' experience in delivering organic treatment solutions.
- Application engineers – have 20+ years providing project management and regulatory compliance performance.
- Compost operators – have 20+ years' experience in composting.
- Compost owner operators – have 20+ years in the business.
- Global partner network of supply partners and technical consultants.
- Project Team members have supplied equipment and services similar in scope for every GORE® Cover facility built in North America.

SG Team members have supplied equipment and services similar in scope for every GORE® Cover facility built in North America. The SG project personnel have performed Scope of Work for projects which included the supply of equipment and services for a composting system for the purpose of composting source separated organics (SSO) and yard waste from residential and commercial collected food waste and green waste materials, biosolids (BS) and municipal solid waste (MSW).

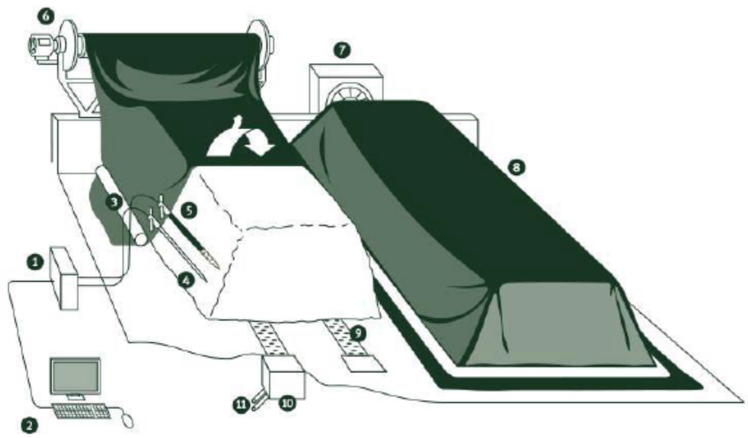
The work included the following:

- System sizing and Mass Balance Calculations
- Design meeting.
- Construction meeting.
- Shipment Delivery and Logistics
- Installation Supervision of In-ground components
- Installation Supervision of Above Ground components
- Assembly assistance for Cover Winding machine
- Start-up and Commissioning of the compost plant
- Operator Training Module #1.
- Operator Training Module #2.
- Operator Training Module #3.
- Air Quality VOC Emission Reduction Validation Test
- Responsible for on-going technical support, repairs, and spare parts.

GORE® Cover Equipment and Service Supply Package

SG Mega™ System	**over 100 tons per day or greater**
SG MidRange™ System	**25- 100 tons per day**
SG Mobile™ System	**below 25 tons per day or demonstration projects**

1 Control system
2 PC
3 Rim weight
4 Temperature sensor
5 Oxygen sensor
6 Cover handling device
7 Aeration fan
8 GORE® Cover
9 Aeration and leachate system
10 Water trap
11 Leachate pipe



The system supply includes:

- GORE® Cover
- In-floor aeration
- Oxygen and Temperature sensors
- Aeration system
- Controllers/data loggers and software
- Mobile Winder Machine
- Operation Manual
- Remote Wireless (Optional)
- Web Based System Monitoring, Inventory Management and Technical Support

The service supply includes:

- Experience gained from GORE® Cover System Global Users
- GORE® Cover System Guarantees and Warranty on covers and system components
- Engineering and System Design Consultation
  - Installation and Start Up Services
  - Post Commissioning and On Going Technical Support
- Comprehensive Training for Site Management and Operators
  - Classroom and On-site training
    - Training I – at a GORE® Cover System reference plant
    - Training II – during system check and start-up
    - Training III – 12 weeks after commissioning
- Additional Customized Trainings upon request
- Periodic Site Visitation and System Performance Check Up

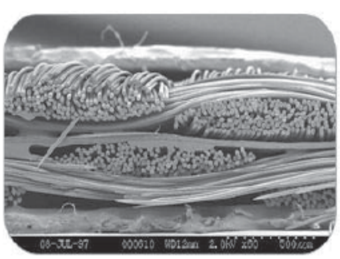
SG Mega™, MidRange™ and Mobile™ System using GORE® Cover

The GORE® Cover technology is the most widely distributed composting system in the world with over 200 facilities located in more than 20 countries treating more than 3.5 million tons of organic waste annually. The system has proven to provide a low risk, low cost solution which can sustainably process a wide range of organic waste in the most varied climate conditions while controlling odors and emissions. More importantly, its simplicity in both construction and operation ensures that a facility can be maintained many years into the future without escalating operating costs which is not often the case with other technologies. Facilities can be built to any size and can also be easily expanded after construction which provides the most flexibility to the end user during the development of its organics processing facility.

W.L. Gore & Associate's "GORE® Cover" is centered on membrane laminate technology similar to that of its world famous GORE-TEX® fabrics used for outerwear and footwear. The integrated system includes the GORE® Cover, in-floor aeration, aeration blowers, oxygen and temperature sensors, controllers, computers, software, cover handling systems, training, engineering guidance, installation support and the experience gained through the many installations over the last ten years. **Official certificates and approvals have been granted to the GORE® Cover as delivering "in-vessel" performance and approved in several countries, including USA and Canada, meeting strict PFRP and high quality compost standards, obtaining Animal by Product Approval as well as meeting strict regulatory compliance standards worldwide.** In the United States, according to the EPA, for biosolids, the GORE® Cover heap model is currently categorized as a covered aerated static pile (CASP).

Facilities using the GORE® Cover technology experience a reduction in odor and is California compliant for reduction of VOCs through the GORE® Cover as recently proven in a demonstration for the Los Angeles County Sanitation Districts, CA USA (pictured right). Taking the odor dispersion modelling of a defined location with the same throughput into consideration the GORE® Cover System has been assessed as equal or better to a tunnel/building system using a biofilters as air treatment. The German Environmental Protection Agency showed that the GORE® Cover technology compared to other in-vessel and open windrow technologies showed lowest GHG emission, Gore having the best control. Other system attributes include a small facility footprint, low energy requirements, low operating costs, short installation times, greater than 99% containment of bio-aerosols and particulate matter, and the production of stable compost in 4-8 weeks.

Making the right choice of membrane impacts the air permeability and the extraction of moisture during composting. The membrane influences the composting process; it prevents the compost product from being too dry or too wet. The membrane allows for an even distribution of air through the entire volume of material, thus ensuring temperatures are achieved throughout the heap. The micro-porous structure of the GORE® Cover membrane practically avoids the penetration of microbes and particulate matter through the membrane.



Microbiological tests have proved that microbes can be reduced by > 99%, thus ensures that workers and nearby residents are protected and safe. The insulating effect of the GORE® Cover and the pressurization by which the system ensures even temperature distribution mean that achieving the necessary temperature for sanitizing (PFRP) the material across the entire cross section of the heap can be assured, even during the winter months and extreme climates. Pathogenic microorganisms are safely destroyed throughout the entire composting material.

Operating Process Description

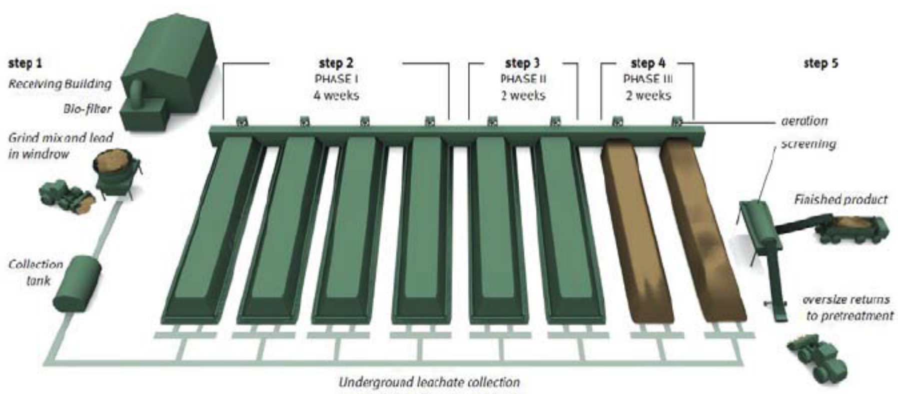
Composting process can be as short as 2 weeks to as long as 8 weeks depending on the local regulations and end user finished product specification. **Described below is typical 6-8 week 3 phase process.**

Phase 1: High Rate Active Composting –21-28 Days (step 2)
The composting process begins with a front end loader moving the material from the mixing area to a heap in the Phase I section to begin the 3 phase – 8 week composting period. Once a heap is built, it is covered, the temperature and oxygen probes are installed and the software is turned on, which then controls the rate of aeration.

Phase 2: Maturation Curing Composting – 14-21 Days (step 3)
After 28 days in Phase I, the GORE® Cover is removed from the heap and the compost is moved by front end loader to a heap in the Phase II area. The material remains in the Phase II area for 2 weeks.

Phase 3: Finishing – 14 Days (optional) (step 4)
After 14 days in Phase II, the GORE® Cover is removed from the heap and the compost is moved by front end loader to a heap in the Phase III area. By the time the material reaches Phase III the compost is sufficiently stable such that the cover is not required. In some cases, such as extreme hot or cold climates, some facilities may option to cover Phase III. The material remains in the Phase III area for 2 weeks.

Typical Composting Operation Layout:



Process flow chart

The GORE® Cover heap model utilizes composting with forced aeration coupled with a semi permeable membrane cover. A standard heap is 26 feet (8m) wide at the base, 164 feet (50m) long and 10-12 feet (3 – 3.5m) in height, each heap contains approximately 1,000-1,200 cubic yards of composting material. Our bunker design allows additional capacity up to 1350 cubic yards. The size and number of heaps is determined based on the total capacity of the project. The heaps are the same size in each of the three Phases. GORE® Covers are used only in Phase I and II. Each heap may have a concrete head wall and side walls to retain the material in each heap on the compost pad. Two aeration trenches are under each heap. These trenches serve as ducts to provide air to the heap and also to collect leachate coming from the heap. Each heap has a blower to provide air to the composting material via the aeration trenches. The trenches are cast in concrete to provide a solid impervious surface. The entire compost pad consists of a concrete slab or asphalt, which allows for the collection of all storm water and leachate.

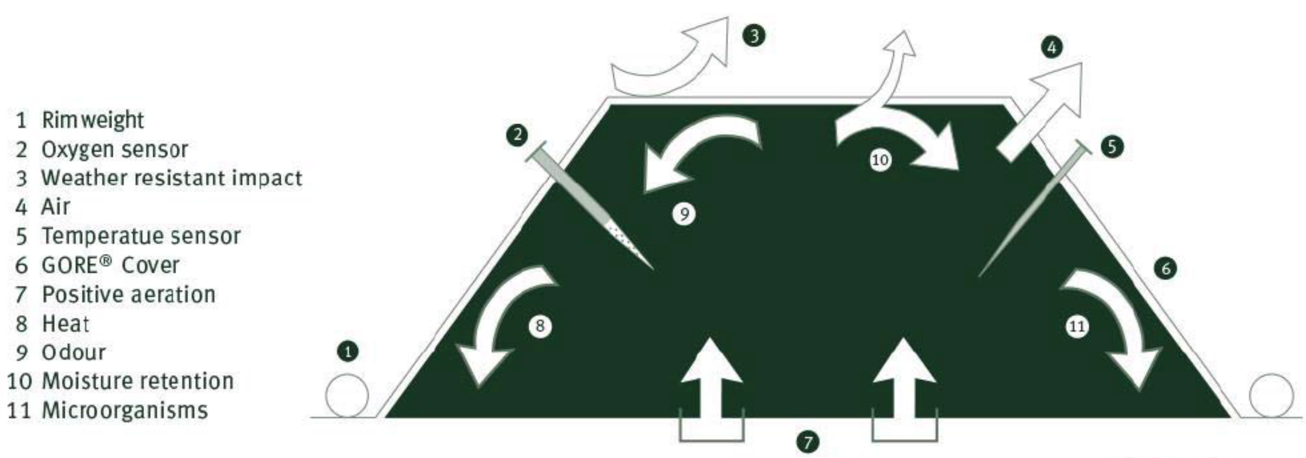
Power Requirements/ Energy Consumption

The energy demand by the GORE® Cover system is calculated **at 1.5 - 2.0 kwH per ton of throughput**, plus the energy used for adjacent equipment, facilities and fuel used for the movement of material. The mobile winder used to deploy the GORE® Cover meets regulatory emission control standards (including California) and is capable to operate in extreme cold climates. The GORE® Cover process is known for having the total lowest cost to operate as compared to other technologies.

Process Control Mechanism – Positive Aeration in Combination with GORE® Cover

GORE® Cover is based on positive aeration in combination with the GORE® Cover. Composting is a biological process with naturally occurring batch to batch variations in input material. The processing technology has to flexibly adapt to these changing conditions. The oxygen controlled aeration of the GORE® Cover System reliably adapts the aeration intensity to the batch by batch variations as well as to the changing oxygen demand in the course of the composting cycle.

- The GORE® Cover has unique physical properties in regards to air permeability which is selectively designed into the membrane and allows evenly distributed air and pressure within a heap.
- The GORE® Cover has unique physical properties in regards to control of moisture transportation which is selectively designed into the membrane and allows specific control of moisture to optimize the composting process.
- The GORE® Cover is weighted (sealed), creating a complete in-vessel enclosure the entire pile can then be pressurized ensuring an even distribution of air throughout the pile.
- The GORE® Cover has even distribution of temperatures across the composting volume.



Pathogen Reduction (PFRP) and Vector Attraction Reduction (VAR)

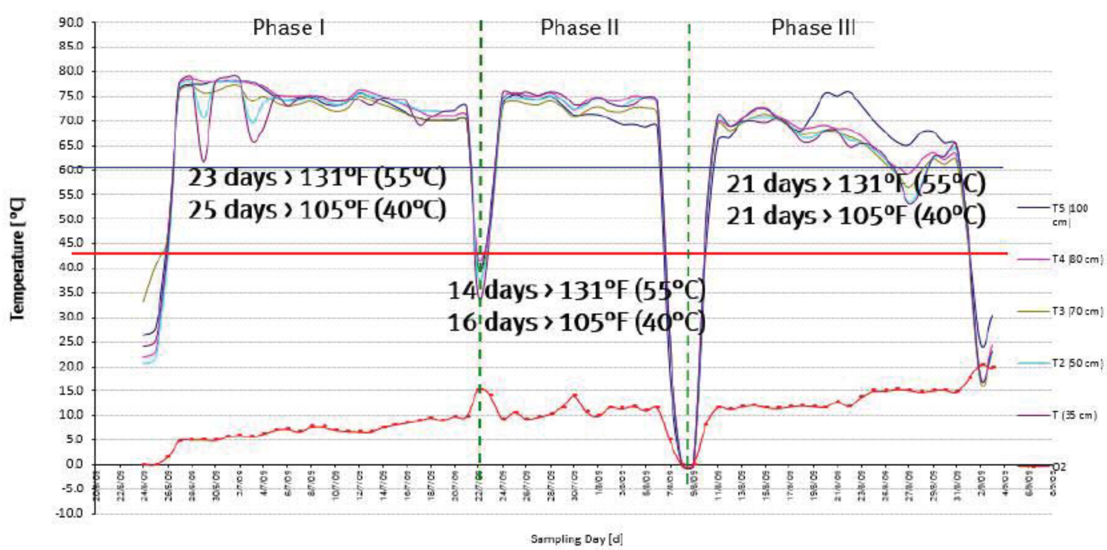
GORE® Cover is permitted to operate in over 20 countries worldwide. In addition to receiving operating permits in various countries meeting strict environmental requirements for odors, VOC emissions, water protection management and pathogen reduction. GORE® Cover has also received permits for a proper technology to meeting specific hygenization standards, such as Animal by-Product Regulations in the UK. In the United States of America (USA) and Canada, Gore® Cover compost facilities are producing Class A and Class AA exceptional quality compost according to US EPA and individual State regulations, the CCME and BQN standards.

Examples of hygenization certificates that have been issued for GORE® Cover include:

- Hygiene Design and Encapsulated System/ In-Vessel (Europe)

- **US EPA Pathogen Equivalency Committee Recommendation for National Equivalency for Alternative 5: Use of PFRP [503.32(a) (7) and (B) (1) of Appendix B (USA)**

April 2010: USA Nationwide Class A Biosolids Compliance: The GORE® Cover technology also received a recommendation of national equivalency from the **EPA Pathogen Equivalency Committee (PEC)** that the GORE® Cover is capable of meeting and/or exceeding criteria for achieving **Class A Biosolids as described in Alternative 5: Use of PFRP [503.32(a) (7) and (B) (1) of Appendix B**. in a covered aerated static pile without the use of an insulating layer of material (such as finished compost).



Typical Temperature Graph for 3 phase 8 week process

VOC Emission Compliance

The following data is in chronological order by date of the testing from demonstration projects and existing full scale composting facilities that are using GORE® Cover having provided data for VOC emission reduction.

Source Testing Prior to California Rule Implementation			
Facility description	**Input Materials**	**VOC Emission Reduction**	**Regulatory Requirement**
Site 1: Oceanside, CA	Green Waste	**98%**	**Rule 1133.3[1]**
Site 2: Everett, WA	Food Waste Green Waste	**96%**	**Air Permit**
Site 3: Los Angeles County Sanitation District (LASCD), CA	Biosolids Green Waste	**91%**	**Rule 4565[2]**
Site 4: Vancouver, BC	Food Waste Green Waste	**95%**	**Pilot Study for Odor/Emissions**

Source Testing for Existing Full Scale Facilities			
Facility description	**Input Materials**	**VOC Emission Reduction**	**Regulatory Requirement**
Site 5: Fontana, CA	Food Waste Green Waste	**89%**	**Rule 1133.3[1]**
Site 6: : Tulare Lake Compost c/o Los Angeles County Sanitation District (LASCD), CA	Biosolids Green Waste	**87% Summer**	**Rule 4565[2]**
Site 6: : Tulare Lake Compost c/o Los Angeles County Sanitation District (LASCD), CA	Biosolids Green Waste	**96.3% Winter**	**Rule 4565[2]**

1: South Coast Air Quality Management District (SCAQMD)
2: San Joaquin Valley Air Pollution Control District (SJVAPCD)

December 2011: California VOC Emission Compliance: **San Joaquin Valley Air Pollution Control District** concurs that the GORE® Cover technology, when properly installed, operated and maintained per Gore specifications, is capable of meeting and/or exceeding the VOC emission requirements of **District Rule 4565 (Biosolids, Animal Manure, and Poultry Litter Operations), District Rule 4566 (Organic Material Composting Operations) and District Best Available Control Technology (BACT) for co-composting operations**.

Encapsulation Approved and Best Available Technique BAT (Europe)

The European TWG Subgroup "Biological Treatment" instructed by the EIPPC Bureau to develop a draft BREF (Best Available Technique (BAT) Reference Document) for Biological Treatments of Waste under the supervision of the responsible Rapporteur Mr. Unico van Kooten, European Secretary of the Dutch Waste Management Association, has agreed to propose… ***"Encapsulation with semipermeable Membrane Covers as BAT. (Best Available Technique)"***

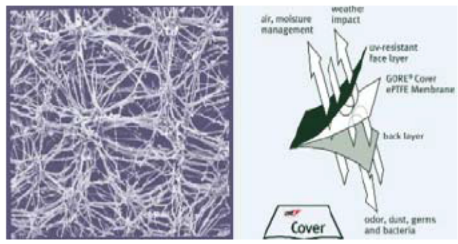
In Paragraph 3 "BAT Conclusions for **Indoor** Composting" of Chapter 5 under Subparagraph 3.3 "Emissions to Air" mentioned technique is described as "Emission Abatement Technique at the Point of Source" which is considered to be applied as an alternative to other emission abatement techniques, like biofilters and wet scrubbers.
The upload of the proposed Chapter 5 as well as a description of "Encapsulation with semipermeable Membrane Covers" for "CHAPTER 4 ~ TECHNIQUES TO CONSIDER FOR THE DETERMINATION OF THE BEST AVAILABLE TECHNIQUE RELEVANT TO BIOLOGICAL TREATMENTS" on BATIS has taken place recently.

Storm Water and Process Liquids (Leachate) Management

The GORE® Cover composting system's water management efficiency is achieved by the well-balanced interaction of the system components and the site's constructed infrastructure.

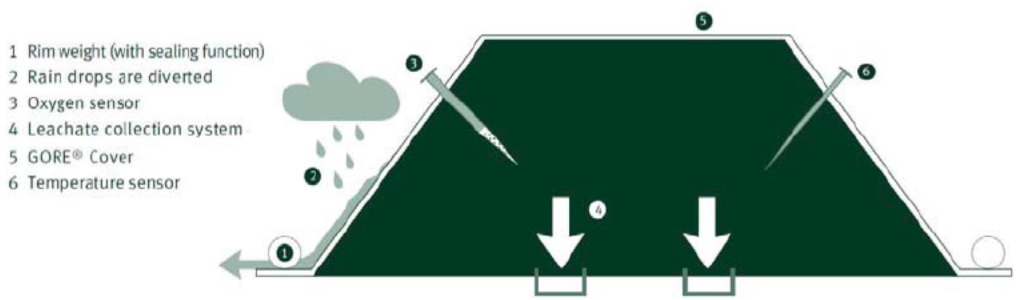
The GORE® Cover - as the critical component - allows for effective management of leachate reduction by two means:

Separation of storm water from leachate: Separation of storm water is achieved by **physically covering the organic material with the GORE® Cover and the GORE® Cover must be sealed to the ground.**

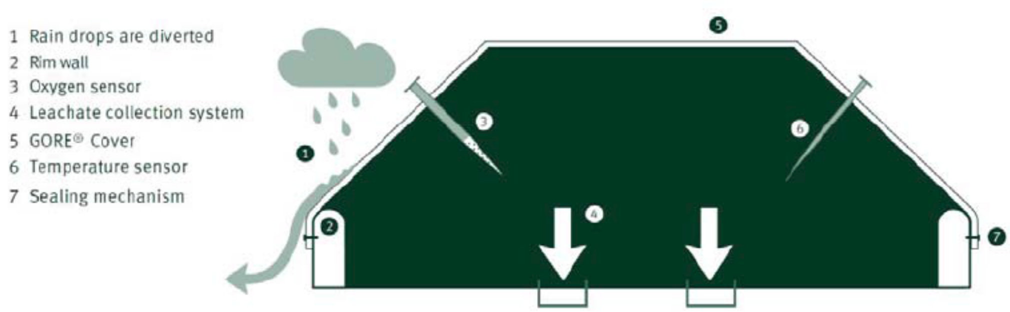


Each membrane pore is 20,000 times smaller than the smallest water drop

Whereas the rain or snow is carried away as run off across the GORE® Cover; **the GORE® Cover is impermeable to liquids**, comparable to a hard paved surface. The run-off water can then be directed by the slope of the hard paved surface or by drainage trench to a storm water system for treatment, holding or discharge as would be the same for an enclosed building or roofed structure. **GORE® Cover delivers in-vessel performance without the need for a building or roofed structure.**



Leachate collection: Leachate is collected under the heaps by a built in-ground trenching system, the built in-ground trench is used both to deliver air to the composting process as well as act as a leachate collection and delivery mechanism. The leachate is directed by drainage piping to a holding system for treatment, reuse or discharge.



Bio Aerosol, Dust Control and Odor Reduction

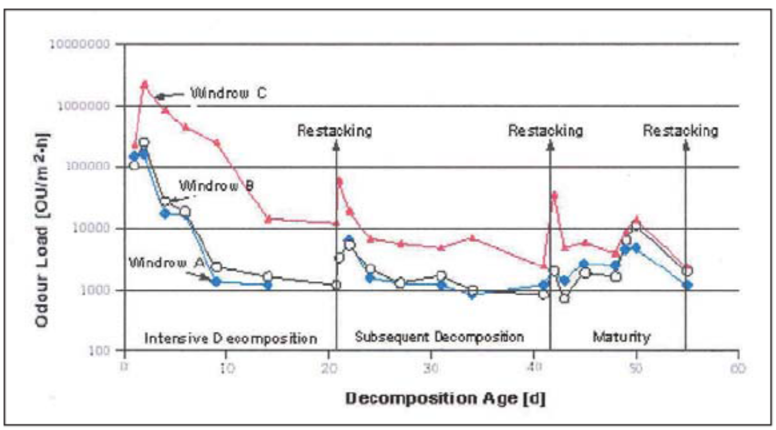
The GORE® Cover - as the critical component - allows for effective emission reduction by three means:

Pathogen retention by the micro porous structure of the GORE ePTFE membrane:
Bio aerosol and dust reduction of > 99% has been proven in microbiological tests. Occupational safety and safety of the residents is thus ensured. Due to the thermal insulation of the GORE® Cover enclosure and the temperature-distributing excess pressure in the system, the temperature required for material meeting PFRP for pathogen reduction; hygenization can be ensured throughout the heap even during harsh winter climate conditions.

Directly retaining odorous compounds passing through the cover:
The GORE ®Cover laminate works against gaseous substances that escape from the composting material as diffusion barrier. A fine film of condensate on the inner side of cover develops during composting that retains odors and other gaseous substances. These gases mostly dissolve in the water film and drip back into the pile, and continue to be broken down by the composting process. This results in a reduction of the overall emission flux.

Minimization of odor formation by achieving optimal process conditions:
The choice of membrane influences the moisture discharge during the composting process. Excessive moisture would result in odor forming anaerobic zones, lack of moisture would stop adequate decomposition of biogenic materials, especially in arid zones.

This DBU research project funded by German Federal Foundation for Environment (DBU) revealed in the year 2000 that the use of an enclosure cover with ventilation (heap A+B) in high rate composting as compared to open heap composting (heap C) leads to a 90% reduction in the odor emissions. If this enclosure cover is also used in the curing phase, the odor flux can be lowered to up to 95%.



Heap C: Open heap composting
Heap A+B: Composting with GORE® Cover
Re-stacking: Re-stacking a heap
Active Composting: Phase I high rate
Curing Composting: Phase II stabilization
Finishing: Phase III maturity
Decomposition age [d]: Number of composting days
Odor load [OU/m²h]: Odor flux [OU/m²h]

Based on these odor measurements, officially taken control measurements as well as on the aforementioned study, a comparative report about the odor emissions was prepared in 2006 by a qualified expert in accordance with the guidelines of the German Environmental Law (GIRL). This sample study confirms that the GORE® Cover System meets or exceeds odor performance as compared to the open or uncovered composting systems, and the GORE® Cover System achieves less odor perception frequencies when compared with other established composting systems, such as enclosed systems using biofilters for emission treatment.

UBA Study Germany: Measuring the GHG Benefits of Composting Source Separated Organics

A study to determine gaseous emissions from composting plants shows that composting using the GORE® Cover procedure is accompanied by lower emissions as compared to other technologies. The project which was sponsored by the Deutsches Bundesumweltministerium (*German Federal Ministry for the Environment*) evaluated multiple technologies under normal operating conditions, including GORE® Cover technology.

The purpose of the project was to study emission measurements with respect to the climate-relevant pollutants methane (CH_4) and laughing gas (nitrous oxide, N_2O), ammonia (NH_3), a climate gas having an indirect effect, as well as the sum parameters for total carbon (total C) and volatile organic compounds without methane (NMVOC: Non-Methane Volatile Organic Compounds) in different composting facilities. The aim was to obtain emission factors of the substances evaluated relative to the composting method used.

The composting plants that were included in the measurement program are classified according to the process types of fully and partially enclosed composting plants (KOA g, tg = container/ tunnel technology), composting under semi permeable membrane (**KOA sM = GORE® Cover technology**), open composting plants (KOA o = open heap) as well as composting plants with dry digestion and aerobic post treatment (KOA V+NR = anaerobic digestion + aerated static pile). In the composting plants source separated organic waste (Bio+Grün= food and green waste) was recycled; green waste recycling only (Grün= green waste) was additionally included for the open heap method.

In Summary, the carbon dioxide equivalent (CO_2 equiv.) determined per ton of recycled biological and organic waste is only 12 kg for the GORE® Cover method whereas the release compared with other technologies in this study amounts to an average of approximately 47 kg. The outcome of the study demonstrated that the GORE® Cover technology as compared to the other technologies had the highest level of control of GHG emissions.

The final report of the UFOPLAN project „Determination the situation with emissions from recycling of biowaste" (FKZ: 206 33 326) can be downloaded under: ***www.umweltbundesamt.de***

- Fully and partially enclosed composting plants (KOA g, tg)
- Composting under GORE® Cover (KOA sM)
- Open composting plants (KOA o)
- AD Dry digestion and aerobic post treatment (KOA V+NR)
- Mixed biological and organic waste (Bio+Grün)

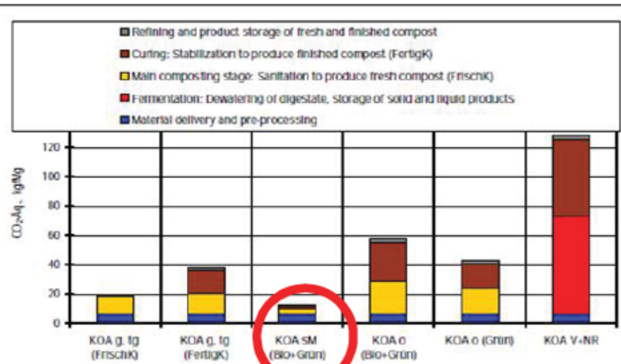


Figure 2: CO_2 eq. differentiated by individual operational units of the treatment process

<u>Source: Situation with Emissions from Recycling of Separated Organic Waste</u>, Gewitra, Dr-Ing. Calton Cuhls, Dipl.-Ing Birte Mahl, Sven Berkau, PD Dr. Joachim Clemens, FKM 206-33-326, December 2008 bifa study 2014

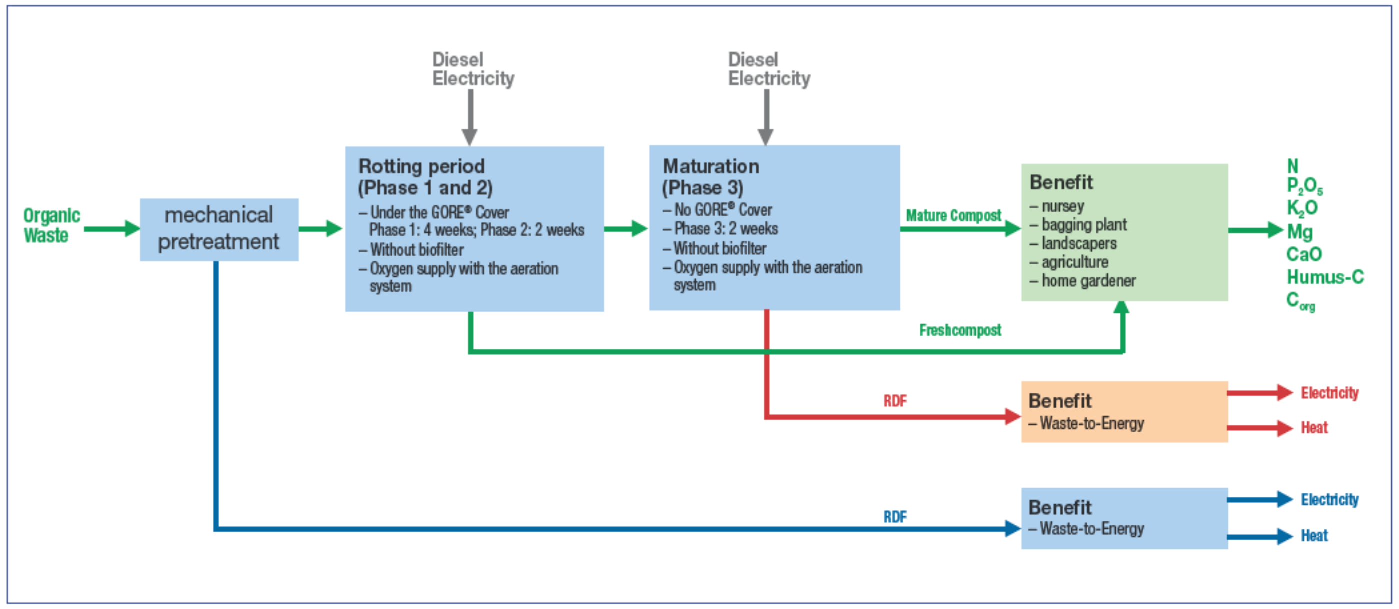
Eco-efficient biomaterial composting via encapsulation with semipermeable membrane cover

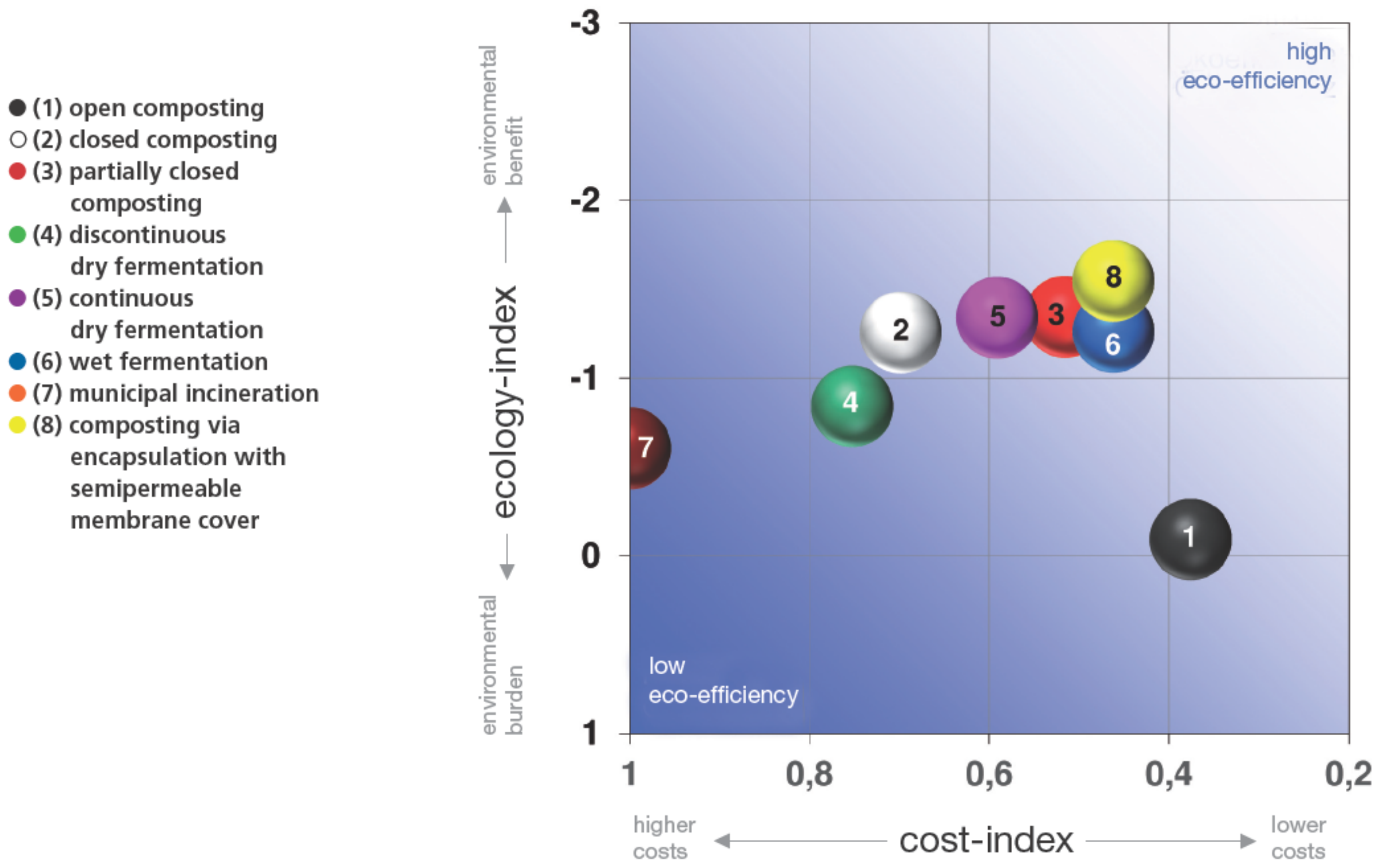
Overall, composting via encapsulation with semipermeable membrane cover resulted in environmental benefits for six of the seven impact categories examined: global warming poten-tial, acidification, terrestrial eutrophication, resource conservation, eco and human toxicity.

This is a result of additional material (nutrients and organic substance from the use of composts) and energy uses (electricity and heat from the thermal recovery of a separated out woody fraction with a high calorific value). As a result, emissions are avoided, which are produced by the conventional production of electricity, heat and mineral fertiliser as well as the supply of peat/bark humus and crop grass.

Due to the design and specific process management of encapsulation with semipermeable membrane cover and the interaction of the semipermeable ePTFE membrane and a condensate film, which forms on the underside of the cover during the process, high emission retention of methane, nitrous oxide and ammonia occur during the composting process compared to other treatment processes. In the impact category photochemical oxidant formation, ozone-forming emissions harm the environment. This is mainly due to emissions of volatile, organic compounds (methane + NMVOC) from the composting process itself.

For the indicative comparison of composting via encapsulation with semipermeable membrane cover with alternative treatment processes, the eco-efficiency of the treatment process was compared with those of alternative processes in a portfolio. To this end, the environmental impacts were plotted against the corresponding costs.





Eco-efficiency portfolio of different biomaterial treatment processes ecology-index < 0 means environmental benefit; ecology-index > 0 means environmental burden; costs index: Scaling of the process-specific costs at the maximum value)

A comparison of all considered parameters and emissions shows that composting via encapsulation with semipermeable membrane cover differs in the following ways compared to closed/partially closed composting: lower electricity requirement and lower process-related C/N emissions due to the emission-reducing effect of the semi-permeable membrane.

There are no differences in the downstream processes of recovering the material products and utilisation of the separated out fraction rich in calorific value and disposal of impurities.

In the portfolio in Figure 1.1, the eco-efficiency of the average plant operation of composting via encapsulation with semipermeable membrane cover is compared with the eco-efficiency of average plants using alternative processes to treat biomaterials.

If fermentation and composting plants are managed well, there are few environmental differences between the alternative treatments – with the exception of open composting.

Composting via encapsulation with semipermeable membrane cover has the lowest ecology-index and is therefore, if average plant operation is considered, it is the process with the highest environmental benefit, but is close to closed and partially closed composting as well as continuous dry fermentation and wet fermentation.

The objective of the comparison of the environmental impacts and costs with those of alternative treament processes was not to identify a blanket, preferred process, but instead to classify composting via encapsulation with semipermeable membrane cover compared to alternative composting and fermentation processes.

Burrtec – West Valley Compost

Site name:	West Valley Compost
Ownership:	Burrtec Waste Inc.
Location:	Fontana, CA
Start-Up in:	November 2014
Technology:	GORE® Cover
Input quantity:	30,000 ton/year
No. of Heaps:	8 Bunkers, 6 covered, 50m x 8m x 3m each
Treatment time:	8 weeks in 3 phases
	4 weeks in Phase 1 covered
	2 weeks in Phase 2 covered
	2 weeks in Phase 3 uncovered
Aeration:	In-Floor
Control Parameters:	Oxygen control mode
Input material:	Source Separated Organics (Residential and Commercial Food Waste)
	Wood Chips, Grass/Straw and Yard Waste
Equipment:	a) Pre-Treatment (grinders, pick line)
	b) Front-end-loader(s)
	c) Mobile Screen
End product:	High Quality finished compost

West Valley Compost start up November 2014. This compost facility at full design capacity will be capable to process upwards of 30,000 ton per years of organic material. Of significant importance to the Burrtec project was the GORE® Cover capability to comply with the state and local regulatory requirements for meeting strict air quality standards for VOC emission reduction; complete separation of Process water (leachate) from storm water and produce high quality finish compost

South Coast Air Quality Management District: Rule 1133.3 Compliance
February 2016, Burrtec completed source testing for reduction of emissions achieving 90% for VOC and 99% for Ammonia emissions. The GORE® Cover solution provided cost saving benefits in both design and operation as compared to the original negative aerated static pile (ASP) design that was previously installed at this location.

Source Testing for Existing Full Scale Facilities			
Facility description	**Input Materials**	**VOC Emission Reduction**	**Regulatory Requirement**
Burrtec: Fontana, CA	Food Waste Green Waste	**89%**	**Rule 1133.3**

Mid Valley Disposal

Site name: Mid Valley Compost
Ownership: Mid Valley Disposal
Location: Kerman, CA
Start-Up in: November 2016
Technology: GORE® Cover
Input quantity: 60,000 ton/year
No. of Heaps: 16 Bunkers, 12 covered, 50m x 8m x 3m each
Treatment time: 8 weeks in 3 phases
4 weeks in Phase 1 covered
2 weeks in Phase 2 covered
2 weeks in Phase 3 uncovered
Aeration: In-Floor
Control Parameters: Oxygen control mode
Input material: Source Separated Organics (Residential and Commercial Food Waste)
Wood Chips, Grass/Straw and Yard Waste
Equipment: a) Pre-Treatment (grinders, pick line)
b) Front-end-loader(s)
c) Mobile Screen
End product: High Quality finished compost

Mid Valley Compost start up is November 2016. This compost facility at full design capacity will be capable to process upwards of 60,000 ton per years of organic material. Of significant importance to the Mid Valley Disposal project was the GORE® Cover capability to comply with the state and local regulatory requirements for meeting strict air quality standards for VOC emission reduction; complete separation of Process water (leachate) from storm water and produce high quality finish compost.

Mid valley received CalRecycle GHG Grant money contributing towards capital equipment for the project.

Source Testing for Existing Full Scale Facilities			
Facility description	**Input Materials**	**VOC Emission Reduction**	**Regulatory Requirement**
Mid Valley Disposal, Kerman, CA	Food Waste Green Waste	**Testing in 2018**	**Rule 4565**

Sustainable Generation's "GORE® Cover" experience is gained through installations in more than 250 plants in more than 20 different countries worldwide. In total, more than 3.5 million tons of organic wastes are treated in sites with annual throughput capacity of 2000 to 200,000 + tons. Site visits and reference information available upon Request.

Green-, Food- and Source Separated Organic Waste:

No	Country	Location	Tons / year	Built
1	USA	Lynden, WA	18,000	2002
2	USA	Maple Valley, WA	40,000	2003
3	Canada	Arthur, ON	80,000	2004
4	USA	Oceanside, CA[5]	1,000	2005
5	USA	Everett, WA	160,000	2005
6	USA	Georgetown, DE[5]	4,000	2006
7	USA	Wilmington, DE	160,000	2009[6]
8	Canada	Kingston, ON	30,000	2009
9	Canada	Niagara Falls, ON	50,000	2009
10	USA	San Diego, CA[5]	1,000	2009
11	Canada	Vancouver, BC[5]	1,000	2010
12	Canada	Pemberton, BC	5,000	2012
13	Canada	Abbottsford, BC	20,000	2013
14	Canada	Sechelt, BC[1, 5]	15,000	2013
15	USA	Upper Marlboro, MD[5]	10,000	2013
16	Canada	Comox, BC[5]	5,000	2013
17	USA	Seaford, DE[2,5]	3,000	2013
18	USA	Queens (NYC), NY	1,000	2014
19	USA	Bolin, TX[2,5]	10,000	2014
20	USA	Fontana, CA	30,000	2014
21	Canada	Belleview, ON	60,000	2015
22	USA	Kerman, CA	60,000	2016
23	Canada	Terrace, BC	15,000	2016
24	USA	Staten Island(NYC), NY[4]	60,000	2017

(1) Fish Waste (2) Chicken Waste (3) Permitting (4) Under Construction (5) Pilot Testing Completed (6) Closed

Biosolids:

No	Country	Location	Tons / year	Built
1	Canada	Edmonton, AB	50,000	2002
2	Canada	Moncton, NB[5]	30,000	2005
3	Canada	Chemanius, BC[5]	15,000	2009
4	USA	American Fork, UT	60,000	2010
5	USA	Los Angeles, CA[5]	1,000,000	2015*
6	USA	Florence, OR[5]	2,000	2013
7	USA	Moorefield, WV	20,000	2013
8	USA	Albany, OR[5]	10,000	2014
9	USA	Chicago, IL[5]	tbd	2015

*Start Up in 2015 for the first 200,000 ton/year capacity.
(1) Fish Waste (2) Chicken Waste (3) Permitting (4) Under Construction (5) Pilot Testing Completed

Post Tunnel / Curing:

No	Country	Location	tons / year	Built
1	Canada	Peel Region, ON[5]	60,000	2009

(1) Fish Waste (2) Chicken Waste (3) Permitting (4) Under Construction (5) Pilot Testing Completed