Design of a Program Monitoring Emissions from Combustion of Construction and Joinery Residue

Technical Requirements
Final Report

<u>Prepared for</u>:
British Columbia Institute of Technology (BCIT)

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SUMMARY

This study lays down the legal, technical and financial requirements for a research project that monitors emissions from combusting construction and joinery residue and demolition wood. The main findings of this report are listed below:

- Background: BCIT seeks to install a biomass boiler running on wood waste from its Joinery and Carpentry workshops. The waste of both departments, however, contains composite materials, such as plywood or medium density fibreboard (MDF) that could emit harmful or toxic substances when being burned.
- Rationale of the study: To date, neither the Ministry nor Metro Vancouver has guidelines that are specific to the burning of construction and demolition material. A study of emissions could provide valuable information for setting emission limits that are specific to construction and demolition (C&D) wood combustion.
- Emission limits: At the time of writing this report it was unclear what emission limits will have to be met. It is clear, however, that Metro Vancouver's Biomass Boiler Regulation does not apply as this Bylaw explicitly excludes materials that contain resins, such as plywood. At the same time BCIT's wood residue cannot be classified as "municipal solid waste" (MSW) as it is produced on site. BCIT will have to apply to Metro Vancouver for an emission permit. The permit might require monitoring emissions.
- Legal monitoring requirements: Legally BCIT's wood residue is not considered MSW. Consequently combusting BCIT's wood will not invoke the MSW-Incinerator Regulation. Yet, the monitoring requirements set forth in this regulation are a good guideline, both in terms of what pollutants to watch for and what monitoring methods and procedures to apply. It will be up to Metro Vancouver as the governing body to decide what pollutants need to be monitored.
- Monitoring strategy: This study proposes a monitoring strategy that takes into account the expected results from a monitoring program, the contamination of the fuel, experiences with wood-fuelled combustors, the small capacity of the biomass boiler (250 kW or 0.9 mmBTU/h) and, last but not least, the cost of equipment versus third-party services. The strategy is focussed on research objectives rather than potential compliance requirements.
- Pollutants to monitor when combusting C&D wood: Analysis of BCIT's wood residue, but also C&D wood waste show very low and low concentrations of trace elements, such as Arsenic, Cadmium, Chromium, Lead and Mercury. Emissions of these elements should not need to be monitored continuously. Instead an annual stack test should suffice. On the other hand, Formaldehyde (CH_2O) is a contentious chemical contained in standard panel products. While not mentioned in the Incinerator Regulation this pollutant should be added to the list of substances to be monitored.
- Monitoring methods: Nine of the 16 substances mentioned in the MSW regulation can be continuously monitored in real-time using an advanced continuous emission monitoring system (CEMS). The remaining criteria air contaminants, such as Dioxin, are emitted at very low concentration and will need to be sampled over long periods. This may be done by automated samplers attached to the stack or measured by a professional stack tester. Alternatively the concentration of these pollutants can be estimated using surrogate indicator substances that are continuously monitored.
- Costs of a monitoring program: The cost of the monitoring program as described in this study is estimated to be $560,000 in capital cost and $45,000 in annual costs for services and consumables, excluding staffing. These costs are mainly based on quotes obtained and include 20% contingencies, but exclude HST. The monitoring equipment will thus exceed the cost of the biomass boiler equipment itself. Reducing the scope of the monitoring program will reduce the overall cost. Downgrading from the four-point CEMS to a single point CEMS and from a two-point sampler to a single point sampler will reduce capital cost by $92,000 for a total of $469,000 in capital cost.
- Architectural impacts and plant design: A detailed monitoring program will require changes to the design of the boiler plant, especially to the fluegas ducts. The plant will likely have to be enlarged to host additional

equipment ranging from control panels to gas bottles. These costs could not be quantified. The monitoring system should be an integral part of the overall design and be taken into consideration from the planning stage on. Adding a monitoring system after the biomass boiler plant has been built will severely limit possibilities and result in increased costs. For the same reason plans to conduct monitoring should be communicated with the supplier of the biomass boiler prior to purchasing equipment.

- Training and education impact: A monitoring program will help instructing future carpenters and cabinet makers on the use of biomass boilers, showing the impact of improper operation on air emissions. More importantly, the proposed monitoring project also opens up opportunities for educational programs on biomass boiler and filtration systems. Last not least BCIT may consider revamping its emission testing and emission test verification program. With the political framework set out as it is and with new policies being implemented, the demand for emission testing services is bound to increase over this decade.

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Conversion of units used in this report:

1 metre (m)	=	3.3	feet (ft)
1 millimetre (mm)	=	0.039	inch (“)
1 square metre (m^2)	=	35	square feet (sft)
1 kilogram (kg)	=	2.2	pounds (lb)
1 nanogram (ng)	=	10^{-9}	grams (g)
1 picogram (pg)	=	10^{-12}	grams (g)
1 cubic metre (m^3)	=	35	cubic feet (cft)
1 cubic metre (m^3)	=	1,000	litres (L)
1 litre (L)	=	0.001	cubic metres (m^3)
1 litre (L)	=	0.265	US gallons (USG)
1 metric tonne (t)	=	2,205	pounds (lb)
1 metric tonne (t)	=	1,000	kilograms (kg)
1 metric tonne (t)	=	1.1	short (imperial) ton
1 pound (lb)	=	2.2	kilogram (kg)
1 kiloPascal (KPa)	=	0.15	Pounds per square inch (PSI)
1 gigajoule (GJ)	=	0.278	megawatthour (MWh)
1 gigajoule (GJ)	=	0.95	mmBTU
1 kilowatthour (kWh)	=	3.6	megajoule (MJ)
1 kilowatthour (kWh)	=	3,415	BTU/h
1 megawatthour (MWh)	=	3.6	gigajoule (GJ)
1 megawatthour (MWh)	=	3.4	mmBTU
1 million British Thermal Units (mmBTU)	=	1.1	gigajoule (GJ)
1 British Thermal Unit (BTU)	=	0.239	watthours (Wh)
1 million British Thermal Units (mmBTU)	=	0.293	megawatthour (MWh)
1 million British Thermal Units per hour (mmBTU/h)	=	293	kilowatts (kW)
1 million British Thermal Units per hour (mmBTU/h)	=	0.293	megawatts (MW)

0. INTRODUCTION

The boom in construction activities in the British Columbia, especially in the Lower Mainland, remains at a high level.[1] About 270,000 tonnes of urban wood waste is landfilled in the Lower Fraser Valley every year.[2] At the same time landfill space is becoming scarcer.

Metro Vancouver plans to reduce the amount of demolition, land clearing and construction (DLC) waste by 80% of 2010 volumes by the year 2020.[3] Metro Vancouver's Integrated Solid Waste and Resource Management Plan "promotes additional diversion of biomass, such as food residuals and treated wood, for use as renewable sources of energy."[3] Concretely, "Metro Vancouver will […] Direct recoverable loads of combustible material received at transfer stations to public or private energy recovery facilities."[4]

The waste diversion strategy particularly includes the use of waste for district heating purposes,[5] albeit in a way that minimizes air emissions that could impact public health and the environment.[6]

The potential for greater use of biomass, particularly DLC wood, in energy generation may be perceived as jeopardizing achievements made in cleaning up Vancouver's air shed. Metro Vancouver, the BC Ministry of Environment and the Fraser Valley Regional District have legislated one of the tightest emission limits in all of North America, regulations that have helped improving air quality in the Lower Mainland over the past decades.

Regulators, the environmental community[7],[8], and the general public are concerned that the waste wood may be contaminated and could potentially create unacceptable levels of air pollution. To date, substances that contain "glue, paint or preservative" may not be burned in Metro Vancouver's jurisdiction without a special permit.

The political push for sustainability forces local governments to make a stark decision between keeping local air quality high AND reducing globally effective GHG emissions. Nowhere in Canada is this conundrum more visible than in British Columbia's Lower Mainland: while the Province is a leader in bioenergy technology and pushes to reduce GHG emissions[9,10,] it also has a mandate to protect its residents, particularly in areas that are, or were, known for poor air quality.

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[1] BCStats, Building Permits, Housing Starts and Sales, see http://www.bcstats.gov.bc.ca/StatisticsBySubject/Economy/BuildingPermitsHousingStartsandSales.aspx

[2] Envirochem Services Inc. on behalf of BC Bioenergy Network, "Biomass Availability Study For District Heating Systems", January 2012, Table 26, page 65, see http://www.bcbioenergy.com/wp-content/uploads/2012/02/Complete-Biomass-Availability-Study-Feb-7-2012-Final.pdf

[3] Metro Vancouver, "Integrated Solid Waste and Resource Management – a Solid Waste Management Plan", July 2010, page 5, see http://www.metrovancouver.org/about/publications/Publications/ISWRMP.pdf

[4] Metro Vancouver, "Solid Waste Management Plan", July 2010, Strategy 3.3 "Utilize non-recyclable material as fuel", item 3.3.1, page 26

[5] Strategy 3.1 'Use waste-to-energy to provide electricity and district heating', page 24 of Metro Vancouver's Integrated Solid Waste Management Plan, see footnote 3

[6] Strategy 1.2 'Reduce emissions from industrial, commercial, institutional (ICI) and agricultural sources at both the regional and local level', page 11 of Metro Vancouver's Integrated Air Quality and GHG Management Plan, downloadable at http://www.metrovancouver.org/services/air/management/ReviewProcess/AirManagmentPlanDocs/DraftIAQGGMP.pdf

[7] The David Suzuki Foundation openly opposed a wood heating system at the False Creek Olympic Village.

[8] "Fuelling a Biomess", Greenpeace Canada, November 2011, see http://www.greenpeace.org/canada/en/recent/Burning-trees-for-energy-puts-Canadian-forests-and-climate-at-risk-Greenpeace/

[9] The BC Clean Energy Act, released in 2010, calls for a 33% reduction of greenhouse gas emissions by 2020.

The British Columbia Institute of Technology (BCIT) is a prime example of the challenges this poses: the School of Construction and the Environment plans to reduce its carbon footprint and material usage by a factor 4 and has implemented a series of energy savings measures. As an example, the School plans to use carbon-neutral wood waste generated by its Carpentry and Joinery workshops to heat part of the campus. The waste of both departments, however, contains composite materials, such as plywood or medium density fibreboard (MDF) that may not be burned without a special permit. The fear is that resins and additives in these materials may emit harmful or toxic substances when being burned. The latter is an assumption legislators had to make in the absence of solid data.

As a research facility, BCIT would now like to monitor what type and what amount of emissions can be expected from combusting its wood residue - or any woody construction waste for that matter - in a small scale biomass boiler (feeding a district energy system) under standard and best practice conditions. Striving to formulate and implement actions that lead to a compatible balance between air quality and climate protection policies, the Ministry of Environment has produced a guideline for MSW combustion that will likely be used as a basis for setting emission limits for large facilities. To date, however, neither the Ministry nor Metro Vancouver have guidelines that are specific to the burning of construction and demolition material in small-scale or district heating plants. Research at BCIT's biomass boiler could build the scientific knowledge base needed to manage this waste source wisely, providing valuable information for setting emission limits that are specific to construction and demolition material combustion.[18]

This report lays down the kinds of questions a monitoring program of this nature should ask and the type of equipment required answering these questions. BCIT has contracted Cornelius Suchy of Canadian Biomass Energy Research (CBER) Ltd. to prepare this study. The report will be used as a part of a business case that establishes the overall cost of a biomass boiler and emission test facility.

[10] The Province of BC was the first jurisdiction in North America to introduce a carbon tax.

1. OBJECTIVES AND EXPECTED RESULTS OF AN EMISSION MONITORING PROGRAM

BCIT plans to install a small (250 kW) biomass boiler plant to test combustion of woody construction materials. The installation will be equipped with a comprehensive emission monitoring program. The immediate objectives of this emission monitoring program are to research the following questions:

- What are the likely contaminants in various types of woody construction materials?
- To what extend do these contaminants leave via the chimney and thus contribute to air pollution?
- What type and amount of criteria air contaminants (CAC) and hazardous air pollution (HAP) can be expected from combusting various types of woody construction materials?
- What operational parameters need to be met to ensure sufficiently clean combustion of these construction materials?
- To what extent can commercially available emission control technologies mitigate the amount of emissions?

The biomass boiler plant will mainly use BCIT's own wood waste from the carpentry and joinery workshops. The project may also test other construction waste that may not originate at BCIT but is imported for the sole reason of combusting it for research. Legally the latter may trigger a need for tighter emission controls and verification that the various emission thresholds have been met.

Apart from research, the goals of the monitoring program include the following:

- Meeting legally binding monitoring requirements;
- Proving to the public that emissions do not exceed mandated or acceptable levels;
- Training students on the use of stack testing equipment.

The larger rationale for the biomass boiler plant itself is:

<u>Short term</u>: Divert waste from landfill and reduce GHG emissions on campus;

<u>Mid term</u>: Showcase best practice and build education programs around this;

<u>Long term</u>: Work with industry partners to produce products with lower environmental impacts when combusted, e.g. in the types of resins used in plywood.[11]

The goals above are not to be confused with the objectives of this study: This report should provide BCIT with the following information that will be required when making a business case for the biomass boiler plant project:

[11] Lignol, a BC company producing biochemicals such as wood-derived resin, is already represented on BCIT's campus.

a) What are the legal requirements when combusting joinery or construction waste?

c) What options are there for monitoring equipment and/or third party monitoring services?

c) What is technically involved when monitoring emissions?

c) What are the approximate costs of equipment and/or services for a monitoring program?

This report is separated into two sections. The first part, Chapter 2, researches the legal aspects of combusting wood residue and legal requirements for monitoring air emissions from the combustion process. The second part, Chapter 3 to Chapter 6 details the tests that need to be conducted and equipment that should be acquired in order (a) to meet the legal requirements and (b) to conduct research on emissions from wood residue combustion. In lieu of a summary, Chapter 7 summarizes the costs of a monitoring program.

2. LEGAL ASPECTS OF COMBUSTING WOOD RESIDUE

This section lays down what type of emissions and what type of monitoring is required from a legal point of view to operate a plant combusting adulterated or contaminated wood waste, such as off-cuts of panel products from joinery or construction waste.

2.1. FEDERAL REQUIREMENTS

There are no requirements from the federal side other than a "Operating and Emission Guideline for Municipal Solid Waste Incinerators" released in 1989 by the Canadian Council of Ministers for the Environment.[12] The guideline is a recommendation only.

The document recommends monitoring background or pre-construction pollution levels at the proposed location of an incineration facility. This would, due to the small size of the combustor that BCIT plans to install, hardly make sense though.

During operation of the incinerator, the document recommends that continuous emission monitoring (CEM) be installed and recorded for the following parameters:

- Opacity (in stack);
- Oxygen (downstream of the boiler);
- Carbon monoxide (downstream of the boiler);
- Hydrogen chloride (in stack);
- Temperature (in the secondary combustion chamber).

The recommended monthly availability factor of all monitors is 95%. The monitors should be capable of signalling poor operating conditions so that corrective actions can be taken.

The guideline also lists anticipated emissions from well-tuned municipal solid waste incinerators operating under good combustion conditions and equipped with a dry scrubber fabric filter. Stated emissions exceed those listed in the provincial factsheet, partly because they are based on best technology available back then (prior to 1989).

A more recent guideline for continuous emission monitoring is Environment Canada's "Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation."[13]

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[12] Canadian Council of Ministers for the Environment , Operating and Emission Guideline for Municipal Solid Waste Incinerator, see http://www.ccme.ca/assets/pdf/pn_1085_e.pdf

[13] Environment Canada, "Protocols and Performance Specifications for Continuous Monitoring of Gaseous Emissions from Thermal Power Generation", Dec 2005, see http://www.ec.gc.ca/Publications/844D7CF3-2F1D-4CA0-9290-0A885806F792/ProtocolsandPerformanceSpecs.pdf

2.2. PROVINCIAL REQUIREMENTS

The Waste Discharge Regulation[14] of the 2004 Environmental Management Act[15] is the provincial act regulating the discharge of waste to the environment, including air emissions. Section 3.1 of the Waste Discharge Regulation states that "'industrial wood residue' does not include the residue of wood treated with glue, paint, a preservative or another substance harmful to plants or animals."

Instead Schedule 1, Section 2 of the Regulation establishes construction waste as "waste […] originating from residential, commercial or institutional sources or from demolition, land clearing or construction sources" and subsequently classifies the burning or incineration of this type of waste as "municipal waste incineration."

The Municipal Solid Waste Incinerator Regulations impose stringent operation and monitoring requirements, such as turndown restrictions, minimum temperature requirements, and auxiliary burners. Operating a combustor or gasifier under these conditions while using the energy created in the process may prove to be challenging. Emission limits are put on 15 substances, including particulate matter, carbon monoxide, sulphur dioxide, nitrogen oxides, acidic compounds, metals and organic compounds – see the table below.

All new facilities are expected to install operational and emission control technologies that will, at minimum, achieve the conditions required by the Ministry and the emission limits in this table. Some pollutants have to be measured and recorded at half-hour intervals. The half-hour limits are numerically higher than the daily limits to represent maximum allowable discharge concentrations over shorter time periods, whereas the daily averages are lower to account for fluctuations over time. Meeting half-hour limits may be challenging during start-up and cool-down phases when the boiler is not at its optimum operating condition.

Particulate matter emissions, for example, are required to be below 9 mg/m^3 during 97% of the operating time. The limit of 28 mg/m^3 is to be met at all times and is intended to ensure emissions are maintained at low levels even during extenuating circumstances, such as a temporary disruption in the emission control equipment.

[14] Waste Discharge Regulation of BC, see http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/50_320_2004

[15] Environmental Management Act of BC, see http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/03053_00

Table 2.1 Emission Limits for Municipal Solid Waste Combustion Facilities in British Columbia
Source: http://www.env.gov.bc.ca/epd/industrial/factsheets/pdf/combustion-msw.pdf

Contaminant	Units	EMISSION LIMITS	
		Daily Average	CEMS ½ Hour Average
Total Particulate Matter (TPM)	mg/m³ @ 11% O_2	9	9[(1)], 28
Carbon Monoxide (CO)	mg/m³ @ 11% O_2	50	100
Sulphur Dioxide (SO_2)	mg/m³ @ 11% O_2	50	190
Nitrogen Oxides (NO_x as NO_2)	mg/m³ @ 11% O_2	190	350
Hydrogen Chloride (HCl)	mg/m³ @ 11% O_2	10	60
Hydrogen Fluoride (HF)	mg/m³ @ 11% O_2	1	4[(2)]
Total Organic Carbon	mg/m³ @ 11% O_2	10	20
Cadmium (Cd)	µg/m³ @ 11% O_2	7	N/A
Mercury (Hg)	µg/m³ @ 11% O_2	20	N/A
Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	µg/m³ @ 11% O_2	64	N/A
Chlorophenols [(3)]	µg/m³ @ 11% O_2	1	N/A
Chlorobenzenes [(3)]	µg/m³ @ 11% O_2	1	N/A
Polycyclic Aromatic Hydrocarbons [(3)]	µg/m³ @ 11% O_2	5	N/A
Polychlorinated Biphenyls [(3)]	µg/m³ @ 11% O_2	1	N/A
Total Dioxins and Furans (as PCDD/F TEQ)	ng/m³ @ 11% O_2	0.08	N/A
Opacity[(4)]	%	N/A	5

Notes:

Concentration units: Mass per reference cubic metre corrected to 11% oxygen. Reference conditions: 20°C, 101.3 kPa, dry gas

N/A = Not Applicable

(1) 97% of the half-hour average values over an annual operating rolling average will not exceed 9 mg/Rm3. The 28 mg/Rm3 half-hour average value is never to be exceeded.

(2) This requirement may be omitted at the discretion of the director if treatment stages for HCl demonstrate that the emission limit for HCl is not exceeded.

(3) Proponents may be able to demonstrate that monitoring both Total Organic Carbon and Total Dioxins and Furans could negate the need to monitor Chlorophenols, Chlorobenzenes, Polycyclic Aromatic Hydrocarbons and Polychlorinated Biphenyls. This would reduce the number of continuously monitored emission parameters from 15 to 11.

(4) Opacity will not be required for compliance purposes for facilities using continuous particulate monitoring systems. Opacity monitoring is recommended for operational monitoring purposes. However, opacity monitoring can be used as a temporary surrogate for total particulate monitoring in the event of a particulate monitoring system failure. Under these circumstances, the emission limit of 5% opacity over a half-hour averaging period should apply.

The thresholds set are rather strict: As an example: Total Dioxins and Furans are required to be below 0.8 nanograms (0.000’000’000’8 grams) per standard cubic meter. Over the course of one year a 250 kW biomass boiler may thus emit no more than 3.4 milligrams of Dioxins and Furans, equivalent to the mass of 30 to 60 grains of table salt. [16]

Other pollutants, such as PCBs (Polychlorinated Biphenyls) have less strict thresholds: the same 250 kW combustor mentioned above would be allowed to emit up to 4.2 grams of PCB per year, equivalent to the mass of less than one tablespoon of granular salt. [17]

The regulation also contains additional operating and monitoring requirements. These include the requirement to operate the plant at no less than 80% and no more than 110% of its design output. Conditions that pertain to temperature and oxygen concentration are to be set and monitored. Other conditions such as residence time of combustion gases, primary and secondary combustion air supply, and auxiliary burner capacity are to be incorporated in the facility design.

Furthermore the public should have online access to continuous emission monitoring system (CEMS) data and an indication of when CEMS data are not available.

The Municipal Solid Waste (MSW) standards may be avoided provided that only fuel originating at BCIT will be combusted. Currently there are no guidelines as to when the above-mentioned standards are invoked. [18]

Even though much larger, the Burnaby Waste-to-Energy plant can be considered to be a benchmark for monitoring requirements, even though the permit was granted in 1995, i.e. prior to the latest MSW regulations. The table below identifies the monitoring requirement for this plant:

[16] A combustor with 250 kW output using 12% moist fuel would exhaust 560 standard m^3 per hour (900 m^3/h at 200°C, 560 m^3/h if the gas were cooled down to 20°C at an atmospheric pressure of 101.3 kPa or 15 PSI and normalized to 11% oxygen in the fluegases). Assuming the combustor would operate 7,500 hours per year at full output, the total mass of Dioxins and Furans emitted during one year would amount to less than 0.0034 grams (3.4 milligrams), the mass of 30 to 60 grains of salt (assuming a weight of 0.058 to 0.12 μg per grain of salt).

[17] Assuming a tablespoon of salt weighs six grams.

[18] Tony Wakelin, Unit Head, Industrial Air Emissions, Ministry of Environment in a conference call with the BC Bioenergy Network, BCIT, CBER, and Metro Vancouver staff on March 9th, 2012, see Minutes of the Meeting in Appendix C.

Table 2.2 Long Term Monitoring Requirements for the Waste-to-Energy Facility in Burnaby

#	Parameter	Threshold	Measurement requirement
1.	Opacity	5%	1-hour averaging of continuous monitoring
2.	Particulate matter	20 mg/m³	Manual stack testing
3.	Carbon Monoxide (CO)	55 mg/m³	4-hour rolling average of continuous monitoring
4.	Sulfur Dioxide (SO2)	200mg/m³	24-hour average of continuous monitoring; Verified by manual stack testing.
5.	Nitrogen Oxides (NOx) expressed as NO2	350mg/m³	24-hour average of continuous monitoring
6.	Hydrogen Chloride (HCl)	55 mg/m³ (wet basis)	Manual stack testing; Continuous monitoring of SO2 will be used as a surrogate for emission monitoring of acid gases, such as HCl and HF. Continuous monitoring of HCl (using a 24 hour average) will be conducted for reporting purposes until the end of the useful life of the HCl analyzer.
7.	Hydrogen Fluoride (HF)	3 mg/m³	Manual stack testing
8.	Total Hydrocarbons (THC)	40 mg/m³	Manual stack testing; Continuous monitoring of carbon monoxide emissions will be used as a surrogate indicator to monitor combustion efficiencies and the discharge of combustibles, such as total hydrocarbons.
9.	Cadmium, Mercury, and Thallium	200 µg/m³	Continuous monitoring of opacity will be used as a surrogate indicator for trace metal discharges
10.	Total of Arsenic, Cobalt, Nickel, Selenium, and Tellurium	1000 µg/m³	Manual stack testing
11.	Total of Antimony, Lead, Chromium, Copper, Manganese, Vanadium and Zinc	5000 µg/m³	Manual stack testing
12.	Mercury	200 µg/m³	Manual stack testing
13.	Cadmium	100 µg/m³	Manual stack testing
14.	Lead	50 µg/m³	Manual stack testing
15.	Sum of PCDD and PCDF	0.5 ng/m³	Manual stack testing using toxicity equivalents
16.	Polyaromatic hydrocarbons	5 µg/m³	Manual stack testing

Source: Metro Vancouver[19]

While BCIT´s wood residue cannot be compared to municipal solid waste (MSW) the monitoring standards established for MSW incinerators are instrumental in identifying the type of pollutants MoE and MV are concerned about and that should be considered when setting up a monitoring strategy.

BCIT may be able to do with less monitoring than described in the table above, provided it can plausible ascertain that thresholds will be met. In the absence of clear guidelines this report bases the monitoring requirements on the MSW standard mentioned above as the worst case scenario. Again, this is not to suggest that BCIT's wood residue may emit these air contaminants, but as a quasi-guideline for monitoring.

[19] Metro Vancouver, "Integrated Solid Waste and Resource Management Plan", July 2010, Appendix A

Legally BCIT's wood residue is not considered MSW because it is generated on site and not imported. Therefor the MSW incinerator regulation does not apply. At the same time BCIT's wood residue cannot be classified as "biomass" as it contains fractions with glue, such as plywood and MDF. The Biomass Boiler Regulation [21] does not apply, triggering a permit application process.

This permit application process requires engagement of the public. When informing the public it is advised that these standards are not referred to as 'MSW standard's as this may create the impression amongst the public that the proposed biomass combustor is a MSW incinerator.

While it is outside the scope of this study to determine the cost and time involved for the permitting, part of the project development will need to be taken into account as an expense when formulating a business case for the biomass boiler project. This may include evaluation of ambient air quality monitoring data of stations close to BCIT's Burnaby campus to obtain data on existing background concentrations of various pollutants.

2.3. MUNICIPAL/METRO VANCOUVER'S REQUIREMENTS

Under provincial legislation, Metro Vancouver (MV), rather than the BC Ministry of Environment (MoE), is the body enforcing emission restrictions and monitoring air quality in the region.[20]

The combustion of wood in Metro Vancouver is legally controlled by the Greater Vancouver Regional District Boilers and Process Heaters Emission Regulation Bylaw No. 1087, 2008,[21] also referred to as the "Biomass Boiler Regulation." According to this regulation, however, biomass may not include substances that contain

> "glue, paint or preservative, or foreign substances harmful to humans, animals or plants when combusted"

as stipulated in the Definitions Section 4 (e) of the "biomass" definition.[22]

On the other hand, the definition of municipal solid waste (MSW)

> "includes refuse that originates from residential, commercial, institutional demolition, land clearing or construction sources."[3,23]

Combusting BCIT's waste on campus will <u>not</u> require a licence under the GVS&DD Municipal Solid Waste and Recyclable Material Regulatory Bylaws 181 and 183, as it is generated on site rather than being

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[20] Section 31 of the Provincial Environmental Management Act gives Metro Vancouver the authority to "provide the service of air pollution control and air quality management and, for that purpose, the board of the regional district may, by bylaw, prohibit, regulate and otherwise control and prevent the discharge of air contaminants."

[21] The Boilers and Process Heaters Emission Regulation Bylaw No. 1087 can be viewed at http://www.metrovancouver.org/boards/bylaws/Bylaws/GVRD_Bylaw_1087.pdf

[22] In this Emission Regulation "biomass" means:

(b) uncontaminated wood waste, such as mill ends, wood chips, shavings, sawdust, sander dust, clean construction waste and hog fuel;

but, unless otherwise authorized by the district director, does not include substances that contain any of the following:

(e) glue, paint or preservative, or foreign substances harmful to humans, animals or plants when combusted;

[23] Greater Vancouver Sewerage and Drainage District, "Municipal Solid Waste and Recyclable Material Regulatory Bylaw No. 181. 1996", see http://www.metrovancouver.org/boards/bylaws/Bylaws/GVSDD_Bylaw_181.pdf

imported. [24] Importing wood waste, such as CDW, however, even for research purposes would require authorization through a Greater Vancouver Regional District Air Quality Management Bylaw No. 937, 1999.[25]

Metro Vancouver will be the body to apply to and has authority to issue a permit and enforce regulations. There is no need for duplicating the process with the BC Ministry of Environment.[18]

[24] Agenda item #4 of the Minutes of the Meeting (see Appendix C) reads: "At Metro Vancouver, BCIT's wood is considered biomass but because of the type of wood product found in the mix (e.g.: plywood and MDF) a permit will be required. Because this is BCIT's own wood stream (not importing any wood waste from external sources), this is not considered Municipal Solid Waste (MSW). The material being considered for this project would be considered a Municipal Solid Waste within Metro Vancouver. The reason it is not considered MSW in this case is the fact that this is BCIT's own wood stream (not importing any wood waste from external sources)."

[25] Greater Vancouver Regional District, Air Quality Management Bylaw No. 1082, 2008; See http://www.metrovancouver.org/boards/bylaws/Bylaws/RD_Bylaw_1082.pdf

3.FUEL ANALYSIS REQUIREMENTS & EQUIPMENT

The second part of this report, Chapter 3 to Chapter 6, lays down the actual monitoring strategy, detailing the tests that need to be conducted and equipment that should be acquired.

This chapter looks at the fuel rather than emissions that the fuel may create. Since the fuel going into the combustor will have a major impact on the types, quality and quantity of emissions coming out of the stack, the fuel will need to be tested prior to combustion.

Other than with fossil fuels, the properties of woody biomass in general, and construction waste in particular can vary widely. The amount and quality of air pollutants released will largely depend on the quality and chemical properties of the fuel combusted. The acronym "GIGO: garbage in – garbage out" summarizes the situation well. Yet, the conditions under which biomass is combusted have an important impact on stack emission levels. The last column in Table 4.1 in Chapter 4 summarizes the main pollutants and the underlying reasons for their emissions.

Most pollutants regulated by the MSW incinerator regulation are at least partly due to the chemical characteristics of the fuel at hand. In order to scientifically relate air emissions to fuel properties, the monitoring program will have to record the chemical properties of the material combusted. Emission data that is not accompanied by the relevant data on fuel properties may satisfy regulators, but will not allow conclusions to be drawn about the impact of the fuel or thresholds achievable using the best commercially available technology. In order to make this a respectable science research project BCIT must include monitoring of fuel properties.

This chapter identifies fuel tests that should be carried out. Factors affecting the type and amount of pollutants emitted include the physical properties (size), thermal properties (calorific value, moisture & ash content), chemical contents (component such as chlorine), and mineral properties (trace elements in the ash). Several tests can be conducted to determine these properties.

Currently there are no generally accepted biomass fuel standards in Canada. For the purpose of research, BCIT may adopt the European Solid Biofuel Standards. CEN/TC 335 allows all relevant properties of the fuel to be described, and includes a classification scheme. Beside the physical and chemical characteristics of the fuel, the standard also provides information on the source of the material. The standard consists of 27 technical specifications.

3.1.WASTE AUDIT

Construction and demolition waste is often considered together as one category although in fact they produce quite different waste streams. Likewise the main wood wastes arising from the Carpentry Department are likely off cuts from structural lumber and boards [26], possibly some lumber packaging (such as pallets). The Joinery Department, on the other hand, uses MDF and hardwood, and has a higher percentage of fines generated by saws, planer, routers etc.

A waste audit consists of two steps:

- Waste sorting and categorization according to the type or original state of the waste (such as 2x4s, plywood sheets, etc)

[26] 'Boards' means sheets of wood, such plywood, MDF, pressboard, particle board etc.

- Classification according to the particle size, once the fuel has been reduced in size, either by chippers or in the form of sawdust.

Companies that conduct waste audits in the Lower Mainland are:

Keystone
1780 West Broadway
Vancouver, BC V6J 1Y1
Tel.: 888-892-1796
www.keystonewaste.ca

Waste Audit Canada
Vancouver, BC
Tel.: 877-488-4088 x 200
western@wasteauditcanada.com

3.1.1. WASTE CATEGORIZATION BY ORIGIN

A waste categorization should be undertaken by sorting, categorizing and weighing the waste by type. This will allow the overall amount of wood containing glues, resins, Melamine etc. to be determined compared to the amount of unadulterated wood. While not legal in BC, many jurisdictions allow burning of contaminated wood as long as it constitutes less than a certain share of the overall amount of wood fuel burned or as long as it is free of Heavy Metals and Halogens (such as Chlorine or Fluorine). [27]

The main categories in terms of the types of waste produced could be as follows:

- Untreated wood waste: virgin wood that has been heat treated or not treated at all, such as dimensional lumber
- Treated wood waste: wood treated on the outside with paint or preservatives, such as window frames, or wood that has been exposed to other building materials, such as concrete forms
- Chemically treated or coated wood waste: reconstituted or coated wood products such as MDF, plywood, Melamine faced boards, etc

A sub-category would determine the exact amount of a certain type of wood waste, for example uncovered MDF, and Melamine faced MDF.

The price for two waste origin audits was quoted as $4,200 for two audits of the same waste streams i.e. BCIT's 40-yard bin.

[27] Austria's FAV directive allows burning of C&D as long as there is no contamination with Heavy Metals or Halogens; there are different thresholds for NOx when burning C&D than for burning clean wood;

Germany's BImSchV directive allows combusting plywood, particle board and MDF as long as it is not painted with preservatives and or as long as these paints do not contain heavy metals or Halogens:

Switzerland's LRV directive does not allow combusting wood that is pressure treated or is painted with chemicals containing halogens, such as Pentachlorphenol.

Additionally all three countries have separate regulations for combustion of C&D

3.1.2. CLASSIFICATION OF FUEL MIXES BY SIZE

A wood fuel classification will require running all off-cuts through a chipper to meet the size requirements of the combustor and any conveying system used upstream of the combustor. Once the wood waste is chipped and blended in with the sawdust, planer shavings etc. and collected in a silo, its size distribution will need to be classified.

Particle size and size distribution is an important parameter for many biomass boilers as their fuel feed systems and combustors are designed with a certain size of fuel in mind. A so-called suspension burner will require all fuel particles to be 1 mm or less in size. Running fuel with the same properties into a grate burner might cause high particulate matter emissions at best, dust explosions at worst. Size distribution also has an effect on the combustor performance.

Too much fine material or too long a piece will reduce the boiler output considerably and worsen the emissions created by it.

The size specifications for wood chips may be adapted from the European Biomass Standard or similar standards. Size specification is usually done using oscillating, rotating, or vibrating screens with various sieve apertures, see Figure 1.1 and Figure 1.2 below.[28]

Fig. 3.1 Sieves used for size graduation tests

Fig 3.2 Mechanical shaker used for sieve analysis.

Once chipping has become a standard procedure, the size distribution of the fuel should not vary substantially, making continuous testing unnecessary.

We recommend outsourcing this test to a waste management company. $500 should be budgeted for a sieve analysis of a single sample. For data accuracy, up to ten samples should be tested per year.

[28] E.g. using the European Standard CEN/TS 15149: Methods for the determination of particle size distribution for solid biofuels.

3.2. CHEMICAL ANALYSES

Combustion of wood – of any solid fuel for that matter – involves gasification and subsequent oxidation of the components of the fuel. For some air pollutants, the amount of emissions is primarily determined by the amount of the source element in the fuel. Fuels high in halogens, such as chlorine – e.g. wood that was transported in, and exposed to, salt water - are more likely to generate Hydrogenchloride (HCl), Chlorophenols, Chlorobenzenes and Polychlorinated Biphenyls (PCBs) than those with no or little chlorine. Also, composite materials with chemical binders, such as resins in MDF, may contain chlorine that is not inherent to the wood itself.

The chemical composition of wood cannot be defined precisely for a given tree species or even for a given tree and certainly not for a composite material. Resins used in plywood or MDF vary largely from supplier to supplier. It is therefore important to know what is in the fuel to gauge what emissions to expect.

The following kinds of laboratory analyses are commonly used to determine the chemical properties of wood fuel.

3.2.1. PROXIMATE ANALYSIS

A proximate analysis determines the moisture content, the percentage of fixed (non-volatile) carbon, the weight fraction of volatiles, and the amount of incombustible material, i.e. ash. All of these parameters will impact the combustion of the particular wood sample. Higher moisture content, for example will likely cool down the flame, resulting in incomplete combustion and a higher ratio of Polyaromatic Hydrocarbons (PAHs).

There are various test methods, most of them used in the coal mining industry. ASTM D3172 and ASTM D5142 are the most frequently used test methods, both covering the determination of moisture, volatile matter, and ash and the calculation of fixed carbon. Some laboratories use ASTM-E871 to determine moisture content and ASTM-E1755 for ash content.

A Proximate Analysis has been quoted by a certified laboratory at below $250 per sample, including $50 for fuel grinding.

3.2.2. ULTIMATE ANALYSIS

Combustion of wood involves two main chemical reactions:

(1) Combining carbon from the wood with oxygen to form carbon dioxide and

(2) Combining hydrogen from the wood with oxygen to form water.

The percentage of carbon versus hydrogen versus oxygen contained in the combustion gases of wood is determined by a chemical analysis termed 'ultimate analyses'. It provides weight percentage of carbon (C), Hydrogen (H), Oxygen (O), Nitrogen (N) and Sulfur (S). These five elements comprise the organic fraction of wood. The ultimate analysis represents the elemental composition of these organic materials as percentages by weight.

ASTM D3176 and ASTM D5373 are two test methods designed for coal and coke but are also applied to biomass.

Some laboratories include Chloride and Fluoride content testing in their ultimate analysis. Chloride content is probably the single most important element to watch for as it can lead to the formation of Hydrogenchloride (HCl), Chlorophenols, Chlorobenzenes and Polychlorinated Biphenyls (PCBs).

An Ultimate Analysis usually includes the calorific value contained in a wood sample. The so-called Gross Calorific Value or Higher Heating Value (HHV) is tested using ASTM D5865. It determines the amount of heat produced by complete combustion of the wood fuel at constant volume with all water or steam condensed to a liquid.

Since water is typically not condensed in a biomass boiler, the Net Calorific Value or Lower Heating Value (LHV) is of more importance. It is typically not measured but calculated from the Higher Heating Value by subtracting the amount of heat released when condensing the steam contained in the fluegases.

The LHV mainly impacts the heat output of the boiler, but it also affects the combustion quality.

An Ultimate Analysis has been quoted by a certified laboratory at below $450 per sample.

3.2.3. MINERAL ANALYSIS

Minerals are the non-combustible components of wood. During combustion and/or gasification, ash is formed from mineral matter. Most of the ash will stay on the grate or in the combustor, but some of the mineral ions will oxidize and volatilize or form particulates. Suspended in the flue gases, these minerals will eventually be emitted into the atmosphere unless condensed or filtered out.

An analysis of the wood sample's ash is carried out to determine not only the composition of the ash, but also to determine the levels at which trace elements occur in ash. High levels of trace elements, such as Cadmium (Cd), Mercury (Hg), Lead (Pb), Arsenic (As), Chromium (Cr) will lead to increased levels of emissions of these elements.

According to the British Columbia Environmental Laboratory Manual EPA Method 200.8 "Determination of Trace Elements in Waters and Wastes by Inductively Coupled Plasma - Mass Spectrometry" is the appropriate test to be applied to measure total trace elements or individual elements, such as Mercury in samples, including wood fuel or wood waste.[29]

A Mineral Analysis has been quoted by a certified laboratory at below $200 per sample.

3.2.4. OTHER ANALYSES

Along with a mineral analysis the ash-fusion temperature should be measured. While only of indirect importance to the emissions, low ash fusion temperatures can lead to clinker formation in the combustor, slagging and fouling in the boiler, seriously impeding clean combustion. Ash fusion temperature is measured by ASTM method D 1857.

These other analyses have been quoted by a certified laboratory at below $350 per sample.

Chemical analyses require rather sophisticated and pricey equipment. It is therefore recommended to outsource fuel testing to an accredited laboratory.

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[29] BC Ministry of Environment, "Trace Metals Analysis by ICP-MS – PBM ", May 2011,
see http://www.env.gov.bc.ca/epd/wamr/labsys/lab-man-09/pdf/trace-metals-analysis-may2011.pdf

Laboratories that offer these types of tests in the Lower Mainland are:

Econotech
Thomas Yuen
852 Derwent Way
Delta, BC, V3M 5R1
Tel: 604-526-4221
thomy@econotech.com

Intertek
Caleb Brett or Martin
3771 North Fraser Way (17),
Burnaby, BC V5J 5G5
Tel: 604-454-9011
E-mail: vancouver.ops@intertek.com

SGS CANADA INC., Minerals Services
Vishwa Sharma
7500 - 76th Street
Delta, British Columbia
Tel: 604-946-2249
E-mail: vancouverdelta@sgs.com

Fuel samples will have to be ground up to a particle size of less than 25 mm (1"). Approximately 3 kg are required for each sample.

The cost of above mentioned laboratory tests range between $1,000 and $1,500 per sample.

4. EQUIPMENT FOR TESTING AND MONITORING STACK EMISSIONS

This chapter lays down what options exist for emission testing and monitoring. The implications and costs for each option are given.

4.1. STACK EMISSIONS TO BE MONITORED

Before identifying how emissions can be monitored, this chapter identifies what emissions should be measured and why they should be monitored.

4.1.1. POLLUTANTS MENTIONED IN THE INCINERATOR REGULATION

Chapter 2 has laid down what types of stack emissions are required to be monitored at municipal solid waste (MSW) incinerators. While BCIT's wood residue does not classify as MSW, it currently remains unclear what the legal monitoring requirements for a biomass boiler at BCIT will be. The list of pollutants stated in the MSW-incinerator regulation (see Table 2.1) can be used as a guideline, indicating what emissions legislators are concerned about and what emissions can be expected when combusting solid waste. Again, using monitoring requirements laid down in the MSW regulation does not implicate that the wood residue boiler planned at BCIT will invoke this regulation.

Table 4.1 below lists all parameters that the incinerator regulation requires to be measured and then lists whether the respective pollutant can be found in stacks of wood-fuelled boilers and what the source of, or the reason for, the emission may be.

Table 4.1 Air Emissions from Combusting Woody Biomass and their Causes

#	Monitoring parameter MSW-incinerator regulation	Observed from wood combustion	Source of emissions or causes of the emission
1.	Total Particulate Matter (TPM)	✓	• Ash content in fuel • Contamination of fuel (e.g. with dirt) • High moisture content of fuel • Incomplete combustion (carbon particles) • High combustion air velocity in the fuel bed area • Insufficient removal of ash from the combustion chamber
2.	Carbon Monoxide (CO)	✓	• High moisture content of fuel – not applicable for BCIT waste Incomplete combustion due to: • Insufficient combustion air/oxygen supply • Incomplete mixing of syngases with combustion air • Combustion temperature too low • Flue gas retention time to short • Frequent start-ups or change in output
3.	Sulfur Dioxide (SO2)	~	• Generally low for wood, for BCIT fuel very low Sulphur content
4.	Nitrogen Oxides (NOx)	✓	• Nitrogen content in the fuel • Oxidation of air borne nitrogen at high temperatures (rare)
5.	Hydrogen Chloride (HCl)	✓	• Chlorine content in the fuel
6.	Hydrogen Fluoride (HF)	~	• Generally low for wood, for BCIT fuel very low Fluoride content [30]
7.	Total Hydrocarbons (THC)	✓	• High moisture content of fuel Incomplete combustion due to: • Insufficient combustion air/oxygen supply • Incomplete mixing of syngases with combustion air • Combustion temperature too low • Flue gas retention time too short • Frequent start-ups or change in output
8.	Cadmium (Cd),	✓	• Only low contents found in BCIT wood,[30] significant in C&D wood
9.	Mercury (Hg),	~	• Very low contents found in BCIT wood,[30] some in C&D wood
10.	Sum of Lead (Pb), Arsenic (As), Chromium (Cr)	~	• Only low contents found in BCIT wood, [30] more in C&D wood
11.	Chlorophenols,	✓	• Chlorophenols content in the fuel (e.g. wood preservatives)
12.	Chlorobenzenes	✓	• Chlorobenzene content in the fuel (e.g. wood preservatives against termites, beetles, ants)

[30] D. Tong, C. Suchy, A. Linsky, A. Hebert: "BCIT Biomass Waste-to-Energy Report", Burnaby, May 2012

#	Monitoring parameter MSW-incinerator regulation	Observed from wood combustion	Source of or causes for the emission
13.	Polyaromatic hydrocarbons (PAHs)	✓	• Plastics, such as polystyrene, polypropylene, in the fuel Incomplete combustion due to: • Insufficient combustion air/oxygen supply • Incomplete mixing of syngases with combustion air • Combustion temperature too low • Flue gas retention time to short • Frequent start-ups
14.	Polychlorinated Byphenyls (PCBs)	✓	• Chlorine content of the fuel
15.	Total Dioxins and Furans	✓	• Chlorine and Fluorine content of the fuel (e.g. in the forms of Dioxin, Furans, PCBs from plastics such as PVCs) Incomplete combustion due to: • Insufficient combustion air /oxygen supply • Incomplete mixing of syngases with combustion air • Combustion temperature too low • Flue gas retention time to short • Frequent start-ups

Most emissions regulated under the MSW-incinerator regulation have also been found in fluegases from wood combustion, albeit usually at lower levels. Yet a monitoring program designed to test various fuels, including wood waste that may not be as clean as BCIT's current waste stock, suggests that there is value in monitoring all of these data.

In case only BCIT's waste is combusted four of the 15 pollutants mentioned in the table above may not need to be monitored. These are Sulfur Dioxide (SO2), Hydrogen Fluoride (HF), Mercury (Hg), and the sum of Lead (Pb), Arsenic (As), Chromium (Cr). All of these elements tested as non-existent or as available at very low concentrations only.

4.1.2. OTHER POLLUTANTS RECOMMENDED TO BE MONITORED

While not mandated by the incinerator regulation, BCIT might consider monitoring Formaldehyde, a chemical that is used in some resins of panel products. Formaldehyde (CH_2O) is a classified as a known human carcinogen.

The presence of a Formaldehyde detector would allow monitoring the benefit of using no-added Urethane Formaldehyde (NAUF) products versus conventional panel products. It should be noted that the presence of resins in general, of Formaldehyde in particular are the reason why BCIT's wood waste falls outside the definition of 'biomass'[31] and may therefore not be burned.

[31] Metro Vancouver By-law 1087

4.1.3. EMISSIONS THAT MAY BE AVOIDED TO BE MONITORED

In case BCIT decides to combust its own wood waste only, the following emissions monitoring may be avoided:

- Sulfur Dioxide (SO2)
- Hydrogen Fluoride (HF)
- Mercury (Hg)
- Lead (Pb), Arsenic (As), Chromium (Cr)

Initial fuel tests of BCIT's waste indicate very low levels of concentration of these elements.[32] Long-term tests of C&D-wood and hog fuel undertaken by the BC Ministry of Environment, however, show that Lead, Arsenic, and Chromium levels in C&D wood can be substantial. Mercury in C&D wood tested about 10 times higher than BCIT's wood waste did. While at low levels, the high toxicity of Mercury may still require the monitoring of emission levels.

Hydrogen Fluoride and Sulfur Dioxide monitoring is usually included as a standard in most continuous emission monitoring systems. There would be little or no savings in capital costs if these two substances were not monitored.

At the current state it is unclear whether the Municipal Solid Waste Incinerator Regulation will be invoked for the wood waste burner that BCIT plans on installing.

4.2. MONITORING METHODS

Monitoring emissions can be done by manual stack testing, by continuous measurements, or automated fluegases sampling. The following description of various technologies is partly based on information provided by vendors.

4.2.1. MANUAL STACK TESTING

Manual stack tests are one-time measurements undertaken at the chimney itself over a period of half an hour to one day. The results provide averages over this period rather than real-time measurements. Stack tests are commonly performed by certified personnel for compliance reasons to verify thresholds are met.

Professional stack testers servicing the Lower Mainland include:

A.Lanfranco and Associates Inc.
Unit 101 – 9488 189th Street
Surrey, BC
Tel: 604-881-2582
Cell: 604-809-3521

[32] Tong, Suchy, Linsky, Hebert, "BCIT Biomass Waste-to-Energy Report", Burnaby, April 2012

McCall Environmental
5111 Eagle Tree Pl
Victoria, B.C.
Tel: 250-381-7482 or 250-962-6921
neil_mccall@telus.net , matt_mccall@telus.net

Source Test Ltd.
Unit #101, 9488 - 189th Street,
Surrey, BC, V4N 4W7
Tel: 604-881-4412
info@sourcetest.com

4.2.2. CONTINUOUS EMISSION MONITORING

So called continuous emission monitoring systems (CEMs), on the other hand, allow tracking the change in concentration of a certain pollutant in very short intervals: The real-time or semi-real time detection and quantification of a pollutant allows relating its concentration in the fluegas to operating parameters of the biomass boiler. CEMS, with a frequency of measurement at real time or up to an hour, also provide quick feedback to the plant operator by measuring emission levels on-site. CEMS most commonly monitor gases such as CO, NOx, SOx that are summarized as criteria air contaminants. Technically a much longer list of pollutants, including toxic metals, acid gases, dioxins, and particulate matter can be monitored continuously.[33]

Continuous emission monitoring systems (CEMS) were initially developed for large power plants, cement kilns and incinerators to provide real time emission data. These data allow the operator to adapt the plant operation accordingly, making sure short term emission limits, such as half-hour thresholds, are not exceeded.

[33] Vanko of Edmonton, AB is a distributor of Finnish-made process gas analyzers that include Methane, Ethane, Ethylene (Ethene), n-Propane, n-Hexane, Formaldehyde, Benzene, Toluene, Styrene, Ethylbenzene, o-xylene, m-Xylene, p-xylene, Chlorobenzene, 1,2-Dichlorobenzene, 1,4-Dichlorobenzene, Benzyl chloride, 3-chlorotoluene, and 2-Fluorotoluene

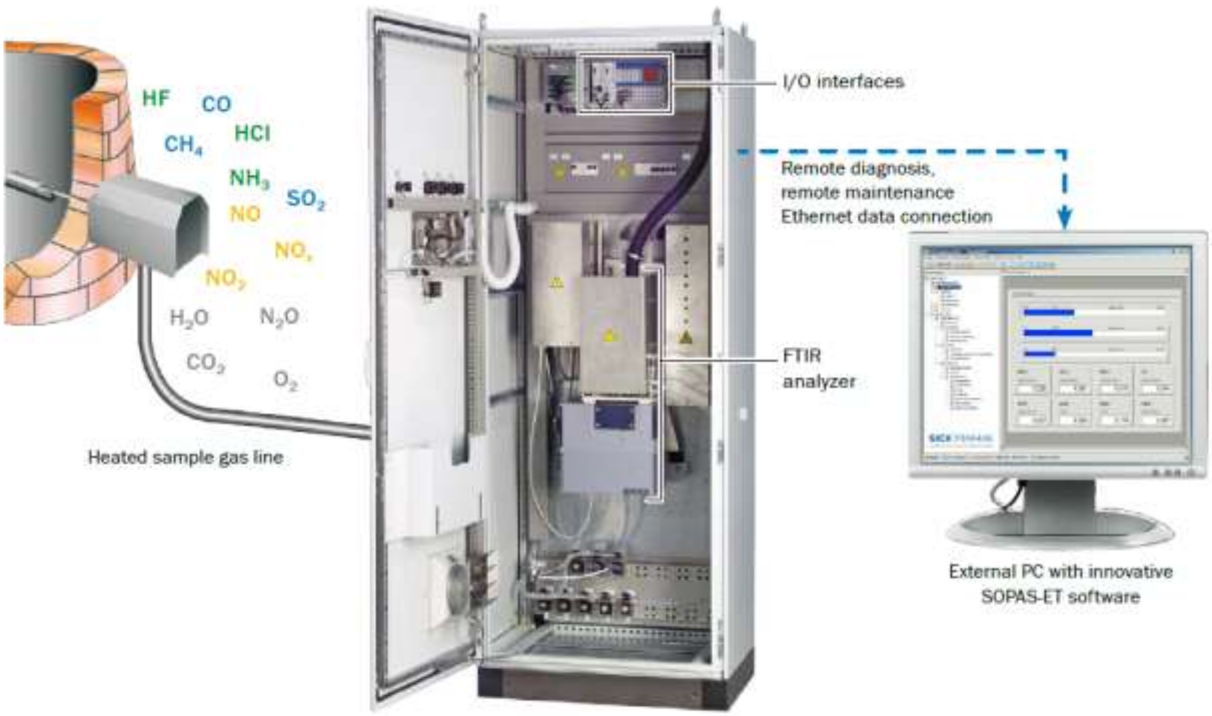

Fig 4.2 Continuous Emission Monitoring System of SICK LTD, Process Automation Division.

Suppliers of continuous emission monitoring equipment include:

CEM Specialties Inc. – supplier of ABB equipment
1100 Dearness Drive
London, Ontario Canada N6E 1N9
Tel: 519-681-9595 x 233(Steve Di Muzio)
dimuzio@cemsi.on.ca (Steve Di Muzio)
www.cemsi.on.ca

Hydroflo Controls Ltd – supplier of Kittiwake equipment
886 Alloy Place
Thunderbay, Ontario P7B 6E6
Tel.: 807-344-4224
robm@hydroflo.net (Robert Mazurkewich)
www.hydroflo.net

Monitoring Solutions, Inc.
78 Route 173, Suite 7, Hampton, NJ 08827, USA
Tel.: 908-713-0172
jnowak@monsol.com (Jim Nowak)
www.monsol.com

Sick Ltd. -- Process Automation Division
Unit #6, 250 West Beaver Creek Rd.
Richmond Hill, ON L4B 1C7
Toll Free: 855-742-5583
wilson.fung@sick.com (Wilson Fung)
http://www.sicknorthamerica.com

Spartan Controls
7500 Winston St, Burnaby, BC, V5A 4X5
Tel: 604-422-3700
fortin.matt@spartancontrols.com (Matt Fortin)
http://www.spartancontrols.com

Vanko Analytics Ltd. – supplier of Gasmet equipment
4408-51 Ave, Edmonton, AB T6B 2W2
Tel: 604-314-3151
jimg@vanko.net (Jim Grimard)
www.vanko.net

A summary of CEMS capabilities and quotes obtained is given in Appendix A.

4.2.3. LONG-TERM SAMPLERS

Long-term sampling is applied to pollutants that exist at low or very low concentrations, such as Polychlorinated Biphenyls (PCB), Polychlorinated Dibenzofurans (PCDF) and Polychlorinated Dibenzo-p-dioxins (PCDD). The same is true for trace metals that are usually present at very low concentrations in the ppb or ppt range in the fluegases of wood combustors. Flue gases samples are collected over time periods of up to several weeks to obtain a cumulative record of source emissions and provide evidence of emission levels.

Since pollutants such as metals or Dioxins may present in a solid form or attached to soot particulates, automated samplers need to extract gases isokineticly.[34] Once extracted, the sample gas is cooled to condense pollutants before they are drawn through filter cartridges. The samples contained in the cartridge can then be sent to a laboratory. The sampler's control system records fluegas volumes, temperatures, measurement times etc for normalization of the results.

[34] To avoid distorting the results, fluegases run through the test filter need to be extracted at the same velocity as the fluegases move in the chimney. This requirement is termed isokinetic monitoring. Non-isokinetic extraction might result in an increased or decreased amount of suspended particles present in the sample gas. The technical requirements for gravimetric test are described by EPA Method 5 or Method 17.

Automated samplers measure continuously, but only deliver an average value for the entire period the stack was sampled. Results are not visible in real time, but only after the sample collected has been analyzed by a laboratory. Disintegrated results or short-term values are therefore not available. Sampling time ranges from six hours to six weeks, depending on the concentration of the pollutant.

Fig 4.3 AMESA Dioxin sampler of Altech Environmental: Sampler and cartridge

Dioxins or trace metals can also be measured by a professional stack tester. The long sampling time and the dependence on an external tester can be accepted for compliance measurements once a year, but may not be conductive when doing research.

Automated samplers are standard in Europe where there are around 160 to 170 units in operation.[35] Countries like Belgium and France have released laws that require every new MSW-incinerator to be equipped with a Dioxin sampler. Existing incinerators have to be upgraded by 2014. According to Environnement SA there is no automatic sampler installed in any of the waste incinerators in North America.

Equipment and commissioning costs are approximately $100,000 for a single sampler including the extraction system and control cabinet. A second sampling box is estimated to be additional $35,000. Two sampling boxes would allow measuring two concentrations of dioxin at the same time, e.g. before/upstream of a filter and downstream/after this filter. Prices stated are budgetary only that need to be refined during the engineering phase.

Suppliers of long-term samplers include:

[35] Telephone conversation with Jürgen Reinmann of Environnement SA Germany, a supplier of automated samplers, on May 4th, 2012.

Altech Environment U.S.A.
2623 Kaneville Court
Geneva, IL 60134
www.altechusa.com
Tel: 630-262-4400 x 210
smorrell@altechusa.com (Seth Morrell)

Sick Ltd. -- Process Automation Division
Unit #6, 250 West Beaver Creek Rd.
Richmond Hill, ON L4B 1C7
Toll Free: 855-742-5583
wilson.fung@sick.com (Wilson Fung)
http://www.sicknorthamerica.com

Fig 4.4 EPA Method 17 particulate sampling kit of APEX Instruments

4.2.4. MONITORING USING SURROGATE INDICATORS

Some pollutants can be monitored using surrogate indicators. Carbon monoxide emissions, for example, can be used as an indicator for the emission of total hydro carbons. The scientific reasoning behind this is that both, CO and TOC are produced when combustion is incomplete.

Likewise monitoring of a certain type of Dioxin may be used to quantify the overall emission of all Dioxins known. The relation between the two emissions concentration should be established though individual stack tests.

4.3. MONITORING STRATEGY

This chapter establishes a strategy on how to measure or monitor emissions from a 250 kW wood waste fuelled boiler.

4.3.1. PARTICULATE MATTER MONITORING

Particulates may be monitored in two ways: gravimetrically and optically. This section explains why both methods should be employed.

Gravimetric Methods

Gravimetric particulate matter measurement systems run fluegases though a ceramic filter that retains particulates, passing the clean gases only. The filter is weighed before and after, allowing determining the weight of particulates that was contained in the volume of fluegases that was run though the filter. A concentration of particulates is calculated by dividing the weight of the particulates trapped in the filter by the amount of fluegas run through the filter.

The filter is weighed using a precision scale, usually not on site but in a laboratory. For accurate results moisture absorbed by the filter during the process needs to be removed prior to weighing.

To avoid distorting the result, fluegases run through the test filter need to be extracted at the same velocity as the fluegases move in the chimney. This requirement is termed isokinetic monitoring. The technical requirements for gravimetric test are described by EPA Method 5 or Method 17.

Fluegases need to be extracted and filtered for at least 30 minutes for each measurement. The lower the concentration of particulates, the longer the measurement period needs to be made. As a consequence gravimetric tests always yield an average rather than a momentary result. Furthermore gravimetric methods allow spot measurements rather than continuous monitoring. Finally, results are not available immediately, but only after filters have been dried and weighed in a laboratory.

Optical Methods

Dust monitors continuously monitor particulate matter concentrations using optical methods, such as forward scattering of a light beam. A laser diode directs a beam of visible light at the dust particles in the fluegas duct or chimney. Particles suspended in the flue gas will scatter the light more the higher the concentration of particles. The light scattered by the particles is recorded by a highly sensitive detector.

The measured scattered light intensity is proportional to the particle concentration (number of particles per m^3) but is less sensitive to the particle size (total particle weight per m^3). In order to relate the detector's signal to a mass concentration (in mg per m^3), reference measurements need to be made using other methods.

Gravimetric comparison measurements using isokinetic gravimetric methods are commonly used for calibration purposes. At least two stack tests need to be conducted. One with flue gases with a high particulate matter concentration and one with low concentration need to be done to calibrate the detector.

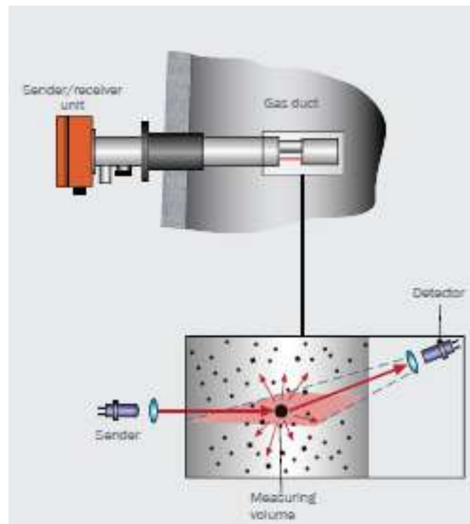

Fig 4.5 Principle of optical in-stack dust monitors measuring particulate matter concentrations
Source: Sick Ltd

Optical particulate monitoring equipment is available for approximately $10,000. Certified test equipment for gravimetric testing, on the other hand, is expected to be above $100,000. Since the calibration will have to be done once a year at most, it will be more cost effective to hire a professional stack tester instead. A gravimetric stack test should be budgeted at $3,000 per test.

4.3.2. MONITORING CRITERIA AIR CONTAMINANTS

Criteria air contaminants (CACs), such as CO or NOx should be continuously monitored as required for incinerators. Tracking these contaminants allow the operating, particularly combustion conditions to be analyzed.

Analytical techniques applied include spectroscopic absorption, luminescence, electroanalysis, electro-chemical analysis and paramagnetism. Calibration is usually done using independent, certified gases.

CEMS consists of a sample probe, a filter, a sample hose (sometimes termed 'umbilical'), a gas conditioning system, a calibration gas system, and a series of gas analyzers which reflect the parameters being monitored. A data acquisition system receives the signal output from each analyzer in order to collect and record emissions data.

Sample gas is drawn into the analyzer from the sampling probe heated filter or sample pre-conditioner, then pumped through a condensate removal system. Any condensate formed is collected then automatically purged. Next, the dried sample gas is filtered again, then flows through a pressure regulator, a liquid blocker, calibration gas valves, low flow switch, flow meter then on to the gas detectors. The detectors are either electrochemical sensors or infrared detectors.

Most CEMS are extractive, i.e. they draw a certain amount of flue gases from the chimney and analyze it using equipment located on the ground and inside rather than at the stack itself. This has the advantage that measurements can be made at several sampling points using multiple extraction systems. We recommend having at least three CEMS sampling points: one right downstream of the biomass boiler, but upstream of either a cyclone or a fluegas condenser; one downstream of this condenser, but upstream of the electrostatic precipitator (ESP); and one downstream of the ESP, i.e. in the chimney.

A sequencer records data from each sampling point at a given sequence, i.e. not simultaneously. Oxygen content is usually measured alongside criteria air contaminants because the O2-concentration is required in the regulatory calculations for emission corrections.

The type of CEMS to be used at a biomass boiler will not require diluting the fluegases. Instead sample gases are conditioned, by a moisture trap and a particulate filter before analyzing the gas. When selecting a CEMS, it should be ensured that filters periodically auto-clean themselves, using an automatic blowback and/or a purge gas, usually nitrogen.

CEMS do have operating costs: Hoses from the flue gas duct to the analyzer need to be heated to avoid condensation and therefore consume electricity. An internal quality assurance check is achieved by daily introduction of a certified concentration of a calibration gas to the sample probe or to the analyzer. Advanced systems auto-calibrate at regular intervals. Purge gas, calibration gases and electricity are estimated to add $200 per month to the operational costs.

Capital costs for a basic CEMS should be budgeted at $120,000 for a total of four gases including reference measurements of Oxygen (O_2) and gas velocity.

4.3.3. MONITORING ACIDIC GASES

Advanced CEMS allow monitoring acid gases such as Hydrogen Chloride (HCl), Hydrogen Sulfide (HS), and Hydrogen Fluoride (HF). The technology involves Fourier Transform Infrared Spectroscopy (FTIR) that allows monitoring these gases simultaneously with criteria air contaminants.

The author of this report did not research prices for stand-alone CEMS for acid gases only. Instead budget prices for advanced (FTIR) CEMS were obtained. Upgrading from a standard CEMS to FTIR including monitoring of acid gases is expected to add $75,000 to the capital costs of a CEMS. This cost is the price difference between a standard CEMS and a more sophisticated CEMS that includes a number of other features. The cost can therefore not be completely attributed to monitoring of acid gases.

4.3.4. MONITORING OF ORGANIC HYDROCARBONS

Organic substances or hydrocarbons are most easily detected using flame ionization technology (FIT), a widely used gas chromatographic detector that is especially sensitive to volatile hydrocarbons, such as Alkanes (Methane, Ethane, Propane, Hexane), Alkenes (Ethylene), aromatic hydrocarbons (Benzene, Toluene, Styrene) and derivatives of these chemicals.

The detector requires a fuel and oxygen to create a flame that the gas sample is exposed to, i.e. has operating costs additional to a purge gas, calibration gases and electricity.

Flame ionization detectors feature very low detection limits, for hydrocarbons in the picogram range (10^{-12} g or one trillionth of a gram). The detector's signal does not distinguish between individual types of hydrocarbons and is best suited for monitoring the concentration of the sum of all hydrocarbons contained in the fluegases.

To detect individual organic substances, the same Fourier transform infrared spectrometry (FTIR) as used for criteria air contaminants is applied. CEMS based on the FTIR technology are able to monitor several gases simultaneously, however, in the parts per million (ppm) range only rather than the parts per trillion (ppt) achievable by flame ionization technology.

Upgrading a standard or advanced CEMS to incorporate a flame ionization detector including ancillary equipment was quoted to add $41,880 to the capital costs. [36] One supplier offered a quote for monitoring 20 individual organic substances along with the standard criteria air contaminants. The quote was $75,000 above the lowest cost standard CEMS, but also included Hydrogen Fluoride and Hydrogen Chloride. The upgrade can thus not be completely attributed to monitoring of hydrocarbons

4.3.5. MONITORING OF METALS (Cd, Hg, Pb, As, Cr)

Metals can be monitored continuously using X-ray fluorescence spectroscopy, measuring the frequency of radiation emitted after the probe has been bombarded with x-rays. By determining the frequency emitted by a particular sample the spectrometer is able to identify the element involved. The intensity of the energy measured by these detectors is proportional to the abundance of the element in the sample. The method works particularly well for heavy trace elements down to a concentration in the ppm range.

Some metals, such as Mercury may be monitored using a different measurement principle: using absorption of light under a magnetic field, known in physics as the Zeeman effect, the system can identify the presence of Mercury at very low concentrations, as low as 0.1 μg per m^3 of fluegas.[37] As a comparison: the legal threshold for Mercury at MSW-incinerators is 20 μg/m^3, see Table 2.1.

The following is a rough estimate of why even the detection level of the Mercury CEMS using the Zeemann effect is unlikely to suffice for the application that BCIT seeks:

A chemical test of BCIT's wood waste undertaken by Econotech Laboratories of Delta, BC, showed a maximum concentration of 0.0026 mg of Mercury (Hg) per kg of ash.[38] Assuming that all Mercury contained in the fuel will be emitted via the stack, this results in a concentration of no more than 0.0055 μg of Hg per

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[36] Quote of Vanko Analytics Limited on May 11, 2012

[37] Sick Canada Ltd. of Mississauga, ON offers a continuous Mercury sampler under the brand name MERCEM 300Z

[38] Econotech Laboratories: Analysis results of five fuel samples received from BCIT on March 12, 2012; report date: April 26, 2012, sent by e-mail to Deacon Tong, BCIT on April 30, 2012

Nm^3 of fluegas, 3,600 times lower than the legal threshold and well below the detection level of the Mercury CEMS.

Other fuels may be more contaminated though. The Ministry of Environment chemically tested samples of construction and demolition (C&D) waste and hogfuel for a period of two years at monthly intervals. The highest concentration of Mercury found in C&D waste was 0.112 mg per kg of ash. [39] Again, making the worst case assumption that every atom of Mercury contained in the fuel will be emitted through the stack, results in a concentration of 0.24 μg of Hg per Nm^3 of fluegas, 83 times lower than the MoE threshold and just above the detection level of the Mercury CEMS.

Mercury CEMS are typically used in thermal power plants, cement plants, or at incinerators, all of them using fuel with orders of magnitude higher Mercury concentrations than biomass or even C&D. Considering the low concentration of Mercury in construction wood in general and BCIT's wood waste in particular, we recommend disregarding continuous emission monitoring of Mercury.

A one-time measurement by a professional stack tester will also come at a much lower price tag than the $182,000 that the Mercury CEMs was quoted at. An inquiry at a professional stack tester yielded additional $500 per test if combined with a particulate test.

4.3.6. MONITORING CHLORPHENOLS

Chlorophenols will have to be tested for in a laboratory along with Dioxins (see Chapter 4.3.8 below). The additional cost for a laboratory test is estimated at $200 per sample.

Chlorobenzene (C_6H_5Cl) is likely either a precursor to the formation of Chlorophenol or will exist for the same reason as Chlorophenol is formed. As a consequence, the rate of formation of Chlorophenols is likely to parallel that of Chlorobenzene. A comparison with CEMS results may allow using Chlorobenzene as a surrogate indicator for Chlorophenol.

4.3.7. MONITORING CHLOROBENZENES

Chlorobenzenes (C_6H_5Cl, 1,2-Dichlorobenzene, 1,4-Dichlorobenzene) can be continuously monitored with an FTIR spectrometer. The chemical is likely a part of the library of the FTIR and will therefore not cause additional investment needs.

4.3.8. MONITORING DIOXINS, FURANS, PCBS AND PAHS

Dioxins[40], such as PCDD, PCDF (Furans) PCBs and PAHs are frequently cited as a main problem associated with the combustion of wood, whether clean wood or contaminated C&D wood. They are also pollutants that can be controlled by operational parameters, especially combustion and fluegas temperatures. Research leading to minimizing Dioxins and Furans would be particularly relevant for best practise recommendations.

Occasional spot measurements by stack testers, however, are unlikely the deliver enough data. Unfortunately there are few technologies available for real-time monitoring of PCDD and PCDFs. The U.S.

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[39] Ministry of Environment: Excel-Spreadsheet titled "Hog and CD testing.xls", received by Alexandre Hebert from Lloyd Phillips on April 25, 2012. A maximum concentration of Mercury recorded over a period of two years is given in Cell C22.

[40] The term 'Dioxin' is often used as an umbrella term for a group of chemical compounds that are members of three closely related families: the polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs) and certain polychlorinated biphenyls (PCBs). The latter two families are technically not Dioxins, but have Dioxin-like properties.

EPA Environmental Technology Verification (ETV) Program's Advanced Monitoring Systems (AMS) Center tested two spectrometers for real-time quantification of Dioxins and Furans.[41] The detectors were tested on fluegases of a 860 kW fossil-fuelled boiler. The assessment yielded low relative measurement accuracy. It also showed that extensive training and experience are required for the operation of the monitoring system.

Two automated samplers that were tested alongside one another achieved higher measurement accuracy, could be installed in less than 48 hours and required no more than one to two hours in training to operate the sampler.

Automated samplers seem to have become a more commonly used solution for dioxin measurement than a real-time detector, especially in countries like Belgium and France where legislation requires all waste incinerators to continuously measure PCDD and PCDF with at least one laboratory analysis every two weeks.

The research might show that other, more easily detectable substances parallel the emission of dioxins and may be used as a surrogate.

4.3.9. MONITORING FORMALDEHYDE

Formaldehyde (CH_2O) can be monitored by advanced CEMS using FTIR spectroscopy. Some equipment suppliers do have Formaldehyde in their library of chemicals to be tested, while other will have to add this chemical to the list of detectable substances, creating additional costs.

4.3.10. RECOMMENDED MONITORING METHODS

This section recommends the monitoring methods to use for each pollutant. Stack tests will have to be done at periodical intervals for compliance reasons, typically once a year.[42] Additional stack tests may be undertaken as required for research purposes.

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[41] Fuerst, Dindal, U.S. EPA, Environmental Technology Verification (ETV) Program, "Dioxin Emission Monitoring Systems", February 2007, downloadable at http://www.epa.gov/etv/pubs/600s07002.pdf

[42] Telephone conversation on May 2nd, 2012 with Rick Essel, operator of a biomass boiler and a CEMS at Sunselect Greenhouses in Delta, BC

Table 4.2 Monitoring Methods recommended for BCIT's fuel testing facility

#	Parameter	Continuous Monitoring	Automated Sampling	Manual Stack Testing	Using Surrogate Indicators
1	Total Particulate matter	✓		✓ (for calibration)	
2	Carbon Monoxide (CO)	✓			
3	Sulfur Dioxide (SO2)	✓			
4	Nitrogen Oxides (NOx) expressed as NO2	✓			
5	Hydrogen Chloride (HCl)	✓			
6	Hydrogen Fluoride (HF)	✓			
7	Total Hydrocarbons (THC)	✓			
8	Cadmium (Cd)			✓	
9	Mercury (Hg)			✓	
10	Sum of Lead (Pb), Arsenic (As), Chromium (Cr)			✓	
11	Chlorophenols			✓	✓
12	Chlorobenzenes	✓			
13	Polyaromatic Hydrocarbons (PAHs)		✓		✓
14	Polychlorinated Byphenyls (PCBs)		✓		✓
15	Total Dioxins and Furans (PCDD & PCDF)		✓		✓
16	Formaldehyde (CH2O)	✓			

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5. EQUIPMENT FOR MEASURING MONITORING & OPERATING CONDITIONS

Combustion parameters, particularly the combustion temperature, the oxygen concentration in the flue, but also the flue gas temperature, can have a significant impact on the emissions created when combusting C&D waste or joinery waste. These conditions will need to be measured and recorded during an emission test.

This chapter lays down what type of equipment is required to monitor the operating conditions.

5.1. STANDARD CONDITIONS AS USED BY METRO VANCOUVER AND THE BC MINISTRY OF THE ENVIRONMENT

Metro Vancouver's Biomass Boiler Regulation, Bylaw 1087, states "All concentrations specified in this Emission Regulation for boilers or process heaters fuelled by biomass are referenced at 8 percent oxygen content in stack gas corrected to dry conditions at 20° Celsius and a pressure of 101.325 kilopascals."

The results of the emission monitoring, typically a concentration of a pollutant in the flue gases, will have to be normalized to these standard conditions to be comparable to each other and to judge whether legal thresholds are met. This requires monitoring fluegas temperatures, fluegas velocities and oxygen content inside the stack.

5.2. FLUEGAS TEMPERATURE

Since gases expand when hot, the concentration of a pollutant in a gas is a function of the fluegas temperature. To remove this unwanted dependency it is common to normalize results to standard conditions, 20°C as stated above. As a consequence, every emission measurement should be accompanied by fluegas temperatures measurements. Gas temperature can be monitored using standard thermocouples or pyrometers.

Most CEMS only offer an analog 4-20 mA input that can be used for recording signals from a thermocouple.

A stand-alone thermocouple, including data processing equipment and datalogger, is estimated to cost $200. One sensor will be required for each sample point.

5.3. OXYGEN CONTENT IN THE FLUEGAS

For the same reason as the temperature, the oxygen content in the fluegas needs to be measured: Adding surplus air or oxygen would dilute the fluegas and hence the concentration of a pollutant. Emission thresholds are referenced at certain oxygen content in the fluegas, 8% in the case of the Biomass Boiler Regulation. Measuring the actual O_2-content allows normalizing a concentration of a given contaminant to standard conditions.

Fig 5.1 In-situ oxygen sensor of MRU Instruments, Inc.

The oxygen content in fluegases can be measured by either a Zirconia (ZrO2) oxygen sensor as used in automobiles (e.g. Bosch lambda sensor) or a tuneable diode laser. The total cost, including data processing equipment and datalogger, is expected to be $17,000. Most CEMS are already equipped with an oxygen sensor though.

EPA regulations allow calculating Oxygen content from CO2 content. This practice is, however, discouraged as it might affect data accuracy. Apart from this, knowing the Oxygen content will also help the assessment of the combustor's performance.

5.4. FLUEGAS FLOW RATE OR VELOCITY IN STACK

The most common way of expressing the amount of pollutant emitted is as a concentration, e.g. in weight of the contaminant per volume of flue gas (e.g. mg/m^3). This allows taking the size of the combustor, or the capacity the combustor is operating at, out of the equation.

The velocity of the fluegas in the stack is also required by the automated sampler that will have to extract fluegases isokinetically, i.e. at the same velocity as inside the stack.

The velocity of flue gases is expected to be rather small, between 1 and 3 m/sec. This precludes standard type vortex meters or anemometers, small propellers that are turned by the moving flue gas. The same is true for pressure sensors, such as Pitot Tubes: differential pressure across the Pitot tube may not be enough to employ this technology.

Ultrasonic methods that use time of flight for measurement cannot be used if CO2-concentrations are above 35% as they are expected to be in the case of the biomass boiler. Resolving this issue was beyond the scope of this study.

Solutions that might work include thermal mass meters, or optical meters. The latter uses laser beams to measure the gas flow by sensing the velocity of microscopic particulates in the fluegas. If located upstream of the cyclone an optical meter should have a strong enough signal from the high particulate concentration.

Total costs for an optical flow meter may be in the range of $5,000 to $30,000. One flow meter will be sufficient as the CEMS will extract only 0.5 liter of fluegas (0.03 m^3/h), less than 0.01% of the total fluegas. A continuous sampler will withdraw approximately 15 litres per minute (0.9 m^3/h), still less than 0.1% of the maximum flue gas rate. The systematic error resulting from this is negligible and can be accounted for.

Suppliers of low-velocity flow meters include:

Tundra Process Solutions
Tel: 403-255-5222
7523 Flint Road S.E., Calgary, AB
T2H 1G3

COSA Xentaur ·
84G Horseblock Road ·
Yaphank, NY 11980 · USA ·
Tel: 631-345-3434
http://cosaxentaur.com

Dwyer Instruments Inc.
102 Indiana Hwy. 212
(P.O. Box 373)
Michigan City, IN 46360 (46361) USA
Tel: 219-879-8000
http://www.dwyer-inst.com

5.5. COMBUSTION TEMPERATURE

The temperature of the combustor will need to be recorded because the unit might perform differently at temperatures lower or higher than the standard temperature recommended by the supplier of the combustor. We recommend monitoring the temperature in the secondary combustion chamber where most of the oxidation happens.

A standard temperature probe (thermocouples or pyrometers) with a 4-20 mA analog signal is available for $200. Additional costs will be incurred since this probe will have to penetrate the skin and refractory of the combustion chamber. Alternatively a signal from the combustor's PLC may be used. This should be discussed with the supplier prior to purchasing the biomass boiler.

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5.6. BOILER OUTPUT

Finally the output of the boiler should be recorded, as the unit might perform differently at full load compared to partial load conditions. Ultrasonic flow meters measure the flow of the boiler water, supply and return temperature and use these measurements to calculate the heat power.

Ultrasonic heat meters for pipe diameters of 2.5' are available at approximately $2,000.

Suppliers of flow meters include:

Aalto Inc. (distributor of Kamstrup meters)
65 Harbour Square # 1202,
Toronto, ON, M5J 2L4,
Tel: 416-360-8300,
info@aalto.ca

Fig 5.2 Flow meter of Kamstrup in the return pipe of a 400 kW biomass boiler

Chapman Burner & Heating Service Ltd
3871 Fraser Way N
Burnaby, BC V5J 5G6
Tel.: (604) 431-5900

TW Mackay & Son Ltd (distributor of Siemens meters)
213-669 Ridley Place
Delta, BC V3M 6Y9
Tel: (604) 540 6082

5.7. FUEL CONSUMPTION AND ASH PRODUCTION

Fuel consumption should be monitored along with heat output, as it allows calculating either the boiler efficiency or the net calorific value of the fuel.

Likewise ash production should be monitored. In total there will be three sources of ash: bottom or grate ash; coarse ash from the dust separator or cyclone; and fine flyash from the electrostatic precipitator.

Both fuel consumption and ash production can be measured by placing load cells – essentially electronic scales - under each of the supporting legs of the fuel silo or the ash hopper, respectively. Alternatively bolt-on strain sensors can be attached to the legs rather than positioned under the silo legs. These stress sensors gauge the strain on the leg and convert it into a 4-20 mA signal that can be calibrated to the weight/mass of the wood waste contained inside the silo.

Fig 5.3 Weight measuring systems: Compression load cell of Omega and bolt-on leg strain sensor of Scaletron, US

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The cost of a complete weighing mechanism for a six-leg silo including display was quoted at $5,000. Individual load cell are available at $250 to $500.

Figure 6.1 in Chapter 6 lays down the location of these load cells and all other monitoring points.

Suppliers of load cells and stress sensors or entire weighing mechanisms for silos include:

Scaletron Inc.
6428 Trans-Canada Highway,
St Laurent, QC,
H4T 1X4, Canada.
Tel: 514 940 0337
www.scaletron.com

Force Flow Inc.
2430 Stanwell Drive
Concord, CA 94520 USA
Tel: 925-686-6700
info@forceflow.com
www.forceflow.com

OMEGA
976 Bergar
Laval, QC
H7L 5A1 Canada
Tel: 514-856-6928
www.omega.ca

6. BOILER PLANT DESIGN AND ARCHITECTURAL REQUIREMENTS

A biomass boiler plant hosting a monitoring program will have to be designed to meet the requirements of this program. As a first step it needs to be decided at how many points the various parameters will be monitored.

In order to quantify the effect of filtering equipment, measurements should be made before and after the filter, i.e. upstream and downstream of the filter. There will be at least one filter, most likely an electrostatic precipitator. Most biomass boilers, however, also have a cyclone taking out coarse flyash. Finally, while not common for boilers of this capacity, it may be considered installing a condenser or economizer. Again, fluegases should then be monitored before and after the cyclone and before and after the condenser/economizer.

This would make a total of four continuous monitoring points. The last three points are optional and only required for research purposes.

1. Downstream of the electrostatic precipitator, i.e. at the chimney;
2. Downstream of the condenser/economizer and upstream of the electrostatic precipitator;
3. Downstream of the cyclone and upstream of the condenser/economizer; and
4. Downstream of the boiler and upstream of the cyclone.

Figure 6.1 illustrates the location of these monitoring points.

The number of monitoring points may be reduced by bypassing the ESP, the condenser, and/or the cyclone. Baffles or a gate would allow switching the fluegases to be monitored with or without the impact of these components. This set-up will reduce costs for multiple access points and monitoring ports, thereby also reducing space requirements inside the boilerhouse. Without taking building and ducting costs into account, savings would be $13,000 per monitoring point, see Table 6.1 below.

Table 6.1 Cost of a Continuous Emission Monitoring System depending on the number of monitoring points

	4 CEMS points	3 CEMS points	2 CEMS points	1 CEMS points
Cost of a Continuous Emission Monitoring System (CEMS)	$286,000	$273,000	$260,000	$247,000

Likewise Dioxin sampling could be done at one rather than at two points, reducing the cost of the automatic sampler from $130,000 to $100,000. A monitoring program aimed at compliance rather than at research would thus be at least $69,000 less.

Monitoring and sampling would have to be done consecutively rather than simultaneously. This will require repeating experiments keeping all operating conditions the same. This might prove to be challenging during the start-up and cool down of the biomass boiler.

6.1. CHIMNEY REQUIREMENTS, SAMPLING PORTS AND SAMPLING PLATFORM

A chimney or stack for a 250 kW biomass boiler typically has a diameter of no more than 250 mm (10"). In order to insert large probes, as used by professional stack testers, the stack might require a larger inside diameter, possibly up to 610 mm (24").[43] This, however, would create very low fluegas velocities, as low as 0.3 m/sec, making isokinetic sampling difficult. The sidewalls create a drag effect that throws off velocity calculations on small ducts.

As a compromise we recommend increasing all ducts and the stack to a diameter of 360 mm (14"). This will ensure laminar flow and reduce the drag effect of the side walls. A 360 mm duct would be only required at segments of the fluegas duct that are accessed by the stack tester, that are equipped with an automated sampler, and that host the gas-flow meter. These segments should have straight pipe runs, as much as four pipe diameters (1.5 m) upstream and two pipe diameters (0.7 m) downstream from any other device or change in flow. Locations are identified in Figure 6.1 below.

It is estimated that increasing the diameter of ducts from 250 mm to 360 mm will add $5,000 in cost. Increasing the 12-meter-high chimney to this diameter is expected to cost an additional $10,000. It should be kept in mind that all ducts downstream of the economizer will have to be in high-grade stainless steel, as condensed fluegases are highly corrosive.

The need for extended straight sections of pipes will require the boiler house to be approximately 7 meter (23') longer than usual. It was beyond the scope of this study to estimate the financial impact that might have on the architecture of the boilerhouse.

The design of the boilerhouse and location of the control cabinet and purge gas bottles (see picture to the right) inside the boilerhouse will have to be adapted to the monitoring requirements. This should already be done at the planning stage.

As for the chimney, each sampling point should have at least two ports at a 90° angle to each other, at least 75 mm (3") in diameter and protruding out from the stack 75 to 100 mm (3-4"). The ports should be at least two stack diameters downstream of the last elbow and at least one stack diameter below the end of the chimney/stack.

Technically the BC Field Sampling Manual requires at least eight ports for stacks with a diameter above 300 mm.[44] It might be argued that the stack diameter was purposely enlarged to improve monitoring conditions.

These ports need to be readily accessible and closable if not needed. Some monitoring equipment comes with clamps that can be welted, crimped or riveted to the stack, while professional stack testers simply require short (100 mm) threaded stubs as described in the BC Field Sampling Manual.[45] Eyebolts need to be attached to the stack outside to suspend equipment with a weight of up to 50 kg (110 lb). The chimney will have to be custom manufactured. The cost for upgrading the stack with the above-mentioned ports is estimated to be $3,000.

Access to the ports at the stack might require a platform attached to the stack itself or to the building (NE-02). A platform would have to be secured with 1.22 m top-rail guard. Alternatively the roof of the boilerhouse may be used as a platform.

[43] E-mail exchange with Matt McCall of McCall Environmental, a certified stack testing company, on May 3rd, 2012

[44] A minimum of eight and a maximum of 24 sample points are required for a stack with a diameter of 30 to 61 cm according to the BC Field Sampling Manual. See Chapter 3 of Part B – Air and Air Emission Testing

[45] See Appendix 1.2a, Figure 1 of the Field Sampling Manual

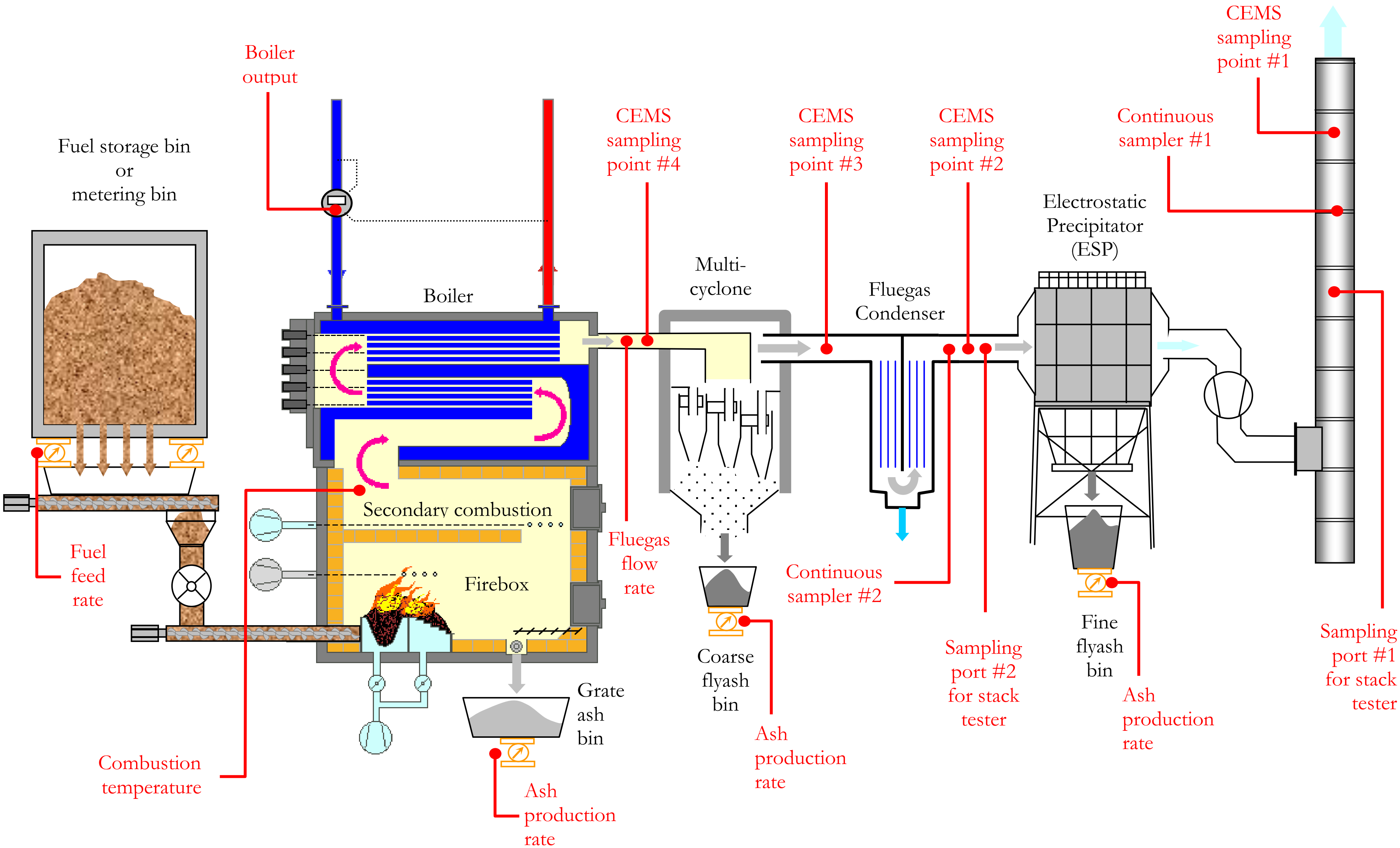

Fig. 6.1 Monitoring points at the biomass boiler plant

7. BUDGET COSTS OF A MONITORING PROGRAM

The following is an estimate of capital and operating costs that BCIT may incur if it follows the monitoring strategy that is suggested in this study. Costs are indicative only with an accuracy of ±20%.

This accuracy cannot be applied to individual line items. Some prices are based on actual quotes received, while others were budgetary prices obtained from suppliers. A number of prices are estimates only that are not supported by a quote.

Table 7.1 Cost of an Emission Monitoring Research Project

	Item	One-time Capital Costs	Recurring or Operating Costs	
			Amount	Annual cost
1.	Waste audits & sieve analysis		6 per year	$14,100
2.	Chemical Fuel Analyses		10 per year	$12,500
3.	Stack tests		1 per year	$7,100
4.	Laboratory tests		12 per year	$3,000
5.	Continuous monitoring system (CEMS), 4 monitoring points	$286,000		$600
6.	Automated sampler, 2 sampling points	$135,000		$400
7.	Other monitoring equipment	$14,500		
8.	Chimney modifications and access to ports	$13,000		
	Sub-total	**$448,500**		**$37,700**
9.	Project management & installation supervision (5%)	$22,000		
10.	Contingencies (20%)	$90,000		$7,500
	TOTAL	**$560,500**		**$45,200**

A breakdown of individual price items can be found in Appendix B.

Downsizing the scope of a monitoring program, e.g. by disregarding the automated sampler, would reduce capital costs. $100,000 (single sampling point) to $135,000 (two sampling points) in capital costs could be replaced by the cost of hiring a professional stack tester instead A single stack test for heavy metals (according to EPA Method 29) and for Dioxins, Furans, PCBs and PAHs (EPA Method 23) was quoted for $31,600. [46] Assuming compliance requires test to be done once a year, the cumulative costs of annual stack tests over the 20 years + lifetime of the biomass boiler would far exceed the initial cost of the sampler. The cost of a single point automated sampler would be justified if more than three stack test are conducted.

Compliance monitoring will require only one rather than two sampling point reducing capital costs by $35,000. Likewise the number of monitoring points can be reduced from four points to one point, saving $39,000 in capital cost. Table 7.2 summarizes the options for a downsized monitoring program that is aimed at compliance rather than at research.

[46] Quote of McCall Environmental dated May 26, 2012

Table 7.2 Capital Costs for Research versus Compliance Monitoring

	Item	RESEARCH (4 CEMS points 2 Dioxin sampling points)	COMPLIANCE (1 CEMS point 1 Dioxin sampling point)
5.	Continuous emission monitoring system (CEMS)	$286,000	$247,000
6.	Automated (Dioxin) sampler **	$135,000	$100,000
7.	Other monitoring equipment	$14,500	$14,800
8.	Chimney modifications and access to ports	$13,000	$13,000
	Sub-total	**$448,500**	**$374,800**
9.	Project management & installation supervision (5%)	$22,000	$19,000
10.	Contingencies (20%)	$90,000	$75,000
	TOTAL	**$560,500**	**$468,800**

*** Indicative price only*

8. GLOSSARY & ACRONYMS

°C	Degree Celsius, sometimes referred to as 'Centigrade'.
AB	Alberta
AMS	Advanced Monitoring Systems
As	Arsenic
ASTM	American Society for Testing and Materials
BC	British Columbia
BCIT	British Columbia Institute of Technology
bdt	Bone-dry tonne, a forestry unit used to measure the pure wood content of moist wood fibre
BTU	British Thermal Unit; an imperial unit used for heat or steam energy; 1,000,000 BTU = 273 kilowatt hours (kW)h
C&D wood, CDW	Construction and demolition wood
C_6H_5Cl	Chlorobenzene
CAC	Criteria air contaminants
CBER	Canadian Biomass Energy Research Ltd.
Cd	Cadmium
CEMS	Continuous emission monitoring system
CH_2O	Formaldehyde
CO	Carbon monoxide
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide-equivalent: a factor taking the potency of a specific GHG into account and comparing it to the GHG effect of CO2
Cr	Chromium
DLC	demolition, land clearing and construction waste
EPA	(US) Environmental Protection Agency
ESP	electrostatic precipitator, a fluegas filtering equipment
ETV	Environmental Technology Verification Program (of the US EPA)
F	Fahrenheit
FIT	Flame ionization technology, a technology used for measuring hydrocarbons
FTIR	Fourier Transform Infrared Spectroscopy
GHG	Greenhouse Gas
GIGO	Garbage in – garbage out

GJ	Gigajoule, an energy unit; 1 GJ is 1 billion Joule; 1 J = 1 Ws (Watt second) 1 GJ = 3.6 MWh = 0.94 mm BTU ; to convert GJ to MWh, multiply by 3.6, to convert MWh to GJ divide by 3.6 1 GJ is equal to slightly more than the energy content of two propane cylinders like the ones used on most gas bar-b-ques. 1 GJ is equal to the energy content of 28 litres of gasoline (at 20°C)
GST	Goods and Service Tax
GVS&DD	Greater Vancouver. Sewerage And Drainage District.
H	Hydrogen
ha	Hectare; the area in a surface of 100 x 100m; 1 ha = 2.47 acre
HAP	Hazardous air pollution
HCl	Hydrogen Chloride
HF	Hydrogen Fluoride
Hg	Mercury
HHV	Higher Heating Value
ICI	industrial, commercial, institutional
kg	Kilogram; 1 kg = 2.2 lb
km	kilometre; 1 km = 1,000 metres = 0.621 miles
kPa	kiloPascal; 1 kPa = 1,000 Pa = 0.15 PSI
kW	Kilowatt; power or capacity measurement unit; 1 kilowatt (kW) = 1,000 W
kW_{el}	kilowatt electrical, indicating electrical power – rather than thermal capacity
kW_{th}	kilowatt thermal, indicating thermal power – rather than electric capacity
lb	Pound, 1 lb= 0.45 kg
LHV	Lower Heating Value: a measure of the calorific content of a fuel. Other than the Higher Heating Value (HHV), this is the energy released after subtracting the latent heat released when condensing the steam contained in the flue gases. For biomass, this value is more representative than the higher heating value as there are no condensing boilers on the market that could make use of the energy contained in the steam.
m	metre
m.c.	Moisture content
m.c. (dry basis)	Percentage of water in relation to the mass of the bone-dry biomass (i.e. without the water contained in the biomass)
m.c. (wet basis)	Percentage of water in relation to the mass of the bone-dry biomass and the water contained in the biomass

m^2	square metre; 1 m^2 = 10.8 square foot
m^3	Cubic metre
m^3	Cubic meter; 1 m^3 = 1,000 litres = 1.31 cubic yard
mA	Milli-Ampere ("milli-amps")
MDF	Medium Density Fibreboard
mg/sm^3	Milligram per standard cubic meter; a unit of concentration of a pollutant in fluegases, corrected to 101 kPa and 20°C
mm	millimetre; 25.4 mm = 1 inch
mmBTU/h	million BTU per hour, an imperial unit used for boiler capacity; 1 mmBTU/h = 273 kilowatts (kW)
MoE	BC Ministry of Environment
MSW	Municipal Solid Waste
MV	Metro Vancouver (aka Greater Vancouver Regional District)
N	Atomic Nitrogen
N_2	Molecular Nitrogen
NAUF	no-added Urethane Formaldehyde
Nm^3	Standard or normal cubic meter, i.e. the volume of a gas if it were at standard conditions of 20°C and 101.325 kPa
NO_x	Oxides of nitrogen, primarily NO and N2O
NO_x	Oxides of nitrogen (NO, NO_2, N_2O)
O&M	Operation and maintenance
ON	Ontario
PAH	Polycyclic Aromatic Hydrocarbons (PAHs), a family of chemicals that come from the burning of wood, fossil fuels, garbage and other materials. PAHs can make breathing more difficult and cause cancer. Source: BC Air Qlity, http://www.bcairquality.ca/glossary
Pb	Lead
PCB	Polychlorinated Biphenyls, Source: BC Air Quality, http://www.bcairquality.ca/glossary
PCDD	Polychlorinated Dibenzo-p-dioxins
PCDF	Polychlorinated Dibenzofurans
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PSI	Pounds per square inch; 1 PSI = 6.9 kPa

S	Sulfur
sec	Second
SO_2	Sulfur dioxide
SO_x	Oxides of Sulfur
t	Metric tonne; 1 tonne = 1,000 kg =2,204 lb
THC	Total Hydrocarbons
TOC	Total Organic Carbon
TPM	Total Particulate Matter
W	Watt
yr.	Year

APPENDICES

Appendix A: Capabilities and Prices of Continuous Emission Monitoring Systems (CEMS)

Appendix B: Detailed budget for a Four-point Emission Monitoring Project

Appendix C: Minutes of the Meeting

APPENDIX A: CAPABILITIES AND PRICES OF CONTINUOUS EMISSION MONITORING SYSTEMS (CEMS)

	Supplier	Sick Ltd	Sick Ltd	Sick Ltd	Vanko Analytics Ltd	Monitoring Solutions Ltd	CEM Specialities Inc.	Hydroflow Controls Ltd
#	Manufacturer Model	Sick FW102	Sick MERCEM 300Z	Sick MCS100FT	Gasmet CEM II	MonSol CEMEX + CEMDAS	ABB	Kitiwake Procal P-200 R
1	Total Particulate matter	✓						
2	Carbon Monoxide (CO)			✓	✓	✓	✓	✓
3	Sulfur Dioxide (SO2)			✓	✓	✓	✓	✓
4	Nitrogen Oxides (NOx)			NO & N2O	NO & NO2 & N2O	✓	NO & NO2 & N2O	NO & NO2 & N2O
5	Hydrogen Chloride (HCl)			✓	✓		✓	✓
6	Hydrogen Fluoride (HF)			✓	✓		✓	
7	Total Hydrocarbons (THC)			✓	✓		✓	✓
8	Cadmium (Cd)							
9	Mercury (Hg)		✓					
10	Sum of Lead (Pb), Arsenic (As), Chromium (Cr)							
11	Chlorophenols,							
12	Chlorobenzenes				✓			
13	Polyaromatic Hydrocarbons (PAHs)							
14	Polychlorinated Byphenyls (PCBs)							
15	Total Dioxins and Furans (PCDD & PCDF)							
16	Formaldehyde (CH2O)				✓			
	Others			CH4, CO2, H2O and NH4	H2O, CO2, NH3, CH4, C2H6		H2O and NH3	CO2, H2O
	Oxygen (O2)			✓	✓	✓	✓	✓
	gas velocity/flow					✓	?	✓
	gas temperature							✓
	extractive	in-situ	✓	✓	✓	✓	✓	✓
	Total	**$10,000**	**$181,650**	**$228,750**	**$275,930**	**$113,000**	**$193,620**	**$316,995**

APPENDIX B: DETAILED BUDGET FOR A FOUR-POINT EMISSION MONITORING PROJECT

	One-time Capital Costs			Recurring or Operating Costs			
	Amount	Unit cost	**Total** capital cost	Amount	Unit cost	Annual cost	**Total Annual cost**
1 . WASTE AUDIT							
1 . 1 Waste type audit				3 per year	$4,200	$12,600	
1 . 2 Sieve analysis				3 per year	$500	$1,500	
							$14,100
2 . CHEMICAL FUEL ANALYSES							
2 . 1 Proximate Analyses				10 per year	$200	$2,000	
2 . 2 Ultimate Analyses				10 per year	$450	$4,500	
2 . 3 Other Analyses				10 per year	$350	$3,500	
2 . 4 Ash Analyses				10 per year	$200	$2,000	
2 . 5 Sample grinding and drying				10 per year	$50	$500	
							$12,500
3 . PARTICULATES							
3 . 1 Optical in-situ monitor	1	$10,000	$10,000				
3 . 2 Stack test (for calibration purposes)				1 per year	$3,000	$3,000	
			$10,000				**$3,000**
4 . CRITERIA AIR CONTAMINANTS (CO,NOx, SOx, incl. O2 and gas velocity)							
4 . 1 CEMS equipment	1	$113,000	$113,00			$200	
4 . 2 Additional monitoring points	3	$13,000	$39,000			$0	
4 . 3 Stack test (for verification purposes)				1 per year	$3,000	$3,000	
			$126,000				**$3,200**
5 . ACID GASES (HCl, HF)							
5 . 1 CEMS upgrade to FTIR	1	$82,000	$82,000				
5 . 2 Stack test (in combination with CAC test)				1 per year	$300	$300	
			$82,000				**$300**
6 . ORGANIC HYDROCARBONS							
6 . 1 Upgrade of CEMS to accept FID	1	$10,000	$10,000			$200	
6 . 2 Flame Ionization Detector	1	$32,000	$32,000			$200	
6 . 3 Stack test (in combination with CAC test)				1 per year	$300	$300	
			$42,000				**$700**
7 . METALS (Cd, Hg, Pb, As, Cr)							
7 . 1 Stack test (in combination with particulate test)				1 per year	$500	$500	
							$500
8 . CHLOROPHENOLS							
8 . 1 Laboratory test				2 per year	$250	$500	
							$500
9 . CHLOROBENZENES							
9 . 1 Part of advanced CEMS equipment							
			$0				

		One-time Capital Costs			Recurring or Operating Costs			
		Amount	Unit cost	**Total** capital cost	Amount	Unit cost	Annual cost	**Total Annual cost**
10 .	DIOXINS, FURANS, PCBS AND PAHS							
10 . 1	Automated sampler	1	$100,000	$100,000			$200	
10 . 2	Second extraction point	1	$35,000	$35,000			$200	
10 . 3	Laboratory tests				10 per year	$250	$2,500	
				$137,000				**$2,900**
11 .	FORMALDEHYDE							
11 . 1	Part of advanced CEMS equipment			$0				
				$0				
12 .	GAS FLOW RATE & TEMPERATURE							
12 . 1	add-on to CEMS (for normalization purposes)	2	$4,100	$8,200				
				$8,200				
13 .	COMBUSTION TEMPERATURE							
13 . 1	Thermocouples	2	$200	$400				
				$400				
14 .	BOILER OUTPUT							
14 . 1	Heat Meter	1	$2,000	$2,000				
				$2,000				
15 .	FUEL CONSUMPTION							
15 . 1	Compression load cell (metering bin)	4	$300	$1,200				
				$1,200				
16 .	ASH PRODUCTION (Bottom Ash & Flyash)							
16 . 1	Compression load cell (grate ash dumpster)	3	$300	$900				
16 . 2	Compression load cell (cyclone ash dumpster)	3	$300	$900				
16 . 3	Compression load cell (ESP ash dumpster)	3	$300	$900				
				$2,700				
17 .	PORTS AND ACCESS TO PORTS FOR STACK TESTING							
17 . 1	Increasing diameter of fluegas ducts	1	$5,000	$5,000				
17 . 2	Increasing diameter of chimney	1	$5,000	$5,000				
17 . 3	Ports at chimney	1	$3,000	$3,000				
				$13,000				
	SUB-TOTAL			**$448,500**				**$37,700**
				92%				
	Project management	5%		$22,000				$0
	CONTINGENCIES	20%		$90,000				$7,500
	TOTAL (excl. HST)			**$560,500**				**$45,200**

green prices: firm written quotes
orange prices: estimates or oral quotes

Not included:

* Increased planning costs
* Increased architectural/building cost
* Staffing of the monitoring equipment

APPENDIX C: MINUTES OF THE MEETING

MINUTES

BRITISH COLUMBIA INSTITUTE OF TECHNOLOGY | bcit.ca

BCIT Biomass Research Project Stakeholders Meeting

Kickoff

03/09/2012 **9:00am** **Phone Conference**

Chair: Alexandre Hebert, BCIT
Minute Taker: Andrea Linsky, BCIT

Present:

BC Bioenergy Network Scott Stanners Michael Weedon	**Metro Vancouver** Larry Avanthay	**BC Ministry of Environment:** Tony Wakelin Lloyd Phillips
BCIT Olga Petrov Andrea Linsky Alex Hebert Deacon Tong	**Canadian Biomass Energy Research Ltd** Cornelius Suchy	

Regrets:

BC Ministry of Environment: Jonn Braman	**BCIT** Jennie Moore	

Agenda item #1: Welcome Opening Remarks and Review of Agenda

Presented by:
Alexandre Hebert

Discussion Points:
Agenda:

1. Review of agenda
2. Introduction of stakeholders
3. Review of project
4. Directed discussion

Actions or Outcomes:
n/a

Agenda item #2: Intro of Stakeholders participating to the conference call

Presented by:
All

Discussion Points:
Each participant described their organization, role and interest in this project.

Actions or Outcomes:
n/a

Agenda item #3: Review of project

Presented by:
Alexandre Hebert and Cornelius Suchy

Discussion Points:

A) BCIT Operations:

- This project originally started with BCIT wanting to use its wood residue from carpentry and joinery departments. BCIT wood programs produce approximately 250 tonnes of wood waste per year (mostly solid wood, with some plywood and MDF). A 250 to 300 kW boiler system could transform the wood from waste to energy and tie-in with BCIT's district energy system to offset approximately 4,000 GJ of natural gas per year.

B) Research:

- A cornerstone of this project is its research component to develop a fuel standard for refuse derived woody biomass and understand the equipment and operating guidelines needed to ensure the cleanest emissions possible. BCIT wants to know what fuel mix [from construction waste] can go in a commercially available biomass system [and what are the associated operating guidelines] to ensure best-in-class emissions that meet or outperform Metro Vancouver standards and BC Ministry of Environment requirements.
- The Ministry of Environment has produced a guideline for MSW combustion that will likely be used as a basis for setting emission limits within authorizations for large facilities - . To date, neither the Ministry nor Metro Vancouver have guidelines that are specific to the burning of construction and demolition material. The BCIT study could provide valuable information for setting emission limits that are specific to construction and demolition material combustion.
- Metro Vancouver developed a study that says that there is about 400,000 tonnes of urban wood waste that is currently ending up in landfill. Metro Vancouver wants to reduce this number by 80% by 2020. One question is: can this wood waste be burned to generate energy and reduce carbon emissions. BCIT believes that this is a bigger question than just "at BCIT" and would like its project to help determine what can be done with this wood waste in BC.

C) Big picture/Future:

- Education: The legacy of the research project should also have value to BCIT and BC. Leveraging biomass technologies will help educate BCIT's students specifically to prepare them for employment in the woodworking trades where sustainability practices are gaining in importance and more specifically, in the field of clean and renewable energy. The proposed project will also be a showcase to the government, institutional, commercial and residential sectors that using wood waste [on a small scale] can be done economically while substantially reducing GHG emissions. A key element to the project is the "showcase building" especially designed for students and visitors with its large size windows, its permanent multimedia signage, and an outdoor mini auditorium to accommodate students and visitors while they learn. BCBN has already offer to partner in order to advance the state of education around biomass in BC.
- BCIT School of Construction and the Environment (SoCE) industry partners: BCIT SoCE also wants to work with industry partners to help change the way that wood products are developed (e.g.: using lignin based binders) in order to allow them to be burned.

Actions or Outcomes:
n/a

Agenda item#4: Discussion

Presented by:
All (Facilitated by Cornelius Suchy – CBER Ltd)

Discussion Points:
Below are presented the key elements that best summarize the discussion:

- Biomass as a clean source of energy: BC Bioenergy Network (BCBN) representatives noted that the system will need to help promote the use of Biomass in BC and prove that emissions can be safe and ideally even better than natural gas (particulate matters) and other forms of energy production in Canada (e.g.: energy from coal). BCIT agrees. BCIT's intention is to keep air particulate emissions significantly below 18 mg/m3 by utilizing best-in-class technologies. The project will have "above requirements" emissions monitoring equipment in an educational setting. This way BCIT can monitor the emissions and teach the public about how clean it is.
- Clarification of Biomass and Waste definition (in BC): [note: the text in this section comes from both the original discussion and a clarification provided by members of the group by email during the minutes (draft) review – refer to Appendix A for more details on the post conference call discussion]. At Metro Vancouver, BCIT's wood is considered biomass but because of the type of wood product found in the mix (e.g.: plywood and MDF) a permit will be required. Because this is BCIT's own wood stream (not importing any wood waste from external sources), this is not considered Municipal Solid Waste (MSW). The material being considered for this project would be considered a Municipal Solid Waste within Metro Vancouver. The reason it is not considered MSW in this case is the fact that this is BCIT's own wood stream (not importing any wood waste from external sources). Metro Vancouver is responsible for permitting. BCIT does not have to apply for a MSW permit, only for a biomass combustion permit. Again, this project falls under Metro Vancouver jurisdiction.

- Using MSW emission guidelines as a reference: MSW emissions guidelines are the most restrictive of the biomass / solid waste regulations. Again, BCIT's wood waste is not MSW. That said, MSW emissions guidelines and monitoring requirements could serve as an "above and beyond" basis for BCIT's research (monitoring) program.
- Need for more knowledge in this area: MOE is very interested this project. There is a need for more knowledge in this area of research. MOE is working on a project with Ramboll in Denmark to acquire more knowledge in this area.
- Need for public engagement: Public engagement will need to be top of mind. This was mentioned multiple times throughout the conversation. BCIT's intentions are to ensure emissions from this project are clean and safe for the public. Even if clean and safe, good communication with public can make the difference between an accepted and rejected biomass combustion project.
- Permitting process: UBC permitting documents could be used as a good example. Larry Avanthay offers to work with Alex Hebert on initiating the permitting process.

Actions or Outcomes:

- Alexandre Hebert to Work with Larry Avanthay to start permitting process.
- BCIT (Alexandre Hebert / Andrea Linsky / Cornelius Suchy) to draft a research plan and submit it to the group for review.

Appendix A

From Lloyd Phillips, MoE - March 20, 2012 2:19 PM:
I'm good with this interpretation (ie, that since the refuse doesn't leave the site it's not considered "waste"--what's more clearly "waste" is the stack discharge). In any event, I don't believe EMA prohibits authorizing MSW via permits, it's just that a permit can't conflict with a Solid Waste Management Plan/Operational Certificate (EMA 24(9)). I believe there are a few examples of permits authorizing MSW discharges (usually mixed with non-MSW) in cases where the discharge isn't large enough to "conflict" with a plan and the regional district has been consulted.

From: Larry Avanthay [Larry.Avanthay@metrovancouver.org] - March 20, 2012 1:36 PM
Clarification of Biomass and Waste definition (in BC): At Metro Vancouver, BCIT's wood is considered biomass but because of the type of wood product found in the mix (e.g.: plywood and MDF) a permit will be required. Because this is BCIT's own wood stream (not importing any wood waste from external sources), this is not considered Municipal Solid Waste (MSW). Metro Vancouver is responsible for permitting. BCIT does not have to apply for a MSW permit, only for a biomass combustion permit. Again, this project falls under Metro Vancouver jurisdiction.

There was confirmation during the discussion that BCIT had no plans to augment the waste wood from the carpentry and joinery shops with similar wood waste material from external sources. Since all the material was to be sourced and chipped on-site it was stated that there would not be a requirement to apply for a licence under our solid waste regulations (GVS&DD Municipal Solid Waste and Recyclable Material Regulatory Bylaw No. 181, 1996
http://www.metrovancouver.org/boards/bylaws/Bylaws/GVSDD_Bylaw_181.pdf).

Further to Lloyd's comment, the material being considered for this project would be considered a Municipal Solid Waste within Metro Vancouver. Our Solid Waste Bylaw does not contain a specific definition for MSW but defaults to the EMA definition (replacement for the Waste Management Act).

I believe the initial conversation was that the material being sourced from the carpentry/joinery shops did not meet the definition of biomass in the Bylaw (GVRD Boilers and Process Heaters Emission Regulation Bylaw No. 1087, 2008) due to the presence of MDF and plywood (glue containing materials). Use of this material as a fuel for a boiler would therefore require that the air contaminants be authorized by the district director which is typically done through applying for a permit (GVRD Air Quality Management Bylaw No. 1082, 2008). I believe it had also been mentioned that Approvals have been used to authorize short term emissions (15 months) but this was not considered an option for this particular project.

From Lloyd Phillips, MoE - March 20, 2012 10:17 AM:
It's noted in the draft minutes that BCIT's material is not MSW. However, I believe it *would* be considered to be MSW, as outlined in the email pasted below (no one has disagreed with its contents). I expect but am not certain that the EMA definition would carry through into Metro Van's regulatory context.