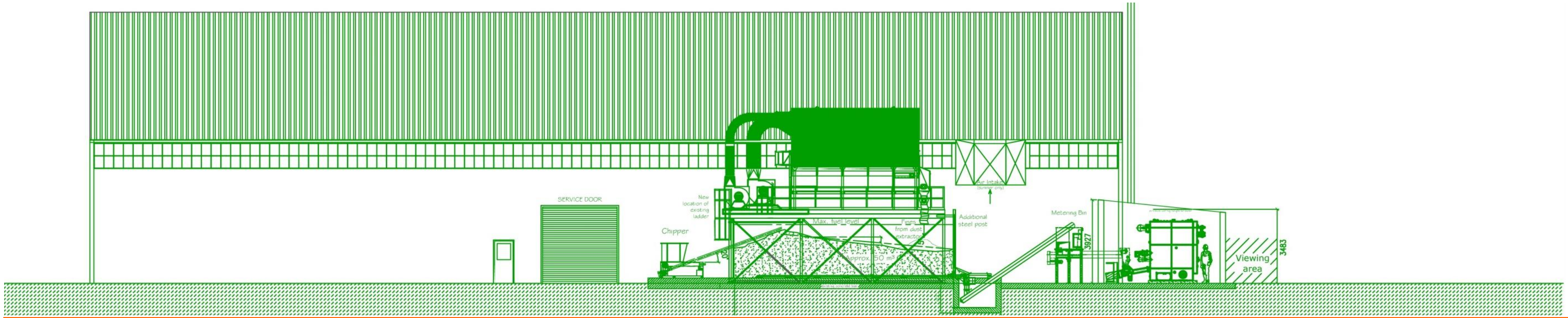


Schematic Design Report

Schematic Design Report
Biomass Boiler Plant at BCIT's Burnaby Campus

DRAFT

Prepared for:

School of Construction and the Environment
British Columbia Institute of Technology
3700 Willingdon Avenue, Burnaby, BC, V5G 3H2

Prepared by:

Canadian Biomass Energy Research Ltd

with

Ing. Aigner GmbH

July 17th , 2013

DRAFT

EXECUTIVE SUMMARY

The School of Construction and the Environment plans to install a biomass boiler that uses wood residue generated mainly by the Carpentry and Joinery Workshop to heat part of BCIT's Burnaby campus. The School has retained Canadian Biomass Energy Research (CBER) Ltd and Ing. Aigner GmbH to prepare a schematic design report for the biomass boiler plant.

Objective of this Report

The purpose of this Schematic Design Report is to develop a viable technical solution for a biomass boiler plant at BCIT's Burnaby Campus. The report is targeted at BCIT staff and decision makers as an audience, illustrating extents and implications of a biomass boiler plant on campus. The design should also be used by the architect as a starting point for planning the enclosures of the plant and its architectural integration into the existing infrastructure.

This report also consolidates the results and advice provided in previous reports and meetings to date regarding the design of a biomass boiler plant. As such sufficient information is provided to move the project to the next stage. The report and plans provided in it is, however, not detailed enough to be used for permitting or procurement purposes. This report is a transition document and as such is not intended as a definitive status of the design of the biomass boiler plant.

Purpose of the Biomass Boiler Plant

The boiler plant has three purposes, listed in their order of importance:

1. Campus heating
2. Education & training (also referred to as 'demonstration')
3. Research

The plant has been planned with these objectives in mind and includes various designs and components that a plant made only to supply heat would not have.

Location and Site Strategy

The plant will become part of BCIT's School of Construction and the Environment and the so-called "Factor Four area". The consensus amongst decision makers at BCIT is that the area around the south-west corner of Joinery Workshop (NE02) of BCIT's Burnaby Campus is the preferred location.

Alternative locations for the boiler plant have been considered during the pre-design phase, but were discarded as less suitable. The main reason for this is that the plant should be located close to the existing dust extraction system that will deliver some of the wood fuel used by the boiler.

General Arrangement

Core components have been arranged in two axes, one along the west wall and the other along the south wall of the Joinery Workshop (NE02). The firebox boiler itself is located at the intersection of these two axes turning the incoming fuel into heat, ashes and exhaust, each of them removed in a different direction. The arrangement also makes use of space that is currently either not used or underused, such as the area below and beside the existing dust extraction system. This minimizes the impact on traffic and the amount of parking space lost.

Summary of Architectural Requirements

The following are requirements that the architect will need to take into account when planning the enclosures of the plant and its integration into the existing campus infrastructure:

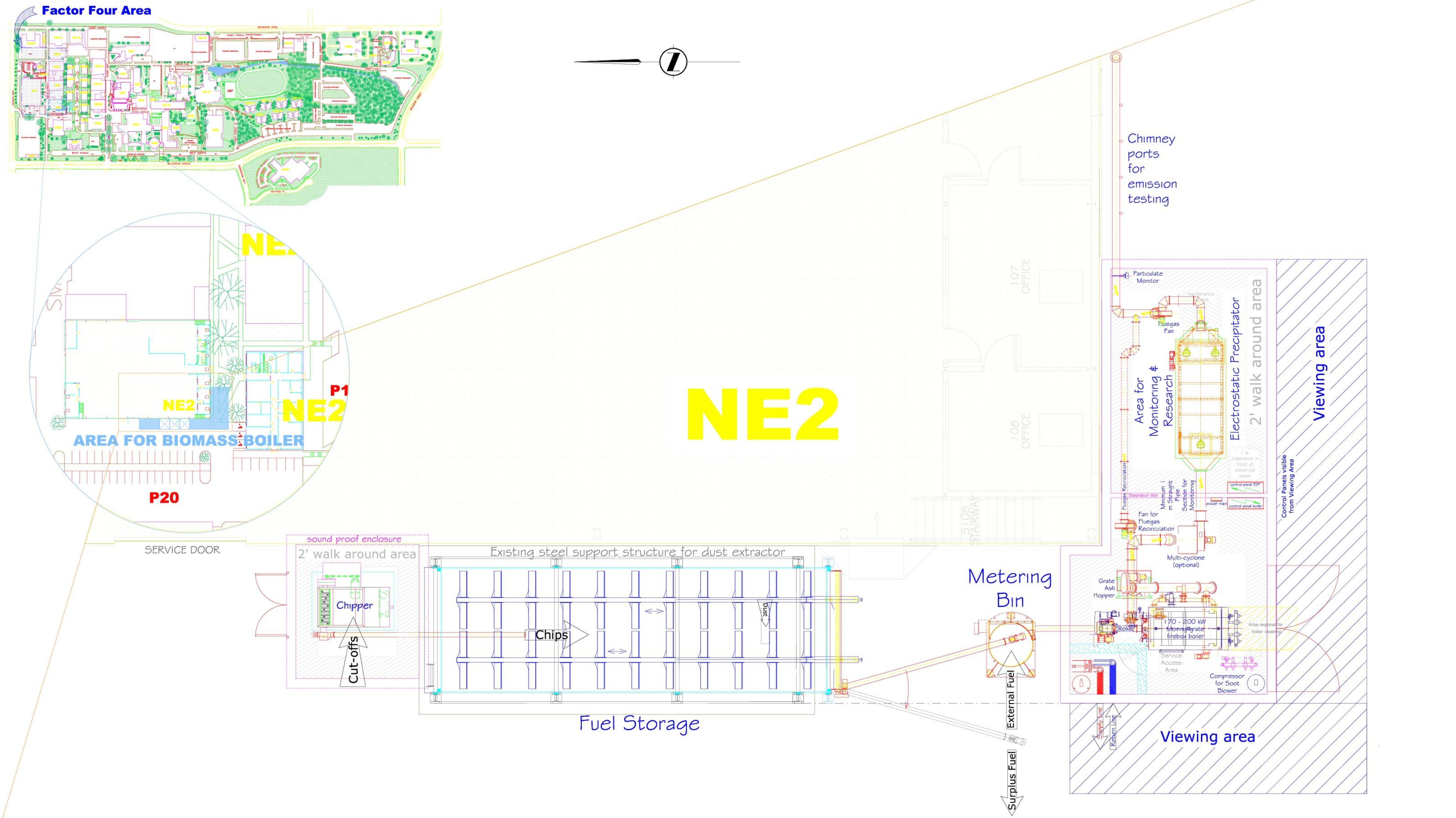
- The chipper will need to have a sound-proof enclosure to allow operating it without disturbing classes.
- The fuel bin will be located underneath the existing dust extractor, using the existing steel columns as a frame for the wall containing the fuel. There will be structural challenges that will need to be resolved by a structural engineer.
- A metering bin will be located between the fuel storage and the firebox boiler. There is no building required for this component. Due to the BC Building Code the metering bin may not be in the same room as the boiler.
- The boiler house will have an L-shaped footprint of approximately 65 m² (700 sft) and should adjoin the south wall of the Joinery Workshop. The minimum ceiling height will be 3.5 m.
- Some of the existing walkway corridor between NE02 and NE21 will be blocked by the boiler plant. This will need to be taken into consideration for the planned redevelopment of NE21 and NE23
- For safety reasons the boiler should be accessible by Facilities' staff only; a wall separating the boiler from the filter will restrict instructors' and students' access to the research and training area in the back of the building.
- Large glass wall(s) on the South face and the West face should make the biomass boiler visible for demonstration and training purposes. The glass walls might have to have a ½ hour fire rating.
- The boiler room will need a large door for introducing the boiler to the building. This door will need to be opened for boiler cleaning.
- Biomass boilers are heavy. The foundation of boiler room will have to be able to withstand 4 tonnes of weight on a 2 m² footprint.
- The boiler will be connected to the existing underground campus heating pipeline that passes the plant location in close proximity. Pipes connecting to the campus heating network would be laid underground, either in a concrete channel or just buried in a ditch.
- With the design provided there would be no major conflict with existing underground services. Part of the plant would be built on top of an existing arm of the storm sewer though.
- When designing the boiler plant a number of codes referenced in the BC Building Code will have to be met, particularly CSA B365 and requirements of the NFPA in regards to spatial separation. The boiler house itself would be classified as Low Hazard Industrial Occupancy. Sprinklers should not be required.
- The boiler room should be designed with 0.6 m (2') wide escape corridors accessible from every point of the plant.

Key Points and Recommendations

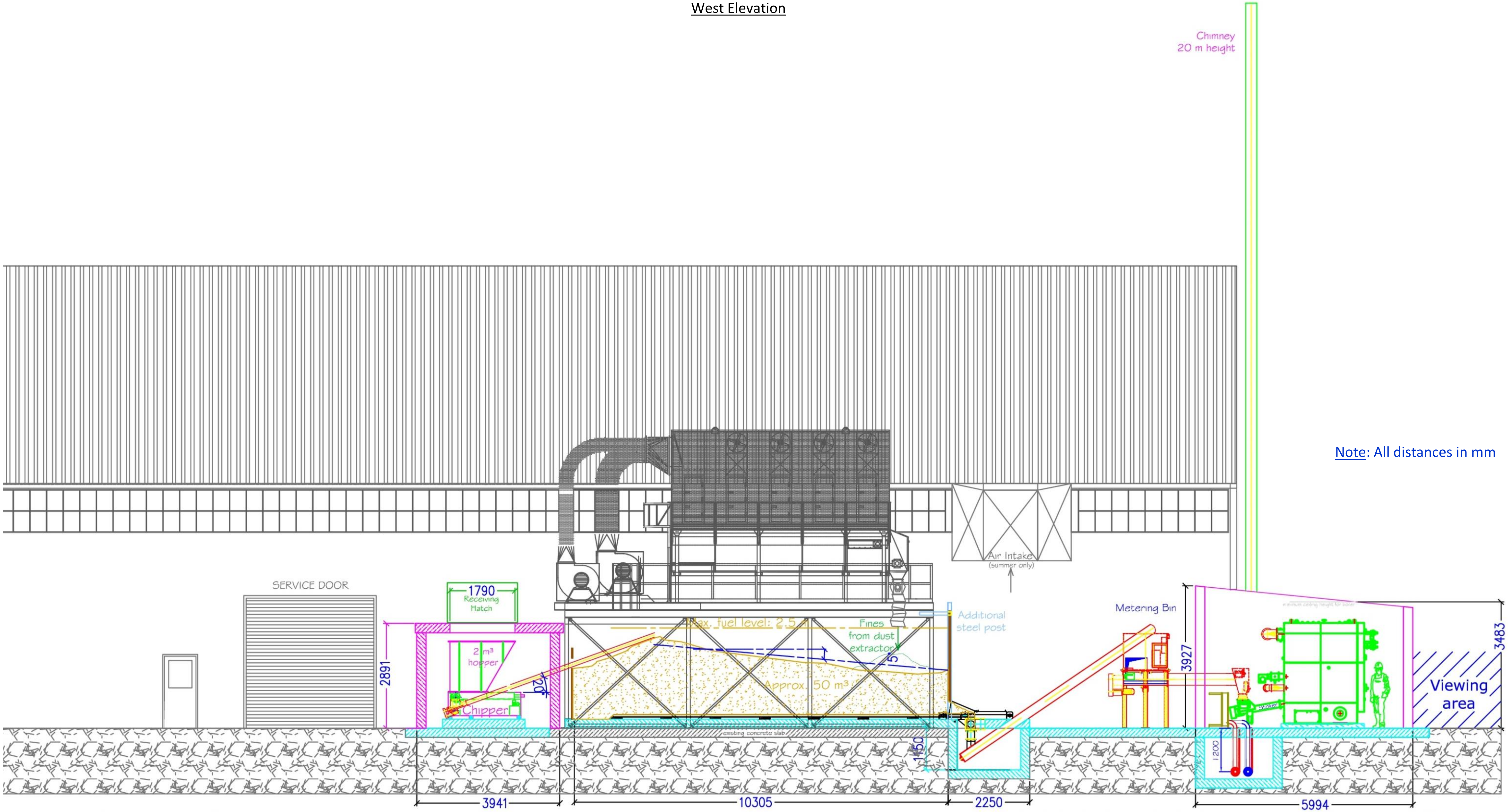
- **Fuel**: 251 tonnes per year of dry wood residue are available, a mix of 9% fines & shavings and 91% solid wood that will need to be chipped. Unless operation of the central boiler plant is changed 42 tonnes (17% of the annual amount) will have to be disposed of during the summer months. The remaining 208 tonnes can be used entirely. No change in residue collection is required, as long as pieces are cut to less than 0.9 m (3') in length and most of the nails are removed.
- **Chipper**: It is recommended using a chipper rather than a grinder for reducing the size of the feedstock material. With a capacity of at least 436 kg/hour (960 lbs/hour) the daily average amount of residue can be chipped within three hours or less, an entire week's waste volume within 15 hours or less. Cut-offs will be delivered by forklift, much the same way as they are delivered to the disposal container now. The chipper will operate unmanned.
- **Fuel Storage**: 10 tonnes or 50 m^3 of fuel storage, equivalent to 10 days of maximum waste production is recommended. While larger than common, this size will allow operating the chipper even if the biomass boiler should be down for an entire week. Likewise it will allow operating the boiler at high fire even if the chipper or its operator is not available for an entire week. Instead of a silo storage common in the wood remanufacturing industry, a walking floor storage system is recommended. This allows making use of the space under the existing steel structure supporting the dust extractor. The structure itself can be used as a frame for the storage;
- **Combustor**: The firebox boiler should have a moving grate design, partly due to plywood and MDF in the fuel, partly to be able to test difficult fuel in the future. The biomass boiler has to operate according to fuel availability rather than heat demand. The unit should be able to combust continuously in the range between 12 and 42 kg/hour. A firebox boiler with a rated output between 170 to 200 kW (depending on the robustness of the design and construction details of the firebox boiler) is best suited to meet this requirement.;
- **Boiler**: It is highly recommended to employ a "warm water" boiler that operates below 100°C and below 206 kPa (30 PSI). This will simplify the requirements of the BC Safety Authority and reduce equipment costs.
- **Ash**: If completely burned BCIT's fuel will generate between 50 and 160 kg of ash a month, in April and October, the months with the lowest and the highest waste volumes, respectively. The ash dumpster will have to be emptied every week at most. Various disposal methods have been discussed, including application to plants on campus and landfilling.
- **Safety**: Biomass boilers can be operated as safely as fossil-fuel boilers, as long as safety devices are in place. Key issues to watch are back burn prevention and dust explosions at the existing dust extraction system
- **Emissions**: Modern biomass boilers can combust biomass fuel in a controlled fashion that reduces, but will not eliminate emissions. Equipped with an electrostatic precipitator the unit should easily be able to meet Metro Vancouver's 18 mg/sm³ threshold for particulate matter. Meeting the NOx—threshold of 200 mg/sm³ will be more challenging and will largely depend on the combustion technology employed.
- **Monitoring and research**: The plant has been designed for operation as a research facility. This includes the possibility to burn test fuels and to monitor various types of air pollutants in the flue gas.
- **Heat usage**: Based on the location of the biomass boiler plant the favoured solution for using heat generated is feeding it into campus heating network. The biomass boiler would operate as a satellite plant, much the same way as the existing gas boilers in the central boiler plant.
- **Interconnection to the Campus Heating Network**: The boiler will feed into the arm supplying the building J.W. Inglis building (NE01) , heating up water returned from NE01 and re-injecting it to the supply line of the same arm. To protect the boiler from poor water quality an indirect connection with a heat exchanger would be beneficial.
- **Heat Storage**: There is no need for heat storage because the carrying capacity of this heat pipeline exceeds the amount of heat the biomass boiler can generate.
- **Other Energy Savings Opportunities:** Currently this arm supplying NE01 is operated at higher than necessary temperatures. Lowering the supply temperature would allow operating the biomass boiler at below 95°C at all times and reduce investment costs.
- **Visibility:** A person hole could be added at the tie-in of the pipes to the existing campus heating network. This person-hole would be under the existing walkway and could have a glass cover for visibility and demonstration purposes.

Conclusions and Next Steps

This report lays down a technical solution taking various constraints and requests into account. Location and foot print of the various components are identified. A number of conceptual alternatives are described. The report should be reviewed by all concerned parties and used as a stepping stone towards the next stage, the permitting phase.


Factor Four Area
NE2
P1
P20
AREA FOR BIOMASS BOILER
NE2
Chimney ports for emission testing
Particulate Monitor
Fluegas Fan
Area for Monitoring & Research
Electrostatic Precipitator
2' walk around area
Viewing area
Control Panels visible from Viewing Area
Fan for Fluegas Recirculation
Multi-cyclone (optional)
Grate Ash Hopper
170 - 200 kW Moving grate firebox boiler
Service Access Area
Compressor for Soot Blower
SERVICE DOOR
sound proof enclosure
2' walk around area
Existing steel support structure for dust extractor
Chipper
Cut-offs
Chips
Fuel Storage
Metering Bin
External Fuel
Surplus Fuel
Viewing area

West Elevation



South Elevation

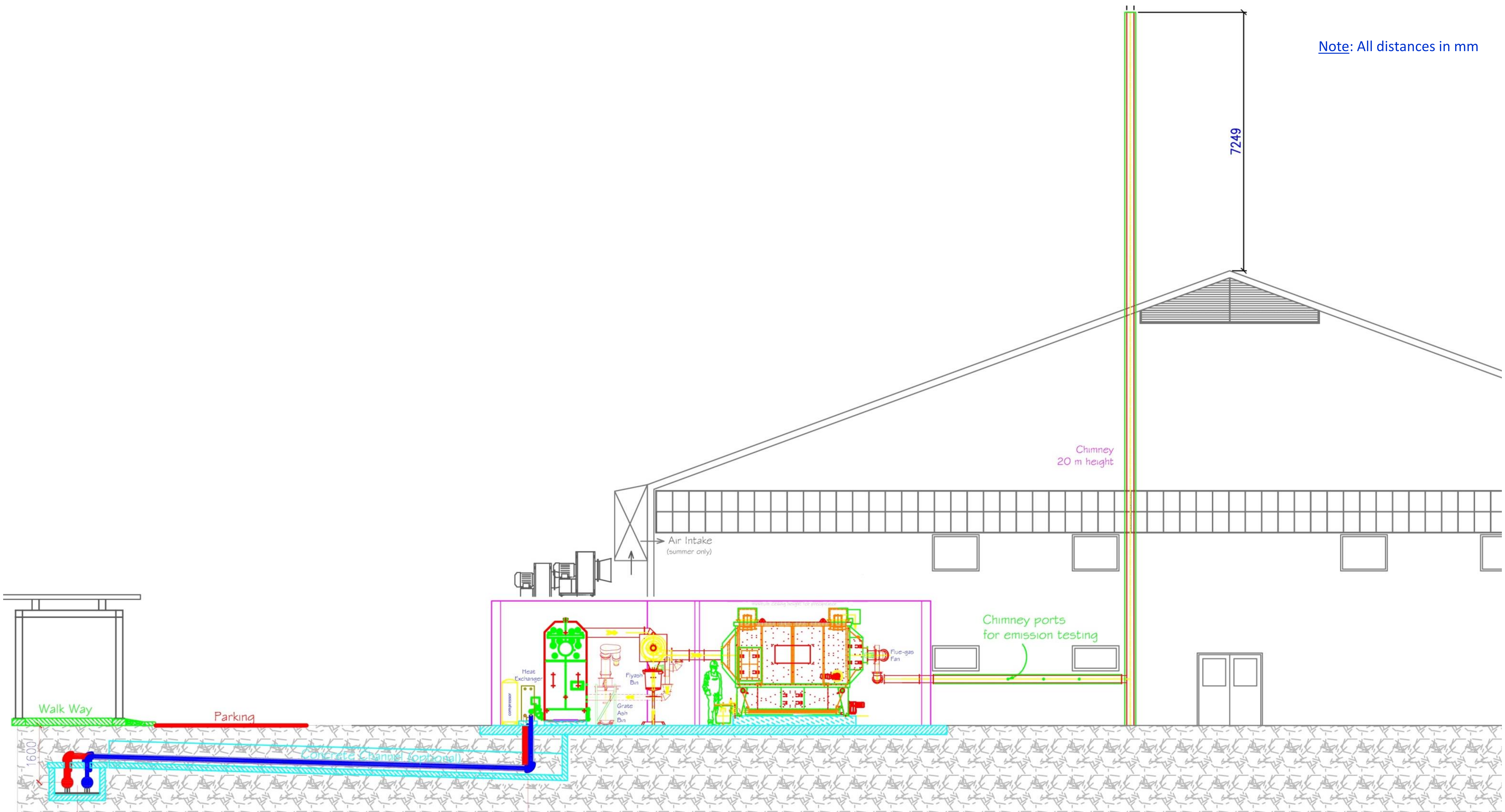


TABLE OF CONTENTS

ACKNOWLEDGEMENT

The authors of this report would like to acknowledge the following persons for their support while conducting the study and during the preparation of this report. This study would have not been possible without their contributions.

- Vanesa Alzate, Energy Specialist, BCIT
- Yves Blaison, Chief Instructor Carpentry Department, BCIT
- Sarah Campbell, Administrative Assistant, School of Construction and the Environment, BCIT
- David Dunn, Chief Instructor Joinery Department, BCIT
- Alexandre Hebert, Energy and Sustainability Manager, BCIT
- Jennie Moore, Director of Sustainable Development and Environmental Stewardship, School of Construction and the Environment, BCIT
- Palvinder Moses, Operations Manager, BCIT
- Marvin Rogers, Director Facilities Services, BCIT
- Rob Sawatzky, Chief Instructor Joinery Department, BCIT
- Craig Sidjak, Director Campus Development, BCIT

This report covers the finding of the schematic design phase for a biomass boiler plant at BCIT's Burnaby Campus. The design phase was preceded by a pre-design phase that consisted of four days of meetings and site visits at BCIT and subsequent evaluation of information and data collected.

INTRODUCTION

The School of Construction and the Environment plans to install a biomass boiler that uses wood residue generated mainly by the Carpentry and Joinery Workshop to heat part of BCIT's Burnaby campus, including its "Factor Four Building(s)". The School has retained Canadian Biomass Energy Research (CBER) Ltd and Ing. Aigner GmbH to develop a workable technical solution for the biomass boiler plant.

All data and numbers provided in this report are preliminary and, based on new information made available, could change during the permitting or engineering design phase. Input from BCIT that requires design changes should be made before the start of the next design phase, i.e. before the permitting phase.

PURPOSE OF THE BIOMASS BOILER PLANT

The boiler plant has three purposes, listed in their order of importance:

1. Campus heating
2. Education & training (also referred to as 'demonstration')
3. Research

The plant has been designed with these objectives in mind.

OBJECTIVE AND SCOPE OF THIS REPORT

The purpose of this Schematic Design Report is to **develop a viable technical solution for a biomass boiler plant** at BCIT's Burnaby Campus. The report is **targeted at BCIT staff and decision makers as an audience**, illustrating extents and implications of a biomass boiler plant on campus. The design should also be used by the architect as a starting point for planning the enclosures of the plant and its architectural integration into the existing infrastructure.

In detail the following design criteria have been established:

- Preliminary calculations have been conducted, establishing base requirements for fuel handling and combustion
- Suitable space has been allocated for individual components and major mechanical installations;
- The flow of material (wood dust and wood chips), fluids (hot water), and gases (flue gases) is indicated; Conceptual alternatives have been developed for a number of components;
- Criteria, limitations and minimum requirements for individual components of the system have been established. These requirements are based on calculations laid down in the preliminary design report;
- Weight, size and other physical characteristics of key equipment relevant for the structural, mechanical and electrical design have been determined;
- General arrangement layouts and outline specifications have been prepared, illustrating and defining the proposed technical solution.

This report also consolidates the results and advice provided in previous reports and meetings to date regarding the design of a biomass boiler plant. As such sufficient information is provided to move the project to the next stage. The report and plans provided in it is, however, not detailed enough to be used for permitting or procurement purposes. **This report is a transition document** and as such is not intended as a definitive status of the design of the biomass boiler plant.

FUEL AVAILABILITY AND CONSTRAINTS

The following considerations and constraints define the operation of the biomass boiler plant:

1. Fuel is available year round. Continuous operation 12 months of the year, however, is currently not possible because there is no – or no access to – heat demand during the summer. The campus heating network does not operate during summer and the heat load of the single biggest consumer, the J. W. Inglis Building (NE01) is 100 days of the year lower than the amount of heat produced by the biomass boiler.
2. During the summer month fuel will need to be either stored or disposed of in other ways; current estimates show approximately 42 tonnes or 17% of the annual fuel incurs during the off-heating season.
3. Fuel storage during the off-heating season would require approx. 200 m^3 (42 t) of fuel to be stored.
4. Space restrictions confine silos to a maximum diameter of 12' (3.7 m). To avoid bridging effects the ratio of the wall height to the silo diameter should not exceed 2:1, i.e. should not exceed 24' (7.3 m), resulting in a storage capacity of 77 m^3 . Three silos would be required to store fuel production during the summer month.
5. Expansion of the campus heating system and its year around operation might make it possible to use heat during summer month in the future. This would potentially make an investment into a large fuel storage system a lost investment.
6. Two alternatives exist: disposing off the wood waste in summer or disposing of the heat generated in summer. The former solution is preferred by the management. In this case the short term storage system needs to be equipped with a disposal screw/chute
7. During periods of low fuel availability the boiler will be turned down manually. The control system of the boiler should allow for this.

Unless changes are made to the way the existing central boiler plant and associated heating network is operated, 42 tonnes of usable wood residue, 17% of the annual amount, will need to be disposed of during the summer months. The remaining 208 tonnes can be used entirely.

LOCATION OF THE BIOMASS BOILER PLANT

Various locations for the biomass boiler plant have been discussed prior and during the pre-design phase.

The plant will become part of BCIT's School of Construction and the Environment and the so-called "Factor Four area". The Factor Four area is comprised of seven buildings ranging from a single-detached home to a four-storey building the size of a football field, covering one-tenth of the built environment and 16% of the floor area of BCIT's Burnaby campus.

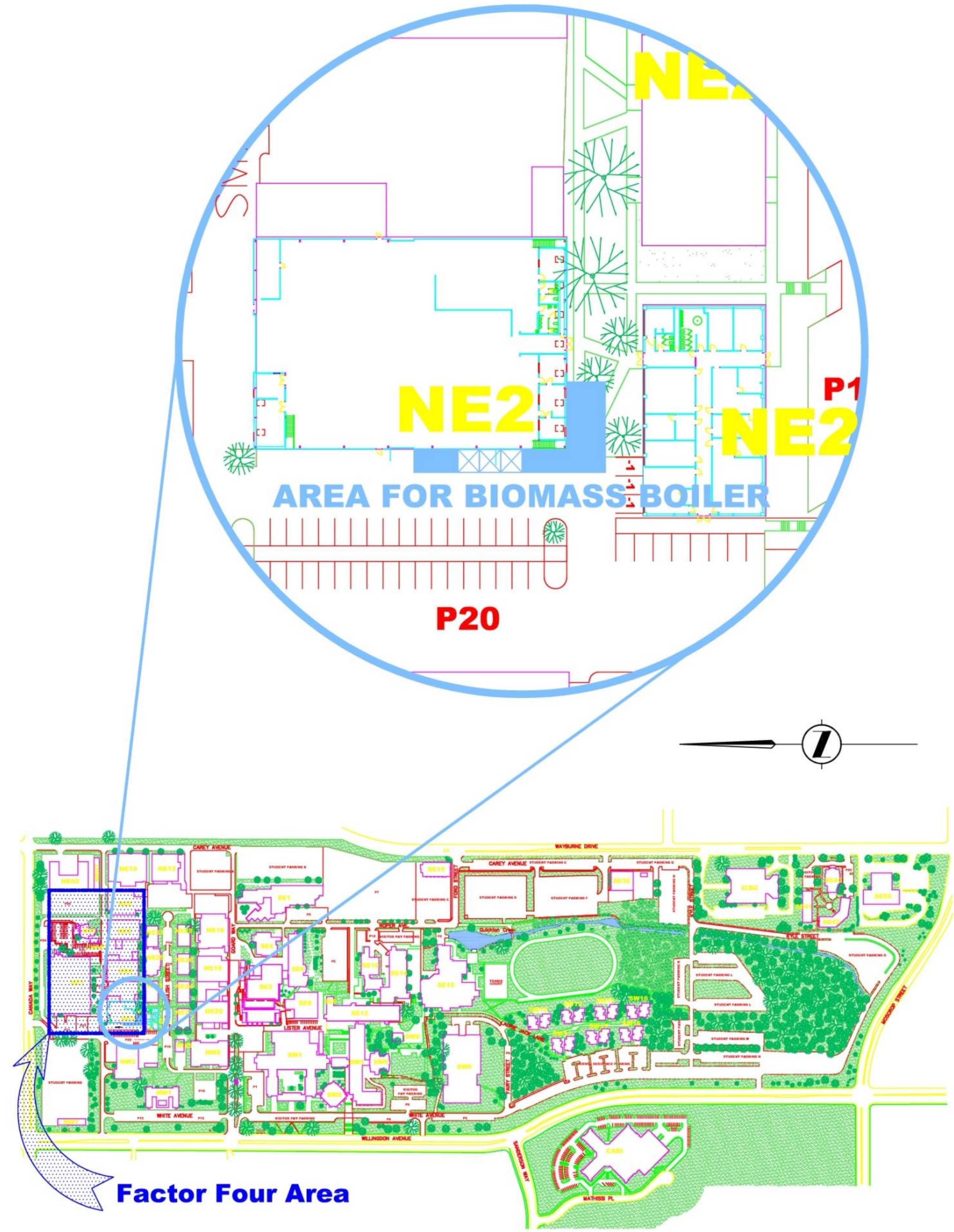
The consensus amongst decision makers at BCIT is that the area around **the south-west corner of Joinery Workshop (NE02) of BCIT's Burnaby Campus is the preferred location**.

Alternative locations for the boiler plant have been considered, but discarded as less suitable. The main reason for this is that the plant should be located close to the existing dust extraction system that will deliver some of the wood fuel used by the boiler. Secondly, the walkway South of NE02 will be redeveloped to incorporate the boiler plant.

The location of the chipper has been discussed during the pre-design stage. Locating the chipper under the canopy between NE02 and NE04 where most of the wood residue is produced would reduce fork lift operation. The canopy is however used for training purposes. Both forklift traffic and the noise of the chipper might disturb classes. This location of the chipper has not been considered further. The preferred location for chipper is adjacent to the dust extractor (north or south).

Some parking lots will be lost as the area and traffic flow is rearranged.

The boiler plant will occupy some of the walkway corridor on the south side of the Joinery Workshop. BCIT plans to redevelop this area when it replaces old buildings on the south side of the walkway (NE21, NE23).



DESIGN REQUESTS AND LIMITATIONS

The following requests and design constraints have been put forward by BCIT's management:

1. The boiler house should adjoin the south wall of the Joinery Workshop rather than being a separate, stand-alone building. As a consequence, at least one window on the south face of NE-02 will be lost. Moreover, fire separation will become a more serious issue.
2. The boiler itself should be only accessible to staff of the Facility Maintenance Department that will operate the plant. This requires (a) separating the boiler from other equipment and (b) equipping the boiler room with glass wall(s) for demonstration and training purposes.
3. Architectural solutions should be left to an architect that will be engaged during the next phase of the project.

CORE EQUIPMENT AND ITS LOCATION

The core equipment of the biomass boiler plant consists of the following components:

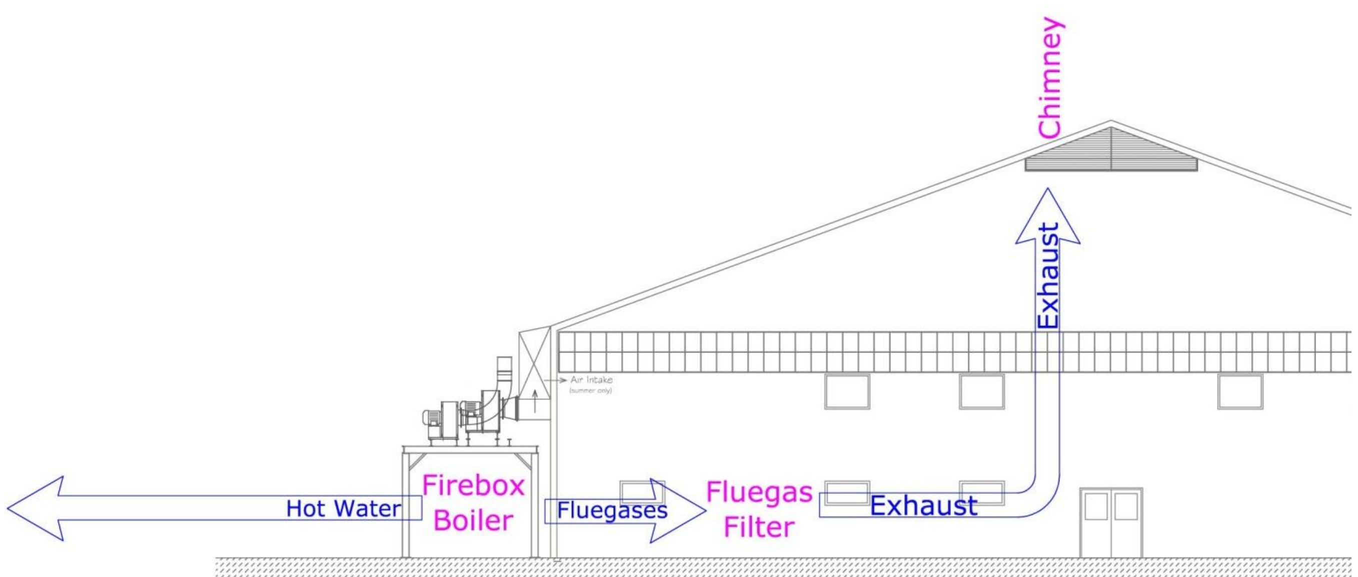
1. The chipper that cuts off-cuts into chips;
2. The fuel storage bin that contains fuel for up to 10 days of operation;
3. The metering bin that monitors fuel consumption and mixes the chips with the dust;
4. The fuel conveying equipment, including the stoker feeding fuel into the combustor;
5. The firebox boiler that combusts the fuel, turning it into heat;
6. The heat transfer system connecting to the campus heating loop;
7. The ash removal system, extracting ash from the firebox, depositing it into a hopper;
8. The flue-gas filter that cleans the exhaust to the required emission level;
9. The emission monitoring devices and testing ports;
10. The chimney exhausting the filtered flue-gases into the atmosphere.

These components have been arranged in two axes, one along the west wall and the other along the south wall of the Joinery Workshop (NE02). The firebox boiler itself is located at the intersection of these two axes, turning the incoming fuel into heat, ashes and exhaust, each of them removed in a different direction.

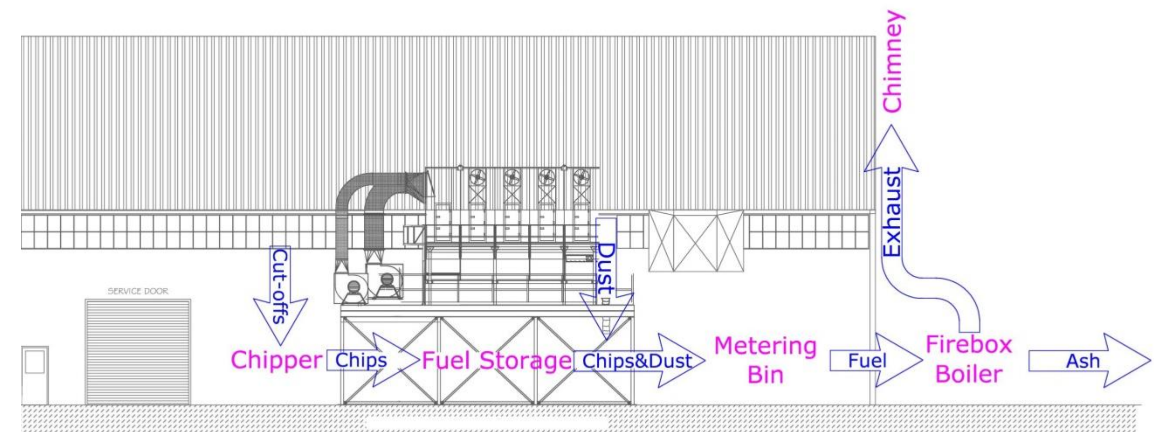
Alternative arrangements are possible but they would make it necessary to change direction in process flow. For example, the chipper could be located on the other (south) end of the dust extractor. Filling the storage bin evenly would be more difficult, reversing the flow of fuel. There would also be conflicts with other equipment located in the area, such as the metering bin.

The arrangement also makes use of space that is currently either not used, or underused, such as the area below and beside the existing dust extraction system.

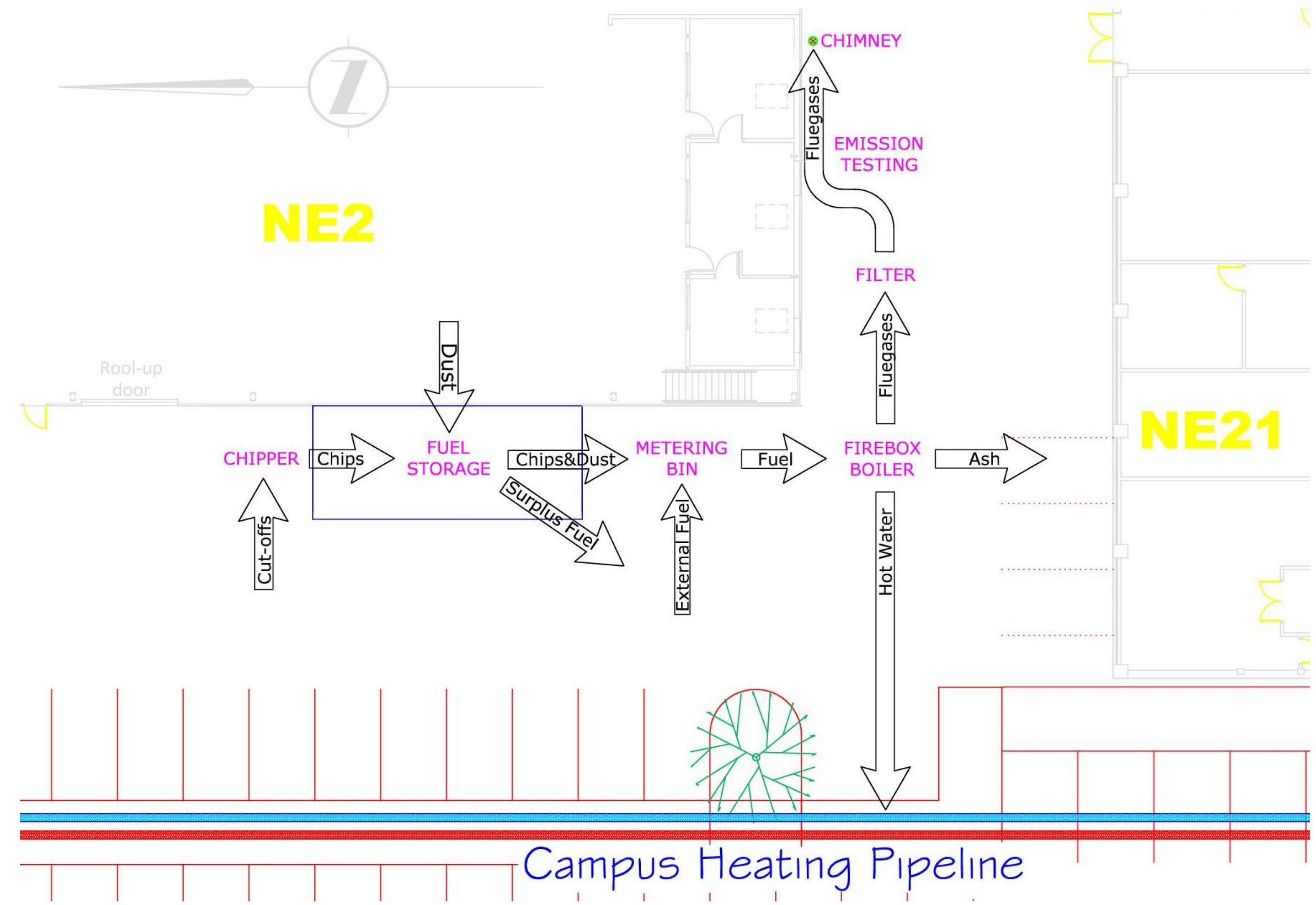
South Elevation



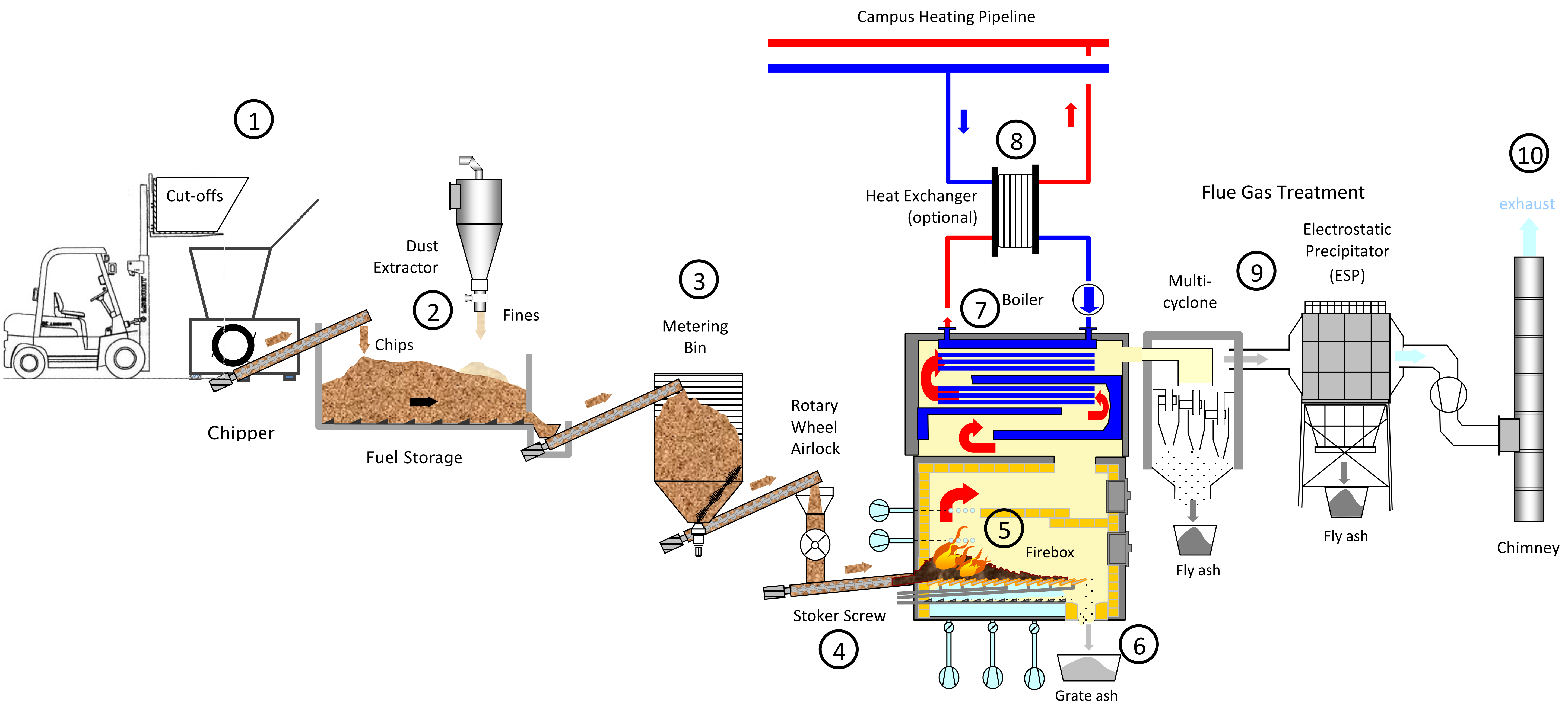
West Elevation



Plan View



GENERAL PLANT PROCESS SCHEMATIC



Note: Monitoring is part of the overall system. Monitoring points are shown in a separate schematic on page 18.

GENERAL PLANT PROCESS DESCRIPTION

The entire wood energy system can be categorized into various processes described below:

1. **Chipping:** Wood cut-offs from various collection points are delivered by a fork lift and tipped into the hopper of the chipper. The unit chips the cut-offs into pieces of no more than 25 mm (1") size. Oversized pieces are removed by an internal screen and reground. An incline auger conveys the chips into the fuel storage bin.

2. **Fuel storage:** A rectangular bin located underneath the existing dust extraction system receives fuel from two sides: coarse ground chips from the rear (north) end and fines from the dust extractor at the front (south) end of the bin. Two push frames with wedge-shaped scrapers reciprocate along the bunker floor, pushing the fuel slowly toward the front end of the storage bin. The reciprocating action also levels out the angle of repose of the wood pile generated by the incoming chips and dust. The mix of chips and dust passes beneath an adjustable 'stopper' gate, then falls into a trough, where a transversal auger takes over the material. Finally the fuel is transported by an incline auger and dropped into the metering bin.

3. **Fuel metering:** The metering bin is a small, cylindrical silo equipped with electronic scales. The metering bin can also be manually filled with other wood fuels for research purposes. A 'Flying Dutchman' silo discharger, rotating on the bottom of the metering bin, reclaims the fuel, breaking down any bridges or 'rat holes' that may be formed by the wood chips. A second incline auger moves the fuel to the stoker unit of the firebox.

4. **Stoking the fuel:** Fuel is stoked into the firebox by an auger. To avoid backfires, fuel needs to pass a rotary safety wheel, a lock that prevents embers or hot gases entering the upstream fuel supply chain.

5. **Combustion:** Fuel stoked into the firebox is combusted on a grate in an electronically controlled fashion. Primary combustion ('gasification') takes place on the flat moving grate. Wood gases escaping from the fuel pile are oxidized in the secondary zone of the combustion chamber located above the grate. Both primary and secondary air supplies are automatically controlled via the flame temperature and oxygen content in the flue gas. The PLC control adjusts the pace of the grates to ensure complete combustion as the fire bed travels along.

6. **Ash removal:** Ash is removed from the firebox by a set of screws. Outside the firebox a screw conveys the ash to an ash dumpster. The ash bin will need to be emptied on a regular basis. Various disposal methods have previously been discussed, including application to plants on campus and landfilling.[i]

7. **Heat production:** Flue gases are drawn from the firebox into the secondary combustion chamber and subsequently into the hot water heater by a frequency-controlled fan. The boiler is equipped with radiant and convection zones that transfer the heat to the water surrounding the fire tubes. A built-in pneumatic cleaning system removes soot that has settled on the flame tubes, thereby extending the period between cleaning.

8. **Heat Transfer:** Hot water generated in the boiler is pumped to the campus heating network. The arm of the heating network connecting the J.W. Inglis Building (NE01) will be used to feed the heat generated into the campus heating network.

9. **Flue gas cleaning:** A grit arrestor (cyclone or multi-cyclone) separates the coarse fly ash (particulate matter = PM) from the flue gases. After this an electrostatic precipitator (ESP) takes out the finer particles. An ESP alone would suffice to meet local air standards. The cyclone/multi-cyclone is optional and suggested for research purposes only.

10. **Exhaust discharge**: Cleaned flue gases are emitted to the atmosphere via an insulated chimney.

These processes will be monitored, partly for process control, partly for research purposes. Flue gases will be tested periodically for legal enforcement reasons.

RESIDUE AVAILABILITY AND FUEL PREPARATION

Wood residue generated at BCIT consists of cut-offs and dust collected from various operations. There is also a small amount of pallets that could be used. Only the cut-offs and pallets will need to be chipped, approximately 87% of the total wood residue produced.

Chipping Capacity Required

As laid down in the pre-design report, waste production varies between 8.9 tonnes per month minimum to 30 tonnes a month during peak times. Of this, only 87% or 26 tonnes a month will need to be reduced in size. The chipper will have to be designed for this peak volume.

Maximum Non-Dust Waste Volumes and Sizes:

Waste type	Waste Details	Maximum amount (in 2012)	Percentage[2]	Maximum Length
Studs	2X4s, 2X6s studs	19.1 t/month	73%	0.9 m (3')
Sheet material	Plywood & MDF, 5 to 25 mm (1/4" to 1")	4.9 t/month	19%	0.9 m (3')
Pallets	Mainly Timber Half Pallet (48'' x 40'')	2.1 t/month	8%	1.2m (48")
Total		**26.1 t/month**	**100%**	

[2] *Percentage according to waste management audit conducted in March 2012*

The capacity of the chipper was calculated based on the following details: the maximum amount of monthly waste to be chipped (26 tonnes) divided by 20 working days a month results in 1.3 tonnes per day. With a capacity of 436 kg per hour the chipper would run on average three hours a day during the peak season, two hours a day during a month with average wood waste production.

It should be noted that the chipper only needs to be loaded and started and does not require an operator to supervise the chipping itself. Refer to section "Chipper Design and Operation" on the next page (page 8) for details.

Size Reduction Technology Options

There are two key technologies for size reduction, chippers and grinders. Generally chippers operate at low RPM and use mainly a cutting action, resulting in clean-cut chips. Grinders operate at higher RPMs, produce more noise, and include a shearing action to break the material.

Chipped Wood

Ground wood

Chippers can produce a clean-cut chip of **25 mm (1") size**. Ground material tends to be rather uneven in size, while chips are more homogenously in size and shape. Wood chunks produced by grinders look like broken pieces and have a higher percentage of fines and splinters than the clean-cut pieces of a chipper. This can cause problems downstream, including bridging effects in the storage system. **It is recommended using a chipper rather than a grinder f**or reducing the size of the feedstock material.

A **built-in sieve screens out oversize pieces** and sends them back for re-chipping. This feature is important as oversized material might clog up downstream augers. Powerful magnets can help remove loose nails and other tramp metal pieces.

Nail Removal

Cutters of a chipper

For efficient chipping sharp cutters are essential. Nails in the wood residue will dull the chipper's cutters, making it necessary to remove as many of the nails as possible before chipping. The blades of the cutters will have to be rotated, sharpened or replaced, depending on amount of non-wood material contained in the material. Nails that passed the chipper should be removed by a magnet.

Feeding Designs

There are two designs of size-reduction equipment on the market: those that are side-fed by a conveyor belt and those are fed from the top. Both are typically equipped with hoppers allowing delivery with forklifts. Conveyor belt grinders are designed for larger volumes than required by BCIT and cost roughly two to three times the price of a top-fed chipper.

Pallets as well as any sheet material that does not fit inside the chipper chamber **will have to be cut in half or crushed before** chipping. This seems an acceptable compromise, considering that pallets only constitute 8% of the material that needs to be chipped.

CHIPPER DESIGN AND OPERATION

Sound-proof Enclosure

Noise levels stated by suppliers of chippers are typically 80 to 90 db. BCIT management would like the **noise generated** to be **less than 60 db to avoid disturbing classes in the adjacent Joinery workshop.** This will make it necessary to enclose the unit with a sound proof building, **approximately 4 x 4 m in foot print**.

The enclosure will have to be designed by the architect to meet this noise threshold. The building would have to be hermetically closed, except for a large door for introducing the equipment and a hatch in the roof of the building for fuel delivery. Both can be equipped with an end-switch that stops the operation of the chipper when the door or the hatch gate is open.

Residue Delivery and Operation of the Chipper

Cut-offs are currently collected in a number of small waste bins located throughout the School of Construction and the Environment, mainly under the canopy between NE02 and NE04. Instead of dumping these bins into the 40 cyd collector bin located next to the canopy, the forklift will deliver them to the chipper on the West face of NE02, adjacent to (North of) the dust extractor. This location allows unrestricted forklift access from the front, i.e. the West side.

These bins are self-tipping and will be emptied into the chipper from the top through a hatch opening in the chipper enclosure's roof. The opening will have to have a length of at least 1.6 m (63"), the width of the largest bins currently in use.

Operation of the Chipper

The hopper of the chipper will have to be large enough to hold the entire content of the delivering bin.

With a volume of 2.0 m³ (2.6 cyd) each of these bins is estimated to hold an average of 100 kg of lumber and boards. At a capacity of 436 kg/h or more it will take the chipper less than 15 min to go through one delivery batch.

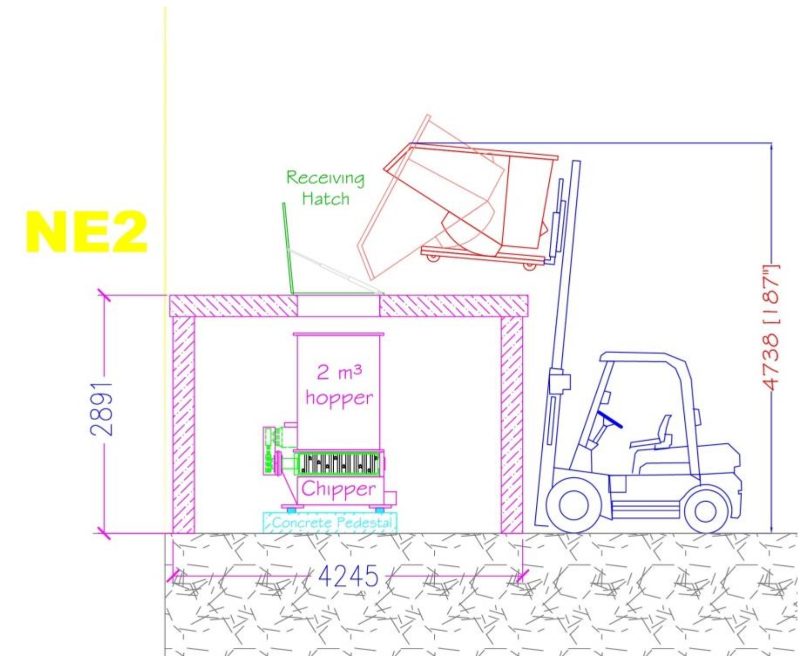
For convenience the hopper could be equipped with a lid that can be remotely opened and closed by the fork lift operator, similar to an automatic garage door opener.

Once it is fed the chipper can be operated unmanned. Assuming an average weight of 100 kg per delivery bin **one bin can be chipped every 15 minutes.** It should be noted that **overall forklift traffic will be reduced because bins under the dust extractor will no longer need to be emptied.**

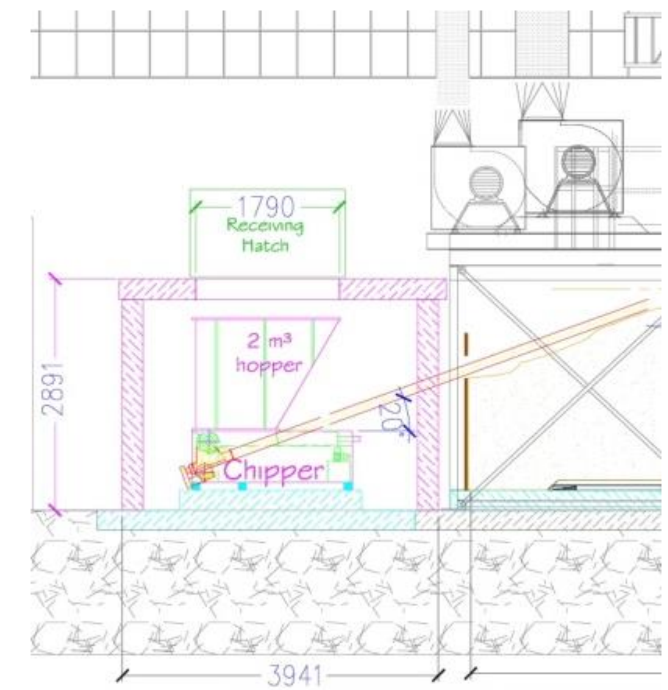
Chip Delivery to the Fuel Storage

Fuel produced by the chipper will be conveyed to the fuel storage bin. This can be done by an incline auger, a conveyor belt or by the existing dust extraction system. The latter would consume more power than an auger or a belt. In order to make the best use of the storage capacity the auger or belt should end in the rear third of the storage bin as illustrated in the elevation drawing on right side of page 10.

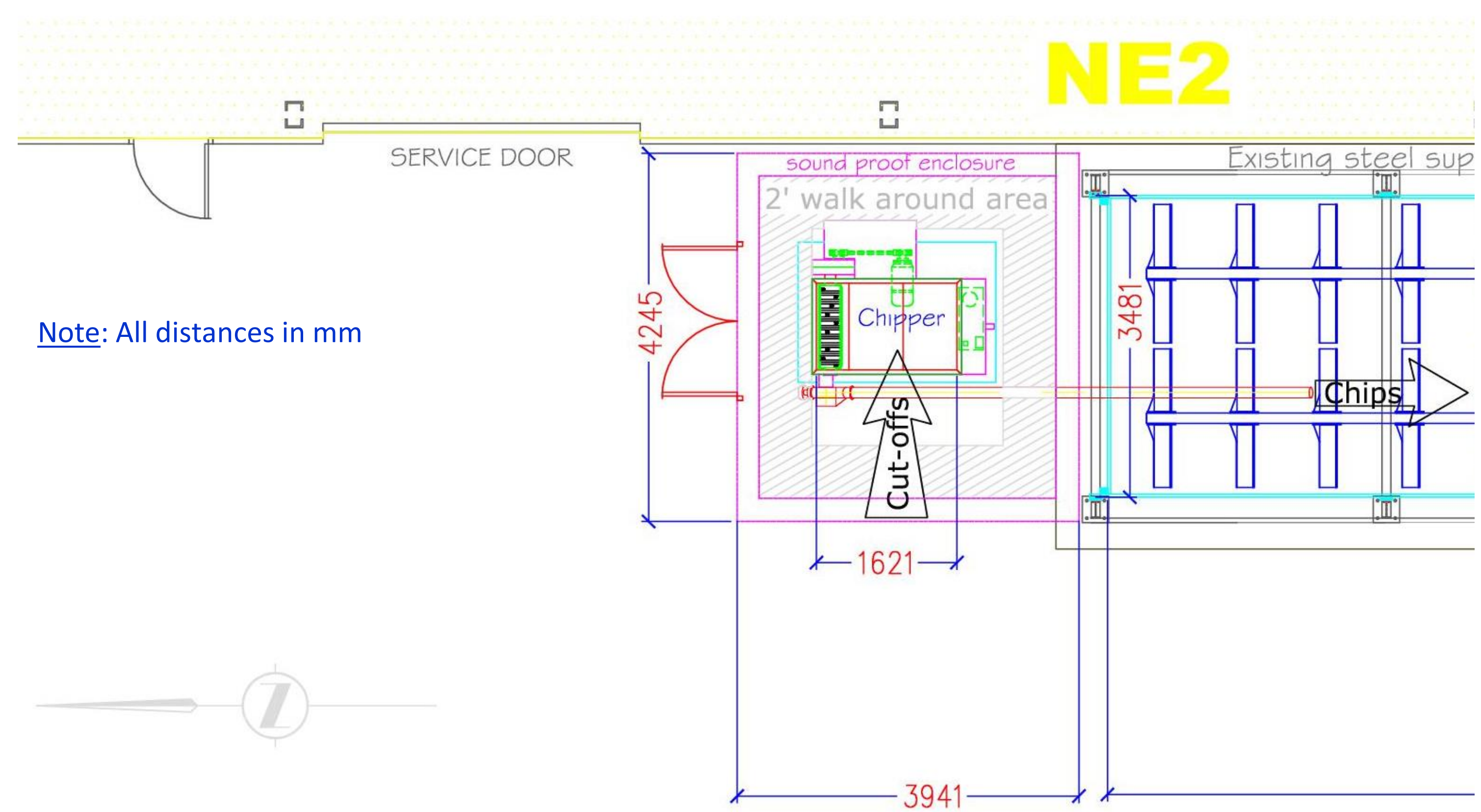
North Elevation of Chipper and its Enclosure



West Elevation



Plan View of Chipper and its Enclosure



Note: All distances in mm

FUEL STORAGE

Fuel storage is necessary because the wood residue production and fuel demands of the boiler do not always match. Wood residue is produced in the daytime five days a week but is consumed day and night seven days a week.

Long-term and Short-term Storage

Currently, continuous operation of the boiler 12 months of the year is not possible because the campus heating network is shut down during summer.

Historic gas consumption data of the central plant indicate that there is a load of approximately 400 GJ of heat a month during the summer months (July and August). Though the biomass boiler plant would be able to supply this summer load, it could not be identified how and what the gas is used for. Forth on this report assumes that the summer load will not be served or replaced by the biomass boiler plant. Instead fuel will need to be either stored or disposed of in other ways during this period.

Current estimates show that approximately 42 tonnes or 17% of the annual fuel is produced during the off-heating season. Storing this amount would require approximately 200 m³ (42 t) of storage volume, e.g. in agricultural style silos.

Space restrictions confine silos to a maximum diameter of 12' (3.7 m). To avoid bridging effects, the ratio of the wall height to the silo diameter should not exceed 2:1, i.e. should not exceed 24' (7.3 m). The resulting storage capacity would be 77 m³ per silo. A total of three silos would be required for storing all fuel generated during the off-heating season. An installation of this size does not fit into the space made available. Architecturally the industrial 'feel' of large silos might not match existing campus development plans.

Moreover, potential expansion of the campus heating system and/or all year-round operation might make it possible to use the heat in the future. An investment in a large fuel storage system could become a lost investment. Seasonal or long-term storage has not been considered further.

Two alternatives exist: disposing of the wood waste in summer or disposing of the heat generated in summer. The former solution is preferred by the management, requiring the short-term storage system to be equipped with a disposal or dumping mechanism.

Storage Size

The fuel storage bin should be large enough to provide fuel to the boiler when no fuel is produced or delivered. As a rule of thumb, storage is designed for at least a long weekend (4 days) to a maximum of one week (7 days). In the case of BCIT the **design volume** taken is not determined by consumption of heat, but by production of wood residue. With a load several times the rated output of the biomass boiler, this boiler will operate depending on fuel availability rather than heat demand.

The maximum amount of chips and sawdust produced during an entire week is 7.5 tonnes or 36 m³. The boiler is designed to combust 1 tonne per 24 hours. Under normal operation, i.e. chipping every weekday from 7:00 am until 2:00 pm, boiler operation 24/7, 2.5 tonne storage would suffice and would never overflow and never run empty, even after a long weekend.

Assuming the chipper is out of commission or its operator unavailable for an entire week, the biomass boiler would require fuel storage of 7.5 tonnes to allow operation at high fire 24/7. Assuming, in another scenario, that the boiler is down for an entire week, 6.5 tonne storage volume would be needed to allow continuing operation of the chipper as usual. This scenario is, however, based on the assumption that the storage is empty at the time that the boiler stops operating. If there were still half a week's residue volume in storage a **storage volume of 10 tonnes or 50 m³** would be required. These numbers are based on the month with the highest recorded waste volume, 30 tonnes.

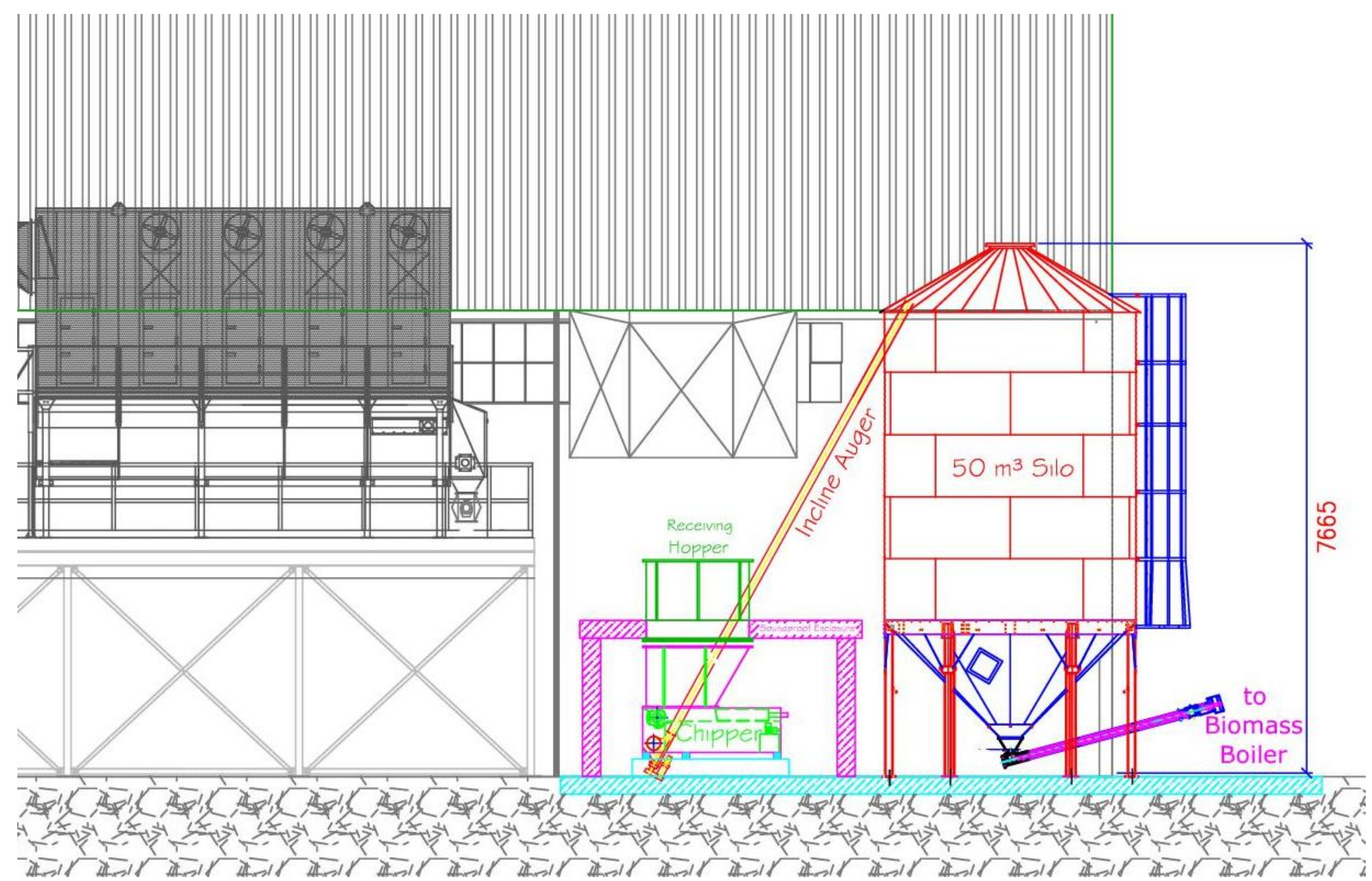
Storage Designs

Two concepts for storing wood fuel exist: cylindrical silos and box-shaped walking floor systems. Silos are usually less expensive but have constraints: to avoid bridging effects inside the silo, the effective wall height should not exceed two times the diameter.

A silo with a diameter of 3.7 m (12') would have to have a wall height of 4.7 m to hold 50 m³. Due to the design of commercially available silos, the overall height would be at least 7.7 m (25'), slightly higher than the west wall of the Joinery workshop. The silo would extend past the South face of NE02. Filling the silo will require a rather steep incline auger that could get damaged during loading the hopper of the chipper. Dust from the dust extraction system would have to be funneled or conveyed to this incline auger or to the hopper of the chipper itself.

Due to these complications, mainly space constraints, silo storage is not the best solution. Instead **a walking floor storage system is recommended.**

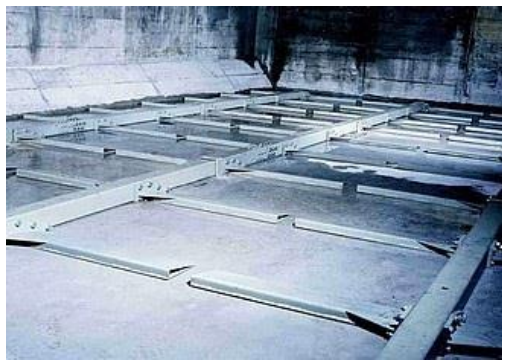
Silo Fuel Storage



WALKING FLOOR STORAGE

Walking floor bins come in various forms: as concrete bunkers; steel structures; or containers. Either one of these designs could be employed. Many European biomass boiler suppliers offer standardized roll off containers. These are generally shorter and narrower than required. A custom size would have to be built. The lowest cost option will be using the existing steel structure of the dust extraction system as a frame.

Concrete Bunker



Container

Steel Frame

General Layout of a Walking Floor Bin

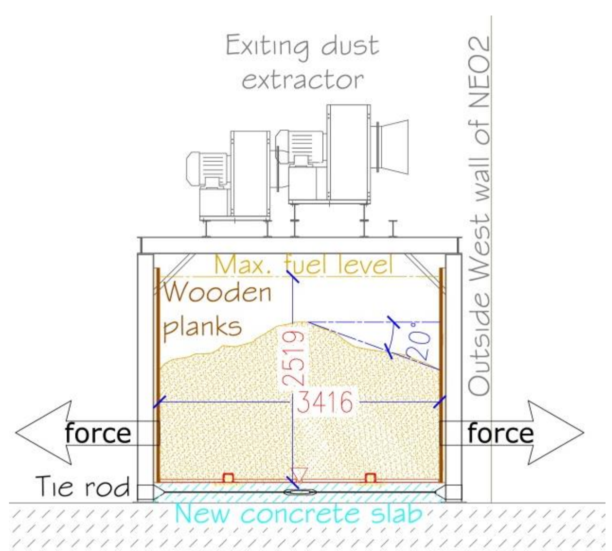
Walking floor bins have a trough at the front end of the unit that material is pushed into. The bottom of this trough will be typically 0.7 m (2’) lower than the bin level itself, requiring either the area to be excavated or the floor level to be raised.

The existing steel structure supporting the dust extractor can be used as a frame for the storage bin, but will require reinforcements. Some of the existing cross ties will have to be taken out in order to use the space. The steel columns, especially those at the front end of the storage bin, will experience lateral outward force from chips being pushed against the front wall and out to the side. To avoid shear force on the existing anchors, ties will have to be added. These ties would be covered by a new 250 mm (12”) layer of concrete poured over top of the existing slab.

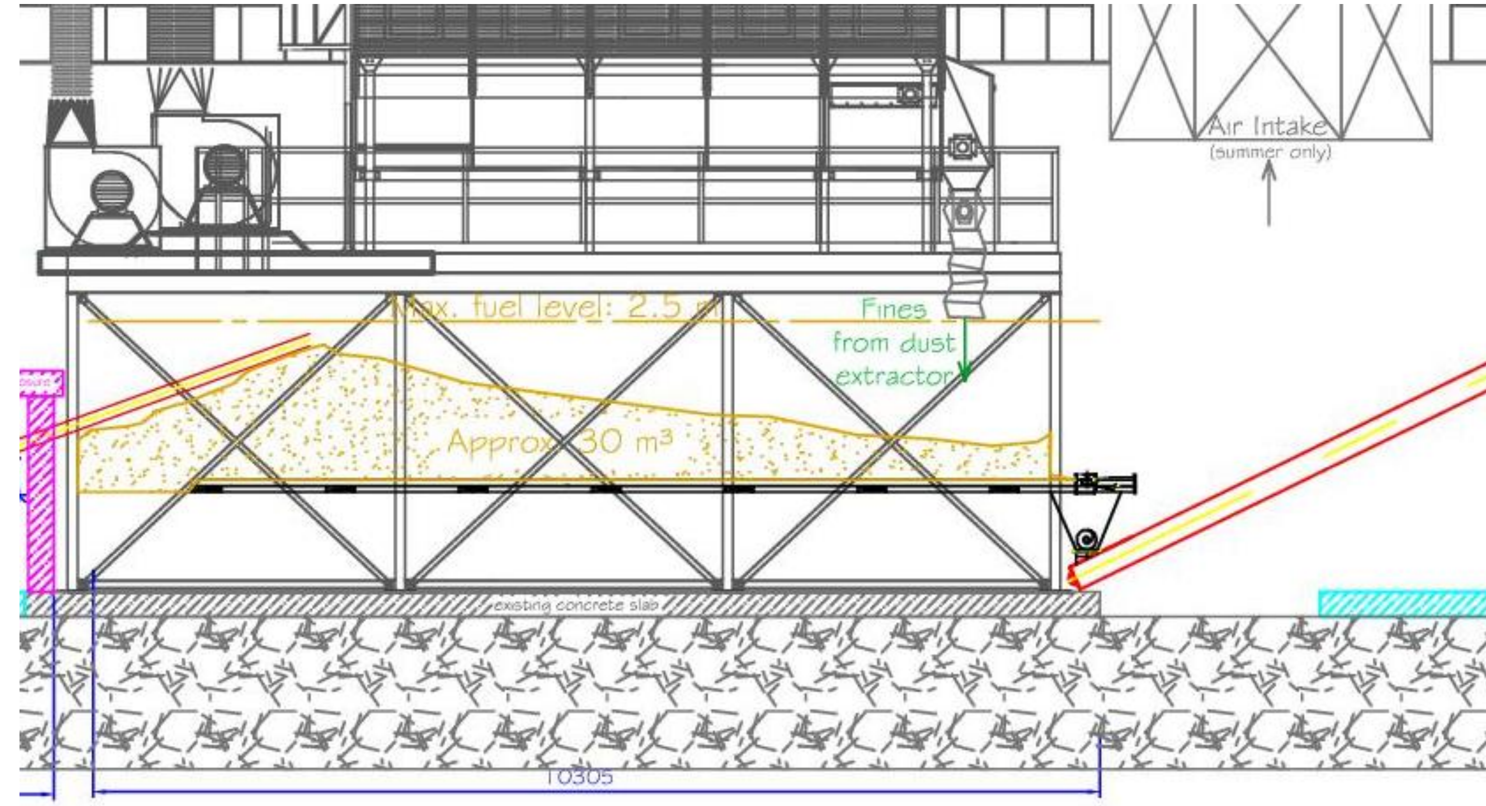
Storage walls can be made of wood, or, for visibility reasons, **out of glass**.

Geometry of the Walking Floor Bin

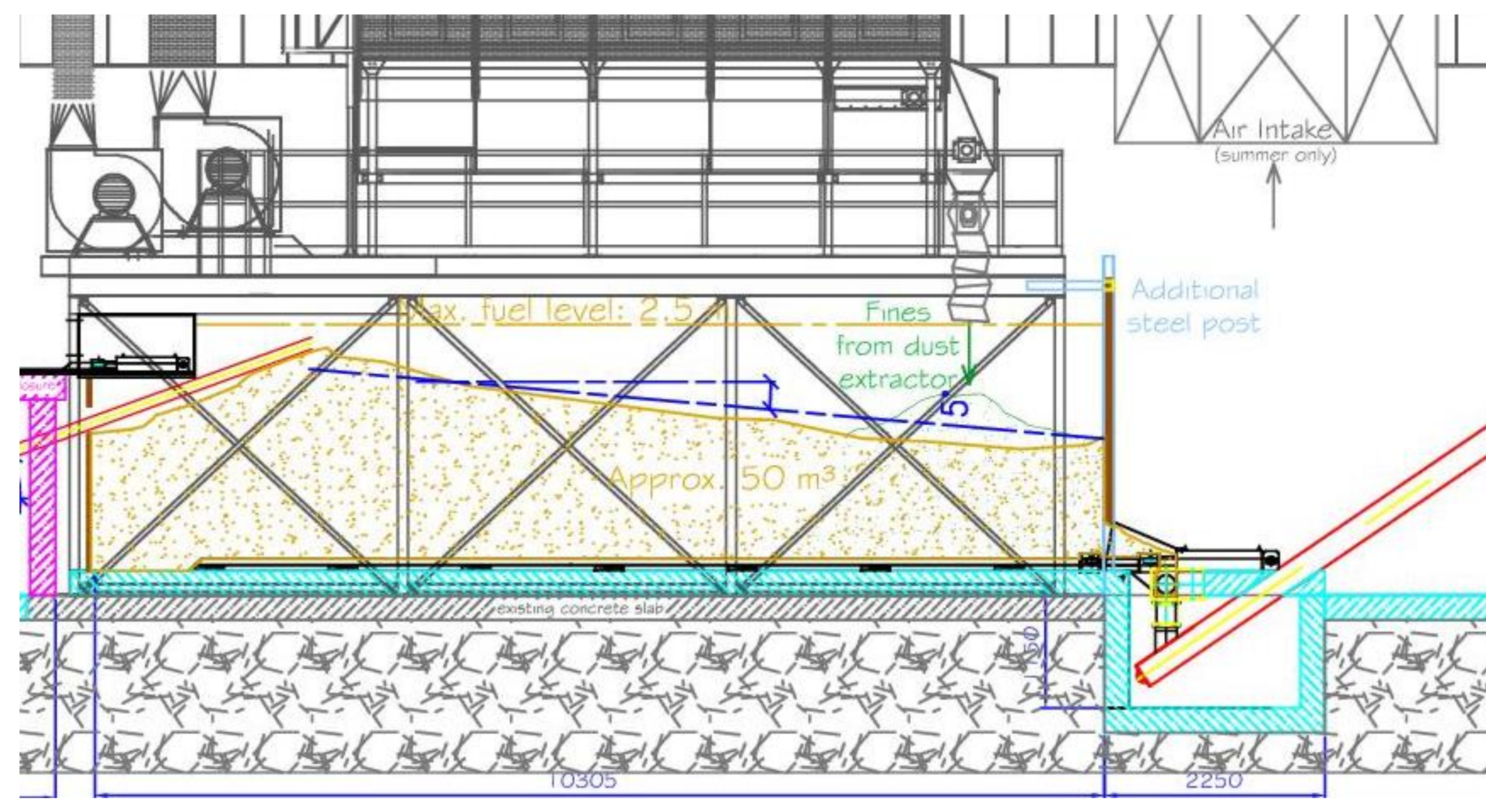
At a width of 3.4 m (11’) and 10 m (33’) length, the average pile height would have to be 1.5 m (5’) to obtain the design storage volume of 50 m³. The actual volume will depend on the angle of repose of the fuel pile. Assuming a pile angle of 5° on the forward slope, of 20° on the backward slope towards the chipper, and 20° towards the sides of the container, the design using the existing support structure (drawing on the bottom right) would provide volume of approximately 50 m³. The container (drawing on the top right) holds only 30 m³ of chips. The container would have to have a lower floor level than shown to meet the 50 m³ design criteria, making some excavation necessary thereby losing its key advantage.



Container Fuel Storage



Steel Frame Storage using the Existing Support Structure



FUEL METERING

A fuel metering bin is recommended for the following four reasons:

1. Monitoring fuel consumption;
2. Adding third-party fuel for testing and research purposes;
3. Creating a homogenous mixture of sawdust and chips;
4. Separating the fuel bin from the combustor for fire safety reasons.

Operation of the Metering Bin

The metering bin is filled from the top by fuel conveyed from the storage bin by an incline auger. This in-feeding auger should not rest on the metering bin to avoid distorting weight measurements.

The same incline auger can also be used to empty the storage bin in the summer, when the biomass boiler will be turned off and no fuel is used. To this end it will have to pivot to an area where a truck or container can be parked. A steel cable attached to the existing support structure could be used to support the auger's top end.

Fuel in the metering bin is reclaimed by an auger rotating inside the cylindrical bin. This rotating auger (called "Flying Dutchman" in the industry) transfers the fuel to a second auger located underneath the bin. This incline auger feeds the fuel to the biomass boiler. Again, in order to avoid distorting measurements, this out-feeding auger should be supported independently and not be directly attached to, or hanging out of, the metering bin.

The metering bin will have a hatch on the top that allows third-party fuel to feed the plant.

Metering Technology

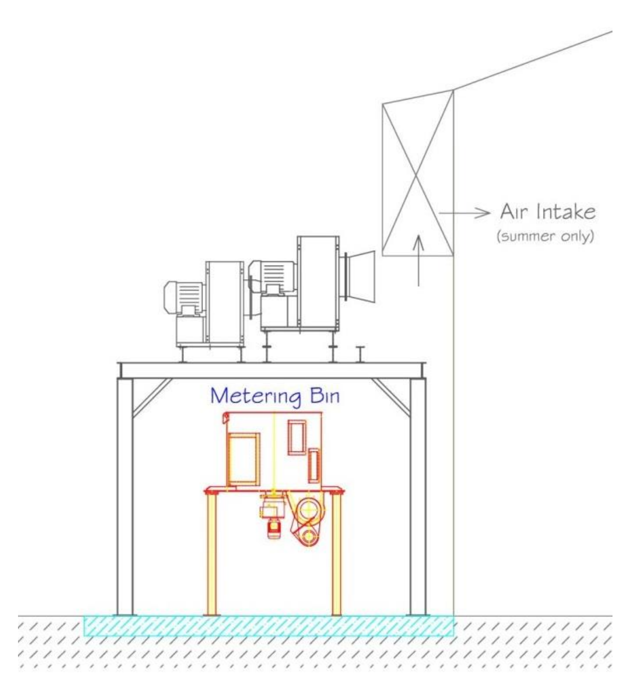
Metering is done by electronic silo-scales as is used for agricultural purposes. These can be located under the feet of the bin or inserted at each of the legs.

In order to obtain accurate results, the in-feeding auger and the out-feeding auger will need to be operated on an alternating basis. Usually these augers are equipped with fixed-speed drives that are switched on and off according to demand. The PLC control will have to take care that the augers are not operated simultaneously. For this reason, both augers might have to be sized to twice the conveying capacity required.

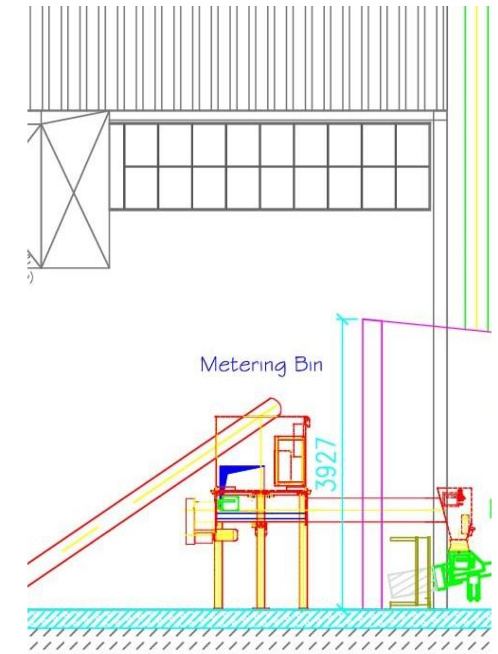
Compression Load Cell

Bolt-on Leg Strain Sensor

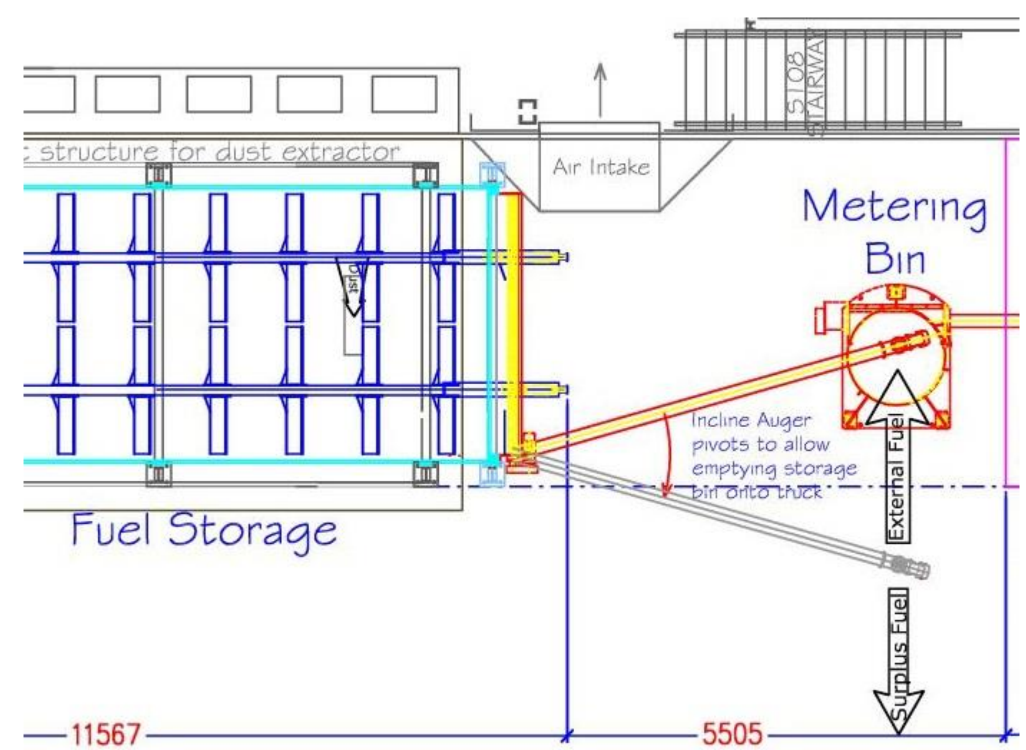
South Elevation Metering BIn



West Elevation Metering Bin



Plan View Metering Bin



FIREBOX BOILER DESIGNS

Three distinctly different designs can be used for the capacity and fuel considered by BCIT.

Suspension burners blow in small wood particles – usually dry shavings – from the top or the side. The hot refractory lining radiates enough heat to ignite the shavings as they enter the hot combustion chamber. All particles combust entirely while they are airborne (in "suspension"). The ignition temperature is monitored by a thermo-element. In the start-up phase the heat required is supplied by an oil or gas burner.

The main advantage of suspension burners are the simplicity of the design requiring no grate, steel or moving parts. However, suspension burners can only handle particles with an average size up to 2 mm (1/16"). Wood chips can only be used with a hammer milling them beforehand. The continuous noise impact is unlikely to be acceptable for BCIT.

Pile burners, also called underfeed stokers, stoke fuel from underneath into retort in the combustion chamber rather than from above onto a grate. At low fire only a trough-shaped retort is filled. As demand for heat increases, more fuel is stoked into the retort, piling up in the trough, moving upward and eventually overflowing onto a sloped secondary grate.

Primary air is supplied from underneath the trough and underneath the secondary grate. The fuel pile burns off from the top and is replenished from below in the trough. At high fire, the secondary grate also receives fuel from the top/side.

Pile burners have fixed cast iron grates and in the absence of moving parts require less maintenance. As fuel is delivered from underneath the pile, the stoker is less exposed to high temperatures from the combustion process. Cooling the stoker with water is therefore not required.

The main advantage of pile burners is that there are no moving parts inside the firebox. They are usually cost-effective solutions for the size of boilers required at BCIT.

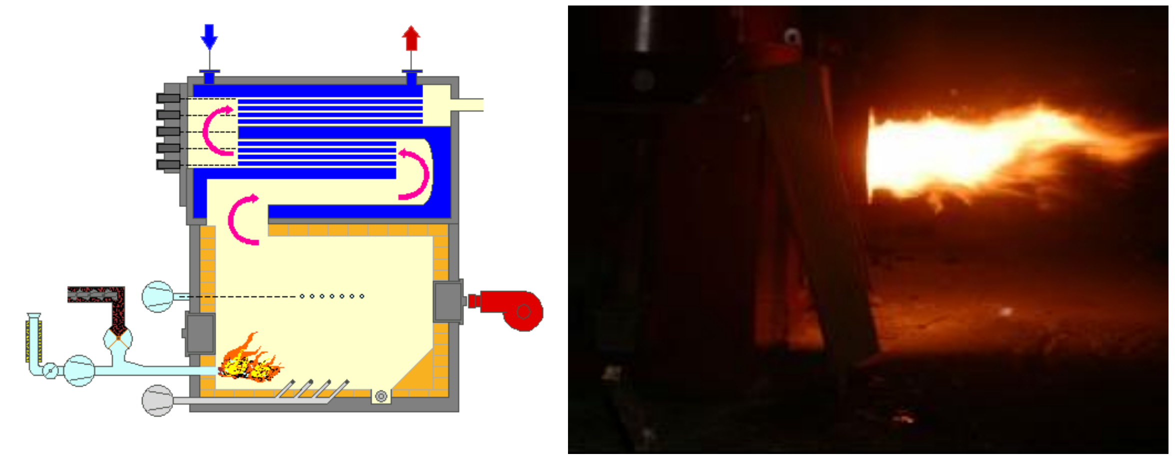
Stoker-spreaders are upgraded pile burners that employ a ram that pushes fuel onto the secondary grate, thereby spreading it out. Stoker-spreaders are a hybrid between a pile burner and a moving grate burner.

Moving grate burners burn the fuel on a moving grate. The grate is sloped, stepped, or horizontal. Reciprocating grates move the fire bed forward until the fuel pile is entirely burned out. A laser sensor at the end of the grate makes sure all embers are completely burned out and only grate ash is left.

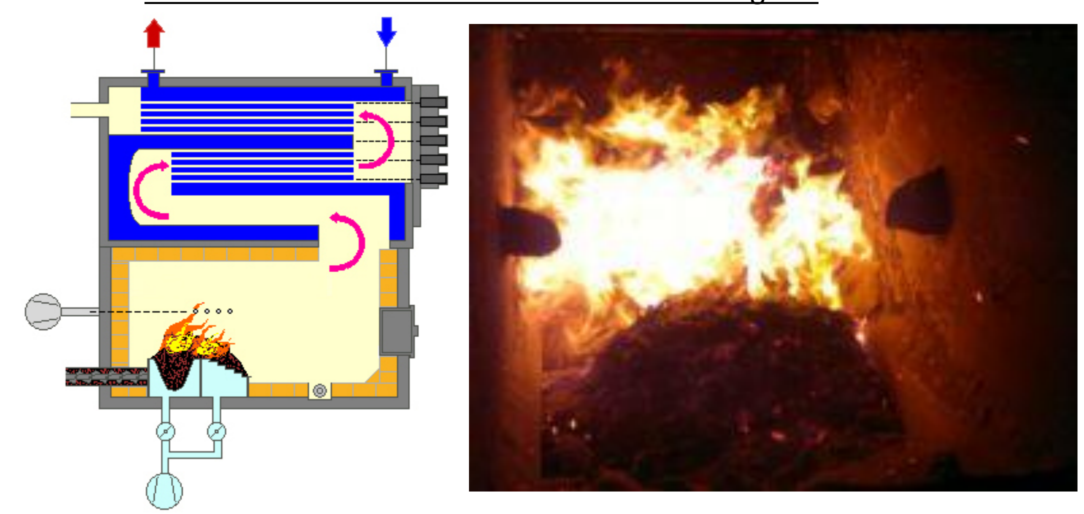
In contrast to pile burners, moving grate burners spread out the fuel over a larger area, maintaining an even bed of fuel across the grates and exposing more fuel to oxygen and allowing higher moisture fuel to be dried prior to combustion. The grate is air and/or water cooled to reduce fire bed temperatures and therewith the chance of fuel clinkering. The continuous movement of the fire bed also reduces formation of large clinkers and ensures they are conveyed to the ash screws which are designed to remove clinker

Moving grate burners are designed to handle difficult fuel, such as wet hog fuel with oversize material and fuel with a tendency to form minor clinker. Chemical lab analyses conducted on BCIT waste indicate that the ash melting temperature is not a problem, as long as the individual fractions of the fuel, especially the MDF and plywood, are well mixed with the remaining wood residue. [ii] Yet, suppliers contacted suggested that **because the fuel at BCIT contains MDF and plywood a moving grate design is recommended**.

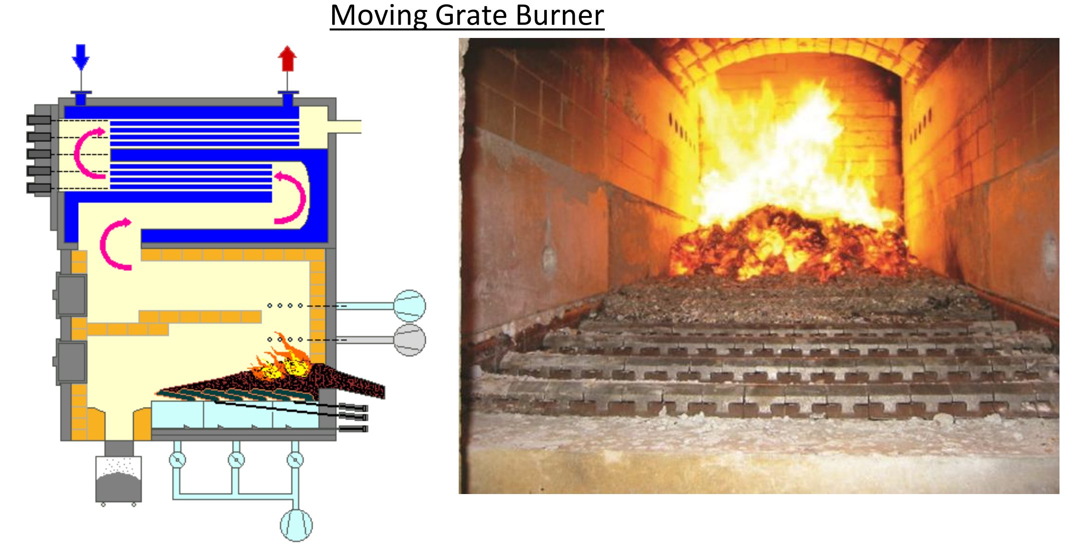
Suspension Burner – no grate



Pile Burner or underfed stoker burners – fixed grate



Moving Grate Burner



FIREBOX BOILER SPECIFICATION

Most biomass boilers of the size in consideration come as a package with the boiler on top of the firebox. The following paragraphs detail key parameters and equipment that should be included in the "package boiler".

Capacity of the Firebox Boiler

The amount of fuel available at BCIT is far less than what would be needed to supply the existing campus heating system, even during the spring and fall when demand is lower. The constraining factor is fuel availability rather than heat demand. The combustor and boiler thus will need to be sized to take the varying fuel availability into account.

Using data from recent years' residue production varies between 9 tonnes per month and 30 tonnes.[iii] At continuous operation 24/7 this relates to **fuel input varying between 12 kg and 42 kg per hour**. Assuming a firebox boiler efficiency of 85% (of Lower Heating Value of the fuel) the corresponding heat output would be 46 kW to 166 kW.

Firebox Boiler Capacity	Minimum	(April)	Maximum	(October)	At rated	output
Fuel availability	8,899	kg/month	30,043	kg/month		
	2,009	kg/week	6,784	kg/week		
			33	m³/week		
Average fuel consumption	12.4	kg/hour	42	kg/hour	53	kg/hour
Lower Heating Value of fuel	15.9	MJ/kg	15.9	MJ/kg	15.9	MJ/kg
Fuel input	197	MJ/hour	663	MJ/hour	847	MJ/hour
	55	kW	184	kW	235	kW
Firebox boiler efficiency	85%		90%		85%	
Boiler output required to burn fuel	46	kW	166	kW	200	kW
Percent of rated output	23%		78%		100%	

Biomass boilers are baseload boilers, i.e. they are not made for an ON/OFF type of operation. Especially the refractory inside the combustor would see significant wear due to thermal expansion and contraction. Being solid fuel fired, it also takes more time starting up a biomass boilers compared to a gas boiler. Last not least emissions are significantly higher during the start-up phase. All of these reasons indicate that sizing the unit so it can operate continuously is important.

Biomass boilers have a limited turndown ratio, typically 1:3 for wet fuel, 1:4 for dry fuel. Oversizing the biomass boiler will result in frequent turn-offs during the time of low fuel supply. A unit rated for 200 kW would have to have a turndown ratio of 23%, slightly less than 1:4 to meet the requirements at low fire during April.

Undersizing the biomass boiler would be hard on the unit too: When operating at high-fire most firebox boilers are not made for continuous operation at 100% of the rated output. A 170 kW unit, for example, would wear out faster when run at 166 kW or 98% of its rated output continuously. A 200 kW unit, on the other hand, could operate continuously at 83% of its rated output during months of high fuel supply.

Choosing the right boiler capacity will depend on the robustness of the unit. A modern lightweight woodchip boiler designed with a fast response in mind can operate less time at high fire than a more traditional heavy refractory lined firebox, and may wear down fast by constant operation at its rated output.

In conclusion it can be said that **a firebox boiler with a rated output in the range from 170 to 200 kW (depending on the robustness of the design) is best suited for the fuel available at BCIT**.

Operation of the Firebox Boiler

The heating plant will initially operate during the heating season only (mid-Sep to mid-June, depending on outside temperatures), i.e. nine month a year. Year-round operation is planned for the future, once there is a demand for heat during the summer time.

The unit should be operated continuously with very few shut-downs and subsequent cold starts, operating between low-fire (12 kg/h fuel consumption, approximately 46 kW heat output) and high fire (42 kg/h fuel consumption, 166 kW heat output).

Manual cleaning and preventive maintenance shut downs require approximately two to four hours of labour. Employing a soot blower should allow increasing intervals between **manual boiler cleaning** to every 1,000 hours of operation, i.e. **seven times a year** if operated during the heating season only.

Auto-Ignition and Idling Mode

Most biomass boilers come with an auto-ignition system that starts up the fire by blowing hot air or a propane flame onto the wood chips. This process takes between a few minutes to a quarter of an hour depending on the chip size and the moisture content of the fuel. In the case of BCIT an electric blow torch should be able to ignite the fuel within minutes. Yet, the boiler will take at least 15 minutes to warm up entirely and get into a stabile mode of operation.

Advanced combustion technologies include a pilot or idling mode that allows feeding just enough fuel onto the grate to keep the fire going and the combustion chamber warm. Once demand picks up or fuel supply increases the unit can quickly ramp up without needing to start the fire with the blow torch. This feature may only be of use for BCIT in case there are times when fuel supply runs short or, in the future, if short-term summertime peaks will need to be met.

Automatic Ash Removal

Fuel to be used at BCIT has been chemically tested to have a low ash content of only 0.6% of the dry wood weight. If completely burned BCIT's fuel will **generate between 50 and 160 kg of ash a month**, in April and October, the months with the lowest and the highest waste volumes, respectively. Most of this will incur as grate or bottom ash inside the firebox; only a small fraction, typically less than 5% will be carried with the flue gases as fly ash.

For convenience and continuous operation it is recommended to include automatic ash removal in the firebox design. Typical sizes of ash dumpsters are 50 to 100 litres capacity, making it necessary to **empty the dumpster every 3 to 5 weeks in April, every to every second week in October**.

ELECTRONIC CONTROL EQUIPMENT

Modern biomass boilers are able to operate at part load, automatically adjusting their output to the demand to the heat demand. Additionally the combustion process itself, particularly supply of combustion air, is controlled according to flue gas parameters and temperatures. This chapter lies down the control concept that is required for the unit at BCIT.

Control Loops

The control of the biomass boiler typically consists out of four interconnected loops with a clear hierarchy. The highest level loop is adjusted first, lower level loops in order of their hierarchy. There is feedback from the lower to the higher level loops though.

1. The highest level loop is the **output control**: It controls the hot water supply temperature by adjusting the amount of fuel stoked into the firebox. This assumes that there is enough fuel at all times
2. Subordinate to this is the **oxygen trim system**. The O_2-content in the flue gases is controlled by trimming the amount of secondary combustion air supplied. This control loop acts significantly faster than the higher level output or temperature control.
3. The **combustion temperature control** loop recognizes changes in moisture content of the fuel and calculates the set-point for the higher level oxygen trim system.
4. **Negative pressure control**: The fourth control loop makes sure that the negative pressure in the combustion chamber is kept at the right level by adjusting the speed of the flue gas fan.

For this project a fifth loop should be added allowing to adjust boiler output to the fuel availability.

Output Control

Biomass boilers are usually operated and controlled according to heat demand, i.e. fuel supply is automatically adjusted to meet the demand for heat. At BCIT demand exceeds supply during most of the year; the demand of NE01 will be above 166 kW except for a few weeks, when heat will be sent back to the central boiler plant. As a consequence the biomass boiler will run at maximum capacity until fuel runs out. The unit will then shut down sending an alarm to the operator notifying her or him of the shutdown. The operator can restart the unit upon pressing a button once fuel is available again. This will have to be done on site.

Because the fuel is very dry re-ignition and start-up will be relatively short. Yet, emissions will increase during the start-up phase until the unit is back up to its normal operating temperature. In order to avoid this ON/OFF operation the output may be controlled according to fuel availability rather than heat demand. This can be done manually or automatically.

Manual Output Control

Boiler output and consequently fuel input can be adjusted manually. The operator would have to check the fill level of the storage system once a week and turn the biomass boiler up or down according to the current or anticipated fuel availability. Adjustment of the boiler output is done at the control panel or “human-machine interface inside the boiler room. Checking the fuel level in the storage will be particularly easy if the storage system is equipped with a transparent wall as suggested for training and visibility reasons.

Monitoring Storage Fill Levels

Alternatively, the fill level of the storage system may be monitored, using this parameter as an input that controls the fuel supply. Monitoring the fill level of the metering bin will not be sufficient, as the metering bin only holds fuel for several hours.

The storage fill level can be measured with light switches or with so-called “bindicators”, see the picture below. The latter require less maintenance, but are more expensive. Light switches or bindicators have a binary output, i.e. only tell if, or if not, the storage is filled to level that they are located at. Several indicators would have to be placed above each other in a stacked order to be able to assess the overall storage fill accurately. The angle of repose of the fuel pile will need to be taken into account. The factors used to extrapolate from the fill level to the storage content likely need adjusting in the PLC software during the commissioning phase.

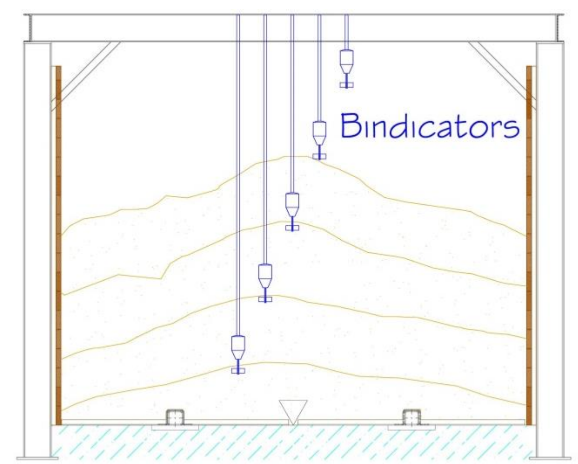
Monitoring the storage fill level will increase costs and may be considered overengineering the system, especially for the small unit as under consideration. The solution that we will ultimately choose will depend on the capability of the PLC that the biomass boiler supplier offers. This will have to be decided in the procurement stage in cooperation with the biomass boiler supplier.

Overall Control Capabilities

Small biomass boilers are often standardized, mass-fabricated, “off-the-shelf” units that do not allow changing the programmable logic control (PLC). The application at BCIT, however, is non-standard in its requirements, making it necessary to tailor the control system to the application at hand. The PLC will have to monitor the entire plant, not only the biomass boiler itself. The monitoring equipment and the flue-gas filter can be controlled independently though.

Bindicator

Bindicator Arrangement



Integration into the existing Building Management System

The control system should communicate with the existing building management system (BMS), a Delta Controls building automation systems. Communication will be two-way only for acknowledging warnings, but not for alarms. Alarms typically require operator intervention, sometimes even restarting the unit. This may not be done remotely. Operational parameters, however, should be displayed on the Delta BMS.

A dedicated telephone line should be installed and connected to a modem inside the control panel. This will allow for servicing and trouble shooting of the plant from the supplier’s office. Remote diagnostics is a standard for most equipment suppliers. Technicians can log into the program, track warnings and error messages, and make changes as required.

FIRE SAFETY

Operating in a public or semi-public facility requires the heating systems to adhere to safety principles, particular fire safety. Key issues to watch are back burn prevention, smoke build-up and dust explosions. The latter already presents a hazard with the existing dust collection and disposal method that should be reassessed.

Other than oil- or gas-fired boilers, solid fuel-fired combustors cannot be easily switched on or off. Even when there is no heat demand anymore, the fuel inside the combustor needs to be completely burned rather than left smouldering. Power outages or a failure of the flue-gas fan can lead to smoke or fire traveling back from the combustion area into the fuel supply chain and – in the worst case – set the fuel storage on fire. This requires additional safeguards:

Continuously Monitored Negative Pressure Operation

The combustion chamber is operated at a negative pressure, typically around -50 Pa that is continuously monitored. As a consequence no flue-gases can escape other than via the smoke stack. A lack of a negative pressure would allow smoke entering the boiler room. In this case fuel supply to the combustor should be stalled triggering an alarm.

Fuel Cut-Off by Pre-loaded Gate

A fast acting pre-loaded gate closes in case of power failure, a positive pressure in the combustion chamber, or in case the fire itself is out. Failure of fire is sensed by a temperature sensor in the smoke stack or the flue-gas duct. The preloaded gate – usually located at the metering bin - is motor opened, but spring closed, i.e. closes without electricity in case of a power outage.

Fire Locks and Sluices

A fire lock prevents the intake of air when stoking fuel, thereby avoiding unwanted or excess air supply to the combustion chamber. Conversely hot flue gases cannot enter the fuel supply chain preventing fire from moving back into the auger or the metering bin.

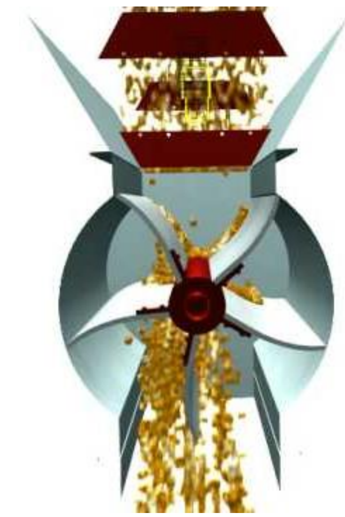
The fire lock also isolates the conveyor from the stoker. Fuel has to physically drop into the lock before being conveyed further. This drop serves to prevent amber travelling back into the fuel auger. Before shutting down – or once elevated temperatures are detected - the fire lock and stoker screw is completely emptied and its contents entirely burned inside the combustion chamber.

Two designs are common: a rotary cell lock has flexible blades driven via the stoker by a covered chain or directly by an electric motor. Unless largely oversized, rotary cell locks can jam and even loose its air lock qualities. Instead some manufacturers use a set of two gates that open alternating. Equipped with blades these two gates act as a type of guillotine, shearing off excess length wood chunks. For the size of biomass boiler in consideration most suppliers only offer rotary cell wheels.

Fuel Stoking

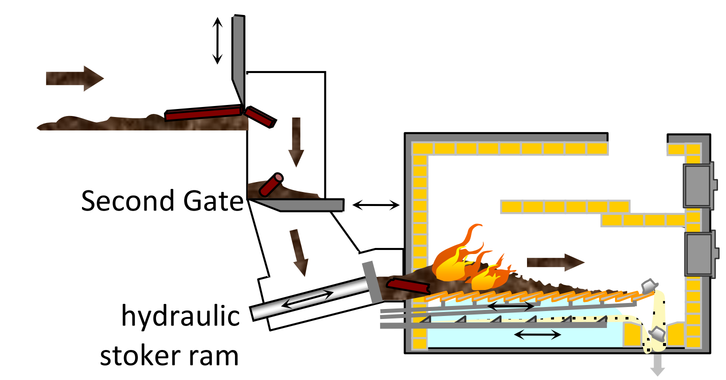
Two designs exist for stoking a moving grate burner: augers and hydraulic rams. Hydraulic rams are uncommon for small units or units with even sized chips. Augers, on the other hand, are low cost and low maintenance provided the fuel specification is met regarding particle size. Oversize pieces and tramp metal can easily jam the auger. A larger diameter auger reduces this risk. In case of a jam, motor overload protection and reversing the motor are standard features. It is recommended to employ an auger with a 200mm (10”) diameter. The occasional nail or screw should pass through it.

Rotary Cell Wheel



Source: www.veengle.com

Alternating Gate Design



Deluge System

As a last resort the fuel supply chain can be flooded: a water valve connected to city water or a water tank opens at elevated temperatures, dousing the metering bin and / or the conveyor and(or the stoker with water. An alarm sounds if there is no water pressure at the deluge valve. The valve is temperature actuated and does not require electricity to open.

Sprinklers

Sprinklers inside the boiler room are uncommon and likely ineffective way of dousing a fire. It is unclear whether the building code requires a sprinkler system for components such as dust collectors. NFPA 664 “Standard for the Prevention of Fires and Explosions in Wood Processing and Woodworking Facilities” does not explicitly demand sprinklers but also suggests a flow rate of 8.15 liter per min per m^2 of sprinkled area. Adding water to the dry fuel will result in swelling that could damage the storage bin and the structure supporting the dust extractor. A fire inside the fuel storage system is likely best dealt with by restricting air access.

Requirements for sprinklers in the boiler room itself are governed by spatial separation requirements of the relevant building code.

Control System

Most PLCs controlling the biomass heating system include alarms that notify the operator. Alarms are usually separated into warnings and alarms that stall operation and require the operator to acknowledge and fix the problem before operation can be continued. A shut-down button on the outside of the plant is recommended. To ensure fuel inside the combustor is completely burned this button should only shut down fuel supply, not the entire plant.

Escape Routes

The boiler room should have 0.6 m (2’) wide escape corridors accessible from every point of the plant.

FLUE-GAS TREATMENT AND EMISSION CONTROL

Solid fuels, such as coal or biomass, need to be converted into a gas before they can be burned. The combustion of biomass is chemically more sophisticated and technically more challenging than burning a fuel that is already a gas, such as natural gas, or that can easily be turned into a gas-like suspension, such as heating oil.

Secondly, different from coal biomass has varying chemical composition, both from specie to specie, as well as regarding the resins used for composite wood products. The changing and sometimes unknown chemical and physical properties add to the complexity of burning biomass in a clean way.

Modern biomass boilers can combust biomass fuel in a controlled fashion that reduces, but will not eliminate emissions. The type and amount of air emissions depend on two key points: what fuel is burned and how it is burned. The following parameters have an impact on the production of standard air contaminants:

- The fuel's chemical composition, such as sulfur or chlorine content, mineral type and content;
- The fuel's moisture content: dry fuel can be burned cleaner than wet fuel;
- The combustion temperature and the control of this temperature;
- The oxygen supplied and the way this oxygen mixes with the wood gases;
- The time wood gases remain in the combustion chamber
- The geometry of the combustion chamber;
- The firebed's size and movement;
- The velocity of the air supplied;
- The flue-gas temperature in the exhaust and chimney.

Since the fuel to be burned at BCIT was lab-tested to be very clean, even clean enough to meet European Class A1 pellet standard, the challenge is reduced to the technology applied and the way the biomass boiler is operated. Yet, forecasting the type and amount of pollutants that will be emitted into the air shed is difficult if not impossible, especially since the supplier of the equipment is not known at this stage.

Air Emissions to be expected

What can be stated safely are criteria that European biomass boilers have to and therefore do meet to be eligible for subsidies. These standards are tighter than those imposed by the local ministry of environment or whatever legal body is in charge of the air shed. All suppliers contacted within this project have previously demonstrated that they are able to meet the following official Austrian thresholds using a variety of fuel, generally fuel of lesser quality than the pellet-grade fuel available at BCIT:

Emission Thresholds for Obtaining Subsidies for Biomass Boilers < 300 kW in Austria:

Air contaminant	Concentration in flue gas* at 11% O_2		Concentration in flue gas* at 8% O_2	Comment
Particulate matter (TPM)	125 mg/sm³	=	163 mg/sm³	With cyclone only, no filter
Carbon monoxide (CO)	475 mg/sm³	=	619 mg/sm³	
Nitrogen oxides (NOx)	250 mg/sm³	=	326 mg/sm³	
Organic carbohydrates	55 mg/sm³	=	72 mg/sm³	Solid organic compounds

(*at 20° C and a pressure of 101.325 kPa)

Metro Vancouver Air Quality Requirements

Currently GVRD Bylaw 1087: Biomass Boiler Regulation controls the emissions from non-agricultural biomass boilers in the area that Metro Vancouver has jurisdiction.

This bylaw is not applicable to the biomass boiler at BCIT because **BCIT's waste is not considered 'biomass'** due to presence of resins (in plywood and MDF). Instead a permitting process has to be undertaken. There are no fixed thresholds for particulates or other criteria air contaminants; the officer in charge may impose any reasonable emission and emission monitoring requirements. It is likely, however, that Bylaw 1087 will be used as a "minimum requirement":

- Total particulate matter < 18 mg/sm³ ;
- Opacity must not exceed 5%;
- Nitrogen oxides < 200 mg/sm³.

(Thresholds are stated at 8% O_2 content in stack gas corrected to dry conditions at 20° C and a pressure of 101.325 kPa)

Bylaw 1087 is currently under review, see Section "Applicable Codes and Laws" on page 27 for more details. The particulate matter emission threshold might be changed to 35 mg/sm³.

Even with these relaxed thresholds the biomass boiler will likely have to be equipped with a secondary flue-gas particulate filter. Various filter technologies are described on the next page.

The amount of NO_x emitted will critically depend on the design of the biomass boiler and the possibility to recirculate cool, oxygen deprived flue gases back into the combustion process. **Low-NOx fireboxes are able to reduce NO_x emissions**. A post-combustion treatment reducing NOx-emissions such as an catalytic reduction using SNCR technology will be prohibitively expensive to consider and will result in slippage emission of urea or ammonia or whatever agent is used to chemically convert the NOx. It is strongly recommended to stay away from post combustion treatment for NOx reduction.

It will remain up to the officer in charge to determine what additional requirements BCIT will have to meet in order to be issued a permit. It should be highlighted that the wood residue considered to fuel the biomass boiler is very clean, in terms of chemical composition clean enough to meet the European A1-class pellet standard. [ii]

PARTICULATE FILTERING

Three types of flue-gas filters are used with biomass boiler of the size and type considered for this project:

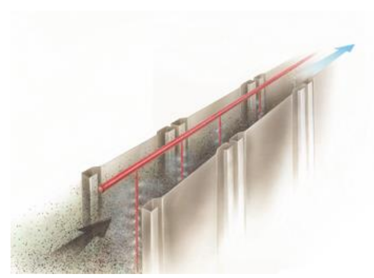
Cartridge filters or baghouses are fabric or ceramic or steel filters with small pores or pathways that allow gas to pass but particulates to be stopped. The particulates removed from the flue gas are collected on the outside of the typically cylinder shaped filter media and add to the filtering properties, but also increase the pressure drop across the filter. This dust 'cake' needs to be periodically removed, usually by a soot blower.

A key disadvantage of baghouse filters is that sparks from the firebox could create a baghouse fire. Fire resistant filter media, such as Teflon felts, ceramic material or stainless steel reduce this chance, but unburned carbon that may constitute part of the cake can still catch on fire.

Baghouse or cartridge filters are not recommended when wet biomass is used. This is a consideration if BCIT chooses to test third-party fuel in the future. Even with dry fuel condensation may clog up the filter.

Cartridge filters are commonly used for smaller (< 1,000 kW) biomass boilers, mainly because of their cost. Above this capacity the increased power consumption of the flue-gas fan may justify other designs.

Electrostatic precipitators (ESP) first spray the flue gas with electrons to charge them, and then they draw the gases through a strong electric field between two plates. The negatively charged particles are drawn to the positive plate where they collect. The cake is occasionally removed by a rapping device.



ESPs are commonly used for larger installations, but recent product development has brought small units to the market.

The main advantages of electrostatic precipitators are the reduced fire hazard and the lower power consumption of the flue-gas fan. At the small size of the installation at BCIT there is little difference in power consumption though. A key disadvantage is the size of the filter. The filter needs to be installed indoors. New small-scale ESPs may be cost competitive to stainless steel baghouses.

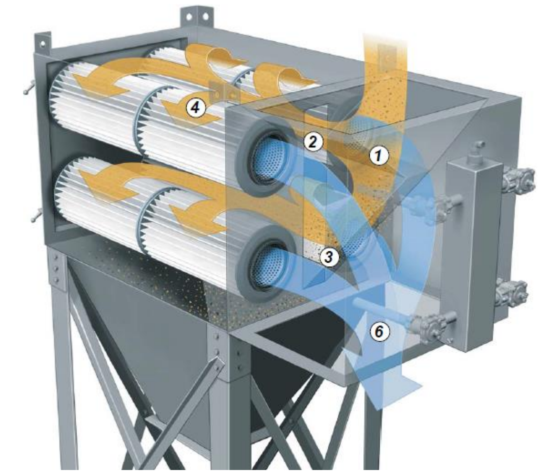
Cylindrical electrostatic precipitators are a new development with a cylindrical geometry rather than two electrode plates facing each other. For stoves they are added to the top of the chimney. Units for the size of combustor required at BCIT they are larger in diameter (0.9 m) and should be installed inside. They require less space than other filter designs and are reportedly rather inexpensive. At the time of writing this report a Swiss product was not yet approved for the North American market.

From a schematic design point of view all of these technologies can be used. Fabric filters should be avoided due to fire hazard, particularly if a moving grate combustor is used. Ceramic and stainless steel filters have a much lower fire risk, but need effective cake removal systems. The fine pores of ceramic filters are known to clog up in the long-term, resulting in a high pressure drop and increased power consumption.

Standard electrostatic precipitators have a large footprint and require a higher ceiling than cartridge filters or the new cylindrical ESPs. The filter room has been designed to host an ESP as the largest possible piece of equipment.

Since the filter will have an effect on the operation of the firebox boiler, it is recommended to discuss the selection of filtering equipment with the supplier of the biomass boiler.

Cartridge Filter



Source: Mikropul

Stainless Steel Mesh Filter

Source: Viessmann

Electrostatic Precipitator

Source: Scheuch

Coaxial Electrostatic Precipitator

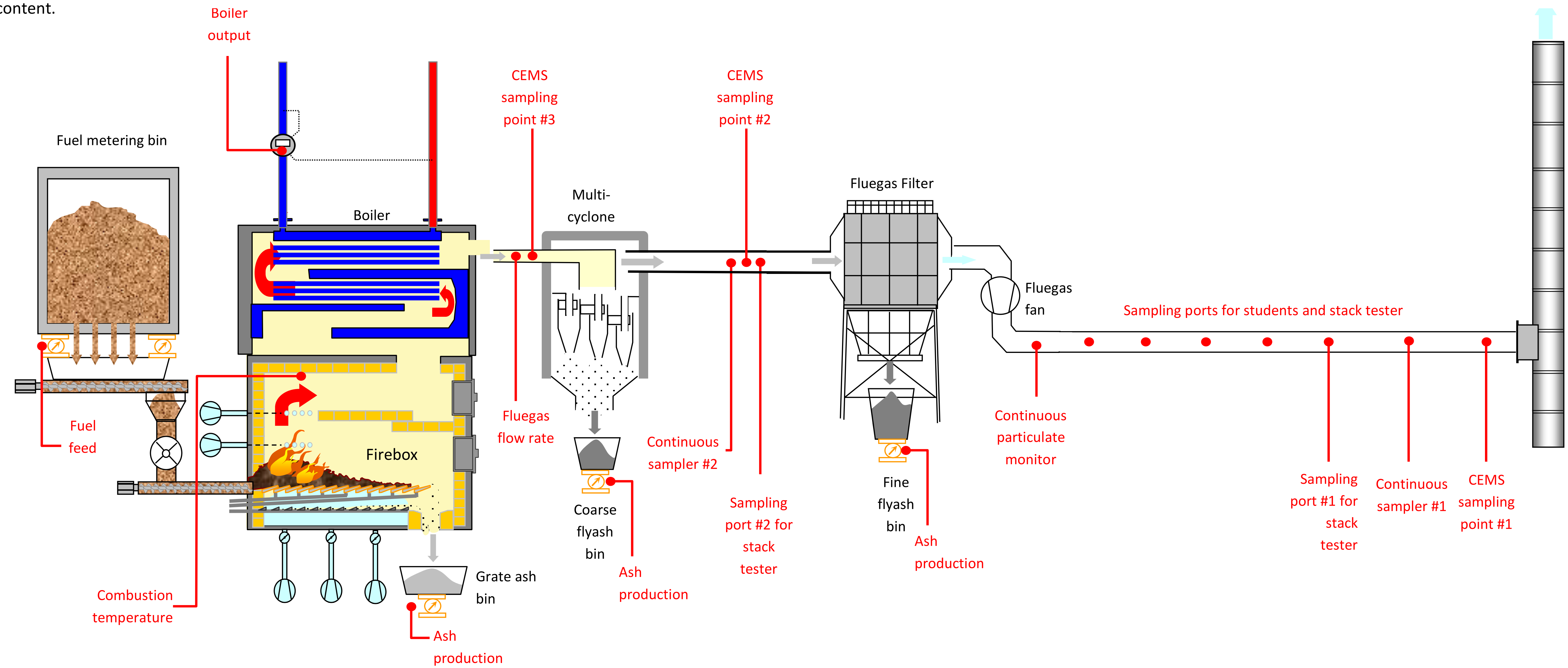
Source: Oekosolve

MONITORING

The plant has been designed for operation as a research facility, particularly in regards to monitoring of air emissions. This design includes the possibility to burn test fuels and to monitor key parameters such as fuel consumption, combustion temperature, heat output and a range of air pollutants at various points of the flue gas ducts. As such the plant the design is ready for research and, if need be, could be retrofitted with monitoring equipment after the plant has been erected.

Because the plant will burn fuel that is classified as "contaminated" as per Metro Vancouver Bylaw 1087 there will likely be a legal requirement to test emissions from the flue gases. Stack testing ports have been located on the horizontal section of the exhaust pipe that is accessible from the ground level. Ports on the (vertical) chimney are not included as they would require a testing platform with a railing and an access ladder. The ground level ports may also be used by students training to become professional stack testers.

The following monitoring points are recommended for research purposes: [iv] Monitoring should include access to parameters measured by the boiler control system, such as combustion temperature and oxygen content.



GENERAL LAYOUT OF THE BOILER PLANT

The following components are part of the biomass boiler plant:

A. **The firebox boiler** is generally a compact design including:

1. A rotary wheel gate for backfire prevention;
2. The stoker: a screw auger or a ram feeding fuel into the firebox;
3. A deluge system dousing the stoker in case of elevated temperatures;
4. The combustor including fans providing combustion air;
5. A de-ashing device removing grate ash from the firebox into an ash hopper;
6. The boiler exchanging heat from the hot flue gases to water;
7. A soot blower, pneumatically cleaning the boiler from fly ash;
8. A control panel, including the human-machine interface (HMI).

B. **The heating installation**, including:

1. A boiler shunt maintaining the required minimum return temperature;
2. Safety devices, such as a low-water shut off valve and a pressure relief valve;
3. A heat exchanger (optional, only for indirect connection);
4. An expansion tank compensating for pressure changes due to water being heated up (optional, only for indirect connection);
5. A pump revolving the water between the boiler and the heat exchanger(optional, only for indirect connection);
6. An (underground) heating pipe to and from the arm of the campus heating network;
7. A pump extracting water from the campus heating supply line, pushing it though the boiler and back to the campus heating supply line.

C. **Flue-gas Treatment**, including:

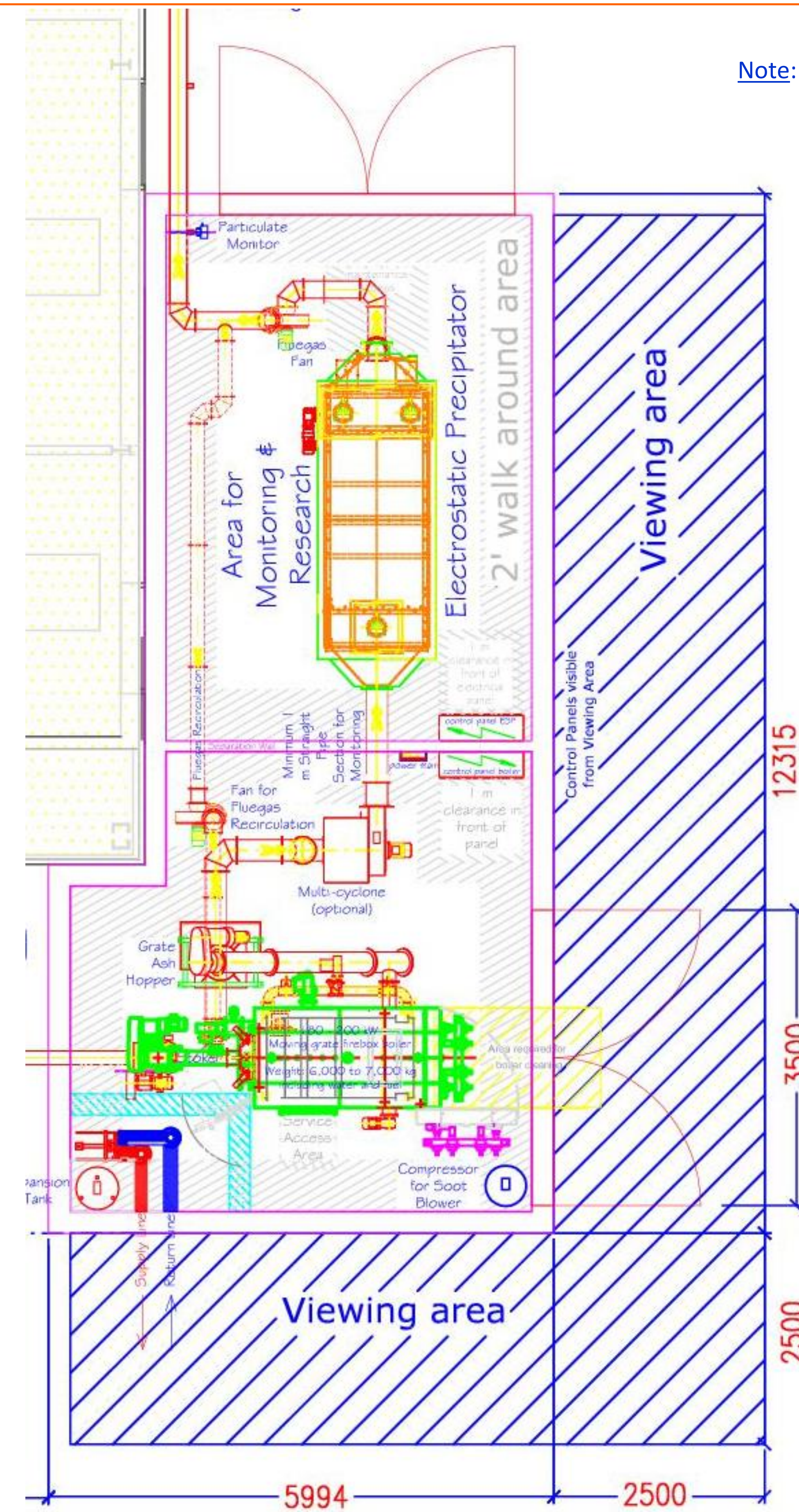
1. A cyclone or multi-cyclone removing coarse fly ash. This cyclone is not necessarily required if a large filter is employed. It is suggested for research purposes only. Flue-gases will pass through unabated if the cyclone's fan is switched off;
2. A filter removing finer particulates. This filter can be a cartridge filter or an electrostatic precipitator. Ducts leading to and from the filter should be at a heights that allows a 6' person to walk underneath without bending;
3. A flue-gas fan, also called an induced draft fan, sucking exhaust from the combustor and through the filters;
4. A flue-gas recirculation line re-injecting clean, but oxygen-deprived flue gases back into the combustor. Flue gas recirculation allows controlling the combustion temperature and O2-content of the exhaust, a standard to limit fire bed temperatures.

D. Emission Monitoring and Testing Equipment

1. Various sensors throughout the plant (see page 18);
2. A flue-gas sampling system;
3. A gas analyzer;
4. Various ports for emission testing.

The drawing to the right is only one of many possible layout arrangements. The exact size, location and orientation will depend on the brand, type and model of biomass boiler and filter purchased.

Note: All distances in mm



EXHAUST HANDLING AND TESTING

The following components are part of the flue-gas exhaust handling system:

Flue-gas Fan

- The flue-gas fan should be located downstream of the filter, allowing the filter to operate at a negative pressure.

Flue-gas Recirculation

- In order to control combustion temperature some of the filtered flue-gases are re-injected back into the firebox. Being deprived of oxygen these flue-gases allow air-cooling the combustion process. See drawing on page 19 for details.

Ports

Flue-gas ducts need to have ports at various locations for the following reasons:

- For official stack tests;
- For monitoring purposes
- For training students on the use of official stack testing equipment

Ports are mainly at eye level in the horizontal section of the chimney, allowing easy access and avoiding scaffolding or additional platforms

Chimney

- The chimney will be attached to the south wall of NE02, close to building eave;
- The minimum stack height must be 20 metres above ground level unless otherwise specified by the district director (Bylaw 1087. This part of the Bylaw may be applied as a minimum requirement).
- The top third of the chimney will be 7.2 m above the building eve and will be free standing. Structural support and/or guy wires might have to be added.
- For a 200 kW unit the chimney's inside diameter should be approximately 200 mm (10")). Larger diameters may be required where there are ports used by the official stack tester.
- The pressure loss of the chimney is expected to be 36Pa for a smooth-walled carrier pipe. (Source: Ecco Supply Inc., Burnaby)
- All ducts carrying hot flue gases need to be insulated to avoid condensation and for safety purposes. 50 mm rock wool with aluminum cladding is a standard.

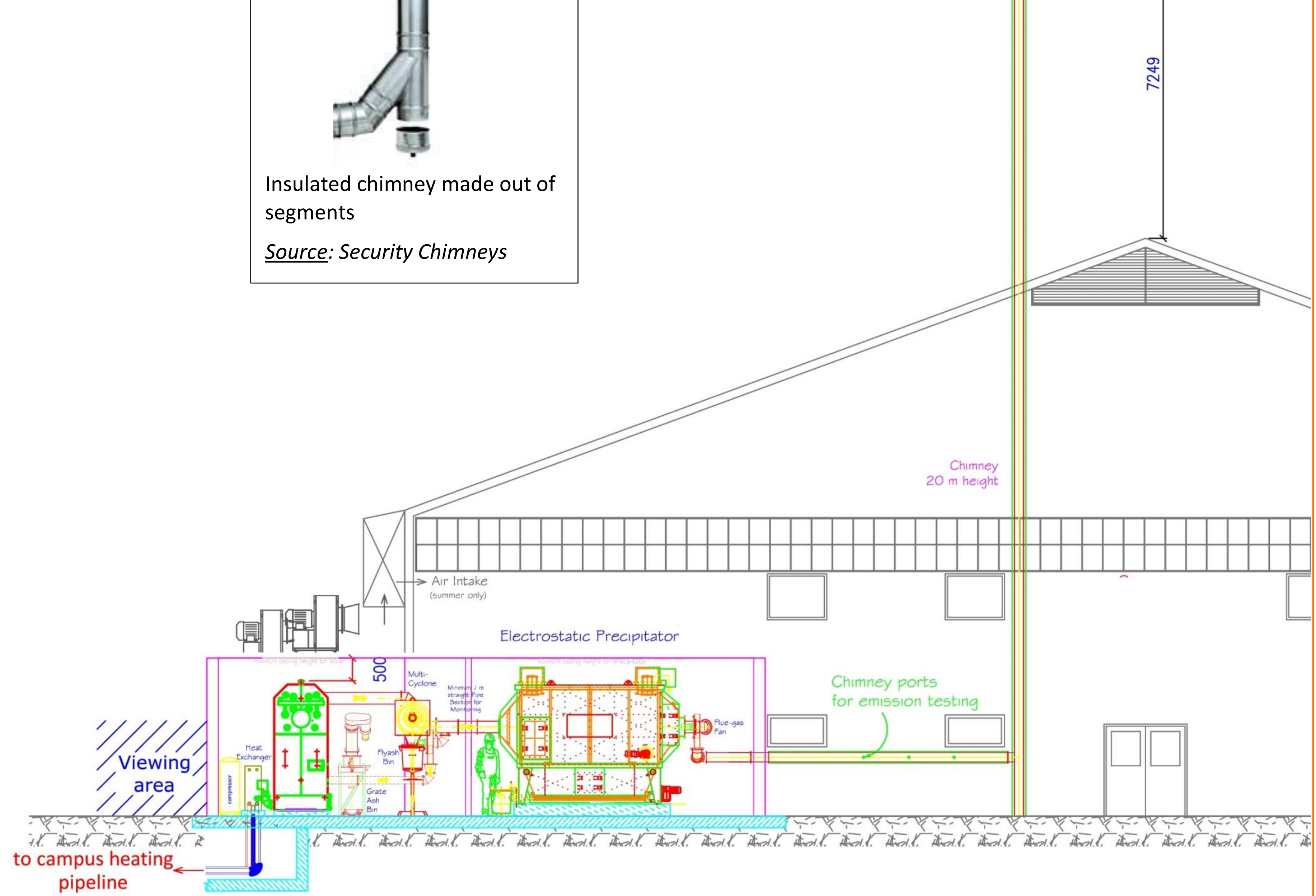
Two design options exist for the chimney. Both are technically viable, but Option (b) below is expected to be less expensive.

(a) A pre-insulated, double walled chimney assembled out of segments. This will require a supporting bar (e.g. an I-bar) for the top third.

(b) A single corten steel pipe insulated after erection. The pipe is structurally self-supporting, as long as it can be securely fastened to the wall.

Insulated chimney made out of segments

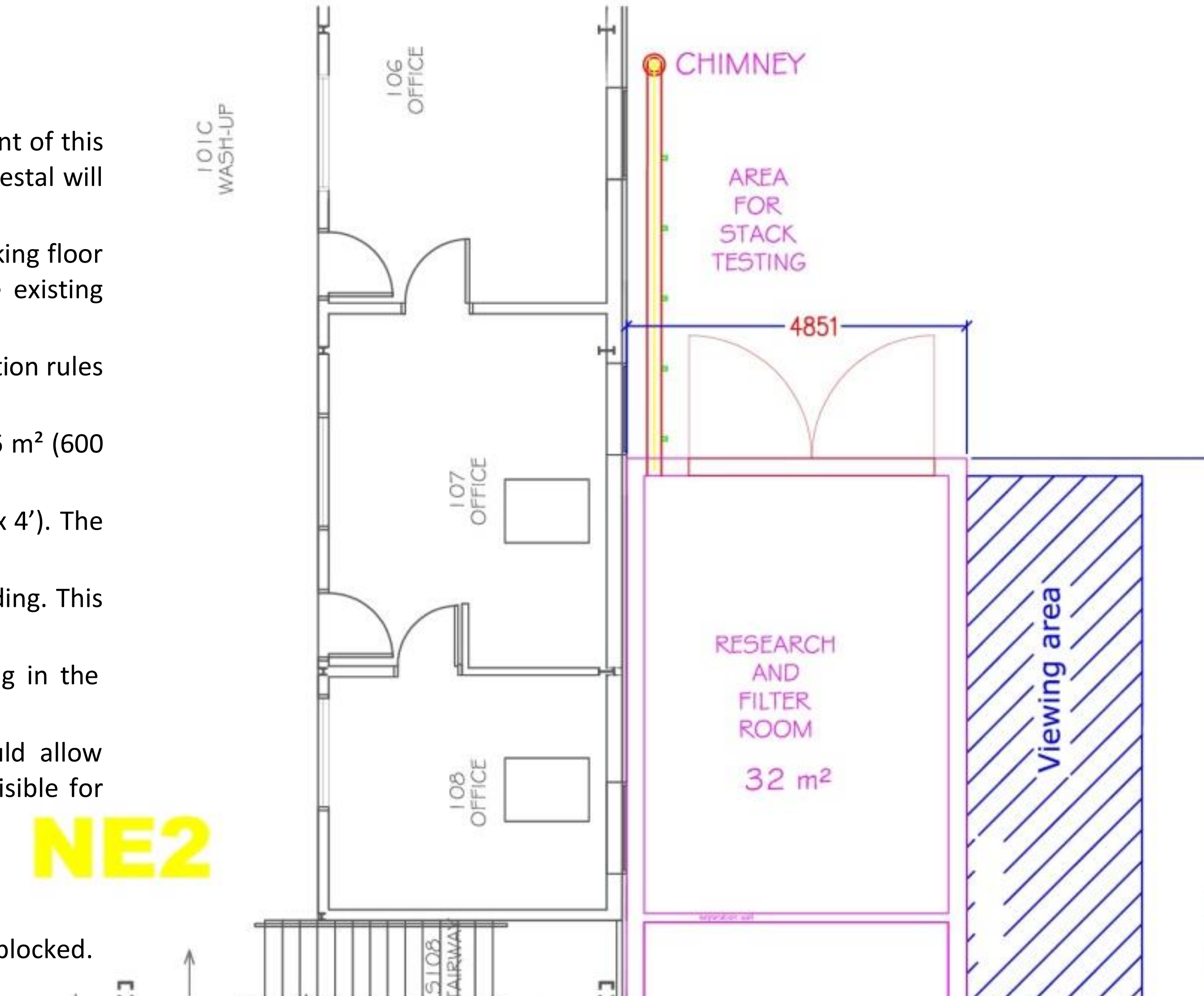
Source: Security Chimneys

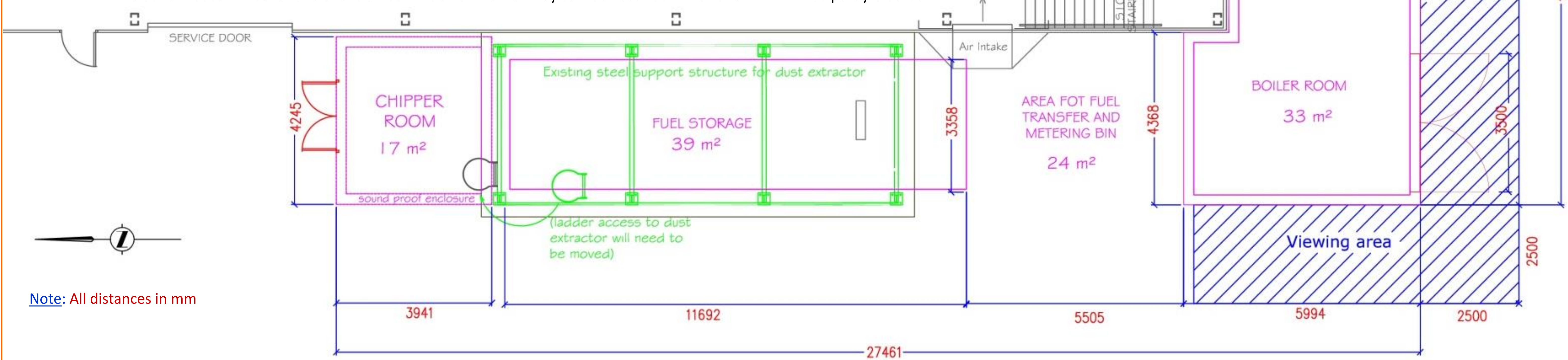


ARCHITECTURAL REQUIREMENTS

The following are requirements that will need to be taken into account by the architect to design the plant building(s):

- The chipper will need to have a sound-proof enclosure to allow operating it without disturbing classes. The footprint of this enclosure will be approximately 4 x 4 m or 17 m² (170 sft), including a 200 mm (10") wall. A foundation and a pedestal will have to be poured. The ceiling should allow for a tall person to stand upright, 2 m (6 ½ ") minimum.
- The fuel storage will be mostly underneath the existing dust extraction system. Hydraulic cylinders driving the walking floor will be located just south of this area, anchored into a new concrete foundation to be poured on top of the existing foundation. The fuel storage should have a cover to protect the fuel from the elements and from arson.
- The metering bin can be under a roof as long as this does not obstruct access for third-party fuel. Due to fire protection rules laid down in the BC Building Code the metering bin cannot be in the same room as the boiler.
- As requested by BCIT's planning department the boiler house has an L-shaped footprint with a net floor area of 56 m² (600 sft). Outside dimensions are roughly or 6 m x 12 m (20' x 40'), including a wall allowance of 200 mm (10").
- The boiler needs a foundation that can withhold approximately 4 tonnes (8,800 lb) on an area of 2.5 m x 1.2 m (8' x 4'). The filter's foundation would be rated for a maximum of 1 tonne (2,200 lb) with a foot print of 3.5 x 1.5 m (11' x 5').
- The boiler room will need a large door, at least 3.0 m high and 1.2 m wide, for introducing the boiler to the building. This door will need to be opened for boiler cleaning.
- The boiler will be connected to the existing underground campus heating pipeline. This will require an opening in the concrete floor and foundation of the boiler house.
- The boiler should be accessible by maintenance staff only; a wall separating the boiler from the filter would allow instructors, and possibly students, access to the research and filter area. Glass wall(s) would make the boiler visible for demonstration and training purposes. The glass walls might have to have a fire rating of ½ hour.
- The boiler room should be designed with 0.6 m (2') wide escape corridors accessible from every point of the plant.
- The minimum ceiling height above the boiler and above the filter is 3.5 m.
- The boiler house will cover one of the office windows. The walkway corridor between NE02 and NE21 will be partly blocked.





INTERCONNECTION TO THE CAMPUS HEATING NETWORK

Several options for using the heat generated by the biomass boiler have been considered:

1. **Connecting to the existing campus heating pipeline** supplying the J. W. Inglis Building, NE01. The pipeline passes the potential future location on the west side of NE02, the Joinery Department, within 15 meters, in a concrete duct 1.6 m below grade.
2. **Supplying NE01 directly**: This would require additional 2 x 200 m of pipe paralleling existing pipes. An initial cost estimate is $200,000 ($1,000 per m of trench). The authors of this report consider this an unnecessary expenditure.
3. **Supplying other buildings in sustainability precinct**: This requires (a) new district heating pipeline and (b) retrofit of heating system inside these buildings. The design of the biomass boiler plant should leave this option open for future implementation.

Based on the physical location of the biomass boiler plant the favoured solution is option (1), feeding into campus heating network. The arm supplying the building J.W. Inglis building (NE01) passes only 13 m (41') west of the future location of the biomass boiler plant, see the plan-view drawing on page 24 and page 25.

Operation of the Campus Heating Pipeline

As mentioned in the pre-design report, currently network temperatures are set to 97°C in the supply line throughout the heating season; return temperatures are typically 83° C or more, depending on the outside temperature and consumption of NE01 and SE02, the two buildings supplied by the arm of the heating network that the biomass boiler would feed into. Both of them only require a maximum of 75°C.

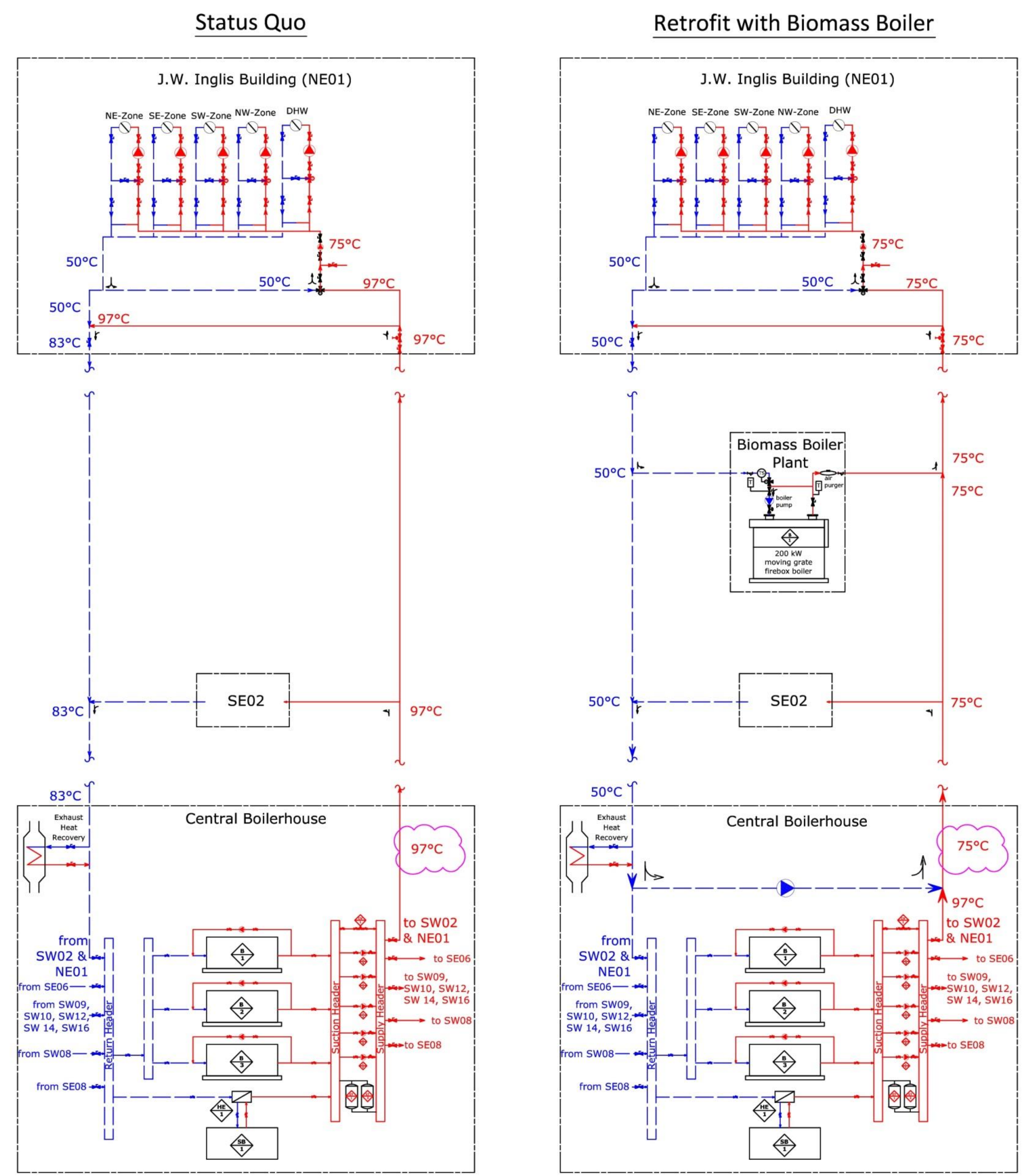
The flow through the pipeline is kept constant and is only adjusted by turning one of the three fixed-speed pumps in operation off or on as the season becomes warmer or colder. As a consequence the return temperature varies throughout the year and even throughout the day.

The existing heat supply of the central boiler plant is unconventional and maybe historically explained by the fact that the previously existing building substations, especially the heat exchanger were removed. Instead a 3-way valve was installed to control building level (secondary) supply temperature and a 2-way valve was added for primary flow control. [v] With this arrangement surplus hot water at too high a temperature is supplied to the building. Excess water supplied is returned directly to the return by an uncontrolled bypass. Water that is too hot is then mixed down by adding secondary return water to the secondary supply side.

Both processes are wasteful in terms of heat losses and pump electricity consumption. Lowering the supply temperature on the primary side to 75°C would mitigate pipeline heat losses and improve the efficiency of the recently installed exhaust heat recovery system. This should be done independently from the biomass boiler installation.

Lower supply temperatures can be achieved by mixing (colder) primary return water to the hot primary supply, downstream of the main header, but upstream of the future tie-in of the biomass boiler.

These retrofits are not a prerequisite for connecting the biomass boiler to the network, but are recommended to allow operating the boiler below 100°C.



Boiler Parameters

The biomass boiler will have to meet the following prerequisites and design criteria:

Protection from condensation and subsequent corrosion: feeding the boiler with water that is too cold will result in flue gases condensing. The resulting condensate is extremely acidic and will corrode the boiler. The problem becomes more pronounced with wet fuel. In order to avoid condensation return water should have a minimum temperature of 60°C for dry fuel, 75°C for fuel with a moisture content of 50% (wet basis).

While BCIT's fuel is rather dry, below 10% moisture content, test fuel that may be used at a later stage may be wet. It therefore recommended setting the return water temperature to no less than 65°C for dry fuel, 75°C for wet fuel. Technically this is achieved by a boiler shunt and a 3-way valve mixing in hot supply water to the return line. The setting can be changed for the duration of a fuel test.

Reducing temperature stress: On the other hand, the higher the supply temperature the more stress and wear there will be on the boiler, but also on components, such as valves downstream in the supply line. For this reason and to stay within ASME Section IV - Hot Water Heating and Supply Boilers it is recommended to constrain the supply temperature to below 95°C.

This design parameter cannot be met when return temperatures exceed 85°C, i.e. during times of low demand. The minimum return temperature is currently 83°C.

Temperature differential: In order to be able to meet the rated boiler output, most suppliers recommend a temperature spread between the supply and the return of no less than 10°C and no more than 20°C. Outside of this window the boiler may not be performing to specification. Lower temperature differentials also require more powerful pumps, resulting in increased electricity consumption.

Applying these three criteria the best solution is withdrawing some of the water from the return line of the arm supplying NE01, heating it up and subsequently re-injecting it into the supply line. Removing water from the supply line and heating this water up is not an option because the water is already close to boiling (97°C). Even if the supply temperature were as low as 75°C, heating up the supply line would be counterproductive to the goal of reducing pipeline heat losses.

The biomass boiler would operate as a remote or "satellite" boiler in the same way the existing gas-fired boilers are operated. Due to its comparatively small capacity it can be run at maximum output though.

Connecting to the Campus Heating Pipeline

There are two ways of tying the biomass boiler into the heating network:

1. Directly, the way the existing boilers are tied into the network
2. Indirectly, with a heat exchanger between the biomass boiler and the heating pipeline

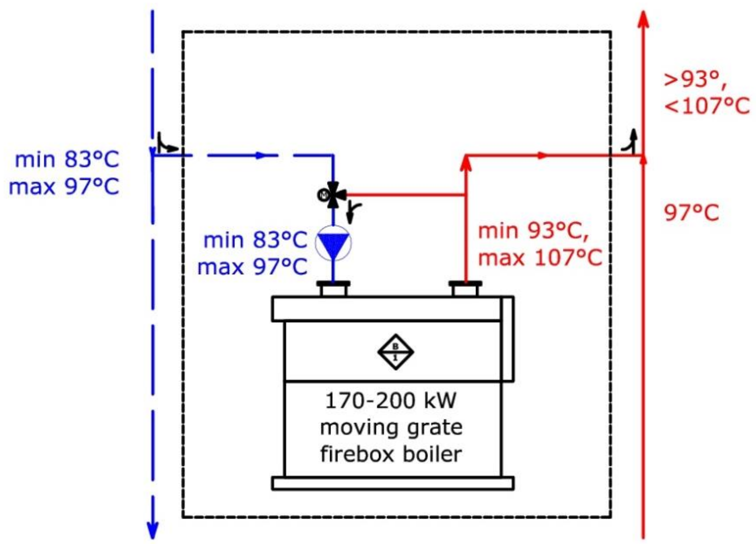
An indirect connection separates the biomass boiler hydronically from the rest of the network. Pressure fluctuations or water impurities in the heating network would not affect the biomass boiler and vice versa. It also protects the boiler should the water in the campus heating pipeline be of poor quality, e.g. corrosive due to oxygen intake or contaminated with sediments, welding beads etc. An indirect connection would, however, require additional investment needs, mainly for the heat exchanger and one additional pump. Technically there would be some, though minor, heat losses at the heat exchanger.

To protect the boiler it is recommended having an indirect connection with a heat exchanger.

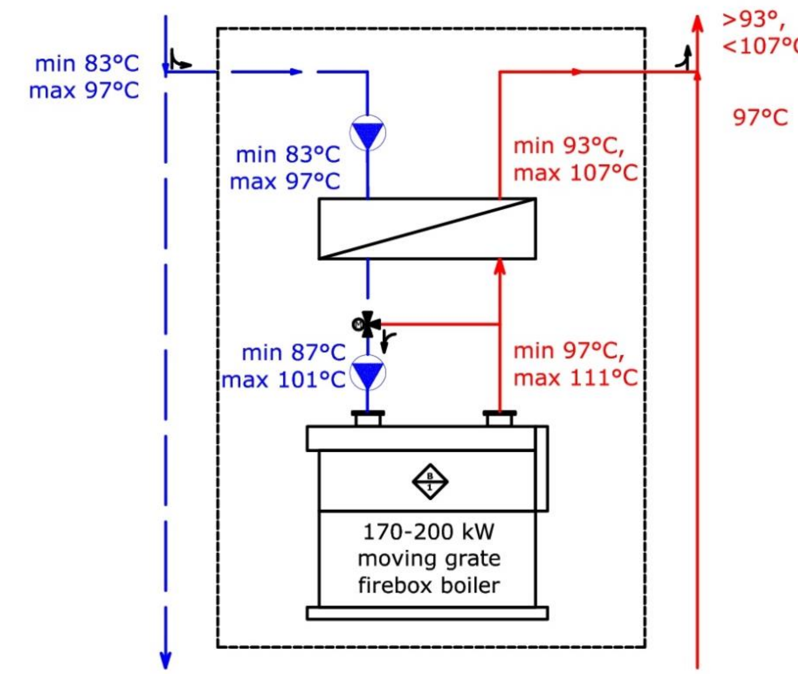
Summary of the Interconnection Concept

- It is **recommended connecting the biomass boiler as a satellite plant**, heating up water returned from NE01 and re-injecting it to the supply line of the same arm.
- During 21 days of the year NE01 is expected to have a daily average load of less than 166 kW. On some of these days some of the heat might be returned to the central plant, increasing the return temperature.
- To protect the boiler from poor water quality an indirect connection with a heat exchanger is recommended.
- Lowering the supply temperature in the main pipeline from currently 97°C down to 75°C would allow operating the biomass boiler at below 95°C at all times. It would also reduce pipeline heat losses and lower supply temperatures can be achieved by injecting return water to the supply line at the boiler house.
- To avoid corrosion, a boiler shunt with a temperature controlled 3-way valve should keep the return temperature into the biomass boiler above 75°C.

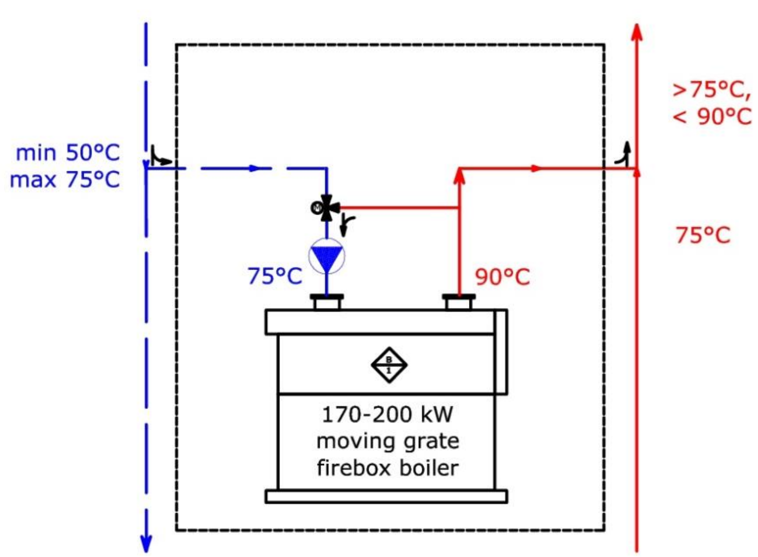
Option1A: High-Temp Network,
Direct Connection



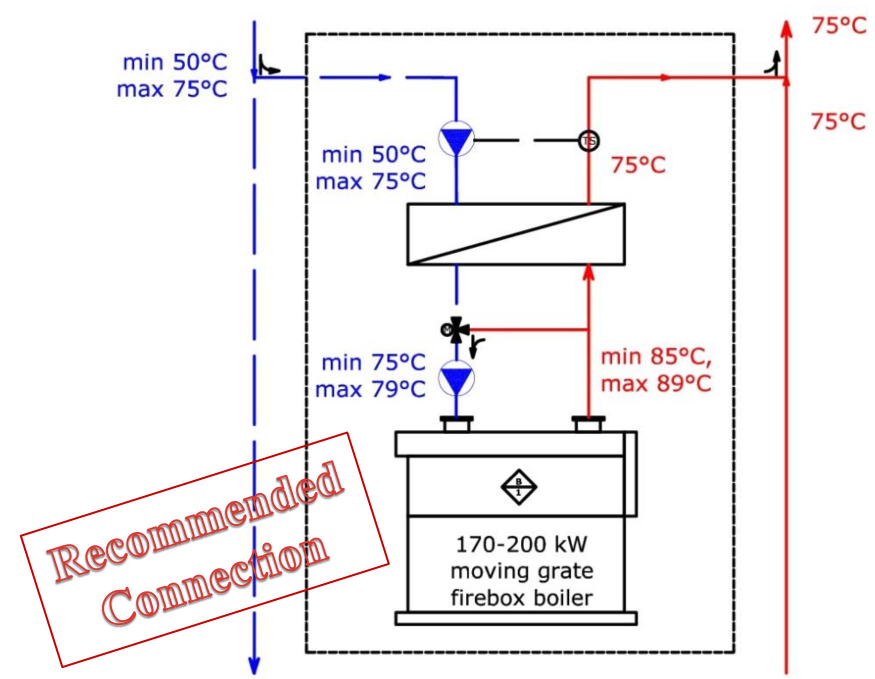
Option 1B: High-Temp Network,
Connection via Heat Exchanger

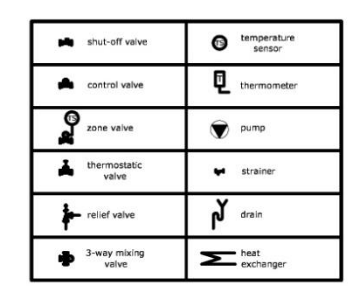


Option 2A: Low-Temp Network,
Direct Connection



Option 2B: Low-Temp Network,
Connection via Heat Exchanger





PHYSICAL TIE-IN OF THE BIOMASS BOILER

A connection to the arm of the campus heating network supplying the J.W. Inglis Building (NE01) will need to be made. The **pipeline passes** the future location on the west side of NE02, the Joinery Department, **within 15 meters**, in a concrete duct 1.6 m below grade. This connection is preferably made below ground and below the frost line depth, i.e. below 150 mm (6”) in Burnaby.

Connection Details

The existing pipeline has a 250 mm (12”) diameter and is at a depth of 1.6 m (5’) where the line from the biomass boiler plant connects to it. The distance from the boiler house to the pipeline is approximately 13 m (41’). The concrete channel hosting the existing pipeline might require modifications, possibly adding a person-hole. This person hole would be in the area of the sidewalk, just south of the roofed part of the walkway. The person-hole would not conflict with the roof support posts. **If a person-hole is added, the top of the hole could be covered by a thick glass making the inside visible for demonstration purposes**.

Pipeline Material

If a low-temperature solution below 95°C as illustrated as Option 2A and Option 2B (see the previous page, page 23) is chosen a lower cost plastic (cross-linked polyethylene = PEX) pipe can be used. High supply temperatures of 95°C as in Option 1 A and 1B (on page 24), on the other hand, require steel carrier pipes. The difference in installed cost will be marginal due to the short pipe length of only 13 m and the straight pipe run. The need for and cost of brass connectors between existing steel pipes and the PEX pipeline will likely make **steel carrier pipes the less expensive option**.

Visibility of the Heating Pipeline

Modern pre-insulated pipelines with waterproof jackets make concrete channels obsolete. Yet for demonstration and teaching purposes a section of the trench or the entire trench containing the pipe could be made visible by adding a concrete channel with a thick- drive-on glass cover.

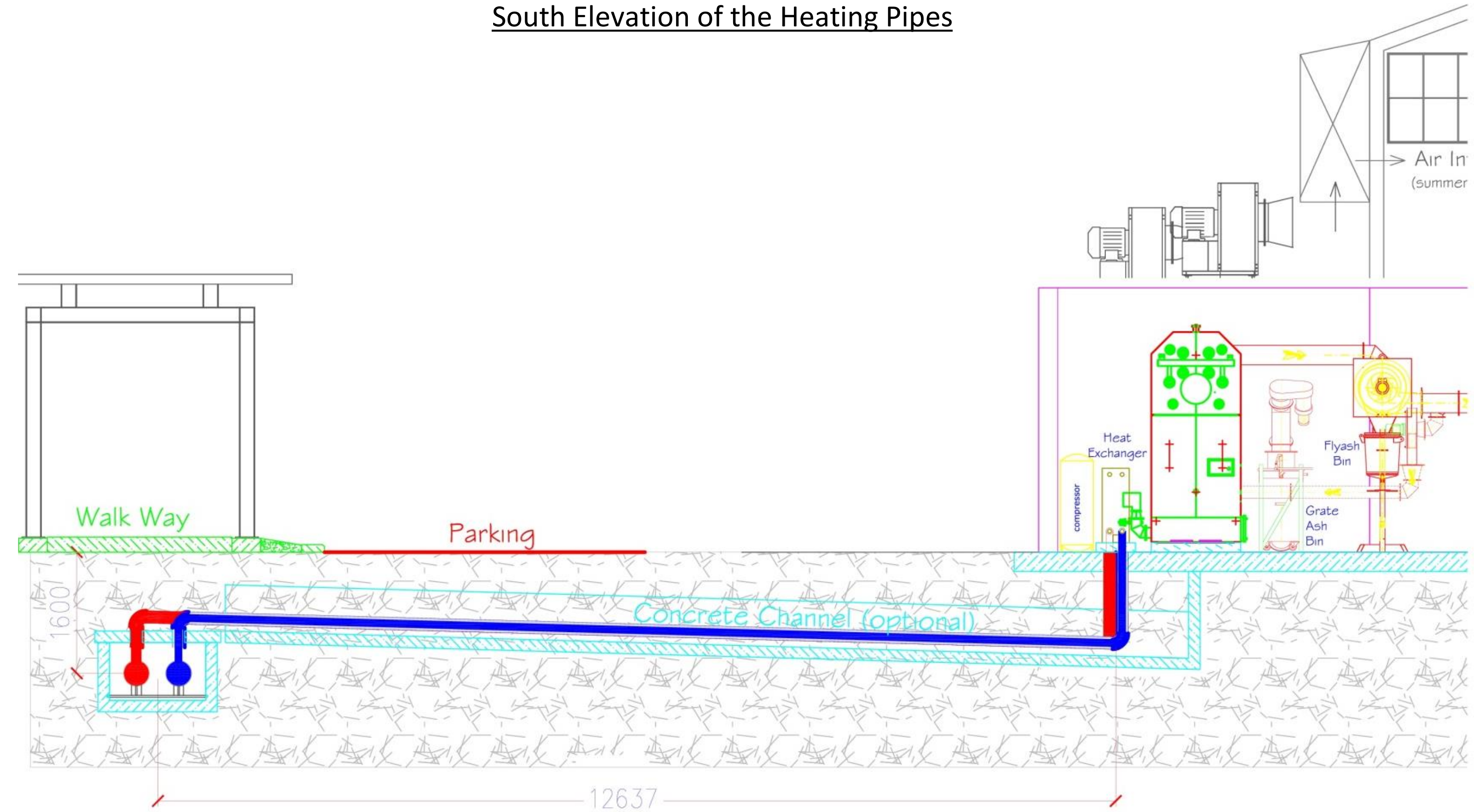
If a concrete channel is used, it should be under a 2° angle to allow drainage of water collecting in the channel.

It should be noted that the pipeline inside the boiler room will be visible and could be used for training and demonstration purposes.

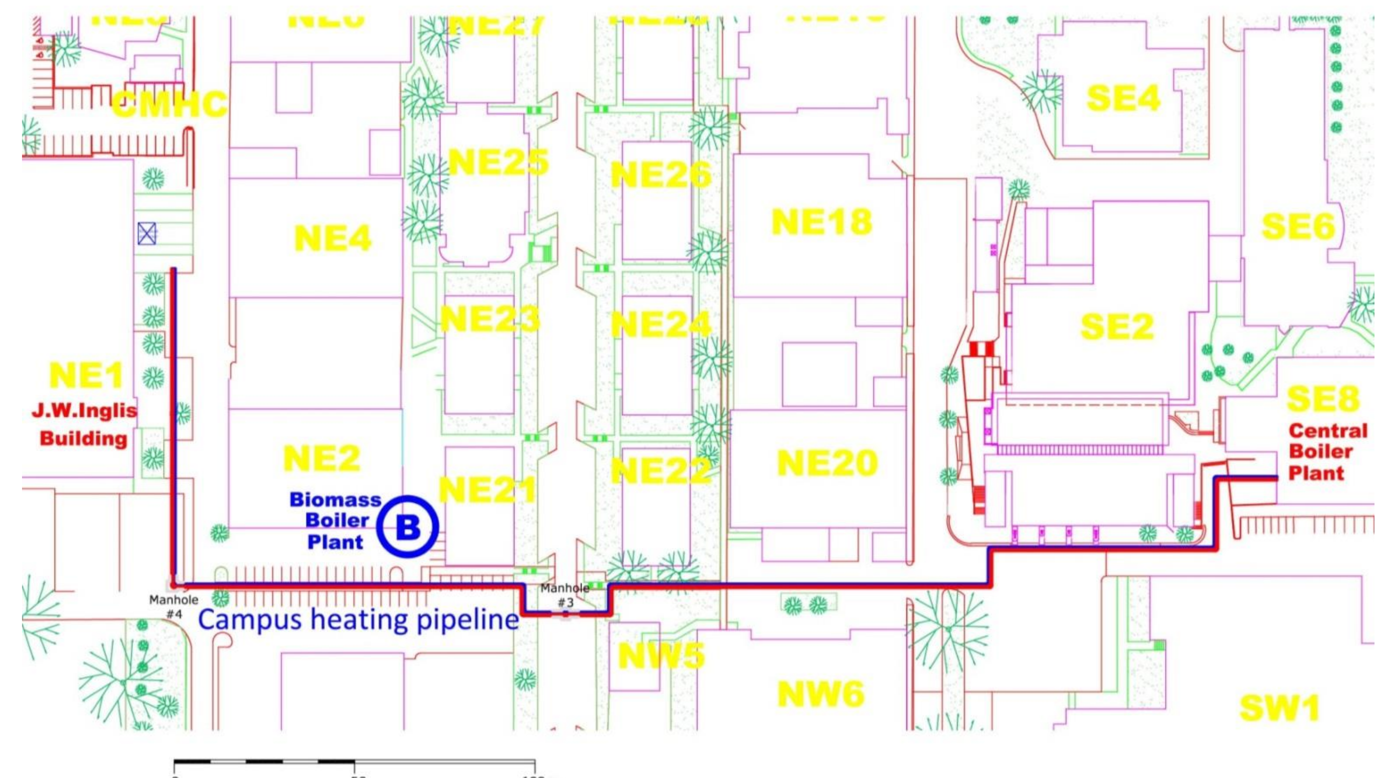
Heat Storage

There is no need for heat storage because the carrying capacity of this heat pipeline exceeds the amount of heat the biomass boiler can generate.

South Elevation of the Heating Pipes



Location of the Campus Heating Pipeline



ELECTRICAL AND OTHER UTILITY SERVICES REQUIRED

The following utility services will be required by the entire biomass heating plant:

Electricity

1. Chipper: 36 HP, 460 V, 3-phase. 36 HP = 27 kW => 59 amps @ 460 V
2. Biomass boiler including ancillary equipment: 20 amps at 240V 3-ph and 20 amps 110 V single ph.
3. ESP: 480 V 3-ph, with a 2 kW circuit breaker drawing 1 kW on average, i.e. 4 amps only.
4. Boiler plant envelope: 5 kW for lighting and receptacles
5. Monitoring equipment: - Sample probe and heated lines (21 m) :7.5 kW, or 31 amps at240 V
   - Analyzer: 3 x 16 A.

More detailed data on power requirements need to be obtained during the procurement phase. **The chipper will be the main power consumer**. Power might be obtained from an electrical box on the west wall inside the Joinery Workshop. An initial investigation showed that there should be sufficient spare capacity available.

Other Utility Services

The following other utility services are required:

- City water/fire water: approx. ¾" , frost protected, protected against closure
- Connection to storm sewer
- Data connection

Impacts to the Campus' water distribution system, sanitary and storm sewer are anticipated to be negligible.

EXISTING UNDERGROUND UTILITY SERVICES

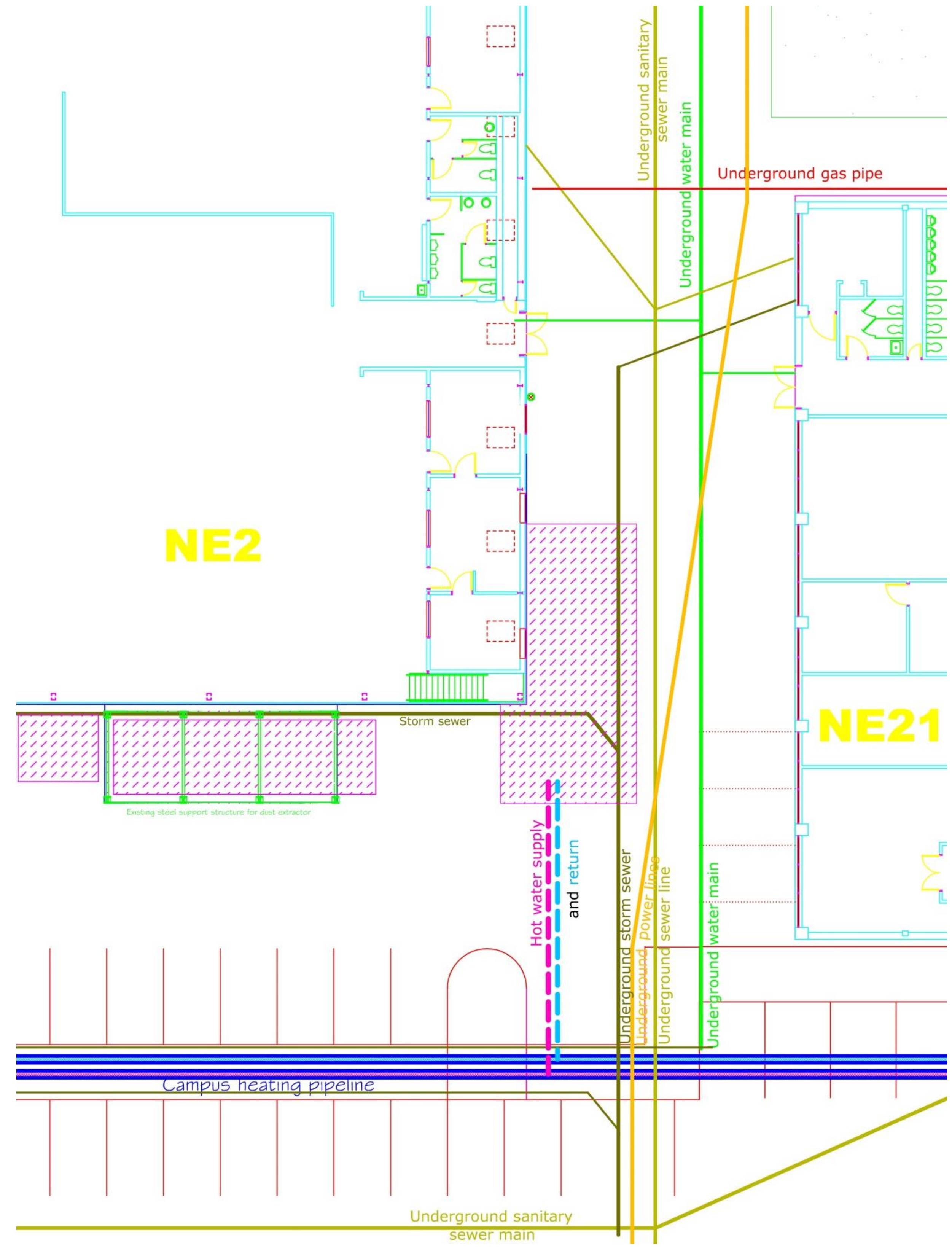
The following underground services are in the area where the biomass plant will be located:

- Storm sewer
- Sanitary sewer
- Water main
- Power line

Gas lines exist east of the future location of the boiler plant, but not in the area that will be covered by the plant.

There would be no major conflict with existing underground services. Part of the plant would be built on top of an existing arm of the storm sewer though. It should be noted that this seems to be an accepted standard as the foundation of the existing support structure for the dust extractor is already above a storm sewer line. The future hot water connection to the underground campus heating pipeline will not cross any of the existing underground services.

Underground Utility Lines



APPLICABLE CODES AND OTHER CONSIDERATIONS

The following codes and laws are likely to impact the construction and operation of the biomass boiler plant. Details will have to be clarified during the permitting phase.

Applicable Codes and Laws

The following codes are applicable to the biomass boiler plant:

1. CSA B366.1, Solid-fuel-fired central heating appliance
2. CSA B365, Installation code for solid-fuel-burning appliances and equipment
3. The BC Building Code, particularly pertaining to the fire code and the spatial separation
4. Parts of Metro Vancouver's Biomass Boiler Regulation 1087, particular pertaining to particulate emission thresholds and chimney height

Bylaw 1087

GVRD Bylaw 1087: Biomass Boiler Regulation is not applicable because BCIT's waste is not considered 'biomass' due to the presence of resins (plywood, MDF). Instead a permitting process has to be undertaken. There are no fixed thresholds for particulates or other criteria air contaminants, but Bylaw 1087 is likely to be used as a minimum requirement.

Bylaw 1087 is currently reviewed by Metro Vancouver. The proposed amendment would have less tight requirements for small systems below 3 MW capacity. For example particulate matter thresholds would be raised from currently 18 mg/sm^3 to 35 mg/sm^3.

Other amendments that are scheduled to take effect in October 2013 and that might affect BCIT are:

- Make air quality dispersion modelling prior to start-up mandatory for biomass fuelled systems to ensure that areas around the facility continue to meet Metro Vancouver air quality guidelines.
- Establish new continuous monitoring requirements to ensure that biomass fuelled systems are monitored for steady operation with an acceptable level of emissions.
- Add new requirements to manual stack testing programs for biomass fuelled systems for additional monitoring of air contaminants of concern.
- Add mandatory tune-up requirements for biomass fuelled systems to ensure continued efficient operation thereby minimizing overall emissions.

Classification of the Plant according to the BC Building Code

According to the BC Building Code the boiler house would be classified as **Low Hazard Industrial Occupancy** – Group F , Division 3 – an industrial occupancy in which the combustible content is less than 50 kg/m^2 or 1,200 MJ/m^2. Enclosing the metering bin will not change the occupancy classification. This assessment is based on the following three parameters:

a) Floor Area of the boiler house = 65 m^2

b) Fuel Content at any time inside the boiler house: max. 200 kg or 720 MJ

c) Combustible Content = Fuel Storage / Floor Area = 200 kg / 65 m^2 = 3 kg/m^2 or 11 MJ/m^2

This classification will have impact on the fire rating of walls and the need for sprinklers that the architect designing the plant will need to take into account.

Spatial Separation

The campus planning department of BCIT requested that the boiler house is adjoined to the Joinery Workshop (NE02) in an L-shape. This has a couple of repercussions on the design of the building:

The walls facing the Joinery Workshop should not have any unprotected openings and should have at least a half-hour fire rating (BC Building Code).

- The wall facing the metering bin needs to have at least a 0.5 hour fire rating (CSA B365 – A 2.2.1)
- According to CSA B365 the boiler house will have to have a permanent opening for natural ventilation air supply of 0.66 m^2 (7 sft) (3,300 mm^2 per kW- CSA B365 - 4.3)
- There are plans to tear down the NE21 Building and replace it with a new one. The maximum amount of unprotected openings on the boiler plant's walls facing NE21 will depend on the new building's design an distance. If the boiler plant will be built before the new NE21, this might have an impact on the design of NE21.

These issues need to be resolved during the permitting or the procurement phase, in part by the architect designing the plant enclosure.

Procurement

While procurement is not part of the scope of this assignment, the following consideration should be given: the entire biomass boiler plant will have several suppliers. If procurement is NOT done by a general contractor, care has to be taken that one of the suppliers is responsible for the control system of the entire plant, from the chipper to the flue-gas filter. Independent control with serial interfaces might lead to problems during operation of the plant.

The supplier most likely to take on the overall plant control is the supplier of the biomass boiler. Many control systems of biomass boilers are custom designed for a particular plant or application.

Anticipated Project Schedule

Approval of Schematic Design:	July 2013
Permitting and Architectural Design:	Aug - Nov 2013
Procurement:	Dec 2013 - Mar 2014
Engineering Design:	Apr 2014 – July 2014
Construction:	Aug 2014 – Oct 2014
Commissioning:	Nov – Dec 2014
Completion:	31. Dec 2014

CONCLUSIONS AND NEXT STEPS

This report lays down a technical solution taking various constraints and requests into account. Location and footprint of the various components are identified. A number of conceptual alternatives are described. The report should be reviewed by all concerned parties and used as a stepping stone towards the next stage, the permitting phase.

APPENDIX: SUMMARY OF KEY PARAMETERS

Fuel

- Mix of 9% fines & shavings and 91% chips (P50) from solid wood
- Species: mostly spruce-pine-fir, some hardwood,
- Contamination: no paint, but resin from MDF and plywood; could contain some nails
- Fuel chemically clean enough to be meet requirements of European Class A1 pellet
- Moisture content: 6% to 12%, average < 10% (wet basis)
- Lower Heating Value: 15.9 MJ/kg
- Third party fuel (such as construction and demolition waste) maybe tested on a short term

Chipper

- Capacity of at least 436 kg/hour (960 lbs/hour). At 30 tonnes a month, the maximum residue production throughout the year, this allows chipping the daily average amount of residue within three hours a day.
- Feed material: studs (mainly 2x4's), 19% sheet material (plywood & MDG), up to 8% pallets (cut in half)
- Material size: up to 0.9 m (3') in length, a small fraction (8%) of pallets up to 1.2m (48") in length; sheet material a maximum of 0.9 m x 0.9 m (3' x 3'). The feed-in chute should be able to accept pieces of this size.
- Other requirements:
  - The chipper should be equipped with a hydraulic feed mechanism into the rotor;
  - Cutters should have multiple sides allowing quick rotation if a blade is dull;
  - The chipper should be equipped with a 1"built-in screen removing oversized chips.

Fuel Storage Bin

- Design: Walking floor 250 mm (12") above grade;
- Storage volume: approximately 10 tonnes or 50 m^3;
- Footprint: 11.6 m x 3.5 m (38' x 12'), including hydraulic cylinders;
- Length of fuel bin (inside): at least 10 m (33');
- Width of fuel bin: no more than 3.55 m, the space available between the legs of the dust extraction structure;
- Bin wall height: maximum of 2.8 m (9').

Combustor

- The combustor will be driven by fuel availability, not by heat demand. The control system has to be designed for this;
- The boiler has to be able to operate between 12 kg/h and 42 kg/h fuel input continuously and on a long term, i.e. 24/7.
- The turndown ratio of the combustor should be 1:4 or 25% of the rated output or better.
- Fuel stoking can be done by (an) auger(s) or a hydraulic ram
- The stoker unit should be equipped with backburn and deluge mechanisms

Boiler

- A boiler with a rated heat output ranging from 170 to 200 kW (depending on the robustness of the design and construction details of the firebox boiler) is likely to meet the fuel constraints.
- It is highly recommended to employ a "warm water" boiler that operates below 207 kPa and below 100°C. This simplifies the requirements imposed by the BC Safety Authority.
- There is no need for heat storage system
- Heat generated by the boiler will be fed directly into the 12" campus heating supply pipe operated at 75°C.

Size and Weight of the Firebox Boiler

- Foot print: approximately 2.5 m x 1.2 m (8' x 4'), excluding attached components such as ash dumpster, depending on the supplier's equipment selected;
- Height: approximately 2.6 m (9') , depending on the supplier's equipment selected;
- Operating weight: approximately 4 tonnes (8,800 lb), including water in the boiler, depending on the supplier's equipment selected.

Size and Weight of the Electrostatic Precipitator

- Foot print: approximately 3.5 m x 1.4 m (11' x 5') , depending on the supplier's equipment selected;
- Height: approximately 3.0 m (10') , depending on the supplier's equipment selected;
- Weight: approximately 1 tonne (2,200 lb) , depending on the supplier's equipment selected.

Architectural Considerations

- The chipper will need to have a sound-proof enclosure to allow operating it without disturbing classes. Noise levels shall not exceed 60 db. The footprint of this enclosure will be approximately 4 x 4 m or 17 m^2 (170 sft), including an allowance for the walls. A foundation and a pedestal will have to be provided. The ceiling should allow for a tall person to stand upright, 2 m (6 ½') minimum, but avoid having to dump the feed material from further up than necessary. The roof of the chipper enclosure will be used for access to the dust extractor.
- The fuel bin is designed to store 50 m^3 (1,765 cft) of chips and sawdust, the residue production during two weeks. Located underneath the existing dust extractor, the fuel storage can use the existing steel columns as part of the wall containing the fuel. The bin will need a cover to protect the fuel from the elements and from arson.
- A metering bin is designed to be located between the fuel storage and the firebox boiler. Due to the BC Building Code the metering bin may not be in the same room as the boiler. The metering bin can be under a roof as long as this does not obstruct access for third-party or test fuel.
- The footprint of the L-shaped boiler house will be approximately 65 m^2 (700 sft) or 6 m x 12 m (20' x 40'), including a wall allowance of 250 mm (10").
- The minimum ceiling height above the boiler and above the filter is 3.5 m.
- The boiler should be accessible by maintenance staff only; a wall separating the boiler from the filter will allow instructors, and possibly students, access to the research and training area. Glass wall(s) will make the boiler visible for demonstration and training purposes.
- The boiler house will cover one of the office windows on the South face of NE02.
- Some parking lots will be lost as the area and traffic flow is rearranged.
- The boiler plant will occupy some of the walkway corridor on the south side of the Joinery Workshop. BCIT plans to redevelop this area when it replaces old buildings on the south side of the walkway (NE21, NE23)
- All enclosures and buildings will have to be designed by the architect to be contracted.

GLOSSARY AND ACRONYMS

‘	foot
“	inch
°C	Degree Celsius.
24/7	24 hours a day, seven days a week
BC	British Columbia
BCIT	British Columbia Institute of Technology
BMS	Building Management System
CEM	Continuous Emission Monitoring
cyd	cubic yard
GJ	Gigajoule
Kg	Kilogram; 1 kg = 2.2 lb
kPa	Kilopascal 103 kPa = 14.9 PSI
kW	kilowatt
lb	Pound; 1lb =0.454 kg
m	Metre
m^2	square metre
m^3	cubic metre
MDF	Medium Density Fibreboard
mg/sm^3	Milligrams of pollutant per cubic metre at a (calculated) temperature of 20°C and a pressure of 103 kPa
mm	millimetre; 25.4 mm = 1 inch
NOx	Oxides of nitrogen, primarily NO and N2O
PSI	Pounds per square inch; 1 PSI = 6.9 kPa
SNCR	Selective Non-Catalytic Reduction is a chemical process that changes NOx into molecular nitrogen (N2)
t	Metric tonne; 1 tonne = 1,000 kg =2,204 lb
t/yr	Tonnes per year

REFERENCES

[i] Lavery: “Ash management Options for Biomass Boiler”, January 2013

[ii] Tong, Suchy, Hebert, Linsky: „BCIT Biomass Waste-to-Energy Report”, Burnaby, May 2012

[iii] Aigner, Suchy: „Pre-design Report Biomass Boiler Plant at BCIT’s Burnaby Campus, March 2012

[iv] Suchy: „Design of a Program Monitoring Emissions from Combustion of Construction and Joinery Residue”, March 2012

[v] Prism Engineering: „Hot Water Distribution System Review“, Burnaby, January 2008