- the integration of education and user experience in order to facilitate behaviour change within the building; and
- post occupancy evaluations.

It is recommended that UBCO's *Design Guidelines* articulate clearly the aspiration and mandate for new and existing buildings relative to the sustainability targets and long-term vision of carbon neutrality and embodied carbon. These guidelines should include, but not be limited to:

- Coordination with UBC Point Grey Campus on L*EED v4 Implementation Guide*, *Technical Guidelines*, etc.;
- The carbon reduction mandate—aspiring to carbon neutrality for each new building;
- EUI Targets per building typology;
- Building specific design strategies—envelope performance, lighting performance, controls, HVAC, water reduction;
- Recommended DES/CHP connection;
- Recommended purple pipe connection;
- Recommended renewable energy readiness;
- Include recommended biodiversity strategies; and
- Include recommended methodology for embodied carbon.

Example of Design Strategies for New Residences:

- Envelope performance—"near" Passive House or Passive House (for Phase 3)
- Efficient LED lighting + controls
- Plug load controls
- Ventilation heat recovery required
- Low flow fixtures / pressure valves
- Pilot purple pipe to determine viability and feasibility to connect to the re-use system
- Option: Sewage Heat Recovery for DHW or DHW Solar Hot Water preheat
- Option: CHP expansion connection with biomass system
- Solar PV ready
- Biogas for cooking (possible partnership)
- Biodiversity/Landscaping strategies
- Irrigation Requirements
- Waste separation and collection strategies

Example of Design Strategies for New Academic:

- Envelope performance—"near" Passive House or Passive House (for Phase 3)
- Efficient LED lighting + controls
- Plug load controls
- Ventilation heat recovery
- Low flow fixtures / pressure valves
- Pilot purple pipe to determine viability and feasibility to connect to the re-use system purple pipe ready
- Lab ACH control / Lab ventilation control
- HVAC efficiency
- Option: DES/CHP expansion connection
- Pilot Solar PV ready
- Biogas for cooking (commercial kitchen)
- Biodiversity/Landscaping strategies
- Irrigation Requirements
- Waste separation and collection strategies

As noted earlier, it is recommended that the UBCO *Design Guidelines* include a section on *Existing Building Guidelines* to provide performance requirements for building upgrades.

Embodied Carbon New Buildings

The UBC Climate Action plan currently includes a reference to tracking embodied energy associated with new construction, existing buildings and infrastructure. However, these emissions are currently not part of the carbon reduction targets of 33% (by 2015), 67% (by 2020) and 100% (by 2050) below 2007 emissions as per the UBC Climate Action plan. These thresholds include Scope 1 and Scope 2 emission reductions only.

The embodied energy content of building materials is covered under the Scope 3 definition in the GHG Protocol. While Scope 3 emissions is part of an organization's total carbon footprint, Scope 3 emissions are currently not required to be reported by GHGRTA. However, an organization can voluntarily monitor and report on these emissions and it is understood that UBC Point Grey is currently doing this in their process.

Appendix I summarizes background information and discuss some of the complexities inherent in calculating embodied carbon for buildings and defining a metric for the campus.

Framework for Embodied Carbon Reporting

It is recommended that UBCO develop a clear process as part of the University's Climate Action Plan and UBCO's *Design Guidelines* to evaluate and understand the embodied energy and carbon content of campus projects over time. This would apply to both upgrades of existing buildings as well as for new building projects. Development of an embodied carbon framework would help UBCO:

- understand the quantity of embodied energy/carbon in materials given the local context;
- evaluate, monitor and track the embodied energy/carbon content over time, similar to a building's operational energy;
- establish realistic targets and metrics for the University on per building basis or as a whole; and
- identify further reduction opportunities linked with having a broader understanding of the business case for reducing embodied carbon.

The following actions are recommended for UBCO:

1. **UBCO *Design Guidelines***

   Develop a requirement as part of UBCO's *Design Guidelines* to calculate the embodied energy content of the specified construction materials and clearly identify the boundaries for what is included and excluded.

   The type of material, volumes, material source location and construction techniques influence the total embodied carbon performance of a project. Evaluating the various building components as part of the design process is necessary to understand a building's total embodied carbon impact as a metric, typically for energy reported as MJ/m^2 and carbon as $kgCO_2/m^2$. Examples of carbon emissions for various commonly used materials in the Vancouver region, as example, are summarized in Appendix I.

2. **Specify a Clear Methodology**

   It is recommended that UBCO's *Design Guidelines* include a preferred embodied carbon calculation methodology for consistency.

   An embodied carbon analysis includes many assumptions over the project life-cycle and is highly location dependent. In addition, it is critical to clearly define the assessment boundaries; what is included and excluded over the life of the building. Fast recurring carbon, such as furniture, IT/computers, etc. can have a very large impact on the life cycle carbon, as compared to slow recurring carbon such as the building structure. For consistency in data, reporting, and tracking, it would be imperative for the University to decide on using a specific tool and methodology for comparability purposes.

There are a number of tools and life-cycle databanks available in the marketplace including the following:

- The Athena Sustainable Materials Institute's (ASMI) EcoCalculator, initially funded by Environment Canada, is the largest database with pre-defined construction assemblies for various regions in North America. This tool is also useful at determining a broader range of building materials effects (i.e., global warming potential, acidification potential, eutrophication potential, and smog potential).
- BEES (Building for Environmental and Economic Sustainability) software developed by the National Institute of Standards and Technology (NIST) is a life-cycle tool focussed on building products.
- National Renewable Energy Laboratory (NREL) US Life Cycle Inventory (LCI) Database provides individual gate-to-gate, cradle-to-gate and cradle-to-grave accounting of the energy and material flows into and out of the environment that are associated with producing a material, component, or assemblies in the U.S.
- Ecoinvent, is a Swiss-led, life cycle inventory database of primarily Europe based manufacturers.

Based on industry experience, the Athena (ASMI) calculator has the most developed database with pre-defined construction assemblies for Canadian climates and is fairly easy to use. This tool is useful for determining a range of LCA implications associated with construction material choices.

3. Recommend Best Practices

Within UBCO's *Design Guidelines*, it is recommended to embed recommendations on Best Practices, such as sourcing locally made products and materials; encourage the use of recycled material and products; consider how demolished existing structures can be used in new construction; and choose new construction materials that have a low carbon content.

4. Establish a Target

It is recommended that UBCO define a target for embodied energy (MJ/m^2) or carbon ($kgCO_2/m^2$) based on building area. Alternatively, over time as the embodied carbon is well understood for the UBCO campus, it could be possible to develop a percentage target for a building typology compared to the expected operational energy.

This would require research and tracking of data over time to establish realistic targets, but would be an interesting comparison to do as part of every new project during the design phase. The modeled carbon emissions due to operations could be compared to the embodied carbon emissions on a per m^2 basis to understand the real impact, and then followed up with operational data when the building is operating. This work has already started at the UBC Point Grey Campus and it is suggested that close collaboration and sharing of data is supported by both campuses.

5. **Establish the Financial Case**

   Currently, the embodied carbon of materials is not included in the Provincial Act reporting requirements for carbon emissions and offsets. While this might change in the future, the financial incentive when choosing assemblies, for example a low carbon wood structure as compared to a cast in place concrete structure, lay in other design implications other than embodied energy. Initiating research now and considering the recurring embodied carbon for a building will be important in understanding the full financial impact, particularly if Scope 3 emissions become a future component of the reporting mandate.

6. **Engage with Academic Research**

   Research on building cycle assessment and embodied carbon has already commenced at UBC and the City of Vancouver. It is recommended UBCO support further research that can inform and frame a UBC policy for embodied carbon.

Understanding embodied carbon of buildings is a complex, yet an important aspect of meeting long-term goals for carbon neutrality or net positive performance and yet there is a very small financial incentive for reducing the carbon impact of building materials. However, as noted in the research to date, there will be a shift in the future when embodied carbon and operational energy switch in terms of level of importance and impact. Green building rating systems such as LEED and the Living Building Challenge are beginning to integrate requirements for ascertaining the life cycle implications of buildings and requiring the offset the carbon emissions associated with the construction process. Given the transitions occurring in the marketplace, it is recommended that undertaking further research and establishing a framework as identified above to evaluate, monitor and track embodied energy/carbon over time should be integrated and considered part of the UBC's updated Climate Action Plan.

"To reach the long term campus carbon neutrality goal, alternative fuel sources need to be considered."

Campus Growth—Energy and GHG Projections

The following section summarizes the projected energy and carbon performance on campus including the existing buildings energy consumption (after upgrades) and new buildings projections with EUI targets up until 2030. The existing buildings and new efficient buildings are compared to a Business As Usual (BAU) case to show relative performance and quantify the performance metrics relative to the long-term performance goals.

BAU case definition

The BAU case includes the following assumptions in addition to the project assumptions outlined in Part 1–3 Context:

- Existing campus buildings: included and based on today's performance—no ECM upgrades (BAU existing buildings)
- New construction building: designed to meet next version of provincial energy code (NECB 2015)
- New construction heating load assumed to be met by mid-efficiency natural gas boilers
- Residences assumed to have PTACs, with electric baseboards for perimeter heating and natural gas to meet ventilation and DHW load
- No expansion of current DES system or connection
- No alternative fuel sources considered in the BAU case

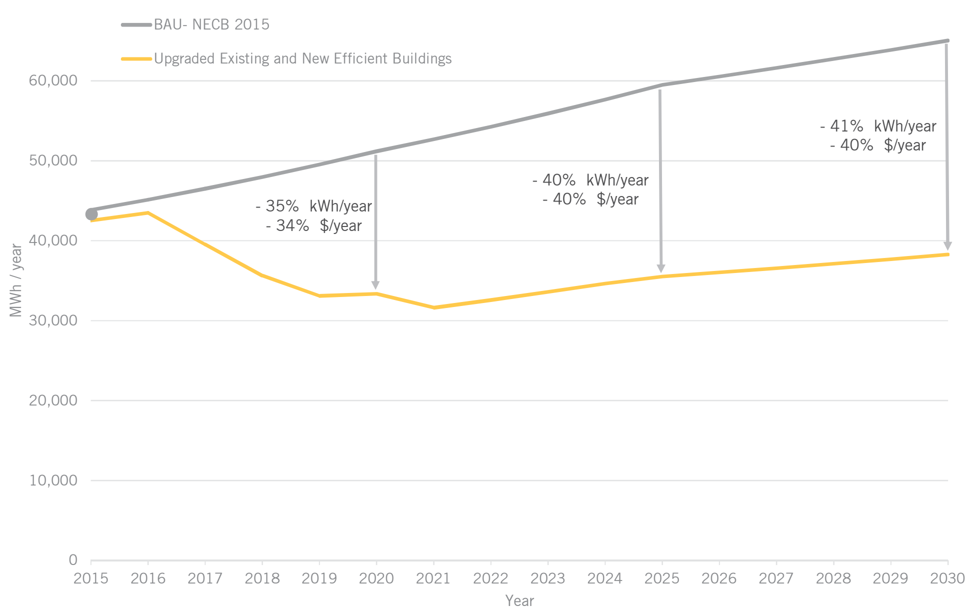

FIGURE 26: CAMPUS ENERGY CONSUMPTION WITH GROWTH—CONVENTIONAL FUEL SCENARIO

The current campus building program areas have been consolidated for each building and summarized in key space categories for the campus. It has been assumed and agreed with UBCO that this program ratio split is carried for the BAU and the new building projections as campus grows, as part of the assumptions for this infrastructure plan.

Campus Energy Consumption Projection with Growth

Figure 26 projects the energy consumption at UBCO over time. It is the combination of existing buildings with energy conservation measures implemented, and new buildings meeting the EUI targets as outline previously, compared to the BAU approach. Note that the energy cost savings shown in this graph are based on today's dollars. Escalation rates and inflation is taken into account in the life cycle costing analysis completed for each proposed measure.

Campus Carbon Emissions Projections with Growth

Figure 27 projects the carbon emissions at UBCO overtime. It is the combination of existing buildings with energy conservation measures implemented, and new buildings meeting the EUI targets as outlined previously compared to the BAU approach. Note that alternative energy sources have not yet been applied to the campus. From this projection, it is clear that meeting the carbon reduction targets as per UBC Climate Action Plan requires consideration of alternative fuel sources.

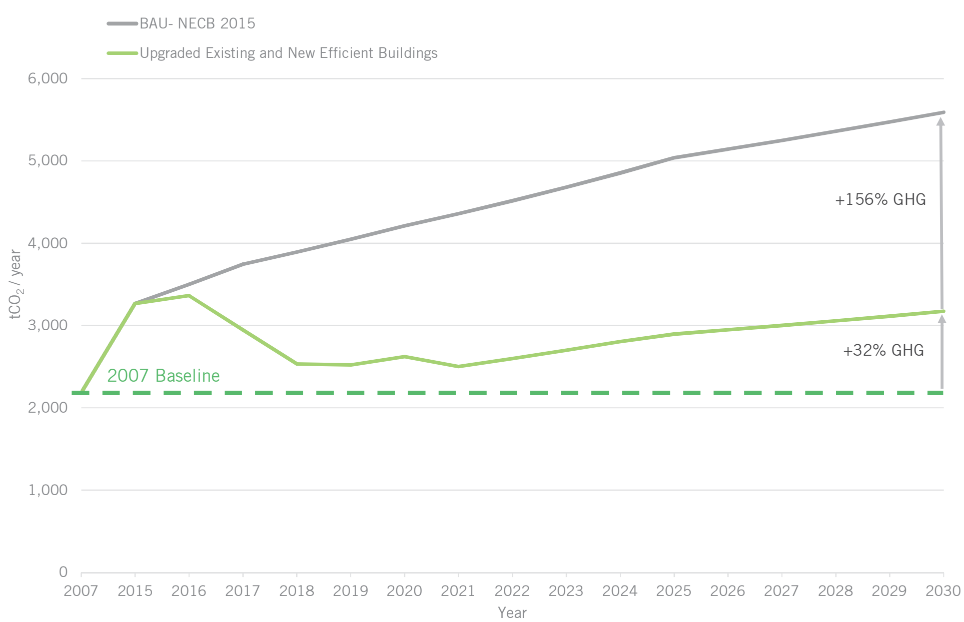

FIGURE 27: CAMPUS CARBON EMISSIONS WITH GROWTH—CONVENTIONAL FUEL SCENARIO

Achieving the Carbon Neutrality Targets

The projection of energy loads as campus grows is a positive one. If efficiency upgrades are implemented for existing buildings and new very efficient buildings are built, despite the campus doubling in building area by 2030, the projected energy consumption, as a campus total, is close to today's energy usage.

However, as per Figure 15, it is evident that to reach the long term campus carbon neutrality goal, alternative fuel sources compared to using conventional natural gas for heating needs to be considered to achieve carbon reductions over the 2007 baseline. Alternatives are summarized in following section.

4.7 CAMPUS SCALE SYSTEMS—MEASURES FOR IMPROVEMENT

Alternative Fuel Sources

The following strategies are discussed in the context of optimizing and expanding the University's infrastructure systems while also being in support of achieving a carbon neutrality goal by 2050:

1. Renewable Energy—Solar HW and Solar PV
2. Waste to Energy
3. Anaerobic Digestion
4. Landfill Gas (Kelowna Partnership)
5. Biomass

Renewable energy strategies have been considered as alternative fuel sources as part of the carbon neutrality and energy reduction goal.

Solar Hot Water Heating

Solar Hot Water Heating	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

Solar hot domestic water heating has been considered as a heating source for residences as an option to connecting to the CHP expansion with a biomass system. The analysis has assumed that all new residential roof areas could potentially be covered with 20% solar hot water heating system. Solar hot water heating is effective for residential buildings and food service buildings that operate in the summer as the solar energy available is greatest during the summer months.

Table 24 summarizes the potential performance outputs based on the assumed parameters for the new residences. Take-offs of new residential buildings roof areas were based on the master plan drawing available in March 2015.

TABLE 24: SOLAR HOT WATER ENERGY SAVINGS COMPARED TO BUSINESS AS USUAL

	CURRENT	PHASE 1 2015-2020	PHASE 2 2020-2025	PHASE 3 2025-2030	TOTAL
Array Roof Coverage* (m^2)	no new	264	916	580	**1,760**
Potential Energy (MWh/yr)	-	151	523	331	**1,006**
Installed Capacity (MW)	-	0.14	0.48	0.30	**0.95**
% of total Energy	-	0.3%	0.9%	0.5%	**1.5%**

This analysis shows that the solar hot water could potentially meet 25-50% of the yearly DHW demand. One issue with this is that during times of maximized output in the summertime, the residences are intermittently or not fully occupied and the domestic hot water load is less compared to other times of the year.

This summary compares the total energy performance to the BAU scenario:

- Offsetting: 180 tCO_2/yr by 2030 (3% of BAU)
- Offsetting: 1,000 MWh/yr by 2030 (1.5% of BAU)
- Offsetting: $34,000/yr by 2030 (0.9% of BAU today's $)

To summarize, while it is imperative to reduce the carbon emissions associated with residential domestic hot water and building heating, the impact of solar hot water heating is small and the payback is not favorable due to the low cost of natural gas. This can, however, be considered as an alternative should building-specific carbon reduction strategies be implemented rather than campus wide strategies (e.g., biomass CHP expansion), especially for those residential buildings that are in operation during summertime when the solar heat is most available.

Solar Photovoltaic Building Scale

Solar Photovoltaic Building Scale	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

Solar photovoltaic (PV) for power generation on a building scale basis has been considered as an option to generate electricity on campus. The analysis has assumed that all new academic roof areas could potentially be covered with 20% PV panels.

According to the National Renewable Energy Laboratory (NREL) several advances have been made in the solar industry and are expected to come to market in the next few years. New cells are more efficient, with a theoretical upper limit of 45% efficient for flat collectors and 30% for thin-film. As some of these technologies might not be "market" ready for building scale implementation, the following assumptions have been made that are somewhat conservative in light of the product development that is happening, but with the market and costing in mind.

UBCO Solar PV efficiencies assumptions:

- 2015-2020: 20% efficiency (based on today's most efficient monocrystalline panel on the market (SunPower type)
- 2020-2025: 25% efficiency (there are products available today as mentioned in above summary from research, but we feel this is more realistic at the non-high-end market)
- 2025-2030: 30% efficiency

The following PV cost assumptions were reviewed and agreed upon with UBCO, and are used to project the future cost reductions for PV. Forecasts were confirmed with Vancouver Renewable Energy (VREC), and the pricing forecast for solar PV used in the analysis are as following:

- 2015-2020: $3.9/W
- 2020-2025: $3/W
- 2025-2030: $2.5/W

Table 25 summarizes the potential performance outputs based on the assumed parameters. Take-offs of new academic building roof areas were based on the master plan drawing available in March 2015.

TABLE 25: SOLAR PHOTOVOLTAIC ENERGY SAVINGS COMPARED TO BUSINESS AS USUAL

	CURRENT	PHASE 1 2015-2020	PHASE 2 2020-2025	PHASE 3 2025-2030	TOTAL
Array Roof Coverage (m^2)	no new	2,331	1,452	1,644	**5,427**
Potential Energy (MWh/yr)	-	493	384	521	**1,398**
Installed Capacity (MW)	-	0.40	0.31	0.42	**1.13**
% of total Energy	-	1.0%	0.6%	0.8%	**2.1%**

The summary of total energy performance compared to the BAU scenario is as follows:

- Offsetting: 14 tCO_2/yr by 2030.............. (0.2% of BAU)
- Offsetting: 1,400 MWh/yr by 2030..... (2% of BAU)
- Offsetting: $107,000/yr by 2030.......... (2.8% of BAU, today's $)

While the imperative is to reduce the power demand and carbon emissions associated with building electrical consumption, the impact of solar PV is small with regards to reducing the total carbon footprint, yet larger on reducing energy cost. Increased efficiencies in the future, and assumed forecast of reduced PV costs will result in a more favorable payback compared to solar hot water panels. The recommended strategy is to make all new academic and residential buildings "PV ready". For Phase 2 or Phase 3 implementation when prices have dropped and panel efficiencies have increased, plugging buildings into generate power could be more financially viable. Note that potential incentives (provincial and/or federal) for PV power should be monitored as they could assist with lowering the financial paybacks.

Solar Photovoltaic Farm—Campus Scale

Solar Photovoltaic Farm—Campus Scale	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

The option of installing a larger scale solar PV system on campus was evaluated. Certain companies have demonstrated promising new flat plate technologies that use a lens plate to focus sunlight by factor of 500 yielding an extremely high efficiency of 32%. This technology has made advances in all-weather performance and in the module's temperature coefficient, improving performance in hot environments which is an important consideration for Kelowna's high summer temperatures. The following was assumed for this system:

- 5 acre (20,100 m2) farm
- 2.1 MW total capacity (with future efficiencies of 35% panels)
- Purchased in Phase 3
- Cost $2.5/W
- Generating: 3,404 MWh/yr (8% of efficient 2030 campus energy)
- Offsetting: 34 tCO_2 /yr (1% of efficient 2030 campus, no biomass)
- Offsetting: $260,000/yr (10% of efficient 2030 campus)

When determining an optimal location for a solar farm, consideration should be given to the following criteria:

- good solar access,
- land that has limited for other uses (e.g., prime farmland), and
- reasonable access to the power grid.

In regards to requirements for the grid: a grid tie inverter is a power inverter which converts DC current from solar systems to the commonly used AC current, and then synchronizes the AC to the utility power waveform so that it can be interfaced with utility power. By connecting this through a net meter, it is possible for power to flow from the solar farm to the utility system and for the solar farm owner to be credited for the excess power generated. The benefit of a grid tie system is that the solar farm can offset loads during solar hours without the need for a storage system (batteries). When not producing, the loads draw power from the utility as normal. FortisBC does not currently have a net metering policy or tariff to allow for this type of energy transaction but it is under consideration.

Giving declining costs and increasing efficiency of solar PV technologies, it is recommended that a large scale system be implemented as part of the 15 year plan for the UBCO Campus. Feasibility for this type and scale of system should be further evaluated in the five to ten year plan. Although, the carbon reduction is not significant, this system would be effective for demand-side management and result in large operational cost savings. It is possible that the grid in the future would allow for feed-in-tariffs that would reduce the payback significantly.

Waste to Energy

Waste to Energy	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

While waste from UBCO operations is not part of the scope for this project, some opportunities for energy use and emission reductions were reviewed.

Waste consumption and waste type breakdown was provided in the 2014 UBCO Waste Audit report. From this, and based on the projected student population growth, the waste volumes were projected up until 2030 (Table 26).

- 170 kg/FTE (2013/2014 info)
- Projected waste generation by 2030: 2,660 tonnes

TABLE 26: UBCO PROJECTED WASTE VOLUMES BY 2030

WASTE TYPE	PROJECTED BY 2030	
Organics (tonnes)	814	31%
Recyclables (tonnes)	952	36%
Remaining Solid Waste (tonnes)	804	30%

After sorting the waste stream into fractions including organic and food waste, reuse/recyclables, contaminated waste, and remaining solid waste, the opportunity for Waste to Energy was considered as it is done elsewhere in large-scale plants. For the UBCO context and size, a small packaged gasifier was reviewed as an option. Gasification to a Stirling engine generates electrical power.

Two options were considered, one including all recyclables and organics for higher energy output, and one only using the remaining solid waste. The overall energy and energy cost saving potential compared to the campus total projected energy load is very small, as summarized in Table 27. Another issue with waste to energy is the remaining solid waste often has a residual carbon emission rate in the range of 400 kg CO_{2e}/tonne of waste due to the presence of fossil fuel materials like plastic bags and other plastic materials. While energy could be generated, the carbon signature makes it not suitable for UBCO and its carbon neutrality goal, and therefore is not part of the final recommendations.

TABLE 27: SUMMARY OF WASTE TO ENERGY SAVING POTENTIAL BY 2030

POTENTIAL GENERATION 2030	2030 AMOUNT (TONNES)	ELECTRICAL ENERGY (MWH/YEAR)	% ENERGY BAU	% ENERGY $ BAU	% TCO_2 BAU
Waste including recyclables, excluding compostables	1,755	1,144	1.6%	2%	+4%
Waste excluding recyclables and compostables	804	524	0.7%	1%	+2%

Anaerobic Digestion

Waste to Energy	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

The organic and food waste from UBCO operations is suitable for treatment on-site so that both reuse/recycle and compostables could be removed from the waste stream going to the landfill.

A potential system might consist of:

- Packaged or other Anaerobic Digestion (AD) Plant that deals with the food waste and the appropriate organic waste. The AD would produce bio-methane that would be cleaned to eliminate materials like H2S that are hard on engines and then combusted in reciprocating engines to produce electricity and heat. The residual solid material then goes to composting.
- Composting of the remaining organic waste, the residual from the AD process and the bio-char from the biomass heating system could be used to produce enriched soil for use on the campus.

The potential for energy production using organic waste to generate power with a Sterling engine were looked at as one option. The potential electrical energy generation compared to campus total projected energy load by 2030 are estimated as follows:

- Generating:........ 395 MWh/yr.........(0.6% of BAU energy)
- Offsetting:.......... 4 tCO_2/yr................(0.06% of BAU, 0.5% with biomass)
- Saving: .... $30,000/yr ....(0.8% of BAU)

The energy production, energy cost and GHG savings with this size of system is small compared to the projected campus energy load, and has not been included

"Opportunity exists to build partnerships with the City of Kelowna and FortisBC to support the long term goals."

in the costing analysis as a strategy for achieving the Campus's carbon neutrality goal. However, it is recommended that a combination of anaerobic digestion and composting should be considered at UBCO as part of the long-term plan and could also be part of the Campus as a "Living Lab" education for students.

The implementation of the AD and composting process will also reduce the amount of waste going to the landfill where this waste will not be a producer of landfill gas. The operational metric of tonnes/FTE/yr to landfill would then be improved.

Landfill Gas (Kelowna Partnership)

Waste to Energy	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

The Glenmore Landfill is located right on the west side of Okanagan campus. There are 300 tonnes of garbage that currently arrives at the landfill every day, and this amount is increasing every year.

The Glenmore Landfill has been collecting landfill gas since 2005 and currently has a micro turbine for electricity generation. It is understood that the Landfill has signed a 15 year "Landfill Gas Purchase Agreement" with FortisBC. It is understood that FortisBC is to buy raw gas and finance, design, build and operate a conversion facility to upgrade the gas to pipeline natural gas quality.

An opportunity exists to investigate and build long-term partnerships with FortisBC and the City of Kelowna on green gas purchase to offset the residual natural gas consumption and support the long-term carbon neutrality goal. Capacity, green gas purchase cost and contractual agreements needs to be evaluated and it is recommended to initiate the exploration of this partnership as part of the 5-year implementation plan to understand the opportunities that could exist.

Green gas would be best used for cooking gas on the campus to provide a carbon neutral energy source. Due to the cost of the green gas (currently about twice the cost of natural gas), the use of the gas for campus heating is not recommended.

Biomass

Biomass and CHP expansion	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

After reviewing the potential carbon neutral energy sources available to UBCO, it was determined that waste wood biomass would be the best campus solution for heating. This section describes biomass as a fuel source and is followed by a recommended and phased approach in 4.8 Campus Scale Systems—District Energy Strategies which describes the different strategies of implementing a carbon neutral heating system as the campus grows over the next 15 years.

Biomass as Fuel Source

Waste wood biomass is a carbon neutral heating energy fuel that is proposed to provide heating energy at UBCO. The waste wood biomass could be sourced from:

- Industrial waste wood from the primary wood product producers in the region,
- Waste wood from the various manufacturing operations such as furniture manufacturing or millwork,
- Clean waste wood from the urban waste stream, and
- Waste wood from clearing or fall down in the region's forests.

Each of these potential waste wood sources should be investigated. The preferred sourcing may consist of a blend of sources that suits seasonal availability. The following analysis is based on combusting the waste wood in a heating boiler. The results from gasification and the heat recovery boiler would be similar but the potential number of heating units to suit the varying load profile and growth of the heating plant make gasification systems impractical.

The energy available from waste wood relies on a couple of key factors:

- The type of waste wood available from hardwoods through soft woods. For this analysis wood chips will be considered as they are the most common type of wood with primary wood product producers, and are available locally.
- The moisture content of the waste wood. Waste wood is usually sold in "bone dry tonnes" while the moisture content of wood varies from about 10% moisture for dried products like wood pellets to 55% for the green wood of a freshly felled tree (see Table 28).

TABLE 28: PROPERTIES OF LOCAL WOOD SOURCES

WOOD SOURCE	ENERGY CONTENT (BTU/LB)	MOISTURE CONTENT (%)	DENSITY TRANSPORT (LB/FT^3)
Wood Pellets	7,937	5	40.5
Forest Wood Chips, dry	5,416	30	14.6
Forest Wood Chips, wet	4,247	50	19.3

Combusting wood with high moisture content requires that a good amount of the moisture in the wood be evaporated before effective combustion of the wood is completed (e.g., an example of this is putting a moist log on a campfire. The log will steam and spit for a while before settling into a burn).

Various boilers are capable of handling a range of moisture content wood fuels. However, once the boiler controls are set up, the type of fuel, the moisture content and the density of the fuel should be reasonably consistent. This is due to the significant volume of biomass fuel that is transferred into the boiler to meet the heating load. Often screw type conveyors are used to feed fuel into the boiler. Once set up, the boiler controls may use something like an additional three revolutions per minute for a given fuel source and temperature offset of boiler supply water temperature. Should a significantly dryer fuel be provided, the boiler controls would feed too much fuel into the boiler and the temperature control system would not work well at all. The boiler controls can be adjusted seasonally to accommodate different seasonal moisture content in the fuel.

The process of combustion of waste wood produces moisture in the flue gas. The moisture content in the flue gas consists of the product of combustion and the excess moisture content evaporated from the source wood. Usually all of the moisture in the flue gas is discharged into the atmosphere. Later in this section, the opportunities to recover heat from the flue gas moisture content will be discussed.

Fuel Sources and Cost of Biomass

Some potential waste wood sources and their cost range in the region have been reviewed with a summary of the research shown in Table 29. Note that transportation costs of biomass varies depending on moisture content. Transport costs for 15% wood chips have been estimated to $0.89/GJ in previous studies completed by UBCO (Stantec Consulting) and have been included as part of the biomass cost in this analysis.

TABLE 29: COST EXAMPLES OF LOCAL WOOD SOURCES

WOOD SOURCE	COST PER GJ OF FUEL	COMMENT	AVAILABILITY EXAMPLE
Wood Pellets	$7-9 /GJ + transport	Range depending on moisture content	Pinnacle Pellet in Armstrong, Virdis Energy's Pellet Mill in West Kelowna, Eagle Valley Pellet in Princeton
Forest Wood Chips, dry to wet	$3-$6/GJ + transport	Example from Enerby plant is $3.5/GJ 5-50%	Adams Lake Tolko, Lavington, Adams Lake
Forest Wood Chips, wet	$4-6/GJ + transport	Depends on moisture content	

In summary, Table 28 and Table 29 show that Wood Pellets that have the highest heat content, the lowest moisture content and the smallest fuel storage volume but are also the most expensive per GJ heat output.

The higher moisture content fuels are the least expensive per GJ heat output, but require significantly more storage volume and trucking cost might be 10-15% higher. The $/GJ is based on normal boiler output with the wet fuel. The proposed flue-gas condensation will boost the heat into the DES system increasing the amount of usable heat from the biomass and reducing the $/GJ for energy delivered.

Boiler Emissions

The combustion of waste wood in a boiler can produce a high particulate level in the flue gas that may be in the 1,000 ppm range. This can be seen with the blue smoke coming off campfires. This level of pollutants in emissions is not acceptable to meet regional regulations and prevent air pollution. Various types of filters can be used to reduce the particulate level include bag filters, cyclone filters and electrostatic filters. Various types of filters can be used but often include electrostatic filters to get down to the 10 to 20 ppm particulate levels for good air quality. The proposed boiler arrangement would use electrostatic precipitators for the best air quality. While 20 ppm is often used in industry, this installation should aim toward the 10 ppm particulate level for best performance. Reduced particulate levels would be best for a flue gas condensing section for high overall boiler efficiency.

Waste Products from the Boilers

The combustion process for wood produces ash that is removed from the base of each boiler. This ash is called bio-char and can be fed into the campus composting system to provide additional nutrients to the compost produced.

There is also flue gas dust collected by the filters and electrostatic precipitators. Flue gas dust could hold contaminants such as mercury, so the flue gas dust collected should be disposed of in an appropriate landfill.

Boiler Flue Gas Condensing

The lumber industry has been a key industry in British Columbia. Waste wood from lumber processing has long been considered an unusable by-product and has been disposed of by burning in beehive burners.

Waste wood has since evolved into a heating source but as the waste wood volume was significant, investments in high efficiency wood boiler systems were not an issue. Now there is competition for the waste wood as an energy resource so there is more incentive for high efficiency heating with waste wood.

Boilers typically keep the flue gas temperature high enough to avoid any condensation in the boiler that would corrode many boiler components and lead to boiler failures. There are opportunities to use the conventional waste wood boilers and condense the flue gas in a separate component after the flue gas particulate has been removed.

Figure 28 shows a number of conventional biomass boilers with a common flue gas collector, flue gas filter, and common flue gas stack. The flue gas condensing component would have a flue gas fan that feeds the flue gas into the condenser. The installation would be similar to the Sofame installations in the steam boiler plants at UBC Point Grey and the Central Heating Plant in downtown Vancouver (Figure 29).

The efficiency of the condenser depends on the temperature of the heating system using the recovered heat. At UBCO, the DES system in winter is proposed to operate in the 16°C supply water temperature range. This low temperature heating source could lead to a very high overall boiler heating efficiency probably over 95%. Should a lower cost biomass fuel (i.e., 35% moisture content) be used with such a flue gas condensing system, the cost of the heat produced for the DES would drop from $5/GJ to $4/GJ.

The use of the flue gas waste heat for DES heating is appropriate in the winter. The potential use of this waste heat in the summer for heating low temperature sources such as significant domestic hot water heating should be investigated.

Biomass flue gas condensing systems are not common in North America. The Clean Energy Research Centre at UBC Point Grey is reported to be working with a flue gas condensing system. Opportunities to obtain outside research funding for the flue gas condensing system should be pursued.

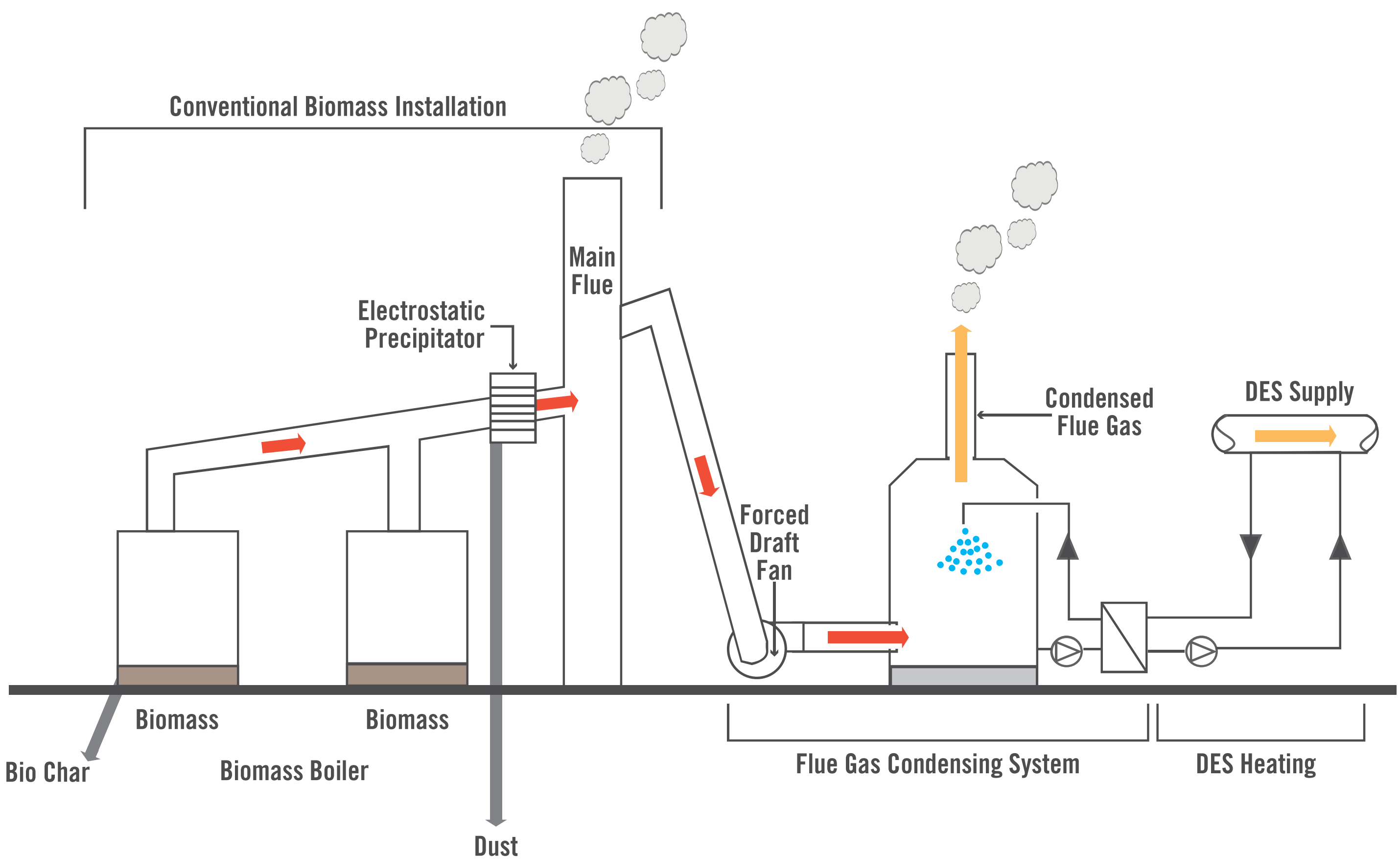

FIGURE 28: FLUE GAS CONDENSING HEAT RECOVERY WITH BIOMASS PLANT

FIGURE 29: FLUE GAS HEAT RECOVERY AT THE CENTRAL HEATING PLANT IN DOWNTOWN VANCOUVER

Boiler Operator Requirements

Initial reviews with the provincial boiler inspector indicate that a separate boiler plant such as the proposed biomass plant can be considered independently of the existing CHP as the boilers do not connect to the same "boiler header" but are connected through the campus CHP piping system. One additional operator would be required for the biomass plant so long as it remains under the 500 m^2 of boiler surface area. Full development of a biomass system may require locating some final biomass boilers in an alternate location to prevent exceeding the boiler surface area restrictions and triggering additional operator requirements.

Table 30 summarizes considerations for a biomass boiler heating system.

TABLE 30: SUMMARY OF CONSIDERATIONS FOR A BIOMASS BOILER HEATING SYSTEM

KEY COMPONENTS	CONSIDERATIONS
Fuel Handling	Delivery and location for storage. The new boiler plant is proposed to be located near the GEO building for good access by trucks.
Fuel Availability	Pellets: Pinnacle Pellet in Armstrong, Virdis Energy's Pellet Mill in West Kelowna, Eagle Valley Pellet in Princeton. Woodchips: Tolko, Lavington, Adams Lake
Storage	Fuel storage on site for at least three of days to meet peak heating loads. Designed carefully to keep the fuel dry.
Transportation	Locally ~32 tonnes/truck, fuel holding space above ground. Example: 1.25 MW running 24/7 requires a truck load refill every five days.
Emissions	Particulates needs to be controlled, but modern systems are low on emissions, < 200 ppm CO 90 mg/m^3 without secondary treatment, can get < 18 mg/m3 with treatment systems.
Maintenance	Ash removal (every 3 weeks—3 months ~15 min). Cleaning and inspection every quarter (~2 hrs).
Operations	One additional operator would be required for the biomass plant so long as it remains under the 500 m^2 of boiler surface area.
Boiler Modules	Multiple boiler modules are recommended to allow effective tracking of the heating load and maintenance of one unit while others are operational.

Biomass Heating Capacity

To get a sense of the required biomass heating capacity with the CHP expansion options studied, Table 31 summarizes a conceptual level analysis of heating loads. Four biomass heating options were looked at:

1. Add capacity with DES HP and expand CHP to serve existing Academic and New Construction;
2. Expand CHP to include existing Academic and Residential, and New Construction;
3. Expand CHP but do not increase capacity of DES, serve existing Academic and New Construction; and
4. Add CHP heat to DES system (compressor boost), serve existing Academic and New Construction.

Options 1 and 2 were determined to be most feasible and included as part of the overall costing analysis. The capital cost estimates in Appendix E also provide cost estimates for option 2 with biomass costs attributed to Phase 2.

TABLE 31: SUMMARY OF HEATING LOAD ESTIMATES FOR CHP EXPANSION OPTIONS

OPTION		PHASE 1 2015-2020	PHASE 2 2020-2025	PHASE 3 2025-2030	TOTAL CAPACITY INSTALL
1. DES HP for DES Boost + CHP with Biomass	MW Heating		6.4	8.1	
	boiler plant	Existing back up boilers	2 x 2.5 MW	2 x 1.0 MW	7 MW
	% of load		78%	87%	
2. Biomass CHP with DES + Existing Residences	MW Heating		13.5	15.0	
	boiler plant	Existing backup boilers	2 x 4.5 MW	1 x 3 MW	12 MW
	% of load		67%	80%	
3. CHP (with Biomass) without Residences	MW Heating		11.4	13.1	
	boiler plant	Existing backup boiler	3 x 2.5 MW	1 x 2.5 MW	10 MW
	% of load		66%	76%	
4. CHP (with Biomass) + DES	MW Heating		9.2	10.9	
	boiler plant	Existing backup boiler	2 x 3 MW	1 x 2.5 MW	8.5 MW
	% of load		65%	78%	

Following discussions with UBCO (April 2016), the options for biomass heating capacity were consolidated to a 6MW and 12MW option. The 6MW biomass heating system is the preferred option as it would maximize boiler heating surface area without triggering full-time boiler supervision. A 12MW biomass system would maximize GHG reductions and enable UBCO to consider future off-site partnerships as a method of reaching carbon neutrality. However, the 6MW system will still provide a large percentage of total campus heating energy as Figure 30 indicates.

Section 4.8 Campus Scale Systems—District Energy Strategies describes the various configurations available to implement a biomass system.

Power Distribution System

Expected load growth on campus is about 1.1 MVA over the next 5 years so the existing distribution system can support the five year load but without full supply redundancy.

The 15 year plan is for the campus building area to double, but business as usual (BAU) load growth which would result in a doubling of the load is not anticipated. Energy conservation measures and technology improvements will result in lower than historical load growth. The FortisBC distribution network will be able to supply campus electrical energy requirements for the 15 year period.

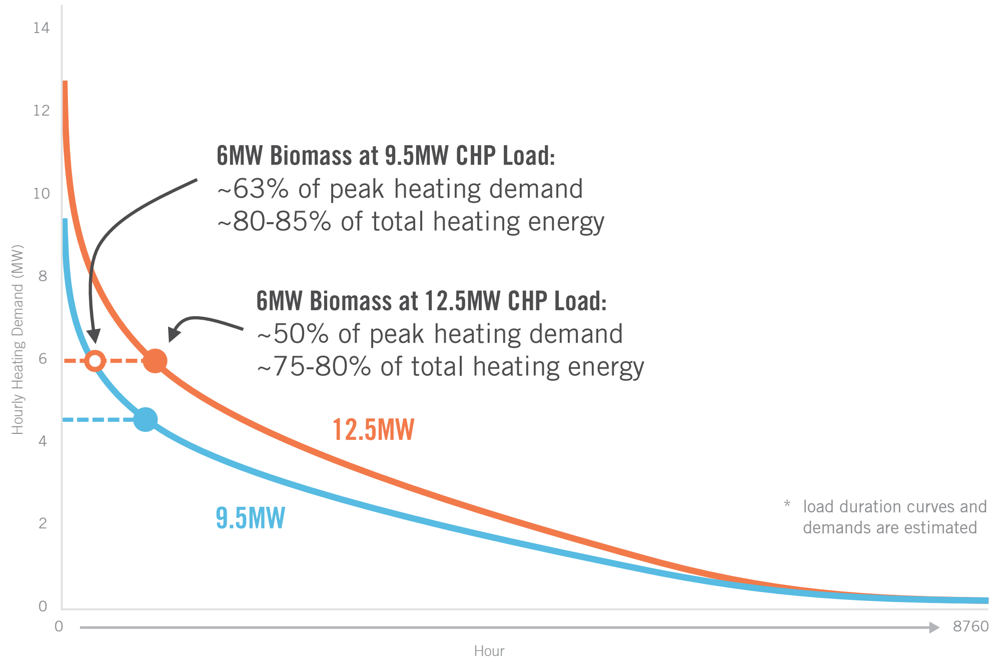

FIGURE 30: SAMPLE LOAD DURATION CURVE

FortisBC can provide up to 20 MVA on a feeder but a 12-14 MVA is preferred as a limit. This means that for the 2050 build out, the campus might need dedicated express feeders from each substation or its own substation fed off the 138 kV transmission line, which currently connects Ellison and Sexsmith. Based on the analysis, it seems that a transmission substation will not be needed in the 15 year plan, there is sufficient electrical capacity through 2030, and most likely will not be needed until at least 2050. In the long-term UBCO may need to become a transmission customer supplied by the 138 kV system that runs parallel to the highway. Land (1/3 Hectare) should be allocated for this in future master plan updates, if and when it becomes necessary. Cost of the sub-station construction and maintenance would be UBCO's responsibility.

Grid Demand Side Management

The peak demand for the Academic campus is a summer air conditioning peak. Residential peak is winter heating. The rate structure provides for a minimum of 75% of the peak demand to be charged every month, therefore reducing the summer peak can produce significant savings. As noted earlier, it is probable that UBCO is paying an excess amount for electrical demand due to the minimum demand ratchet clause for both academic and residential buildings. There is certainly an opportunity to reduce the demand charges.

Because UBC pays for energy and power demand at the bulk distribution rate, large scale demand management could be implemented by integrating the electrical metering with the Building Automation Systems (BAS) and reducing the large electrical loads through the ECM measures discussed previously.

Future "Smart Grid" technologies may also help with the peak demand reduction strategies. Smart Grid is technology in which the electrical grid uses advanced communications and information technology to gather and process data from energy suppliers and consumers to reduce energy demand and consumption, while improving reliability of the system. While this technology is not new, it is still in its infancy in B.C. In the near future everything from HVAC equipment to refrigerators may be available with a Smart Grid interface which will allow the device to vary its energy use based on real time data on the instantaneous cost of that energy. This will help to offset high peak demand charges which currently can only be controlled by implementing complicated peak demand reduction algorithms and hardware. Procurement and operational policies will need to take advantage of Smart Grid technology as it becomes more prevalent. Utilization equipment such as appliances, office equipment and HVAC controllers with Smart Grid technology enabled, may eventually communicate with the power grid to prioritize usage so that peak demand is minimized. A power factor for the two electrical energy and power meters is quite good so minimal savings are available from power factor correction programs, but power factor correction should continue to be implemented as needed at each new building to maintain the high power factor.

A central solar PV "farm" is under consideration for future development, as outlined in the "Renewable Energy—Solar HW and Solar PV" section. FortisBC does not currently have a net metering policy or tariff to allow for this type of energy transaction, although it is under consideration.

Evaluation Criteria for Campus Scale Alternative Fuel Measures

Based on the four evaluation criteria established for the project, a number of the renewable alternative fuel source measures studied are highly supportive of:

1. Contributing to meeting the following whole systems infrastructure study goals by 2050;
2. Minimizing life cycle costs;
3. Being relatively easy to implement and maintain; and,
4. Contributing to the long-term adaptability and resiliency of the campus.

A summary of the evaluation is presented in Figure 31: Evaluation of Alternative Fuel Source Measures.

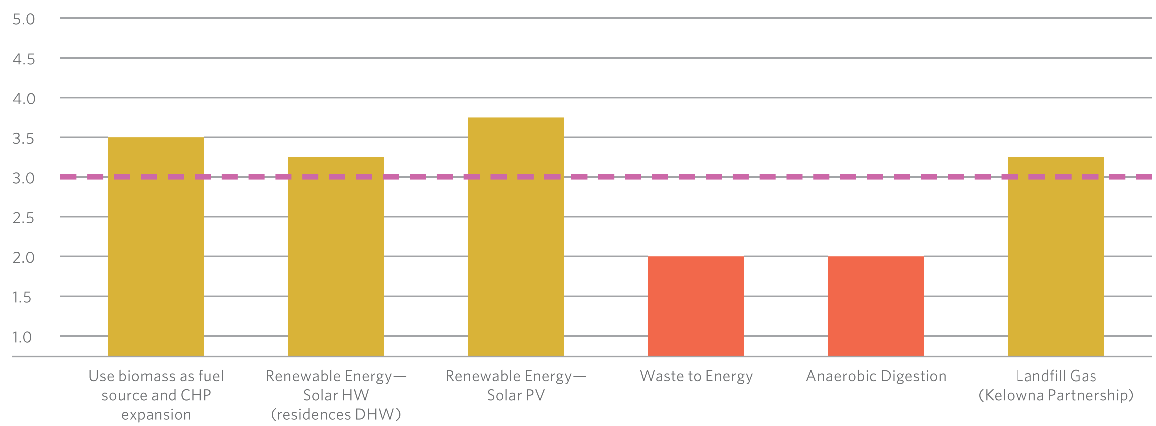

FIGURE 31: EVALUATION OF ALTERNATIVE FUEL SOURCE MEASURES

The use of biomass as a heating source, renewable solar HW and solar PV were evaluated and met the criteria. Investigation into off-site partnerships for green gas is also recommended as a long-term carbon neutrality opportunity. It should be noted that the solar HW option for residences scores well despite the long payback. This measure is not recommended as a priority if the residences are connected to the CHP biomass system as a carbon neutral source for DHW heating. However, this measure could be a good candidate for the residences that are highly occupied in the summer months should they not be connected to the biomass CHP system.

> *"The DES system operation can be improved to expand operation as heat rejection, heat transfer, and heating system."*

4.8 CAMPUS SCALE SYSTEMS—DISTRICT ENERGY STRATEGIES

UBCO recognizes that a district energy system is key to enabling future reductions in GHG emissions from campus operations. In the face of increasing activity and scrutiny, federally and internationally, on the issues of climate change, it is imperative that a campus strategy is selected that ensures future energy demands are met while subsequently addressing the trend to reach carbon-neutrality. The current central heating plant (CHP) and district energy system (DES) are functional, but do not prevent the increasing environmental costs associated with their natural gas GHG emissions. Substantial GHG emissions can be eliminated as the result of optimizations to current building operations, but most significantly a conversion to a carbon-neutral heating fuel source like biomass.

The following sections describe recommendations for improving the existing district energy systems and presents different configurations for future campus expansion.

Improving DES Operation

The following approach is proposed to improve and expand the operation of the DES in all modes.

Heat rejection system for summer air conditioning

The existing and expanded campus buildings have a need for summer time heat rejection. While many of the recommended ECMs and design guidelines for new building construction work to reduce the cooling loads, cooling will be a significant component of summer building operations.

The following options are proposed to increase the capacity of heat rejection in the DES to serve the campus Academic Buildings:

1. Close the DES loop on the West side of the campus to provide increased flow capacity and flexibility to serve new buildings.
2. Add a second DES supply/return pair of pipes from the GEO Building to the DES loop to increase the flow rate capacity to about 7,500 gpm.
3. Add closed circuit coolers or cooling tower/heat exchangers to the GEO building to provide heat rejection to meet the 7,500 gpm proposed DES flow rate.
4. For additional heat rejection as the campus grows, additional closed circuit coolers or cooling towers/heat exchangers can be added to the DES loop at appropriate locations so the 7,500 gpm flow rate would not be a capacity limitation.
5. All of the closed circuit coolers or cooling towers should be provided with reclaimed water to eliminate the need for potable water for these units as discussed in other sections.
6. As existing air cooled chillers need replacement, water cooled chillers connected to the DES should be considered as the electrical power for the chiller operation is much lower with water cooled equipment for reduced electrical energy use.

See Figure 32 on the conceptual plan of closing the DES loop and piping connection to DES.

Following additional discussions with UBCO (April 2016), a draft of the District Energy System Cooling Capacity Upgrade Report 5 April 2016 by Smith + Anderson Falcon was shared and a discussion on the report was requested. The report presented four options to deal with rejecting heat from the DES:

- Option 1: Provide a Third Fluid Cooler to the DES Cooling Source
- Option 2: Provide a New Heat Pump to the DES Connected to the Ground Source

- Option 3: Provide a New Heat Pump to the DES Connected to the Fluid Coolers in the DES Plant
- Option 4: Reconfigure Fipke Primary Energy Systems

Based on a review of these options, the following observations are made.

Option 1 suggests adding a third fluid cooler; however, the cost of this option appears to be higher than one would expect. Previous suggestions made in the Whole Systems study of adding a cooling tower with a heat exchanger would be more economical and only require approximately a third of the space.

Option 4 suggests raising the DES loop temperature to increase the efficiency of the cooling and heating sources. Raising the temperature would require significant additional electrical energy. This would be energy intensive and increase operating costs. The phrasing in the report suggests that entire loop temperature will be raised. If that is correct, there would be severe repercussions on the HDPE piping if there are no expansion provisions (such as bellows). This could lead to serious expansion and thermal stresses, and would require further expansion compensation analysis.

Neither of the options investigated touch on the importance of reducing the amount of cooling load going into the DES. The ECMs presented in Section 4.5 Existing Buildings – Measures for Improvement are recommended for implementation prior to adding any additional cooling capacity.

Heat transfer system between building heat pumps in cool weather

The DES/aquifer system operates most efficiently in cool weather by transferring heat from building cooling systems to other building heating systems to provide the lowest cost, heating source with very low GHG emissions. This operation should be further developed with existing building upgrades and new buildings. The following list of building systems require cooling year round and would be suitable for acting as a winter heating source for the DES to avoid purchasing additional heating energy sources:

1. Server, data and other equipment rooms with a data centre (e.g., the library).
2. Building electrical transformers that reject a couple of percent of the electrical energy to the building.
3. Interior building cooling with systems like fan coils or chilled beams that have a cooling need in the winter.

Heating source for building heat pumps in the winter

The purpose of adding heat to the DES is to allow the existing and new building heat pumps to operate consistently and efficiently in the winter without concerns about low temperature trip outs and freezing of heating source lines. A review of the shop drawings for some of the existing building heat pumps show planned source heating water temperatures in the 5°C to 10°C range. As discussed in the aquifer heat exchanger section, these temperatures are not readily available from the DES after the building separation heat exchangers.

The existing Academic buildings currently connected to the DES have a peak heating load in the range of 6.4 MW. If heated by the heat pumps at a COP of 3, this would require 4.2 MW of DES source heat with the rest coming from the compressor heat. The two boilers installed in the GEO building have a combined output of about 2 MW so additional heat is required.

To enable operation of the building heat pumps for winter heating, additional heat must be provided to the DES loop. 16°C has been chosen as an example of the temperature range proposed. Detailed studies of the building heat exchanger performance and the operating characteristics of the various heat pumps on campus are recommended to select an ideal temperature range. The DES heating supply temperature does not have a significant effect on the heating source performance over a reasonable temperature range.

A number of low temperature (16°C) heating source options have been considered for the DES (refer to Table 14 for a basic summary of the energy operating cost and the emission rate for various heating sources available for the campus):

1. Add capacity with a large ground source heat pump (GSHP with 2 acres field assumed). With a COP-5, this would generate approximately 1.2 MW of heat on the DES side.
2. Add capacity with a large heat pump located in the GEO Building that would extract heat from the aquifer (5°C cooled to 2°C) to provide the low temperature heat and produce about 2.8 MW of heat that would be a significant contribution to the existing DES loop capacity.
3. Add capacity with a large heat pump that would extract heat from the sewage main leaving the campus. Considering about 1/3 of the daily sewage flow and a 5.5°C sewage temperature difference, only 0.1 MW of heat would be produced. This is not enough to meet demand.
4. Add heat from the biomass CHP system that would provide carbon neutral heat to the DES through heat exchangers.
5. Add heat from the biomass boiler flue gas condensation that would provide the 16°C low temperature heat while significantly improving the overall combustion efficiency of the boiler plants.
6. Existing gas-fired boilers would provide peak heating load capacity and backup.

Options 1–3 are not recommended for further investigation. Option #2 does not provide the full amount of heat required by the DES and additional heat (i.e., CHP heat) would be required. Operating Option #2 with a leaving water temperature of just 2°C provides a very slim margin of error and a real risk of freezing and damaging the heat pump should any unexpected operating conditions occur. To reduce the risk of freezing, the addition of glycol or a similar antifreeze to the loop was suggested. However, this would result in a reduction in heat transfer capability and an increase in heat pump energy. This reduction in heat transfer ultimately leads to a lower capacity and is not recommended. These recommendations would result in the aquifer loop no longer being used during heating season. Lastly, Option #3 would not be sufficient to meet campus demand.

It is recommended that Options #4, #5 and #6 be pursued for final consideration and are investigated in further detail for this analysis. Option #4 provides carbon neutral heat; and Option #6 provides backup and peak heat capability. Option #5 is the best solution as the required capacity is available with campus build out and a waste energy heating source is being used with no additional fuel cost. With these proposed DES system improvements in place, it is recommended that each of the existing and new academic buildings be provided with DES connections as appropriate.

Figure 32 shows an example of how the connection could work for the various options to boost the DES system. Alternatively, use heat from the biomass flue gas as per option #5.

UBCO has indicated a desire to correct the DES system operations and to prove out the operational characteristics. While the expansion of the CHP heating water system might be extended to provide connections to the new buildings being constructed in Phase 2, the installation of the biomass heating system would be moved to a Phase 2 installation. The existing backup boilers in the CHP would provide the required additional heating energy.

The operational verification of the DES would include:

- Installation of a heat exchanger in the GEO Building to heat the DES water flow from the CHP heating plant. This verification cycle could occur with the CHP piping extension as part of the biomass plant being installed early to allow the testing of various existing building heat pump operations. Should the CHP piping connection to the GEO or new Biomass Building be delayed to coincide with the Biomass system installation, a CHP/DES heat exchanger could be installed in the Science Building. The existing boilers in the GEO building would also provide heat to the DES loop.
- Addition of a new cooling tower/plate heat exchanger at the GEO Building would provide additional peak load and backup heat rejection capacity to serve the existing cooling loads as well as the cooling loads from the new buildings to be constructed.

The goal of these improvements for heating is to provide a warmer DES supply temperature to the buildings of about 16°C so that the building heat pumps can operate in a stable manner to heat the buildings. With gas fired boiler heat going into the DES during the testing period, there would be some reduction in GHG emissions from the existing operations as about 2/3 of the building heating would be coming from gas with about 1/3 coming from cleaner electricity with the compressor energy. When the flue gas recovered heat is used, there would be no GHG emissions from the heating energy provided to the DES.

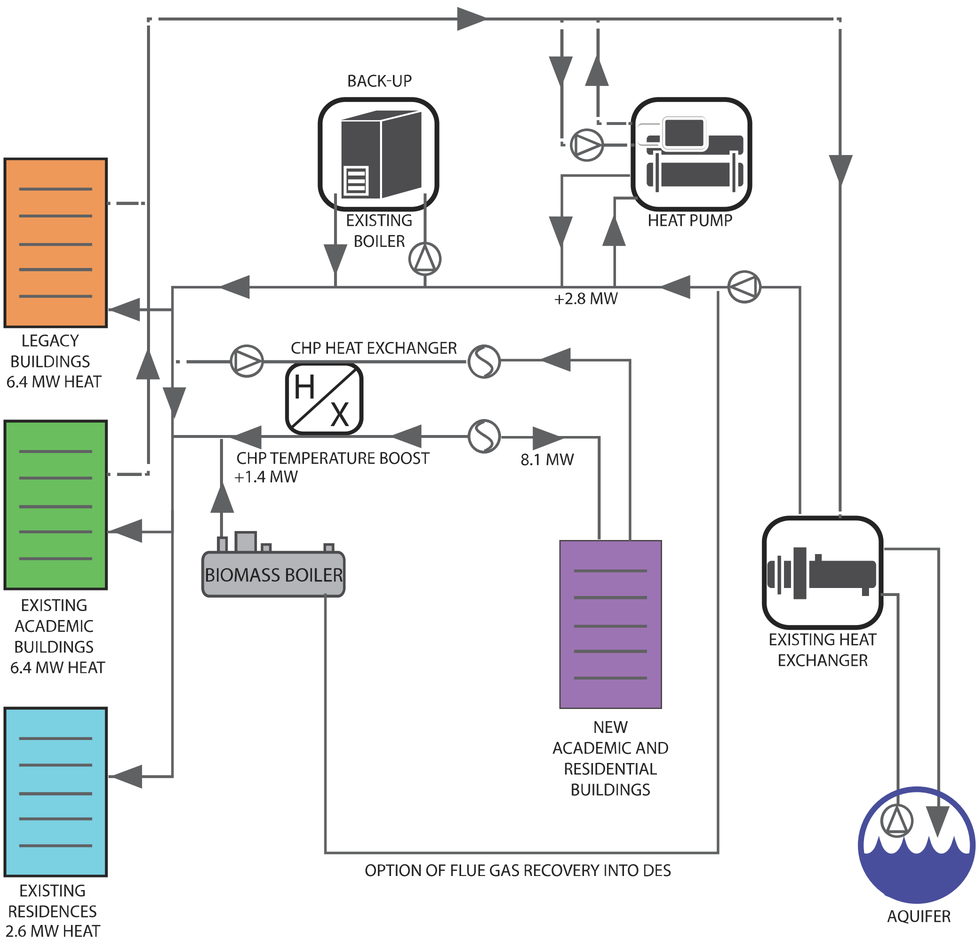

FIGURE 32: CONCEPT OF ADDING DES HEAT/CAPACITY (OPTIONS) AND CONNECTING EXISTING BUILDINGS TO CHP

Recommended Approach for CHP Expansion

In initial discussions with UBCO, it was decided that the *Whole Systems Infrastructure Plan* consider the expansion of the CHP system using the existing peaking boilers for additional heat and defer the installation of a potential biomass heating system to Phase 2.

Following the presentation of this recommended approach, two additional district energy configurations were requested for consideration by UBCO (April 2016) and are denoted as Configuration B & C in subsequent sections.

The configuration of district scale infrastructure for the approach recommended in the main body of this report is indicated as Configuration A.

Outlined below is our recommended approach for upgrading UBCO's energy systems to a carbon neutral heating system over the next 15 years in five-year phases. This phased approach is reflected in the capital cost and life cycle cost analysis. Refer to Summary of Carbon Reduction Scenarios and Section 4.11 Costing Analysis for further analysis of the greenhouse gas saving potential and economic analysis.

Phase 1: 2015 to 2020

Phase 1 includes the construction of a number of new campus buildings (Figure 33). The CHP piping network expansion includes service connections to the new buildings and some upgrades to sections of the existing CHP piping network to accommodate the increased heating water flows.

The existing gas fired boilers in the CHP boiler room, starting with the condensing boilers and following with the Bryan standby boilers, would provide the peaking and backup campus heating capacity. As the implementation phase of the recommended Energy Conservation Measures is being delayed somewhat, it is recommended that UBCO confirm sufficient heating capacity to heat Phase 1.

Connections to the existing residential buildings along the new CHP piping route are indicated. These connections could be done in Phase 1 or later in Phase 2 when the biomass plant energy is available.

It is anticipated that the residential buildings will continue to use electric heat for perimeter heating with local air-cooled air conditioning. Heat pump air conditioning models should be considered as the electrical heating energy used would be reduced. CHP heating for residential buildings would deal with domestic hot water heating and ventilation air heating. The CHP connection to the existing residential buildings can occur when there are major building upgrades or as the new CHP piping passes by the buildings.

Phase 2: 2020 to 2025

Phase 2 includes a number of new academic and residential buildings and the CHP expansion to serve them (Figure 34). Distribution piping to the new residential buildings will also connect to the existing residential buildings as the piping goes past them. A multi-boiler biomass system would be developed near the GEO Building as there is good access for the large biomass delivery trucks. With the installation of the biomass boilers, heat exchangers for heating the DES with both CHP heat (initial testing and backup) and the flue gas condensation system would be provided.

The size of the biomass heating plant would nominally meet the peak heating requirements for the new buildings and a good portion of the existing buildings connected to the CHP for about 50% to 60% of the connected peak load. The