4 ENERGY+CARBON

Goal

Achieve a net positive performance in operational energy and carbon.

The consultant team undertook an extensive review of UBCO's technical information and data related to buildings, energy systems, utilities, and campus infrastructure to support the analysis undertaken in the category of the energy and carbon goal. Information provided by UBCO includes, but is not limited to, UBCO's updated Campus Plan, applicable campus plans, campus policies, utility data, commissioning reports, energy audit data, carbon emissions reporting, O&M manuals, drawings of existing buildings, studies completed by UBCO relative to performance, DES system operation, VFA Ltd.'s Asset Funding Needs Report, and occupant and behavior change reports.

This chapter summarizes the existing conditions related to campus energy performance, opportunities to meet the long term energy and carbon goals, and identifies recommendations for improvements.

4.1 THE OPPORTUNITY

In 2010, UBC established a long-term vision and framework for attaining carbon neutral operations by 2050. The *Whole Systems Infrastructure Plan* outlines an approach for achieving carbon neutrality for UBC Okanagan Campus assuming the doubling of campus building area and population by 2030. Through implementation of a multi-pronged approach, UBCO could realize the following milestone targets:

- by 2020 achieve 32% energy use reduction and 33% carbon reduction as compared to BAU;
- by 2025 achieve 38% energy use reduction and 73% carbon reduction as compared to BAU; and
- by 2030 achieve 40% energy use reduction and 79% carbon reduction as compared to BAU (46% carbon reduction compared to the 2007 baseline).

The subsequent chapter presents the suggested measures and analysis undertaken to define the metrics for the energy and carbon goal, and implementation of them.

Approach to Achieving Carbon Neutrality

The *Whole Systems Infrastructure Plan* recommends the following framework for achieving an optimized campus system and the long-term campus energy and carbon goals:

1. Form a campus energy management team to implement the *Infrastructure Plan* recommendations;
2. Create a revolving fund to finance ongoing energy improvements. This fund could be established from savings gained from the implementation of electrical and demand-side savings measures;
3. Establish baseline utility model in order to track savings;

4. Develop a campus-wide Behaviour Change and Engagement Strategy to promote and support campus awareness for resource conservation and DSM strategies required for whole systems plan implementation;
5. Develop and implement existing buildings energy conservation measures to achieve 5 year plan targets, reduce energy consumption of district energy systems, and make capacity available for future growth;
6. Update campus *Design Guidelines*, *Technical Guidelines*, and *LEED v4 Implementation Guide* with guidance for energy performance of new construction and energy efficient systems;
7. Expand CHP and DES piping systems as the campus constructs new academic and residential buildings;
8. Phase in fuel switch to carbon neutral sources to serve academic and residential buildings;
9. Plan for and pilot the integration of renewable energy technologies (i.e. solar PV) as the business case becomes more viable; and
10. Consider off-site partnerships to reach carbon neutrality by 2050.

Section Outline

This chapter contains the following sections in regards to the campus energy infrastructure:

- **Campus Energy and Carbon Performance:** includes Campus energy, Greenhouse gas (GHG) and energy cost performance as well as existing buildings' energy performance.
- **Existing Infrastructure:** includes an outline of the existing DES system, CHP system, power distribution and natural gas pipeline on campus.
- **Assessment of Existing Buildings:** includes findings on the various typologies of the campus existing buildings, their system performance issues and identification of opportunities for upgrades.
- **Existing Buildings—Measures for Improvement:** outlines of suggested energy conservation measures, performance saving potential, and recommended implementation for existing buildings.
- **New Construction—Measures for Improvement:** proposes EUI targets for the new buildings and a high level outline of strategies and projected energy load for the new buildings based on the EUI target.
- **Campus Growth—Energy and GHG Projection:** summarizes the projected energy and GHG emissions for campus as it grows, without consideration of alternative fuel sources.
- **Campus Scale Systems—Measures for Improvement:** outline of alternative fuel sources to achieve carbon neutrality.

- **Campus Scale Systems—District Energy Strategies:** outline for improvements to current district energy systems, alternative configurations for district scale infrastructure, and the recommended approach.
- **Carbon Reduction Scenarios:** summarizes six scenarios and their relative carbon and life cycle cost performance. This section includes additional steps recommended to achieve carbon neutrality by 2050.
- **Implementation Plan:** outlines an implementation plan for realizing the energy and carbon reduction opportunities.

4.2 SUMMARY OF EXISTING CONDITIONS

Campus Energy, GHG and Energy Cost Performance

Performance data of the existing campus was provided, analyzed and summarized. The energy and carbon data and fuel split (gas vs electricity) are based on utility data for January 2013 to January 2014, and are used as a baseline. The campus 2007 carbon emissions are outlined, and serve as a baseline as part of the UBC Climate Action Plan. As noted in section 3, the campus has experienced significant growth since 2007, making the baseline lower when compared to current campus operations. This makes meeting the long-term carbon targets using this as the baseline more challenging. Table 10 summarizes UBCO's energy and carbon performance data for 2013.

TABLE 10: UBCO 2013 PERFORMANCE METRICS

METRIC	AMOUNT	COMMENT
Campus EUI	334 kWh/m^2	Average EUI on campus Academic + Residences
Campus Energy Consumption[1]	45.6 GWh	Gas 35%, Electricity 65%
Campus Energy Cost	$2.7 million	Gas 20%, Electricity 80%
Campus Carbon Emissions[2]	3,317 tCO_2/yr	Gas 96%, Electricity 4%
Campus 2007 Baseline	2,186 tCO_2/yr	

[1] 2013 utility data for baseline

[2] Buildings 2013 were 3,201 tCO_2/yr with emissions factors: Natural Gas 180 tCO_2/GWh and Electricity 10 tCO_2/GWh.

Energy and carbon cost rates

Based on the utility information, electricity accounts for 65% of the overall campus energy consumption and 80% of the overall energy cost per year; while natural gas accounts for as much as 96% of the campus carbon emissions. The challenge facing UBCO is that the cheaper natural gas fuel has high emissions, and the more expensive electricity has low emissions. Table 11 summarizes the energy and carbon cost rates for UBCO.

TABLE 11: UBCO ENERGY + CARBON COST RATES

FUEL	ISSUE	UTILITY COSTS[2]	CARBON EMISSIONS
Electricity[1]	High cost / low emission rate	0.079$/kWh North Feeder 0.074$/kWh South Feeder	10 tCO_2/GWh[1]
Natural Gas	Low cost / high emission rate	0.028 $/kWh (7.91 $/GJ)	180 tCO_2/GWh
Carbon Tax	Added to fossil fuel purchase	$30/$tCO_2$	n/a
Carbon Offsets	Cost each year for UBCO	$25/$tCO_2$	n/a

[1] BC Ministry of the Environment. 2014. B.C. Best Practices Methodology For Quantifying Greenhouse Gas Emissions Including Guidance for Public Sector Organizations, Local Governments and Community Emissions. Ministry of Environment, Victoria B.C., November 2014.

[2] Based on 2013 utility information.

"Campus building heating by natural gas must be reduced to achieve significant greenhouse gas emission reductions."

Figure 15 presents the fuel fix mix, cost and greenhouse gas emissions profile for the UBCO campus. This fuel mix is important to understand how it will influence and drive decisions based on the *Whole Systems Infrastructure Plan* objectives. Tackling the more expensive electricity energy to achieve cost savings can be used to finance measures that support large carbon reductions and is a recommended strategy presented in this infrastructure plan.

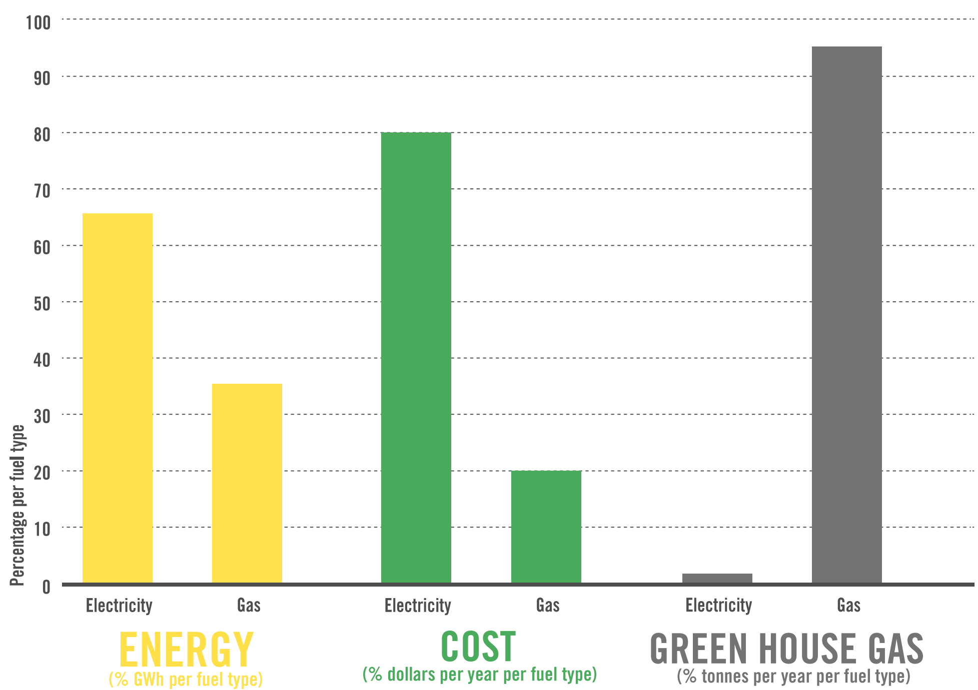

FIGURE 15: 2013 FUEL CONSUMPTION, COST, AND GREENHOUSE GAS EMISSIONS

Campus Carbon Emissions

The Province of British Columbia's *Green House Gas Reduction Target Act (GHGRTA)* required that all public sector organizations (PSO's), and BC Government facilities, be carbon neutral in their operations as of 2010. Organizations must show this by implementing greenhouse gas reduction measures, report an emissions inventory and then purchase offsets for any remaining emissions to achieve net zero carbon emissions. The GHG Protocol categorizes these direct and indirect emissions into three broad scopes:

- **Scope 1: All direct GHG emissions.** Example of Scope 1 emissions are combustion of fuels to produce heat, cooling, and/or electricity within buildings owned by the reporting organization.
- **Scope 2: Indirect GHG Emissions.** Example of Scope 2 emissions are emissions released by energy suppliers in the combustion of fuels to produce heat, cooling and/or electricity for purchase by the reporting organization.
- **Scope 3: Other indirect emissions.** Example of Scope 3 emissions are the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity, electricity-related activities not covered in Scope 2 (distribution & transmission), outsourced activities, waste disposal, etc.[1]

While Scope 3 emissions are 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.

The UBC Climate Action Plan currently includes mention of Scope 3 emissions for new construction, existing buildings and infrastructure. However, these emissions are currently not part of the UBC 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.

For UBCO the Scope 1 and Scope 2 emissions are categorized and include building emissions from electricity use and building heating, transportation (campus fleet only), paper and supplies and fugitive emissions, summarized in Figure 16.

1 World Resources Institute. Greenhouse Gas Emissions Protocol Revised Edition. http://www.wri.org/publication/greenhouse-gas-protocol [June 2015]

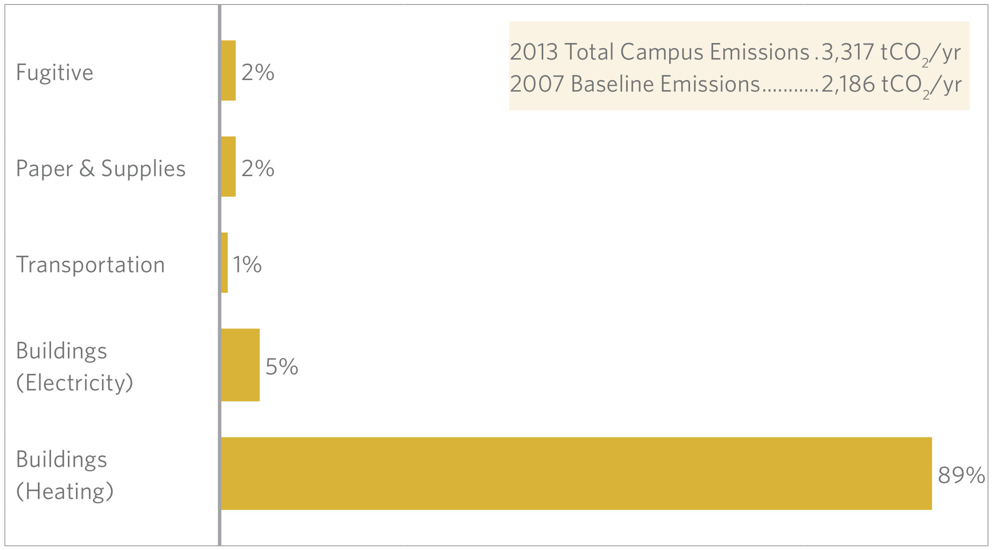

FIGURE 16: UBCO CAMPUS CARBON EMISSIONS, BASED ON CNAR 2012 DATA

Campus buildings are responsible for 94% to 96% (94% is reported 2013 and 96% is reported 2007) of overall campus emissions per year, and of that, building heating by natural gas is the key end-use that must be reduced to achieve significant greenhouse gas emission reductions. This study focuses only on the campus building emissions.

The cost of carbon includes the carbon tax which is currently \$30/tCO_2 as part of the cost of fossil fuel purchase, as well as the carbon offset costs \$25/tCO_2 that the University needs to pay in order to meet the requirements of the GHGRTA for public sector organizations. Looking forward, the University should expect to see an increase in the Provincial carbon tax as the government updates its Climate Action Plan.

UBCO pays the following costs for carbon based on year 2013 reported data:

- Carbon tax 2013...........................$86,246
- Carbon offsets 2013...................$90,725
- Total cost of carbon 2013..........$176,971

Carbon emissions savings over time are important when considering a fuel switch as offsetting emissions saves operational cost and form part of the cost-benefit analysis.

Campus Existing Building Energy Performance

The existing campus building stock have been evaluated to understand the building typologies, the HVAC system types, and the energy performance. This analysis revealed that some of the newer buildings on campus like the Reichwald

Health Sciences Centre, the Engineering Management Education building and the University Centre are among the highest energy consumers on campus.

The system types and connections to the campus wide infrastructure varies for the existing buildings, but generally can be categorized as follows:

- **6 Academic "Legacy" Buildings:** District Energy System (DES) + Central Heating Plant (CHP)[2]
- **5 Academic "New" Buildings:** District Energy System (DES) + Water Source Heat Pumps + Backup boilers
- **18 Residential Buildings**: Packaged Terminal Air Conditioning Units (PTAC's) with Make-Up Air Units (MAU), Groundsource Heat Pump (Purcell), all electric Heat Pump (Cascades)

A more detailed discussion of the buildings and their HVAC performance are included in Section 4.4 Assessment of Existing Buildings.

The Table 12 summarizes the consolidated energy and energy cost performance per key building typology based on the 2013 data set. One key challenge with the data was consistency in reporting from a number of utility sources. The data used in the below figures are based on the most consistent set of data provided for the year of 2013.[3] Note that some of the smaller buildings and some exterior lighting is not included in these totals. Also, since 2013 the campus has undergone an optimization program for the legacy buildings which has realized some savings that are not included in these totals.

TABLE 12: UBCO 2013 ENERGY USE FOR EXISTING BUILDINGS PER TYPOLOGY

EXISTING BUILDING TYPOLOGY	AREA M^2	GAS CONSUMPTION GJ	GAS CONSUMPTION KWH	% OF TOTAL	ELECTRICITY KWH	% OF TOTAL
Academic Legacy (on CHP)	34,697	24,318	6,755,001	41%	6,397,251	25%
Academic Legacy separate boiler	4,797	2,379	660,833	4%	747,713	3%
Academic New Buildings	43,302	16,175	4,493,056	28%	12,786,864	50%
Residential	49,899	8,741	2,428,056	15%	4,530,243	18%
Service GEO	454	6,863	1,906,389	12%	900,821	4%
TOTAL	**133,149**	**58,476**	**16,243,335**	**100%**	**25,362,892**	**100%**

2 One of the Legacy buildings are on stand alone boiler
3 Natural Gas consumption is extracted from "FY13 of Utility Expenses by Type and Account" excel file provided on 20141216. Electricity consumption is extracted for the same time period (January 2013–January 2014) from the "Building Consumption 2013 of the UBC-Okanagan Electrical Energy Sustainability Co-op Study."

Figure 17 summarizes the energy utilization intensity (EUI) of existing academic and residential buildings on campus, split per fuel source.

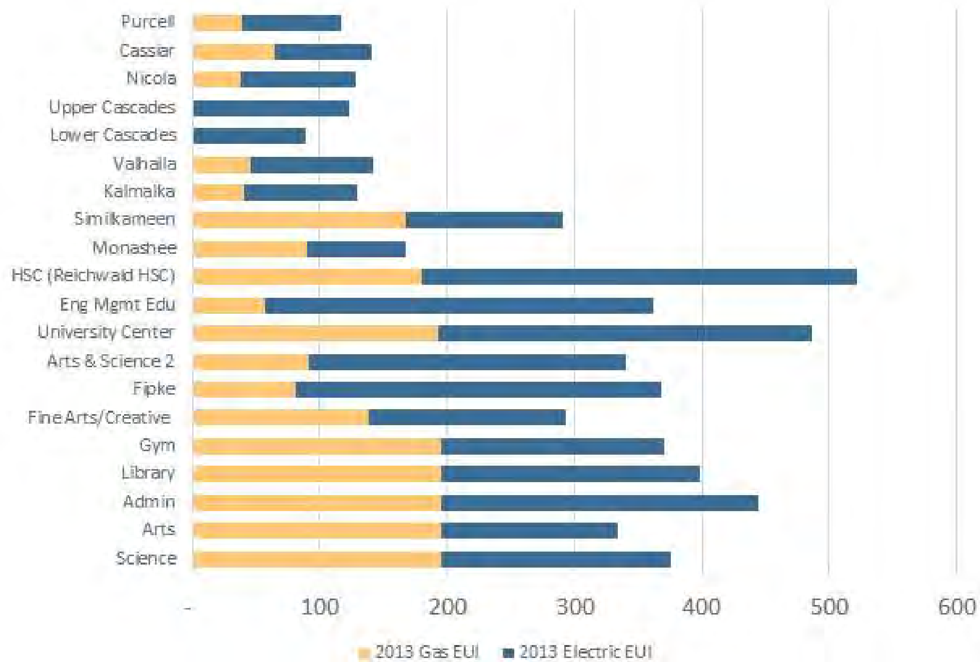

FIGURE 17: 2013 EUI SUMMARY FOR UBCO EXISTING BUILDINGS

Residences

The average EUI for the residences is 147 kWh/m^2. The natural gas consumption is attributed to ventilation air heating in make-up air units (MAU) and domestic hot water (DHW) consumption. Perimeter heating is generally electric resistance heating or heat pumps. Two of the buildings, Upper and Lower Cascades are all electric including MAU and DHW heating. Two of the residences, Similkameen and Monashee are part of the older campus building stock from 1992 and shows a much higher EUI compared to the other buildings. It was confirmed by UBCO staff that no envelope upgrades have been completed since construction of any of the campus buildings, and both Similkameen and Monashee are in need of upgrades. Purcell is the most efficient building and one of the newer residences built in 2010 with a horizontal ground source heat pump (GSHP) system and solar hot water for domestic hot water (DHW) preheat.

Academic Legacy Buildings

The average EUI of the academic legacy buildings is 369 kWh/m^2. These buildings were connected to the DES system in Phase 2 of the DES evolution, but also have stand-alone, air-cooled chillers for summertime operation. They are supplied by heat from the CHP plant. Natural gas consumption in the EUI has been prorated for these buildings based on the energy meter in the CHP plant hence, include the efficiencies of the plant and distribution. Separate metering of the heat from CHP to these buildings would further help identify the natural gas EUI and reduce building EUIs by some 20-25% for heating.

Most of the legacy buildings have been part of the FortisBC "Building Optimization Program," completed in June 2015 which has resulted in energy reductions, as such, the EUI numbers reported from 2015 might be lower compared to this 2013 data set used in this study.

Table 13 summarizes the projected savings from completing this program.[4] The projected operational costs savings are in the range of $150,000 per year, and indicate the potential for investing in upgrades in existing buildings.

TABLE 13: UBCO BUILDING OPTIMIZATION PROGRAM SAVINGS

BUILDING	KWH SAVINGS	GJ SAVINGS	$ SAVINGS	PAYBACK EXCL. SES	COST EXCL. SES	SES COST	TOTAL COST
Arts	72,000	580	$12,000	2.0	$23,575	$8,600	$32,174
CCS	182,800	450	$12,500	1.1	$14,316	$7,781	$22,097
Library	86,100	38	$4,491	1.8	$8,274	$3,140	$11,414
Admin	(43,300)	840	$9,860	1.7	$16,963	$7,371	$24,334
Science	26,400	2,130	$30,460	1.4	$42,281	$7,410	$49,691
TOTAL	**324,000**	**4,038**	**$69,311**	**1.5**	**$105,409**	**$44,800**	**$150,209**

Academic New Buildings

The average EUI of the new academic buildings is 415 kWh/m^2. These buildings could be expected to perform better as they are built between 2008 to 2011 with newer technologies and some of them are LEED Gold certified buildings. These buildings are connected to the DES system with building-side water source-heat-pumps for heating and cooling and each have standalone boilers. There are some issues with the heat-pump performance and the DES connection as described in the "Existing District Energy System (DES)" section, and as such these buildings require change-over to the gas boiler heating during high demands. Some of these buildings have lab exhausts, of which some have heat recovery, but not all. Each building was deliberately built with a different HVAC distribution system. They are also high electricity users, and it has been found in reviewing the power demand curves, as per Figure 25, that high electricity use in the academic buildings is also occurring during unoccupied times, when this is not required.

It is identified that large saving opportunities exists to reduce energy, energy cost and greenhouse gas emissions by reviewing the current operation of the existing academic buildings on campus.

4 SES Consulting. 2015. Summary of Project Results to date for the Fortis Building Optimization Program. June 15 2015

"Large saving opportunities exist to reduce energy, energy cost, and greenhouse gas emissions by optimizing the campus' existing building operations."

4.3 EXISTING CAMPUS INFRASTRUCTURE

Existing District Energy System (DES)

The existing infrastructure includes an internal campus District Energy System (DES) that operates as an ambient loop system and serves most of the academic buildings but not the residential buildings. This system started out as an open loop aquifer system that has evolved into a closed loop system over the years through three phases of major development and upgrades. Refer to historic information on the evolution of the DES in Appendix G.

The DES max flow observed during the peak of summer was 4200 but the CTQ modelling shows the existing configuration still has capacity. For current campus distribution and building connections, see Figure 18. Key components of this system include:

- Aquifer wells that provide up to 3,000 gpm (189 l/s) of aquifer water at about 10°C year round;
- Groundwater recharge wells and infiltration basins;
- Three aquifer to DES shell and tube heat exchangers;
- Distribution pumps variable speed;
- 400mm supply/return pipes from GEO building that branch in North and South piping forks;
- Two gas fired boilers to raise the DES temperature in winter (1,114 kW and 973 kW output);
- Two closed circuit coolers at about 400 tons heat rejection each;
- Connections to building heat pumps through plate heat exchangers; and
- Energy meters on building heat exchangers.

Use of the groundwater portion of this system has been studied extensively as it is limited in both its capacity and its operating temperatures. The aquifer is regulated by The Ministry of Environment and is currently limited to 3,000 gpm (189 L/s) maximum extraction. The aquifer water is drawn up to the GEO Building by well pumps and put through a bank of three shell and tube heat exchangers. The aquifer water is returned to the ground through a recharge field and injection well. Shell and tube heat exchangers are used to allow cleaning but they do not have a good approach (difference between entering aquifer temperature and leaving DES water temperature).

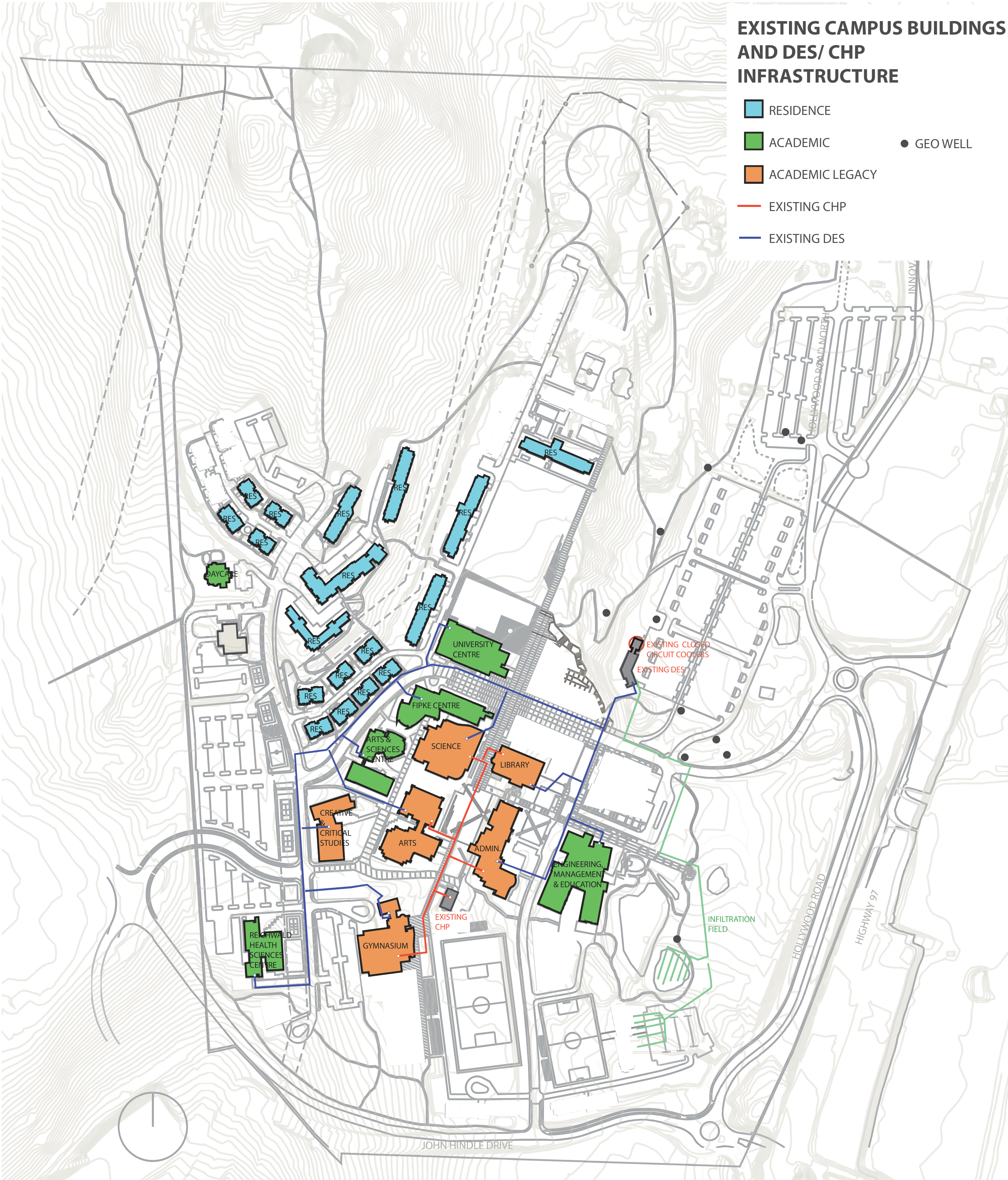

FIGURE 18: EXISTING CAMPUS CHP AND DES DISTRIBUTION SYSTEM

The DES/Aquifer system has the following operating modes:

1. **Summer heat rejection loop:** In summer, the DES/aquifer system is used to reject heat from the campus building heat pumps. There are two closed circuit coolers that provide additional heat rejection and it is understood that these are at full capacity with no redundancy.
2. **Intermediate heat transfer between buildings:** In intermediate weather, the DES can accept heat rejection from some buildings and provide a heating source for other buildings.
3. **Cool weather heat source loop:** In winter, it was hoped that the DES would act as a heat source for the heat pumps in the buildings but many buildings cannot use the DES when outdoor temperatures approach freezing. The DES is currently not effective at heating below freezing. There are gas fired boilers in the GEO Building that add heat to the DES system.

From discussions with UBCO Facilities and Maintenance staff and from a review of operations reports pertaining to the DES and aquifer, there are three main issues to consider for the DES and are discussed below:

1. Aquifer and DES Heat Transfer Capability;
2. Cool Weather Heat Transfer Between Buildings; and
3. Winter Heating.

DES to building plate heat exchangers in two recent buildings operate at 1.1° approach, significantly lower than the aquifer heat exchangers.

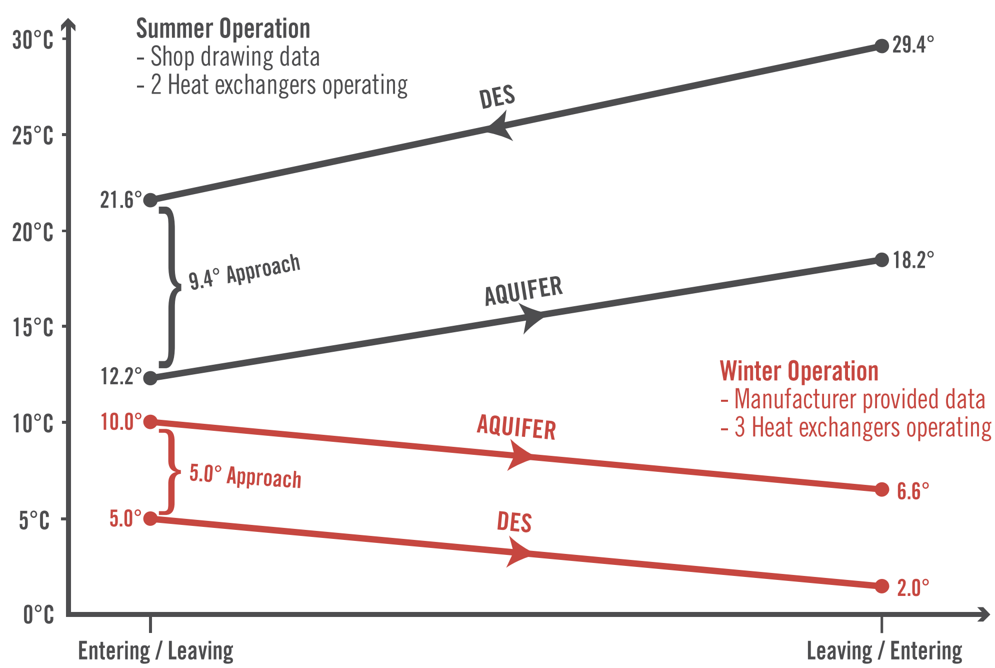

FIGURE 19: AQUIFER TO DES SHELL AND TUBE HEAT EXCHANGERS

Aquifer and DES Heat Transfer Capability

The DES transfers heat between building heat pump systems in cool weather works quite efficiently, but there are limited heat rejection sources for winter operation.

In cooler weather, the two gas boilers in the GEO Building and excess heat rejected from buildings provide heating to the DES. Heat pumps in the buildings then transfer this heat to a higher temperature to heat the building. As the winter weather reaches freezing, the DES cannot supply enough heat causing the legacy academic buildings to shift over to the CHP while the new academic buildings continue to extract heat but supplement it with on-site boilers. The existing three shell and tube heat exchangers are cleanable, a necessity due to the challenging aquifer water quality. Shell and tube heat exchangers by design do not allow for a small approach which significantly limits their capabilities and performance.

Interestingly, the maximum shell side (DES) flow rate per heat exchanger is about 1,200 gpm so if the DES flow rate ever goes above 3,600 gpm, it will not all fit through the heat exchangers. The DES flow rate through these heat exchangers is currently limited to 80% of the aquifer flow rate by the operators. Any remaining DES water flow bypasses the heat exchangers. Key observations on the performance of these heat exchangers are as follows:

1. The 9.4°C approach during the summer operation is very high. Operating three heat exchangers instead of two will improve the capacity of heat rejected but the approach would not necessarily change if the flow rates increased (see Figure 19).
2. A winter performance review with the heat exchanger manufacturer, Armstrong, indicated the winter approach is smaller at 5°C, but this significantly reduces the heat available from the aquifer for the building heat pumps.
3. The DES flow rate is a maximum of 4,200 gpm now and may be increased to 7,500 gpm with new feed lines to/from the GEO Building to the DES piping system.

Cool Weather Heat Transfer Between Buildings

In cool weather, the DES does a good job of accepting heat rejection from some buildings and providing a heating source to other buildings. This operation provides some of the most efficient building heating with very low GHG emissions. A potential source of heat rejection from existing and new academic buildings should consider the DES for heat rejection/heating.

Winter Heating

With the three heat exchangers operating in parallel, the 10°C aquifer water temperature would result in a DES winter supply water temperature of only 5°C, that is too cold for significant heat extraction by the building heat pumps. So the aquifer is not an effective heat source in the winter. As there are separation heat exchangers between the DES and the building loop for the heat pumps, appropriate temperatures for the building heat pumps could not be achieved.

The existing buildings with heat pumps connected to the DES shut down operations with the DES for heating when the ambient temperature approaches freezing as the DES does not provide an appropriate heating source, and need to use the building backup boilers (new academic buildings) or CHP heating (legacy buildings). In addition, the DES boilers need to operate to add heat to the DES loop.

Alternative Options

A number of alternative options for campus heating were identified and considered at an early stage of this study. Some initial metrics of the various energy costs and emission rates of the heating sources were developed to understand the feasibility of each source, summarized in Table 14. This basic data on fuel costs and emissions quickly points toward those options with a combination of low energy costs and emissions. In light of the long term carbon target and also from an operational cost perspective, the options highlighted are deemed most appropriate.

TABLE 14: OPTIONS FOR 1 MWH OF HEAT FROM VARIOUS SOURCES (PUMP POWER NOT INCLUDED)

HEATING SOURCE	$/1 MWH OUT	GHG KG	COMMENT
Electric Resistance Heat	$73.5	10	
Condensing Gas Boiler	$42.6	200	
Biomass Boiler	**$26.8**	**0**	
Building Heat Pump (HP) / Waste Heat	**$26.3**	**3.6**	Similar to GSHP
Building HP + Condensing Boiler	$53.6	132	Boiler heats loop and HP transfers to Building
Building HP + Biomass Boiler	**$43.5**	**3.6**	Boiler heats loop and HP transfers to Building
Building HP + Large Aquifer HP	**$38.1**	**5.8**	Large HP extracts heat from Aquifer to distribute to hydronic HPs
Building HP + Biomass Flue Gas	**$26.3**	**3.6**	

Based on this preliminary evaluation, the options with low GHG and low costs were considered feasible options, including looking at improving the DES with increased temperature from aquifer heat pump, sewage heat recovery or adding heat from the CHP with biomass as fuel source, alternatively, switch the CHP to biomass boiler for best carbon reduction potential. These options and recommendations are discussed in greater detail in Section 4.7 Campus Scale Systems—Measures for Improvement.

Existing Central Heating Plant (CHP) System

The academic core of the campus, referred to as Academic Legacy Buildings, is served by an older Central Heating Plant (CHP) system. For current campus distribution and building connections, see Figure 15 (refer to loop layout existing campus).

This system supplies hot water to the legacy buildings (with DES) heat exchangers to meet peak wintertime heating loads. The CHP plant consists of:

- three newer condensing boilers installed in 2013: two at 3,300 MBTU/h and 1 at 1,800 MBTU/h.
- two older mid-efficiency Bryan 6,500 MBTU/h boilers for backup/ redundancy.
- The piping infrastructure system is from 1991 and consists of 6″ supply and return pipes.

The boiler upgrade in 2013 increased plant efficiency and capacity and improved the turn down ratio for lower load conditions. The majority of the heating in the academic buildings are supplied by these natural gas boilers with a large carbon footprint. Part of the issues found in operation is the third floor Science building and Gymnasium that are connected to the current CHP but not to the DES. These building connections are driving loads for the CHP earlier and later in season than desired, and resulting in increased carbon emissions.

Strategies to expand the CHP network to connect new buildings and convert over to a biomass fuel source for carbon neutrality goals is recommended as outlined in the Biomass and CHP Expansion section.

Existing Power Distribution System

The campus receives its electrical energy supply from the FortisBC 12.5 kilovolt (kV) distribution network. Power enters the site and is metered at the distribution voltage at two locations, near the south and north roundabouts. The distribution network is supplied from two FortisBC substations located near Quail Ridge (Ellison Substation) and on Sexsmith Road near Pinto Road (Sexsmith Substation). Currently Ellison (north) substation supplies the entire campus. The Sexsmith (south) sub is the back up.

Ellison (north) station has about 5 MVA available but it also feeds the airport and Innovation Place so load will continue to grow on and off campus. Ellison is configured for a second transformer which would add a minimum of 20 MVA so capacity can be increased in the future and a dedicated (express) distribution line feed could be run to the campus. Sexsmith (north) station is near capacity. Feeder to the campus from Sexsmith might not be able to supply the entire campus at peak. Some load shedding could be required if the Ellison station went down and supply was from Sexsmith. FortisBC plans call for a new 32 MVA transformer 2017-2019.

On-campus electrical distribution infrastructure consists of switching cubicles fed from each metering point and then a 350 MCM loop feeder which provides robust and redundant supply to the main academic buildings. The switches allow back feed should a fault occur somewhere in the line. Most building transformers in the main academic area are loop fed as well, meaning the can be fed from two directions. The 350 MCM loop is limited to about 7 MVA but could be upgraded.

The feeds to the residential building are radial currently. Consideration should be given to completing the loop feed to University Centre, future University Commons, Kalamalka, Nicola, Purcell and future Skeena. The relatively short tap to the Geoexchange building is also a radial feed.

A new feed is not anticipated along John Hindle from Glenmore although FortisBC will likely install conduit for future use. The north Glenmore area is fed from Sexsmith so no additional redundancy would be gained from a feed to campus along that route.

Strategies for demand side management and discussion on capacity as the campus expands is outlined in Section 4.8 Campus Scale Systems—Measures for Improvement.

Existing Natural Gas Pipelines

Two high pressure gas pipelines service the campus by FortisBC:

1. one along Discovery Avenue that follows University Way; and
2. one that runs through the student residences.

FortisBC owns the gas line up to campus building meters. FortisBC does not anticipate any capacity issues as the piping is sized to handle projected future growth over the next 20 years. There is also a secondary distribution system serving the buildings.

4.4 ASSESSMENT OF EXISTING BUILDINGS

Demand Side Management Electrical

The peak demand for the campus is a summer air conditioning peak. The rate structure provides for a minimum of 75% of the peak demand to be charged every month so reducing the summer peak can have significant savings.

To help understand where some of the large electricity loads are taking place, load projection curves were extracted for academic buildings and residences based on the north and south feeder meters, see Figures 20 and 21. Different times of year were projected to see how the load differs with season.

Figure 20 for the academic buildings shows the peak in summertime which probably is due to summertime cooling if the buildings, to a large extent, are unoccupied at this time. The March curve is flat throughout the day and night, while it would be expected to see a significant drop in the electrical load during nighttime when lights, plugs and HVAC systems should be turned off.

Figure 21 for the residences shows electrical peak load during January. This is likely due to the electrical perimeter heating. The October and June plots shows a flat line indicating there is no load difference during night-time and daytime operation, despite occupancy sensors on much of the lighting as well as window sensors for the PTAC units. It is clear from these graphs that there is a need to understand what systems are running at nighttime and which ones could be shut down (i.e., lighting in common areas, plug-loads in the suites and review of the MAU and PTAC system operations).

From these figures, it is apparent that the buildings are not operating optimally, and there is a large opportunity for significant cost savings that can be used to fund other energy reduction measures.

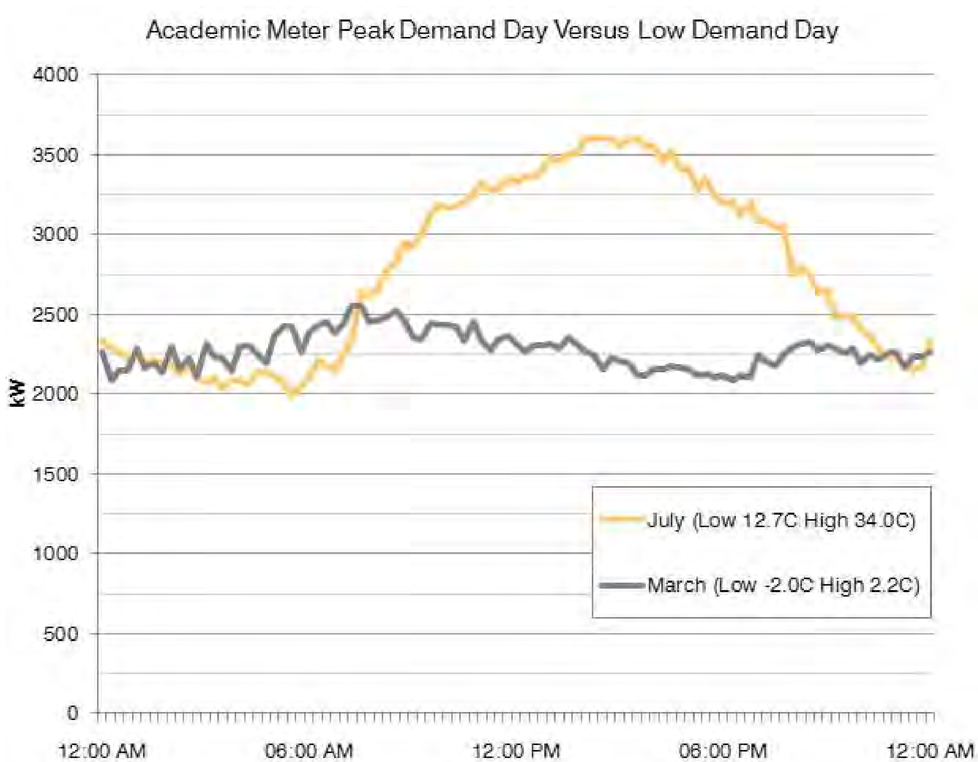

FIGURE 20: ELECTRICAL LOAD CURVE FOR ACADEMIC BUILDINGS—SUMMER (JULY) AND SPRING (MARCH) OPERATION

Academic Example:
500 kW reduction @ 108hrs/wk
= 2,808,000 kWh
= $214,000/yr

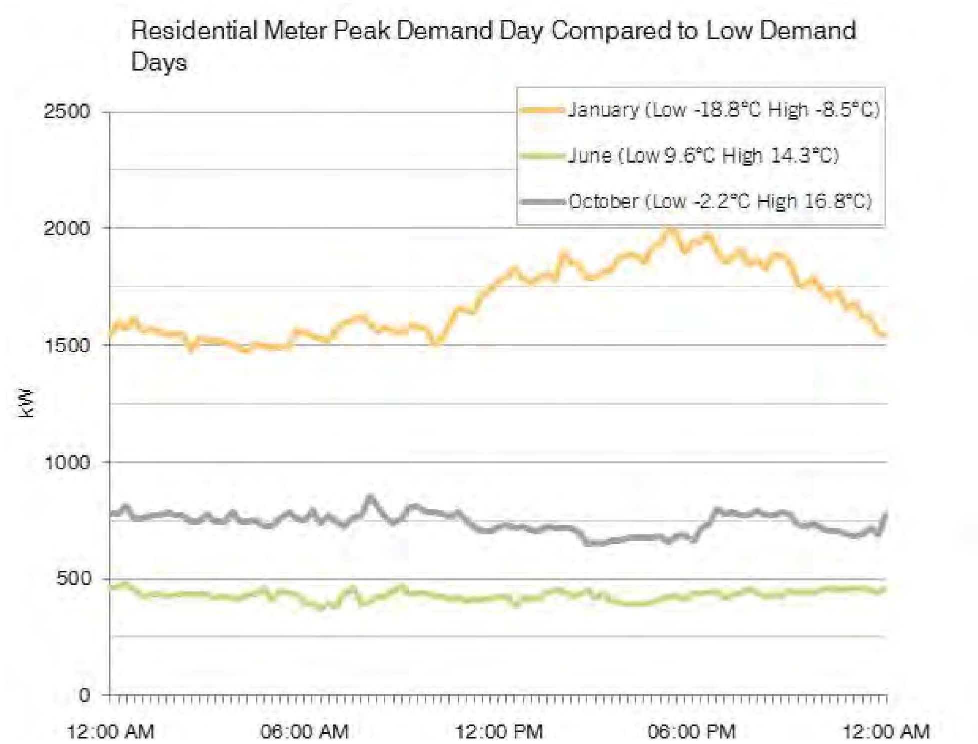

FIGURE 21: ELECTRICAL LOAD CURVE FOR RESIDENTIAL BUILDING—WINTER (JANUARY), SUMMER (JUNE) AND FALL (OCTOBER) OPERATION.

The flat demand curves outside of the summer cooling (academic) and winter heating (residential) indicate a relatively constant electrical demand whether students and staff are present or not. Many systems should be shut down when the space is not occupied to save significant energy use and cost. Considering the 75% of peak demand as the minimum monthly demand charge, the academic peak of some 3,700 kW would suggest a minimum monthly demand charge of 2,775 kW that is in excess of the March peak demand of some 2,500 kW. Similarly in the residential charges, the peak winter demand of some 2,000 kW would suggest a minimum demand charge of 1,500 kW again well in excess of the June and October demand usages for additional electrical demand costs.

As an example, a 500 kW reduction at nighttime (academic example) could result in $214,000/yr in operational savings that could fund investment in reduction strategies elsewhere. Over a 5 year period, this cost could accumulate to $1,070,000 cost savings based on today's energy cost excluding escalation rates.

Reducing electrical demand is embedded within a number of the energy conservations measures (ECMs), but additional efforts focusing on demand-side management reductions and turning systems off when not needed could show further savings in addition to the ECMs. This opportunity is further presented in Section 4.5 Existing Buildings—Measures for Improvement.

Legacy Academic Buildings

The older academic core of the campus, referred to as Legacy Academic buildings, are served by the Central Heating Plant (CHP) system (with the exception of one building that has a standalone boiler) as well as connected to the DES system. The Academic Legacy buildings currently have stand-alone cooling systems (heat pumps) and it has been found they are not fully compatible with the DES system, resulting in two key issues: 1) they do not use the DES during summer for cooling, and 2) change-over from the DES connection to CHP gas boilers occurs at approximately 0°C, which means that natural gas is used as the sole heating source on cold days.

Legacy building mechanical systems are aging and many require repairs. For example, the Science building heat recovery system is not working fully. The existing building envelope has not been upgraded since construction and is reaching a life of 20-25 years. Building interior lighting generally consists of standard fluorescent and compact fluorescent luminaires with some LED technology having been installed as retrofits. Some of the older buildings did originally have occupancy sensors installed, but because the technology was not well developed, many of these have been removed or bypassed. Now that occupancy sensing technology has improved and is a code requirement in new buildings, it would make sense to look at re-implementing these controls and expanding them. Electrical plug-load controls are generally not installed.

The Legacy buildings have had some energy efficiency upgrades as part of the FortisBC Building Optimization project. Additional opportunities identified for the Legacy buildings studied in the "Existing Buildings Measures For Improvement" section, include lighting retrofits, demand side management strategies, building occupancy, controls for ventilation, heat recovery, lab airflow monitoring and ventilation reduction strategies.

New Academic Buildings

The New Academic buildings on campus are connected to the DES system with building-by-building water source heat pumps to provide both heating and cooling. The New Academic buildings have stand-alone back up boilers for building heating as well as for domestic hot water. The cooling system uses the DES with the heat pumps. These buildings have various HVAC distribution systems within each building. Three of the New Academic buildings have heat recovery on the lab exhaust systems, but it has been identified that opportunities exists to improve these systems and control ventilation air. The current configuration of the DES does not provide sufficient source heat to match the energy required by heat pumps in cool weather so these buildings shift to their own boilers for heating. The buildings also require the on-site boiler for domestic hot water heating.

With the low heating capability from the DES, there have been some reliability issues with the hydronic heat pumps as equipment approaches the limits of their operating range and shut down. The recommended system upgrades should provide the heat pumps with stable winter and summer operating conditions.

Building interior lighting generally consists of standard fluorescent and compact fluorescent luminaires with some LED technology installed as retrofits. Electrical plug-load controls are generally not installed.

There are large opportunities for savings in the Academic buildings. Lab spaces in particular are very energy intensive. Airflow monitoring and ventilation reduction strategies will result in large HVAC savings. As the current DES/WSHP connection has performance limitations, there is high reliance on the building boilers that requires high carbon intensive energy.

Opportunities for energy use reductions include lighting retrofits, demand side management strategies, building occupancy, heat recovery, lab airflow monitoring and ventilation reduction strategies. Recommissioning of all of these buildings is recommended as part of the implementation of the energy conservation measures as some of them have the highest EUIs on campus.

Residential Buildings

Residential buildings are currently not connected to either the DES or the CHP system (i.e. are not centralized). Most of the residential buildings have packaged terminal air conditioning (PTAC) units in the residential suites, electrical baseboards for perimeter heating. Make-up air units (MAU's) use natural gas for ventilation, and natural gas is used for domestic hot water (DHW) heating in the majority of the residences. A few buildings are all electric including the Upper and Lower Cascades which are heated with heat pumps and electric DHW. Many of the residences have heat recovery systems installed. Purcell has a GSHP horizontal field providing heating, and 10 solar hot water panels on the roof for DHW preheat. This is the lowest energy consuming building on campus.

There are direct digital controls (DDCs) at each building, but these are used for metering only and not connected to equipment. The systems were found to run 24/7, even during low summertime occupancy use, although some of the residences are used for conferences in the summertime.

Opportunities exists for possible decommissioning in the summertime, lighting retrofits, heat recovery, and either building scale measures, or, CHP district energy connection with alternative energy source for carbon neutrality. This is further explained in Section 4.5 Existing Buildings—Measures for Improvement. The residential buildings are not good candidates for DES connection as they are a heating load only. The air conditioning systems generally use individual, air cooled units. A connection to the CHP system would be better as it is a heating system delivering the heat directly to the building ventilation and DHW systems.

4.5 EXISTING BUILDINGS—MEASURES FOR IMPROVEMENT

The general approach to achieve energy and carbon reduction savings is to focus first on reducing the building load as much as possible through passive systems; second on using energy more efficiently in the building by optimizing system performance and operations; and lastly, on supplying energy from renewable, carbon neutral sources. Figure 22 shows this approach and energy reduction hierarchy.

The Legacy Academic buildings have already undergone some energy efficiency upgrades as part of the FortisBC Building Optimization project that was completed in June 1015. This work showed projected operational cost savings of $150,000/yr for these buildings, demonstrating the opportunity for significant cost and energy savings that can result from fine-tuning existing building performance. This *infrastructure plan* is based on the 2013 energy use data as annual operating data following the upgrades was not yet available.

Energy Conservation Measures (ECMs)

A number of energy conservation measures (ECMs) have been identified for the existing buildings with the potential to significantly reduce current operational energy consumption, operational costs, and GHG emissions. The ECMs identified focus on achieving larger scale impacts in order for the overall campus to meet its sustainability goals, rather than focusing on building level measures as required by cyclical maintenance.

The results provide an order of magnitude values, which are useful in identifying key opportunities and areas for further detailed study. Table 15 summarizes the energy conservation measures analyzed as part of this infrastructure plan.

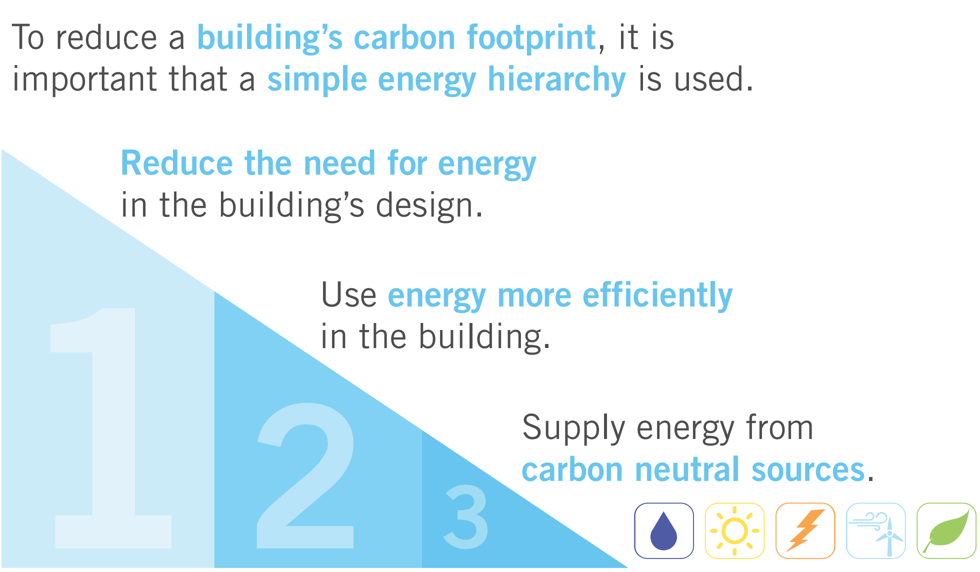

FIGURE 22: GENERAL APPROACH FOR ACHIEVING ENERGY EFFICIENT AND LOW CARBON BUILDINGS

TABLE 15: EXISTING BUILDING ENERGY CONSERVATION MEASURES

ECM	DESCRIPTION
ECM 1/2	Building Use Consolidation (combined with ECM 2)
ECM 1/2	Lab ACH Night Set back (combined with ECM 1)
ECM 3	Lab air heat recovery, unoccupied airflow reduction
ECM 4	Lab Air Quality Management—Indoor air quality monitoring AirCuity
ECM 5	Lab EA Plume Height Reduction / Wind system
ECM 6	Academic Building HVAC night / (Excluding Labs)
ECM 7	Sewer Heat Recovery Residences
ECM 8	Washroom Exhaust Heat Recovery Residences
ECM 9	Residential Heat Pump (for ventilation)
ECM 10	Residential Hybrid DHW System
ECM 11	Lighting Power Upgrades (Academic+Residences)
ECM 12	Plug Load Controls
ECM 13	Exterior Lighting Upgrades
ECM 14	Academic Heat Recovery Chiller

The total projected energy reductions, energy cost savings, and GHG reduction potential for the ECMs are summarized in Table 16, 17, and 18 after the ECMs are described.

ECM 1—Building Use Consolidation

The campus has lower occupancy in summer (e.g. 15% of winter student enrollment), and currently there is no summer shut-down or use consolidation. As a result, all buildings are fully operational and consume excess energy to cool, ventilate and illuminate unoccupied spaces during summer months. This could be improved with selective building occupancy and space use consolidation.

This ECM optimizes summertime building operation and occupancy. Currently, approximately 40% of peak occupancy is present during the summer months (compared with winter, occupancy). However, currently 100% of academic buildings are operating and conditioned during summer, and HVAC systems are cycling on/off and all running.

Large energy savings are available by occupying the most efficient Academic buildings, and allowing all others to be unused and HVAC systems shut off as much as possible (unconditioned & implement setbacks). Lower peak summer cooling demands is a large benefit, as it will expand summer cooling capacity in addition to reducing electrical demands. This ECM assumes no occupancy or plug load reductions, which would be an additional benefit. It assumes that 50% of annual HVAC electricity and 25% of annual lighting electricity is consumed during summer months.