system. Most of the New Academic buildings are adjacent to both the DES and CHP piping systems. Configuration B suggests that individual projects could decide which system to connect to for heating as there are differences in operating costs. Configuration C allows for a connection to just the DES system for heating. In both cases, there would be DES connections for cooling heat rejection.

### Existing Academic—Engineering, Health Sciences, and Science Building Level 3

Both configuration approaches propose a connection of the Engineering, Management, and Education building and the Reichwald Health Sciences Centre to the CHP. This should also apply to the significant heating loads of Science Building's Level 3 addition. There is a question of when to connect to the CHP, given that these two buildings are large energy consumers. The option of waiting until the end of life of the relatively new boilers would be after 2030 and would have a significant impact on campus GHG emissions (see Table 38 in Risks Associated with Delaying Building Conversion). It is recommended that once the biomass system is operational, the conversion of these existing packaged boiler systems be considered to reduce GHG emissions and energy operating costs.

### Remaining Existing Academic—Existing Boilers

Configuration B suggests a CHP connection to replace the existing building standalone boilers. This could be toward the end of the boiler life or shortly after the biomass plant is implemented to reduce campus GHG emissions. Due to the significant building system changes required to utilize a lower temperature DES heating system, Configuration C suggests a major heating system conversion to DES-only at the mid-life refit of these buildings. This would occur after 2030 and relies on sufficient funding at that time to allow for the replacement of the heating systems. As budgets could continue to be tight in the future, there is some risk of not being able to afford the extensive system refit.

### New Residential

The new Residential units would be heated and cooled with Packaged Terminal Air Conditioning units (PTAC) that are also air-source heat pumps. The heat pump approach will reduce the expensive electrical energy used for heating. The make-up air and exhaust systems would be connected to heat recovery units to reduce the heating load. Heat pumps connected to the DES would provide heating for both the make-up air and domestic hot water heating. The make-up air system would also provide tempered air in the summer.

Standalone residential boilers for make-up air and domestic hot water heating were considered but not suggested due to the additional GHG emissions from boilers and future conversion costs should a district energy connection be required. Should the DES or CHP piping expansion be an issue for a residential project, air source heat pumps for heating/cooling ventilation air and heating domestic hot water should be considered. Air-source heat pumps are discussed in detail as ECM 9 in 4.5 Existing Buildings – Measures for Improvements. A building sewage heat recovery for DHW heating is another option for consideration and likely more effective than the air-source heat pumps. Sewage heat recovery for residences is discussed in detail as ECM 7 in 4.5 Existing Buildings – Measures for Improvements.

In scenarios where new residential buildings are not connected to a central heating system, it is recommended that UBCO establish EUI targets that are near to or at Passive House standards. Section 4.6 New Construction – Measures for Improvement provides recommended EUI targets for new building development on campus with incremental improvement over a 15 year period. Moving towards such targets will facilitate reducing demand for energy and GHG emissions associated with new residential developments on campus.

### Existing Residential after Mid-Life Refit

When the existing residential units are ready for a mid-life refit, they should be upgraded as indicated in the New Residential section. The Monashee and Similkameen buildings are approaching their mid-life refit and will be the first two major renewal projects. Fortunately, they are adjacent to the existing DES piping system. Similar to new residential building, should the DES or CHP piping expansion or connections be an issue, air source heat pumps for heating/cooling ventilation air and heating domestic hot water should be considered. Air-source heat pumps are discussed in detail as ECM 9 in 4.5 Existing Buildings – Measures for Improvements. Existing residential buildings that are currently on all electric also have the opportunity to switch to DES heating when they are up for a major building refit. This switch would not be impractical or a financial barrier if it coincides with the major refit. Existing residential on the geo-source system would not be recommended for connection to the CHP or DES.

### Risks Associated with Delaying Building Conversions

Another strategy that has been requested is to align the conversion of existing buildings to a CHP connection with their boiler end-of-life replacement or mid-life building refit. This strategy will delay the GHG emission reductions from a building conversion and is not recommended for the following reasons:

- Boiler failures are often unpredictable. When a premature boiler failure occurs, a replacement boiler is typically ordered immediately due to building occupant needs, and the timeframe required to re-fit a CHP piping connection. An unscheduled replacement of boilers would further delay a CHP connection or incur additional unnecessary costs.
- Mid-life building refits or major building renewals often prioritize student teaching enhancements over building envelope and HVAC system improvements. Due to budgetary constraints, building systems upgrades are often neglected.

- Biomass conversions provide the greatest benefit when their loads are maximized. By deferring the connection of a building to a CHP connection, there are reductions in GHG emissions and operational costs that are unrealized.
- Most of the mid-life and boiler life conversions are after 2030 so the GHG reductions and operating cost reductions available would be delayed.

Table 38 summarizes information provided in Table 9: Summary of UBCO Existing Building Stock and the years built of each campus building. A typical mid-life refit and boiler replacement schedule of 25 years would result in the conversion of several of these buildings past the 2030 timeline. This would delay significant GHG reductions to beyond the required 2030 campus GHG reduction goals.

### TABLE 38: EXISTING ACADEMIC AND RESIDENTIAL BUILDINGS ESTIMATED BOILER REPLACEMENT

| BUILDINGS | | YEAR CONSTRUCTED | YEAR FOR BOILER REPLACEMENT AND MID-LIFE REFIT* |
|---|---|---|---|
| Academic | Engineering, Management, and Education | 2010 | 2016 |
| | Reichwald Health Sciences Centre | 2011 | **2036** |
| | Arts and Sciences Centre | 2010 | **2035** |
| | Fipke | 2008 | **2033** |
| | University Centre | 2009 | **2034** |
| Residential | Monashee | 1992 | 2017 |
| | Similkameen | 1992 | 2017 |
| | Kalmalka | 2005 | **2030** |
| | Valhalla | 2005 | **2030** |
| | Nicola | 2010 | **2035** |
| | Cassiar | 2010 | **2035** |

* Estimate (based on 25 year replacement schedule)

## Summary of Alternate Configurations B and C

The additional study commissioned by UBCO (April 2016) provides two new alternate configurations for the implementation of district scale infrastructure. While these two configurations provide a potential lower capital cost option due to the lower cost of DES piping as opposed to CHP piping, they do not realize as significant GHG emissions reductions due to the continued use of gas fired boilers. Additionally, heating provided via the DES will inherently incur a higher operational cost from the operation of building heat pumps. Ultimately, the recommendation of Configuration A and the expansion of the CHP network still remains.

## Summary of Carbon Reduction Scenarios

In order to understand the overall impact of the recommended infrastructure and energy conservation measures, six scenarios were analyzed to compare and contrast the trade-offs between biomass heating options, expansion of district scale infrastructure, and carbon performance. These scenarios show the combined potential for the Campus to achieve its long-term energy and carbon reductions goals.

The first four scenarios represent the initial carbon reduction scenarios developed for UBCO, whilst Scenario 5 and 6 represent the analysis completed in April 2016. Scenario 5 and 6 also account for a revised implementation schedule of ECMs that has commenced since Fall 2015 and based on feedback gathered from UBCO's team.

These six scenarios documented in Table 39 include:

- Scenario 1—Academic+Residences upgrades with ECMs. (No fuel switch)
- Scenario 2—Academic ECM upgrades, improve and connect to Biomass CHP. No ECMs or CHP expansion to Residences. (12MW Biomass)
- Scenario 3—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences. (6MW Biomass)
- Scenario 4—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences, solar PV. (6MW Biomass)
- (New) Scenario 5—Academic ECM upgrades with revised implementation schedule, DES+CHP connection to all new buildings, CHP connection to existing academic. (6MW Biomass)
- (New) Scenario 6—Academic ECM upgrades with revised implementation schedule, DES to all new buildings, conversion of existing academic to DES-only. (6MW Biomass)

It should be noted that Scenario 3 and 4 show UBCO's preferred and recommended approach to implement a 6MW biomass system in Phase 2 following CHP network expansion and prioritized ECMs.

Figure 40 shows how UBCO could achieve an 79% reduction compared to a BAU case and a 46% reduction compared to the 2007 target baseline, despite doubling its building area and population.

## TABLE 39: SUMMARY OF CARBON REDUCTION SCENARIOS

| DESCRIPTION | 2030 GHG REDUCTION COMPARED TO 2007 BASELINE | 2030 GHG REDUCTION COMPARED TO BAU |
|---|---|---|
| **Scenario 1: Academic + Residences upgrades with ECM's (No fuel switch)** | | |
| Academic Buildings and Residences are upgraded with ECMs as per Appendix J, and no fuel switch is implemented. | +32% | -49% |
| **Scenario 2: Academic ECM upgrades, improve and connect to biomass CHP, no ECMs or CHP expansion to residences** | | |
| Academic Buildings are upgraded with ECMs, as per Appendix J.<br><br>The DES system is improved with HP boost for capacity and the existing academic buildings and all new buildings are connected to biomass CHP expansion. The existing residences remain with no ECM upgrades or CHP expansion.<br><br>**12MW Biomass conversion** | -58% | -84% |
| **Scenario 3: UBCO's Preferred Option—Academic ECM upgrades, DES improvements, CHP/ Biomass expansion to new Academic and Residences.** | | |
| Academic Buildings are upgraded with ECMs, as per Appendix J.<br><br>Configuration A: DES is optimized. Existing academic and all new buildings are connected to new Biomass/CHP expansion.<br><br>**6MW Biomass conversion** | -46% | -79% |
| **Scenario 4: UBCO's Preferred Option—Academic ECM upgrades, DES improvements, CHP/ Biomass expansion to new Academic and Residences, plus Solar PV** | | |
| Academic Buildings are upgraded with ECMs, as per Appendix J.<br><br>Configuration A: DES is optimized by providing additional heat via CHP. Existing academic and all new buildings are connected to new Biomass/CHP expansion. Solar PV installed.<br><br>**6MW Biomass conversion** | -47% | -80% |

| DESCRIPTION | 2030 GHG REDUCTION COMPARED TO 2007 BASELINE | 2030 GHG REDUCTION COMPARED TO BAU |
|---|---|---|
| ADDITIONAL ANALYSIS ON CONFIGURATION B & C (APRIL 2016) | | |
| **Scenario 5: DES for Heat Sharing, CHP for Peak Heating** | | |
| Academic Buildings are upgraded with ECMs following a revised (April 2016) implementation schedule.<br>Configuration B with DES and CHP expansion to all academic buildings and DES to all residential buildings.<br>6MW Biomass conversion | -35% | -75% |
| **Scenario 6: DES-only for Heating and Heat Sharing** | | |
| Academic Buildings are upgraded with ECMs following a revised (April 2016) implementation schedule.<br>Configuration C with DES Expansion to all new Academic and Residential buildings. Conversion of all existing buildings to DES-only.<br>**6MW Biomass conversion** | +15% | -55% |

Appendix J includes a detailed outline of the scenarios, what measures are included and their combined energy and carbon performance.

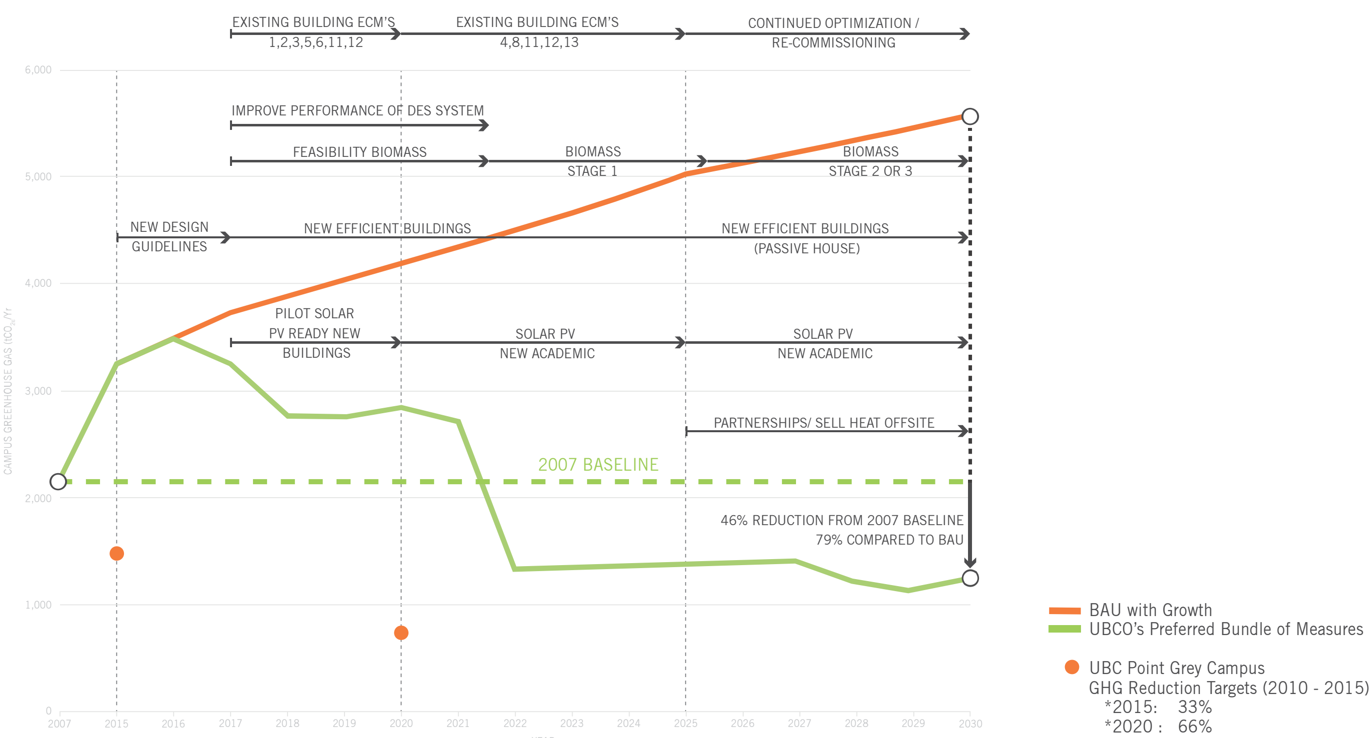



FIGURE 39: SUMMARY OF UBCO CARBON EMISSION POTENTIAL WITH SCENARIO OF MEASURES

## Performance Metrics

Based on the analysis undertaken for the *Whole Systems Infrastructure Plan*, Table 40 illustrates milestone performance metrics that are possible based on the measures implemented over time by 2030.

TABLE 40: UBCO ENERGY AND GREEN HOUSE GAS PERFORMANCE METRICS BY 2030 FOR SCENARIO 3 AND CONFIGURATION A

| METRIC | | CURRENT PRACTICE (2013) | 2030 BUSINESS AS USUAL | 2030 WITH PROPOSED MEASURES[3] | REDUCTION (COMPARED TO 2013) |
|---|---|---|---|---|---|
| Campus Energy Use Intensity (EUI) | $kWh/m^2/year$ | 334 | 220 | 129 | 61% |
| Green House Gas Emissions (GHG)[1] | Tonnes/year | 3,317 | 5,591 | 1,177 | 65% |
| Green House Gas Emissions (GHG)[2] | Tonnes/year | 2,186 | 5,591 | 1,177 | 46% |

[1] Compared to current practice (2013 data).

[2] Compared to 2007 GHG baseline.

[3] The projected savings only include building efficiency and alternative fuel measures, excluding other scope 2 emission measures for paper, transportation, etc.

## Additional Steps to Achieve Carbon Neutrality by 2030-2050

There is a small residual amount of carbon emissions left for heating as well as electricity. Additional steps recommended for the campus to achieve carbon neutrality by 2030–2050, and include the following:

- **Initiate collaboration with the Landfill/FortisBC for green gas purchase for the campus.**
  - Green gas could be used primarily for cooking in commercial kitchens, and would come at a higher cost than natural gas approximately $17.1/GJ (premium $9.14/GJ).

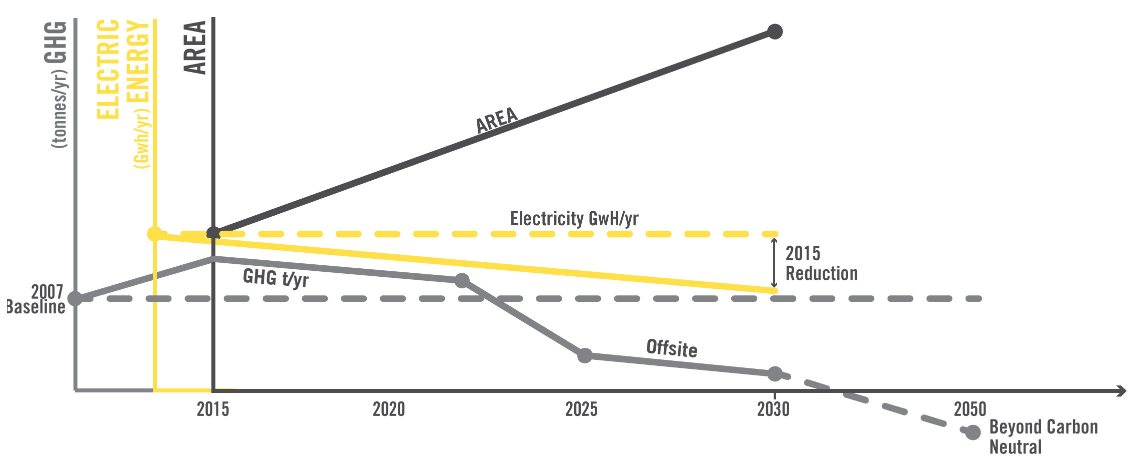



FIGURE 40: CAMPUS POTENTIAL TO ACHIEVE THE LONG-TERM TARGETS DESPITE DOUBLING IN AREA BY 2030

- **Sell heat to off-site users.**
  - Explore a potential partnership with Environment Canada's Mountain Weather Office that is located on Campus, and/or
  - Explore partnerships with the planned adjacent Airport Park Development. Depending on the timing of the development, a partnership should be explored. From a high level estimate, selling heat to 40,000 $m^2$ of an office space in this climate could help offset the residual carbon emissions needed to attain the Campus's neutrality goal.
- **Phase in "PV Farm".**
  - As costs decline and panel efficiencies increase. We recommend that this approach is considered as part of Phase 3 of this Infrastructure Plan, but there is potential to look at this earlier in Phase 2 with expansion in Phase 3 as costs decline.
- **Address the residual Scope 2 emissions.**
  - Switch the Campus vehicle fleet to electric vehicles. This has not been studied as part of this *Infrastructure Plan*.

## Campus Scale Energy and Waste Systems Maps

In summary, Figures 41 and 42 show conceptually the different energy and waste infrastructure components on campus, renewable technologies and the interrelationships between them. For example, bio-char, a byproduct from the biomass system could be diverted to an on-site composting facility. Excess heat generated on campus could be sold off-site as a carbon offset strategy. In both cases, the maps show the relationship with different, but complementary systems or uses required to support the University's long-term carbon goals.

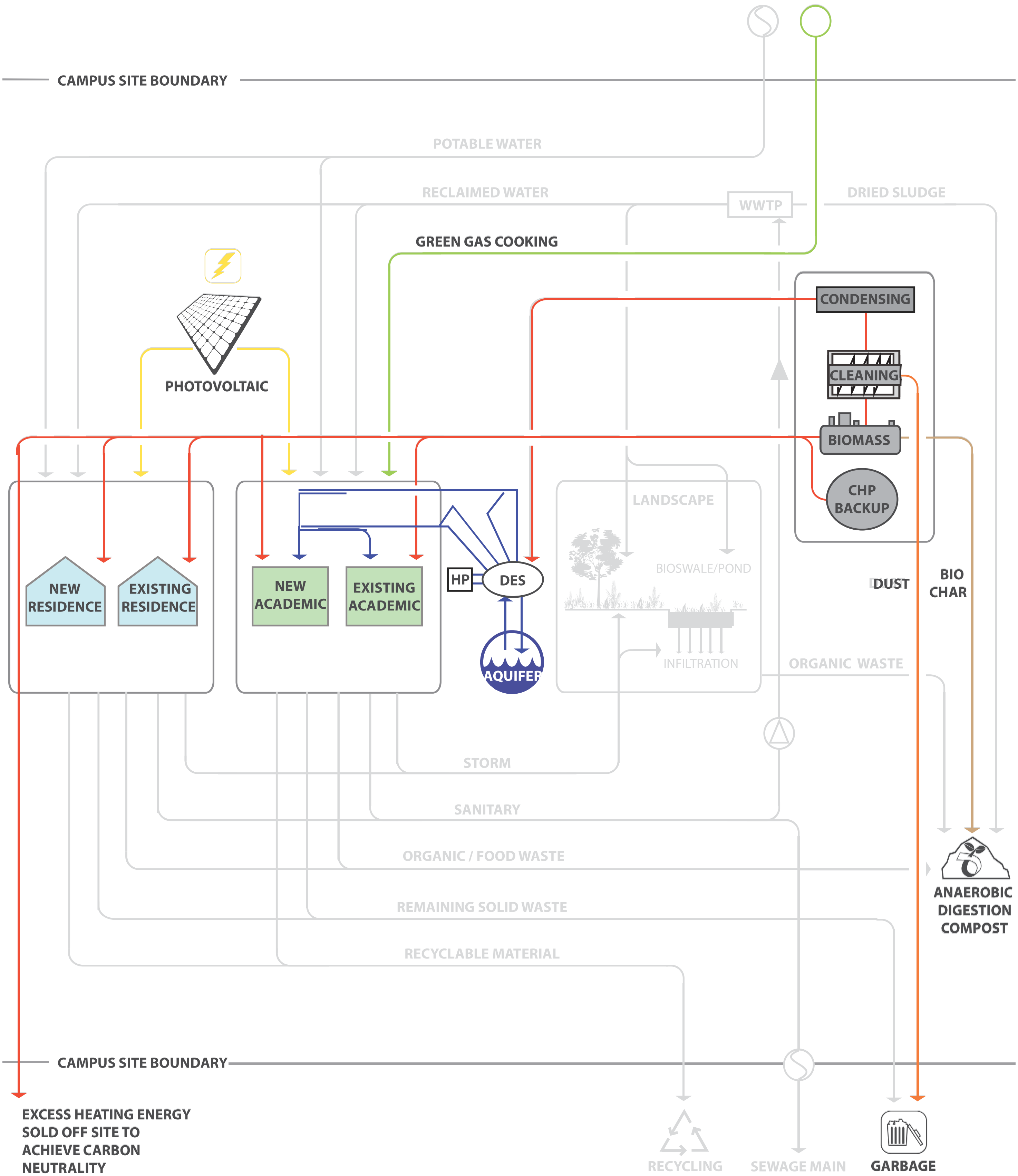



FIGURE 41: ENERGY SYSTEMS MAP

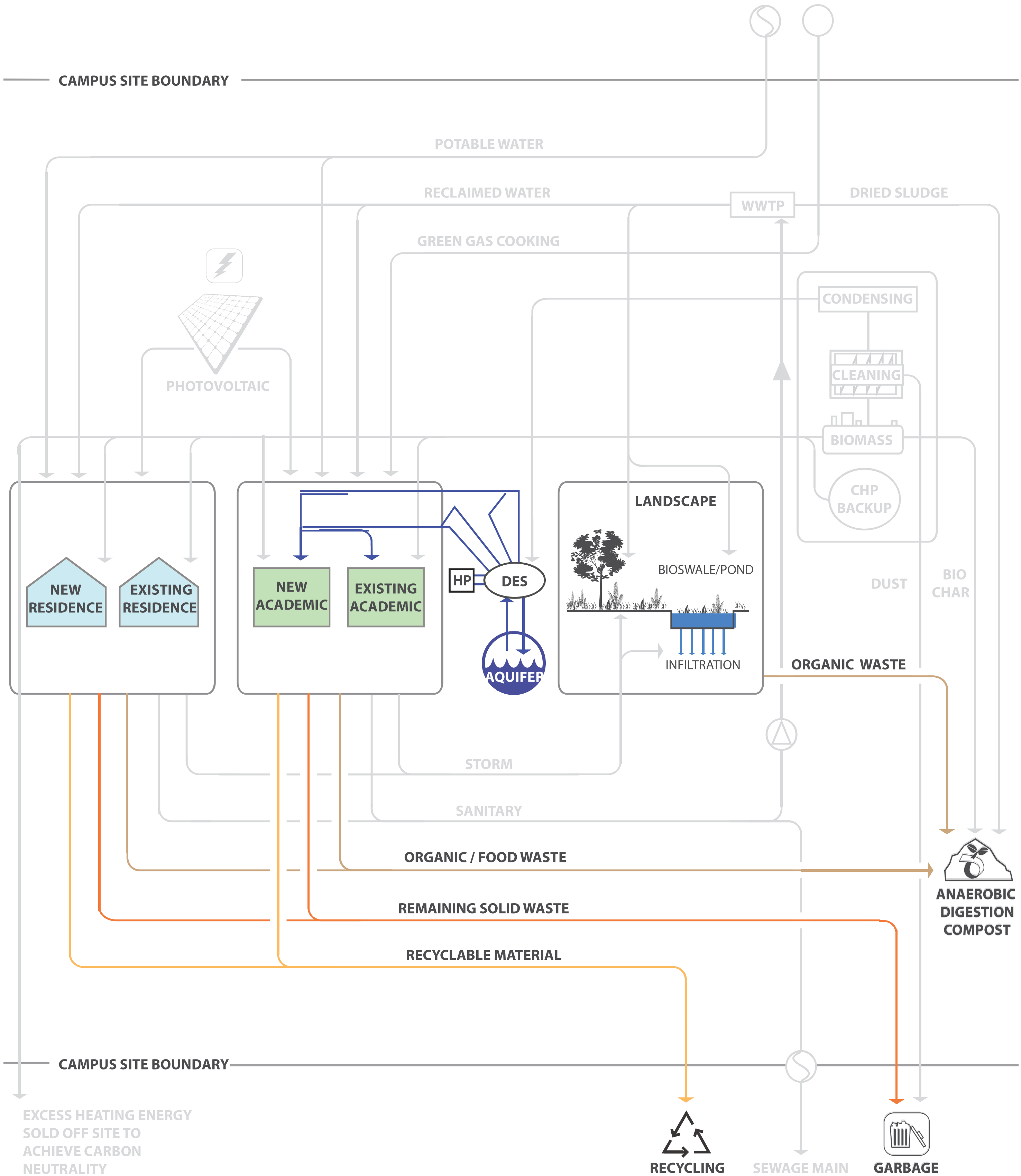



FIGURE 42: WASTE SYSTEMS MAP

## 4.9 COSTING ANALYSIS — SOLAR TECHNOLOGIES

This section presents the cost analysis for the solar PV, solar hot water, and solar farm options presented in the Whole Systems Infrastructure Report. Details on the costing analysis, capital cost outlines, detailed assumptions, and cash flow analysis can be found in BTY's Economic Modelling Report in Appendix E.

Table 41 summarizes the life cycle cost analysis for solar PV, solar hot water for buildings, and the concept of a solar farm, and the phase in which these costs would be incurred.

These costs are based on an estimated surface area and solar production potential for each solar technology, as presented in a preceding section. It should be noted that as a first step, it is recommended that UBCO pilot building retrofits and new construction projects with either solar hot water or PV technology to assess the incremental cost of adopting these technologies. A nominal allowance for upgrading the roof structure to support Solar PV, if installed in the future, is estimated at $50/sqm of the roof area.

PV costs attributed to Phase 1, as an example, are based on 20% of new constructed academic roof area to be covered with PV.

### TABLE 41: COSTING ANALYSIS—ALTERNATIVE FUEL SOURCES

| CAPITAL COST | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | 2030-2065 | TOTAL | SIMPLE PAYBACK (YEARS) | NPC TO 2030 $ |
|---|---|---|---|---|---|---|---|
| Solar PV for Buildings | $1,648,300 | $873,600 | $932,400 | $0 | **$3,454,300** | **26** | **1,907,700** |
| Solar Hot Water for Buildings | $526,500 | $1,781,300 | $1,102,200 | $0 | **$3,410,000** | **After 50 years** | **2,129,900** |
| Solar PV Farm with Increased Efficiencies | $0 | $0 | $5,250,000 | $0 | **$5,250,000** | **23** | **1,868,200** |

| SAVINGS (ESCALATED $) | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | 2030-2065 | TOTAL |
|---|---|---|---|---|---|
| Solar PV for Buildings | ($245,400) | ($425,500) | ($786,200) | ($3,190,900) | **($4,648,000)** |
| Solar Hot Water for Buildings | ($36,000) | ($145,600) | ($234,600) | ($2,310,300) | **($2,726,500)** |
| Solar PV Farm with Increased Efficiencies | $0 | $0 | ($1,914,200) | ($7,769,500) | **($9,683,700)** |

- With escalation of 5% after 2018, the simple payback would be reduced from 26 years to 22 years,
- With escalation of 10% after 2018, the simple payback would be reduced from 25 years to 18 years,
- With escalation of 20% after 2018, the simple payback would be reduced from 25 years to 13 years.

# 4.10 COST ANALYSIS — DISTRICT SCALE INFRASTRUCTURE

Given the financial investment of expanding a campus scale energy system, consideration was given to the business case for expanding the CHP network and transitioning to a district scale centralized heating system.

## Business Case—Academic Building

To examine the cost and energy savings potential of a centralized heating system for newly constructed buildings, an example 30,000 $m^2$ building of academic typology was studied. The capital cost is limited to a portion (based on share of load) of the CHP distribution mains, the building's own branch connection to the mains and the heat exchanger and controls in the building. No additional boiler capacity was included for the CHP scenario in Phase 1 due to the existing spare boiler capacity, planned implementation of ECMs, and improved efficiency standards of newly constructed buildings. This aligns with the preceding analysis demonstrating that overall heating load at 2030 remains the same despite a growth in campus size. This is independent of the implementation of the DES, DES/CHP inter-connection and Biomass, and none of the costs associated with these moves has been included in this analysis. Table 42 summarizes the key factors assumed and resulting savings.

### TABLE 42: CHP VS STANDALONE BUILDING BOILER PERFORMANCE FACTORS

| | Area $m^2$ | Heat Load $W/m^2$ | Peak Heat Load MW | Heating Consumption $kWh/m^2$ | Building Heating Consumption (excluding efficiencies) MWh |
|---|---|---|---|---|---|
| Example Academic Building Typology | 30,000 | 67 | 2.0 | 53.6 | 1,608 |

| Source | Boiler Requirements | Annual Efficiency | MWh/year | Capital Cost Estimate |
|---|---|---|---|---|
| Base Case: Individual Building Boilers | 2 x 1.2 MW (sized at 60% peak load capacity) | 80% | 2,010 | $736,600 |
| CHP Plant | 1 x 1.7 MW (0.85 Diversity Factor) | 84% | 1,914 | $552,000 |

### TABLE 43: CHP VS STANDALONE BUILDING BOILER LIFE CYCLE COST ANALYSIS

| CAPITAL COST | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | TOTAL |
|---|---|---|---|---|
| Base Case: Individual Building Boilers (2 X 1.2 MW) | $736,600 | $0 | $0 | **$736,600** |
| Savings (Escalated $) | ($20,180) | ($25,100) | ($27,700) | **($254,600)** |

The comparison between connecting a new academic building to a CHP plan instead of installing individual boilers demonstrates the potential:

- Capital cost savings of $132,000 in connecting new academic buildings to the CHP Plant.
- Mechanical room savings of $57,000 and 15 m2 reduction in room size.
- Energy savings of 96 MWh/year realized by a connecting new building to a CHP plant.
- Total life cycle cost savings of $254,600 over 15 years.

## Business Case—CHP Network Expansion and CHP Biomass Conversion for UBCO Campus Scenario

A separate analysis was conducted to better understand the business case for transitioning to a centralized heating system versus a distributed boiler approach. This analysis accounts for both new and existing campus buildings and follows an agreed upon phasing schedule. This was followed by a second analysis to provide the business case for converting the natural gas CHP to a carbon-neutral biomass fuel source. In both cases, it was assumed and agreed upon with UBCO that the BC carbon tax would double during the period 2018 to 2020 and remain stable thereafter.

### CHP expansion vs Distributed boiler

The basis for the following business case analysis assumes the connection of all eligible existing buildings not currently connected to the CHP. The phasing of the connection of existing buildings was agreed upon with UBCO and is presented below:

1. Monashee (1992) and Similkameen (1992), are both nearing their mid-life renewal, and will be connected to the CHP at the beginning of Phase 2. The cost of Monashee and Similkameen's tie-in to CHP mains will not be accounted for in this analysis as the costs are included under the scope of the building renewal;
2. Upper/Lower Cascades residential buildings are on electric heat and will not be connected to the CHP;
3. Purcell is on a ground-source heat pump and will not be connected to the CHP;
4. Residential buildings: Kalmalka (2005), Valhalla (2005), Nicola (2010), and Cassiar (2010) will be connected to the CHP at end of Phase 3; and
5. Academic buildings: Engineering, Management and Education (2010), Reichwald Health Sciences Centre (2011), Arts and Sciences Centre (2010), Fipke (2008), and University Centre (2009) will be connected at end of Phase 3. Similar cost and no savings.

The baseline for this business case assumes no expansion of the CHP network and all new construction to utilize individual building boilers. For this baseline, existing buildings refits will require boiler replacements instead of transitioning to the CHP.

The CHP expansion business case assumes that all new construction will connect to a newly expanded CHP network. Existing buildings with distributed boilers will transition to the CHP following the above phasing, as opposed to requiring a boiler replacement. To account for the additional load on the CHP plant, an additional 4 MW of capacity will be required in Phase 2. All piping mains are sized to account for phase 3 building connections and the associated costs are included in the analysis.

In both cases, it was agreed with UBCO that there will be no difference in staffing (FTE) requirements when moving from distributed to centralized systems. Boiler room savings in new buildings due to moving to a centralized system are accounted for in the cost estimate. A gas consumption savings of approximately 7% by moving to a centralized heating system was assumed. This accounts for the existing mix of mid and high efficiency distributed boilers, and distribution losses for a centralized heating system. A boiler peak demand savings of 30% by moving to a centralized system, and full implementation of UBCO's preferred ECMs documented in earlier sections of this study is also assumed (refer to Section 4.10 Business Case–Academic Building).

The results of this business case analysis are presented in Table 44 in the summary section.

### CHP Conversion to Full (12MW) Biomass

As indicated in the main body of the study, the *Whole Systems Infrastructure Plan* presented and recommended the scenario of converting the CHP system to a biomass fuel source in Phase 2 as a strategy to realize significant greenhouse gas emission savings. This scenario assumes that full expansion of CHP network is the baseline.

The conversion to a 12 MW biomass scenario plans for an installation of a 6 MW biomass plant in Phase 2, and an additional 6 MW of biomass capacity added in Phase 3. The sizing of this capacity was based on requirements set forth by UBCO with a goal in mind to maximize GHG savings with the potential for future off-site partnerships.

It was agreed with UBCO that there will be no difference in staffing (FTE) requirements between the CHP expansion and the conversion to biomass scenario, and therefore was not considered as part of the costing analysis.

With a switch to a renewable fuel source, UBCO expressed a requirement that 100% natural gas backup be available for the planned biomass capacity. It was agreed that existing boiler capacity of approximately 12 MW would be sufficient for the natural gas backup. This existing capacity was derived from a combination of:

- 6.3 MW CHP,
- 2 MW GEO building,
- 2 MW HP Operations (Winter) (electric compressor energy at 1/3 of existing academic buildings @ 6.4 MW), and
- Approximately 2 MW from the Engineering, Health and Science 3 Buildings.

The revised phasing of existing buildings to the CHP sees the majority of buildings switched only at the end of Phase 3. This incurs a capital cost while subsequently delaying a significant portion of GHG and operational costs savings to the end of the schedule. While this scenario considers existing building system replacement schedules, it should be noted that significant additional GHG savings can be realized by increasing the utilization of the biomass system following its installation. This can be achieved by accelerating the transition of existing buildings to a centralized heating source immediately after the biomass plant is implemented.

The results of this business case analysis are presented in Table 44 the summary section.

### CHP Conversion to Partial (6MW) Biomass

Further analysis was conducted to present an alternate approach to the 12MW conversion to biomass with an emphasis on balancing overall GHG savings with an increased awareness of capital costs. For this approach, a 6 MW biomass plant was sized to maximize the biomass utilization without triggering additional staffing requirements. With a flue gas condensation capacity in the 1 MW range, the total resulting heating output would be approximately 7 MW. This scenario would see significant capital costs savings while still realizing a considerable amount of GHG savings (79%). The existing CHP boilers would continue to operate for peaking and backup loads.

Additional discussions with UBCO (April 2016) concluded that a 6MW biomass plant would be preferred and is used as the basis for our recommendations moving forward.

The results of this business case analysis are presented in Table 44 the summary section.

### Summary of Converting to Biomass

Table 44 summarizes the business case analysis for a:

1. campus-wide CHP expansion,
2. conversion to a 12 MW biomass system, and/or
3. conversion to a 6 MW biomass system.

## TABLE 44: BUSINESS CASE SUMMARY

| CAPITAL COST | | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | TOTAL | SIMPLE PAYBACK (YR) | GHG SAVINGS OVER BAU |
|---|---|---|---|---|---|---|---|
| 1. | Campus-wide CHP Expansion | $566,700 | $2,758,200 | $1,936,800 | $5,261,700 | After 2050 | 41% |
| 2. | Conversion to Biomass 12MW Capacity | $0 | $14,171,700 | $16,034,000 | $30,205,700 | After 2050 | 89% |
| **3.** | **Conversion to Biomass 6MW Capacity** | **$0** | **$14,379,300** | **$0** | **$14,379,400** | **28** | **79%** |

The business case analysis above identifies the financial viability of moving to a centralized heating source independently of converting to a biomass system. The payback periods are different from those presented in subsequent sections of the study and highlight the challenges of analyzing each system in isolation. This business case follows a revised phasing of existing buildings as agreed upon by UBCO. However, the revised phasing results in a high capital cost with a delayed return due to the late connection towards the end of Phase 3.

Secondly, while the implementation of ECMs have been accounted for to provide an accurate estimation of energy use, their associated capital costs and payback contributions have been excluded. Section 4.5 Existing Buildings – Measures for Improvement and 4.13 Funding Mechanisms identifies the implementation of ECMs that result in large operational costs savings that could be used to fund the transition to a centralized biomass plant.

The advantage of a centralized heating system is only fully realized when the conversion to a renewable fuel source, such as biomass, occurs. The conversion to CHP while remaining on natural gas, incurs a high cost with a low return due to relatively small efficiency gains when compared to a standalone condensing boiler. The bundled approach proposed in the main study identifies opportunities to optimize GHG reductions and capital cost payback. However, these benefits may be lost when examined separately.

To improve the financial viability, a 6 MW biomass plant provides the best return while realizing significant GHG reductions. As noted in the report, the campus cannot achieve carbon neutral operations simply through the use of a biomass heating system. Lingering emissions exist from electricity and gas used for cooking. To offset these residual emissions, the CHP heating grid could be expanded to serve off-site customers and this would allow for the financial feasibility of the larger 12 MW biomass heating plant.

## 4.11 COST ANALYSIS — CARBON REDUCTION SCENARIOS

As presented in Section 4.8, the following six scenarios represent a bundled-approach to the implementation of energy conservation measures, district scale infrastructure, and renewable energy options. Capital costing was completed for the first four scenarios developed for UBCO, whilst no costing was completed for scenario 5 and 6 (April 2016).

**Scenario 1**—Academic + Residences upgrades with ECMs (No fuel switch)

**Scenario 2**—Academic ECM upgrades, improve and connect to Biomass CHP. No ECMs or CHP expansion to Residences

**Scenario 3**—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences

**Scenario 4**—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences, solar PV

**Scenario 5**—DES for Heat Sharing, CHP for Peak Heating (No detailed costing conducted)

**Scenario 6**—DES for Heating and Heat Sharing (No detailed costing conducted)

Scenario 3/4 are considered UBCO's preferred options to optimize existing building performance through the implementation of ECMs, expansion of the CHP network, and conversion to a biomass fuel source in Phase 2. This scenario enables UBCO to use savings generated in the first phase of the Plan to fund conservation measures in later phases.

A summary of the detailed cost analysis is presented below and details relating to capital costs, detailed assumptions, and cash flow analysis can be found in BTY's Economic Modelling Report in Appendix E.

Table 45 summarizes the life cycle cost analysis based on four scenarios for improving campus performance.

Sensitivity analysis, based on variations in capital cost, was completed for the four scenarios presented above and is summarized below for UBCO's preferred scenario 3 or 4:

- Scenario 3—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences: the payback would be reduced from 23 to 18 years should the capital cost be 30% less.
- Scenario 4—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences, solar PV: the payback would be reduced from 23 to 18 years should the capital cost be 30% less.

It is also important to note as the cost of carbon taxes and off-sets increase, the savings realized for UBCO will become greater and the payback will be reduced. With the pending update to the Provincial Climate Action Plan it is anticipated that the carbon tax will double and this should be considered as part of the overall decision to move towards a carbon neutral fuel source. The economic modelling of scenarios 1-4 did not account for doubling of carbon tax after 2018. The current Provincial Climate Action Plan targets a 33% greenhouse gas reduction over 2007 levels by 2020 and an 80% reduction by 2050. For details refer to BTY's Economic Modeling Report in Appendix E for the complete sensitivity analysis.

## TABLE 45: COSTING ANALYSIS—DISTRICT ENERGY SYSTEMS

| CAPITAL COST | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | TOTAL | 2030-2050 | TOTAL | SIMPLE PAYBACK (YEARS) | DISCOUNTED PAYBACK (YEARS) | NPC TO 2030 $ |
|---|---|---|---|---|---|---|---|---|---|
| Scenario 1—Academic + Residences upgrades with ECM's (No fuel switch) | $3,379,400 | $5,212,400 | $197,700 | $8,789,500 | $0 | $8,789,500 | 8 | 8 | ($8,320,900) |
| Scenario 2—Academic ECM upgrades, improve and connect to Biomass CHP. No ECM's or CHP expansion to Residences | $17,724,800 | $4,485,600 | $15,959,400 | $38,169,800 | $0 | $38,169,800 | 19 | 27 | $11,679,500 |
| Scenario 3—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences | $8,294,600 | $27,397,200 | $19,002,900 | $54,694,700 | $0 | $54,694,700 | 23 | 35 | $19,246,700 |
| Scenario 4—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences, solar PV | $9,942,900 | $28,270,800 | $19,935,300 | $58,149,000 | $0 | $58,149,000 | 23 | After 35 years | $21,161,400 |

| SAVINGS (ESCALATED $) | PHASE 1 2015-2020 | PHASE 2 2020-2025 | PHASE 3 2025-2030 | TOTAL | 2025-2045 | TOTAL |
|---|---|---|---|---|---|---|
| Scenario 1—Academic + Residences upgrades with ECM's (No fuel switch) | ($4,739,700) | ($8,924,100) | ($11,334,500) | ($24,998,300) | ($67,185,400) | ($92,183,700) |
| Scenario 2—Academic ECM upgrades, improve and connect to Biomass CHP. No ECM's or CHP expansion to Residences | ($5,513,200) | ($10,065,800) | ($13,057,500) | ($28,636,500) | ($79,891,700) | ($108,528,200) |
| Scenario 3—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences | ($5,208,400) | ($10,833,200) | ($14,111,700) | ($30,153,300) | ($86,548,000) | ($116,701,300) |
| Scenario 4—Academic ECM upgrades, DES improvements, CHP biomass connection to Academic and Residences, solar PV | ($5,422,400) | ($11,275,800) | ($14,929,300) | ($31,627,500) | ($91,341,500) | ($122,969,000) |

## 4.12 IMPLEMENTATION PLAN

A bold shift and commitment by UBCO is required to demonstrate a regional leadership position in implementing energy conservation and greenhouse gas reductions that will lead to operational cost savings and support mitigation of climate change. This leadership position will require taking a long-term vision to overcome near-term financial obstacles for the proposed energy and carbon conservation plan. UBC's newly formed Energy and Water Services Advisory Board will support UBCO's leadership and will play an important role in peer reviewing the technical and financial feasibility of projects in support of achieving the campus's long-term energy and carbon goals.

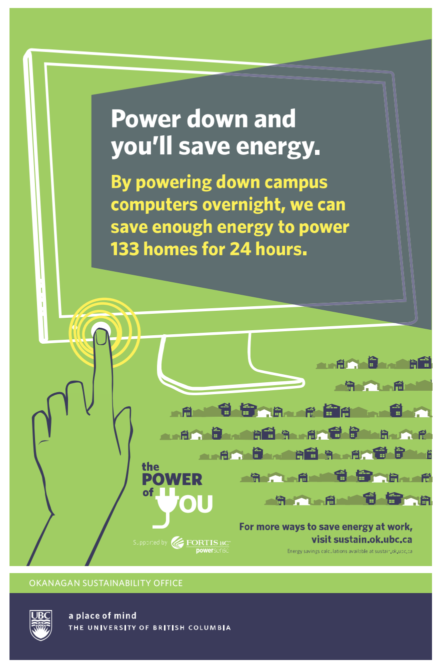
This section and Table 46 summarize the near and long-term implementation actions that are required to support this plan, along with recommended steps for:

- establishing an energy team,
- optimizing the DES system,
- sequencing recommendations for the energy systems, and
- prioritizing other actions for optimizing the performance of the campus.

### Campus Energy Team Development

A dedicated Campus Energy Team is recommended to realize the full extent of energy conservation opportunities and operational savings. This option is preferred over hiring an Energy Service Contractor (ESCO) or a third party consultant team, and is justified based upon the experience gained from developing a similar team on the UBC Point Grey campus. The Campus Energy Team should be responsible for:

- Championing the long-range Infrastructure Plan;
- Managing the energy plan, and monitoring, reporting, and verifying energy savings;
- Driving implementation of the demand-side management measures;
- Identifying and implementing no cost/low cost re-commissioning measures;
- Developing supporting policies;
- Developing occupant engagement programs to support re-commissioning efforts;
- Addressing performance gaps for new buildings; and
- Collaborating with research programs at UBCO.



*"A dedicated Campus Energy Team is recommended to realise the full extent of energy, cost and GHG savings."*

The energy team should be capable of:

- Achieving a targeted % reduction in energy, greenhouse gas, and energy cost per year (adjusted for growth);
- Developing energy projects (technical and economical);
- Auditing and implementing re-commissioning measures; and
- Supporting the design process for major projects.
- The development of this energy team is recommended to start immediately and is the critical component to kick-start the 5-year implementation plan.

## Optimization of the Existing DES

The DES optimization in Phase 1 is best accomplished by:

- Conducting detailed studies of the building heat exchanger performance and the operating characteristics of the various heat pumps on campus to select an ideal operating temperature;
- Improving compatibility of existing buildings with DES operating temperatures;
- Reducing the unnecessary cooling load in the summer by not conditioning academic building areas that are not occupied (ECM 1/2);
- Reducing the interior cooling load by reducing the cooling of electrical components that operate continuously with little or no occupancy (electrical demand curves for the Academic);
- Reducing the winter heating loads by adjusting lab air flows, having operational heat recovery systems, shut down/reduce air flow to areas with low/no occupancy (ECM 3,5,6);
- Reducing electrical loads for lighting by lighting system upgrades (ECM 11); and
- Adding existing and new continuous cooling system heat rejection (data rooms) to reject the heat to the DES to assist winter heating (e.g., Library). The UBCO energy team could assist with identifying additional waste heat sources.

As the new buildings are added in Phase 1, there will be additional heat rejection to the DES from the cooling systems. There should be some reduction in the cooling heat rejection due to ECM 1/2, but backup capabilities do suggest an additional cooling tower/HX be added at the GEO Building in Phase 1. From a reliability perspective, this should already have been installed.

With the proposed shift to biomass heat with flue gas heat recovery in Phase 2, it is suggested that the CHP piping to the proposed biomass plant and GEO Building be installed early so that there is one heating season prior to the biomass system coming on line where the heat pump systems in the existing buildings can be operated for a time period to work out any problems. With the nominal 2 MW of heat available from the GEO Building boilers, groups of two or three existing buildings at a time can use the DES source heat to test out operations for a time period before cycling to the next group. This approach can also be used to test systems in newly constructed buildings, as needed.

In sum, the following actions are highlighted UBCO's energy team:

1. Perform further detailed studies on the selection of appropriate district scale infrastructure strategies (DES vs CHP) for the various building types.
2. Identify additional waste heat sources that could reject heat into the DES during the winter e.g. data centres and electrical rooms.
3. Confirm sufficient existing heating capacity to heat Phase 1 buildings.
4. Perform a study to show the performance (energy and cost) of the DES and the building side heat pumps during summer winter and shoulder seasons. Use this information to improve management of DES.
5. As part of the detailed feasibility for converting the CHP to biomass, evaluate the feasibility of using recovered heat from the flue gas as a heating source for the DES.
6. Following a successful biomass conversion, consider expediting the connecting academic buildings with standalone packaged boilers to CHP. This will immediately help to reduce GHG emissions and energy operating costs.
7. Prior to implementation of the biomass conversion, test the operation of the DES in cold winter heating mode by connecting the CHP and DES directly.
8. As the campus reaches full build out, loop the DES distribution in order to reduce system pressure and increase system flows (as per CTQ study) and add additional cooling towers as appropriate. Existing air cooled chillers, as they require it, could be replaced by water cooled chillers to reduce electrical energy use.

## Sequence of Recommended UBCO Energy System Upgrades

The following summarizes the recommended upgrades of the UBCO energy systems to reduce energy use and cost, reduce GHG emissions, improve operating efficiency, and accommodate the doubling of the area of the campus by 2030.

**Phase 1** consists of improving the operating efficiency of the existing buildings through ECMs and accommodating the growth of new buildings on campus. The steps consist of:

a. Reducing the excess use of electricity by significantly reducing the electrical use and demand when the buildings are not occupied. As the expenditure for electricity on campus is 80% of the annual energy costs, operating cost savings in electricity can fund other initiatives. See overall demand reduction recommendations and ECM 12.

b. Consolidate the use of buildings in the summer when program areas are underutilized to realize significant electrical operating savings. Figure 20 shows academic building peak electrical use in summertime which probably is due to summertime cooling, but to a large extent these buildings are unoccupied at this time.

c. Occupancy is low. Similarly, laboratory ventilation rates can generally be reduced when not occupied (see ECM 1/2 and 3).

d. Implementing heat recovery from exhaust air and plume heights can result in savings, as laboratory facilities are typically the highest energy users per square meter (ECMs 3 and 4).

e. Reducing or shutting down the remaining academic building systems when unoccupied can result in additional energy reductions (see ECM 5).

f. Re-lamping of the existing academic buildings with lower power LED lights for reduced lighting energy use and lower cooling load requirements (see ECM 11).

These recommendations will reduce the electrical energy demand and use as well as peak heating and cooling loads for the existing academic buildings while maintaining appropriate operating conditions.

The CHP and DES piping systems should be extended to serve the new buildings as appropriate. As the new piping goes by existing residential buildings, there is an opportunity to provide CHP heating to the ventilation and domestic hot water systems as appropriate. It has been identified that in Phase I there is the potential to connect the EM&E building to the CHP, given that new boilers are required. The campus therefore needs to consider the capacity of CHP to provide heat to EM&E as well as to new buildings; or alternately identify retrofits needed to allow 100% DES connection to the EM&E building.

While these energy use reductions are being carried out, the campus will continue to grow. An additional cooling tower/HX should be added to the GEO Building to accommodate the increased heat rejection from cooling loads. The

CHP and DES piping distribution systems should be upgraded and expanded to serve the new buildings.

In the transition between Phase 1 and Phase 2, there is the opportunity to verify and commission the winter operation of existing and new building heat pumps using the DES/GEO boilers as a heat source.

**Phase 2** brings a further expansion of buildings on campus and the addition of a biomass heating source to the CHP and DES systems. Any of the ECM issues identified for Phase 1 should be completed, if not already done.

The CHP and DES piping systems will be expanded as appropriate to suit the new buildings. As the new piping goes by existing residential buildings, there is an opportunity to provide CHP heating to the ventilation and domestic hot water systems as appropriate. The DES flow rate capacity will be increased by an additional connection to the GEO Building to meet the increased campus size.

A waste wood, 6MW biomass heating system with flue gas heat recovery is proposed to add capacity to the CHP and DES heating systems as well as provide a fundamental shift to a zero carbon emission heating fuel. It is proposed that the biomass heating system be the lead CHP heating system with the existing gas boilers modulating with shifts in the heating load. Modular biomass boilers will be sequentially shut down at lower heating loads. The maximum use of the biomass heating system should be made to reduce the campus heating operating cost and GHG emissions.

The biomass flue gas heat recovery system will be the primary heating source for the DES winter operation. As the recovered heat does not require the purchase of additional biomass fuel, it is essentially free of a fuel cost leading to cost efficient operation.

As academic and residential buildings reach their mid-life refit, the buildings will be upgraded with new building systems, as appropriate. These costs are not included in this study but will result in more efficient building operations.

**Phase 3** consists of the completion of a number of the system initiatives.

Additional buildings will be added to complete the planned expansion of the campus by 2030. The CHP and DES piping systems will be extended to serve all of the new buildings while remaining existing buildings will be connected as appropriate. The DES piping loop branches will be interconnected.

Additional biomass boiler modules will be added to meet the majority of the campus heating load with a carbon neutral fuel. There will still be some remaining GHG emissions due to peak loading and electrical related emissions. There is an opportunity to increase the size of the biomass heating system if off-site heating customers can be served. This could result in the carbon neutral operation of the campus building systems by using carbon offsets in the off-site heating system.

In summary, consideration should be given to the following as the campus grows and energy infrastructure expansion is executed over the next 15 years:

- Add heat rejection capacity to the DES as soon as possible in order to provide redundancy for existing campus cooling load and provide capacity needed for future growth.
- Expand DES for all future academic buildings and look for opportunities for heat rejection to the DES in the winter.
- As campus grows construct the additional DES connection to GEO-exchange building in order to increase the DES flow rate and capacity.
- Expansion of the CHP for ventilation and DHW heating in student residences and peaking/backup in academic buildings makes better business sense than distributed packaged systems.
- Expansion of a separate biomass plant connecting to the CHP will likely require an additional staff member. However, maintenance savings from avoiding packaged boilers are expected to be similar to the additional O&M cost of supervision.
- Expand CHP to all future buildings and all existing buildings as packaged systems reach end of life.
- Perform a detailed feasibility analysis to confirm business case for connecting all buildings to the CHP, and conversion to biomass, including the recovery of waste flue gas heat for both CHP and DES, an evaluation of O&M impact and costs of connecting buildings expected during the 5 year plan, and allocation of costs between SHHS and Facilities.

### TABLE 46: IMPLEMENTATION PLAN FOR ENERGY/CARBON CONSERVATION MEASURES

| Energy/Carbon Conservation Measures | <5 Years | 5-10 Years | 10-20 Years |
|---|---|---|---|
| Develop a 2 person dedicated energy team on campus to implement the infrastructure plan, monitor and report on campus energy and carbon performance. | ● | | |
| Establish 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 | ● | | |
| Develop a campus-wide Behavior Change Engagement Strategy to promote and support campus awareness for resource conservation and DSM strategies required for whole systems plan implementation | ● | | |
| Energy Conservation (ECMs) Existing Buildings: Implement ECMs 1, 2, 3, 5, 6, 11-12 to realize large electrical demand and cost savings, and make capacity available within existing DES for future growth. | ● | | |

| Energy/Carbon Conservation Measures | <5 Years | 5-10 Years | 10-20 Years |
|---|---|---|---|
| Energy Conservation (ECMs) Existing Buildings: Continue to Implement ECMs 4, 5, 8, 11-13 to realize large electrical demand and cost savings. ECM 8 and 13 consider as part of cyclical maintenance programs. | | ● | ● |
| Implement electrical demand reduction strategies when not occupied to reduce electrical energy use, and to expand capacity of DES. | ● | ● | |
| Engage UBCO Risk Management Services for lab air change rate reductions and other lab measures. | ● | | |
| Commission students to do background studies: summer/winter occupancy, lab energy reduction opportunities, electrical demand, night/weekend shut-downs. | ● | ● | |
| Continue with re-commissioning efforts on campus to improved existing building operations. | ● | ● | ● |
| Campus Scale Infrastructure: Perform a study to show the performance (energy and cost) of the DES and the building side heat pumps during summer winter and shoulder seasons. This study should also identify additional waste heat sources that could reject heat into the DES during the winter e.g. data centres and electrical rooms. Use this information to improve management of DES. | ● | | |
| Campus Scale Infrastructure: Complete a detailed business case and feasibility study for CHP and biomass expansion system integration. As part of this study, evaluate the feasibility of using recovered heat from the flu gas as a heating source for the DES. | ● | | |
| Campus Scale Infrastructure: Develop a biomass heating plant to feed into the CHP and configure biomass flue gas heat recovery system to heat DES in the winter. Prior to implementation of the biomass conversion, test the concept for flu gas heat recovery by connecting the CHP and DES directly. | | ● | ● |
| Campus Scale Infrastructure: Connect the DES loop south campus, add cooling towers for heat rejection. | ● | | ● |
| Campus Scale Infrastructure: Complete final infrastructure expansion in Phase 3. | | | ● |
| Update UBCO's *Design Guidelines*, *Technical Guidelines*, *LEED Implementation Guide*, and *Project Design Briefs* with guidance for energy performance of new construction and energy efficient systems. | ● | | |
| Pilot solar ready buildings to determine incremental costs of implementing solar PV on new construction projects. | ● | | |
| Plan for the integration of renewable energy technologies (i.e., building level PV, and solar PV Farm) as the business case becomes more viable. | | ○ | ● |
| Set up the program and start research for development of strategic Embodied Carbon Framework and include recommendations in UBCO's Design Guidelines. | ● | | |
| Consider off-site partnerships with City of Kelowna FortisBC, adjacent Airport Development, to establish availability of green gas for cooking, and to sell excess heat off-site to reach carbon neutrality by 2050. | ● | ● | ● |

## 4.13 FUNDING MECHANISMS

There are several opportunities that UBCO can explore to the fund the energy and carbon measures presented in this *Infrastructure Plan*.

As indicated previously, UBCO has already realized immediate operational cost savings from the implementation the FortisBC Building Optimization, completed in June 1015. This work showed projected operational cost savings of $150,000/yr for the buildings analyzed in the study. Similarly, UBCO's successful implementation of the Power of You energy engagement and awareness program has also resulted in operational savings.

Combined, these savings should be captured in a revolving fund that can grow and provide the initial seed funding to kick-start the implementation of recommendations found within the *Whole Systems Infrastructure Plan*. For example, this seed funding could provide the capital for establishing an energy management team on campus or funding for other priority measures noted in this plan.

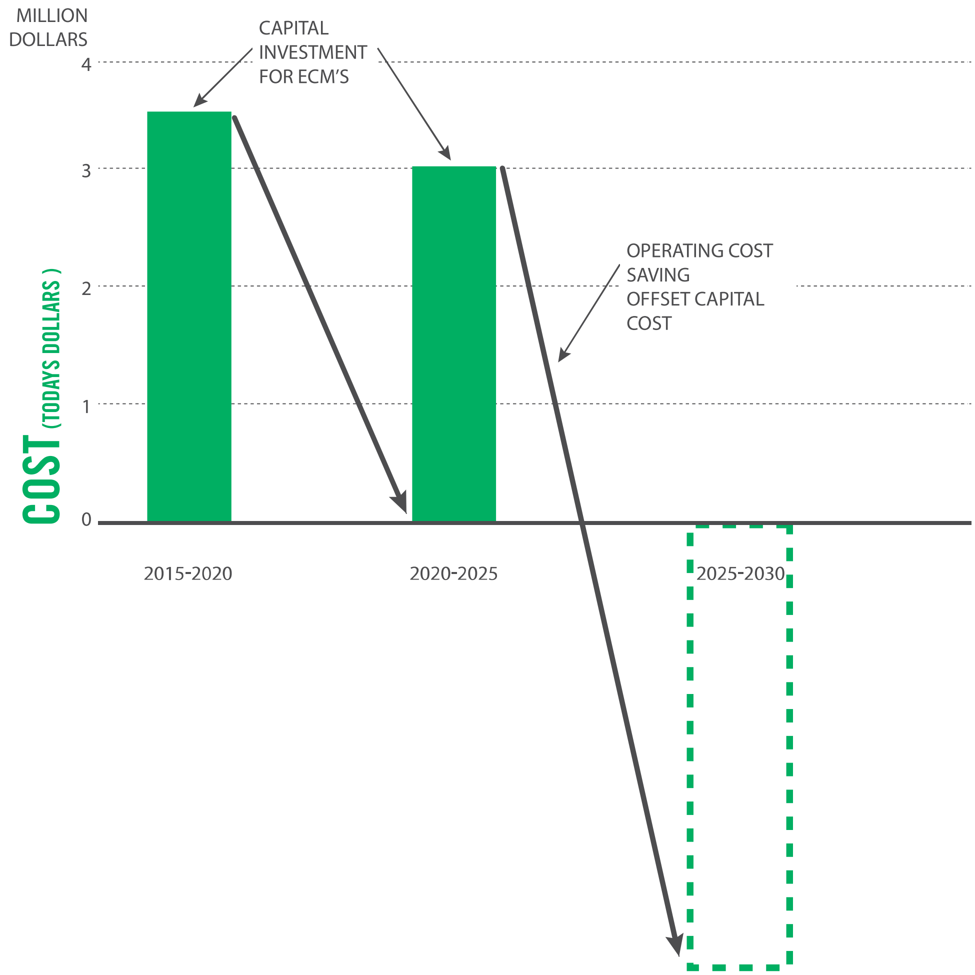



FIGURE 43: CAPITAL INVESTMENTS (EXISTING ECMS) PAYING OFF OPERATIONAL SAVINGS OVER TIME

Additionally, initial investment in those ECMs that realize near-term electrical energy use savings (with limited GHG reductions) can provide funds to carry out the ECMs that are related to reductions in gas use (less operating cost reductions but significant GHG reductions). A combination of electrical and gas use reductions in the existing buildings can lead to $9.63 million in savings from 2015 to 2030 by the application of the ECMs. Similarly, as seen with the Power of You campaign, there will continue be significant opportunity for electrical demand-side savings and potentially within the range of $100,000 per year in electrical savings.

Figure 43 shows how investments in ECMs between 2015 to 2020 are effectively offset by the accumulated energy cost savings until the next wave of capital investments in ECMs starts in the 2020 to 2025 time frame. The graph clearly shows that the earlier that the ECMs are implemented, the faster the energy savings accrue to offset the investment costs, and provide early reductions in GHG emissions.

It should be noted that switching to biomass as a fuel source also reduces operating cost as the cost of biomass fuel including transportation is cheaper than natural gas (based on today's fuel cost data). Figure 44 shows an estimate of how campus operating cost per building area will reduce from around $20/m$^2$ today to $7/m$^2$ by 2030 (in today's dollars) if UBCO upgrades its existing buildings, builds new efficient buildings, and switches to a biomass system as alternative fuel source.

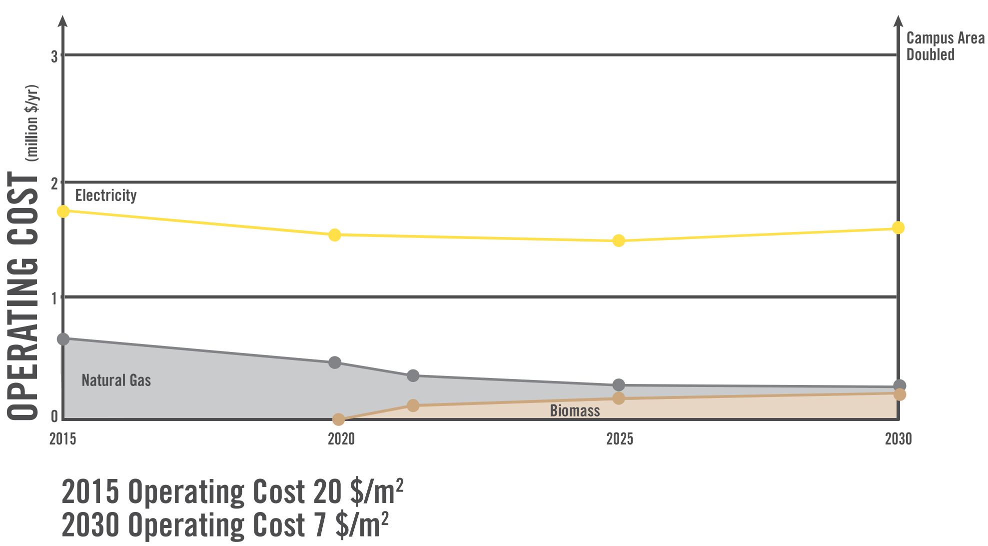



FIGURE 44: CAMPUS OPERATING COST REDUCTION OVER TIME WITH SWITCH TO CHEAPER BIOMASS FUEL

Additional funding sources that should be explored in greater detail include, but not limited to:

1. **Government funding** (e.g. Carbon Neutral Capital Fund).
2. **Regular Work Program funding** (e.g. deferred maintenance, routine capital).
3. **Return on investment funding:** Treasury loan based on agreed capital, term and lending rate, repaid through operational cost savings.
4. **Public private partnership:** Third party owned and operated infrastructure.
5. **Major project funding 1:** Project budget allocation for integration of project boundary with existing infrastructure.
6. **Major project funding 2:** Development levy for funding of infrastructure growth.
7. **Donor funding/Campus Plan initiative:** To fund incremental costs above BAU.

## Incentives

FortisBC provides incentives for new construction and retrofit programs through its Custom Business Efficiency Program. The program includes: funding for an energy modelling study, support from the PowerSense technical advisor, rebates for energy efficient measures including lighting and lighting control systems and whole building systems including mechanical. Baseline for lighting is the BC Building Code (Currently ASHRAE 90.1-2010 or National Energy Code for Buildings (2011) and rebates for lighting are $0.10 per annual kWh saved. Incentives are not included in the cost-benefit analysis as part of this study.