ECM 1 can theoretically be implemented immediately, it is low cost and requires UBCO coordination. However, in reality with complex logistics and many unknowns, it is recommended to implemented as much as possible as an ongoing effort. This ECM should be included early in the 5 year plan.

This ECM has overlap with ECM 2, and the total savings are consolidated for these two measures.

BENEFITS	CHALLENGES
• Low capital cost • No new infrastructure • Large operational energy and cost savings • Demand side management • Expands DES cooling capacity	• Logistics • Timing • Minimal carbon reduction

ECM 1—Building Use Consolidation	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 2—Lab ACH Night Set back

Labs account for 17% of academic spaces (wet labs and general labs), but they are very energy intensive and operate 24/7. This ECM analyzes air changes per hour (ACH) during the night-time when labs are unoccupied, while still maintaining the required indoor conditions and air quality. This ECM was investigated as there is potential for large energy savings (electricity and gas).

Some labs have already reduced ventilation rates, but these can reduced much further during long unoccupied periods such as at night. Night-time setbacks (assume for 50% of hours) do not impact peak demands or equipment capacity. Lab ventilation was reduced to 50% air change rate during night time (i.e. 10 ACHs set back to 5 ACH). Savings were calculated as a percentage reduction of annual lab heating gas and HVAC electricity. Implementing this ECM is very achievable, it requires a one-time control schedule adjustment.

Night set backs are also low cost, easily implemented and result in notable gas and electricity savings. ECM 2 is recommended to be immediately incorporated in UBCO's 5 year plan as part of ongoing maintenance & building commissioning.

ECM 2 has overlap with ECM 1, and the total savings are consolidated for these two measures.

BENEFITS	CHALLENGES
• Low capital cost, short payback • No new infrastructure • Large energy and energy cost savings • Large carbon reduction	• Logistics • Timing

ECM 2—Lab ACH Night Set-Back	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 3—Lab air heat recovery, unoccupied airflow reduction

This ECM analyzes recovering heat from the lab exhaust air, captured for building reuse. To be conservative this ECM assumes that all lab spaces already have night-setbacks so there is no overlap (see ECM 2 for details; daytime 10 ACH and night-setback to 5 ACH). Even with night setbacks assumed, a lot of air is being conditioned and exhausted from labs, so there is potential for significant heat recovery. Currently a few buildings' systems already have heat recovery, and this ECM is in addition and applied to all other lab areas.

Space setpoints in winter are assumed to be 21°C occupied and 18 °C unoccupied, based on coordination with building operations and list of systems setbacks provided from UBCO. Heat recovery effectiveness is estimated at 50%, meaning half of the sensible heat in the exhaust air is usable for heating cooler incoming outdoor air. Heat recovery effectiveness was artificially chosen low, at only 50%, to capture other system losses (i.e., increased fan and pump energy), and as it may not be implemented on each/every system. New heat recovery equipment will need to be installed in lab exhaust air (EA) systems, such as; heat wheel, run-around coil, and/or Water-to-Water HP.

ECM 3 has a higher cost as it requires new equipment to be installed, however it will result in significant energy cost and GHG emission reductions, and is recommended to be included in the 5 year plan.

This ECM has overlap with ECM 1 and 2, and the savings are based on these measures being implemented.

BENEFITS	CHALLENGES
• Energy and energy cost savings • Large carbon reduction	• Capital Cost • Maintenance

ECM 3—Lab air heat recovery, unoccupied airflow reduction	BIODIVERSITY	WATER	STORMWATER	**ENERGY**	WASTE

ECM 4—Lab Air Quality Management—Indoor air quality monitoring AirCuity

Air quality is very important in lab spaces, when various chemicals and occupants may all be sharing a space. This ECM utilizes a control system that employs accurate indoor air quality sensors to modulate lab ACH during occupancy while maintaining and monitoring indoor air quality. A benefit of this ECM is that equipment lasts longer. This ECM was considered by UBC Point Grey, but was not implemented due to the additional sensors, required calibration and maintenance.

The energy savings were estimated based on actual installed fan power and independent case studies as published by AirCuity. The AirCuity system provides real-time air quality sampling (via air quality sensors and a network of air sampling tubes) with the aim to reduce air change rates when air quality is good. The results estimate 30% of cooling energy, 50% of gas heating and 50% of fan energy savings during daytime occupied hours. A new air quality monitoring system will need to be installed in each lab EA system, in order to monitor and modulate air flow rates. Supply and return air boxes will also need to be installed. They accurately track air flow differential, as oppose to standard VAV boxes that would not be as accurate.

ECM 4 and 5, while different, both result in less HVAC energy by reducing the amount of air associated with labs. They each require additional monitoring systems to be installed to control air flow rates. These can be included in the 10 year plan, as they require time to complete upgrades and integrate to existing systems. ECM 4 will be more disruptive for occupants as it will likely involve work throughout the exterior and interior of buildings.

BENEFITS	CHALLENGES
• Large energy cost savings • Good carbon reduction • Improved indoor air quality	• Capital Cost • Maintenance

ECM 4—Lab Air Quality Management—Indoor air quality monitoring AirCuity	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 5—Lab EA Plume Height Reduction / Wind system

The exhaust air (EA) plume height is required to ensure adequate dispersion of any contaminants the EA lab may contain so that the impact on adjacent buildings and people is minimized. However, the required plume height may be adjusted for outdoor weather conditions including wind direction and speed as well as ambient temperature. This ECM implements a control system and monitors outdoor weather conditions, to reduce Lab EA plume height as appropriate.

This is only applicable for Strobic type fan systems, which induce outdoor air into the EA stream to generate plume height. ECM 4 and 5 do not overlap, as ECM 4 involves reducing room air flow while ECM 5 involves reducing the amount of air induced by Strobic exhaust fans.

The energy savings were estimated based on actual installed fan power and independent case studies (CPP UBCO study of fan energy savings). The CPP study covers all Strobic fan systems in buildings; SCI, ASC, EME, FIP, and HSC (RHS). The annual Strobic fan energy savings are estimated at 61%, there are no cooling or heating savings. A new outdoor weather monitoring system will need to be installed and integrated with existing lab EA systems, so that induced air can be modulated based on outdoor and wind conditions.

ECM 4 and 5, while different, both result in less HVAC energy by reducing the amount of air associated with labs. They both require additional monitoring systems to be installed to control air flow rates. These can be included in the 10-year plan, as they require time to complete upgrades and integrate with existing systems. ECM 4 will be more disruptive for occupants as it will involve work throughout the exterior and interior of buildings.

Based on UBCO feedback and review, ECM 5 is recommended for implementation in the 5 year plan.

BENEFITS	CHALLENGES
• Large fan power reductions • Energy cost savings	• Capital Cost • Low carbon reductions • Maintenance

ECM 5—Lab EA Plume Height Reduction / Wind system	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 6—Academic Building HVAC night / (Excluding Labs)

Many of the academic buildings already have an unoccupied setback schedules for non-lab spaces, approximately 72% by area that shut systems off or set back temperature. This ECM estimates the energy savings by implementing setbacks in the remaining spaces without them (GYM, SCI 1st & 2nd floor, FIP except theatre, ASC 2nd & 3rd floors, RHS). It does not include labs (separately counted, refer to ECM 2).

Unoccupied setbacks are implemented for 10 hours on weeknights and 12 hours on weekends; net 44% time the HVAC system is shut off. It is assumed there are no nighttime cooling energy savings, due to OA economizer availability. Implementing this ECM is very achievable, it requires a one-time control schedule adjustment.

Night set backs are also low cost, easily implemented and result in notable gas and electricity savings. ECM 6 is recommended immediately, it can be incorporated in UBCO's 5 year plan as part of ongoing maintenance and building commissioning.

BENEFITS	CHALLENGES
• Short payback • No new infrastructure • Large energy and energy cost savings • Large carbon reduction	• Logistics • Timing

ECM 6—Academic Building HVAC night / (Excluding Labs)	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 7—Sewer Heat Recovery Residences

Heat can be recovered from residential sewer discharge, and the heat can be utilized to reduce energy needed for domestic hot water (DHW). The average person consumes 12.7 gal/day of DHW (per ASHRAE), all of which gets discharged after use without fully utilizing all available heat.

To target GHG emissions, this ECM is applied to all residential buildings with DHW gas systems. This ECM was implemented as much as possible, and each residential building was looked at. Except the Cascades did not have the infrastructure to support this ECM, they were not included as they have an all electric systems.

Sewage heat recovery was looked at with a system like the Pirhana, for more detailed info see Appendix H. It has a COP of 5.14 and 82% heat recovery effectiveness (from Pirhana report findings). The small amount of electricity consumption to operate the system, is more than offset by heating gas savings. However, the capital cost of a new Pirhana type system retrofitted into existing buildings can be prohibitive.

ECM 7 can be included in the long-term plan for further study. While sewage heat recovery is currently a cost prohibitive option, this may become feasible in the future by coordinating the implementation with other residential work. This ECM is more cost prohibitive for retrofits but far more applicable for new residential projects. It can provide large GHG emission reductions for all residences as an alternative to connecting to CHP expansion with biomass.

BENEFITS	CHALLENGES
• Modest utility cost savings • Carbon reduction	• Capital cost • Maintenance

ECM 7—Sewer Heat Recovery Residences	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 8—Washroom Exhaust Heat Recovery Residences

Heat can be recovered from residential washroom exhaust air systems. This ECM targets all residential buildings with gas heating systems and roof level exhaust outlets. After coordination with UBCO it was determined feasible for 100% of the Monashee and Similkameen buildings exhaust air systems. A heat recovery system is already implemented in Nicola, Cassiar, Cascades and Purcell. This ECM is only suitable for buildings with centralized, vertical exhaust air systems, and would be difficult to implement in Kalmalka and Valhalla.

Spaces are assumed to be air conditioned 24/7 with 21°C setpoints. Similar logic to ECM 3, the heat recovery effectiveness is estimated at 50% to be conservative and account for system losses. New heat recovery equipment will need to be installed in washroom exhaust air (EA) systems (such as new rooftop heat recovery unit), and can be implemented as existing systems need to be replaced. The capital cost of this may be prohibitive if there is no central exhaust system, and many small dispersed EA systems.

ECM 8 does not have large savings on a campus scale, as it has already been implemented at some residences and is only recommended for an additional two buildings. Based on UBCO's feedback, this ECM is not recommended for the 5 year plan, but should be considered as part of cyclical maintenance in Phase 2 and 3. For new buildings, heat recovery is highly recommended as a best practice.

BENEFITS	CHALLENGES
• Modest utility cost savings • Carbon reduction	• Long payback • Maintenance

ECM 8—Washroom Exhaust Heat Recovery Residences	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 9—Residential Heat Pump (for ventilation air heating and cooling)

This ECM is applied to all residences with gas heating systems, which is all residences except the Cascades. Air-source heat pumps (ASHP) are an energy efficient way of heating residences. An additional benefit is large GHG savings by replacing gas heating systems with lower carbon electricity consumption. Spaces are assumed to be conditioned 24/7 with 21°C setpoint.

Air-to-air HP efficiency varies by outdoor temperature. Below 4°C heat pumps operate in defrost cycle (supplemental heating is required), the gas savings were de-rated by an estimated 50% to account for this. Below -8°C the heat pumps cannot operate, and as such there are no gas savings during these times, limiting carbon reductions. The existing gas heating system was assumed to be at 90% efficient MAU which is high, as most older systems are 80% rated with lower annual efficiencies. The capital cost of installing a heat pump, the fact that it uses more expensive electricity to run the compressors, in addition to maintaining existing gas heating systems, makes this ECM less economically feasible. There is a bonus of providing cooling or tempering of the ventilation air for buildings that operate in the summer. If an AC unit were required anyway, the air source heat pump modification would be a small incremental cost. Summer cooling may be a requirement for summer use buildings in the future as the summers are getting warmer.

ECMs 9 and 10 should be evaluated in comparison to connecting to a campus wide CHP expansion with biomass for residences to achieve the long term carbon plan. The cost of installing ECM 9 HPs and ECM 10 hybrid DHW heat pump in addition to maintaining existing boilers required, may or may not be worth the potential gas and GHG emission savings. ECM 9 should be prioritized above

ECM 10, as it has much higher impact due to frequency and duration of space heating compared to DHW usage. These measures are included in the Bundle comparison, see "Bundles of Measures for Carbon Neutrality" section, but are not included as the recommended option to achieve the most carbon savings compared to the option of connecting existing residences to CHP expansion with biomass.

BENEFITS	CHALLENGES
• Modest utility cost savings • Large carbon reduction	• Capital cost • Maintenance

ECM 9—Residential Heat Pump (for ventilation)	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 10—Residential Hybrid DHW System

A hybrid electric DHW heat pump ECM is applied to all residences with gas DHW systems. The DHW heat pump connects to the existing hot water system, in parallel to a gas hot water tank, and allows gas to shut off when the hybrid DHW operates (during operation electricity is consumed). This allows for electricity and gas fuel switching. This DHW heat pump-type equipment cannot operate below 7°C ambient temperature, resulting in no gas savings during these times. Hence it limits the carbon reduction potential. Gas savings were discounted for lower summer occupancy (May to September).

The DHW heat pump has a COP of 2.5. The daily ambient outdoor air temperature, from historical weather data, was used to determine that the system can operate for 34% of annual hours. When it is cold outside, the DHW heat pump cannot operate, and when it is hot out demand is low. Similar to ECM 9, the capital cost of installing a new DHW heat pump, the fact that it uses more expensive electricity to offset cheaper gas, and integrating it with the existing gas system, makes this ECM less economically feasible.

ECMs 9 and 10 should be evaluated in comparison to connecting to a campus wide CHP expansion with biomass for residences to achieve the long term carbon plan for the campus. The cost of installing ECM 9 HPs and ECM 10 hybrid DHW HPs, in addition to maintaining existing boilers required, may or may not be worth the potential gas and GHG emission savings. ECM 9 should be prioritized above ECM 10, as it has much higher impact due to frequency and duration of space heating compared to DHW usage.

BENEFITS	CHALLENGES
• Some carbon reduction	• Low operational cost savings • Capital cost • Maintenance

ECM 10—Residential DHW Hybrid System	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 11—Lighting Power Upgrades (Academic+Residences)

Lighting power accounts for approximately 15-20% of the existing campus buildings annual energy use[5]. The savings associated with this ECM are based on a lighting takeoff from the existing building drawings (academic+residences) and it is recognized that some lighting upgrades have taken place in the existing buildings.

This ECM recommends opportunities for further significant savings by upgrading the lighting system to current LED technology through the use of luminaire retrofit kits and LED replacement lamps. In conjunction with any retrofit program, illumination levels should be reviewed and adjusted so that spaces are not over lit (or under lit). Occupancy sensor lighting controls should be added wherever possible. Addition of daylight sensing controls should be considered in locations where upgrades to dimmable LED luminaires/lamps are made and daylight is available. These lighting controls are consistent with the current Provincial Energy code, NECB 2011. Some of the residences have limitations on LED upgrades and this has been taken into account.

Because the hours of operation in the residential building student rooms and suites is low, investment should be first made in retrofitting academic buildings first where the hours of operation are longer. Some retrofits have already been made including some upgrades to LED. Continuing this program especially as LED efficiency continues to improve will see even better energy results. ECM 11 is recommended to be included in the 5 year plan and to be continued in the 10 year plan for longer term implementation for buildings that have already undergone some lighting upgrades.

BENEFITS	CHALLENGES
• Large operational cost savings • Demand side management • Short payback	• Compatibility with existing lighting fixtures • Low carbon savings

ECM 11—Lighting Power Upgrades	BIODIVERSITY	WATER	STORMWATER	ENERGY	WASTE

ECM 12—Plug Load Controls

Receptacle load control is generally not applied to existing buildings but account for approximately 10-15% of the existing campus buildings[6].

This ECM recommends receptacle load controls in the form of occupancy sensor power bars for office spaces and other areas where plug loads can be reduced without impacting research and other important functions. Software policies should be reviewed to ensure computers shut down when idle or not in use. For the residences receptacle load controls should be considered in the form of

5 Based on energy audit data completed by SES Consulting for existing legacy buildings
6 Based on energy audit data completed by SES Consulting for existing legacy buildings

occupancy sensor power bars and vacancy sensor controls for the rooms. This ECM assumes that 20% of the electrical plug-load can be reduced, which is a conservative assumption as it is possible to reduce plug-loads further if these kinds of measures are carefully implemented.

In conjunction with receptacle load control measures, behaviour change by residents and staff needs to be encouraged to teach occupants to turn off loads when they are not required.

ECM 12 is recommended to be implemented in the 5 year plan for immediate energy cost reductions and demand side management.

BENEFITS	CHALLENGES
• Low hanging fruit • Large operational cost savings • Short payback • Demand side management • Easy to install and manage	• Behavioral change • Low carbon savings

ECM 12—Plug load controls	BIODIVERSITY	WATER	STORMWATER	**ENERGY**	WASTE

ECM 13—Exterior Lighting

Exterior lighting is currently a combination of metal halide and compact fluorescent building mounted luminaires and high pressure sodium and metal halide area lights which are being converted to LED.

This ECM recommends upgrading the exterior lighting system to LED to save on exterior lighting power and operational costs. Luminaire takeoffs have been done for all campus buildings to estimate the saving potential. Illumination levels should be reviewed and adjusted as part of the upgrade program to ensure adequate lighting levels from a safety perspective at nighttime. The current provincial energy code (NECB 2011) also requires daylight control on exterior lighting that is recommended to be considered for the existing operations.

ECM 13 is not recommended in the 5 year plan; rather it should be considered as part of policy updates to UBCO's *Design Guidelines* and implemented in Phase 2 and 3 as operations and maintenance cost savings are better understood.

BENEFITS	CHALLENGES
• Some operational cost savings • Demand side management	• Low carbon savings • Longer payback

ECM 13—Exterior Lighting	BIODIVERSITY	WATER	STORMWATER	**ENERGY**	WASTE

ECM 14—Academic Heat Recovery Chiller

Legacy buildings are connected to DES as well as CHP for heating, but use air-cooled-chillers for cooling. During shoulder seasons with simultaneous heating and cooling demands, a heat recovery chiller can result in heat savings. The heat created by the chiller can be captured and used for heating in the DES system for a low heat sink temperature of 16°C and higher heat pump efficiency COP. Another way of looking at it is that a heat recovery chiller runs more efficiently by rejecting heat into the CHP. This ECM is applied only to legacy buildings: Science, Arts, Admin, Library, Gym and Fine Arts/Creative Studies. The energy savings are estimated by chiller electricity savings, with no gas savings.

The shoulder season typically occurs when outdoor temperatures are between 13°C and 24 °C, which makes up 28% of annual hours. The average chiller efficiency was assumed to be 0.9 kW/ton. Based on engineering best practices, the heat recovery chiller was sized for 20% of the peak cooling capacity. This ECM is most cost effective if implemented when the existing chiller has reached the end of its life or if additional capacity is required. Otherwise the capital cost of installing a new heat recovery chiller, and integrating it into the existing systems, is cost prohibitive and disruptive to building operation.

While ECM 14 has some operational cost savings, it shows moderate carbon reductions with long payback. This measure is not included in the *5-Year Plan*. Independent of this ECM, when air cooled chillers require replacement, also consider going to water cooled chillers connected to the DES to reduce summer electric demand.

BENEFITS	CHALLENGES
• Operational cost savings • Energy savings • Demand side management	• Low carbon savings • Maintenance of heat pumps

ECM 14—Academic Heat Recovery Chiller	BIODIVERSITY	WATER	STORMWATER	**ENERGY**	WASTE

Recommissioning

All buildings can benefit from recommissioning and appropriate operational scheduling. Implement set-backs as much as possible to reduce HVAC energy consumed during unoccupied and night times. Lighting retrofits, typically incentive based, can reduce electricity consumption. Recommissioning is currently occurring for some buildings on campus. This effort is recommended to continue and expand by setting up a dedicated Campus Energy Team to help implement, monitor and take ownership of delivering continued savings. Recommissioning and an Energy Team are recommended to be set-up and organized as part of the 5-year implementation plan.

Recommissioning	BIODIVERSITY	WATER	STORMWATER	**ENERGY**	WASTE

Cyclical Maintenance

This study does not focus on building by building specific systems or measures; however, end of life upgrades should be considered in light of the long term sustainability goals and it is recommended that the UBCO *Design Guidelines* include a section on existing building upgrades.

The Residences are built between 1992 and 2010, with the majority of construction happening between 1992 and 1994. The Academic Legacy buildings are built between 1992-2004, and the Newer Academic buildings between 2008-2010. It has been recognized that two of the residences, Monashee and Similkameen, both built in 1992, are especially in need of upgrades, and it is also understood that none of the buildings have undergone envelope upgrades since their construction.

As building envelopes and roofs need major upgrades or replacement, the thermal and air tightness of the envelope components should be upgraded to reduce the amount of annual energy needed. Thermal imaging is very effective to identify weak spots in building envelope and it is recommended to be part of a campus policy for any upgrades. As a number of buildings are reaching their end of life for envelope performance, it is recommended that envelope upgrades are completed as high performance to reduce the loads as much as possible and provide improved thermal comfort. See Section 4.6 New Construction—Measures for Improvement, Passive House Concept for ideas of thermal performance values. Building upgrades also provide opportunities to update the building mechanical systems and install water reuse systems.

Opportunities exist, but are not limited, to:

- Envelope upgrades
- Stand-alone HVAC system vs connecting to campus expanded CHP with biomass (as recommended in this study)
- Chiller to HR chiller for simultaneous heating/cooling opportunities
- Boilers converted to heat pumps, alternatively connecting to campus expanded CHP with biomass
- Heat recovery ventilation
- Lighting upgrades
- Purple pipe ready

It is recommended that UBCO focus on maximizing efficiency and minimizing carbon emissions when cyclical replacements are required. The incremental cost and the energy business case should be evaluated as part of this process for each major building and system upgrade.

Existing Buildings Energy, Cost and GHG Saving Potential

The performance of the suggested ECMs have been summarized to understand the potential for total energy savings (natural gas and electricity), GHG reductions, and energy cost savings compared to existing campus operations. Figure 23 summarizes the overall existing buildings' reduction potential.

The following sections summarize the saving potential per ECM per year, with suggested phasing.

It should be noted that some of the ECMs, due to the fuel source mix they reduce, result in the following three scenarios:

1. large cost savings as well as GHG savings;
2. large cost savings but small GHG savings; and
3. small cost savings but large GHG savings.

As mentioned, large electricity savings result in large operational costs but not as large GHG emissions. These measures are important to invest in from a power demand reduction standpoint, and the operational savings can be used to fund carbon reduction measures.

Recognizing that electrical demand can be reduced further by focussing efforts on demand-side management strategies, an additional savings of $100,000 per year (1,300 MWh) has been accounted for in the ECM 1/2 performance analysis.

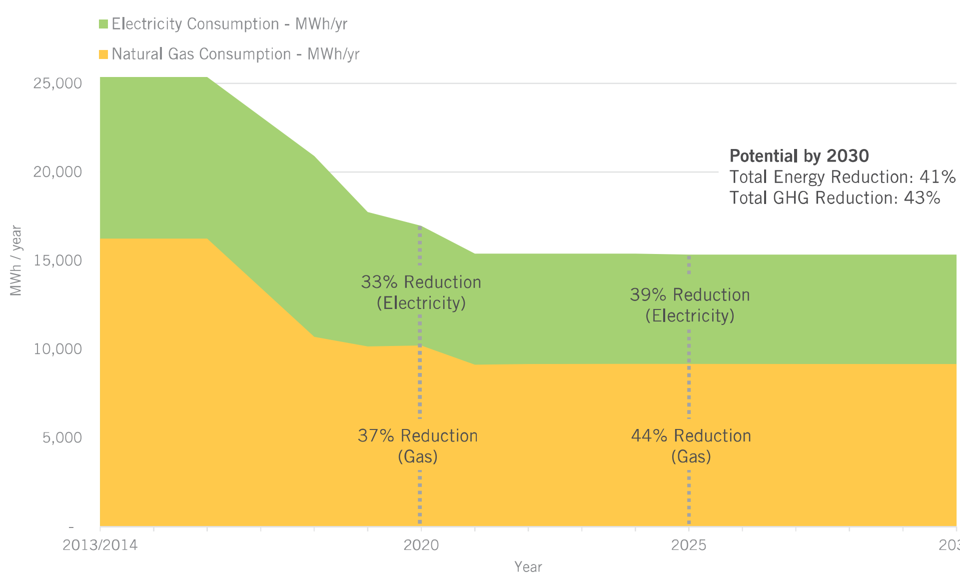


FIGURE 23: SUMMARY OF EXISTING BUILDING ENERGY REDUCTION POTENTIAL [BY IMPLEMENTING ECMS (TODAY'S DOLLARS)]

ECM Energy Savings

In consultation with UBCO, Table 16 summarizes ECMs prioritized per phase, and associated energy savings (natural gas and electricity).

TABLE 16: SUMMARY OF TOTAL ENERGY SAVING POTENTIAL— (KWH) PER ECM PER PHASE

ECM	ECM DESCRIPTION	KWH SAVINGS PER YEAR, PER PHASE AND ECM		
		2015-2020	2020-2025	2025-2030
ECM 1/2	Building Use Consolidation (combined with ECM 2)	—	—	—
ECM 1/2	Lab ACH Night Set back	6,002,328	—	—
ECM 3	Lab air heat recovery, unoccupied airflow reduction	4,392,806	—	—
ECM 4	Lab Air Quality Management—Indoor air quality monitoring AirCuity	—	2,137,731	—
ECM 5	Lab EA Plume Height Reduction / Wind system	857,200	—	—
ECM 6	Academic Building HVAC night / (Excluding Labs)	815,930	—	—
ECM 7	Sewer Heat Recovery Residences	—	628,435	—
ECM 8	Washroom Exhaust Heat Recovery Residences	—	130,000	—
ECM 9	Residential Heat Pump (for ventilation)	—	373,570	—
ECM 10	Residential Hybrid DHW System	—	156,842	—
ECM 11	Lighting Power Upgrades (Academic+Residences)	1,276,504	297,268	—
ECM 12	Plug Load Controls	320,231	320,231	—
ECM 13	Exterior Lighting	—	51,286	51,286
ECM 14	Academic Heat Recovery Chiller	—	379,427	—

In summary, the energy consumption saving potential for the ECMs compared to current campus operations, is as follows:

- **Energy Savings per Year after 2030[7]: .... 18,200 MWh**
- **Energy Reduction Potential Compared to Today:.......... 44%**
- **Accumulated Energy Savings 2015-2030[8]:.................... 181,900 MWh**

Large cost savings as well as GHG savings

Large cost savings but small GHG savings

Small cost savings but large GHG savings

The cost and emissions savings tradeoffs are important to understand when prioritizing investment in the various measures, depending on the desired result (i.e., carbon reduction or cost savings). The major impact per ECM has been highlighted with the color scheme noted above.

7 This excludes ECM 10, as ECM 7 is included. ECM 10 is an alternative to ECM 7 to reduce GHG from DHW in residences and ECM 10 is included as the more effective option in the total summary.

8 Assuming phasing of the ECMs during the 15 year period

ECM GHG Savings

The combined GHG reductions (natural gas and electricity) per ECM are summarized in Table 17.

TABLE 17: SUMMARY OF TOTAL GHG SAVING POTENTIAL—(TCO_2) PER ECM PER PHASE

ECM	ECM DESCRIPTION	TCO_2 SAVINGS PER YEAR, PER PHASE AND ECM		
		2015-2020	2020-2025	2025-2030
ECM 1/2	Building Use Consolidation (combined with ECM 2)	—	—	—
ECM 1/2	Lab ACH Night Set back	291	—	—
ECM 3	Lab air heat recovery, unoccupied airflow reduction	791	—	—
ECM 4	Lab Air Quality Management—Indoor air quality monitoring AirCuity	—	186	—
ECM 5	Lab EA Plume Height Reduction / Wind system	9	—	—
ECM 6	Academic Building HVAC night / (Excluding Labs)	87	—	—
ECM 7	Sewer Heat Recovery Residences	—	139	—
ECM 8	Washroom Exhaust Heat Recovery Residences	—	23	—
ECM 9	Residential Heat Pump (for ventilation)	—	141	—
ECM 10	Residential Hybrid DHW System	—	46	—
ECM 11	Lighting Power Upgrades (Academic+Residences)	8	6	—
ECM 12	Plug Load Controls	3	3	—
ECM 13	Exterior Lighting	—	1	—
ECM 14	Academic Heat Recovery Chiller	—	4	—

Large cost savings as well as GHG savings
Large cost savings but small GHG savings
Small cost savings but large GHG savings

The cost and emissions savings tradeoffs are important to understand when prioritizing investments in the various measures, depending on the desired result (i.e., carbon reduction or cost savings). The major impact per ECM has been highlighted with the color scheme noted above.

In summary, the greenhouse gas reduction potential for the ECMs compared to current campus operations is as follows:

- **Carbon Emission Savings per Year after 2030[7]:............ 1,698 tCO_2/yr**
- **Carbon Reduction Potential Compared to Today: 53%**
- **Accumulated Carbon Savings 2015-2030[8]: .... 16,979 tCO_2**

ECM Energy Cost Savings

The combined energy cost savings (from natural gas and electricity) per suggested ECMs are summarized in Table 18 with recommended phasing. Note that the cost savings shown here are based on today's cost and compared to current campus operations.

TABLE 18: SUMMARY OF TOTAL ENERGY COST SAVING POTENTIAL—($/YR) PER ECM PER PHASE (BASED ON TODAY'S $/KWH COST)

ECM	ECM DESCRIPTION	$ SAVINGS PER YEAR, PER PHASE AND ECM		
		2015-2020	2020-2025	2025-2030
ECM 1/2	Building Use Consolidation (combined with ECM 2)	—	—	—
ECM 1/2	Lab ACH Night Set back	400,473	—	—
ECM 3	Lab air heat recovery, unoccupied airflow reduction	148,605	—	—
ECM 4	Lab Air Quality Management—Indoor air quality monitoring AirCuity	—	121,982	—
ECM 5	Lab EA Plume Height Reduction / Wind system	65,447	—	—
ECM 6	Academic Building HVAC night / (Excluding Labs)	42,639	—	—
ECM 7	Sewer Heat Recovery Residences	—	14,803	—
ECM 8	Washroom Exhaust Heat Recovery Residences	—	4,398	—
ECM 9	Residential Heat Pump (for ventilation)	—	5,813	—
ECM 10	Residential Hybrid DHW System	—	860	—
ECM 11	Lighting Power Upgrades (Academic+Residences)	102,666	24,927	—
ECM 12	Plug Load Controls	25,963	25,963	—
ECM 13	Exterior Lighting	—	3,916	3,916
ECM 14	Academic Heat Recovery Chiller	—	28,969	—

In summary, the operational energy cost saving potential for the ECMs compared to current campus operations is as follows:

- **Energy Cost Savings per Year after 2030[9]: $1,010,000**
- **Energy Cost Reduction Potential Compared to Today: .. 41%**
- **Accumulated Energy Cost Savings 2015-2030[10]: .... $10.058 million (including carbon offsets)**

9 This excludes ECM 10, as ECM 7 is included. ECM 10 is an alternative to ECM 7 to reduce GHG from DHW in residences and ECM 10 is included as the more effective option in the total summary.
10 Assuming phasing of the ECMs during the 15 year period

Cost Analysis—Existing Building ECMs

Tables 19 summarize the costing analysis for the existing building ECMs on an individual basis. Details on the costing analysis, capital cost outlines, detailed assumptions, and cash flow analysis can be found in BTY's Economic Modeling Report in Appendix E. Bundles of recommended measures are combined in Section 4.8 Carbon Reduction Scenarios.

TABLE 19: CAPITAL COST AND ESTIMATED SAVINGS FOR EXISTING BUILDING ECMS

CAPITAL COST		PHASE 1 2015-2020	PHASE 2 2020-2025	PHASE 3 2025-2030	2030-2050	TOTAL	SIMPLE PAYBACK (YEARS)	NPC TO 2030 $
ECM 1+2	Building Use Consolidation / Lab ACH Night Set Back	$593,400	$0	$0	$0	$593,400	4	(3,607,100)
ECM 3	Lab Air Heat Recovery, Unoccupied Airflow Reduction	$1,114,600	$0	$0	$0	$1,114,600	7	(753,600)
ECM 4	Lab Air Quality Management—Indoor Air Quality Monitoring	$0	$2,511,200	$0	$0	$2,511,200	19	862,200
ECM 5	Lab EA Plume Height Reduction / Wind System	$720,100	$0	$0	$0	$720,100	12	(32,000)
ECM 6	Academic Building HVAC Night Setback (Excluding Labs)	$174,000	$0	$0	$0	$174,000	6	(311,800)
ECM 7	Sewer Heat Recovery Residences	$0	$1,676,500	$0	$0	$1,676,500	After 35	1,072,200
ECM 8	Washroom Exhaust Heat Recovery Residences	$0	$209,300	$0	$0	$209,300	29	114,400
ECM 9	Residential Heat Pump (for Ventilation)	$0	$260,000	$0	$0	$260,000	No Payback	209,100
ECM 10	Residential Hybrid DHW System	$0	$710,200	$0	$0	$710,200	No Payback	490,900
ECM 11	Lighting Power Upgrades (Academic + Residences)	$555,400	$147,600	$0	$0	$703,000	6	(1,743,700)
ECM 12	Plug Load Controls	$221,800	$233,000	$0	$0	$454,800	11	(106,400)
ECM 13	Exterior Lighting	$0	$174,700	$197,700	$0	$372,400	24	144,200
ECM 14	Academic Heat Recovery Chiller	$0	$1,306,600	$0	$0	$1,306,600	32	730,000
Total Capital Cost		**$3,379,300**	**$7,229,100**	**$197,700**	**$0**	**$10,806,100**		

SAVINGS (ESCALATED $)		PHASE 1 2015-2020	PHASE 2 2020-2025	PHASE 3 2025-2030	2030-2050	TOTAL
ECM 1+2	Building Use Consolidation / Lab ACH Night Set Back	($1,407,300)	($2,577,300)	($2,910,500)	$0	($6,895,100)
ECM 3	Lab Air Heat Recovery, Unoccupied Airflow Reduction	($740,500)	($1,053,200)	($973,400)	$0	($2,767,100)
ECM 4	Lab Air Quality Management—Indoor Air Quality Monitoring	$0	($794,700)	($871,800)	($5,646,700)	($7,313,200)
ECM 5	Lab EA Plume Height Reduction / Wind System	($150,000)	($416,000)	($482,100)	$0	($1,048,100)
ECM 6	Academic Building HVAC Night Setback (Excluding Labs)	($163,900)	($286,100)	($305,000)	$0	($755,000)
ECM 7	Sewer Heat Recovery Residences	$0	($89,500)	($117,000)	($712,800)	($919,300)
ECM 8	Washroom Exhaust Heat Recovery Residences	$0	($31,100)	($28,800)	($240,500)	($300,400)
ECM 9	Residential Heat Pump (for Ventilation)	$0	$16,300	$34,400	$0	$50,700
ECM 10	Residential Hybrid DHW System	$0	($8,900)	($9,100)	$0	($18,000)
ECM 11	Lighting Power Upgrades (Academic + Residences)	($676,700)	($1,508,500)	($1,728,100)	$0	($3,913,300)
ECM 12	Plug Load Controls	($61,500)	($340,500)	($395,700)	$0	($797,700)
ECM 13	Exterior Lighting	$0	($50,700)	($109,100)	($543,800)	($703,600)
ECM 14	Academic Heat Recovery Chiller	$0	($149,500)	($213,400)	($1,251,100)	($1,614,000)
Total Savings (Future Values)		**($3,161,500)**	**($7,653,300)**	**($8,828,300)**	**($8,612,200)**	**($28,255,300)**
Savings NPC		**($2,517,200)**	**($4,792,700)**	**($4,152,500)**		**($11,462,400)**

Evaluation Criteria Existing Building ECMs

Based on the four evaluation criteria established for the project, ten of the 14 proposed existing building energy conservation measures are supportive or highly supportive of:

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

A summary of the evaluation is presented in Figure 24 Evaluation of Existing Building Measures.

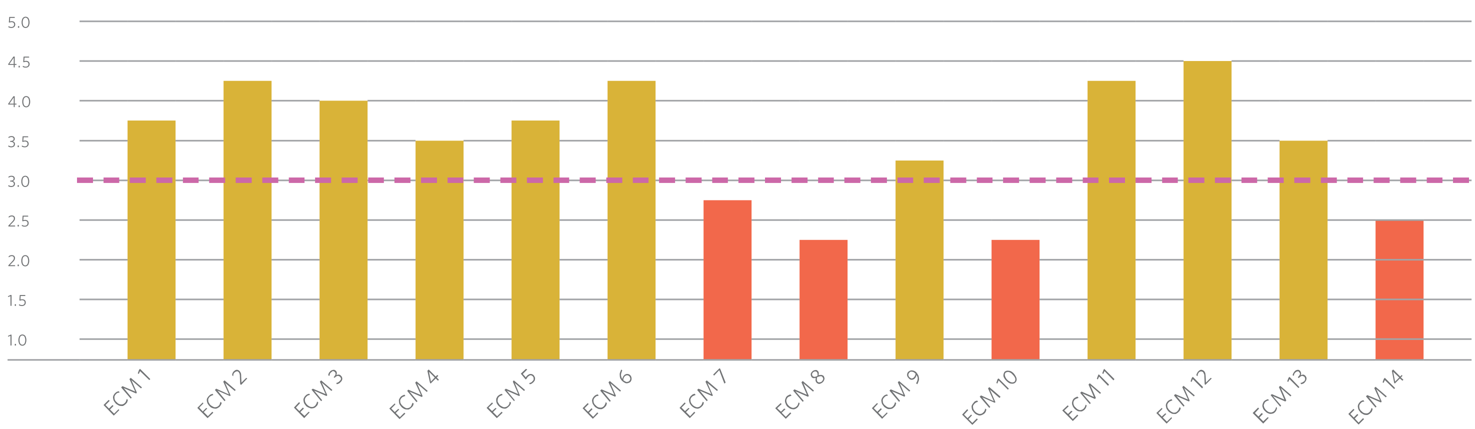


FIGURE 24: EVALUATION OF EXISTING BUILDING ECMS

In consultation with UBCO, the following ECMs were selected for implementation within the 5 year plan: ECM 1, ECM 2, ECM 3, ECM 5, ECM 6, ECM 11, and ECM 12. Whereas, ECMs 8 and 13 are considered as good practice and are recommended as part UBCO *Design Guidelines* updates and as part of cyclical upgrades of these systems in latter phases of implementation.

ECMs that are not recommended include: ECM 7, ECM 9, ECM 10. Note that these are residential ECMs where the evaluated systems are not cost beneficial and not as effective in reducing the carbon emissions compared to the option of connecting residences to the CHP with biomass for carbon neutrality as the more effective alternative. Note that sewage heat recovery for new buildings could still be an effective and viable option to be considered to achieve large carbon reduction savings.

Table 20 summarizes UBCO's preferred ECMs and implementation sequencing of them. As discussed for each ECM, certain ECM measures are easily implemented, and can result in immediate costs savings which could assist with funding carbon reduction based measures at a later date.

ECM	DESCRIPTION
ECM 1	Building Use Consolidation (combined with ECM 2)
ECM 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

Implementation Recommendations of Existing ECMs

TABLE 20: IMPLEMENTATION PLAN FOR EXISTING BUILDINGS ENERGY CONSERVATION MEASURES

Existing Buildings—Measures	<5 YEARS	5-10 YEARS	10-20 YEARS
ECMs			
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		●	●
ECM 14—Academic Heat Recovery Chiller			
Programs and Policy			
Develop a Campus Energy Team for continuous optimization of existing (and new) buildings	●	●	●
Commission students to do background studies: occupancy, lab energy reduction opportunities, electrical demand, and night/mechanical shut downs.	●	●	●
Engage Risk Management Services for lab ACH reduction.	●	●	●
Develop a funding program to use capital savings for energy infrastructure investments	●		
Develop education and training for behavioral change/implementation	●	●	●

**ECM is not recommended as the most cost effective option for the residences to achieve high carbon reductions as compared to connecting to a campus-wide CHP system with biomass as a heating source. Note that these building scale systems could still be a viable option on separate cases if upgrades are necessary and early carbon reductions are desired.

Residences and GHG Reductions

Residences currently account for 15-20% of total campus GHG emissions. This building typology and its natural gas consumption (mainly for ventilation and domestic hot water) is critical to address in order to achieve UBCO's long-term energy and carbon neutrality goals, both for existing buildings and for new construction.

Four suggested scenarios that address Existing Residences relative to UBCO's carbon neutrality goal are presented in Table 21.

TABLE 21: SUGGESTED SCENARIOS TO ACHIEVE CARBON NEUTRALITY—EXISTING RESIDENCES

SCENARIO	DESCRIPTION	BENEFIT	CHALLENGE	RECOMMENDATION
1. Business as Usual (BAU): No ECMs or Biomass CHP expansion to Residences	No implementation of ECMs for residences or connection to Biomass CHP expansion to reduce current carbon footprint	Low capital cost	No GHG reductions and it will be hard to achieve the long term carbon goal.	Not recommended
2. Residences Building scale ECMs, No Biomass CHP	Implement building scale ECMs (7,8,9 or 10) to reduce carbon, such as sewage heat recovery, heat pump preheat (ventilation and DHW)	• Achieve quick carbon EUI reductions. • Smaller commitment keeping a de-centralized system.	• Not cost effective as it uses more expensive electricity to offset high carbon less expensive natural gas. • Does not achieve carbon neutrality for residences.	Not recommended generally based on evaluation criteria, but is the next best option to achieve the long term carbon reduction goals for UBCO.
3. Residences connected to Biomass CHP (no ECMs)	Do not invest in building scale ECMs, but invest in CHP expansion with biomass as fuel source. Connect existing residences as new buildings come online.	• Significant GHG reductions. • Smaller mechanical system as HX replace boilers. • Operational cost savings as biomass fuel is half the cost of natural gas.	• Smaller EUI reductions. • Commitment to provide piping and transforming current residential HVAC system.	• Recommended to achieve maximum GHG savings • Indicated to be more cost effective than building scale measures (scenario 2).
4. Upgrade residences when needed, every 20-25 years	Apply building scale upgrades to residences when cyclical maintenance is required.	• Small commitment • Lower capital cost	Small EUI and GHG reductions. Will not quickly contribute to achieving the long-term goals.	Not recommended as it does not move the University towards its long-term targets quickly.

As noted earlier, two residential buildings are due for mid-life upgrades and others will follow. It is recommended as part of the UBCO *Design Guidelines* to address not only best practices for New Construction, but also along with this develop *Existing Building Design Guidelines* for upgrades. This could include, but is not limited to:

- Upgrade building envelope, insulation, air tightness, windows and frames;
- Upgrade building mechanical systems including suite HVAC, connection to CHP, Ventilation air heat recovery if appropriate, hydronic heating for make-up air, hydronic heating for DHW;
- Upgrade fixtures to high efficiency fixtures as outlined in the Water Chapter;
- Upgrade the building to be purple pipe ready;
- Connect to CHP for heating ventilation and DHW;
- New lighting and controls, BMS controls, suite occupancy switches; and
- Renewable energy connections.

4.6 NEW CONSTRUCTION—MEASURES FOR IMPROVEMENT

This study assumes that the UBCO Campus will double in building area, with an additional 87,000m^2 of academic space and 68,600m^2 of residential space by 2030. This would be in addition to the 82,700m^2 of academic and 49,500m^2 of residential building area as per the current existing campus. The rate of adding new buildings, as agreed by UBCO, is aggressive.

Incorporating energy efficiency in the new buildings by first reducing loads, then selecting an efficient system to meet the load, and further by, looking at renewable or carbon neutral energy sources to meet the load, should apply to all new builds, and it is recommended that UBCO's *Design Guidelines* clearly state the performance levels expected for new construction in order to achieve its long term carbon neutrality goal.

Proposed EUI Targets for 2020, 2025 and 2030

In order to project the energy load as campus grows over time, the *Whole Systems Infrastructure Plan* proposes EUI targets for new buildings to improve efficiency of the building stock over time and as the market evolves.

The recommended targets are derived and based on research leading to an ASHRAE Board Approved Plan for various published energy standards and included in the "ASHRAE Vision 2020—producing Net Zero Energy Buildings". The ASHRAE Standard 90.1 2010, one of the current BC Provincial energy code options, is the starting point for the proposed evolution of the energy standard. The ASHRAE 90.1 2013 Standard has been published and it is on track for the proposed reductions. Based on feedback from stakeholders involved with the development of the NECB code, the NECB will generally be consistent with the proposed ASHRAE energy reduction proposal.

These milestone reductions have been applied to the probable next version of the current BC provincial energy code, the draft NECB 2015 (taken from the National Code Public Review of NECB, dated 2013-09-23). This draft version of the code utilizes a shift toward the Energy Use Index (EUI) in kWh/m^2/yr and breaks down suggested EUI per building typology (office, education, residences applies to the campus). It should be acknowledged that the NECB 2015 EUI table is based on energy modelling of the NECB 2011 code.

The projection of the EUI targets until 2030 are consistent with the current 2015 Point Grey Campus targets and evolve following the proposed ASHRAE 90.1 standard reductions.

The NECB 2015 EUI targets are calculated based on NECB 2015 and based on NECB Kelowna heating degree days:

- Kelowna climate zone........................5 (Table 3.2.2.2 NECB 2011)
- Kelowna heating degree days...........3,400 HDD (<18°C)

The EUIs are calculated as per proposed NECB 2015 Table 8.4.1.2.:

- Offices ....EUI (kWh/m^2) = (0.008*3,400+95) = 122
- Education ....EUI (kWh/m^2) = (0.016*3,400+88) = 142
- Residences......EUI (kWh/m^2) = (0.012*3,400+94) = 135

In addition, separately derived targets for labs are modeled after the UBC Point Grey Campus targets for labs with low/high fume hood density and adjusted for heating degree days in Kelowna.

These EUI targets would be based on the electrical and heating usage (established from building energy metering) if the buildings are connected to the district energy system, excluding the effect of combustion efficiency at the boiler plants and distribution losses. As per NECB 2015 draft, plug-loads are included in these EUIs.

As discussed with UBCO, it was agreed that the typology education EUI is not the best representation for classrooms as the NECB 2015 code includes K-12 schools which includes kitchens, gyms, etc. It was agreed that a more reasonable target for the classroom type spaces is to match the office EUI target.

Based on above assumptions for 2025, 2020 and 2030, Table 22 recommends EUI targets for UBCO new construction projects.

PROPOSED EUI TARGETS

2015-2020
***25% reduction** over NECB 2015 (aligned with UBC Point Grey Targets)*

2020-2025
***40% reduction** over NECB 2015.*

2025-2030
***50% reduction** over NECB 2015.*

For Labs, using UBC Point Grey EUI targets adjusted for Kelowna heating degree days.

TABLE 22: PROPOSED EUI TARGETS FOR UBC OKANAGAN CAMPUS

	NECB 2015 (KWH/M^2)	PHASE 1 2015-2020 25% REDUCTION	PHASE 2 2020-2025 40% REDUCTION	PHASE 3 2025-2030 50% REDUCTION
Offices	122	92	73	61
Education[1]	122	92	73	61
Residences	135	101	81	67
Labs—high fume[2]	716	537	430	358
Labs—low fume[2]	571	428	343	286

* To get a total EUI add 20% to the above figures to account for plug loads.

[1] The Education EUI was replaced with the Office EUI as agreed with UBC.

[2] The Lab EUIs are based on the UBC Point Grey Lab EUI Report, fume hood high/low density, and have been adjusted for Kelowna HDD.

Using the existing campus residences as an example, the EUIs range from 88 to 291 kWh/m^2. Purcell is the lowest at 88 kWh/m^2 which is one of the newer and more efficient buildings with a ground source heat pump and solar hot water panel for DHW. If this building did not use the ground with efficient heat pump as a heating source, the EUI would be closer to the current NECB 2015 target.

The existing campus' new academic buildings range from 340 to 522 kWh/m^2, this includes on average 4% wet labs and 7% dry labs which drives up the EUI slightly. Significant attention should be given to the construction and scheduling operation of new academic buildings to achieve the proposed targets.

The EUI targets for Phase 3 buildings, both academic and residences, are in the 60-70 kWh/m^2 range for site energy. This is near to the EUI range of Passive House or "near Passive House" performance. Using this design concept requires a focus on maximizing envelope performance, minimizing active systems, and potentially using renewable energy to offset some of the energy load. The following section discusses Passive House performance requirements.

Passive House Concept

Passive House is a concept of very low energy consumption buildings that has evolved from Europe since the early 1990's. This concept, has in the past mainly been applied to residential buildings, but more and more commercial scale projects are certified and operating successfully as Passive House, including large multi-unit residential buildings (MURBs) and recently, a office tower (21 storeys) in Vienna, Austria.

The Passive House design concept focuses on five basic principles to significantly lower a building's energy load:

1. Super insulated envelope;
2. Thermal bridge free;
3. Airtight shell;
4. Superior glazing; and
5. Ventilation preheat / Heat recovery.

Some of the key benefits of Passive House design are:

- Heating energy and cost reduced ~80 to 90%;
- Improved occupant comfort;
- Heating load has to be < 15 kWh/m^2;
- Cooling load has to be < 15 kWh/m^2; and
- Primary Energy has to be <120 kWh/m^2.

As Passive House energy consumption is measured and calculated based on primary energy factors[11] (or source energy), the actual building EUI (site energy) would be in the range of 44 kWh/m^2 (based on an all electric building) to 77 kWh/m^2 (based on 50% electric, 50% natural gas). Given UBCO's long term goal of carbon neutrality and the low carbon emission from power generation in the region, achieving the 60-70 kWh/m^2 range as a Phase 3 Target indicates that the buildings would be designed to Passive House, or at least "near-passive house" standard.

11 Currently the Passive House primary energy factors for electricity is 2.7 and natural gas is 1.1. It is currently debated whether the primary energy factor for electricity is representable for the hydro electricity context in BC, but as of the date of this report, these factors currently stand as part of the International Passive House Institute requirements.

Table 23 provides Passive House suggested performance parameters for this climate. "Near Passive" parameters are suggestions, the optimal point for performance vs payback should be evaluated on a per building basis.

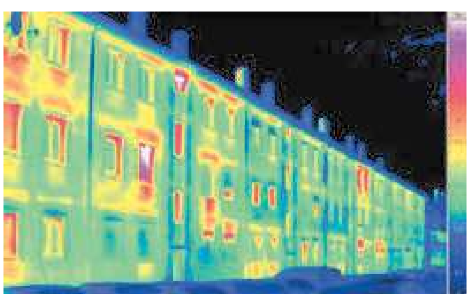
TABLE 23: ENVELOPE PERFORMANCE BASED ON BUILDING STANDARD

Envelope Assembly	NECB 2015	"Near Passive"	Passive House
Roof	R-31	R-45	R-52
Exterior Wall	R-20	R-35	R-44
Below Grade Walls	R-15	R-20	R-30
Floors	R-31	R-35	R-44
Slab on Grade	R-7.5 for min 1.2 m	R-20	R-33 full slab
FDRW*	Max 40%	Max 30-40%	None specified—orient south as much as possible and shade
Windows Vertical U-value	U-0.39 (R-2.6)	U-0.2 (R-2.5)	U-0.14 (R-2.5)
Windows Vertical SHGC	Not specified	0.3-0.4**	0.4-0.5**

* total vertical fenestration AND door area to gross wall area ratio (as per NECB 2015)
** if glazing percentage is limited, from an energy perspective, keep the SHGC a bit higher for more passive heating. If glazing area > 40%, reduce to SHGC < 0.3.

Passive House and Existing Building Upgrades

Applying the Passive House concept to existing envelope upgrades is also a viable technique for improving the performance and comfort of UBCO's existing building stock. The example below is an apartment building in Hamburg, Germany, before and after the envelope was upgraded to Passive House standards.



Before: Heating energy demand: 290 kWh/m2

After: Heating energy demand: < 20 kWh/m2

Thermal imaging can be used to identify weak points in existing building envelope performance, and show the improved benefit from an envelope upgrade. This is recommended to be included in the UBCO *Design Guidelines* for existing building upgrades.

New Building Energy Projections

Based on campus growth and proposed EUI targets progressing over time, Figure 25 summarizes the projected energy performance of the new buildings as compared to a BAU case. The split between heating and electricity energy loads are based on benchmark data for different building typologies and end-uses (lighting, plug-loads, heating, cooling, fans, pumps, DHW, process loads). The BAU case for the new building is defined as meeting NECB 2015 without additional reductions. Note that alternative energy sources have not yet been applied to this growth projection, it is based on building EUIs. It has also not yet accounted for any of the buildings to be connected to the district energy plant, as such, they are assumed to have 85% efficient heating systems.

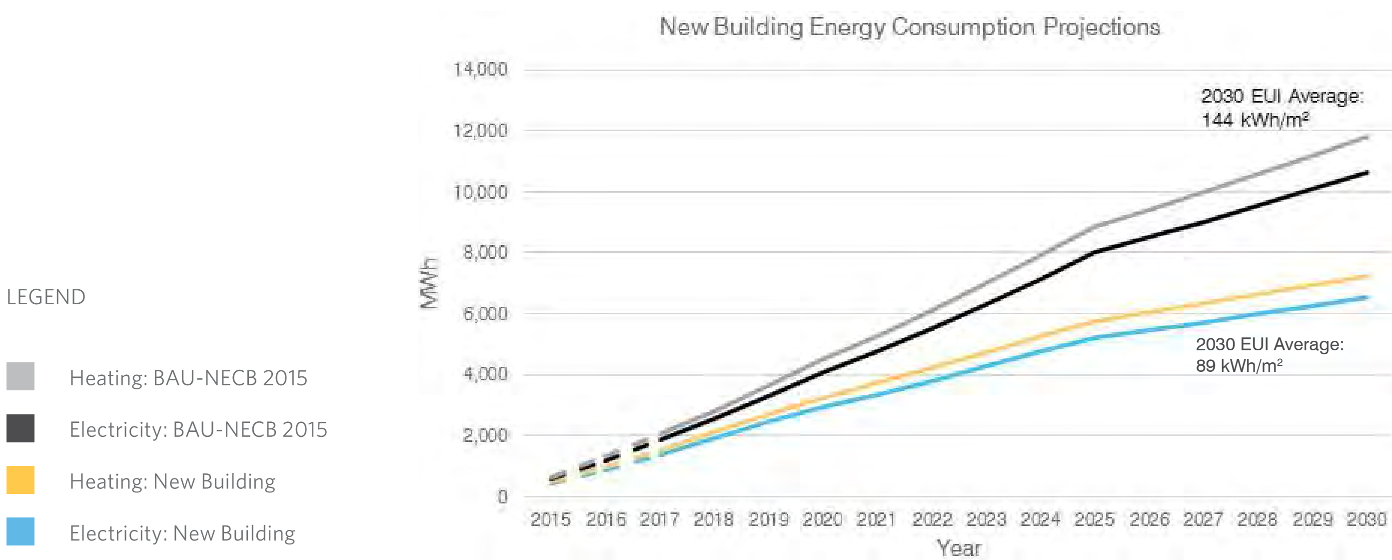


FIGURE 25: NEW BUILDING ENERGY COMSUMPTION PROJECTIONS WITH GROWTH 2015-2030

Design Process and Building Design Guidelines

In order to achieve these improvements in energy performance targets for new construction, UBCO will be required to take some action from a design, construction, commissioning and operations standpoint.

From a design perspective, UBCO should advocate for:

- the enabling of an integrated design process;
- early energy modeling to understand impacts and trade-offs of design decisions;
- good envelope enclosure that eliminates thermal bridging and reduces air leakage;
- fully shaded envelopes during the cooling season;
- daylighting of buildings;
- commissioning of buildings to ensure systems operate as intended;