UTown@UBC
Community Energy and Emissions Plan

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UTown@UBC Community Energy and Emissions Plan Executive Summary

UTown@UBC, UBC Vancouver's on-campus residential community, aims to provide a living, working and learning environment. It currently houses approximately 8,500 residents in student accommodations and an additional 8,000 permanent community residents. UBC is targeting an additional 8,000+ student beds by 2030 in order to meet its goal for 50% of the full-time student enrolment. Meanwhile, neighbourhood build-out is projected to conclude by 2041 with a population of approximately 24,000 residents, requiring rapid building development. With these population targets and developments come increased sustainability challenges, such as increased greenhouse gas emissions on campus. The UTown@UBC Community Energy and Emissions Plan presents a comprehensive framework to achieve reductions in the use of energy, and to reduce GHG emissions within the community.

The Province of BC measures local governments' greenhouse gas (GHG) emissions in the Community Energy and Emissions Inventory (CEEI). The inventory includes emissions from building energy use, transportation and solid waste. Applying a modified CEEI approach to the UTown@UBC context, it was found that over half (51.5%) of UTown@UBC's GHG emissions are resultant from building energy use. Another 40% comes from UNA and student resident transportation. The remaining 8.5% is attributable to solid waste.

The building energy and transportation emissions are almost entirely resultant from fossil fuel use. 53% of the emissions are resultant from natural gas use in providing heating energy to buildings. 43% of emissions are due to burning gasoline in vehicles. Providing thermal energy through renewable energy and addressing transportation - mostly off-campus trips - are key actions to achieving energy efficiency and emissions reductions for UTown@UBC.

With the population set to triple and the building floor space set to nearly quadruple in the next 37 years, UTown@UBC's GHG emissions are estimated to follow suit, increasing by 260% over 2007 levels by 2050 in a business as usual scenario.

Two scenarios of energy efficiency, renewable energy, public transportation and waste reduction measures were explored to determine their effects on emissions reductions. Scenario 1 explored an aggressive suite of measures, attempting to achieve BC Provincial equivalent emissions reduction targets of -33% by 2020 and -80% by 2050, under 2007 emissions levels. Scenario 2 explored an even more aggressive suite of measures, attempting to achieve UBC Climate Action Plan equivalent targets of -67% by 2020 and -100% (carbon neutral) by 2050, also under 2007 levels. Despite the actions explored, neither of these sets of targets were able to be met.

The scenarios demonstrated the magnitude of the emissions reduction challenge. It was determined that the rapid rate of population and building growth made achieving the emissions targets cost prohibitive for the community. Thus, a Recommended Scenario was developed with a more gradual approach to energy efficiency implementation and emissions reduction, as detailed on the next page.

Actions Modelled in the Recommended Scenario	
Categories	**Recommended strategies/targets**
Behaviour change	
	2% savings in energy consumption per square metre.
Transportation	
Vehicle kilometres travelled (VKT)	No change in kilometres travelled per person.
Mode split	Off-campus walking trips increase from 0% to 3% by 2050; on-campus walking trips increase from 68% to 76%. Off-campus cycling increases from 11% to 17% by 2050; On-campus cycling increases from 12% to 20%. Off-campus transit increases from 30% to 45%.
Vehicle type	Average fleet fuel efficiency increases to 40 km/l of gasoline by 2050 reflecting an increase in electric vehicles in the fleet. Vehicle mode share decreases as walking, cycling and transit mode shares increase.
Energy efficiency	
Building performance (average for all building types)	UNA 2007-2013: 186 ekWh/m2 2013-2018: 160 ekWh/m2 2018-2050: 140 ekWh/m2 Student residences 2007-2013: 244 ekWh/m2 2013-2050-115 ekWh/m2
Retrofits	2.5% of pre-2014 building stock is retrofit per year, achieving energy savings of 20%.
Energy generation	
District energy	TRIUMF/natural gas district energy installed in 2015. Natural gas is replaced with biogas/biomass in 2040. Common spaces in pre-2014 UNA buildings are attached to district energy at a rate of 2.5% per year.All new UNA buildings are connected to district energy starting in 2015. All new student residences are connected to the Academic District Energy System starting in 2015. Existing student residences are connected as soon as feasible.
Waste	
Solid waste production	UNA waste drops to 0.5 tonnes per capita by 2050. Student residences waste drops from 0.7 tonnes per capita to 0.3 tonnes per capita.
Solid waste diversion rate	Waste diversion rate increased to 70% by 2020 for UNA and maintained at 70% until 2050. Student residence waste diversion rate increased to 80% by 2050.
Liquid waste treatment	Metro Vancouver Iona Island

These actions are able to reduce emissions to 9,312 tonnes carbon dioxide equivalent (tCO2e) by 2050. The bulk of the reductions are from a new neighbourhood district energy system in 2015 that recovers waste heat from TRIUMF and ultimately replaces all natural gas use with biogas/biomass by 2050. This system supplies heat to all new buildings. Existing buildings are added to the system over time. Connection to the existing Academic District Energy System will result in similar emissions reductions for Student Housing. Other significant emissions reductions stem from energy efficiency retrofits to existing buildings, shifting off-campus transportation to sustainable transportation modes, and waste reduction and diversion in UNA buildings and student residences.

Electricity use is reduced by almost 50% in UNA buildings over a business as usual scenario by 2050 due to energy efficiency retrofits, improvements to the REAP building standard and the new district energy system. Electricity use is reduced in student residences by about 35% by 2050 using similar measures.

Based on the Recommended Scenario, the following emissions and energy targets are recommended for UTown@UBC:

GHG emissions

- 18% reduction over BAU by 2020
- 85% reduction over BAU by 2050
- 60% reduction over 2007 levels by 2050

Electricity

- 16% reduction over BAU by 2020
- 36% reduction over BAU by 2050

To achieve these targets, 18 actions are recommended. 8 fall under UBC jurisdiction, 5 under UNA jurisdiction and 5 are joint responsibilities, as they have related benefits and require support from both UBC and UNA in order to succeed.

Recommended Action Summary, UBC Responsibilities

Theme	Recommendation
Buildings	1. Incrementally improve REAP.
	2. Establish an energy efficiency target for student residences.
District Energy System (DES)	3. Implement a low carbon DE system servicing all new buildings starting in 2015.
	4. Starting in 2040 replace all natural gas in the DES with biogas or biomass.
	5. All new student residences connect and all existing residences connect to the academic district energy system when boilers are replaced.
Retrofits	6. Retrofit 2.5% of student residences per year to achieve 20% energy savings per year. Connect common areas to the DES.
Behaviour Change	7. Implement a transportation behavior change program for students that is integrated with behavior change programs for UNA residents.
	8. Implement a waste behavior change program for students that is integrated with UNA behavior change programs.

Recommended Action Summary, UNA Responsibilities

Theme	Recommendation
Behaviour Change	9. Implement a behaviour change program to support energy efficiency.
	10. Implement a behavior change program to support mode shifting away from vehicles using the model of the Smarter Travel Choices Program.
	11. Investigate a personal carbon trading program of UTown@UBC as an integrated approach to behavior change.
	12. Implement a waste reduction plan for UNA.
Other	13. Maintain and enhance urban agriculture.

Recommended Action Summary, UNA and UBC Joint Responsibilities

Theme	Recommendation
Data	14. Increase the precision of the electricity and emissions data collected by UTown@UBC.
Retrofits	15. Identify economic and policy instruments to encourage energy efficiency improvements during major retrofits. Educate residents on the benefits of such an undertaking.
	16. Undertake buildings retrofits that upgrade UNA buildings as they undergo major retrofits. Educate residents on the benefits and support residents during the transition.
	17. Connect common areas of pre-2014 UNA buildings to the district energy system as they are retrofit or major equipment is replaced at the end of its life. Educate and support residents during the transition.
Transportation	18. Determine the UNA's role in contributing to the implementation of a rapid transit system in conjunction with Translink, City of Vancouver and MetroVan, and perform further UNA transportation surveys.

The energy and emissions challenge for UTown@UBC is clear. With such rapid population and building growth, substantial efforts in providing sustainable energy, energy efficiency, sustainable transportation options, waste reduction and diversion options, and behaviour change incentives are required to achieve meaningful energy use and emissions reductions by 2020 and 2050. This CEEP details a path to achieving these reductions in a manner that is both innovative and economical.

1

UTown@UBC
CEEP Context

1.1 Project Purpose

UTown@UBC represents UBC's on-campus residential community, including student and non-student housing. UTown@UBC provides a living, working and learning environment to its 8,500 student and 8,000 community residents. UBC is targeting an additional 8,000+ student beds by 2030 in order to meet its goal to house 50% of the full-time student enrollment. Neighbourhood build-out is projected to conclude by 2041 with a population of approximately 24,000 residents. Alongside UTown@UBC, the UBC campus accommodates various shops, services and cultural amenities, including athletic fields and arenas, museums, art galleries, performance art, a hospital, and parking facilities.

In 2011, UBC and the University Neighbourhoods Association (UNA) sought to develop a Community Energy and Emissions Plan (CEEP) for UTown@UBC. UNA approximates a municipal council for the residential areas of UBC campus and includes five distinct neighbourhoods. UTown@UBC's CEEP addresses energy use and GHG emissions reductions direction for the UNA Neighbourhoods and UBC Student Housing. The CEEP establishes energy and GHG emissions-related priorities for the community and defines goals and direction against a baseline and a business as usual scenario. The plan is complementary, although not analogous, to the UBC Climate Action Plan, and aims to guide UTown@UBC to a more sustainable future for its residents.

1.2 Global Climate Context

The Earth's climate is determined by its ability to both trap and reflect heat from the sun and to circulate it through the atmosphere and the oceans. When this capacity is altered, the Earth's climate can change. The term "climate change" refers to a change in the average state of the climate. Annual climate data has shown noticeable temperature highs and lows, but over long periods of time there has been a discernible warming trend across the globe. The global average temperature over the first decade of the 21st century was significantly warmer than any preceding decade on record over the past 160 years.[1] The overwhelming majority of scientists agree that this is due to rising concentrations of heat-trapping greenhouse gases in the atmosphere caused by human activities.[2] The increase in these gases alter the Earth's ability to naturally regulate the climate.

The impacts of climate change are becoming more apparent. Two thousand species are moving away from the equator at an average rate of more than 15 feet per day to avoid increasing temperatures, a rate two to three times faster than previously reported.[3] The impacts of weather events on the built environment are another climate change indicator, particularly relevant to municipalities. Munich Re, a large re-insurance company, reported that 2010 brought the second-highest number, after 2007, of loss-related weather catastrophes since their records began in 1980.[4]

The Stern Review, an economic analysis of climate change, was released in 2006.[5] The review determined that climate change is the largest market failure ever seen. The report stresses that the benefits of strong and early action on climate change (i.e.: mitigation efforts) far outweigh the economic costs of inaction. The Review estimates that if action is not taken, base climate change costs and risks will be equivalent to losing at least 5% of global GDP each year, now and forever. If a wider range of risks and impacts is taken into account, damage estimates could rise to 20% of GDP or more. In contrast, the costs of action – reducing greenhouse gas emissions to avoid the worst impacts of climate change – can be limited to around 1% of global GDP each year. Climate scientists believe that emission reductions (and especially reductions in fugitive methane emissions) in the near-term are vital, such that the value of early emission reductions is greater than those which may be achieved several decades in the future.[6]

1 Hadley Centre (2011). Evidence: the state of the climate. UK Met Office. Available at: http :// www . metoffice . gov . uk / media / pdf / m /6/ evidence . pdf

2 Intergovernmental Panel on Climate Change (2007). Climate Change Synthesis Report: 2007.

3 Chen et al. (2011). Rapid Range Shifts of Species Associated with High Levels of Climate Warming. Science 19 August 2011: 1024-1026.

4 Munich Re (2011). Topics Geo. Natural catastrophes 2010- analyses, assessments, positions. Available at: http://www.munichre.com/publications/302-06735_en.pdf

5 Stern, N. (2006). "Stern Review on The Economics of Climate Change (pre-publication edition). Executive Summary". HM Treasury, London.

6 Cox, P. et al. 2010. Methane radiative forcing controls the allowable CO_2 emissions for climate stabilization. Current Opinion in Environmental Sustainability. Volume 2. Issue 5, Pages 404-408.

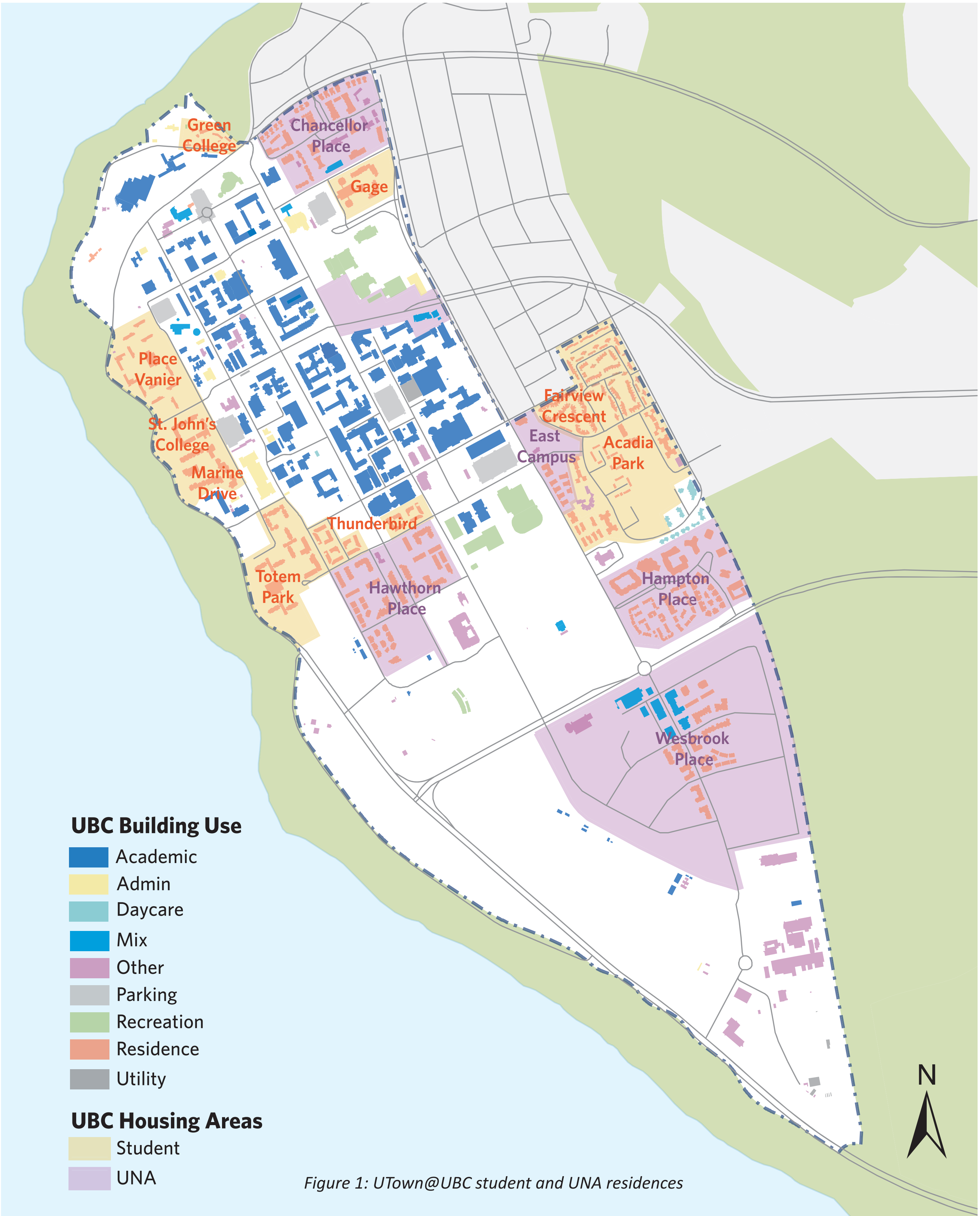


Figure 1: UTown@UBC student and UNA residences

1.3 UBC and UNA Sustainability Commitments

UBC has been at the forefront of efforts to embed sustainability into higher education for at least fifteen years. The UBC Sustainability Initiative is guided by two key themes: the campus as a living laboratory and the University as an agent of change.

UBC produced a Climate Action Plan (CAP) in 2010, committing to these actions for the Point Grey Campus:[7]

- Establishing UBC's 2008 energy and emissions baseline;
- Articulating a Vision for Climate Action;
- Setting out emissions reduction targets for 2015, 2020 and 2050;
- Putting forward a series of actions to reduce emissions across campus, and;
- Outlining an implementation and management framework to guide UBC in its climate action efforts.

UBC has established three milestones for its GHG reduction targets, en route to a zero carbon campus:

1. Reduce emissions 33% below 2007 levels by 2015.
2. Reduce emissions 67% below 2007 levels by 2020.
3. Reduce emissions 100% from 2007 levels by 2050 (Net Positive Campus).

The UNA also has a sustainability strategy covering the five residential neighbourhoods. Its commitment is to:[8]

- Be responsible stewards of air, land and water of the UNA neighbourhoods;
- Provide projects and programs that enhance the ability for residents to live, work and play sustainably, and;
- Find cost effective solutions for sustainability for the UNA community.

The strategy includes commitments to community engagement, energy conservation and emissions reduction, waste reduction, natural areas and local food and cost effective services and programs. While the strategy does not identify specific targets, it does seek to demonstrate leadership for other communities and includes a focus on learning. The UNA's community sustainability goals apply to three primary operational areas of responsibility: buildings, parks and public areas, and transportation:

- Community Engagement
- Community Energy Conservation and Emissions Reduction
- Community Waste Reduction
- Community Water Conservation
- Natural Function, Features and Local Food
- Cost Effective Services and Programs

1.4 UTown@UBC Project Context

The energy and emissions context of UTown@UBC is a starting point for determining energy efficiency and emissions reductions actions. Building energy generation and use, transportation, and waste disposal are all important considerations in making programming and infrastructure decisions to achieve energy and emissions reductions. This section presents on overview of UTown@UBC's energy consumption and emissions production.

1.4.1 Local Energy Profile Overview

BC's Community Energy and Emissions Inventory (CEEI) lists energy and emissions data for each municipality. It includes GHG emissions from residential and commercial buildings, private and commercial transportation, and solid waste, but not from agriculture, deforestation, liquid waste, industry, agricultural transportation, marine or air travel.[9, 10]

Figure 2 depicts UTown@UBC's emissions sources summary and Figure 3 its emissions by fuel type (from CEEI data that was

7 UBC Climate Action Plan, 2010.

8 The UNA Sustainability Strategy was provided by UNA staff.

9 BC Ministry of Environment CEEI. http://www.env.gov.bc.ca/cas/mitigation/ceei/index.html

10 GHG emissions from deforestation and agriculture are provided for information only as memo items and are not counted in the total emissions in CEEIs for regional districts. The Government of BC indicates that this information should not be used for decision-making purposes. CEEI uses actual data from energy utilities for buildings but estimates GHG emissions from vehicles and solid waste.

constructed for UTown@UBC[11]). Emissions are presented in tonnes of carbon dioxide equivalent (tCO_2e). CO_2e measures the global warming potential of a given gas (e.g.: methane) in terms of the amount of CO_2 that produces the same global warming effect. Figure 3 tells us that addressing UTown@UBC's dependence on fossil fuels as an energy source is a priority in achieving emissions reductions. Figure 4 show UTown@UBC's energy baseline as of 2007.

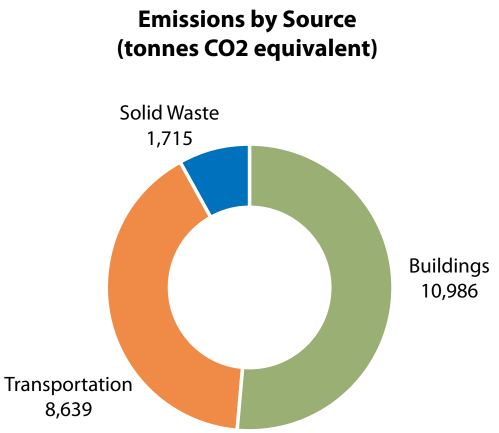


Figure 2: UTown@UBC GHG Emissions by Source

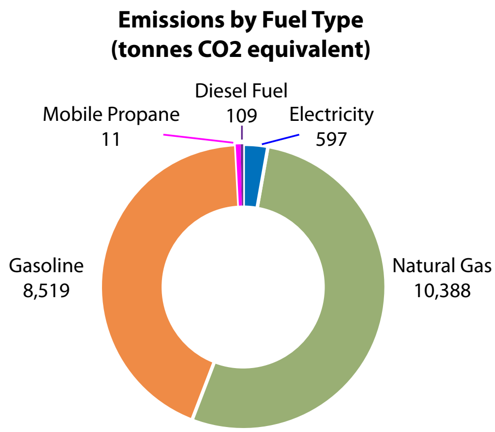


Figure 3: UTown@UBC Emissions by Fuel Type

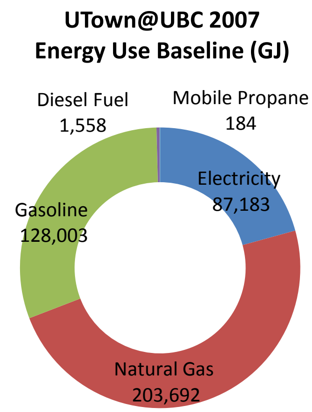


Figure 4: 2007 Energy Baseline

1.4.2 UTown@UBC Building Energy Use

The constructed UTown@UBC CEEI data allowed identification of energy consumption by type for residential and commercial buildings in the UNA. Student residence building energy use intensity (EUI, kWh/m2/yr) was determined through actual energy consumption data. Energy consumption for UNA buildings is not tracked at a community level. It was calculated by validating the available 2007 CEEI data with available data from 8 previously audited buildings. Electricity consumption was calculated from the CEEI data (90 kWh/m2/yr) and natural gas consumption was extrapolated from the results of the audit sample (96 kWh/m2/year).

Based on electricity and gas EUIs provided by UBC (Figure 5), weighted average EUIs were calculated and used to project electricity and natural gas consumption for future construction.

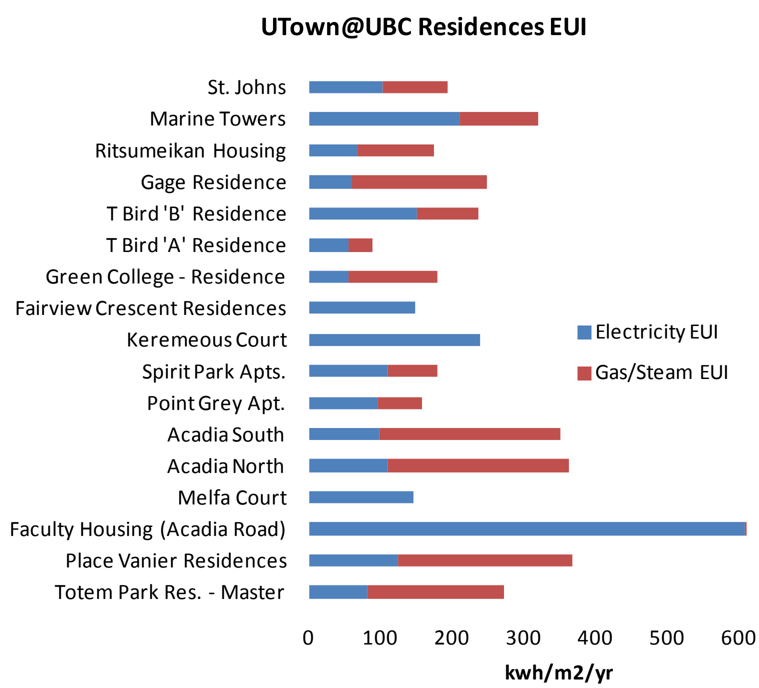


Figure 5: UTown@UBC Energy Use Intensity per Building

1.4.3 UTown@UBC Solid Waste GHG Emissions

UTown@UBC produces 8,504 tonnes of solid waste each year, a portion of which is likely construction waste. The waste is hauled off campus and disposed of 350 kilometres away in Cache Creek. This waste results in 1,715 tCO_2e annual GHG emissions, not including those produced in hauling it to its disposal site. Liquid waste is pumped to the MetroVan Iona Island Wastewater treatment facility in Richmond, about 15 kilometres south of UBC.

11 The CEEI for UNA was constructed by subtracting the GHG inventory for the UBC academic campus from the CEEI data available for a larger sub-area reported on by CEEI. UBC student housing is included in the UBC academic campus data and is therefore not included in the UNA CEEI.

1.4.4 UTown@UBC Transportation Energy and Emissions

Figure 6 and Figure 7 show the modal split of trips made on and off campus for student and UNA residents. Most student trips are on campus while most UNA resident trips are off campus. Walking is preferred on campus. Public transit is preferred for off campus trips for students, while driving alone is preferred by UNA residents. Emissions from off campus driving are a key area of improvement.

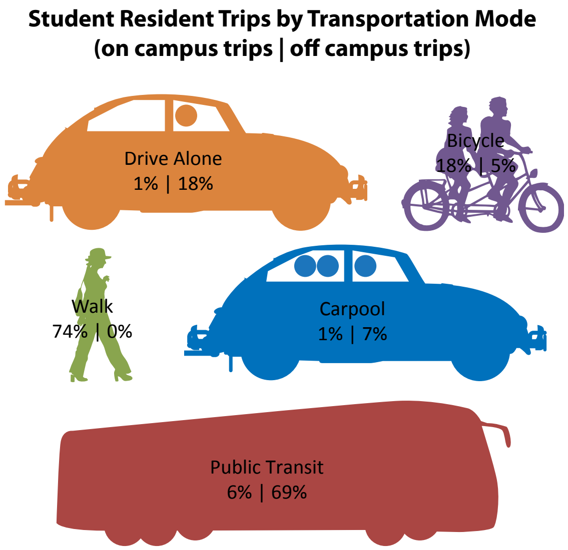


Figure 6: Student Resident Trips by Transportation Mode

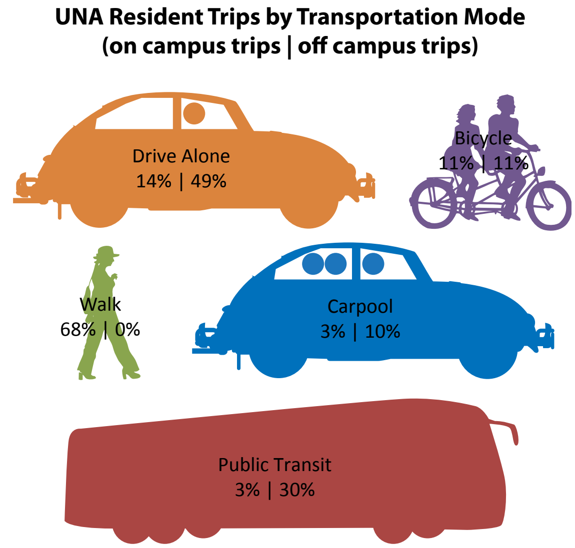


Figure 7: UNA Resident Trips by Transportation Mode

Figure 8 shows the results of a 2011 Vancouver Transportation Survey for on campus destinations. The Student Union Building is a popular destination, while several other academic buildings are frequented similarly. Figure 9 shows emissions by vehicle type used by UTown@UBC residents. Small cars have more emissions than other vehicle types, however the per car emissions amount is much smaller than that of trucks, SUVs and large cars. There are more small cars on campus than trucks, SUVs and large cars combined, yet their total emissions is less than those of the other vehicles combined. Large vehicle emissions are an area of improvement.

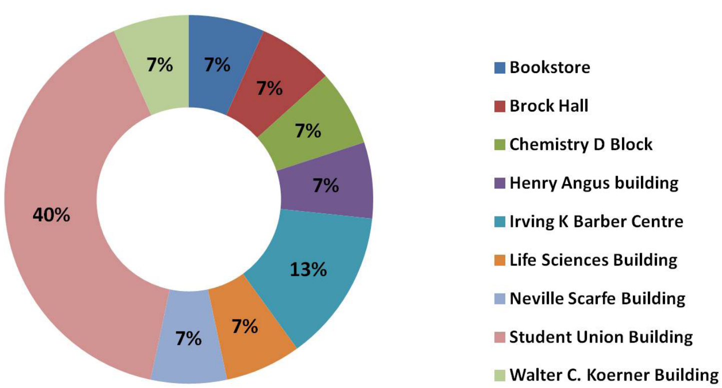


Figure 8: On Campus Destinations (2011 Vancouver Transportation Survey)

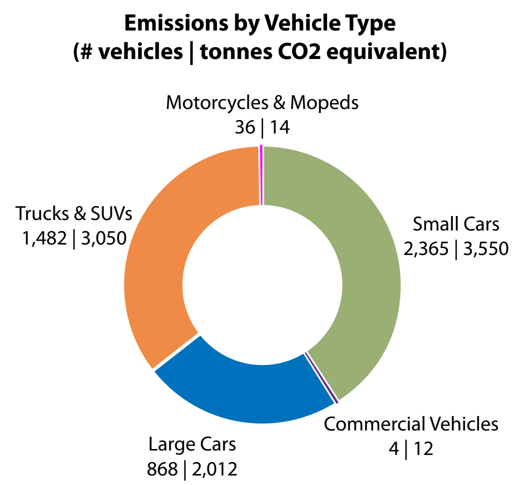
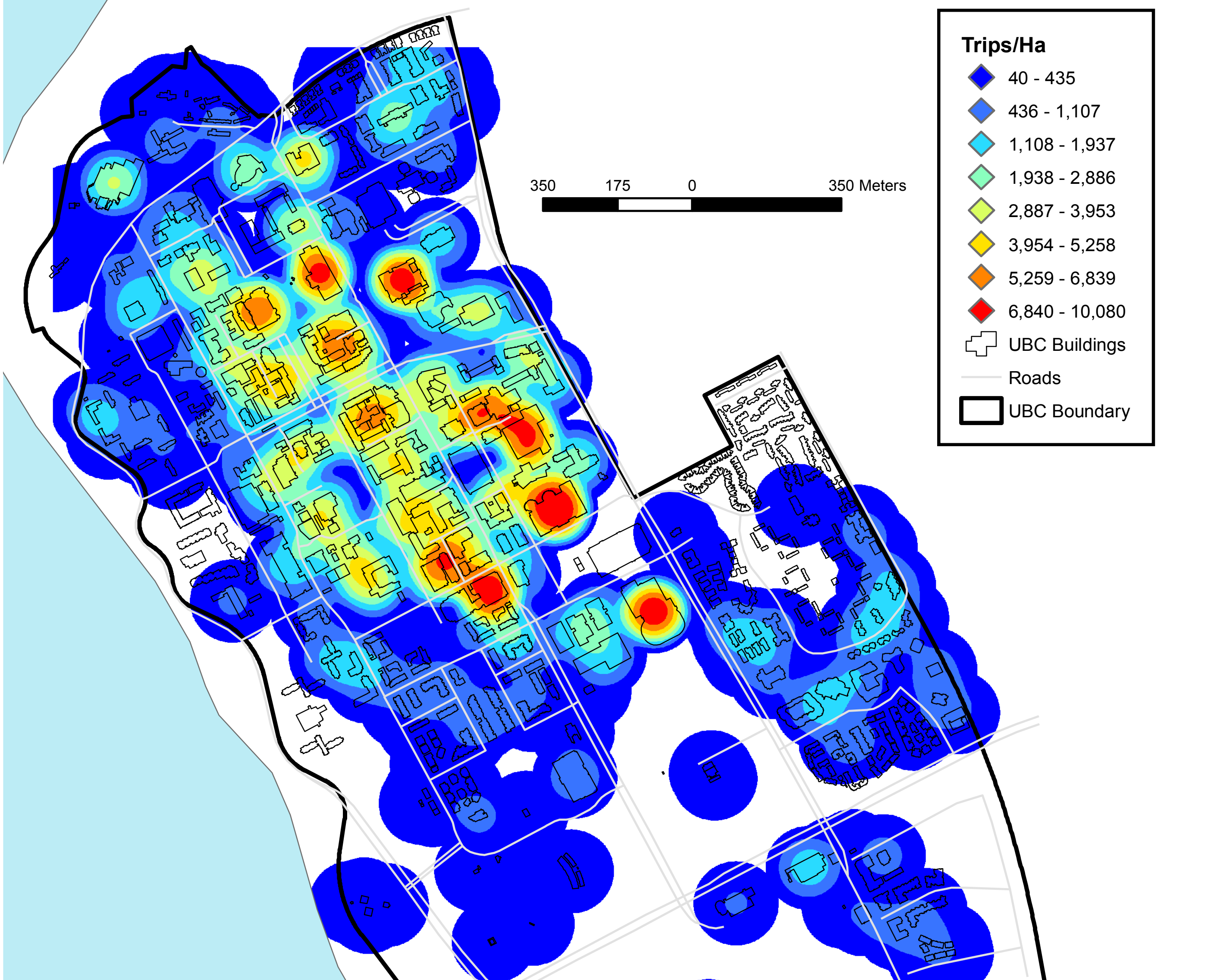


Figure 9: UTown@UBC Emissions by Vehicle Type

Figure 10 is a 'heat map' of on-campus destinations, using all transportation modes. It indicates the 'attractiveness' of each destination (not the actual number of trips made) by assigning trip weights to different destinations based on their size and use. Figure 11 shows the locations of off campus trips, as indicated by the Transportation Survey (note that this survey had a relatively small sample and it is recommended that further surveys are completed to improve information). Trips between campus and the Cambie Street area are often for services and amenities. Further trips are for commuting to work, visiting family and friends or special trips. Figure 9 and 10 were used to calculate the average trip length from dwellings (origins) to on- and off-campus destinations. Note that the majority of student travel is to on-campus destinations, while the majority of UNA resident travel is to off-campus destinations.

Figure 10: Trip Frequency Estimate Map of On-Campus Destinations



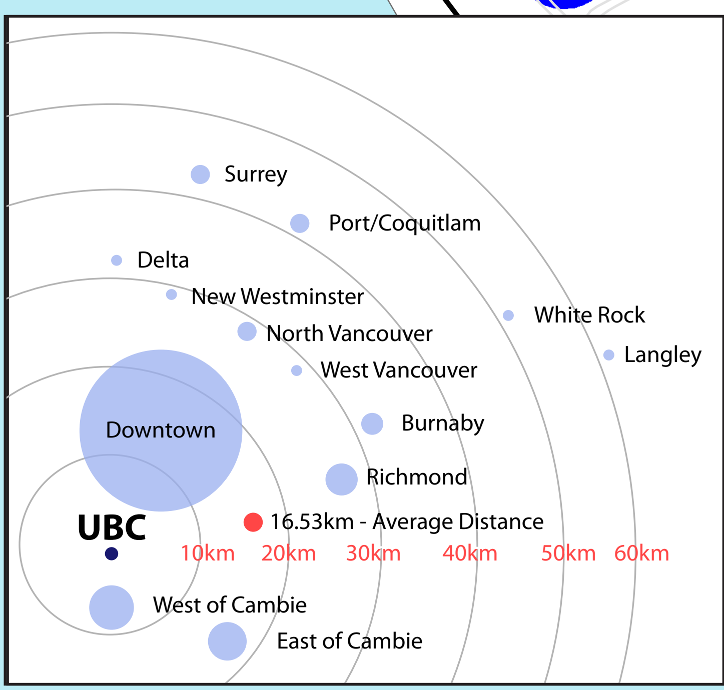


Figure 11: Off Campus Destinations (2011 Vancouver Transportation Survey, May 2011, NRG Research Group).

1.4.5 UTown@UBC Projections

The UBC Point Grey Land Use Plan[12] states targets for on-campus population and building floor areas up to 2050. These two factors influence energy use and emissions production in terms of per capita building energy use, transportation (number of trips made) and waste production. The target UNA resident population is 27,200 people by 2035, which stays constant to 2050. Student beds are projected to reach 16,500 by 2035 and 20,300 people by 2050. Figure 12 and Figure 13 show the projected and total populations.

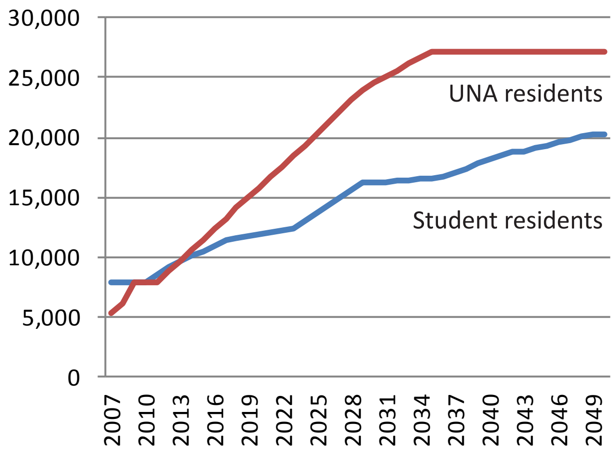


Figure 12: UTown@UBC target student and UNA resident populations

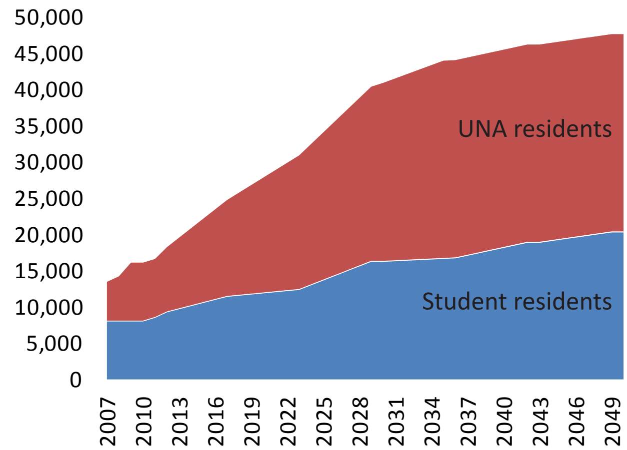


Figure 13: Target total UTown@UBC populations

Figure 14 shows the expected magnitudes of building floor areas. Student and UNA residence floor areas are expected to roughly double and triple by 2050, respectively. Projected floor areas are an important factor in modelling energy and emissions factors.

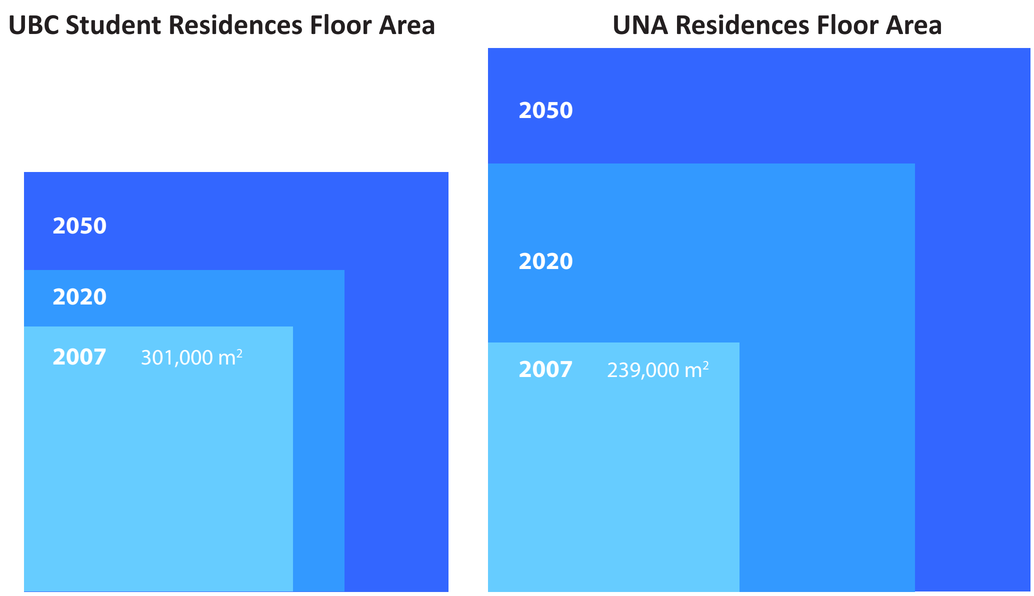


Figure 14: UTown@UBC floor area projections

UTown@UBC annual GHG emissions amounts were estimated to be 23,223 tCO2e in 2007 (baseline year). Based on the target population increases on campus, the floor area increases and the accompanying increase in activity (e.g.: increased energy use, vehicle trips), GHG emissions are projected to climb. Figure 15 shows the relative projected emissions for the years 2007, 2020 and 2050.

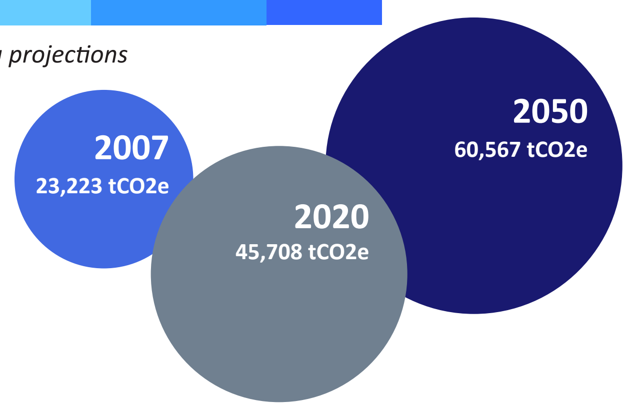


Figure 15: GHG emission projections for UTown@UBC

12 UBC Campus and Community Planning. *Land Use Plan for The University of British Columbia Point Grey Campus*, March 1,2011.

2

Modelling an Energy and Emissions Future for UTown@UBC

2.1 Modelling the Options for UTown@UBC's Energy and Emissions Future

In order to assess and compare emissions reduction and energy efficiency strategies, three scenarios were developed for the period of 2007 (base year) to 2050: Business as Usual (BAU), Scenario 1 (BC Emissions Targets) and Scenario 2 (UBC Emissions Targets). Each scenario modelled different actions in the transportation, energy efficiency, energy generation and waste realms. Emissions from air travel and food transportation and avoided commuting emissions reductions due to increased percentage of students, staff and faculty living on campus are analyzed and discussed in Appendix 2 but are not included in the main analysis. These emissions are outside of the scope defined by the Provincial Government's Community Energy and Emissions Inventory and this project at this time. A final set of recommendations was drawn from these scenarios, taking elements of each while ensuring economic viability.

The BAU Scenario assumed no additional efforts beyond those already planned were made to specifically address emissions production and energy use. Current trends, UTown@UBC and UBC plans, and the estimated uptake of certain current technologies (e.g.: electric vehicles) inform the BAU Scenario. Scenario 1 modelled actions attempting to achieve the Provincial emissions reduction targets of 33% emissions reduction by 2020 and an 80% reduction by 2050, both against 2007 levels. Scenario 2 modelled actions attempting to achieve the UBC academic campus Climate Action Plan emissions reduction targets of 33% by 2015, 67% by 2020 and 100% (carbon neutral) by 2050, also against 2007 levels. Figure 15 depicts the emissions reduction trajectories required to meet each set of targets. The large difference between these targets and the BAU emissions levels demonstrates the magnitude of the challenge in achieving these emissions reductions targets.

As detailed in Appendix 2, the scenario analysis revealed that even taking aggressive emissions and energy efficiency actions was insufficient to achieve the emissions reduction targets in either scenario (i.e.: the emissions reductions trajectories in Figure 16 were not achieved). The combination of actions achieved significant emissions reductions, but still fell short of the 80% and 100% emissions reductions by 2050 targets. This is due to the rapid rate of population and building growth, which make reducing absolute emissions very challenging and costly in the short term, undermining the affordability of UTown@UBC. Drawing from these scenarios, a Recommended Scenario (Figure 17) was constructed to assess a more gradual implementation of elements, like low carbon district energy, with a focus on economic viability. Table 1 details the assumptions in the Business as Usual and Recommended Scenarios, highlighting the difference in actions between the two.

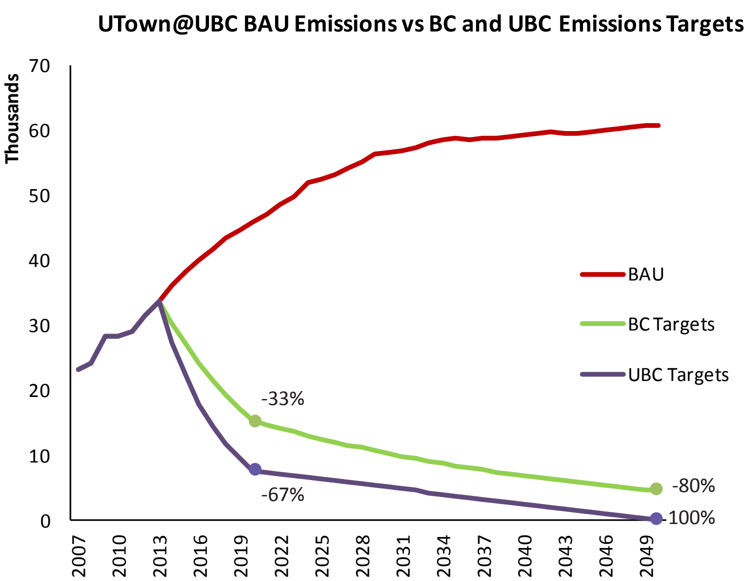


Figure 16: BAU emissions compared to GHG reductions required to meet Provincial and UBC targets.

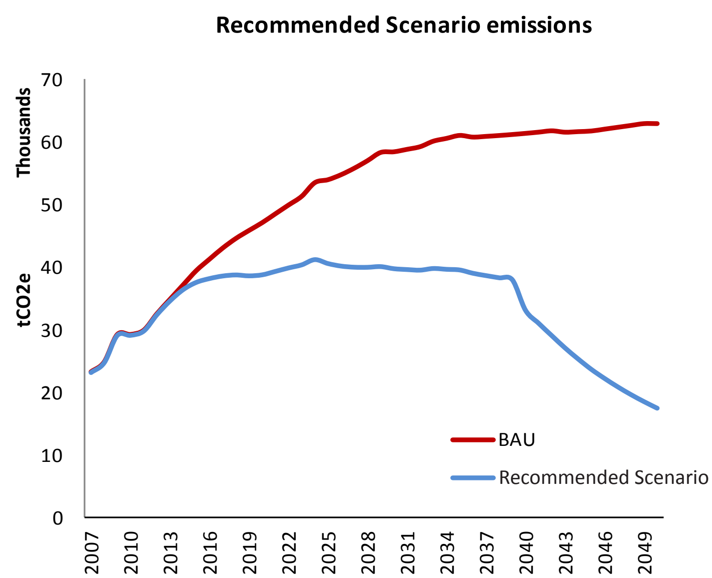


Figure 17: Final Scenario emissions comparison to BAU

Table 1: Targets Modelled in the Recommended Scenario		
Categories	**Business As Usual**	**Recommended strategies/targets**
Behaviour Change		
	Existing behaviours projected out.	2% savings in energy consumption per square metre.
Transportation		
Vehicle kilometers travelled (VKT)	Existing VKT maintained.	Existing VKT maintained.
Mode split	Current mode split maintained until 2050.	• Off-campus walking trips increase from 0% to 3% by 2050; on-campus walking trips increase from 68% to 76%. • Off-campus cycling increases from 11% to 17% by 2050; On-campus cycling increases from 12% to 20%. • Off-campus transit increases from 30% to 45% (including RRT trips).
Vehicle type	Current vehicle mix maintained; fuel efficiency standards improved to match federal standards.	Average fleet fuel efficiency increases to 40 km/l of gasoline by 2050 reflecting an increase in electric vehicles in the fleet. Vehicle mode share decreases as walking, cycling and transit mode shares increase.
Energy Efficiency		
Building performance	UNA 2007-2050: 186 ekWh/m2	UNA 2007-2013: 186 ekWh/m2 2013-2018: 160 ekWh/m2 2018-2050: 140 ekWh/m2
	Student residences 2007-2050: 244 ekWh/m2	Student residences 2007-2013: 244 ekWh/m2 2013-2050-115 ekWh/m2
Retrofits	No retrofits.	2.5% of pre-2014 building stock is retrofit per year, achieving energy savings of 20%. New and existing student residences are connected to the Academic District Energy System starting in 2015.
Energy Generation		
District energy	No district energy. Existing fuel mixes maintained.	• Phase I (2015-2040): Waste heat/natural gas district energy installed. • Phase II (2041-2050): Natural gas is replaced with biogas/ biomass. • Common spaces in pre-2014 UNA buildings are attached to district energy at a rate of 2.5% per year. • All new student residences are connected to the Academic District Energy System starting in 2015. Existing student residences are connected as soon as feasible.
Waste		
Solid waste production	UNA waste maintained at 1.2 tonnes per capita (0.63 tonnes per capita to the landfill). Student residence waste maintained at 0.7 tonnes per capita.	UNA waste drops to 0.5 tonnes per capita by 2050. Student residences waste drops from 0.7 tonnes per capita to 0.3 tonnes per capita.
Solid waste diversion rate	Existing UNA waste diversion rate of 45% maintained.	Waste diversion rate increased to 70% by 2020 for UNA and maintained at 70% until 2050. Student residence waste diversion rate increased to 80% by 2050.
Liquid waste treatment	Metro Vancouver Iona Island	Metro Vancouver Iona Island

Absolute GHG emissions continue to climb until 2024, driven primarily by the addition of new UTown@UBC buildings and the fuel mix used to heat the buildings. Population increase results in additional GHG emissions from on and off-campus transportation until 2020-2022, at which point improvements in vehicle efficiency and an increasing transit mode share result in a decrease in the absolute emissions from this sector. The replacement of natural gas in the neighbourhood district energy system in 2040 with biomass or biogas, the elimination of fossil fuels from the Academic DE System by 2050, and the cumulative impact of retrofits stabilizes and, by 2040, reduces absolute GHG emissions from buildings at UTown@UBC. A depiction of the effects of actions modelled in the Recommended Scenario vs the BAU Scenario is shown in Figure 18 (the term "residence" in the following graphs refers to student residences). In 2050, the BAU Scenario reaches 60,567 tCO2e in annual emissions while the total amount of emissions in the Recommended Scenario is 9,312 tCO2e. The Recommended Scenario emissions are 4,667 tCO2e greater than an 80% reduction over BAU (4,645 tCO2e - equivalent to the Provincial reduction target by 2050) and 9,312 tCO2e greater than a 100% reduction over BAU (0 tCO2e - equivalent to the UBC CAP reduction target by 2050).

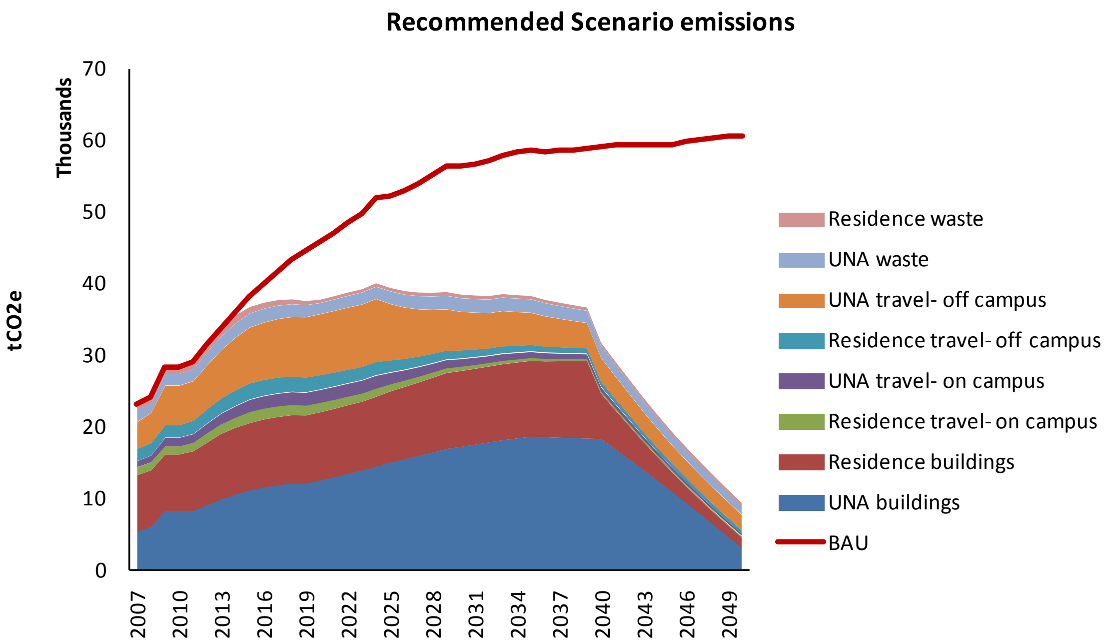


Figure 18: Recommended Scenario GHG emissions by source

The emissions factor for electricity from BC Hydro is very low, thus GHG emissions associated with UTown@UBC buildings are driven primarily by the provision of thermal energy. Heating in UNA buildings is currently 80% natural gas and 20% electricity. Increased energy efficiency standards in REAP and in student residences will reduce the overall thermal and electrical demand in new building stock. The addition of the district energy system in 2015 facilitates fuel switching from natural gas to waste heat extracted from cooling towers in the short term. As the number of buildings increases, additional natural gas capacity is required to supplement waste heat until either biomass or biogas is substituted for natural gas beginning in 2040. Note that only the building stock constructed after 2015 is connected to district energy, and common spaces in pre-2015 stock are connected to the district energy system at the rate of 2.5% per year according to a retrofit schedule. The retrofit schedule is intended to correspond with the end-of-life replacement of boilers and other equipment and/or major renovations or updates, thus reducing the cost of energy upgrades.

Figure 19 shows the emissions reduction contribution of each Recommended Scenario action. The most significant source of GHG emissions reductions is the introduction of district energy (including the substitution of biomass/biogas for natural gas in 2040), which totals more than 51% of the cumulative reductions by 2050. The combination of per capita waste reduction from 1.2 tCO2e to 0.5 tCO2e by 2050 and an increased diversion rate for UNA residents from 45% to 70% by 2050 results in almost 12% of the cumulative GHG reductions. The addition of improved REAP and augmented energy efficiency standards for student residences and a retrofit program are also effective measures.

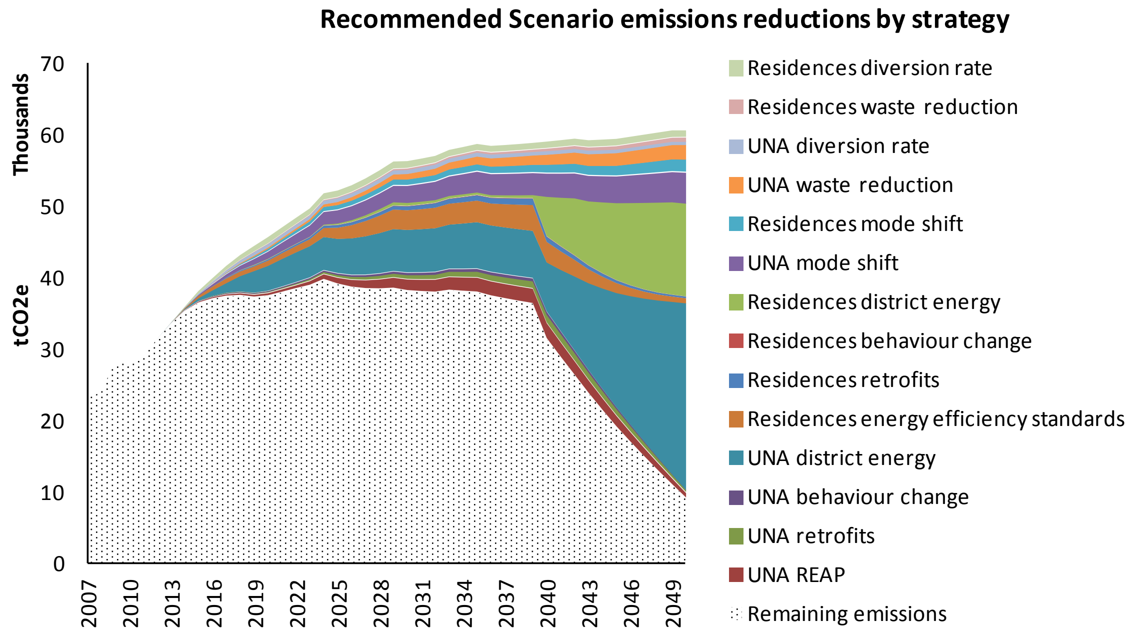


Figure 19: Effects of Recommended Scenario actions on GHG emissions reductions

Figure 20 shows the cumulative effects of each strategy's emissions reductions between 2007-2050. District energy accounts for almost half of the total savings. Sustainable transportation for UNA residents, energy efficiency improvements in student residences and UNA waste reduction account for more than another third. Other measures combine for the remainder of reductions.

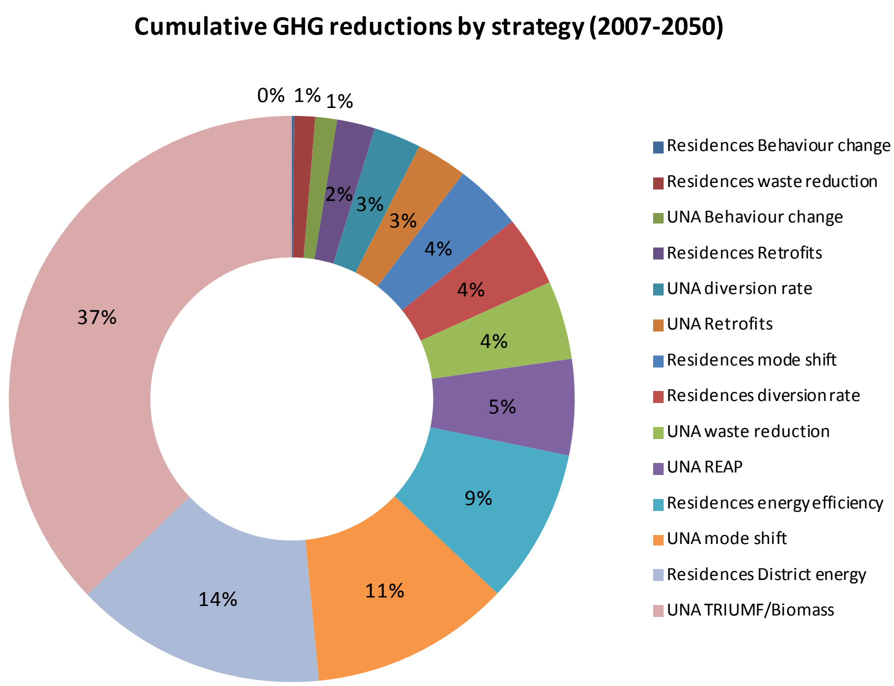


Figure 20: Cumulative emissions reduction effects by strategy

Behaviour change plays a relatively smaller role in terms of absolute reductions but is a critical educational approach for instituting a culture of conservation and creating the public support for REAP, district energy, energy efficiency retrofits and transportation mode shift.

2.2 Natural Gas Use in the Recommended Scenario

For UNA buildings, natural gas consumption reduction is driven predominantly by new district energy which displaces natural gas consumption with waste heat (Figure 21). In 2040, the remaining natural gas use in the district energy system is substituted by biogas or biomass (the steep drop-off in the figure). District energy connection occurs as buildings are constructed from 2015; the reductions are incremental (buildings constructed in 2014 are district energy ready but the district energy system is not online until 2015). Further reductions result from efficiency improvements for new builds as determined by REAP, an energy efficiency retrofit program, and a process of connecting heating in common areas in the pre-2014 buildings to the district energy system.

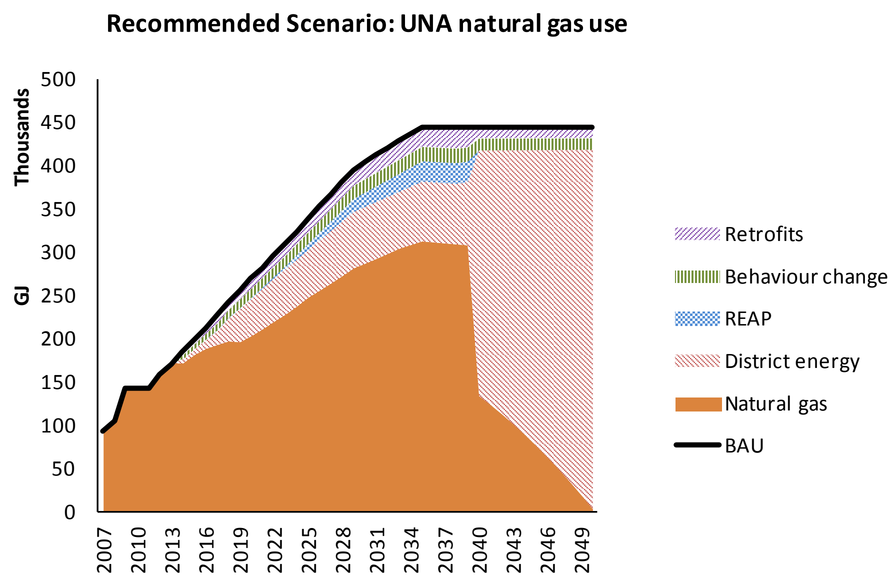


Figure 21: Recommended Scenario UNA building natural gas use.
Gas use reduction shown as patterns.

For student residences, efficiency standards in post-2014 building stock reduce the heat demand by 54% by 2050. This substantial efficiency gain begins in 2014. When natural gas is displaced by biogas/biomass in the academic district energy system beginning in 2040, the benefit of energy efficiency and retrofits declines as natural gas use declines.

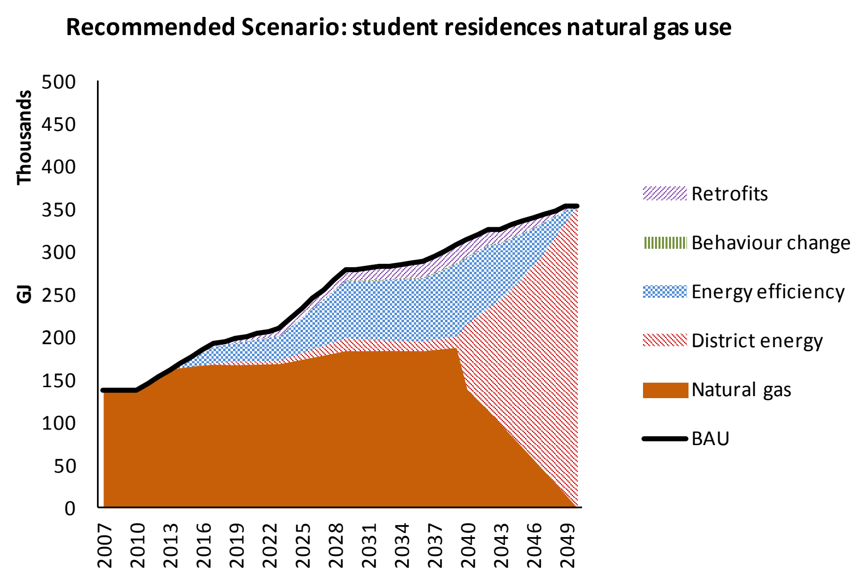


Figure 22: Recommended Scenario student residences natural gas use.
Gas use reduction shown as patterns.

Retrofits become an increasingly important aspect of the energy management strategies, targeting the existing building stock which is both less efficient and is not connected to the academic district energy system.

2.3 Electricity Use in the Recommended Scenario

The most significant electricity reductions (Figure 23 and Figure 24) result from increasing REAP efficiency requirements in UNA buildings and increased efficiency performance in student residences beginning in 2014, which drop electricity consumption by almost 50%. A new district energy system in 2015 displaces the heat load from electric baseboards and adds an electrical load from the heat pump for TRIUMF. After build-out, retrofits continue to improve the efficiency of the pre-2014 building stock.

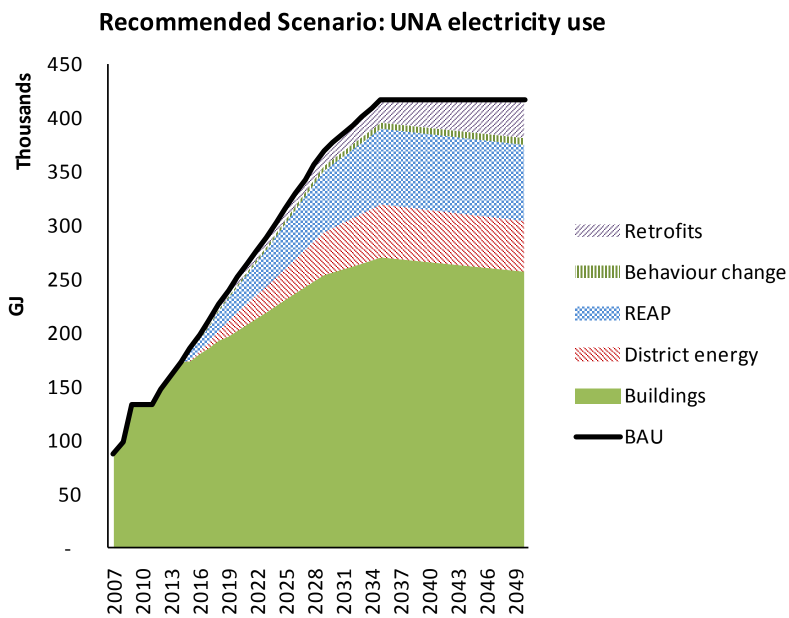


Figure 23: Final Scenario UNA electricity consumption.
Electricity use reduction shown as patterns.

Consumption reductions in the student residences result primarily from increased energy efficiency targets and a retrofit program. Since there is a more limited thermal electric load in the student residences, new district energy does not result in a significant electricity reduction.

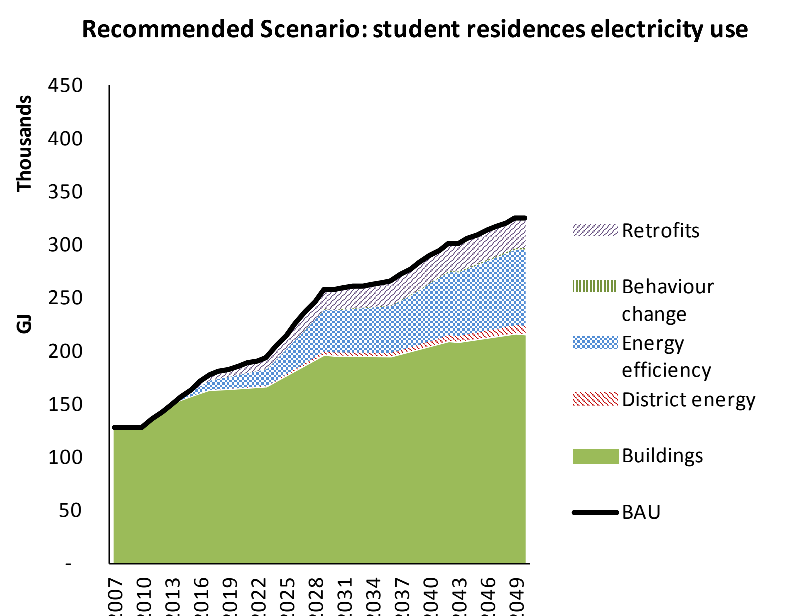


Figure 24: Final Scenario student residences electricity consumption.
Electricity use reduction shown as patterns.

3

Recommended Targets and Actions

3.1 Emissions and Electricity Targets in the Recommended Scenario

There are two different approaches to establishing GHG targets, an absolute target and a relative target. An absolute target is a desired amount of emissions below UTown@UBC's present total emissions. A relative target is a desired amount of emissions below UTown@UBC's projected emissions level under the BAU Scenario. These approaches are two ways of describing the same reductions.

The rapid targeted increase in UTown@UBC population and buildings means that short term absolute reductions are challenging and costly to achieve. Tracking of both absolute and BAU targets is recommended. While more difficult to achieve, absolute targets are a more meaningful demonstration of UTown@UBC's GHG emissions as the capacity of the climate to absorb GHG emissions is finite. BAU targets are useful because they are a more accurate representation of the magnitude of effort employed to achieve the targets.

Based on the analysis presented here, the following relative targets are recommended for UTown@UBC.

Electricity

- 16% reduction over BAU by 2020
- 36% reduction over BAU by 2050

GHG emissions

- 18% reduction over BAU by 2020
- 85% reduction over BAU by 2050
- 60% reduction over 2007 levels by 2050

The figures below display relative versus absolute emissions and electricity targets. The absolute targets are included in the graphs as an additional reference.

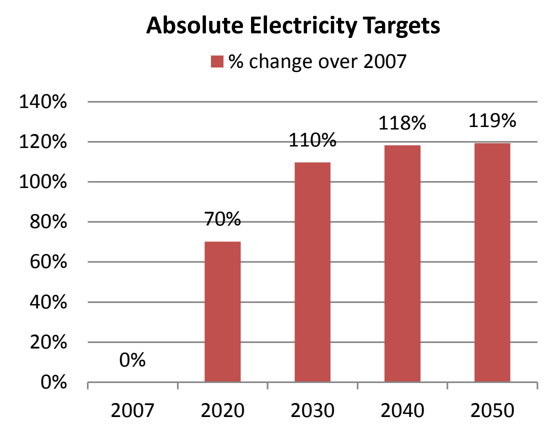


Figure 25: Absolute GHG targets by year.

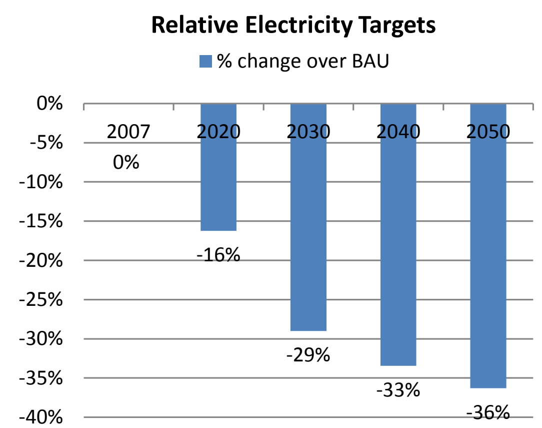


Figure 26: Relative GHG targets by year.

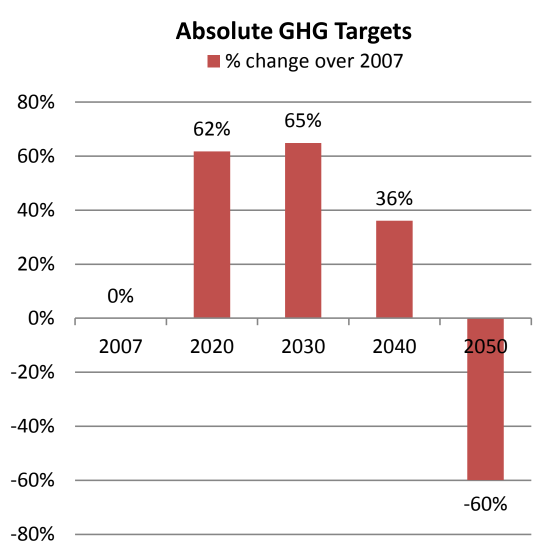


Figure 27: Absolute electricity targets by year.

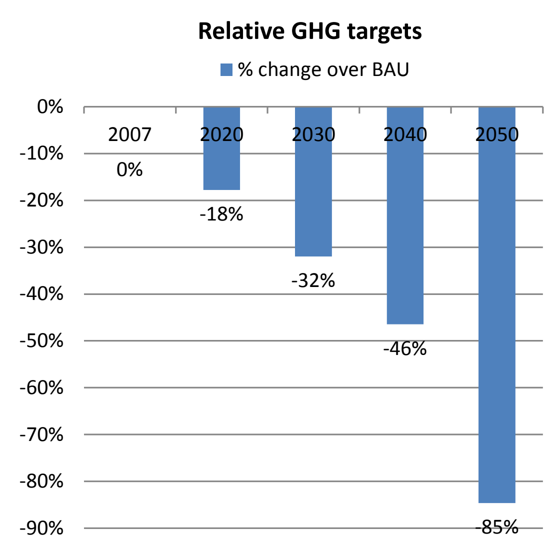


Figure 28: Relative electricity targets by year.

3.2 Recommended Actions

To achieve the emissions reductions and energy efficiencies of the Recommended Scenario, there are 18 recommended actions to undertake.

Table 2: Recommended Action Summary, UBC Responsibilities

Theme	Recommendation	Benefits	Costs	Potential GHG reductions	Potential electricity savings
Buildings	1. Incrementally improve REAP.*	• Cost savings of $40,000 per year for a 102 unit apartment building with aggressive set of energy measures.	• Efficiency gains can be economically achieved by improving building envelope.	Targets 5% of UTown@UBC buildings cumulative GHG reductions. Represents savings of 610 tCO2e in 2050.	Reduces annual UTown@UBC electricity consumption by 71,000 GJ by 2050.
	2. Establish an energy efficiency target for student residences.**	• Significant energy efficiency cost savings.	• Efficiency gains can be economically achieved by improving building envelope. • Revolving loan fund can also finance energy efficiency investments.	Targets 8% of student residences cumulative GHG reductions. Represents savings of 716 tCO2e in 2050.	Reduces annual electricity consumption in student residences by 62,000 GJ by 2050.
District Energy System (DES)	3. Implement a low carbon DES servicing all new Neighbourhood buildings starting in 2015.	• Control fuel costs. • Energy cost savings. • Educational benefits.	• Capital cost of $68.6M. • Additional 6.75 FTE. • Capital cost between $14- $28.5M for biogas system in 2040. • Operational costs between $200,000 and $4M for biogas system in 2040.	Targets 15% for student residences cumulative GHG reductions. Represents 13,012 tCO2e savings in 2050. Targets 38% for UNA cumulative GHG reductions. Represents savings of 26,152 tCO2e in 2050.	Reduces annual electricity consumption in UNA by 47,007 GJ by 2050.
	4. Starting in 2040 replace all natural gas in the Neighbourhood DES with biogas or biomass.				No change.
	5. All new student residences connect and all existing residences connect to the academic district energy system when boilers are replaced.				Reduces annual student residence electricity consumption by 8,447 GJ by 2050.
Retrofits	6. Retrofit 2.5% of student residences per year to achieve 20% energy savings per year. Connect common areas to the DES.	• Target energy savings from existing buildings. • Costs can be combined with major renovations.	• Minimize financial costs by combining energy retrofits with end of life replacements or major retrofits.	Targets 2% for student residences cumulative GHG reductions. Represents savings of 245 tCO2e in 2050.	Reduces annual UTown@UBC electricity consumption by 27,684 GJ by 2050.
Behaviour Change	7. Implement a transportation behavior change program for students that is integrated with UNA behavior change programs. The UBC Transportation Plan should integrate these mode shift targets.	• Helps people use existing transit options. • Saves individuals money. • Increases transit use. • Increases active transportation. • Educational opportunity. • Systematic approach to behavior change.	• Integrate with SHHS Residence Life Program.	Targets cumulative GHG reductions of 0.1% on buildings and part of 4% in transportation. Represents savings of 16 tCO2e in buildings and 1,700 tCO2e in transportation in 2050.	Reduces annual electricity consumption by 6,026 GJ by 2050.
	8. Implement a waste behavior change program for students that is integrated with UNA behavior change programs. The UBC and UNA waste plans should aim to achieve these waste targets.	• Reduces UBC operational costs.	• 1 FTE for UBC to target waste reduction and waste diversion.	Targets 5% of the cumulative GHG reductions up until 2050, 1,497 tCO2e per year by 2050.	None

* UNA: 160 ekWh/m2 by 2014 (44 ekWh/m2 electric); 140 ekWh/m2 by 2019 (43 ekWh/m2 electric).

** Student residences: 115 ekWh/m2 by 2014 (63 ekWH/m2 electric).

Table 3: Recommended Action Summary, UNA Responsibilities

Theme	Recommendation	Benefits	Costs	Potential GHG reductions	Potential electricity savings
Behaviour Change	9. Implement a behaviour change program to support energy efficiency at UTown@UBC. 10. Implement a behavior change program to support mode shifting away from vehicles using the model of the Smarter Travel Choices Program. 11. Investigate a personal carbon trading program of UTown@UBC as an integrated approach to behavior change.*	• Helps people use existing transit options. • Saves individuals money. • Increases transit use. • Increases active transportation. • Educational opportunity. • Systematic approach to behavior change.	• 2-4 FTE to run behavior change programs for UNA • Program research and design with students.	Targets cumulative GHG reductions of 1% on buildings and part of 11% in transportation. Represents savings of 64 tCO2e in buildings and 4,318 tCO2e in transportation in 2050.	Reduces annual electricity consumption by 1,487 GJ by 2050.
	12. Implement a waste reduction plan for UNA aiming for an ultimate target of zero waste.	• Reduces UNA operational costs.		Targets 7% of the cumulative GHG reductions up until 2050: 2,613 tCO2e per year by 2050.	None
Other	13. Maintain and enhance urban agriculture.	• UNA objective • Improves health and wellness • Educational benefit	• Additional maintenance costs. • Soil provision and other infrastructure such as water.	Reduces GHG emissions associated with transportation (See discussion items)	None

Table 4: Recommended Action Summary, UNA and UBC Joint Responsibilities

Theme	Recommendation	Benefits	Costs	Potential GHG reductions	Potential electricity savings
Data	14. Increase the precision of the electricity and emissions data collected by UTown@UBC.	• Increase the accuracy of the baseline data.	• Creating a UTown@UBC CEEI (with BC government). • Transportation survey project (~$20,000).	None	None
Retrofits	15. Identify economic and policy instruments to encourage energy efficiency improvements during major retrofits. Educate residents on the benefits of such an undertaking.	• Strategies could include applying REAP to major renovations, planning permission requirements, incentive programs or other measures.	• Study cost is approximately $20-50,000.	Supportive measure; no reductions.	Supportive measure; no reductions.
	16. Undertake buildings retrofits that upgrade UNA buildings as they undergo major retrofits. Educate residents on the benefits and support residents during the transition.	• Target 2.5% of the buildings per year to achieve 20% energy savings per year. • Operational (thermal and electrical) costs are reduced.	• Minimize financial costs by combining energy retrofits with end of life replacements or major retrofits.	Targets 3% of UNA cumulative GHG reductions. Represents savings of 312 tCO2e in 2050. Significant GHG savings resulting from connecting pre-2014 building stock to district energy, captured in the district energy reduction for UNA buildings.	Reduces annual UNA electricity consumption by 34,549 GJ by 2050.
	17. Connect common areas of pre-2014 UNA buildings to the district energy system as they are retrofit or major equipment is replaced at the end of its life. Educate and support residents during the transition.	• Control fuel costs • Energy cost savings			Reduction captured in district energy savings.
Transportation	18. Determine UTown@UBC's role in contributing to the implementation of a rapid transit system in conjunction with Translink, City of Vancouver and MetroVan.	• Enables convenient and fast public transit to and from UBC.	• No significant immediate costs. • Potential contribution to capital construction costs.	Targets part of 12% of cumulative GHG reductions. Represents savings of 3,450 tCO2e in 2050 in UNA and 1,358 tCO2e for student residences.	None.

* There has been extensive investigation into personal carbon allowances (PCA) or domestic tradable quotas but a pilot project has never been enacted. The PCA would cover all the direct energy used by individuals within UTown@UBC as well as on-ground travel (everything over which UTown@UBC has a direct or indirect influence). Every time a person pays an energy bill, crosses the UBC boundary in a car, takes transit or purchases goods (each good would be assigned a carbon footprint) they would have to surrender carbon 'credits' from their account, or pay the additional cost of buying carbon credits at the market price. People would be allocated an equal per capita allowance, which would reduce annually at the rate necessary to meet long-term emissions reduction targets.

Appendix 1

Project Methodology

Project Methodology Overview

The Community Energy and Emissions Plan is a culmination of four major areas of public and professional contributions resulting in a suite of recommended actions. The input sources are:

1. Public: student and UNA residents;
2. UTown@UBC project staff employed by UBC;
3. UTown@UBC and UBC stakeholders including staff, students, and operations and management personnel; and
4. The project consultant team.

The CEEP was conducted in four phases that followed the public engagement progression of engaging, learning, contributing and doing, as summarized in Table 5.

Table 5: Project Description by Phase

1. Engaging	2. Learning	3. Contributing	4. Doing
• Establishing a public engagement framework • Project launch event: 5 Pecha Kutcha talks • Project website • Collecting sustainability ideas • Stakeholder interviews **Technical work** • UTown@UBC background contextualization • GIS context mapping • Community Energy and Emissions Inventory development • Energy and emissions data collection	• Low Carbon Community World Cafe • Public vision questionnaire **Technical work** • Energy and emissions baseline establishment • Business as Usual scenario development • Alternative energy options development • Residential Environmental Assessment Program (REAP) evaluation	• Stakeholder workshops • Public action questionnaire **Technical work** • Future scenario development • Final mapping • Screen and refine alternative energy options	• Plan refinement • Engagement evaluation **Technical work** • REAP integration • Recommended actions

The project background review, stakeholder interviews, ideas collection and public engagements culminated in a suite of sustainable transportation, energy efficient buildings, renewable energy production, waste and minor land use suggested actions. These actions were modelled in three scenarios over the period from 2007 (baseline year) to 2050. The scenarios included Business as Usual, a scenario based on UTown@UBC achieving the Province of British Columbia's GHG reduction targets (33% below 2007 levels by 202, 80% below by 2050) and a scenario based on achieving UBC's Climate Action Plan targets (carbon neutral by 2050). The scenarios were presented to stakeholder groups for identification of priority action elements and clarification of which elements to model further in each scenario. Recommended actions were derived from the modelling results and used to develop a recommended emissions reduction scenario.

Vision elements for the UTown@UBC CEEP were developed through public engagement efforts, including discussions at the launch event, discussions at the World Cafe public event, responses to an online questionnaire, ideas posted to an online ideas voting platform, and meetings with stakeholders. A summary of the vision elements is given in Table 6.

Table 6: CEEP Public Vision Elements

Sustainable Transportation	Energy Efficient Buildings	Renewable Energy Production	Waste	Other
• Increased transit service • Improved transit connections • Rail/high speed transit to campus • Free transit in main corridor • Implement a UNA bus pass • Community shuttles • Bike share • Car share • Electric vehicles and bikes • Hybrid and fuel cell buses • Reduce campus fleet use • More bike infrastructure	• Resident education program • Incentives for home efficiency upgrades • Improve green building standards • Set energy and carbon targets • Aim for regenerative buildings • Engage stratas in energy efficiency measures • Develop energy efficiency retrofit strategy • Improve water use efficiency • Increase use of efficient lighting • Use only cold water	• District energy systems • Explore on-building solar	• Resident education program • Incentives and/ or requirements for retailers to be responsible for packaging waste • Improved recycling options • Using waste to produce energy • Ban organics in the waste stream • Localize composting • Create a venue for exchanging items • Set maximum garbage bag rates per household	• More distributed amenities • More variety of amenities and healthy food options • More community gardens • More fruit trees and edible landscapes • UNA has greater voice in decision making • Replace gasoline powered landscaping equipment with electric • Discourage pet ownership
• Sustainability education programs across all categories				

The vision elements were combined to form a UTown@UBC CEEP Vision Statement:

> *The UTown@UBC Community Energy and Emissions Plan is a living document that guides UBC and UNA in action towards energy efficiency and emissions reductions targets through efforts resulting in more sustainable transportation options, more energy efficient new and existing buildings, on-campus renewable energy production, less production of, and improved treatment of, solid and liquid waste, and continued support of urban agriculture and forests at UBC.*

This vision statement guided the energy and emissions elements selection for scenario modelling and shaped the choice of recommended actions resulting from the modelling and public discussion.

Appendix 2

Scenario Modelling Details

1. Modelling Summary

SSG's GHGProof model was used to analyze past and present energy and emissions patterns, project the impact of future energy and emissions patterns and generate scenarios that achieve desired energy use and emissions amount targets. It is important to note that, like any model, GHGProof's outputs do not represent actual outcomes. Rather, it illustrates the effects of choosing among various actions. Modelling the potential effects of new energy efficiency measures in buildings, adding local renewable energy production, diverting solid and liquid waste, and making transportation more sustainable allows informed decision making on what actions will have the most positive effects through increasing energy efficiency and reducing GHG emissions.

GHGProof was used to explore:

- Alternatives: variations of building standards, energy technologies and transportation options.
- Consequences: immediate and cumulative effects are expressed through the outputs of the analysis.
- Causations: causal bonds between alternatives and consequences are illustrated using transparent equations between assumptions and inputs.
- Time frames: periods of time between implementation of the alternatives and the unfolding of their consequences.

GHGProof uses a large number of assumptions, drawing where possible on local studies and otherwise employing provincial or national averages. All of the assumptions are adjustable in order to test different possibilities. In the baseline, assumptions are calibrated to align the model with the relevant categories from the Community Energy and Emissions Inventory data. Specific CEEI data is not available for UBC and UTown@UBC. There is reliable data available for Metro Vancouver Area A, in which UBC resides. 2007 UTown@UBC CEEI data was created by subtracting known energy and emissions data for UBC's academic buildings (as provided in UBC's Climate Action Plan and from the University Endowment Lands) from Area A's totals. The remaining data was adjusted using UTown@UBC buildings and operations energy data. Thus a best estimate of UTown@UBC's energy and emissions was provided for the baseline data. An action is recommended to improve the baseline data over time.

2. Modelling Discussion Items

The modelling process is able to accommodate certain types of data, like those in the CEEI data constructed for this project. Others are difficult to include for various reasons. Figure 29 describes three different types of community inventories: 1) Pure geographic; 2) Geographic-plus; and 3) Consumption-based. BC's CEEI data is a geographic-plus approach in that it includes local emissions from natural gas combustion and transportation emissions, but it also includes off-site emissions from waste, transportation (travel to and from) and electricity production. The geographic-plus approach was used for UTown@UBC analysis. Following are a few modelling discussion items responding to community feedback during the project. They are related to a consumption-based inventory (i.e.: not used for this project).

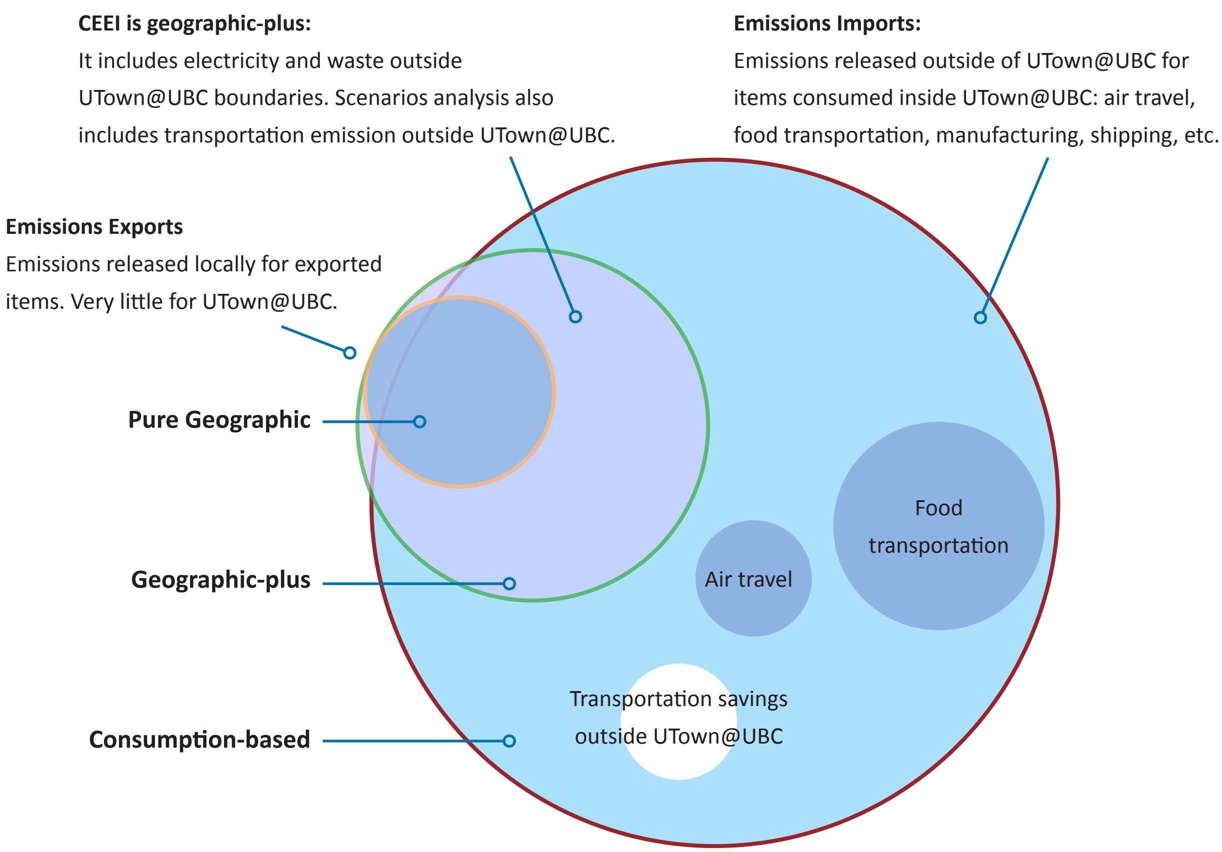


Figure 29: Types of community inventories.

2.1 Emissions Related to Forests

Emissions associated with forest area were considered, with 54 hectares of forested land in UTown@UBC absorbing 217 tCO2e per year (at a rate of 4.0 tCO2e/ha/year) while releasing 81 tCO2e per year in soil emissions for a net store of 135 tCO2e.[13]

2.2 Agricultural Production Emissions

Emissions associated with transporting food to UTown@UBC was also considered. Assuming each person on campus consumes 580 kg of food per year,[14] two Ontario studies' estimates for GHG emissions for transportation from an imported basket of food versus food transported from farmers markets were illustrated (Figure 30). No equivalent study has been completed in BC. One study[15] found grocery store food (i.e.: imported food) emissions to be 1.0 kg CO2 per kilogram of food (Figure 30, low estimate) while a second study[16] determined grocery store food emissions to be 1.3 kg CO2 per kilogram of food (Figure 30, high estimate). On-campus food production at the UBC farm, in community gardens or in integrated agricultural landscapes reduces these emissions, however, the limited campus area available for food production means that emissions reductions opportunities are limited at UTown@UBC.

13 Aalde, H., Gonazlez, P., Gytarsky, M., Krug, T., Kruz, W., Ogle, S., et al. (2006). 2006 IPCC Guidelines for National GHG Inventories: Chapter 4: Forest Land. Forestry.

14 B.C. Ministry of Agriculture and Lands, 2006. *B.C.'s Food Self-Reliance*. Retrieved from www.agf.gov.bc.ca/resmgmt/Food_Self_Reliance/BCFoodSelfReliance_Report.pdf.

15 Stephen Bentley, 2005. *Fighting Global Warming at the Farmer's Market*. Retrieved from www.foodshare.net/files/www/Food_Policy/Fighting_Global_Warming_at_the_Farmers_Market.pdf.

16 Xuereb, M. (2005). Food miles: Environmental implications of food imports to Waterloo Region. Region of Waterloo Public Health.

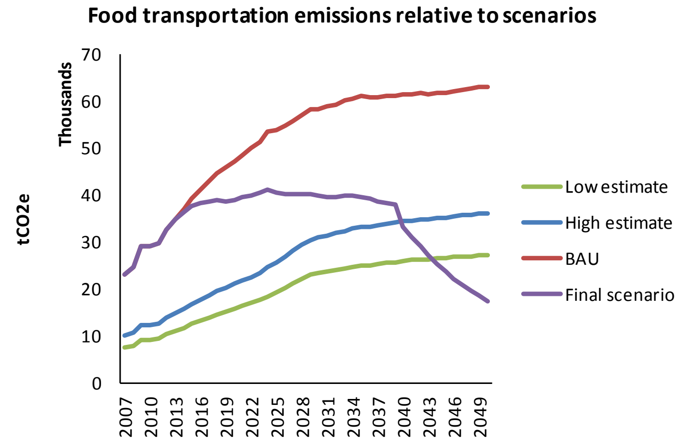


Figure 30: Comparison of emissions related to food transportation with scenarios

2.3 Commuting Emissions Reduction

A major benefit of on-campus residential expansion to create live/work communities is the accompanying reduction in commuting by students, staff and faculty. With increased on-campus population, on-campus services will increase, reducing the need for off-campus trips and increasing the viability of walking and cycling to key destinations. The vehicular mode share of on-campus trips is 17% (single driver and car-pooling) whereas the commuting vehicular mode share is 24%. The mode share benefit is accentuated by the fact that on-campus trips average just 1.7km whereas off-campus commuting trips average 16.5km. Thus, every person living on campus (who would otherwise have been living off-campus) represents a significant GHG emissions reduction. This information was not included in the scenario modelling because the scope did not include students or staff commuting to UBC from outside UTown@UBC. Further, understanding the influence of additional UTown@UBC destinations was limited by travel data availability.

The emissions benefit from reduced commuting was calculated by multiplying the number of new on-campus student beds by ten trips per week by 48 weeks per year using a transportation emissions factor representing the relative mode share of transport options. For UNA residents, it is assumed that 50% of households have one resident who works at or attends UBC (as is currently the case) and that they would have otherwise had to commute from destinations off-campus. It is also assumed that the other residents who do not work at UBC are travel neutral, i.e.: their travel by mode and by destination would be the same whether they live in UTown@UBC or otherwise. Note that this calculation assumes BAU conditions. If rapid rail transit were introduced, for example, the GHG reduction from transit would be less than other BAU conditions which assumes a higher degree of diesel in the transit emissions factor. Figure 31 illustrates that the emissions reduction associated with reduced commuting reaches -8,700 tCO2e by 2050.

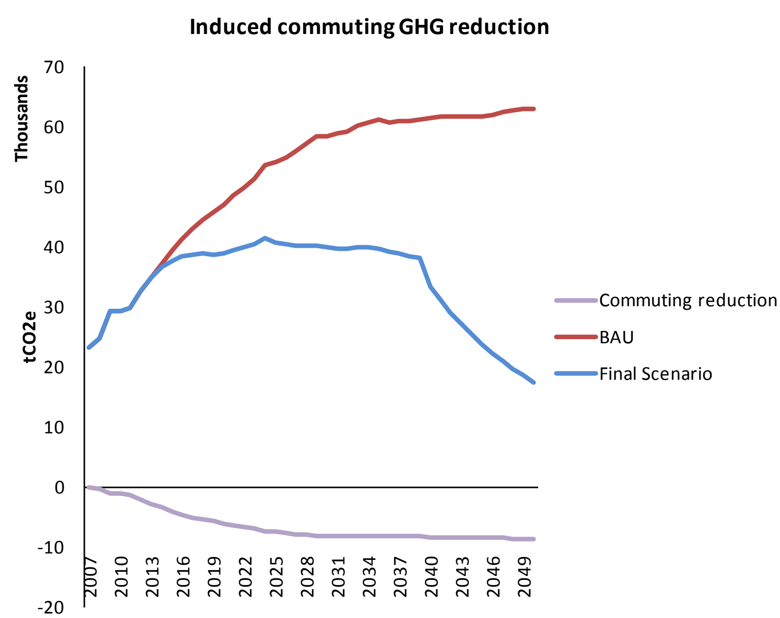


Figure 31: Induced commuting reduction from housing more students, staff and faculty on campus

2.4 Air Travel Emissions

The UBC Climate Action Plan captures emissions resulting from air travel related to UBC business and some of the air travel emissions from UNA residents are captured by the UBC Climate Action Plan, resulting in double counting, as a large number of UNA residents are employed at UBC (over 50% of residential units in the UNA have one or more occupants who work or study at UBC).

Air travel GHG emissions were estimated by calculating the per capita revenue passenger kilometres (RPK) for Canada for 2010, totalling 3,775 RPK/capita (i.e.: assuming the average UTown@UBC resident is equivalent to the average Canadian in terms of their air travel). The Government of Canada's 2012 aviation strategy annual fuel efficiency targets (0.2% fuel efficiency improvement until 2020) were included.[17] Figure 32 provides an indication that the inclusion of air travel could have a significant impact on UTown@ UBC GHG emissions. This initial estimate of air travel emissions is 18,000 tCO2e of annual emissions by 2050.

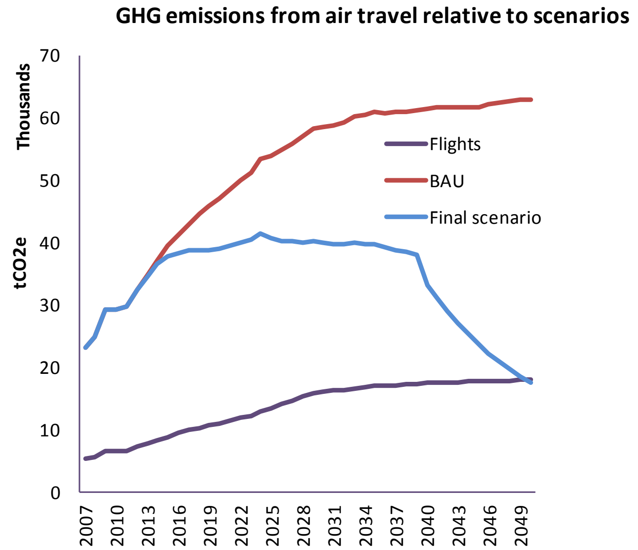


Figure 32: Estimate of air travel related GHG emissions for UNA residents

2.5 BC Hydro Emissions Factors

The BAU Scenario is calculated according to standard practice, which assumes that BC Hydro's published emissions factor is constant even as UBC's electricity demand increases. The Pacific Institute for Climate Studies published a paper that notes the following: [18]

> *"BC Hydro reports on only a subset of emissions associated with generation and delivery of electricity... BC Hydro does not report on the emissions associated with electricity that it imports to meet domestic demand while using its own hydro supply to satisfy more lucrative markets. If electricity sold by BC Hydro is sold as a low carbon product, the carbon intensity of electricity delivered to BC has to reflect the gross imported power."*

If BC Hydro were to sell electricity as a low carbon product at some point in the future the carbon intensity of electricity increases from 24 to 84 tCO2e/GWh. A value of 24.2kg CO2e/GJ was used in the modelling.

17 Government of Canada, 2012. Canada's Action Plan to Reduce Greenhouse Gases from Aviation. Retrieved from www.icao.int/environmental-protection/Documents/ActionPlan/AviationGHGActionPan_En.pdf

18 Dowlatabadi, H. (2011). Lifecycle analysis of GHG intensity in BC's energy sources. ISIS, Sauder School of Business, UBC and Pacific Institute for Climate Solutions. Available at: http://pics.uvic.ca/sites/default/files/uploads/publications/Lifecycle%20analysis%20of%20GHG%20intensity%20in%20BC%27s%20energy%20sources%20.pdf

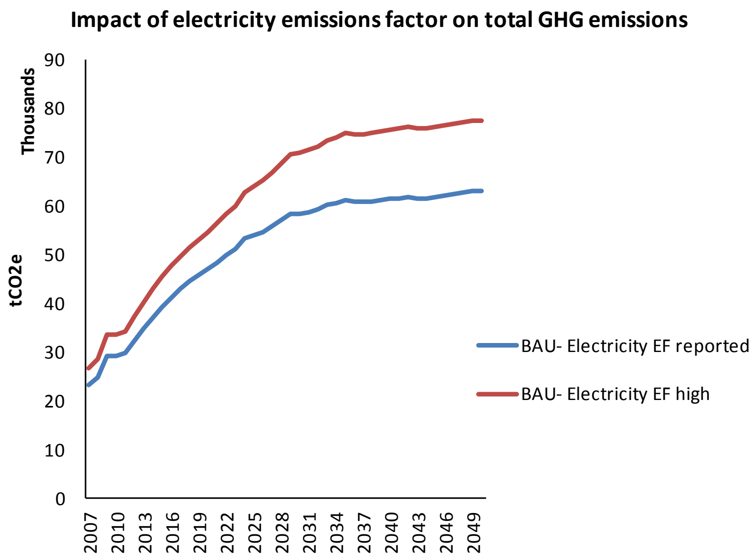


Figure 33: Electricity emissions factor influence on GHG emissions

3. Modelling Three energy and Emissions Scenarios for UTown@UBC

Three scenarios explored approaches to energy efficiency and emissions reduction actions between 2007 and 2050:

- **Business as Usual (BAU):** GHG emissions from, and energy use of, student residences and UNA buildings were projected, assuming no not-already-planned additional efforts were to be made to specifically address emissions production and energy use. The constructed 2007 CEEI data is used as baseline inputs for the model. Current trends, UTown@UBC and UBC plans, and the estimated uptake of certain current technologies (e.g.: electric vehicles) inform the BAU Scenario. Buildings and transportation behaviours were modelled separately for UNA and for UBC student residences due to their inherent differences.
- **Scenario 1, BC Targets:** Actions were modelled to achieve the Provincial emissions reduction targets of 33% emissions reduction by 2020 and an 80% reduction by 2050, both under 2007 levels.
- **Scenario 2, UBC Targets:** Actions were modelled to achieve the UBC academic campus emissions reduction targets of 33% by 2015, 67% by 2020 and 100% by 2050, also under 2007 levels.

Table 7 summarizes the GHG emissions projections for the BAU Scenario and the reduction targets for the two scenarios. Figure 15 depicts emissions for each scenario, showing the magnitude of the challenge in achieving Scenario 1 and Scenario 2 emissions reductions targets. Table 7 summarizes the transportation, energy efficiency, energy generation and waste actions modelled for each scenario.

Table 7: Emissions by Year (tCO2e)

		2007	2020	2050
BAU	GHG (tCO2e)	23,223	45,708	60,567
	Natural gas (GJ)	139,000	167,718	352,845
	Electricity (GJ)	127,853	185,297	324,548
Scenario 1: BC Targets		23,223	15,327	4,644
Scenario 2: UBC Targets		23,223	7,663	0

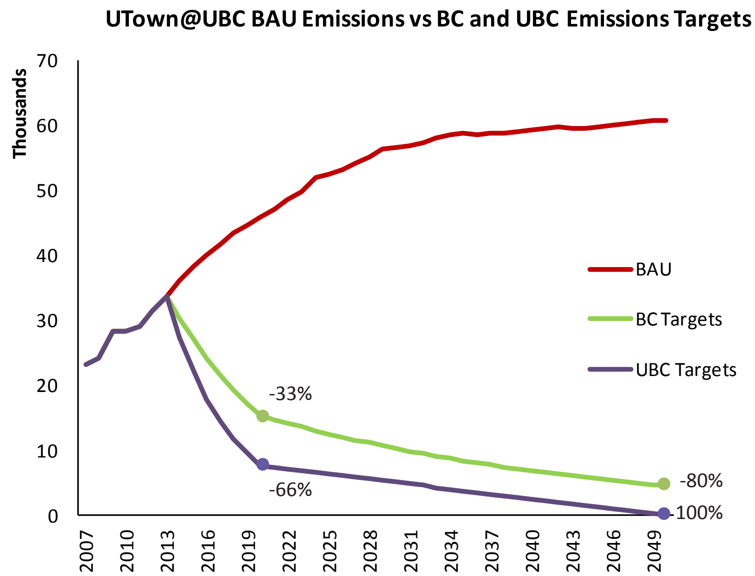


Figure 34: BAU emissions compared to GHG reductions required to meet Provincial and UBC targets.

Table 8: Actions Modelled for Each Scenario			
Categories	**Business as usual**	**Scenario 1: BC Provincial Targets** 33% reduction by 2020 80% reduction by 2050	**Scenario 2: UBC CAP Targets** 33% by 2015 67% by 2020 100% by 2050
Behaviour change	Existing behaviours projected out.	Campus carbon account for student and faculty.	Internal carbon trading for students and faculty (carbon allowances).
Transportation			
Vehicle Kilometres Travelled	Substantial reduction in commuting due to increased building on campus.	No change in VKT.	No change in VKT.
Mode split	Walking and cycling rates stay the same.	Increase in walking and cycling rates through urban design.	Increase in walking and cycling through personalized transportation program.
Vehicle type	Limited uptake of electric vehicles.	Incentivized uptake of electric vehicles including transit through car share, car coop, parking incentives.	Incentivized uptake of electric vehicles including transit through car share, car coop, parking incentives. Also natural gas for commercial vehicles.
Energy efficiency			
Building envelope	REAP continues as planned. (Minimum REAP). Minimum occurrence of retrofits.	Application of medium REAP standard. Medium occurrence of retrofits.	Application of maximum REAP standard. Maximum occurrence of retrofits.
Energy generation			
CHP/District energy	No additional.	District energy provided to neighbourhoods from TRIUMF waste energy. Energy hybrid configurations/ Organic Rankine Cycle Turbine.	100 % district energy by 2050 with cogeneration (biogas from organic materials) and TRIUMF waste energy.
Waste			
Solid waste production	Projected out based on current per capita generation.	10% reduction by 2020 over 2010 levels (MetroVan target).	20% reduction by 2020 over 2010 levels, 50% by 2050 over 2010 levels.
Solid waste diversion rate	Projected out based on current diversion rates.	70% by 2015, 80% by 2020 (MetroVan target).	80% waste reduction by 2020.
Liquid waste treatment	MetroVan Iona Island.	MetroVan Iona Island.	MetroVan Iona Island.

Table 9 on the following page presents the modelling results summary. Scenario 2 is essentially a more ambitious version of Scenario 1 in terms of actions modelled. Even though aggressive actions were modelled in trying to achieve the targets in both scenarios, the emissions reduction targets were not met, as shown in Figure 36 and Figure 37. The Recommended Scenario discussed in Section 3 drew elements from these 3 scenarios (i.e.: it is not a replication of Scenario 1 or 2, rather a suite of actions that are based on the modelling analysis).

Table 9: Scenario analysis results in relation to emissions reduction targets							
	2007	2020			2050		
		BAU	Scenario 1	Scenario 2	BAU	Scenario 1	Scenario 2
UNA (tCO2e)	11,569	29,261	15,963	13,416	36,138	10,988	5,688
% change*	-	253%	138%	116%	312%	95%	49%
Student residences (tCO2e)	11,654	16,447	6,625	5,102	24,429	5,887	2,741
% change*	-	141%	57%	44%	210%	51%	24%
Total (tCO2e)	**23,223**	**45,708**	**22,588**	**18,518**	**60,567**	**16,875**	**8,410**
% change*	**-**	**197%**	**97%**	**80%**	**261%**	**73%**	**36%**

*over 2007 levels

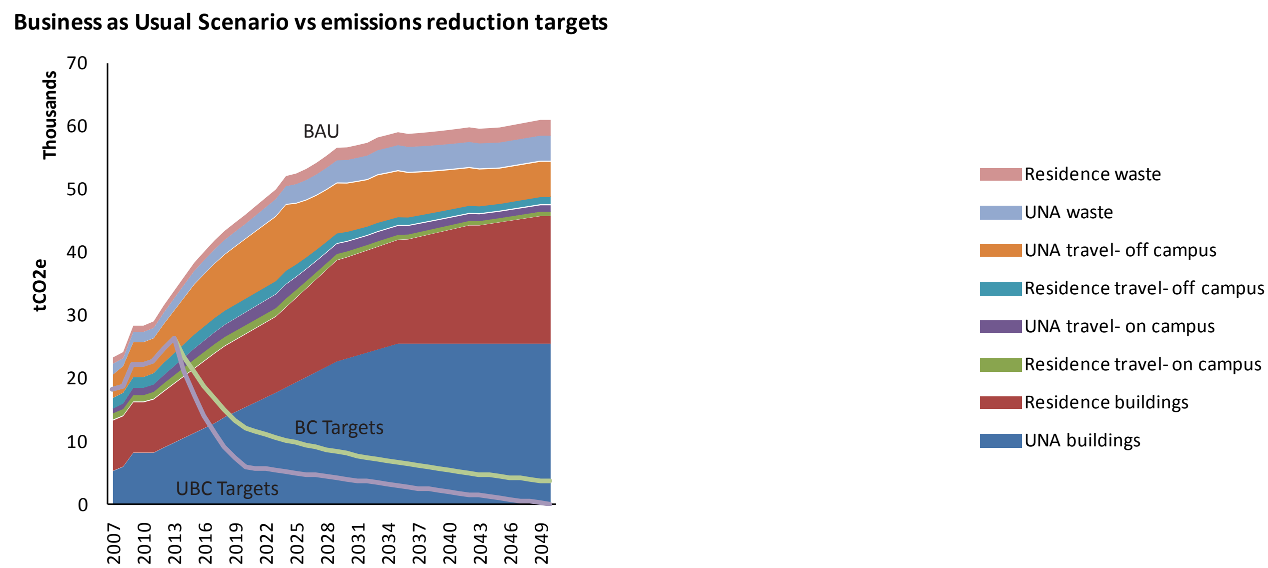


Figure 35: BAU emissions comparison to BC and UBC emissions targets.

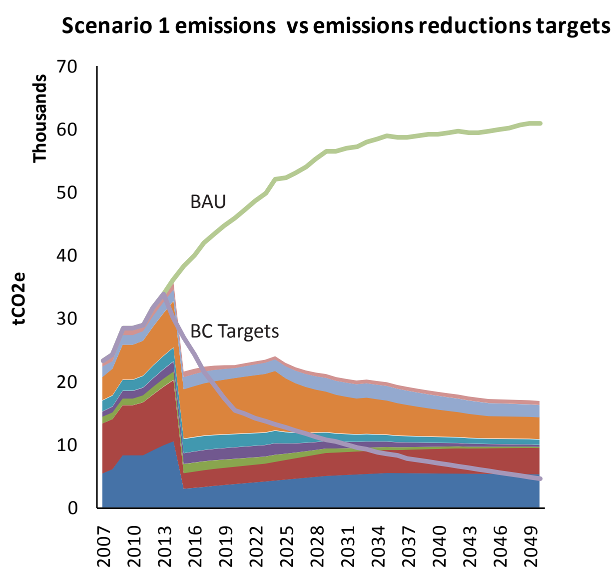


Figure 36: Scenario 1 emissions comparison to BC emissions targets.

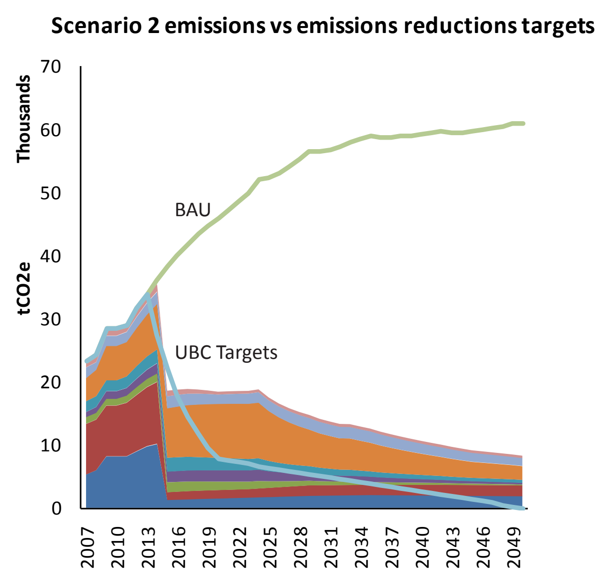


Figure 37: Scenario 2 emissions comparison to UBC emissions targets.

Figure 36 and Figure 37 illustrate the potential emissions reductions in each scenario from the projected BAU levels. The BAU Scenario is the top line of each chart. Each coloured area represents a reduction in emissions as the result of a particular strategy.

The majority of emissions reductions for both Scenario 1 and 2 is the result of a new district energy system, which directly offsets natural gas. In Scenario 2, the greater efficiencies resulting from the maximum combination of energy conservation measures in REAP result in the second most significant source of reductions. Retrofits, transportation mode shift and waste diversion at UNA and in student residences all contribute to a secondary cohort of reductions.

The most significant driver for emissions reductions in Scenario 1 is the adoption of a district energy system (DES) that derives waste heat energy from TRIUMF. In Scenario 2, natural gas used for back-up boilers in the DES is replaced by carbon neutral biogas, further reducing building-related GHG emissions. The GHG benefits of other actions including behaviour change, retrofits, and the minimum combination of REAP are less significant. However, Scenario 2 shows that if the level and pace of investment increase in each of those areas, more significant GHG emissions reductions are possible in the areas of retrofits, energy efficiency in new construction, waste management and transportation. The scenarios illustrate the magnitude of meeting both the Provincial emissions reduction goals and the UBC Climate Action Plan goals for a community developing at the rate of UTown@UBC. Even with aggressive sustainability actions in transportation, energy and waste, the 80% and 100% by 2050 emissions reductions goals are unrealized.

4. Strategies to Reduce Energy and GHG Emissions from Buildings

District Energy

UTown@UBC has two key strategies to reduce GHG emissions and energy consumption from buildings: the Residential Environmental Assessment Program (REAP) building standard and district energy. REAP encompasses a number of different strategies and district energy systems can be implemented in a variety of ways. A feasibility study for a UNA district energy system was completed in which a concept with TRIUMF waste heat recovery as the primary alternate heat source was evaluated.[19] The system converted the heat using an electrically powered 4 MW heat pump, and secondary/peaking heat sources from four 10 MW natural gas boilers, installed in a phased process as the neighbourhoods develop. The electrical load in this study is from plant auxiliaries (pumps, HVAC, etc.) and the natural gas/heating oil is for peaking and back-up.

In Scenario 1 the proposed district energy system replaces the BAU energy mix with waste heat recovered from TRIUMF cooling towers, and a mix of biomass and/or biogass. In Scenario 2 the remaining fossil fuel used is replaced biogas, generated either on or off campus. The fuel mix for each scenario is illustrated in Figure 38.

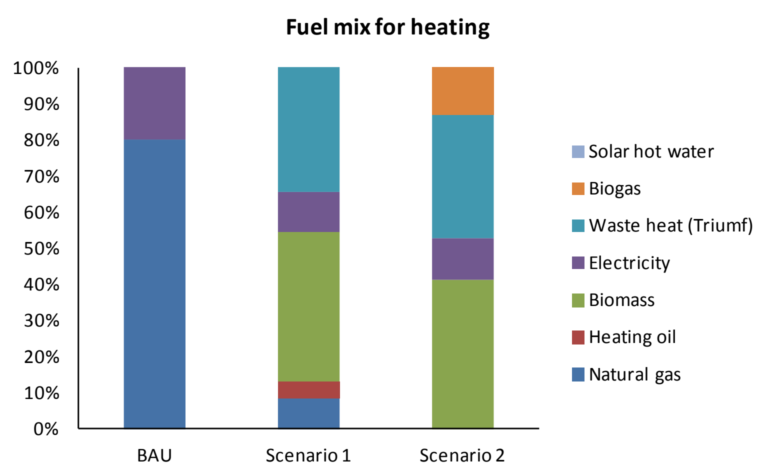


Figure 38: Fuel mix used in the UNA district energy system for building heating for three scenarios.

Most natural gas use is replaced by a waste heat and biomass/biogas district energy systems to produce energy for UNA buildings. Heating oil and natural gas still provide 13% of the heating energy in Scenario 1. In Scenario 2, all heat production related GHG emissions are eliminated by provision of heat through 100% renewable sources (biogas, waste heat and biomass district energy systems plus hydro electricity).

In Scenarios 1 and 2, all new student residences are connected to the Academic District Energy System starting in 2015. Existing academic buildings are connected as feasible until all are connected by 2020 and emissions reduce as per the academic DES plan.

19 University of British Columbia Neighbourhood District Energy System Technical Feasibility Study Report, April 27, 2012 draft.

Energy Efficiency

In a separate but related project, SSG worked with EnerSys and Enerficiency Consulting to evaluate the energy performance of future versions of REAP. Using the results from this project, the REAP baseline design was applied to the new building stock in the BAU Scenario, the minimum combination of REAP measures to Scenario 1 and the maximum combination of REAP measures to Scenario 2. Table 10 and Table 11 describe the REAP assumptions for each scenario. High-rise buildings are considered concrete construction while low-rise are considered wood frame.

Table 10: Scenario 1 REAP Measures

Measure	High-rise	Low-rise
Wall R-16 exterior insulated system	x	
Roof R-26 insulation (up from R-20)		x
Add Argon with warm edge spacers to windows	x	x
Common lighting load reduction from 0.65 to 0.55 w/ft2	x	x
Corridor and stair lighting occupancy sensors	x	x
Suite lighting reduction from 0.84 to 0.65 W/ft2	x	x
Exterior lighting reduction (parkade motion sensors)	x	x
High efficiency condensing boilers	x	x
Exhaust heat recovery	x	x

Table 11: Scenario 2 REAP Measures

Measure	High-rise	Low-rise
Reduce wall glazing to 40%	x	
R-15 wall glazing system with insulated balconies	x	
Wall R-24 (2*6 with exterior rigid insulation)		x
Increase roof insulation to R-40 from R-26		x
High performance triple pane windows	x	x
Window sensors coupled to heating	x	x
Zone control and sub-metering of hot water and direct hot water	x	x
High efficiency direct hot water heating	x	x

These measures result in lower energy use intensity (EUIs) for both high-rises and low-rises (Table 12). From a GHG perspective, the primary gains are related to fuel switching for heating. Electricity consumption drops from 90 kWh to between 52 and 56 kWh/m2 between 2012 and 2013 as new buildings cease to use electric baseboard heating in the BAU and Scenarios. Figure 39 and Figure 40 show the EUIs across scenarios. The fuel mix in Figure 38 is used to provide the heating energy in the corresponding scenarios.

Table 12: Scenario EUIs (kWh/m2)

	High-rise	Low-rise
BAU	234	178
Scenario 1	149	127
Scenario 2	104	102

Figure 41 shows the energy savings and payback periods of the various energy conservation measures proposed for REAP maximum. Many measures have long paybacks, requiring innovative funding mechanisms to enable developers to incorporate them into buildings without significant cost increases. When the measures are bundled together, the overall payback is 21.9 years.

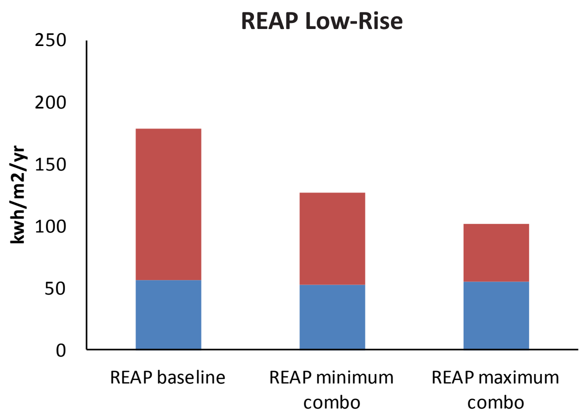


Figure 39: Modelled REAP low-rise building EUIs

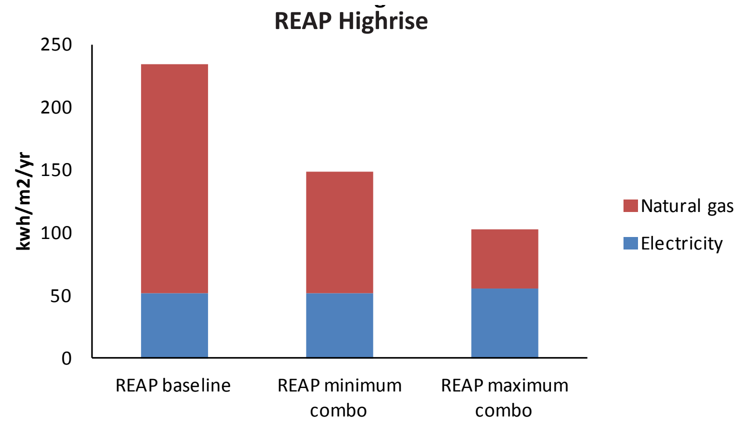


Figure 40: Modelled REAP high-rise building EUIs

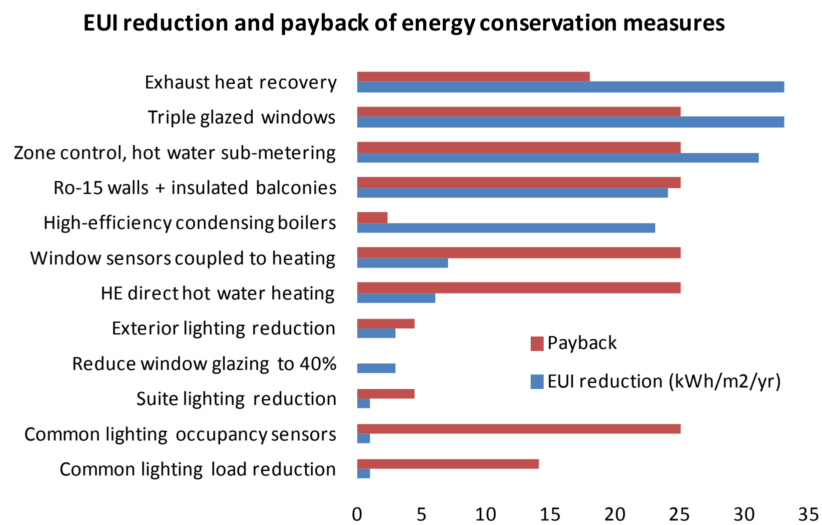


Figure 41: Modelled REAP high-rise building energy use intensities

Retrofitting existing UNA buildings

The BAU scenario assumes no additional retrofits of the existing building stock. Scenario 1 assumes the implementation of a new REAP standard by 2015, leaving a building stock of 534,267 m2 consuming approximately 40% more energy. It is assumed that 1.5% of this building stock is retrofitted each year, achieving average energy savings of 25% each year (note that REAP minimum represents almost 40% savings over the pre-existing building stock). Scenario 2 assumes 2.5% of the building stock is retrofitted each year, with total energy savings of 40% (note that REAP maximum represents an 82% reduction over the existing building stock). The Recommended Scenario recognizes that retrofits must be combined with major renovations, at end of building life, to be affordable.

Energy efficiency for student residences

While REAP applies only to UNA buildings, energy efficiency targets were also modeled for student residences. In Scenario 1, energy consumption was assumed to increase by 34% for new construction by 2050. In Scenario 2, a 50% improvement was assumed. It is assumed building energy efficiency improves incrementally over the period between 2014 and 2050. In Scenario 1, 5% of the pre-2015 building stock is retrofitted, achieving a 10% savings in energy consumption. In Scenario 2, 5% of the pre-2015 building stock is retrofitted achieving a 20% savings in energy consumption.

5. Behaviour change

Behaviour change effects on electricity and natural gas consumption were evaluated by assuming cumulative reductions of 0.2% per year in Scenario 1 and 0.3% per year in Scenario 2 (i.e.: residents have an escalating conservation ethic). This translates to a 6% and 11% reduction by 2050 over 2013, respectively. For comparison, a BC Hydro conservation program targeted 300,000 participants. 10% of people targeted participated, of which just 20% achieved the targeted savings of 15%. The other 80% of participants averaged savings of 4.5%. Participation in the second year increased significantly.[20] This experiment shows that while energy savings resultant from behaviour change are small, these efforts are critical to building stewardship and the success of other measures such as transportation mode shift and waste management.

6. Transportation Emissions in the 3 Scenarios

The student and UNA resident populations have very different travel behaviours, thus the two groups were modelled separately. Major on and off-campus destinations were identified and given weighting factors corresponding to estimations of how often they are visited. Summarized in Table 13 and Table 14, the more frequented the destination, the higher the weighting value.[21]

Table 13: On campus destination weighting factors

Destination	Weighting
Bookstore	0.1
Brock Hall	0.1
Chemistry D Block	0.1
Henry Angus Building	0.1
Irving K Barber Centre	0.2
Life Sciences Centre	0.1
Neville Scarfe Building	0.1
Student Union Building	0.6
Walter C. Koerner	0.1

Table 14: Off campus destination weighting factors

Destination	Weighting
West of Cambie	0.42
East of Cambie	0.21
Downtown peninsula	0.09
Richmond	0.08
Burnaby	0.06
Surrey	0.03
North /West Vancouver	0.03
Coquitlam/Port Coquitlam	0.03
Delta, New Westminster	0.02

GIS mapping was used to calculate average distances from each neighbourhood to on- and off-campus destinations. A weighted average was calculated for off-campus trips (14.27km) and on-campus trips (1.73km). BAU Scenario mode shares were assigned according to data from UBC's 2011 Vancouver Transportation Survey. The on-campus driving mode share is reduced from 14% to 2% in Scenario 1 and to 1% in Scenario 2 by 2050, reflecting efforts to get people out of cars and walking or cycling on campus (generally less than 1 km). Figure 42 and Figure 43 reflect the travel mode shift across the three scenarios for on- and off-campus travel.

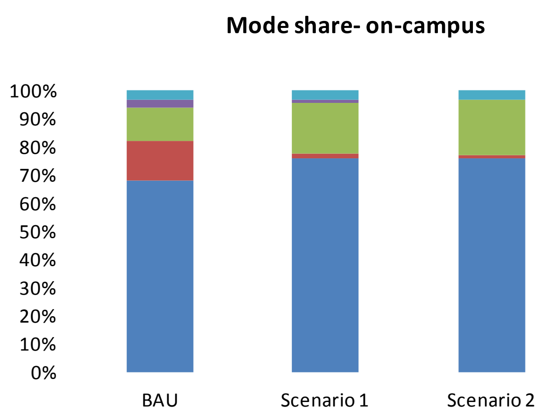


Figure 42: Shifting residents from cars to transit and active transportation on campus

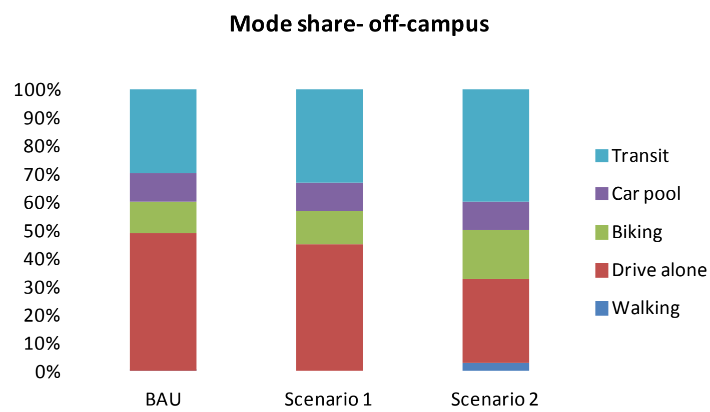


Figure 43: Shifting people out of cars and in to active transportation and transit off campus

The potential for walking and cycling for off-campus trips was calculated using a distance decay map. The most important destinations were found to be within cycling distance. Figure 44 shows typical off-campus destinations and Figure 45 shows typical walking and cycling distance maximums. Campus destinations are all less than 2km from any point on campus, making it very walkable and

20 Bonneville Power Administration (2011). Residential behaviour based energy efficiency program profiles. Available at: www.bpa.gov/energy/n/pdf/BBEE_Res_Profiles_Dec_2011.pdf

21 These weights are based on the results of UBC's 2011 Vancouver Transportation Survey.

cyclable. Scenario 1 assumes driving trips fall from 49% to 45% of mode share by 2050 while Scenario 2 assumes it falls to 30%. In both cases the majority of the difference goes to public transit and the minority to cycling, with a small increase in walking for Scenario 2. Projected federal fuel efficiency standards and low carbon fuel regulations are assumed for all three scenarios. In Scenarios 1 and 2 the electrification of the public transit system was increased, reflecting the introduction of electricity-powered rapid rail transit and more hybrid electric buses. The resulting increase in electricity consumption is not captured as part of the UTown@UBC analysis as the transportation system is not run by UBC or UNA, however this does reduce the emissions factor for public transportation.

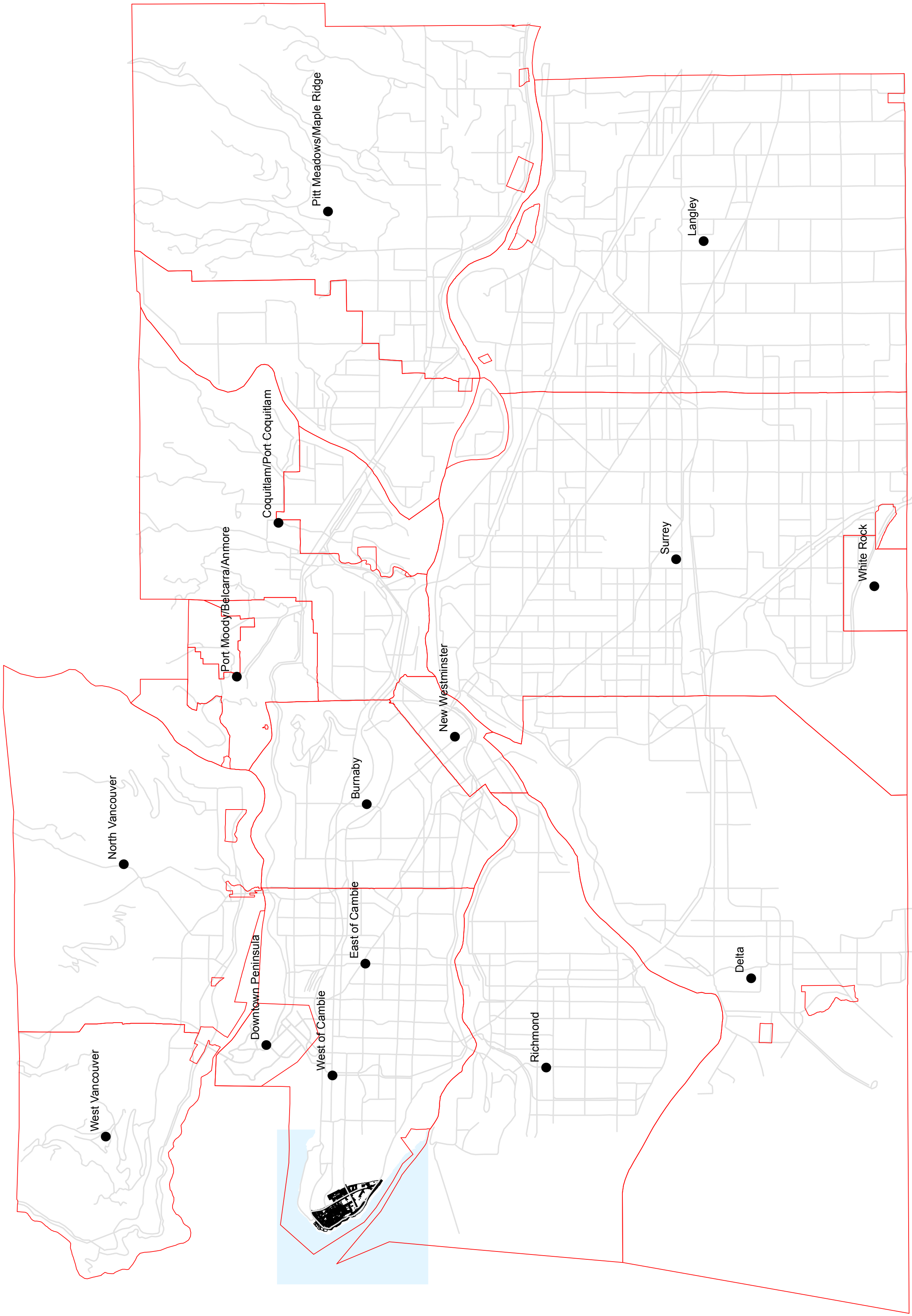


Figure 44: Off-campus destinations

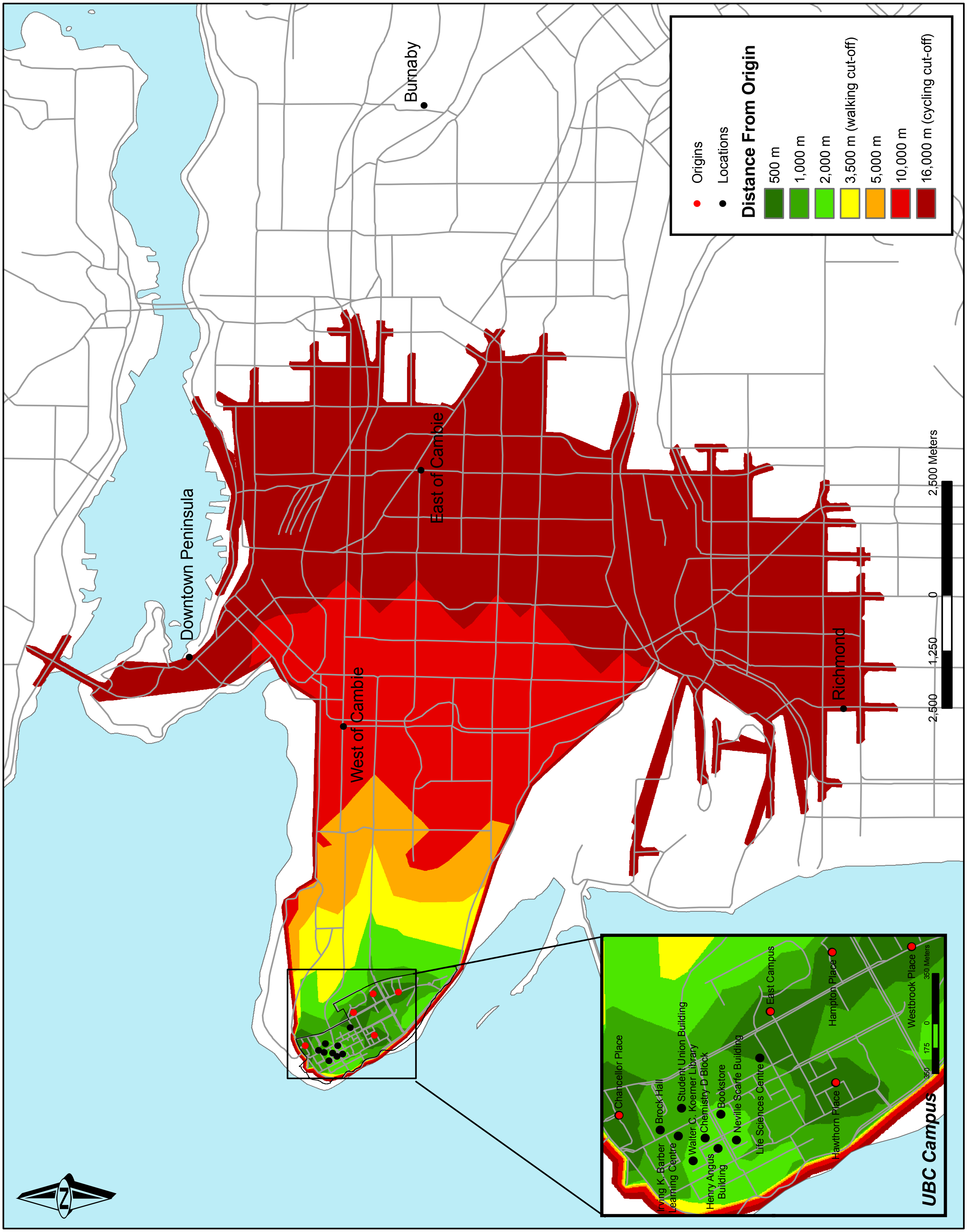


Figure 45: Off-campus distance decay map

7. Waste Emissions Considerations

Based on the constructed CEEI data, UTown@UBC residents produce 5,404 tonnes of landfill waste annually. However, because this gave suspiciously high per capita waste, the average per capita landfill waste from the City of Vancouver was used: 0.6332 tonnes per capita per year. The UNA reports a diversion rate of 45% for multi-family units. The BAU Scenario assumes a diversion rate of 45% climbing to 60% by 2050. Scenarios 1 and 2 assume a 70% diversion rate beginning in 2020 and use this rate until 2050, while assuming a total annual waste reduction.

The student residences produce 0.7 tonnes of annual waste per capita with a 43% diversion rate, resulting in 0.4 tonnes per capita directed to the landfill. The BAU Scenario uses diversion rate targets of 60% by 2015 and 80% by 2020 from the Waste Action Plan (not yet formally adopted by UBC). Student residence diversion rates are the same in the scenarios as in the BAU, while a decrease in per capita waste production is assumed.

8. Scenario Modelling Results

Taking all of the assumptions and analysis from the previous sections, the BAU, Scenario 1 and Scenario 2 GHG emissions projections were modelled. Figure 46 shows the emissions results for each scenario. In 2050 the BAU Scenario is projected to reach 60,567 tCO2e of emissions while Scenario 1 will achieve a level of 16,874 tCO2e and Scenario 2 will achieve a level of 8,409 tCO2e. Figure 47 and Figure 48 show the GHG reductions magnitudes by strategy.

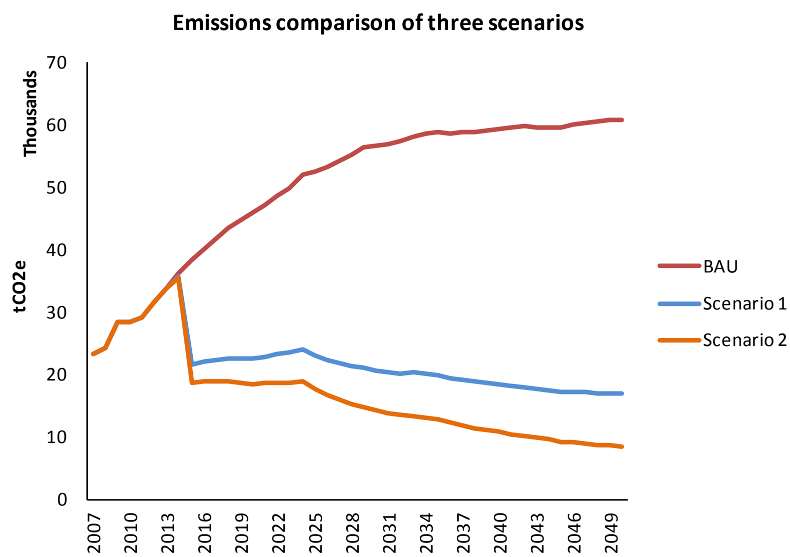


Figure 46: Projected emissions levels for all modelled scenarios

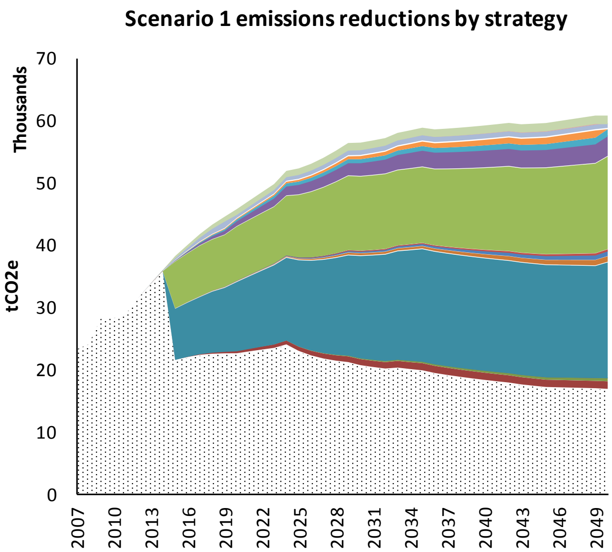
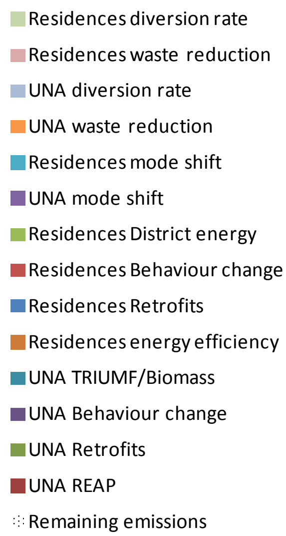


Figure 47: Scenario 1 GHG reductions by strategy



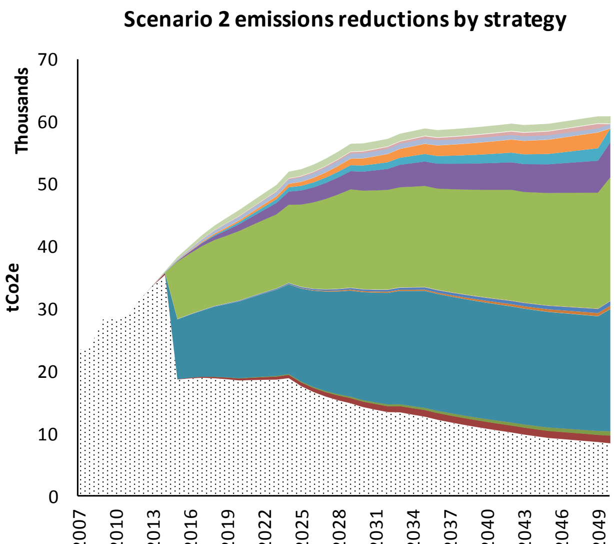


Figure 48: Scenario 2 GHG reductions by strategy

9. Electricity Use Implications

Electricity implications were also analyzed for each of the scenarios for UNA (Figure 49 and Figure 50) and student residences (Figure 51 and Figure 52) separately. A heat pump to extract waste heat from TRIUMF is an additional electrical load (red curve in). The BAU assumes an EUI of 90 kWh/m2/yr with electric baseboards in the UNA buildings. In 2015 onwards, minimum REAP measures significantly reduce the EUI to 53 kWh/m2/yr in Scenario 1 and 55 kWh/m2/yr in Scenario 2. Continuing existing building (pre 2015) retrofits account for increasing reductions over BAU. Behaviour change yields a small reduction.

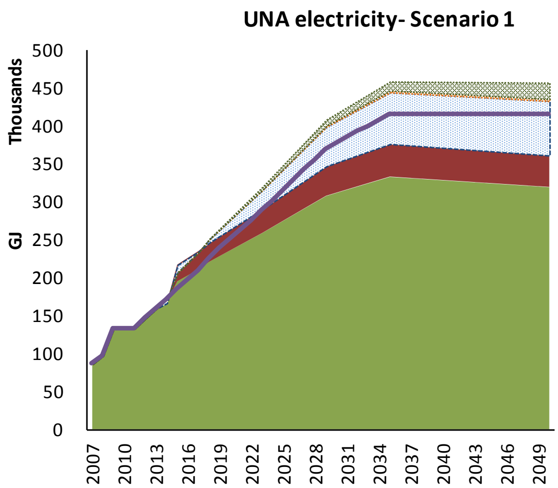


Figure 49: UNA building electricity use in Scenario 1

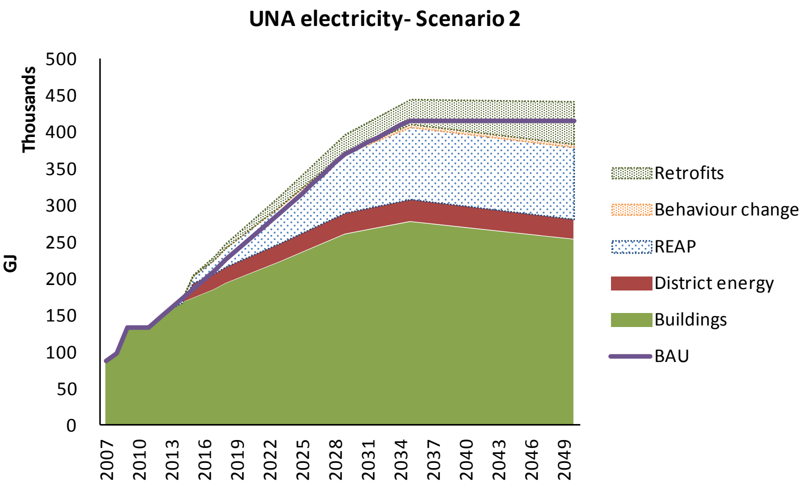


Figure 50: UNA building electricity use in Scenario 2

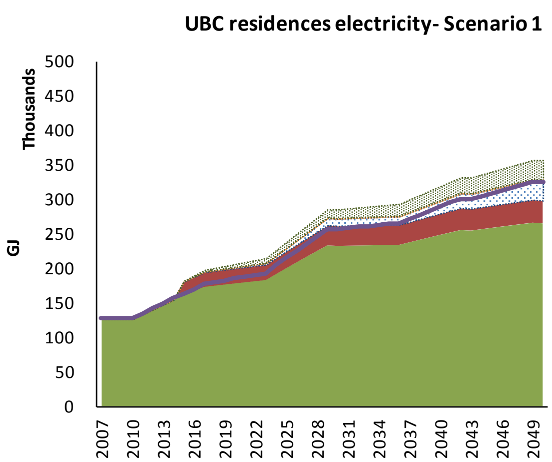


Figure 51: UBC student building electricity use in Scenario 1

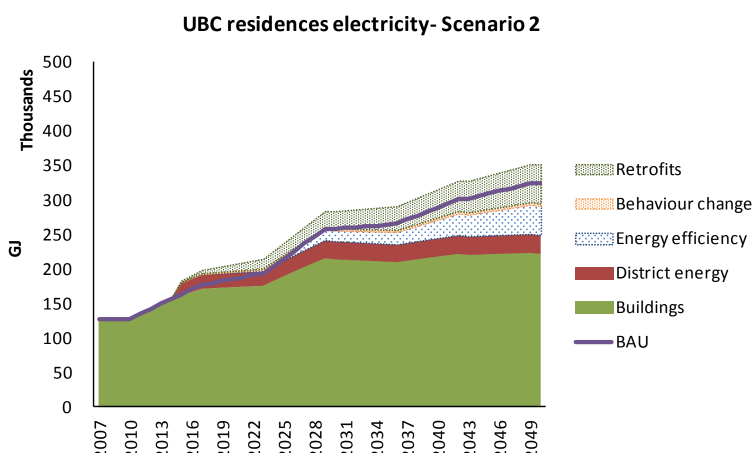


Figure 52: UBC student building electricity use in Scenario 2

By 2050 in Scenario 2, REAP accounts for a 24% reduction over BAU, retrofits result in 14% savings and behaviour change represents a 1% savings. Total electrical savings, including the additional electrical load from the heat pump, total 32% by 2050 over BAU. The same additional electricity load from the heat pump in the district energy system is evident in Scenarios 1 and 2 for student residences. In the residences, additional energy efficiency measures in new construction reduce electricity demand incrementally until 2050. In Scenario 2, the total electrical savings by 2050 is 23% over BAU including the increase for a heat pump. Energy efficiency standards for new construction represent a 13% reduction, behaviour change represents a 0.9% reduction and retrofits represent a 17% reduction. In contrast, Scenario 1 achieves a total electricity use reduction of just 8% by 2050 over the BAU.

Both Scenarios 1 and 2 can incorporate combined heat and power (CHP) systems from both biomass and biogas. It is anticipated that a significant portion of the projected electricity increase can be offset by the electricity generated from CHP systems. Additional electricity generation would also result if a CHP system were used for the biomass component of the district energy systems in Scenarios 1 and 2. A preliminary analysis of the potential electricity generation from a biogas CHP is shown in Table 15.

Table 15: Biogas CHP electricity generation			
Electricity (GJ/yr)	**Electricity MWh)**	**Food waste + soiled paper (tonnes/yr)**	**Fuel Source**
100,000	27,778	100,000	95% of the City of Vancouver's food waste
200,000	55,556	207,300	48% of Metro Vancouver's food waste

In both scenarios electricity consumption increases because UNA's building code (REAP) improvements do not reduce electricity consumption and the district energy system used in both scenarios relies on the addition of a heat pump extracting energy from waste heat from TRIUMF.[22] Some electrical consumption is also added by the uptake of electric vehicles. However, in Scenario 1, the district energy system includes a biomass combined heat and power generator which would more than offset the increased electricity consumption. In Scenario 2, the addition of a biogas CHP unit would provide further electricity generation capabilities, varying in magnitude depending on whether the facility is on or off campus (these options are explored in the next section).

Table 16: Projected electricity consumption and production in Scenario 2		
	2007	**2050**
UNA consumption	87,173 GJ/yr	311,896 GJ/yr
Student residences consumption	127,853 GJ/yr	280,959 GJ/yr
Biogas CHP production	-	Low: 100,000 GJ/yr High: 200,000 GJ/yr
Biomass CHP production	Not analyzed	Not analyzed

Table 17 provides a summary of the impacts of different proposed strategies on GHG emissions and electricity consumption.

Table 17: Relative emissions reduction and electricity consumption impacts of strategies			
Sector	**Strategy**	**GHG Impact**	**Electricity Impact**
Data	1. Revise the baseline	No reduction	None
Buildings	2. REAP	High reduction	None
	3. TRIUMF district energy system with biomass	High reduction	Medium increase, plus new generation
	4. Biogas CHP	High reduction	New generation
	5. Building retrofit program	Medium reduction	High reduction
Transportation	6. Rapid rail transit or equivalent	Medium reduction	Medium increase
	7. Personal transportation planning	Medium reduction	None
Waste	8. Source reduction program	Low reduction	None
Other	9. Urban agriculture	High reduction	None
	10. Personal GHG certificates	Low reduction	Low

22 The modeling of future versions of REAP includes energy efficiency improvements in lighting, but these gains are offset by an increase in the number of fans required in heat recovery HVAC systems. The most significant gains are on the heating side of the equation.

10. Natural Gas Use Implications

REAP and the district energy system have significant impacts on natural gas consumption, almost eliminating its use in Scenario 1 (displaced by heat from TRIUMF and biomass), and fully eliminating it in Scenario 2 (Figure 53 and Figure 54). The impact of REAP in Scenario 1 is marginal as the EUI for natural gas consumption declines from 90 kWh/m2/yr to 82 kWh/m2/yr. In Scenario 2 the remaining natural gas is replaced with biogas. Natural gas consumption in student residences parallels that of the UNA buildings with the exception that the REAP energy efficiency targets are less aggressive (Figure 55 and Figure 56).

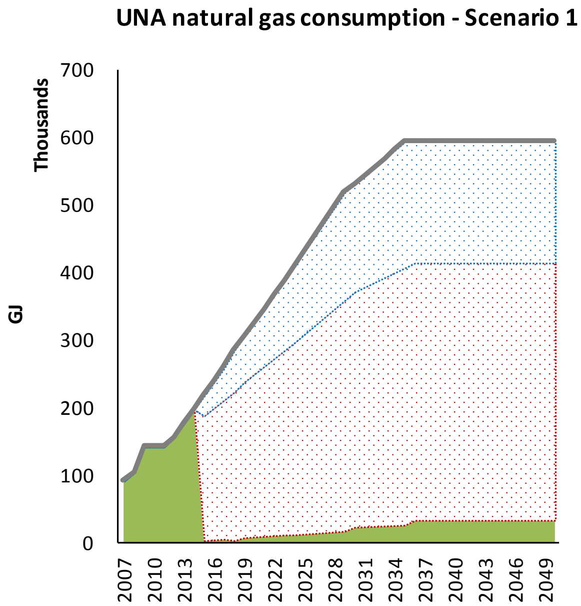


Figure 53: Scenario 1 UNA building natural gas consumption

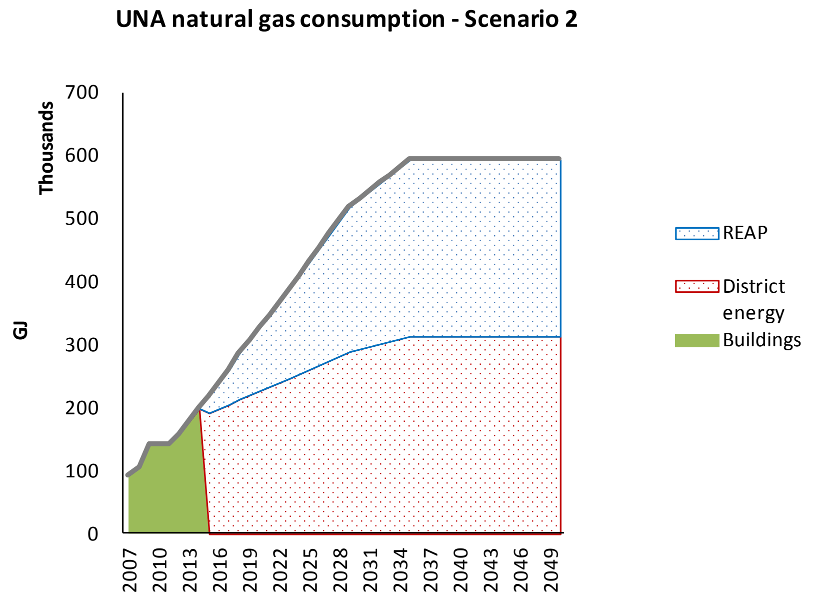


Figure 54: Scenario 2 UNA building natural gas consumption

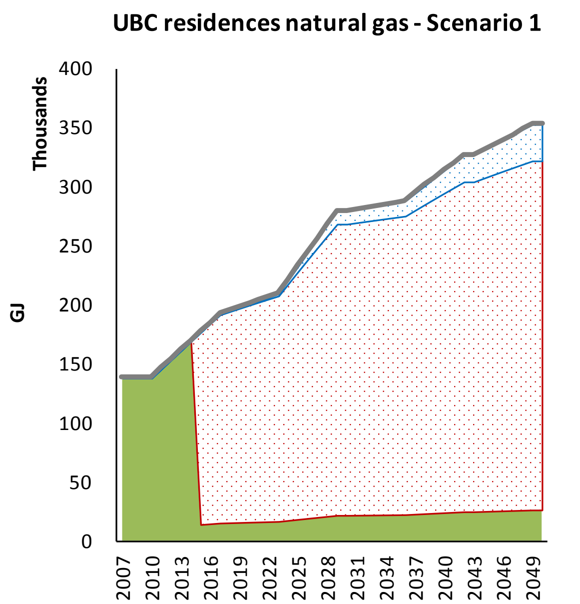


Figure 55: Scenario 1 student buildings natural gas consumption

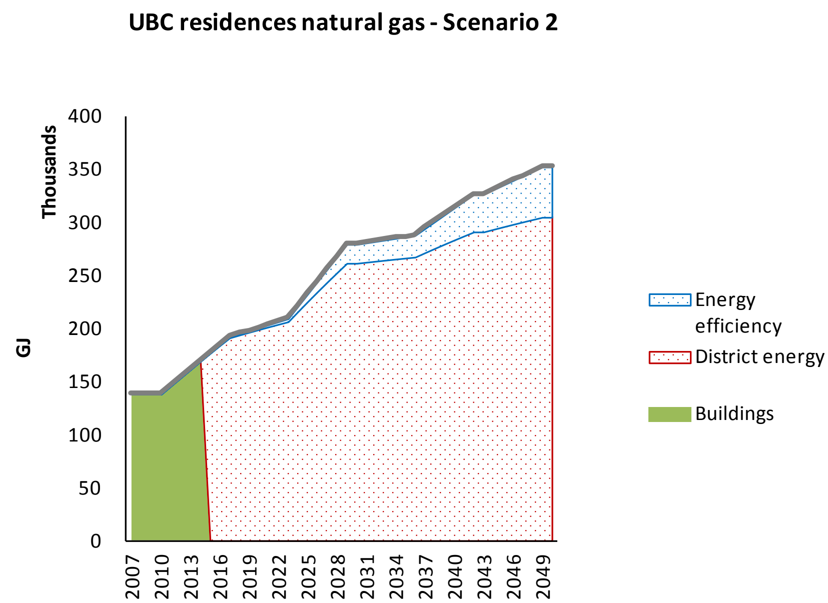


Figure 56: Scenario 2 student buildings natural gas consumption

11. Scenario Results Analysis

As shown earlier, UNA and student residence buildings are responsible for the large majority of UTown@UBC emissions. District energy and energy efficiency measures have a profound effect on building emissions. Total GHG emissions drop and flat line even as the overall area of buildings almost triples in the UNA and doubles for student residences. The actions modelled in the two scenarios do not reduce emissions sufficiently to achieve the BC Government or UBC targets. As described in Appendix 4, an on- or off-campus biogas energy plant could offset all remaining emissions by eliminating all natural gas consumption for back-up boilers for the district energy system. Additionally, the biogas plant can generate significantly more natural gas than is required for this purpose, creating additional GHG emissions reductions as well an opportunity for carbon offset investment.

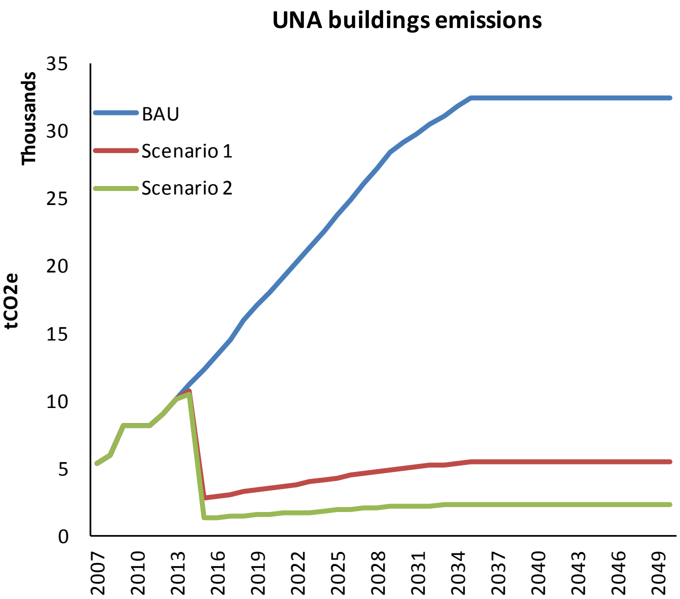


Figure 57: UNA buildings emissions projections for all scenarios

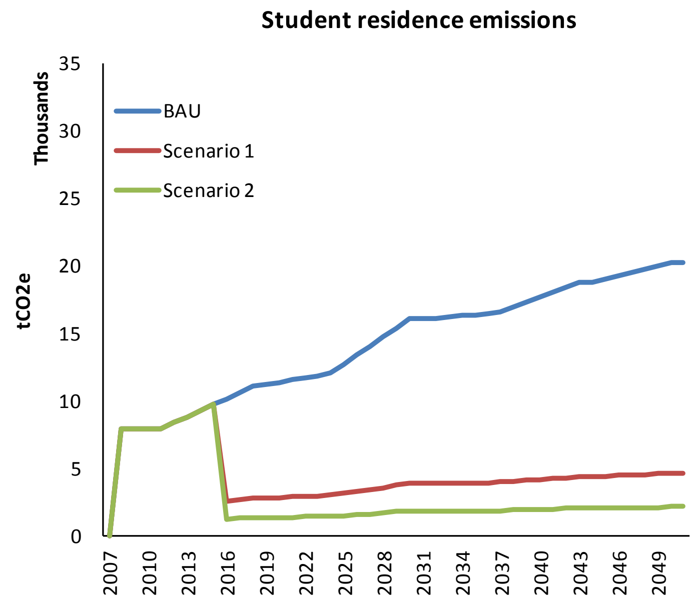


Figure 58: Student residence emissions projections for all scenarios

12. Sensitivity analysis

A sensitivity analysis was performed to calculate the impact of uncertainty on key variables (Figure 59). For the BAU scenario, trip length, UNA building energy consumption and the mode share of driving on and off campus was increased by 10%; the walking and transit mode shares were decreased correspondingly. Waste production rates were decreased by 10%. The results indicate that a 10% increase in any one variable does not result in variation in the overall result that exceeds plus or minus 10%.

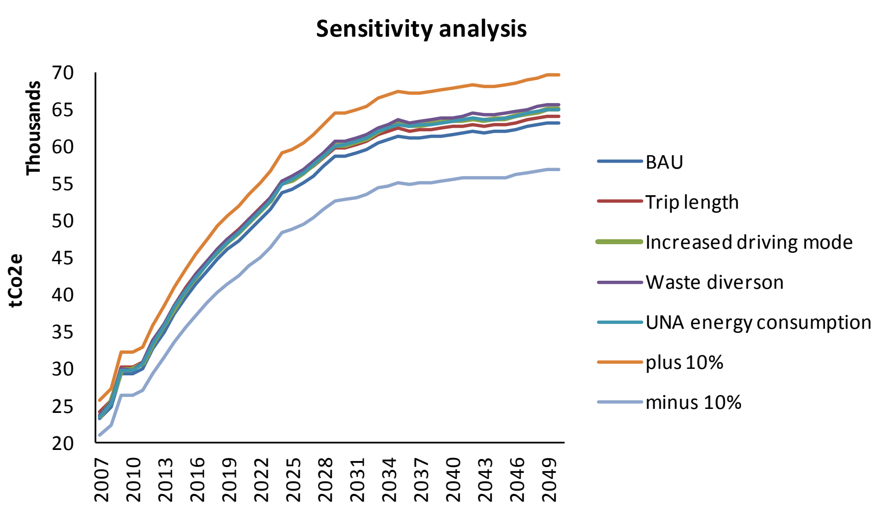


Figure 59: Key variable uncertainty sensitivity analysis

13. Scenario Targets Discussion

Both scenarios fail to achieve their emissions reduction targets of 80% (Scenario 1) and 100% (Scenario 2) under 2007 levels by 2050, as summarized in Table 18.

Table 18: Projected 2050 emissions levels for Scenarios 1 and 2			
Scenario 1		Scenario 2	
Target: 80% under 2007	Modelled Result	Target: 100% under 2007	Modelled Result
4,688 tCO2e	16,874 tCO2e	0 tCO2e	8,409 tCO2e

A district energy system (e.g.: biogas) installed between 2015 and 2018 would allow UTown@UBC to achieve a 2020 emissions reduction target of 33% below 2007 levels. As discussed in the previous section, offset or induced emissions reductions could make major contributions in achieving UTown@UBC's emissions reduction targets, making UTown@UBC carbon positive. Table 19 summarizes these contributions. A biogas district energy system is explored in the next section.

Table 19: Induced emissions reductions			
Reduction Measure	Description	Reduction Amount	Degree of Certainty
Biogas reduction (from DE system)	In addition to the displaced GHG emissions from natural gas (not induced reductions) the biogas generator also results in avoided methane emissions from waste that would have otherwise gone to the landfill and avoided emissions from fertiliser production and use, a by-product of biogas generation.	Between 67,000 tCO2e and 140,000 tCO2e per year	High
Commuting reduction (from moving students onto campus)	UBC plans to significantly increase the population of students living on campus and residents of UNA. Those students would otherwise be commuting to campus by various modes. Similarly, approximately 50% of UNA residents work at UBC and the while the other 50% will be commuting off-campus, the mode share of UBC residents is considerably less carbon intensive in comparison with Metro Vancouver residents.	Reduction increases to 8,695 tCO2e per year by 2050	Medium
Food miles reduction (from local food production)	If UBC produces more food for consumption on campus, there is less need for food importation, thus reducing food transportation emissions.	Reductions not modelled	Low

Appendix 3

Modelling Assumptions

This appendix summarizes the modelling assumptions used by GHGProof to generate the Business as Usual and two Scenarios projections. Note that senior government regulations on fuel efficiency (Federal) were included in the BAU but because of UNA's higher energy efficiency standard, REAP, provincial building code changes were not included.[23]

1. Population

Category	Assumption	Source
Student residences	2012: 9,268	University of British Columbia (2012). The University Community on Campus: UBC's Housing Action Plan. http://hap.ubc.ca/files/2012/09/The-University-Community-on-Campus-UBCs-Housing-Action-Plan.pdf
UNA	2010: 3,282 dwellings	University of British Columbia (2012). Annual Report from the Development Permit Board. http://bog2.sites.olt.ubc.ca/files/2012/11/6.8_2012.12_DPB-Report.pdf
UNA population per household	2011: 2.4	Statistics Canada. 2012. GeoSearch. 2011 Census. Statistics Canada Catalogue no. 92-142-XWE. Ottawa, Ontario. Data updated October 24, 2012. http://geodepot.statcan.gc.ca/GeoSearch2011-GeoRecherche2011/GeoSearch2011-GeoRecherche2011.jsp?lang=E&otherLang=F. Note: 10% reduction over Statistics Canada average for Vancouver CMA to account for smaller households

2. Buildings

Category	Assumption	Source
Student residence area	39 GSM	UBC Vancouver Campus Plan: Part 4 Reference Material, pg. 4
UNA- BAU electricity	90 kWh/m2/yr	UNA CEEI
UNA- BAU gas	96 kWh/m2/yr	Energy audit of 9 UNA buildings
Student residences- BAU electricity	118 kWh/m2/yr	Normalized data from 2009 to 2010- provided by UBC
Student residences- BAU gas	128 kWh/m2/yr	Normalized data from 2009 to 2010- provided by UBC

3. Energy Efficiency (Scenarios 1 and 2)

Proposed REAP standards going forward exceed ASHRAE 90-1-2010 by between 27% and 49%, depending on the building type and the combination of energy efficiency strategies.

REAP high rise energy savings	Baseline- 100% Minimum- 64% Maximum- 44%	EnerSys, Enerefficiency and SSG (2012). UBC Residential Environmental Assessment Program Energy Modelling Project. Prepared for UBC.
REAP low rise energy savings	Baseline- 100% Minimum- 71% Maximum- 57%	Ibid
REAP high rise electricity	Baseline- 52 kWh/m2/yr Minimum- 52 kWh/m2/yr Maximum- 55 kWh/m2/yr	Ibid
REAP low rise electricity	Baseline- 56 kWh/m2/yr Minimum- 53 kWh/m2/yr Maximum- 55 kWh/m2/yr	Ibid
REAP high rise gas	Baseline- 182 ekWh/m2/yr Minimum- 97 ekWh/m2/yr Maximum- 48 ekWh/m2/yr	Ibid
REAP low rise electricity	Baseline- 122 kWh/m2/yr Minimum- 74 kWh/m2/yr Maximum- 47 kWh/m2/yr	Ibid

23 A detailed analysis of REAP including a comparison with other building standards was completed as a stand alone project: UBC Residential Environmental Assessment Program Energy Modeling Project, April 5, 2012.

4. Energy Efficiency (Recommended Scenario)

Category	Assumption	Source
REAP 2014-2018	Electric- 44 kWh/m2/yr Thermal- 116 kWh/m2/yr	UBC
REAP 2018-2050	Electric- 43 kWh/m2/yr Thermal- 97 kWh/m2/yr	UBC
UBC Student residences- 2014-2050	Electric- 63 kWh/m2/yr Thermal- 52 kWh/m2/yr	UBC
Retrofits (student housing and UNA buildings)	2.5% of the pre-2014 building stock retrofitted annually resulting in average energy savings of 20%.	Modelled

5. Emissions factors

Category	Assumption	Source
Natural gas	50.16 kgCO2e/GJ	BC Ministry of the Environment. (2012). 2012 BC best practices methodology for quantifying greenhouse gas emissions. Retrieved from http://www.env.gov.bc.ca/cas/mitigation/pdfs/BC-Best-Practices-Methodology-for-Quantifying-Greenhouse-Gas-Emissions.pdf
Heating oil	70.05 kgCO2e/GJ	Ibid
Biomass	0 kgCO2e/GJ	Ibid
Electricity	6.9 kgCO2e/GJ	Ibid
Electricity	84 tCO2e/GWh	Dowlatabadi, H. (2011). Lifecycle analysis of GHG intensity in BC's energy sources. ISIS, Sauder School of Business, UBC and Pacific Institute for Climate Solutions. Available at: http://pics.uvic.ca/sites/default/files/uploads/publications/Lifecycle%20analysis%20of%20GHG%20intensity%20in%20BC%27s%20energy%20sources%20.pdf

6. District energy

Category	Assumption	Source
BAU	No district energy system	Modelled
Scenarios 1 and 2	District energy system services all post-2014 buildings and all pre-2014 buildings by 2050.	Modelled
Recommended Scenario	District energy system services all post-2014 buildings starting in 2015, all residences by 2050 and all common areas in pre-2014 UNA buildings at a rate of 2.5% per year.	UBC

7. District energy - energy supply mix (BAU, Scenarios 1 and 2)

Category	BAU	Scenario 1	Scenario 2
Natural gas	0%	9%	0%
Heating oil	0%	4%	0%
Biomass	0%	41%	41%
Electricity	0%	11%	11%
Biogas	0%	34%	34%
Waste heat	0%	0%	13%
Solar hot water	0%	0%	0%
Source	Current condition	FVB Energy (2012). University of British Columbia Neighbourhood District Energy System Technical Feasibility Study Report.	Modelling assumption

8. District energy - energy supply mix (Recommended Scenario)

Category	2015-2019	2020-2025	2026-2033	2034-2040	2041-2050
Natural gas	47%	60%	67%	69%	0%
Heating oil	1%	1%	1%	1%	1%
Electricity	4%	4%	3%	3%	0%
Biogas/biomass	0%	0%	0%	0%	69%
Waste heat	48%	35%	29%	27%	27%

Source: UBC Sustainability Office

9. Agriculture

Category	Assumption	Source
Emissions factor local food	0.13 kgCO2e/kg	Bentley, S., & Barker, R. (2005). Fighting Global Warming at the Farmer's Market. Toronto. ON.
Emissions factor imported food	0.5 tCO2e/year/ capita	Ibid
Emissions factor imported food high	1.3 kgCO2/kg food	Xuereb, M. (2005). Food miles: Environmental implications of food imports to Waterloo Region. Region of Waterloo Public Health.

10. Waste

Category	Assumption	Source
UNA- landfill waste	2007- 5404 t	Enerficiency Consulting (2012). UNA Community Energy and Emissions Inventory.
UNA- landfill waste	0.6332 tCO2e/capita	Average solid waste production in City of Vancouver per capita. City of Vancouver Community Energy and Emissions Inventory (2007).
UNA diversion rate- 2012	45%	http://www.metrovancouver.org/region/breakfasts/Presentations/ Nov7BreakfastPresentation.pdf
UNA diversion rate- 2020	70%	http://www.metrovancouver.org/region/breakfasts/Presentations/ Nov7BreakfastPresentation.pdf
Emissions factor- landfill waste	0.32 tCO2e/t	Enerficiency Consulting (2012). UNA Community Energy and Emissions Inventory.
Student residence waste	2010: 3,100 t	UBC Vancouver Campus Zero Waste Action Plan, pg. 6
Student residence diversion rate	2012: 43%	UBC Vancouver Campus Zero Waste Action Plan
Student residence diversion rate	2015: 60%	UBC Vancouver Campus Zero Waste Action Plan
Student residence diversion rate	2020: 80%	UBC Vancouver Campus Zero Waste Action Plan
UNA annual per capita waste reduction-Scenario 1	2.5%	Modelled- declines from 1.8 t per capita to 0.8 t per capita
Student residences annual per capita waste reduction- Scenario 1	0.8%	Modelled- declines from 0.7 t per capita to 0.5 t per capita
UNA annual per capita waste reduction-Scenario 2	3.6%	Modelled- declines from 1.8 t per capita to 0.5 t per capita
Student residences annual per capita waste reduction- Scenario 2	2.2%	Modelled- declines from 0.7 t per capita to 0.3 t per capita

11. Modes

We assume that 2011 UBC Transportation Survey results represent students (actually 80% students with the remainder being staff and faculty). We assume the UNA survey does not include students whereas 13% are students.

Student resident

Mode	On campus (%)	Off-campus (%)	Source
Walk	74	0	NRG Research Group (2012). 2011 UBC Transportation Survey.
Drive alone	1	18	Ibid
Bike	18	5	Ibid
Carpool	1	7	Ibid
Transit	6	69	Ibid

UNA resident

Mode	On campus (%)	Off-campus (%)	Source
Walk	68	0	NRG Research Group (2012). 2011 UBC Transportation Survey.
Drive alone	14	49	Ibid
Bike	11	11	Ibid
Carpool	3	10	Ibid
Transit	3	30	Ibid

Commuter (non-residents)

Mode	Commute (%)	Source
SOV	18.1	NRG Research Group (2012). 2011 UBC Transportation Survey.
HOV	6	Ibid
Transit	65.3	Ibid
Bike	8.4	Ibid
Walk	0.8	Ibid
Other	1.4	Ibid

12. **Destinations**

Student residents - on campus

Destination	Weight	Source
Bus loop	0.7	NRG Research Group (2012). 2011 UBC Transportation Survey.
SUB	0.6	Ibid
Irving K Barber	0.2	Ibid
Bookstore	0.1	Ibid
Chemistry D Bloc	0.1	Ibid
Life Sciences Centre	0.1	Ibid
Brock Hall	0.1	Ibid
Henry Angus Building	0.1	Ibid
Walter C Koerner Library	0.1	Ibid
Neville Scarfe Building	0.1	Ibid

Student residents - off campus

We assume that the destinations and weight of the destinations is the same for student residents leaving campus for bars, shopping and other reasons.

Destination	Weight	Source
West of Cambie to UBC	0.41	NRG Research Group (2012). 2011 UBC Transportation Survey.
East of Cambie to Boundary	0.21	Ibid
Downtown peninsula	0.09	Ibid
Richmond	0.08	Ibid
Burnaby	0.06	Ibid
Surrey	0.03	Ibid
North Vancouver	0.03	Ibid
Coquitlam/Port Coquitlam	0.03	Ibid
Delta	0.02	Ibid
New Westminster	0.02	Ibid

UNA residents - on campus

We assume the same set of core destinations on campus for UNA residents and students. These are the major employment generators, a key destination for UNA residents and most shopping and other types of trips occur off campus.

Destination	Weight	Source
Bus loop	0.7	NRG Research Group (2012). 2011 UBC Transportation Survey.
SUB	0.6	Ibid
Irving K Barber	0.2	Ibid
Bookstore	0.1	Ibid
Chemistry D Bloc	0.1	Ibid
Life Sciences Centre	0.1	Ibid
Brock Hall	0.1	Ibid
Henry Angus Building	0.1	Ibid
Walter C Koerner Library	0.1	Ibid
Neville Scarfe Building	0.1	Ibid

UNA residents - off campus

We increased the weight of downtown peninsula and Richmond, as major employment locations and that because the UNA residents use the car more, they travel further afield.

Destination	Weight	Source
West of Cambie to UBC	0.41	NRG Research Group (2012). 2011 UBC Transportation Survey.
East of Cambie to Boundary	0.21	Ibid
Downtown peninsula	0.09	Ibid
Richmond	0.08	Ibid
Burnaby	0.06	Ibid
Surrey	0.03	Ibid
North Vancouver	0.03	Ibid
Coquitlam/Port Coquitlam	0.03	Ibid
Delta	0.02	Ibid
New Westminster	0.02	Ibid

Commuting (non-resident)

Destination	Weight	Source
West of Cambie to UBC	0.15	NRG Research Group (2012). 2011 UBC Transportation Survey.
East of Cambie to Boundary	0.1	Ibid
Downtown peninsula	0.5	Ibid
Richmond	0.05	Ibid
Burnaby	0.06	Ibid
Surrey	0.03	Ibid
North Vancouver	0.03	Ibid
Coquitlam/Port Coquitlam	0.03	Ibid
Delta	0.02	Ibid
New Westminster	0.02	Ibid
West Vancouver	0.01	Ibid
Port Moody/Belcarra/Anmore	0.005	Ibid
Pit Meadows/Maple Ridge	0.005	Ibid
Langley	0.005	Ibid
White Rock	0.005	Ibid

13. Private vehicles

Title	Value	Source
Number of vehicles in a municipality by type	See the CEEI	Enerficiency Consulting (2012). UNA Community Energy and Emissions Inventory.
Model year 2016[1]	6.29 L/100km	US EPA. (2012). EPA and NHTSA Set Standards to Reduce Greenhouse Gases and Improve Fuel Economy for Model Years 2017-2025 Cars and Light Trucks.
Model year 2025	4.16 L/100km	Ibid
Compact car- 2025	3.85 L/100km	Ibid
Mid-size car-2025	4.28 L/100km	Ibid
Full size car-2025	4.90 L/100km	Ibid
Small SUV-2025	4.95 L/100km	Ibid
Large pick-up truck-2025	7.13 L/100km	Ibid
Electric vehicles	5 Km/kWh	Community Energy Association. (2011). A primer on the transition to electric vehicles in Metro Vancouver. Metro Vancouver.
Electric vehicles	2017- 0.3% 2031- 16% 2041 -29%	BC Hydro. (2012). *2012 Integrated Resource Plan Appendix 2011 Electric Load Forecast* (pp. 1–111). Victoria, BC.

14. Trips
We calculated off-campus trips from the UNA Survey based on the number of times UNA residents leave campus for different purposes. Because these numbers are estimated we will use a range to assess the impact.

Student Resident

Trips	Weekly	Source
On-campus	35-50	Modelled
Off campus	2	Modelled

UNA Resident

Trips	Weekly	Source
On-campus	35-50	Modelled
Off-campus	6	NRG Research Group (2012). 2011 UBC Transportation Survey.

15. Airplane travel

Category	Assumption	Source
Average airplane emissions per Canadian	410 kgCO2/capita	Air Transport Association of Canada (2012). 2010 Canadian aviation industry report on greenhouse gas emissions reductions. Available at: http://airlinecouncil.ca/pdf/2010_Rpt_GHG_reductn_Eng.pdf
Fuel efficiency improvement	99.8% per year	Government of Canada (2012). Canada's action plan to reduce greenhouse gas emissions from aviation. Available at: http://www.icao.int/environmental-protection/Documents/ActionPlan/AviationGHGActionPan_En.pdf

Appendix 4

UTown@UBC Energy Infrastructure Options

Although the CEEP scope is limited to UTown@UBC, the work terms of reference stipulate that an integrated approach be taken, in which opportunities for joint planning should be exploited. The energy infrastructure portion of this report therefore considers:

1. The needs of community groups within UTown@UBC, including University Neighbourhood Association (UNA) Neighbourhoods, UBC Ancillary Services, Student Housing and Hospitality Services, Athletics and Recreation, Parking and Access Control Services, Continuing Studies, and UBC Tenants.
2. Plans for sustainable energy infrastructure in the academic campus, as well as resources in the surrounding community. This holistic and integrated approach is in keeping with UBC's education and research philosophy.
3. Integration among sources (e.g. solar, waste heat, and clean source-separated organic waste from municipal, commercial, and UBC's agricultural sources); and
4. Integration across disciplines (e.g. water infrastructure, energy infrastructure, land use planning, architecture, transportation, and standards for building design).

The constructed CEEI data and scenario analysis identified UTown@UBC's energy and emissions needs and resources. Strategies to satisfy these needs with resources available to UBC were developed by asking these questions:

1. Regarding *needs*:
   - What quantities and qualities of energy (e.g. form, quality, location) do UBC and UTown@UBC require?
   - How are these needs likely to change over time?
2. Regarding *resources*:
   - What sources of wasted resources do UBC and UTown@UBC have access to?
   - How are these sources likely to change over time?
3. Regarding *strategies*:
   - What strategies could be used to recover value from wasted resources to meet UBC and UTown@UBC's needs?
   - What human resources do UBC and UTown@UBC have access to that could be used to facilitate these strategies?
   - What synergies could exist between these strategies and UBC's research and education priorities?

The work involved identifying options for alternative energy and greenhouse gas reductions from these sources:
1. Waste heat from:
   - Wastewater
   - Exhaust air
   - Electrical transformers
   - Stack gases
   - Process loads (e.g. TRIUMF)
2. Resources from liquid waste:
   - Micro-hydro from stormwater
   - Non-potable water from stormwater
   - Nutrients from wastewater and biosolids
3. Resources from solid waste:
   - Biofuels from clean organic waste
   - Nutrients from clean organic waste

The costs and benefits of these strategies were evaluated, including:
1. Economics: initial cost, ongoing cost, savings, and net revenues;
2. Environmental aspects: resource conservation and GHG emission changes based on Provincial (*BC Reporting Regulation*) and international standards (*IPCC Guidelines for National Greenhouse Gas Inventories*); and
3. Social: jobs created, community impacts, support for UBC's research and education plans, and intangible costs and benefits.

The following sections outline the greenhouse gas reduction strategies developed for UTown@UBC and UBC.

Strategy 1: The Biomethane Energy Research Centre

UBC's Vancouver campus already incorporates elements of the energy supply chain, including industrial natural gas boilers serving the Academic District Energy System. The university has recently taken a further step by building the UBC Bioenergy Research and Demonstration Facility (BRDF), which incorporates gasification of dry biomass to produce electricity and heat.

A reliable guideline for choosing energy conversion technologies for organic material is that thermal processes are best suited for dry organic waste (e.g. wood waste), and biological processes are best suited for wet organic waste (e.g. food waste). The practical reason for this division is that the water content of food waste facilitates biological conversion, but hinders thermal conversion. In addition, the lignin in wood waste is refractory to normal biological processes which could yield energy. The ecological reason is that the most important nutrients in food waste are lost when burned, but conserved through aerobic or anaerobic composting.

A biological process by UBC to recover energy and other resources from wet organic waste would be complementary to the existing thermal process at the UBC BRDF. One such biological process is modelled here because of its potential to provide significant greenhouse gas reductions. The process is referred to in this report as the UBC Biomethane Energy Research Centre (BERC).

Description of Anaerobic Digestion

Anaerobic digestion is a type of composting which converts most of the carbon in organic waste to methane and carbon dioxide, while preserving compounds of nitrogen, phosphorous, potassium, sulphur, and micronutrients in organic waste. The residual material from anaerobic digestion (digestate) is an excellent slow-release fertilizer. Unlike aerobic composting, anaerobic digestion produces biogas (approximately 2/3 methane, and 1/3 carbon dioxide) which can be burned in a boiler for heat alone, burned in a cogeneration process to produce heat and electricity, or upgraded to biomethane for injection in the natural gas distribution system or to replace liquid fossil fuels in vehicles. The most common classes of digesters are mesophilic which operate at 37ºC, and thermophilic which operate at 55ºC.

In Canada, anaerobic digestion is most commonly used in wastewater treatment facilities to generate biogas from biosolids, though farm digesters based on manure are becoming more common here. Several thousand anaerobic digesters operate in Europe, and over 1.5 million digesters operate in India. Although aerobic composting is more widely understood in BC, interest in anaerobic digestion is increasing in part because of carbon taxes, Provincial objectives for greenhouse gas reductions, and Provincial regulations requiring methane to be captured from landfills.

Potential Sources of Organic Waste

UBC's Vancouver Campus

UBC's Vancouver Campus Zero Waste Action Plan describes operational and institutional sources of solid waste, for a total of approximately 9,000 generated tonnes in the 2010-11 Fiscal Year.[24] Since 8% of campus solid waste is now diverted to composting, and a further 31% of campus solid waste consists of organic material which is landfilled, the total amount of organic waste generated by the campus is 45% of the total of approximately 9,000 tonnes, or 4,000 tonnes per year.

City of Vancouver

Metro Vancouver generates an estimated 327,300 tonnes of food waste per year, and a further 89,000 tonnes of soiled paper (i.e. paper used to wrap food, unsuitable for recycling) for a total of 452,000 tonnes of organic waste per year.[25] Since the population of Metro Vancouver is approximately 2,400,000 and the population of the City of Vancouver is approximately 650,000, Vancouver's share of the regional total of compostable waste will be an estimated 122,000 tonnes of organic waste per year. Soiled paper would help to balance the carbon to nitrogen ratio in an anaerobic digester.

24 UBC. 2012. Vancouver Campus Zero Waste Action Plan.

25 Metro Vancouver, 2008 Data.

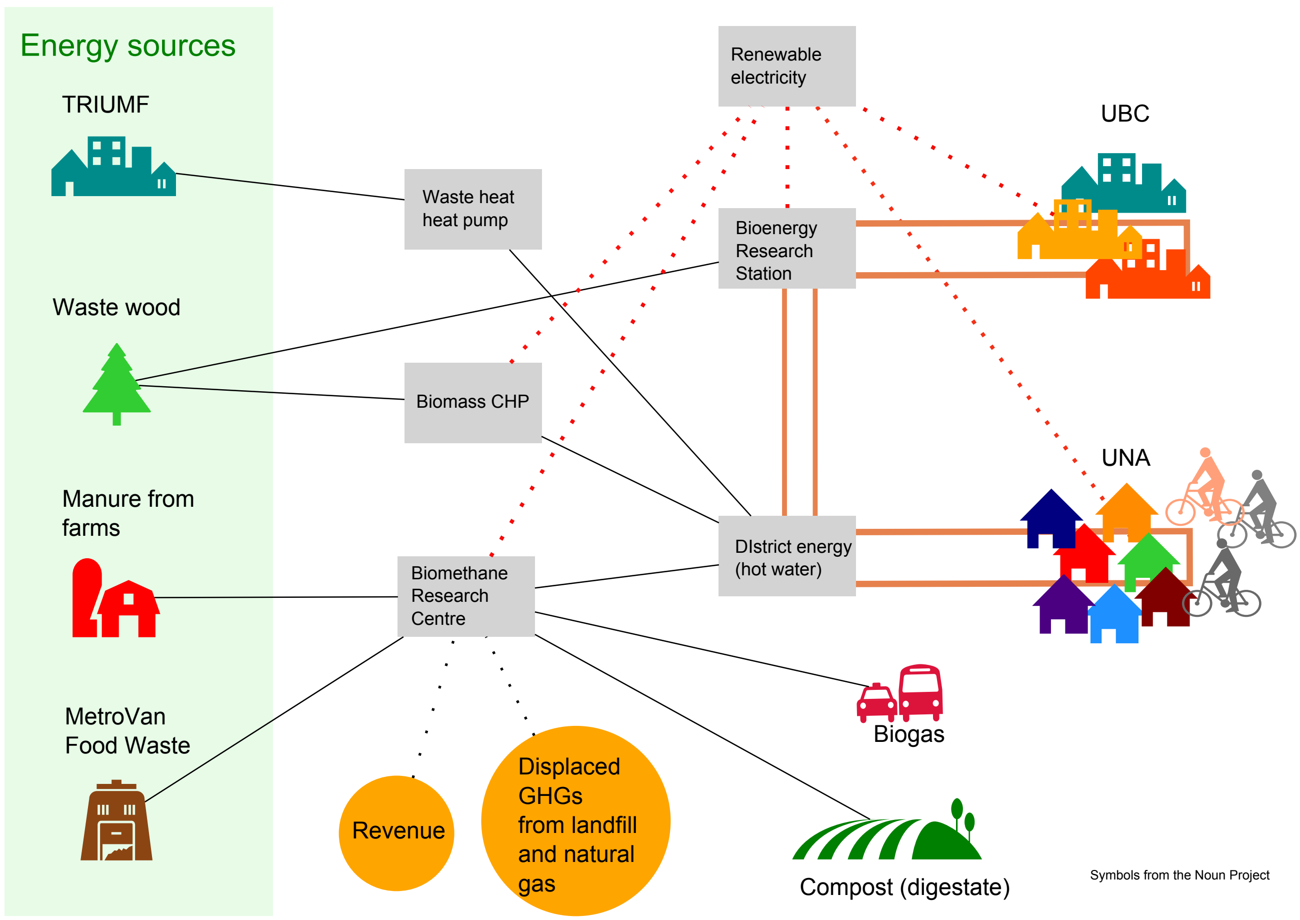


Figure 60: Diagram of the Biomethane Energy Research Centre resource flows

Configuration

The UBC Biomethane Energy Research Centre would incorporate the following components:

a. Pre-processing to remove contaminants from source-separated organic waste.
b. Heating of the feedstock to digester temperatures.
c. Mesophilic anaerobic digestion.
d. Collection and upgrading of raw biogas to biomethane.
e. Wastewater treatment.

If a *Biomethane Energy Research Centre* is located on the Vancouver campus rather than on a farm, then the facility could also include:

a. An enclosed receiving facility operating under negative pressure. Air vented from the facility would flow through a biofilter to remove odours.
b. Digestate dewatering and drying facilities.
c. Storage for dry digestate/compost, for sale during summer months.

Uses for Biomethane

Sulphur compounds can be scrubbed from raw biogas using relatively inexpensive technologies. Scrubbed biogas (65% methane) could be burned in a boiler, or in an internal combustion engine for trigeneration of heat, cooling, and electricity. If a small, demonstration Biomethane Energy Research Centre is located on UBC's Vancouver campus, then scrubbed biogas could either be used for cogeneration to provide electricity and heat to the planned Neighbourhood District Energy System, or used to displace a portion of the natural gas in the campus Power Plant. If the BERC is located in the area of UBC Farm, then biogas would need to be transferred through a small, dedicated pipe of approximately 2.4 kms to the Power Plant. This pipe could potentially share trench space with district energy piping.

Biogas can be further upgraded to pipeline-quality biomethane in a process which removes most of the carbon dioxide. Biomethane can then replace natural gas in CNG vehicles, or be sold to FortisBC as Renewable Natural Gas. If a larger UBC Biomethane Energy Research Centre is located outside of UBC's Vancouver campus, it may be possible for UBC to negotiate a fee for the delivery of biomethane on a nominated basis through the utility's transmission system. In this arrangement, UBC could potentially be both the producer and consumer of Renewable Natural Gas. Biomethane can also be synthesized into liquid fuels.

BERC Scenarios

Four scenarios were modelled for a UBC Biomethane Energy Research Centre, as summarized in Table 20.

Table 20: UBC BERC scenarios descriptions

Scenario	One	Two	Three	Four
Description	Demonstration Digester on Main Campus	Offset Main Campus Emissions	Offset UTown Residence Gas	Offset all UBC GHG Emissions
Objective	A BERC of this capacity would just cover its own costs.	A BERC of this capacity would result in GHG emission reductions equal to all of the emissions of the Vancouver campus.	A BERC of this capacity would produce enough biomethane to replace the natural gas consumed by UTown@UBC.	A BERC of this capacity would result in GHG emission reductions equal to all of the emissions of UBC's operations, including Scope 3.

The following sections describe the greenhouse gas implications as well as the environmental, social, and economic costs and benefits of a Biomethane Energy Research Centre.

Greenhouse Gas Analysis

The greenhouse gas emissions and reductions associated with a UBC Biomethane Energy Research Centre have been estimated by asking: what greenhouse gas emissions would be directly generated, and what emissions would be indirectly avoided by this approach?

Combustion of Fossil Natural Gas

Regarding the analysis of greenhouse gas emissions from the combustion of natural gas, the BC Reporting Regulation Methodology Manual GWP of 21 has been used in order to maintain consistency with the reporting requirements which apply to UBC. Interestingly, one recent study suggests that leaks of methane from hydraulic fracturing mean that the greenhouse gas emissions associated with natural gas may actually be twice as high as coal over a twenty-year period.[26]

Combustion of Biomethane

Consistent with the guidance in the BC Reporting Regulation Methodology Manual, carbon dioxide emissions from biogenic material are considered current and therefore carbon-neutral.

Emissions Associated with Anaerobic Digestion

The fugitive emissions from anaerobic digestion and from the process of upgrading raw biogas to biomethane have been included in the analysis.

Avoided Emissions Associated with Fertilizer Production

Digestate/compost contains nitrogen, phosphorous, potassium compounds, and micronutrients, and the production of these nutrients from artificial and mineral sources gives rise to greenhouse gas emissions. The extent to which these emissions would be avoided by a UBC Biomethane Energy Research Centre have been estimated by calculating the nutrient content of digestate and applying emission factors to each type of nutrient.[27] Estimated emission reductions from this source are 500 tonnes per year for Scenario One and 2,000 tonnes per year for Scenario four.

Avoided Emissions Associated with Hauling Waste

It is certain that the emissions associated with hauling garbage to the Cache Creek landfill would be reduced if a portion of organic waste from the Greater Vancouver area is diverted to a UBC Biomethane Energy Research Centre in the Fraser Valley. These estimated values have not been included in the total emission reduction figures however.

26 Howarth, R. et al. 2011. Methane and the greenhouse-gas footprint of natural gas from shale formations. Climatic Change. Volume 106, Number 4, Pages 679-690.

27 Wood, S., Cowie, A.. 2004. A Review of Greenhouse Gas Emission Factors for Fertiliser Production. (Prepared for IEA Bioenergy). New South Wales, AUS: Research and Development Division, State Forests of New South Whales: Cooperative Research Centre for Greenhouse Accounting. 20pp.

Avoided Landfill Gas Emissions

Organic material gradually decays in a landfill to produce methane over time, and landfill gas emission modelling is therefore based on a time-series calculation. Emissions are compared here on a steady-state basis to provide a clear picture of the difference in emissions among the four scenarios.

Provincial greenhouse gas reporting regulations do not currently require methane emissions from industrial landfills or from municipal landfills to be included in emission inventories. The Global Warming Potential (GWP) for methane was however revised by the IPCC in 2007 to 25, to reflect the current understating of the capacity of the atmosphere and biosphere to degrade methane into carbon dioxide.[28] As a result, the IPCC GPW of 25 tCO2e per tonne of methane has been used in the analysis of landfill methane emissions in this report.

Further, GWP values of 21 or 25 for methane are based on expected effects over 100 years. Methane decays into carbon dioxide in the atmosphere and to a lesser degree in soil, with a half-life of approximately thirteen years. As a result, the GWP of methane in the near-term is significantly higher, at 72 over twenty years. Climate scientists have also begun to point out that reducing methane emissions will have a significant benefit in the near term.[29]

Methane emissions that would be avoided by diverting source-separated organic waste from landfills were estimated by asking:

1. What is the efficiency of landfill gas capture systems?
   This value determines the proportion of methane generated by decomposing waste which would be prevented from entering the atmosphere. The estimate of landfill gas capture system efficiency is based on measured flow rates of landfill gas, and deposition rates of mixed municipal waste.
2. How much landfill gas would the diverted organic waste otherwise generate in a landfill?
   This estimate is based on methane generation rates for organic waste alone, and also takes into account the estimated landfill gas capture rate.

The efficiency of landfill gas capture systems is a key element of this analysis. Landfills in British Columbia which are modelled to emit more than 1,000 tonnes of methane per year are required by regulation to capture landfill gases.

Efficiency of Landfill Gas Capture

Estimates of the efficiency of Landfill Gas capture systems vary considerably, depending on assumptions made.[30] Several factors may contribute to variability in estimates of Landfill Gas capture efficiency, including:

1. Models of Landfill Gas capture efficiency depend on the methodology chosen (e.g. BC Ministry of Environment or IPCC) a wide variety of assumptions concerning the physical configuration of the landfill, the quantity and composition of waste which has been deposited historically, the choice of ultimate methane yield factors for each type of deposited waste, the choice of rate constants (the inverse of half-life decay periods) for each type of deposited waste, moisture conditions within the landfill, leachate management practices, the type and extent of landfill cover, the delay between the time waste is deposited in the landfill and the time Landfill Gas collection piping is installed, whether landfill gas composition and gas flow rates are both measured continuously or only intermittently, and so on.
2. A portion of methane is generated in a landfill after waste is deposited but before Landfill Gas capture piping is installed. A US study of 327 landfills in thirty-six states found that an average of only 57% of the active area of these landfills is devoted to Landfill Gas recovery. This study also surveyed twenty-four California landfills with Landfill Gas capture systems, and found that on average only 35% of generated methane is captured.[31]
3. Temperatures within landfills rise as organic waste decomposes, which tends to accelerate the rate of decomposition and therefore the rate of generation of methane. Temperatures above 40ºC have been reported in the literature, and elevated temperatures can also be observed in landfill leachate.[32] It is interesting that these reported temperatures are higher than

28 Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: The Physical Science Basis. Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing, Table 2.14. 106pp.

29 Cox, P. et al. 2010. Methane radiative forcing controls the allowable CO2 emissions for climate stabilization. Current Opinion in Environmental Sustainability. Volume 2, Issue 5, Pages 404-408.

30 Golder Associates Ltd. 2008. Cost Estimation Model for Implementing GHG Emission Reduction Projects at Landfills in British Columbia. Prepared for the BC Ministry of Environment. 41pp.

31 Themelis, N. et al. 2007. Methane Generation in Landfills. Renewable Energy 32 (2007) 1243–1257

32 Lefebvre, X. et al. 2000. The Role of Aerobic Activity on Refuse Temperature Rise. Waste Management & Research. 2000 18: 444

those at which mesophilic anaerobic digesters operate: this class of digester converts the majority of available carbon in organic materials to methane and carbon dioxide within twenty days.

4. The Capital Regional District has evaluated the Landfill Gas capture rate of its Hartland Landfill at 39% in 2008 and 34% in 2009.[33]
5. The City of Delta reports that the Landfill Gas capture efficiency of the Vancouver Landfill was 41% in 2009.
6. After investing significant time and resources capital to improve the landfill gas capture rate of the Regional Landfill, the Regional District of Nanaimo estimates its capture efficiency at approximately 40%.[34]

Avoided Methane Emission Estimates

To estimate the methane emissions that would be avoided by diverting organic waste from landfills, the emissions from organic waste alone (as opposed to mixed municipal waste) were estimated using the First Order Decay (FOD) method, per IPCC (2006) and Conestoga-Rovers & Associates Ltd. (2009): [35] [36] [37]

$$\text{Methane Generation} = L_0 * (EXP(-k*c) - EXP(-k*T)) = \text{tonnes } CH_4\text{/tonne of organic waste}$$

Table 21: Estimate of avoided landfill methane emissions

	Cache Creek	Vancouver	Units	Notes
Year Landfill Opened	1989	1966		
Year Diversion Begins	2016	2016		1.
Annual Precipitation	269	1,277	mm/year	2.
Rate Constant, k	0.05	0.11	1/year	3.
Half-Life of Methane Generation	13.9	6.3	years	4.
Methane Generation Potential, L_0	160	160	m^3 of CH4 per tonne of organic waste	5.
Methane Generated	77.70	104.47	kg CH4/tonne of organic waste	6.
Estimated Landfill Gas Capture Rate	65%	41%		7.
Methane Released	27.20	61.64	kg CH4/tonne of organic waste	8.
CO_2e Released, Net of Landfill Gas Capture	0.680	1.541	tCO2e/tonne of organic waste	9.
Proportion of Total	25%	75%		10.
Weighted Value		1.327	tCO2e/tonne of organic waste	11.

Notes for Table 21

1. Assuming that a UBC Biomethane Energy Research Centre would be operating by 2016.
2. Per the Landfill Gas Generation Assessment Procedure Guidance Report.
3. Per the Landfill Gas Generation Assessment Procedure Guidance Report (Table 5.2), Decomposable Waste. Based on the annual precipitation at Cache Creek of 269 mm, with leachate recirculation, and annual precipitation in Vancouver of 1,277 mm.
4. The inverse of the rate constant, k.
5. Per the Landfill Gas Generation Assessment Procedure Guidance Report (Table 5.1), Decomposable Waste for organic waste alone. It is possible that the actual value for organic waste alone will be higher, and an analysis based on IPCC (2006) could be completed for comparison purposes.
6. Per the First Order Decay method.

33 Envirochem Services Inc. for the Capital Regional District. 2009. 2010. Review of The Hartland Landfill Gas Monitoring Program and the Data Collected in 2009. 250pp.

34 Personal communication between Stephen Salter, PEng and Helmut Blanken, PEng, Superintendent of Engineering and Disposal Operations, Regional District of Nanaimo.

35 Intergovernmental Panel on Climate Change. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 2: Waste Generation, Composition and Management Data. 26pp.

36 Intergovernmental Panel on Climate Change. 2006. 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 5: Waste. Chapter 4: Biological Treatment of Solid Waste. 8pp.

37 Conestoga-Rovers & Associates Ltd. 2009. Landfill Gas Generation Assessment Procedure Guidance Report (Prepared for BC Ministry of Environment.) Conestoga-Rovers & Associates Ltd., Richmond B.C. 81pp.

7. Based on reported values for the Cache Creek and Vancouver landfills.[38 39 40]
8. After accounting for landfill gas capture.
9. After accounting for landfill gas capture rates, and based on a Global Warming Potential value for methane of 25.[41]
10. Estimated division of solid waste from the City of Vancouver to each landfill.
11. Blended emission factor, weighted by the portion of solid waste from the City of Vancouver estimated to go to each landfill.

Based on this estimated emission factor for organic waste alone in landfills, changes in greenhouse gas emissions were estimated. The results are summarized for Scenario Two in Table 22 and Scenario Four in Table 23 and presented graphically in Figure 61.

Table 22: Estimate of GHG emissions and reduction, BERC Scenario Two

Source	Activity Data	Units	EF	Units	GHGs (t/year)	Notes
Displaced Natural Gas	111,417	GJ/yr	0.050287	tCO2e/GJ	(5,603)	1.
Landfill Methane	46,200	t/yr	1.327	tCO2e/t of waste	(61,316)	2.
Fertilizer Replacement:						
Nitrogen	429	t/yr	1.9512	tCO2e/t	(837)	3.
Phosphorous	146	t/yr	1.0518	tCO2e/t	(154)	3.
Potassium	109	t/yr	1.1243	tCO2e/t	(108)	3.
Losses, AD	46,200	t/yr	0.500	g CH4 per t of substrate	485	4.
Losses, Upgrading	1,918	tCH_4/yr	0.5%	t CH4 per t of CH4	240	5.
Total					**(67,293)**	

Table 23: Estimate of GHG emissions and reductions, BERC Scenario Four

Source	Activity Data	Units	EF	Units	GHGs (t/year)	Notes
Displaced Natural Gas	230,987	GJ/yr	0.050287	tCO2e/GJ	(11,616)	1.
Landfill Methane	95,800	t/yr	1.327	tCO2e/t of waste	(127,145)	2.
Fertilizer Replacement:						
Nitrogen	889	t/yr	1.9512	tCO2e/t	(1,734)	3.
Phosphorous	304	t/yr	1.0518	tCO2e/t	(319)	3.
Potassium	227	t/yr	1.1243	tCO2e/t	(226)	3.
Losses, AD	95,800	t/yr	0.500	g CH4 per t of substrate	1,006	4.
Losses, Upgrading	3,976	t/yr	25.000	tCO2e/tonne of CH4	497	5.
Total					**(139,537)**	

Notes for Table 22 and Table 23

1. Per the BC Reporting Regulation Methodology Manual.
2. Per the analysis in this section.
3. Per A Review of Greenhouse Gas Emission Factors for Fertiliser Production.
4. IPCC suggests a default value of 1 gram of methane per wet kg of substrate. The value of 0.5 grams has been used here since the specified digester configuration includes a secondary storage stage with gas capture.
5. Limited to 0.5% of the upgraded methane, by passing off-gas from the biomethane upgrader through a flameless oxidizer or catalytic converter.

38 Golder Associates. 2008. Cost Estimation Model for Implementing GHG Emission Reduction Projects at Landfills in British Columbia. 41pp.

39 Golder Associates. 2012. 2011 Annual Report Cache Creek Landfill Cache Creek, BC. 26pp.

40 City of Vancouver. 2012. 2011 Annual Report for the Vancouver Landfill. 40pp.

41 Intergovernmental Panel on Climate Change. 2007. Climate Change 2007: The Physical Science Basis. Chapter 2: Changes in Atmospheric Constituents and in Radiative Forcing, Table 2.14. 106pp.

Since the methods used to estimate the efficiency of landfill gas capture depend strongly on the assumptions made, and since methods may vary among consultants, local governments, and over time, UBC's investigation of the biomethane option should include a careful evaluation of the estimates of landfill gas capture efficiencies in regional landfills, to confirm estimates of the expected greenhouse gas reductions.

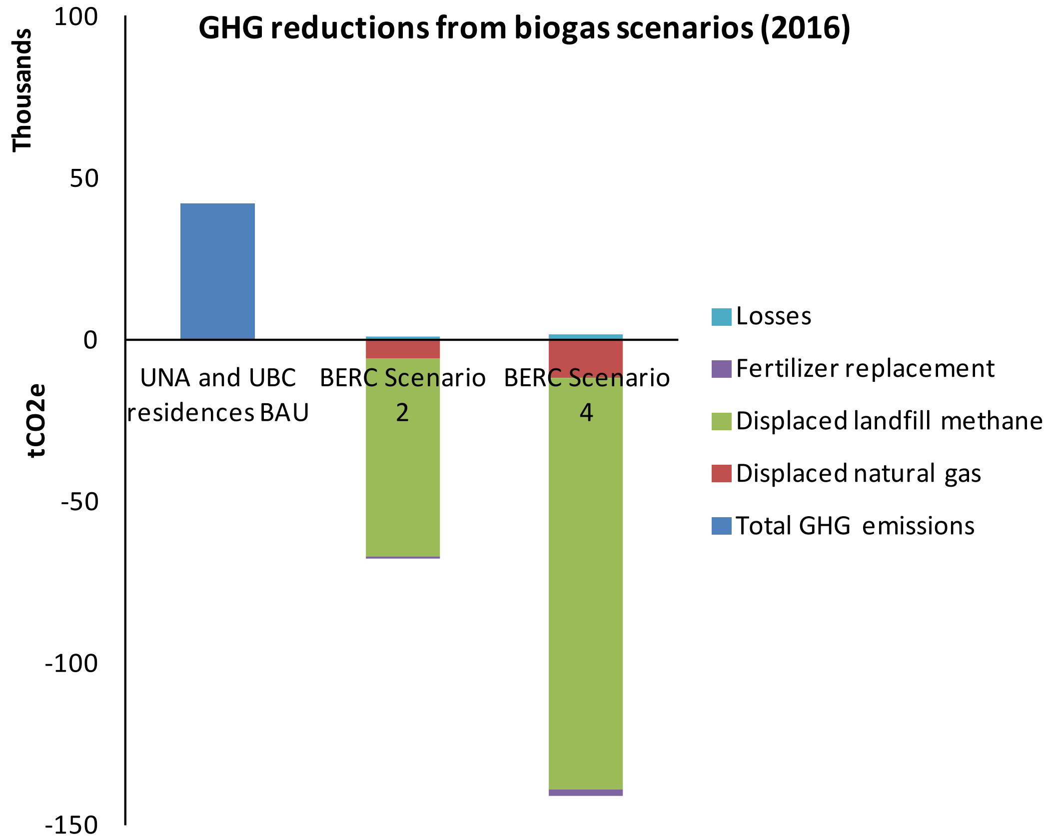


Figure 61: Estimated annual emissions reductions from implementing BERC Scenarios 2 and 4

Economic Costs and Benefits

A UBC Biomethane Energy Research Centre would require an initial capital investment, as shown in Table 24, but in all scenarios the facility would more than cover its capital and ongoing costs. The table also shows that economies of scale mean larger facilities will have a higher return on investment than smaller ones.

Environmental Costs and Benefits

A UBC Biomethane Energy Research Centre would:

1. Result in GHG reductions of 32,000 (Scenario One) to 139,000 tCO2e (Scenario Four) per year. All four scenarios would more than offset the greenhouse gas emissions of UTown@UBC.
2. Conserve between 54,000 GJ/year (Scenario One) and 230,000 GJ/year (Scenario Four) of natural gas.
3. Recover nutrients to provide a more sustainable, slow-release form of fertilizer for the benefit of Fraser Valley farms. Displacing a portion of artificial fertilizer on farms will result in further greenhouse gas reductions.

Social Costs and Benefits

A UBC Biomethane Energy Research Centre would support farms in the Fraser Valley, create local sustainable employment of between five and ten full-time jobs, reduce the financial burden of municipal solid waste management to taxpayers, reduce the number of trucks hauling waste to landfills, and serve as a demonstration that sustainable infrastructure can be both economically and environmentally sustainable.

Table 24: Summary of Estimated Annual Revenues and Costs, BERC Facility					
Scenario	**One**	**Two**	**Three**	**Four**	**Notes**
	Demonstration Digester	Offset Main Campus Emissions	Offset UTown Residence Gas	Offset all UBC GHG Emissions	
Logistics					
Natural Gas Consumption (GJ/year)	177,487	177,487	**177,487**	177,487	1.
Estimated Biomethane Production (GJ/year)	54,350	111,417	**179,354**	230,987	2.
Diversion of Vancouver's Organic Waste (%)	20%	41%	66%	85%	3.
Diverted Organic Waste, UTown@UBC (tonnes/yr)	22,500	46,200	74,400	95,800	4.
Compost Produced (tonnes/yr)	11,000	22,400	36,000	46,400	
Truck Deliveries per Day	3.4	7.0	11.3	14.5	5.
Estimated Annual Revenues					
Receiving Fees	$1,125,000	$2,310,000	$3,720,000	$4,790,000	6.
Compost Sales	$330,000	$672,000	$1,080,000	$1,392,000	7.
Natural Gas	$425,000	$871,000	$1,403,000	$1,806,000	8.
Carbon Tax	$82,000	$167,000	$269,000	$346,000	9.
Carbon Offsets	$68,000	$139,000	$224,000	$289,000	10.
Estimated Savings and Revenues, Total	$2,030,000	$4,159,000	$6,696,000	$8,623,000	
Estimated Annual Costs					
O&M	$820,000	$1,360,000	$1,970,000	$2,440,000	11.
Amortization	$1,000,000	$1,412,000	$1,781,000	$2,022,000	12.
Estimated Annual Cost, Total	$1,820,000	$2,772,000	$3,751,000	$4,462,000	
Estimated Annual Net Savings and Revenues	**$210,000**	**$1,387,000**	**$2,945,000**	**$4,161,000**	13.
Estimated Capital Cost	$14,100,000	$19,900,000	$25,100,000	$28,500,000	14.
Estimated GHG Changes					
GHG Reduction, Natural Gas (tonnes/yr)	(2,733)	(5,603)	(9,019)	(11,616)	15.
GHG Reduction, Landfill Methane (tonnes/yr)	(29,862)	(61,316)	(98,743)	(127,145)	16.
GHG Reduction, Fertilizer Replacement (tonnes/yr)	(535)	(1,099)	(1,769)	(2,279)	16.
GHG Increase, AD and Methane Slip (tonnes/yr)	353	725	1,167	1,503	18.
GHG Reduction, Total (tonnes/yr)	(32,777)	(67,293)	(108,365)	**(139,537)**	
GHG Emissions, UTown@UBC BAU (tonnes/yr)	8,925	8,925	8,925	8,925	19.
GHG Emissions, Net of UTown@UBC BAU	(23,852)	**(58,368)**	(99,440)	**(130,612)**	20.
GHG Emissions, UBC Vancouver Campus	58,353	**58,353**	58,353	58,353	21.
GHG Emissions, UBC, Scope 3	64,600	64,600	64,600	64,600	22.
Total UBC Emissions	122,953	122,953	122,953	**122,953**	23.

Notes for Table 24

1. This is the estimated natural gas consumption of UTown by the year 2015.
2. Based on the typical moisture content, volatile solids content, and rate of volatile solids conversion for source-separated organic waste.
3. This is the percentage of Vancouver's organic waste, currently disposed of in landfills, which would be diverted to the UBC Biomethane Energy Research Centre in each scenario.
4. This is the quantity of Vancouver's organic waste, currently disposed of in landfills, which would be diverted to the UBC Biomethane Energy Research Centre in each scenario.
5. Based on 30-tonne trucks.
6. Based on receiving fees of $50 per tonne, which is comparable to other diversion alternatives in the Lower Mainland (e.g. composting).
7. Based on a price of $30 per green tonne of compost at 50% moisture. The assumed price is conservative, because the nutrients in compost from this process have a greater value in terms of the conventional fertilizers they would displace.
8. Based on UBC's average cost of fossil natural gas over the previous two years, of $7.82 per GJ of gas. This is a simplifying assumption: UBC would need to negotiate a rate to transport biomethane produced at its facility through the local gas utility, consistent with the British Columbia Utilities Commission Act.
9. Based on the Provincial carbon tax of $1.50 per GJ of gas.
10. Based on the Provincial requirement for a carbon neutral public sector, and the price of carbon offsets of $1.25 per GJ of gas. Revenue estimates do not account for the potential to sell carbon offsets for GHG reductions over and above those required by Provincial regulations.
11. Including operations, maintenance, supplies, and technical support.
12. Based on a 25 year amortization and an interest rate of 5%.
13. It is likely that the capital cost of a farm-based facility will be lower than estimated here, since elements of required infrastructure (e.g. a means of storing digestate during the winter) are already in place in dairy farms. Capital cost estimates do not assume grant funding.
14. Capital cost estimates are based on the values for comparable projects, except that if facilities of the size modelled for Scenarios Two, Three, and Four are located on farms, it may be possible to use existing facilities for storing digestate. To be conservative however, the cost of facilities for storing digestate over the winter months and odour mitigation infrastructure have been included for all four scenarios.
15. These are the emissions that would be avoided by replacing fossil natural gas with biomethane from a UBC Biomethane Energy Research Centre, based on emission factors from the BC Reporting Regulation Methodology Manual.
16. These are the methane emissions from landfills that would be avoided when organic waste is diverted to the UBC Biomethane Energy Research Centre. A detailed explanation of this calculation is shown in the Greenhouse Gas Analysis section above.
17. Emissions associated with replacing artificial and mineral fertilizer with digestate on farms.
18. These are the fugitive methane emissions from anaerobic digestion and the biomethane upgrading process.
19. Greenhouse gas emissions from fossil natural gas combustion within UTown@UBC as of 2015, and based on emission factors from the BC Reporting Regulation Methodology Manual.
20. Total greenhouse gas emission reductions resulting from the operation of the UBC Biomethane Energy Research Centre, less greenhouse gas emission from UTown@UBC as of 2015.
21. Source: UBC Vancouver Campus 2010 GHG Emissions Inventory.
22. UBC's Scope 3 emissions, from 2011 Carbon Neutral Action Report - UBC Vancouver.
23. The total greenhouse gas emissions from all UBC activities, including Scope 3.

Synergies with UBC's Priorities

A UBC Biomethane Energy Research Centre would offer a number of synergies with UBC's education, research, and sustainability interests, including:

1. A UBC Biomethane Energy Research Centre would result in significant greenhouse gas reductions, from 32,000 to 139,00 tCO2e per year. Two effects would contribute to these reductions: replacement of fossil natural gas by biomethane, and avoided emissions from decomposing organic waste in the landfills.
2. Preliminary modelling suggests that a UBC Biomethane Energy Research Centre could be economically self-supporting, and would provide net revenues to UBC, thus demonstrating that the most environmentally sustainable strategies can also be the most economically sustainable.
3. The facility would support UBC's goals of increasing local food production by providing waste heat to greenhouses and a low carbon source of soil amendments..
4. A UBC Biomethane Energy Research Centre would support a number of sustainability and research interests of the UBC Dairy Education & Research Centre, including energy and nutrient recovery research.
5. A campus scale facility would support a number of UBC Farm operation objectives. UBC Farms reports that it would like to replace or expand their organics composting facility; an anaerobic digester would have net environmental, social, and economic benefits. UBC Farms also plans to expand its greenhouse space and to increase its production of food.
6. Locating and developing a UBC Biomethane Energy Research Centre would involve an interesting stakeholder engagement processes, which could further explore the question of how individuals form opinions regarding their relationships with energy, water, and waste, and how they form opinions regarding the costs and benefits of sustainable infrastructure.
7. The biomethane produced by the UBC Biomethane Energy Research Centre is a flexible form of energy: if injected into the natural gas distribution network, it can displace (on a nomination basis) natural gas in any boiler, small natural gas appliance, or cogeneration facility within UBC's organization. Biomethane could also replace fossil fuel in vehicles equipped to burn Compressed Natural Gas (CNG).
8. Compost (digestate) from the UBC Biomethane Energy Research Centre could be used on the UBC Farm (24 hectares) to displace artificial and mineral fertilizers. Compost from a larger UBC Biomethane Energy Research Centre could be sold to Fraser Valley farms.
9. The next best option for food waste is conventional aerobic composting. While composting would recover nutrients, it would not recover bioenergy. In addition, composting results in greenhouse gas emissions of approximately 0.193 tCO2e per tonne of organic material composted.[42]
10. The facility would demonstrate that sustainable infrastructure can be incorporated in to communities.
11. The UBC Biomethane Energy Research Centre would emphasize the interconnections among water, energy, food, and climate change, and the role of sustainable food production in reducing greenhouse gas emissions is significant: food consumed by the average US household is responsible for 8.8 tCO2e per year, versus 4.1 tCO2e per year for the family car.[43]
12. The facility would support UBC's living laboratory goals. Producing biomethane from food waste would support a number of current research and education priorities for UBC, including biofuels, sustainability, greenhouse gas reduction strategies, conversion of biomethane to liquid fuels, nutrient recovery, and sustainable food production.
13. The facility would present opportunities for collaboration in new areas of research for UBC with world leaders in countries such as Sweden, Germany, and France. These new areas could include improvements to practices for managing optimum biological processes within digesters, contaminant separation, pre-treatment of organic waste to enhance biogas yields, novel digester configurations, technologies for upgrading biogas to biomethane, and technologies for converting biomethane into hydrogen and liquid biofuels. These areas of research would include the disciplines of biology, bio-technology, agriculture, chemistry, engineering, sustainability, geography, and the social sciences.
14. Compost from a UBC Biomethane Energy Research Centre would support agriculture in the Fraser Valley, as carbonaceous materials, water, and nutrients from organic waste would be returned to soil thus closing an ecological loop, promoting beneficial soil micro organisms, reducing pollution of surface waters by artificial an mineral fertilizers. Digestate is also less expensive for farmers than artificial and mineral fertilizers.
15. Anaerobic digestion and diversion of food waste from landfills supports a number of sustainability objectives in Metro Vancouver and the City of Vancouver (see the City of Vancouver's Greenest City 2020 Action Plan). The facility would also directly help Metro Vancouver and the City of Vancouver achieve their solid waste diversion targets

42 IPCC. 2006. IPCC Guidelines for National Greenhouse Gas Inventories, Table 4.1.

43 New Scientist. 2008. What is your dinner doing to the climate? Issue 2673.

16. If a smaller UBC Biomethane Energy Research Centre is developed on the UBC campus, it could be possible to use waste heat from TRIUMF to maintain digester temperatures. If biogas is used for cogeneration, heat could feed the Neighbourhood District Energy System, and electricity produced would offset electricity consumed on the campus, including electricity consumed by TRIUMF. This would form an elegant juxtaposition of earthy and advanced technologies, working in synergy.
17. If organic waste from the Greater Vancouver area is diverted to a UBC Biomethane Energy Research Centre in the Fraser Valley, then a proportion of trucks hauling waste to the Cache Creek landfill would travel a shorter distance, for example 120 kms from Vancouver to the Fraser Valley versus 340 kms from Vancouver to Cache Creek.

Developing an Anaerobic Digestion Facility

Potential Locations

The Biomethane Energy Research Centre could be located:

1. On the UBC campus, within the boundaries of the 24 hectare UBC Farm.
2. At the UBC Dairy Education & Research Centre in Agassiz.
3. At another BC farm.
4. At a BC industrial site, in partnership with an industrial organization.
5. At a municipal site, in partnership with a local government.
6. On land purchased for this purpose by UBC.

A facility located on the UBC campus would necessarily be smaller than one located elsewhere. A small facility on the UBC campus could however provide fertilizer for UBC Farms, as well as research, demonstration, and educational value. In addition, biogas from a facility located near to a future Neighbourhood District Energy System could be used generate electricity and heat, rather than for upgrading to biomethane. One potential location on the UBC campus could be within the boundaries of the UBC Farm: in this location, access for delivery trucks would be via SW Marine Drive.

Other advantages and disadvantages of each potential location could be explored in a later stage of development of the UBC Biomethane Energy Research Centre.

Development Stages

UBC could quantify the costs and benefits of developing a UBC Biomethane Energy Research Centre through a Request for Proposals designed to obtain input from firms that are actively designing and building anaerobic digestion facilities in North America. The RFP could be published internationally, to invite proposals from firms that have European experience and also have operations in North America. UBC staff will need to develop expertise in anaerobic digestion, which can be achieved in stages, and with the help of a qualified firm selected by UBC through a Request for Proposals process. Staff could also visit comparable installations in Canada and the United States. Developing a UBC Biomethane Energy Research Centre will require negotiations with the City of Vancouver and Metro Vancouver, to secure deliveries of source-separated organic waste.

Regulatory Aspects

In developing an anaerobic digestion facility, UBC or UBC's partner will need to work with the following regulators:

- Ministry of Agriculture (Nutrient Management Plan)
- Agricultural Land Commission (Land Use)
- Ministry of Environment (OMRR)
- BC Utilities Commission

Strategy 2: District Energy Hybrid Configurations

District energy distribution systems normally include one supply pipe and one return pipe. For the Neighbourhood District Energy System, UBC could implement a hybrid district energy distribution configuration incorporating three pipes for high-temperature supply, medium-temperature return, and low-temperature return. This configuration would take advantage of cascading arrangements in which heat loads are supplied in series in order to maximize temperature drops and efficiency. This would also enable heat recovery from various lower-temperature sources. By providing a low-temperature return to the boilers, this hybrid configuration would allow boiler economizers to operate at maximum efficiency. Potential sources of medium-temperature waste heat are listed below.

New residential buildings could also be served by the return line of the Academic District Energy System, to lower the overall return temperature, and to therefore increase heat recovery efficiency. Residential and commercial buildings in the East Campus, Acadia East, and Acadia West could potentially be served in this way. Although this strategy would increase the load on the Academic District Energy System Energy Plant, part of the load could be provided from waste heat recovered from stack gases.

Sources of Waste Heat

Stack Gas Economizers

The seasonal efficiency of natural gas boilers is typically 75% to 80%, and the seasonal efficiency of biomass boilers 70% to 75%. These efficiencies can be increased by approximately 10% by means of economizers designed to recover energy in boiler stack gases which would otherwise be wasted. The key to successfully recovering energy from this source is to provide the economizers with sink or use for energy at a temperature below that of the stack gases. If the temperature of the heat exchange medium in the economizer (e.g. thermal oil, water, or air) is lower than the stack gas dew point, then significantly more energy can be recovered. Below the dew point, the economizer will receive both sensible heat, and also latent heat from condensing water vapour.

A hybrid district energy distribution system incorporating three pipes, as described above, would provide a low-temperature flow to boiler economizers. Energy from this source would otherwise be wasted.

TRIUMF

The quantity of waste heat that could be recovered from the TRIUMF facility as 5 MW_{th} today increasing to 8.5 MW_{th} after expansion of the facility, for a total of 66,000 MWh_{th} (137,000 GJ) per year. The report developed a concept for recovering energy from the research facility's cooling water at 25ºC by means of heat pumps, and delivering this energy to a Neighbourhood District Energy System at 60-75ºC.[44] The study that determined this also estimates this approach would reduce greenhouse gas emissions from the UTown@UBC community by 5,300 tonnes per year initially, increasing to 12,000 tonnes per year at full build-out (Phase 4).

Exhaust Air

Stantec has estimated that approximately 9,000 MWh_{th} (32,400 GJ) per year could be recovered from twenty-four buildings on the Vancouver campus at an estimated capital cost of approximately $12 million, and an overall cost of $33.64/MWh over twenty-five years.[45] This approach has been demonstrated in the CIRS building, which recovers heat from fume hood exhaust vents of the adjacent Earth and Ocean Sciences building.

Power Transformers

Recovery of waste heat from power transformers has been demonstrated in the Tate Modern Art Gallery in London. Beginning in 2011, the gallery has been provided with 600 kW of heat from the adjacent Bankside Substation. This approach has also been used elsewhere.[46]

UBC's Vancouver campus is served by the North and South Campus Substations. The university is considering the option of increasing its electrical capacity with the addition of a new 61 MVA transformer, an upgrade which would likely be required to serve any significant new heat pump capacity on the campus. If the new transformer is 98% efficient and operates at 75% of capacity

44 FVB Energy Inc. 2012. University of British Columbia Neighbourhood District Energy System Technical Feasibility Study Report. 109pp.

45 Stantec. 2009. Alternative Energy Feasibility Report For University of British Columbia, Phase One-Step Two. 200pp.

46 Zhao, Y. et al. 1995. A heat-pump system for heat recovery at a substation. Energy, Volume 20, Issue 3, March 1995, Pages 243–245.

on average, then in theory it will waste approximately 8,500 MWh_{th} (30,700 GJ) per year. The installation of a new transformer would need to be designed to facilitate heat recovery, taking into account safety, operating, and maintenance requirements. Power transformers are designed to operate at 60C, and heat pumps operating at a high coefficient of performance could be used to increase the temperature of recovered energy. This source would result in very low greenhouse gas emissions, and could be located within a reasonable distance of the Academic District Energy System or Neighbourhood District Energy System distribution piping.

Wastewater

The City of Vancouver's Southeast False Creek Neighbourhood District Energy System has demonstrated the practicality of recovering heat from wastewater in the local context (larger systems have been in operation in Norway, Sweden, and elsewhere for several decades), especially if heat recovery infrastructure is installed in concert with other, needed upgrades.

Based on a population of 18,000 in 2012, approximately 6,400 MWh_{th} (23,000 GJ) could be recovered each winter from the community's wastewater. If the population of UTown@UBC increases to 30,000 then approximately 10,600 MWh_{th} (38,300 GJ) could be recovered.

Strategy 3: Cogeneration of Electricity

UBC anticipates that the capacity of electrical supply infrastructure to the Vancouver campus will need to be increased in the near-term. Stantec has estimated the cost of a third feed with a capacity of 61 MVA from BC Hydro at approximately $10 million.[47] UBC could evaluate the costs and benefits of strategies which could be alternatives to an upgrade, or which could reduce the size and cost of an upgrade.

First, UBC could ask how the lifecycle cost of investments in electricity conservation on the campus (including initial investments and energy savings) would compare with the lifecycle cost of an upgrade (including initial costs and ongoing energy costs). Second, UBC could compare the costs and benefits of an upgrade with those of cogeneration. Larger-scale cogeneration could be provided through gas turbines operating in a combined cycle with steam turbines or with Organic Rankine Cycle (ORC) turbines. Smaller-scale cogeneration could be incorporated into the planned natural gas Power Plant to generate more modest amounts of electricity, where an ORC would scavenge heat from the natural gas boiler stack gases. In either case, fuel for cogeneration could be provided by biomethane from a Biomethane Energy Research Centre.

In evaluating the costs and benefits of cogeneration, UBC could consider not only BC Hydro's standing offer rate, but also the benefit of reducing peak demand charges.

UBC could evaluate the costs and benefits of large scale electricity storage on the campus, to determine if storage could obviate the need for capacity increases in electrical supply, and could reduce demand charges by smoothing peaks in demand. UBC could investigate current best practices in this area, such as flow batteries (e.g. vanadium flow technology). UBC could also model the costs and benefits of using smart grid technology which would allow recharging stations to use the storage of electric cars for storage and discharge during peak demand times.

Strategy 4: Micro-Hydro

UBC's Vancouver campus has generous winter precipitation averaging 1,277 mm per year, peaking at over 190 mm on average in November.[48] The fact that the campus is approximately 70 metres above sea level begs the question: what if stormwater were collected and discharged through a micro-hydro turbine?

Conceptually, campus stormwater could be collected into one or more wetlands (a wetland already exists in the vicinity of the UBC Farm), then discharged after treatment in the wetland through a single pipe and micro-hydro turbine.

A simple order-of-magnitude estimate could include only impervious surfaces. Currently, buildings and roads cover a total of 111 hectares on the Vancouver campus.[49] If it is assumed that 80% of precipitation falling on these two types of surface flows to storm

47 Stantec. 2009. Alternative Energy Feasibility Report For University of British Columbia, Phase One-Step Two. 200pp.

48 National Climate Data and Information Archive, Canadian Climate Normals 1971-2000.

49 UBC. 2009. UBC Campus Plan, Part 4 - Reference Material. 10pp.

sewers, then a maximum average monthly rate and an average winter rate of stormwater flow can be estimated. Based on these rough approximations, a micro-hydro Kaplan turbine with an efficiency of 88% and a generator efficiency of 93% could potentially yield 26 kW during the peak month of November, and a total of 210 MWh per year. It is very unlikely that a micro-hydro installation of this size could recover its costs.

At this rate, the value of micro-hydro based on campus stormwater could be considered for its demonstration and education value rather than for its economic or environmental benefits, unless:

- UBC plans to replace significant amounts of stormwater infrastructure, or install new stormwater infrastructure for example in the new residential areas for UTown@UBC.
- UBC determines that managing stormwater on the campus, rather than discharging stormwater to the City of Vancouver, could reduce the university's future infrastructure costs or its ongoing costs of stormwater utility payments.

As an alternative, or in addition to micro-hydro, UBC could consider using a simple hydraulic ram on the stormwater line to pump clean stormwater to an elevated storage tank for reuse on the campus.

Other Strategies

Fuel Switching Options

Biodiesel and Bioethanol

It is practical to burn biodiesel and bioethanol in boilers to replace fossil natural gas, but several drawbacks to this option exist. First, the relatively high greenhouse gas footprint of current sources means that emissions from biodiesel (12,600 tonnes per year) and bioethanol (11,400 tonnes per year) would actually be higher than the BAU emissions of natural gas (8,900 tonnes/year) of UTown@UBC. This consideration alone is enough to disqualify biodiesel and bioethanol at this time. If biodiesel or bioethanol could be bought from lower-carbon sources in the future, the water footprint and Indirect Land Use Change implications of the new sources would then need to be evaluated.

In addition, the price of biodiesel at the time of this report was $1.50 to $1.80 per litre, and the price of bio-ethanol was $1.00 per litre. Bio-ethanol has only 2/3 of the energy content of biodiesel, which puts its price per unit of energy close to the lower end of the price range for biodiesel. At this price, biodiesel is significantly more expensive than natural gas.

Renewable Natural Gas

FortisBC markets biomethane from anaerobic digesters and landfill gas capture projects as Renewable Natural Gas. Although the utility's current offering limits the nominated biomethane content to 10% of a gas customer's total consumption, it may be possible for large organizations to negotiate a fee for the delivery of biomethane, on a nominated basis, through the utility's transmission system. In this arrangement, UBC could potentially be both the producer and consumer of Renewable Natural Gas (as would be the case if UBC develops a UBC Biomethane Energy Research Centre) or only the consumer of Renewable Natural Gas produced by others.

Biomass

The option of biomass as an energy source for a Neighbourhood District Energy System has been developed for UBC. It is estimated that this option would reduce greenhouse gas emissions by 5,300 tonnes per year initially.[50] This option could use urban wood waste which would otherwise go to lower-value fates, including landfilling.

In another option for biomass supply, UBC could engage contractors or UBC employees to reclaim wood debris from the UBC foreshore, chip the material, process it to remove salt, and provide this material to a future biomass boiler for the Neighbourhood District Energy System or to the existing biomass gasifier.

Greenhouse/Building Hybrids

In the vicinity of the UBC Farm, any new buildings could be designed to incorporate rooftop greenhouses. Exhaust air from the building could flow through the greenhouse, providing heat and modest amounts of CO_2 to enhance plant growth. Fresh make up air

50 FVB Energy Inc. 20120. University of British Columbia Neighbourhood District Energy System Technical Feasibility Study Report. 109pp.

could enter the building via the greenhouse at other times, taking advantage of solar heating: air could be exchanged between the greenhouse and the building it is incorporated into in different directions at different times, depending on the energy needs of the building and greenhouse.

The greenhouse would also provide additional insulation to the building, and the greenhouse floor could incorporate Phase Change Materials for thermal mass, to modulate diurnal temperature variations. Water from the greenhouse roof could also be collected for irrigating plants and for non-potable uses within the building.

Adsorption Cooling

UBC has approximately 900 tons of chiller capacity.[51] Rather than replace existing chillers as they reach their end of life with electrical chillers, UBC could consider installing adsorption chillers in individual buildings, supplied with heat from the district energy system. The benefit of this approach is that it would reduce demands on the campus electrical system, and would provide a modest increase in summer loading for boilers.

UBC has an interest in increasing the amount of food provided to the Vancouver campus from UBC Farm. UBC could consider building a food storage facility, with cooling provided by adsorption chillers connected to the district energy system. Such a facility could make produce available over a wider range of months, and could reduce the amount of driving by campus residents.

Thermal Storage

UBC could model the costs and benefits of two forms of thermal storage. First, large-scale thermal storage tanks could be integrated into the Academic District Energy System and Neighbourhood District Energy System. Storage of this type could smooth peaks in demand, and could potentially decrease the total capacity of boilers required to serve peak demands. Working against this idea is the fact that the incremental cost of increases in the peak capacity of boilers tends to be reduced by economies of scale - the flattening of the upper end of the cost curve. Working in favour of this strategy is the fact that peak demand for district energy systems tends to be served by fossil fuel sources, with attendant higher greenhouse gas emissions.

Thermal mass could also be integrated into all new buildings, in the form of conventional or Phase Changing Materials. This approach would have the potential to not only decrease peak boiler capacity, but also district energy system distribution capacity and capital cost.

51 Stantec. 2009. Alternative Energy Feasibility Report For University of British Columbia, Phase One-Step Two. 200pp.

Conclusions

1. UBC has several very good opportunities to reduce the greenhouse gas emissions of UTown@UBC, and of UBC's operations in total. These opportunities include:
    a. A Neighbourhood District Energy system that takes advantage of waste heat from TRIUMF, and potentially biomass energy, and;
    b. A Biomethane Energy Research Centre to recover energy and nutrients from organic waste.

    These strategies are complementary to the university's investments in energy conservation.

2. A small demonstration Biomethane Energy Research Centre could be located on the Vancouver campus. The value of a system of this size would be limited to its research and demonstration aspects.

3. A larger Biomethane Energy Research Centre could be located at the UBC Dairy Education & Research Centre in Agassiz, or the site of an agricultural, industrial, or municipal partner in BC. A larger centre would result in greater benefits:
    a. If 41% of the organic waste currently disposed of by the City of Vancouver is diverted to such a facility, the resulting emission reductions would equal the current UBC Vancouver campus emissions of 58,353 tonnes per year.
    b. If 85% of the organic waste currently disposed of by the City of Vancouver is diverted to such a facility, the resulting greenhouse gas emission reductions would equal all of UBC's current emissions (including Scope 3) of 122,900 tonnes per year.

4. Apart from greenhouse gas emission reductions, a UBC Biomethane Energy Research Centre would result in a number of other environmental benefits and would also be economically sustainable, generating several million dollars per year in savings and net revenues for UBC.

5. UBC's emission reduction strategies integrate very well with UBC's proprieties for research, education, and sustainability.

Recommendations

1. UBC should seriously investigate the option of developing a small Biomethane Energy Research Centre on the Vancouver campus, or a larger facility in the Fraser Valley, potentially at the UBC Dairy Education & Research Centre in Agassiz. UBC could consider quantifying the costs and benefits of this option by means of a Request for Proposals designed to obtain input from firms which are actively designing and building anaerobic digestion facilities in North America. Many of these firms base their technologies on current European experience. UBC's investigation of this option should also include a careful evaluation of the estimates of landfill gas capture efficiencies in regional landfills, to confirm estimates of greenhouse gas reductions.

2. Regarding the strategy of anaerobic digestion, UBC should act quickly on this initiative since local governments are currently developing plans to increase the diversion of solid waste away from landfills.

3. Wastewater piping infrastructure for new areas of development within UTown@UBC should be designed to allow recovery of heat from wastewater by means of heat pumps.

4. In addition to meeting the requirements of REAP, all new buildings within the scope of UTown@UBC should include the following energy-related features:
    a. Hydronic heating systems designed for connection to district energy, and also designed to use relatively low supply temperatures which are compatible with sources of waste heat.
    b. Passive solar heating.
    c. Heat recovery with air-to-air heat exchangers.
    d. Heat recovery from drainpipes serving showers, dishwashers, and washing machines.
    e. Facilities for collecting recyclable materials, including organic waste.

5. UBC should integrate its planning to simultaneously maximize greenhouse gas emissions, maximize the educational value, and maximize the economic value of investments in sustainable infrastructure. The scope of integration should include physical aspects of water, solid materials, and energy, as well as the organizations of UBC, the City of Vancouver, Metro Vancouver, and potential partners in agriculture and industry.

6. Water and energy are interrelated, since managing water consumes energy, and producing energy consumes water. In addition, UBC spent $1.8 million on potable water in fiscal 2011. Therefore, UBC could consider adding a reclaimed water line to all new district energy trenching, to provide reclaimed water to existing buildings. Further, in addition to meeting the requirements of REAP, all new buildings within the scope of UTown@UBC should include the following water-related features:
    a. Dual supply piping to allow reclaimed water to be used for non-potable applications.
    b. Dual wastewater piping to allow greywater to be treated and reclaimed on site.
    c. Rainwater capture.
    d. Green spaces irrigated with reclaimed water designed to provide shade and evaporative cooling in summer.

Appendix 5

Multi-Criteria Analysis

This matrix tabulates the strategies assessment by the consulting team using a multi-criteria analysis exercise.

Assign each strategy a score between 1 and 5 for each criteria . 1 = poor, 2 = fair, 3 = good, 4 = great, 5 = excellent	On-Campus Energy Production					Building Energy Efficiency			Transportation				
	Biomass District Energy	Biogas District Energy	PV Electricity	Solar Hot Water	Heat Pumps	Minimum REAP Standard	Mid-range REAP Standard	Maximum REAP Standard	Increased Bus Transit	Light Rail Transit	Minimum EV Uptake	Mid-Range EV Uptake	Maximum EV Uptake
A. Environmental													
1. Maximizes greenhouse gas emission reductions	4	5	1	2	5	1	3	5	2	3	1	2	3
2. Minimizes energy consumption	5	5	4	3	2	1	3	5	4	5	1	1	1
3. Minimizes pollution of air, land, and water	4	4	5	5	5	1	3	5	2	5	2	3	4
Sub-Total	13	14	10	10	12	3	9	15	8	13	4	6	8
B. Social													
1. Supports UBC's Strategic Plans & Learning Laboratory Initiative	3	5	4	4	4	2	2	2	4	5	2	3	4
2. Minimizes impacts on neighbourhoods (noise, visuals, odour, dust)	3	3	5	5	4	2	2	2	4	5	3	4	5
3. Maximizes local employment and economic development	5	5	3	3	2	2	3	4	3	5	1	1	1
Sub-Total	11	13	12	12	10	6	7	8	11	15	6	8	10
C. Economics													
1. Minimizes lifecycle cost	5	5	2	2	4	3	4	5	4	4	2	2	2
2. Maximizes net revenues for UBC	5	4	1	2	3	4	2	1	4	3	2	2	2
3. Minimizes risks related to changes in fuel availability and price	5	5	3	4	4	1	3	5	4	5	3	4	5
4. Maximizes potential for funding through innovation grants	4	5	4	3	5	1	3	5	1	3	2	4	5
Sub-Total	19	19	10	11	16	9	12	16	13	15	9	12	14
D.													
1. Makes the most efficient use of resources, including waste	5	5	2	3	5	3	3	5	4	5	2	2	2
2. Maximizes reliability (robust equipment, simple to maintain)	4	4	5	4	5	3	3	3	4	5	3	3	3
3. Proven design, experience with installations is available elsewhere	5	5	5	5	5	5	5	5	4	5	1	1	1
Sub-Total	14	14	12	12	15	11	11	13	12	15	6	6	6
Grand Total	57	60	44	45	53	29	39	52	44	58	25	32	38

Appendix 6

Building Code Best Practices Review

Building Energy Codes – Review of Current Standards and Best Practises

Starting in Scandinavia in the 1960's, building energy codes are now in use in most developed (and many developing) countries. However, there is a wide range of standards being applied with little coordination between jurisdictions. Most countries (and often individual states/provinces or municipalities) have their own energy codes, usually both a residential and a commercial version. In BC (and many other jurisdictions), high-rise multi-family buildings are considered as commercial buildings and follow the commercial energy code.

There have been a number of major reports issued in the past few years on the state of building energy codes. The International Energy Agency (IEA), with the Organization for Economic Co-operation and Development (OECD) published *Energy Efficiency Requirement in Energy Codes, Energy Efficiency Policies for New Buildings* in 2008, which examines current standards for energy codes in OECD countries. In 2009, the Building Codes Assistance Project (BCAP) of the Alliance to Save Energy published *Building Energy Codes – Best Practices Report for APEC Economies*, which identifies best practises for developing, implementing, and enforcing building energy codes. Also in 2009 was published *Shaping the Energy Efficiency in New Buildings: A Comparison of Building Energy Codes in the Asia-Pacific Region* by the US Department of Energy.

Features of Energy Codes

Most energy codes share some similarities. The following are common features of some or all energy codes:

Residential vs Commercial

Generally codes are different for commercial versus residential buildings, due to their different construction standards, occupancy, and operation. Residential codes tend to be simpler with more prescriptive requirements. High-rise multi-family buildings are usually considered under commercial energy codes, and their design and construction is closer to that of commercial.

Consideration of different building components

Virtually all codes address insulation levels in walls and roofs. Most also include sections for windows, heating, ventilating, and air-conditioning (HVAC) equipment, and lighting. Most, but not all, codes also address windows, HVAC equipment, and lighting. The most comprehensive codes also incorporate standards for service water heating and electrical power, and have an option for assessing building performance as a whole.

Alternative compliance methods

Most codes provide alternate methods of compliance, ranging from mandatory requirements to whole building analysis. Trade-offs are usually allowed within a component of the building (e.g. poorer wall insulation in exchange for better windows), while some codes allow the total energy consumption of the building to be compared to a baseline to prove compliance (whole building simulation).

Variations for climate

Most codes that serve large areas have adjustments for climate, although climate zones are often quite broad.

Renewable energy

While a number of codes address renewable energy, it is usually in the context of being used to trade-off some other requirement. Renewables are rarely a stand-alone requirement of the code, although this has been done in some jurisdictions (notably Merton in the United Kingdom).

Codes and Standards in Use Today

No jurisdictions stand out as having particularly advanced standards relative to others, although Northern Europe and the US tend to lead the way.

United States

In the United States, the federal Department of Energy issues 90.1 and IECC as model codes. Most states adopt these codes as state codes, although some jurisdictions use their own codes, either more or less stringent.
ASHRAE 90.1 is the best known commercial energy code, published by the American Society of Heating, Refrigerating, and Air-conditioning Engineers. This is an international organization, although it is largely North American based. This code is updated every 2-3 years by committees with a wide range of stakeholders. 90.1 covers most aspects of building energy use and allows considerable flexibility in meeting the standard, including whole building simulation modelling. 90.1 forms the basis of the BC Building Code energy requirements as well as LEED.

The International Energy Conservation Code (IECC) is used as a model residential code in the United States. It includes requirements for small commercial buildings. It covers building envelope, HVAC, and electrical power, including lighting. The IECC is not as comprehensive as 90.1, as residential buildings tend to be simpler. It includes an option for whole building simulation modelling.

Europe

In Europe there is no common model code. The European Union has published the Energy Performance in Buildings Directive, which requires countries to have an energy code in place but does not state what the form or standard that code must take. It also requires buildings to have energy performance certificates and to have regular inspections of heating and cooling equipment.

Other Countries

Many other countries have developed their own codes, with Korea and Japan being some of the first to introduce energy codes. Although 90.1 may be used as a starting point for some codes, no code has surfaced as a model internationally.

Canada & British Columbia

In Canada, the federal government publishes the Model National Energy Code for Buildings (MNECB), but provinces are free to enact their own standards. MNECB has not been updated since 1997, but a new version is due to be released shortly. No jurisdiction has adopted MNECB as a code, although it has been the basis for some voluntary programs. Much of the MNECB is similar to ASHRAE 90.1.

Although the federal government also publishes a Model National Energy Code for Houses (MNECH), it has gained very little attention and has not been adopted anywhere.

In BC, ASHRAE 90.1 - 2010 is the energy code for commercial buildings (including high-rise residential). For residential and small commercial buildings, there are only requirements for insulation levels in roofs, walls, and floors. However, efficiency requirements for windows and furnaces as well as some other equipment are covered by the BC Energy Efficiency Act. As an alternative compliance method, houses may meet Energuide 77.

Voluntary Programs and Standards

Leadership in Energy and Environmental Design (LEED)
LEED is the best established voluntary standard for commercial and high-rise residential buildings. It uses a points system to address all issues of buildings design. For energy, LEED requires buildings to be 23% more efficient than MNECB or 10% more efficient than 90.1 – 2007. This requires building to have computer simulations performed (although there are some prescriptive alternatives for smaller buildings of a certain type).

Built Green
Built Green is a Canadian standard developed by the building industry. It uses a points system similar to LEED, but focused on residential buildings. For energy performance, Built Green requires Energuide 80 or an equivalent number of points. Although an Energuide rating is required as part of Built Green, either the rating or prescriptive requirements can be used to meet the standard.

Energuide
Energuide is a home rating system developed by the federal government. It uses a computer simulation package to assess the energy performance of residential buildings. While developed for single family homes, Energuide can be used for some types of multi-family buildings. The Energuide rating system takes into account building envelope and HVAC systems.

Passive House
This is a European standard for very high efficiency housing. Developed in Austria, it has seen increasing popularity as people look for more aggressive efficiency standards. Although the Passive House standard has guidelines for various components of the building, it is based on achieving a heating energy requirement of 15 kWh/ft^2 and is generally flexible in how that is achieved. Passive House is one of the few codes or standards to have a requirement for air leakage - 0.60 air changes at 50Pa.

Comparison of REAP to Other Codes

When REAP was introduced in 2005 there was no energy code for high-rise multi-family and minimal standards for low-rise. Since then 90.1 - 2007 has been introduced for high-rise and standards for low-rise have been increased. This has left REAP lagging the provincial code in some areas. Because REAP has the same requirements for high-rise and low-rise, the actual performance of these buildings is quite different due to different construction standards. REAP does incorporate some components not included in other codes, such as efficient appliances and programmable thermostats.

High-rise Multi-Family
The largest difference between REAP and other codes is in the wall construction for high-rise buildings. REAP specifies the amount of insulation required, while 90.1 specifies the overall thermal transmittance of the wall. Since most high-rise walls are metal frame with considerable heat loss through the metal frames, the overall wall R-value of buildings constructed to REAP insulation levels is quite low. Roof insulation levels exceed that of 90.1, but because there is limited roof area on high-rise buildings, this does not impact energy performance significantly.

REAP also does not pose any limitations on window area. As high-rise multi-family buildings in Vancouver tend to have very large window areas, this hurts energy performance.

Measured energy consumption is not a requirement under any of the codes referenced here. But the recent REAP energy modelling project provides energy performance for REAP, 90.1, and some alternative combinations of energy conservation features, based on typical high-rise construction. A REAP building consumes 15% more heating energy than one built to 90.1-2007, while the proposed minimum and maximum combinations consume 39% and 69% less, respectively.

Note: REAP will be revised to reflect inclusion of mid and high rise MURBs.

Low-rise Multi-Family
For low-rise buildings, REAP sets a standard slightly higher than the BC Building code for walls and similar for most other areas. Since low-rise buildings are generally wood-frame, thermal bridging is not such an important issue as in high-rise (and the BCBC specifies

insulation rather than overall wall transmittance as well). Window area is also not such an important issue in low-rise, as these tend to have much smaller window areas.

Although the low-rise BC Building Code was not modelled in the recent REAP energy modelling project, REAP was found to be the same as 90.1-2007 for low-rise. The proposed minimum combination would results in 39% less heating energy, while the maximum combination would result in a 61% reduction.

The IEA report provides residential insulation and window requirements for various OECD jurisdictions. Comparing these to REAP, the most stringent codes call for 74% higher wall insulation and nearly double the roof insulation. Windows are 40% better.

The Passive House standard gives an idea of what ultra-high performance residential codes might look like. Insulation and window requirements are more than double REAP, with an 88% reduction in heating energy. Importantly, the Passive House calls for very tight envelopes with limits on air leakage, something not found in any of BC's current codes (although air leakage testing is part of the Energuide rating used by Built Green).

Best Practises in Code Development

The following recommendations are drawn from the IEA, BCAP, and DOE reports referenced above.

Technical Requirements

- There should be separate codes for residential and commercial sectors, acknowledging the different construction practises between the sectors.
- Codes should be regularly updated to maintain relevance with changing market standards.
- All aspects of a building should be incorporated into the code, not just envelope requirements. Provide options for analysis of energy use at the whole building level.
- There should be recognition of climate differences.
- Enforcement Policies and Practises
- Compliance must be mandatory, not voluntary.
- Thorough enforcement is essential. This should include both plan checking and site inspections of at least some buildings, if not all. Inspectors need to be thoroughly trained in the code and how to inspect for compliance.
- There should be meaningful penalties for non-compliance.
- Track compliance rates to determine where the code can be improved and any gaps in education and understanding.
- Implementation Support
- Provide energy code training and certification for both building designers and code officials.
- Support voluntary high performance incentive programs. These programs are important for moving the market forward to support future code changes.
- Use building energy certification/labelling to give energy use a higher profile with the public.

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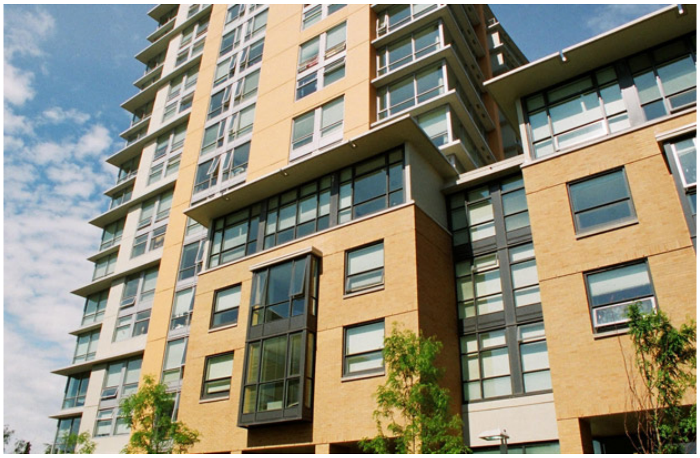




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