Energy and Climate Change at the University of British Columbia: Background Report

Prepared for UBC Energy Round Table and APSC 498H
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List of Abbreviations

CBSM- community based social marketing
CH_4 - methane
CO_2 – carbon dioxide
CO_2-e – carbon dioxide equivalent emissions
GHG – greenhouse gas, such as carbon dioxide, methane and nitrous oxide
GJ – gigajoule, equals 1 million joules
GPC – green power certificate
GSHP – ground source heat pumps
HVAC – heating, ventilation and air conditioning
IPCC – intergovernmental panel on climate change
J – joule, measure of energy
kW – kilowatt, equal to 1000 watts or 1000 joules of energy per second
kWh – kilowatt hour, equal to 1000 watts used for one hour, or 3 600 000 J
N_20 – nitrous oxide or dinitrogen monoxide
PV – photo voltaic, refers to solar panels that are used to produce electricity directly
REC – renewable energy credits
SNHU – Southern New Hampshire University
UBC-V – University of British Columbia Vancouver Campus
UBC-O – University of British Columbia Okanagan Campus

Executive Summary

This report examines UBC's energy system through a climate change perspective. It is intended to provide background knowledge for an energy round table that will develop policy recommendations for climate mitigation at UBC. An emphasis is placed on energy used as electricity and energy used for heating, whereas energy for transportation is not covered. Conclusions are drawn from reviewing and summarizing academic literature, institutional information and discussions with experts. Areas that may warrant research are identified.

The UBC Sustainability Office has completed a GHG (greenhouse gas) inventory for 2006, which estimates that UBC (Vancouver and Okanagan) campuses emitted roughly 154 500 tonnes of CO2-e. New provincial legislation in BC requires UBC to be carbon neutral by 2010. This means that in addition to reducing its GHG emissions, UBC will have to pay for an amount of GHGs equivalent to its emissions to be sequestered or prevented from entering the atmosphere. A carbon tax has also been introduced in BC. UBC will have to pay millions of dollars in carbon offsetting and carbon tax for its GHG emissions. This increases the economic feasibility of projects that reduce emission.

Natural gas consumption is the largest single contribution to UBC's GHG emissions, this is mainly used for heating campus buildings via a central heating system. UBC uses more electrical energy then any other energy form. The UBC GHG inventory estimates that electricity use accounts for 14% of UBC GHG emissions. Although BC's energy grid is reputed to be "clean", it does have negative impacts. Hydroelectric power produces GHG when organic material decays in flooded areas and this was not considered for UBC's GHG inventory. Therefore, reducing energy use could result in higher GHG reduction than what would be estimated. Purchasing Green Power Certificates for all of UBC's power demands would almost eliminate UBC's electricity related climate footprint.

A number of initiatives have been taken to reduce UBC's energy consumption. These include:

- Establishing sustainability coordinators who promote sustainable behaviour among departments using community based social marketing techniques
- Energy efficient upgrades at UBC-V including ECOTrek and Electrek
- Purchasing certified green power credits (GPCs) from BC Hydro
- Production of biodiesel fuel from waste cooking oil on campus to run campus equipment

These projects have already significantly reduced UBC's GHG emissions. UBC estimates that ECOTrek reduces annual emissions by 8 000 tonnes, and that the sustainability coordinator program reduces electricity costs by $75 000 per year. Expanding upon these successes will be an effective way to further reduce UBC's climate footprint. Savings from energy conservation is used to fund the UBC Sustainability Office.

Replacing energy infrastructure at UBC with cleaner alternatives will help reduce UBC's climate footprint. Heat pumps are being used to provide low emission heating at UBC-O, but could also be utilized on other UBC properties. Potential heat sources include water (including ocean), ground, air, and waste heat such as wastewater, ventilation, and sewage. There may be potential for biogas and biomass to be utilized on both campuses but it is limited in scope by the availability of waste material. UBC-O may have access to biomass as an energy source. Harnessing solar energy on all UBC properties is worth further investigation, especially solar hot water heating.

Recommendations for UBC to move beyond climate neutral[1] with respect to energy include:

- produce renewable heat and electricity on campus and at research facilities
- purchase green power certificates for all of UBC's electricity consumption
- expand upon community based social marketing programs such as the Sustainability Coordinator program and efficiency retrofits such as ECOTrek
- integrate waste sources into energy systems.

The UBC energy round table will gather input, ideas and knowledge from the campus community, evaluate these ideas and decide on the best actions and synthesize this knowledge into policy recommendations.

Introduction

This report is intended to provide background information for an energy round table that will make policy recommendations for UBC's Climate Action Framework. The Climate Action Framework will be a strategy document outlining how the university will move beyond climate neutral[1], achieving a net greenhouse gas (GHG) output of zero and becoming a leader in producing climate change solutions.

This report is also written for a SEEDS (Social, Economic and Environmental Development Studies) course, which satisfies the impact of technology on society credit for engineering students. This is an appropriate topic for such a course because climate change is a global issue that has arisen from the interaction between society, technology and the environment. It could be argued that technology is a product of society and that technology also shapes society. For example, society has created the automobile, which has resulted in a "car" culture. The use of technologies such as the combustion engine release greenhouse gases into the atmosphere that cause global warming. Furthermore, societies' demand for technology to make everyday life easier has resulted in an unsustainable rate of resource consumption, thus producing more greenhouse gas emissions. Technology is used to avoid labour rather than energy use (Wackernagel and Rees, 1996). Human impact on the environment is increasing even more rapidly due to technology than due to population growth (Wackernagel and Rees, 1996).

Perhaps technology plays a role in the dichotomy between humans and the environment, and the view of nature as a resource belonging to humans. Many would argue that this view of nature has resulted in the current sustainability issue that we face (Robinson, 2003). Human Ecologist, Keith Morrison suggests that many people in society are not fulfilling the need to find a sense of purpose and meaning, and instead they are compensating by over consuming (K. Morrison, Lincoln University New Zealand, Personal Communication, April 22, 2008).

Also, it could be argued that climate change is a result of this unsustainable lifestyle, as over consumption of fossil fuels is resulting in excessive GHG emissions. As explained by Dr. R. Pachauri, chairperson for the Intergovernmental Panel on Climate Change (IPCC) "…we are endangering all species on earth, we are endangering the future of the human race" (as cited in Nooryani and Chipman, 2007, ¶ 9). The urgency of the climate change issue is made clear in the fourth assessment report by the Intergovernmental Panel on Climate Change (IPCC). This report states that "warming of the climate system is unequivocal…" (IPCC Working Group I, 2007, p.5) and that

[1] Beyond climate neutral is a phrase used by the UBC Climate Action Partnership to explain their vision of UBC having a net effect on the climate that helps to reduce climate change.

“most of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic greenhouse gas concentrations” (IPCC Working Group I, 2007, p.10), where “very likely” is used to refer to a 90% probability of occurrence. With climate models, the IPCC shows that even if all greenhouse gas (GHG) concentrations were to be fixed at year 2000 levels (zero new emissions) the average global temperature would rise 0.6°C by the end of the century (IPCC Working Group I, 2007, p.7).

It is projected that climate change will have many negative effects on societies and people. This includes negative heath effects on millions of people, especially those with low capacity to adapt to change, such as people with little or no income or limited access to resources. These effects include increased malnutrition, death, disease, and injury from extreme weather (IPCC Working Group II, 2007).

The university is a great environment to reshape societies to become sustainable[2] and thus a key institution to take leadership on climate change mitigation. Future leaders, research and new ideas come out of institutions such as UBC.

Energy use is the largest source of greenhouse gas emissions at UBC (UBC Sustainability Office, 2008). Therefore, reducing energy consumption and energy emissions has huge potential for reducing the institution’s impact on the climate and planet. This report focuses on energy used for heating buildings and water, and all electricity consumption on the campus. Energy for transportation will not be discussed in depth in this report as there is a separate UBC round table on transportation.

[2] This was the main theme of University of Victoria Environmental Law and Policy Professor Michael McGonigle’s speech at the 2007 UBC Student Environment Centre’s annual conference: Seeds for Change. This was also the theme for the book, Planet U by McGonigle and Starke (M. McGonigle, Personal Communication, January 19th, 2007).

1.0 Sustainability at UBC

UBC is one of the leading universities with respect to sustainability. This section explores what this means and how it connects to climate change.

1.1 What is Sustainability?

There are many definitions of sustainability. Generally, the Brundtland Commission[3] is credited with having popularized the term sustainable development. It is described as development that "…meets the needs of the present without compromising the ability of future generations to meet their own needs" (as cited, "University of Calgary, n.d., para. 1). This definition represents an anthropocentric viewpoint. A more modern definition that encompasses a broader range of concerns is given by Jonathan Porritt from the UK Sustainability Commission: "sustainable development is a process which enables all people to realize their potential and improve their quality of life in ways which protect and enhance the Earth's life-support systems" (as cited, University of Calgary, n.d., para. 1). Sustainability is increasingly being used to refer to the broader range of concerns over the issue of our planet's fate including anthropocentric and non-anthropocentric concerns (Robinson, 2003). This is similar to Porritt's definition of sustainable development.

The sustainability of the planet is currently a major concern because human demands and impacts outweigh what the planet is capable of supplying and absorbing over the long term. Rees (2006), with the ecological footprint concept, shows that human demands on the planet exceed the sustainable limit by about 20%. Ecological footprint analysis calculates the amount of ecologically productive land that is used to meet human demands. If everyone lived like the average North American it would take an additional four planet earths to sustain human populations (Rees, 2006). Another source of concern is that humans are causing the first mass extinction in the Earth's history that is caused by another species (Hawken, 1993, p.26).

Climate change is arguably the most pressing environmental issue today. However, we must be aware that it is part of a larger sustainability problem: solutions to the climate change problem must also be sustainable and not just have the same impact via a different mechanism. For example, switching to electric cars in a region where the electricity is generated using fossil fuels (or another source that results in high GHG emissions) would just change the location of emissions and do nothing to

[3] the World Commission on Environment and Development produced a report called "Our Common Future" in 1987, this is referred to as the Brundtland Commission (Wackernagel and Rees, 1996)

reduce emissions[4] (Evans, 2007). Another example is using a power source that may have other sustainability consequences such as nuclear power with its waste problem. It must be recognized that there is an environmental and/or social impact associated with the use of almost any energy source.[5] Solutions that can be applied over the long term are needed, in addition to short term measures that will be stepping stones to achieving long term sustainability.

1.2 UBC's Sustainability Policy[6] and the Climate Action Framework

As recognized in UBC's Sustainable Development Policy: human demands on the planet are so great that "they threaten the future well-being of all living species" (Halifax Declaration[7], cited in UBC, 2005b, section 1.1). The objectives of UBC's sustainable development policy include developing an environmentally responsible campus and being a leader in sustainable development through teaching, research and operations. This is a responsibility that UBC has as an education and research institution (UBC, 2005b). UBC, the institution, has committed itself to "demonstrating the means to a sustainable community on its campuses" (UBC, 2005b, section 1.3). This includes all of UBC's operations. UBC's sustainability goal is also reflected in the university's mission and vision statement (President's Office, 2006).

The Sustainable Development Policy states that the university seeks to become a "centre for teaching and learning" about sustainability. Through this policy, UBC is committed to conserving resources, minimizing energy intensity and involving sustainable development concepts in decision making (UBC, 2005b). The policy also specifies that targets, timelines and priorities for accomplishing sustainability objectives are to be developed with input from faculty, staff and students. This has lead to the creation of a sustainability strategy for the University in 2006.

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[4] This scenario could result in an increase in GHG emissions due to energy loss from conversion and transmission (see section 2.1).

[5] This of course depends on how the source is used, for example one could argue that passive solar design has no negative environmental or social impact; whereas, photovoltaic solar power has a social and environmental impact because of the space required, and the energy and mining that is necessary for solar panel production.

[6] UBC's sustainable development policy leaves the definition of sustainable development open to interpretation, although there is a focus on the social, economic and environmental aspects of sustainability. Leaving the definition of sustainability open allows a definition to emerge from attempts to implement it rather than serving to restrict its development (Robinson, 2003).

[7] The role of universities in advancing sustainability was recognized in the Halifax and Tallories declarations, which UBC is a party to.

In addition to UBC's commitment to sustainability, escalating concerns over climate change have led to the recent development of the community round table process which will guide the development of UBC's Climate Action Framework; an integrated climate management strategy for the university.

2.0 UBC's Climate Footprint[8]

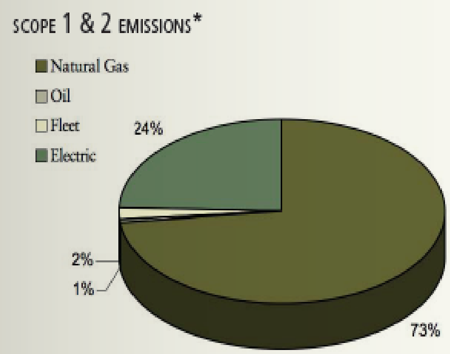
A comprehensive GHG inventory has been completed by the UBC Sustainability Office for 2006 (see Figure 1).

Figure 3: GHG Emissions by Scope, 2006 (measured in tonnes CO_2 equivalent[9])

2006 GHG EMISSIONS INVENTORY

Scope	Source	Total Emissions
Scope 1	Natural gas	66,000
	Oil	500
	Fleet	2,000
Scope 2	Electricity	22,000
Scope 3	Buildings**	12,000
	Air travel	15,000
	Commuting	26,000
	Waste	1,000
	Paper	1,000
	Fertilizer	100

* Based on emissions factors that are subject to change
** Embodied energy in building construction



* Under the Provincial carbon-neutral mandate, UBC will be responsible for offsetting Scope 1 and 2 emissions + emissions associated with paper consumption.

(UBC Sustainability Office, 2008)

These emissions were calculated using the world resources institution Corporate Accounting and Reporting Framework for GHG emissions. They have been broken down into scope as follows:

Scope 1: Direct GHG Emissions

[8] The term "climate footprint" is used in this report climate footprint is defined as the ecological footprint associated with GHG emissions.
[9] Carbon dioxide equivalent emissions are calculated by assigning global warming potential factors to greenhouse gases as follows: $CO_2 = 1$, $CH_4 = 21$, $NO_2 = 310$ (L. Ferris, UBC Sustainability Office, personal communication, April, 11 2008), for example 1 tonne of CH4 is considered equivalent to 21 tonnes of CO_2 in potential contribution to climate change

- Owned or controlled by the institution

Examples: Steam plant, fleet vehicles, refrigerants

Scope 2: Electricity – Indirect GHG Emissions

- Purchased electricity consumed by the institution.

Scope 3: Other Indirect GHG Emissions

- Consequence of the activities of the institution, but occur from sources not owned or controlled by the institution.

Examples: Faculty air travel, commuting

According to the UBC Sustainability Office (2008a), Scope 1 and 2 emissions and emissions from paper consumption will be required to be offset under the Provincial carbon-neutral mandate. Scope 1 and 2 emissions total 99 486 tonnes CO_2 equivalent (CO_2-e) (UBC Sustainability Office, 2008a) and emissions associated with paper use total 1000 tonnes CO_2-e (see Figure 1), therefore UBC would be required to offset about 100 500 tonnes CO_2-e if UBC's GHG emissions stay at 2006 levels. UBC's Scope 3 emissions total 55 100 tonnes CO_2-e (UBC Sustainability Office, 2008a), therefore the UBC's total GHG emissions is approximately 154 500 tonnes CO_2-e. UBC's energy use (Scope 1 and Scope 2) accounts for approximately 64% of UBC's total emissions.

2.1 Introduction to Energy

It can be argued that energy is generated from three main sources: the burning of fossil fuel, nuclear reactions, and various renewable sources such as solar energy, and wind energy (Evans, 2007). The energy generated by these sources is carried by steam, electricity, hydrogen and other carriers, to where it can perform useful work. The energy conversion chain (Figure 2) is important to consider when comparing efficiencies of different technologies (Evans, 2007).

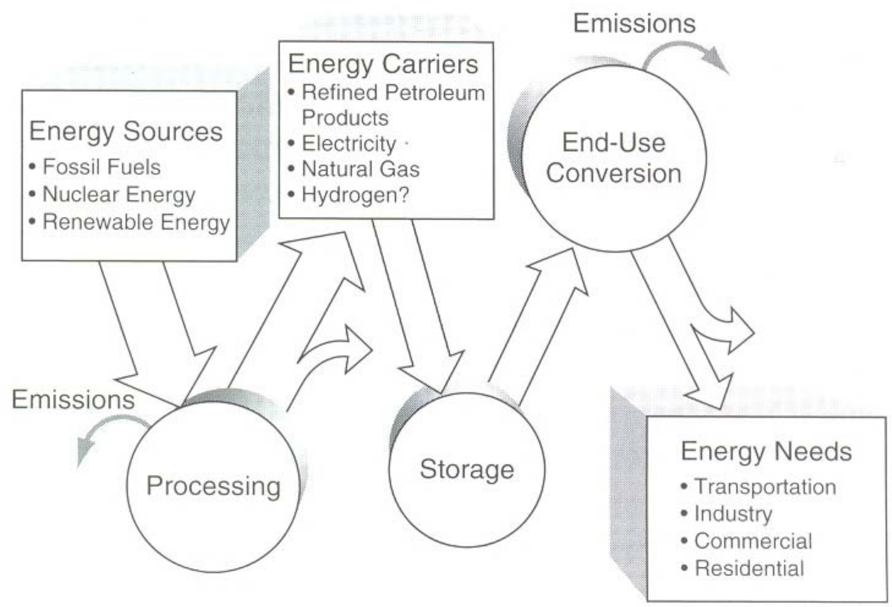


Figure 2 – Energy Conversion Chain (Evans, 2007)

When considering energy sources, it is important to consider the losses that occur each time energy is converted and transmitted. To accurately calculate the emissions of an energy conversion device such as a vehicle or wind turbine, we need to account for the emissions that occur during the acquisition of the energy source, refinement and end use. The efficiency over the entire energy conversion chain for a device is called the “well to wheels” efficiency and is effectively demonstrated in a Sankey diagram below (Evans, 2007).

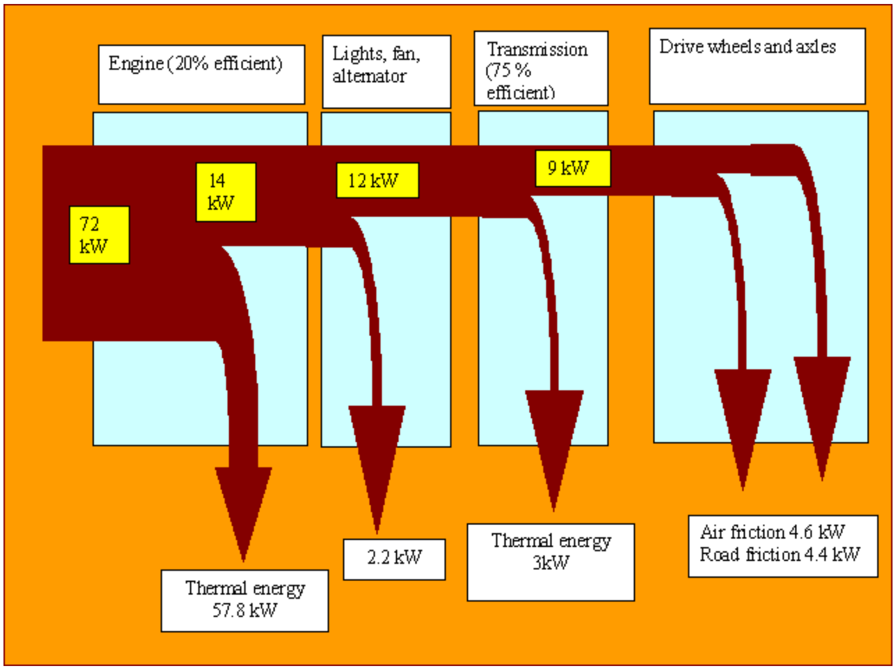


Figure 3 – Sankey Diagram for the Efficiency of a Vehicle (Antoine Education, n.d.)

Energy density[10] is also important in the consideration of energy sources. This is a major challenge with utilizing most renewable energy sources. For example, many wind turbines, or a large hydro electric dam would be required to produce the same amount of energy that could be produced from a relatively small amount of fossil fuel. Scaling up of renewable energy extraction to meet large demands, such as building a large hydro power station, results in other sustainability consequences (Fearnside, 2004; Rosenberg, Berkes, Bodaly et al., 1997).

Although certain energy sources may have a smaller impact than others, no energy truly comes free of emissions or impact. Therefore, there is no single energy solution that can solve the climate change problem. An integrated approach is needed (Evans, 2007). As stated by the IPCC "there is no single economic technical solution to reduce GHG emissions from the energy sector" (IPCC Working Group III, 2007, p. 254). The largest sustainable reductions of GHGs must come from reducing demand[11]. Using appropriate technology will become more economical with the recently introduced provincial climate change legislation (see section 5.0).

[10] Energy density can be defined as energy per unit area, or energy per unit volume, for example the maximum energy density of solar energy is about 1 kW/m^2 on the earth's surface (Evans, 2007).
[11] Robinson (2004) claims that sustainability is a human behavior issue and Evans (2007) states that reducing demand is one of humankind's most important options.

2.1.1 BC's Electricity Supply

BC Hydro claims that 90% of BC's electricity comes from hydro power, almost all of this comes from large dams (BC Hydro, 2007). 7.5% of BC Hydro's power comes from the Burrard Thermal Plant which relies on natural gas and the remaining 2.5% is purchased from unspecified sources (BC Hydro, 2007).

Although hydro electric power is, by most people, considered "green" or "clean" energy, there are significant impacts of large scale dams. Flooding causes GHG emissions, and directly impacts ecosystems and people (Fearnside, 2004; Rosenberg et al., 1997). The breakdown of organic material in the areas flooded from damming produces CO_2 and CH_4. In some cases, dams may have a similar GHG output to a coal fired power plant (Rosenberg et al., 1997). While it is true that the GHG output of a flooded area will decrease with time, the steady state level of output is higher than typical natural land cover such as peat land or forest (Rosenberg et al., 1997). According to Rosenberg et al. (1997) there has been little research done on the GHG emissions and impacts of large scale hydro projects and Fearnside (2004) suggests that further research is required to properly understand GHG emissions from hydro power.

Canada's Greenhouse Gas Inventory in 2004 claims that BC's electricity generation results in emissions of 24 tonnes CO_2 equivalent per gigawatt hour (Hanova, Dowlatabadi and Mueller, 2007). However, when taking into account the electricity imported from other provinces such as Alberta (where electricity generated has a higher GHG intensity[12]) every Gigawatt hour of electricity used in BC has 84 tonnes of CO_2 equivalent emissions. Both of these figures for Greenhouse Gas intensities do not take into account the emissions from the flooded land from hydro dams. Therefore, it could be concluded that the (Hanova et al., 2007) estimate of 84t/gWh is too low. This figure is used in UBC's 2006 greenhouse gas baseline (L. Ferris, personal communication, March 6 2008).

Also social impacts should be considered: loss of recreational areas, displacement of human settlements and human support systems such as fishing, hunting and food collection areas especially for First Nations who might be dependent on such areas for their livelihoods. The flooding from large scale hydro has also caused bioaccumulation of methylmercury in fish which also impacts First Nations groups who utilize this food source (Rosenberg et al., 1997).

[12] GHG intensity is defined as the amount of green house gas emissions per amount of electricity (Hanova, et al., 2007)

2.2 Energy Use at UBC

As explained earlier, heating and electricity use account for roughly 63% of UBC's emissions of GHG (UBC GHG Baseline, 2008). UBC energy consumption can be divided into two major categories: natural gas and electricity.

2.2.1 Electricity

In the 2006 calendar year, UBC (Vancouver and Okanagan) had an indirect GHG output of about 22 365 tonnes of CO_2 equivalent from electricity use (L. Ferris, UBC Sustainability Office, personal communication, March 6 2008). This accounts for about 14% of UBC's total GHG output according to UBC's GHG inventory for 2006 (UBC Sustainability Office, 2008a).

For the 2006 fiscal year, UBC used approximately 130 million kWh (or 468 000 GJ) of electricity (O. Henderson, personal communication, November 29, 2007). UBC uses far more electrical energy compared to energy from natural gas.

It is important to consider the emissions associated with this energy use, although it may be difficult to calculate. Reducing UBC's electricity consumption could help prevent future energy developments and the associated impacts on climate, society and ecosystems. As explained in section 2.1.1, UBC's estimated GHG emissions due to electricity use is too low because it does not take into account emissions from decaying organic matter in flooded areas, thus reducing electricity use could do more to reduce GHG emissions than expected.

2.2.2 Natural Gas

Most of UBC's natural gas is for heating via the steam plant which is a district heating system that produces steam from large natural gas boilers, and distributes it through underground steam pipes. However, additional natural gas in consumed through cooking in cafeterias and restaurants, as well as in labs and workshops at UBC.

For the 2006 calendar year, UBC's GHG output from natural gas consumption was about 66 000 tonnes of CO_2 equivalent for the Vancouver and Okanagan campuses (UBC Sustainability Office, 2008). This accounts for 43% of UBC's climate footprint.

According to Orion Henderson, UBC Energy and Climate Change Manager, UBC-V purchased 62 000 gJ of natural gas for its core buildings during the 2006 fiscal year (personal communication, November 29, 2007).

3.0 UBC's Reduction Initiatives

UBC has taken a number of steps to reduce greenhouse gas emissions, the main initiatives are outlined below to provide ideas for further development.

3.1 ECOTrek and Electrek

ECOTrek is the largest campus retrofitting project in Canada and has spanned about four years, starting in 2002. UBC estimates that ECOTrek has reduced annual emissions by 8 000 tonnes (UBC Sustainability Office, 2008a). The total cost of the ECOTrek project was $38 million. It was funded by UBC Treasury and also received a BC Hydro incentive of $4 million. The energy reductions from this project are guaranteed by Energy Performance Contracting, a system where the contractor is paid with the savings generated from the project. This project is expected to save UBC $2.6 million annually, including avoided maintenance (UBC, 2006).

The work completed includes installing energy-efficient lighting, upgrading the steam plant and the steam distribution system, as well as upgrades to the ventilation systems in more than 100 buildings (BC Hydro, 2006). Computer automation systems to control heating and ventilation were installed in many buildings (BC Hydro, 2006). Utility meters (electricity, steam and water) were installed in most academic buildings along with low-water-use fixtures. Also, upgrades were made to street and path lighting (BC Hydro, 2006).

MCW Contracting completed a feasibility study for the Vancouver campus, in December 2002. In addition to the work completed, the study also involved consulting with maintenance staff to identify building energy losses, a review of campus lighting (only some facilities covered), sensors for lighting control, and alternative energy generation and vending machines (MCW, 2002).

MCW proposed many upgrades, however not all of these have been carried out. For example, their recommendation to cover the Empire pool has not yet been implemented. This leaves room for the successes of ECOTrek to be expanded upon. Other MCW recommendations that might be considered for future projects include converting air conditioning systems to "flow volume based on temp. requirements" to reduce fan power, installing automated controls for buildings including shutdown periods during hours of non use (MCW, 2002). Also, controls for vending machines to shut down when not in use (by sensor), training maintenance staff, converting lights to compact fluorescents and retrofitting street lights are areas that might have room for expansion (MCW, 2002).

At the time of this report a technical project report on ECOTrek has not been completed and there is very little information available[13] on what exactly has been done. It is recommend that the MCW feasibility study, recommendations and work completed be reviewed before proceeding with further energy retrofits.

Another major energy retrofit project carried out by UBC was Electrek. This is a lighting fixture retrofitting project carried out in 2002 that cut UBC's electricity consumption by 11% (UBC, 2002). Light fixtures in fifty campus buildings were replaced with more efficient lighting (UBC 2002). There is still room for UBC to expand this success. A potential policy could be to ban the purchase of incandescent lighting.

With the growing momentum for climate change mitigation at UBC and the new legal and financial incentives for mitigation, it is likely that the successes of ECOTrek and Electrek can be expanded upon. Reviewing details of what was carried out and what was considered for both projects could be a good starting point towards future energy efficiency upgrade projects at UBC.

3.2 Biodiesel

Biodiesel is a fuel that is similar to diesel but has been derived from crops such as canola or rape seed. Even though biodiesel burns cleaner (Ellis, 2005) and is, by some, considered a "carbon neutral" fuel source, it is not necessarily sustainable or carbon neutral. This depends on the source of biodiesel. Clearing rainforest to plant biodiesel crops would release huge amounts of carbon and cause other environmental and social problems. Biofuel production is currently driving up food prices and could result in food shortages (Runge and Senauer, 2007). "Filling the 25-gallon [95 L) tank of an SUV with pure ethanol requires over 450 pounds [230 kg] of corn -- which contains enough calories to feed one person for a year" (Runge and Senauer, 2007, ¶6). Understanding the source and implications of biodiesel is essential for choosing alternative energy sources.

Biodiesel can also be made from waste cooking oil, which is what has been done in the past at UBC through the UBC Biodiesel Project. UBC used this biodiesel in their fleet, including landscaping equipment (Ellis, 2005). This is a very effective use of a waste material. Positive sociological impacts of such a biodiesel project include a community connection to energy resources, re-establishing a connection to cyclic processes of ecosystems by recycling a waste stream, increased energy security and raising awareness about renewable energy (Ellis, 2005).

[13] Neither a feasibility study nor a technical project report was available at the time of this report. Sharing detailed project information on projects such as ECOTrek may be useful for other universities to reduce their GHG emissions, this could potentially be a "beyond climate neutral" action for UBC.

Unfortunately, the UBC Biodiesel Project is no longer producing biodiesel (N. Ellis, personal communication, November 2007). Producing biodiesel from waste cooking oil would help reduce UBC's carbon footprint by reducing diesel consumption and waste on campus. Most of this oil is likely hauled to the landfill using large trucks, which emit CO_2, where it then decomposes to produce methane and more CO_2.

3.3 Sustainability Coordinators and Ambassadors

The Sustainability Coordinator program that is run by the sustainability office is a means to promote sustainable behaviour such as reduced energy consumption. Sustainability Coordinators "inspire colleagues to make positive changes in energy use, waste generation and transportation. They provide information about the environmental impacts of daily activities" (UBC Sustainability Office, 2008c). Sustainability coordinators (SCs) volunteer two to four hours per month, during work time, and are supported by their supervisors. The Sustainability Ambassador program is similar to the SC program, but for students who live in residence on campus (UBC Sustainability Office, 2008c). UBC claims that the Sustainability Coordinator Program saves $75 000 in annual electricity costs (UBC Sustainability Office, 2008a).

These programs apply community based social marketing techniques to promote behavioral changes. Community based social marketing (CBSM) is based on identifying barriers to and benefits of sustainable behavior then addressing these key elements holistically using psychological and social research techniques (McKenzie-Mohr and Smith, 1999). CBSM is a crucial tool for developing effective programs to reduce energy consumption which is one of the most important methods of tackling climate change.

4.0 UBC's Reduction Opportunities

UBC has great potential for reducing GHG emissions, with leading research being done on climate change mitigation and the progressive university atmosphere which has in the past driven social change.

4.1 Energy Conservation

It could be argued that one of the largest factors affecting climate change is over-consumption; many devices and appliances are left on when not in use. Only using energy for necessary needs could significantly reduce the university's climate footprint. Examples of this include opening the blinds in a lecture theatre to allow enough light in for students to take notes rather than running half of the lights with the blinds closed, or wearing a sweater in the winter instead of heating a building to a summer like climate. Many simple actions like switching off lights and other electrical devices when not in use add up to significant savings. Education is essential for individual energy reduction, but is not the only factor involved in changing behaviour.

In addition to voluntary measures, UBC will likely have to utilize other incentives for energy reductions at the individual level. One idea is that each department at UBC could pay for their energy consumption from their yearly budget, thus having a financial incentive for reduction.

Firm energy reduction targets must be established in order to make significant progress towards reducing energy consumption. GHG offsetting[14] will likely play a significant role in achieving climate neutrality; however, innovative solutions to reduction must also be focused on in order to produce changes that can be applied outside the UBC community. A good assessment process will be crucial for moving the institution beyond climate neutral.

4.2 Green Energy Certificates

A green energy certificate or renewable energy credit is a mechanism that allows customers, usually businesses, to pay for an amount of green, renewable or emissions free energy that is equal to the amount of electricity that the customer uses.

Other universities are purchasing certified green energy, for example the University of Canterbury in New Zealand, a partner university with UBC, purchases all of their electricity from a source that is certified as carbon neutral (University of Canterbury, n.d.).

4.2.1 Background on Green Energy Certificates

Throughout the world there are variations of this concept in place. In the US, a business called Green-e sells green power credits. Green-e suggests that these green power credits should go towards expanding renewable energy use, not just fill a pre set government quota (Green-e, 2007). Businesses that purchase “green electricity” from Green-e use their purchase as a promotional tool, by putting a Green-e logo on

[14] Offsetting emissions to become carbon neutral or climate neutral involves doing an activity (often paying for) that sequesters GHG emissions or prevents emissions elsewhere from entering the atmosphere. Companies such as Offsetters.ca, sell “carbon credits” that fund projects such as ground sourced heat pumps to reduce emissions

their product. These “Green Power Products” also get consumers to learn about renewable energy and environmental impact (Green-e, 2007).

One example of renewable energy credit (REC) purchasing is Southern New Hampshire University’s (SNHU) policy to purchase enough RECs to account for their total energy consumption for the next 15 years. They have set up a renewable energy hedge fund, which fixes the rate for the RECs which will fund future renewable energy projects, while allowing the university to keep its existing energy supplier (SNHU, 2007).

4.2.2 BC Hydro’s Green Power Certificates

A Green Power Certificate (GPC) is a product that BC Hydro sells that represents one megawatt hour of green electricity that has been certified by EcoLogo^{M}. For each GPC BC Hydro ensures that “EcoLogo^{M} certified electricity enters the BC Hydro grid generated from new (post-2001) environmentally low-impact, socially responsible qualified green projects” (Personal Communication, BC Customer Services Representative, November 2007). This purchased electricity likely does not go directly to the consumer but enters the grid. GPCs create market demand for sustainable electricity by allowing individuals or companies to subsidies renewable energy projects. This system is independently audited and provides a mechanism for individuals or organizations to subsidize renewable energy and create demand (BC Hydro, 2005). As demand increases BC Hydro purchases more green power.

UBC is already purchasing some Green Power Certificates for its green buildings, but there is potential for this to be expanded.

4.3 Energy Efficiency

Even though efficiency can reduce energy use significantly, efficiency gains do not always mean reduced ecological footprint (Wackernagel and Rees, 1996) or reduced climate footprint. We have to be careful that energy efficiency measures are not just diverting our emissions to other sources. For example if money is saved from using a more efficient technology and this money is then spent on consumption in another area, the net footprint could be even larger (Wackernagel and Rees, 1996). UBC funds the sustainability office with money saved from sustainability projects (UBC Sustainability Office, 2008b), this approach addresses this issue raised by Wackernagel and Rees.

Many others (McDonough and Braungart, 1998; Robinson, 2004; Hawken, 1994) also suggest that efficiency is not enough to solve our problems. For example, if everyone consumes a certain resource more efficiently and the number of people consuming this resource is increasing, the resource is still being depleted. Sustainability is not just about being efficient. The concept of eco-effectiveness says that resources should be used more effectively so that waste streams are utilized and closed loops systems are developed (McDonough and Braungart, 1998). An example of this is the cogeneration plant at the Vancouver Landfill (see section 4.4.4).

Efficiency is a very important tool for GHG reduction, but not an answer on its own. The climate change problem must be viewed holistically. Using efficiency gains with other tools such as an intensive community based social marketing campaign to reduce consumption will ensure that overall emissions are reduced rather than just emitted by another source. Emissions associated with the manufacture and transport of new equipment should also be considered when looking at efficiency retrofits.

4.4 Low Emission Energy Development

Another way of reducing UBC's carbon footprint is by utilizing cleaner technology for heat and electricity. This section examines a number of technologies that UBC could consider pursuing to reduce GHG emissions.

4.4.1 Heat Pumps

Heat pumps are a proven energy efficient technology used for heating buildings and can be utilized to preheat hot water. Heat pumps can be used to extract heat energy from the ground (ground sourced heat pump, GSHP), water or air. They operate in a similar manner to a refrigerator: a compressor converts a refrigerant fluid from a liquid to a gas and back to a liquid and so on, thus increasing and decreasing the temperature of the fluid. This changes the potential for heat to flow into the fluid from a heat source or out of the fluid into a building. Heat pumps can also be operated in reverse to provide cooling. For GSHPs, the cooling operation in the summer will recharge the heat source (ground or water) so the energy can be used in the winter (Community Energy Association [CEA], 2007). Most heat pumps operate on electricity. They are highly effective with a coefficient of performance from 2 to 5, which means that they release 2 to 5 more energy in the form of heat energy then the electrical energy that they consume (CEA, 2007). Heat pumps have a high capital cost, but are becoming more popular as energy prices increase. They will pay for themselves in a number of years with the energy they save depending on the medium used. Air-source heat pumps work well in climates such as that of Vancouver where a typical payback period would be three to six years (CEA, 2007).

Heat pumps can also be set up to extract heat from lakes, ponds or the ocean (CEA, 2007). Flowing water adds to the effectiveness by increasing the heat transfer.

Extracting heat from the ocean may be worth investigation at UBC's Bamfield Marine Station; however this has not been explored in this paper.

For residential buildings a GSHP typically cost $10 – 25 000; however, this equates to an annual savings of $400 – 700 compared to a gas furnace (CEA, 2007). This means a typical payback period would be about 20 years (CEA, 2007). However, the economics of heat pumps varies significantly for each individual case. The capital cost can be reduced by installing multiple individual sets of loops at a time, which has been done for the Sun Rivers development near Kamloops (CEA, 2007).

For small office building GSHPs cost about $80 -100 000, with a typical payback of 10 -15 years. Roof top heating, ventilation and air conditioning (HVAC) systems can be replaced with air source heat pumps, this can be quite feasible if it is time to upgrade (CEA, 2007).

For new construction at UBC, GSHP should be considered, especially for buildings with heating and cooling requirements. Buildings with water-loop heating systems can be retrofitted for GSHP, many buildings at UBC have water-loop heating systems. According to two UBC professors, "a geothermal heating system for a large building could reduce costs by 75 per cent" (Meech and Ghomshei, 2008, ¶ 1). Ground source heat pumps have a 25-year life cycle and are virtually maintenance free, while ground loop piping should last more than 50 years (Hanova et al., 2007).

UBC Okanagan is planning to heat all new buildings with a heat pump system that will tap into a large underground aquifer. This will save $100 000 per year in energy costs (Mortenson, 2005). Retrofitting old buildings will also be looked into. The heat pump system at UBC O will replace the old gas boiler system. This plan will avoid 1 900 tonnes of carbon dioxide emissions per year (Mortenson, 2005).

4.4.2 Heat Recovery Opportunities

Exploiting opportunities to recover heat from waste air, water and sewage can be very effective for reducing GHG emissions and saving money.

Exhaust air heat recovery uses a heat exchanger to warm incoming air with warm air that is being ejected from a building (such as contaminated air from a laboratory, workshop, swimming pool, or washroom). Typical heat recovery ventilators cost $500 - $1000 for residential size and can be economic for buildings with a central exhaust fan (CEA, 2007).

Wastewater heat recovery opportunities also exist at UBC (H. Dowlatabadi, personal communication, November 2007). Heat pumps can be used to extract heat from grey water and sewage. This would be particularly effective for hospitals, which have a large quantity of warm waste water (CEA, 2007). For sewer systems, a heat pump can be used to extract the heat picked up by a heat exchanger in contact with the sewer. This could simply be a pipe wrapped around the sewer pipe. The heat recovered could then be used to heat nearby buildings or to preheat hot water.

Ice rinks are another building of importance for waste heat recovery. The large amount of heat emitted can be captured and used for water and space heating. Ground "fields" can store the heat extracted by the refrigeration process so that it can later be used for heating. One example of this is the Cariboo South Recreation Centre in 100 Mile House, where the heat emitted from cooling the ice is used to heat the stands and other areas of the building (CEA, 2007). Huge savings can be realized by building an integrated system such as 100 Mile's, where the payback period is about two and a half years (CEA, 2007).

4.4.3 Cogeneration

Cogeneration refers to the production of heat and electricity at the same time. At UBC this would mean converting the steam plant into a power plant and using the steam produced as a by product for heating. This was done at the University of Calgary, with an increased natural gas consumption of about 25% (University of Calgary, 2007). In Alberta, where fossil fuels are the main source of electric power, cogeneration results in a reduction of GHG emissions by using natural gas more intensively (University of Calgary, 2007).

The benefit of cogeneration is that heat is a major by product of electricity generation (for a steam power plant) and more energy can be captured from a fuel source if this heat is used.

This idea has been proposed at UBC in the past; however, pursuing what was proposed would result in an increase in natural gas consumption (UBC 2005). Increasing UBC's natural gas consumption to generate electricity (in addition to heat) would likely result in higher GHG emissions even when accounting for the losses in transmitting electricity since most of BC's electricity is not generated from fossil fuels.

Producing electricity on campus from fossil fuels could be a step backwards considering fossil fuel supplies are diminishing, and UBC could purchase certified green electricity to account for all of its electricity use with little climate footprint. As the boilers in the steam plant are more than 37 years old and approaching their time for upgrade or replacement (UBC 2005) it may be appropriate to start investigating alternatives to natural gas based heating at UBC rather than further upgrades to the steam plant.

4.4.4 Biomass and Biogas

Both biomass and biogas have potential for heating, electricity and transportation. Biomass is renewable organic material such as wood waste, animal manure or sewage (CEA, 2007). Biogas is the gas released from the decomposition of biomass. For heating, biomass or biogas can be burned; however, emission controls are often required for particulates (CEA, 2007). Biomass can be converted into biofuels and used for transportation, in a similar manner to natural gas or propane (CEA, 2007). Biomass and biogas projects are most feasible in areas where there is access to waste organic material, for example biomass power plants may be an appropriate option in communities with a sawmill industry (CEA, 2007).

Anaerobic digestion is the decomposition of organic material without oxygen by means of micro-organisms. This is more commonly done with sewage or manure and produces biogas, which is mainly methane and CO_2 (CEA, 2007). This is typically a slow process, often taking 30 days (CEA, 2007). Harmful trace gases should be removed before it is burned (CEA, 2007).

Landfill gas is given off by the decomposition of municipal solid waste and consists of about 50% methane. The Vancouver Landfill has a cogeneration plant that operates on landfill gas, producing electricity which they sell to BC Hydro for green energy credits, and heat which is sold to Can Agro greenhouses (CEA, 2007).

Digester gas results from the break down of sludge at wastewater treatment plants. It is typically used to heat the building it is located in, and the excess is often flared. One example of this is the Prince George Waste Water Treatment Facility (CEA, 2007).

Gasification involves heating biomass, with limited oxygen to produce syngas which is hydrogen and carbon monoxide (CEA, 2007). Syngas can be used for electricity generation or heating[15] and may become an important fuel for fuel cells (CEA, 2007).

There might be potential small scale applications for biomass and biogas at UBC Vancouver and Okanagan campuses. For example, the C.K. Choi building at UBC has a composting toilet system for the whole building that stores waste in tanks in the basement. The gas could be collected and burned for heating. Similar systems could be established for new buildings. Also, it might be worth looking into collecting biogases from UBC's compost.

[15] see Dockside Green development in Victoria www.docksidegreen.com

4.4.6 Solar

Solar energy can be used for either direct electricity generation using photovoltaic (PV) cells or for water or space heating. Will McDowall from the Community Energy Association in Vancouver suggests that PV be looked into at UBC (personal communication, November 2007).

The University of Calgary has a 65 000 kW PV array which provides most of the power for its Child Development Research Centre (University of Calgary, 2008). This project might provide some insight into possibilities for power generation at both UBC campuses. See below for a comparison of sunshine at UBC-V, Kelowna and Calgary.

Location	**Average Sunshine Hours per year**	**% of Daylight Hours with Sunshine**
Vancouver	1838	38.5
Kelowna	1954	40
Calgary	2405	52.5

Table 1 – Sunshine Comparison for Vancouver, Kelowna and Calgary[16]

This data shows that solar electricity generation may not be as feasible at UBC as at the University of Calgary. However, with new financial incentives for GHG reduction in BC, solar may become a feasible mitigation strategy and is worth further investigation.

One important consideration is the emissions from manufacturing and transporting the energy conversion devices such as solar panels. To ensure actual reductions in GHG output this must be considered. It has been found that it generally takes between one and four years for the emissions saved from using a solar panel to “payback” the emissions that result from its manufacture, this is referred to as energy payback (National Renewable Energy Laboratory, 2004).

Solar heating is much more efficient than PV. Solar heating would be applicable to both campuses. There are three common types of solar collectors used for heating. Glazed collectors are the most common in Canada (CEA, 2007). They are insulated on the sides and back, glass (or plastic) on front allows sun in, air is warm around pipes. Unglazed collectors are simple and low cost. They do not have glazing to retain heat. Evacuated tube collectors have liquid is in a glass vacuum tube, very well insulated. They are more expensive but produce very hot water in cold climates. Solar hot water heating can be very cost effective for pools (CEA, 2007).

[16] Data from Environment Canada (2004) for 1971-2000

Bennett (2007) analysed the potential for solar hot water heating in the Chemical and Biological Engineering (CHBE) Building at UBC-V and found that 25% of the annual hot water demands for this building could be met with solar. Part of this hot water load is used for space heating, therefore 25% represents a significant contribution. Bennett did the analysis for glazed solar collectors, therefore it is possible that significantly more of the hot water demand for CHBE building could be met with vacuum tube collectors.

In addition to solar hot water there are other ways to utilize solar energy for heating. Solar air heating is one example. A large dark metal panel with air holes in it for the air intake of a building can save a significant amount of energy by preheating the incoming air. This system typically would have a bypass for summer (CEA, 2007).

Passive solar design is another technique for utilizing the sun's energy to heat buildings. South facing windows with a thermal mass inside building such as stone work or concrete that will absorb heat and release it after the sun goes down can be very cost effective (CEA, 2007).

A guide to approximate costs of solar systems is shown below:

Residential pool system, unglazed collectors	$4,000	7–9 year payback
Residential domestic hot water system, glazed collectors	$5,500	25–35 year payback
Municipal pool	$100,000 – $200,000	8–12 year payback
Solar air, industrial	$120,000 – $150,000	3–5 year payback

Table 2 - Solar Heating Costs (CEA, 2007)

The CEA suggest that it is more cost effective to incorporate solar heating into new buildings. A good example of the economics of solar heating is the Hyde Creek Recreation Centre in Port Coquitlam which uses solar heating and saves about $4 000 per year (CEA 2007). Similar savings could likely be realized at UBC which has several swimming pools.

4.4.7 Wind

It is unlikely that the Vancouver or Okanagan campuses have enough wind for power generation by wind to be feasible. However at UBC's Bamfield marine station wind power may be feasible (D. Steyn, personal communication, November 27, 2007). Wind power requires high and consistent wind speeds; only a small amount of power available from low speed wind. Wind has a low energy density (Evans, 2007) and the amount of power available for a given rotor area increases cubically with wind speed (Piggott, 1997).

4.4.8 Tidal and Wave Energy

Electricity can be generated from waves and currents created by changing tides. Tidal is utilized by either damming a bay and installing a turbine in the dam, or installing a free standing turbine that resembles a wind turbine in an area where there is a high tidal current.

Unfortunately the Vancouver campus does not have either large tidal currents, or consistently high waves. Creating a dam would likely have large social and environmental consequences. Therefore, it is unlikely that tidal or wave projects would be feasible on the Vancouver campus although these options might warrant further investigation at the UBC Bamfield Marine Station.

5.0 UBC's Financial Incentives for Reduction

With the recent introduction of climate legislation in BC, UBC is required to become "carbon neutral" starting in 2010. The Greenhouse Gas Reduction Targets Act (BC Government, 2007) states that all government institutions are to:

- minimize greenhouse gas emissions starting in 2008
- be carbon neutral in business travel for 2009, through offsetting emissions
- be "generally" carbon neutral starting in 2010

BC's GHG emissions are to be 33% below 2007 levels by 2020 and 80% below 2007 levels by 2050.

The BC Government's budget for 2008 has introduced a carbon tax which will be phased in over four years (BC Government, 2008). The carbon tax starts at $10 per tonne in 2008 and increases by $5 per tonne per year until it 2012 when it will be at $30 per tonne (BC Government, 2008). With the 2006 baseline, if UBC does nothing to curb its emissions, by the year 2012, UBC will be required to pay close to $ 3.75 million in offsetting costs and carbon tax (L. Ferris, personal communication, March

6, 2008). This provides a large economic incentive for UBC to begin to reduce its GHG emissions.

6.0 Conclusion

Increasing knowledge and concern about climate change and sustainability demands climate change mitigation. Because climate change is a sustainability issue it should be addressed holistically to avoid simply diverting the source or location of impacts.

Universities have an opportunity to make a significant contribution to climate change mitigation because they produce future leaders and research. UBC has a responsibility to be a leader in climate change mitigation because it is a centre for teaching and learning, this is recognized in UBC's sustainable development policy.

The UBC Sustainability Office has completed a comprehensive GHG inventory for 2006, which shows that UBC (Vancouver and Okanagan) emitted roughly 154 500 tonnes of CO2-e. Under the Provincial carbon-neutral mandate UBC would be required to offset approximately 100 500 tonnes CO2-e, this will cost UBC millions of dollars due to this recent legislation and the introduction of a carbon tax in BC. This makes investing in reducing emissions much more economically feasible than it has previously been.

Energy use accounts for a majority of UBC's emissions. It is necessary to consider the entire energy conversion chain and energy density when evaluating technologies for climate change mitigation. Utilization of any energy source results in environmental and/or social impacts. The largest sustainable reductions of GHG emissions will have to come from reducing demand. Natural gas combustion is the largest single contribution to UBC's GHG emissions at 43%, almost all of this natural gas is used by the steam plant (at UBC-V) for heating campus buildings. UBC uses more electrical energy then any other form of energy. The UBC GHG inventory estimates that electricity use accounts for 14% of UBC GHG emissions. This estimate is low because it does not take into account GHG emissions from decaying organic material in areas flooded by hydroelectric dams.

UBC has significantly reduced its GHG emissions through several initiatives. ECOTrek and Electrek are two successful energy efficient upgrade projects that have been completed at UBC-V. Both have room for expansion. Savings from ECOTrek were guaranteed through a system called Energy Performance Contracting, where the contractor is paid with money from energy savings generated by the project. Biodiesel has been produced at UBC in the past and could be an effective way to utilize waste cooking oil that would otherwise be transported to a landfill where it would break down into GHGs. The Sustainability Coordinator and Ambassador program at UBC is an important program that uses community based social marketing techniques to promote sustainable behaviour including energy conservation

In addition to continuing and expanding past initiatives there are also many other opportunities for GHG reduction that could be investigated at UBC. Providing incentives for energy conservation may be an effective way to further reduce demand. UBC could nearly eliminate its climate footprint by purchasing Green Power Certificates for all of its electricity consumption. Using energy more efficiently at UBC can reduce emissions as long as the money saved is not spent on other activities that result in emissions. Replacing energy infrastructure at UBC with cleaner alternatives will help reduce UBC's climate footprint. Heat pumps are being used to provide low emission heating at UBC-O, but could also be utilized on other UBC properties. Potential heat sources include water (ocean or lake), ground, air, and waste heat including wastewater, ventilation, and sewage. Cogeneration has proposed in the past at UBC, but would likely result in higher GHG emissions. There may be potential for biogas to be utilized on both campuses but it is limited in scope by the availability and quantity of waste material. UBC-O may have access to biomass as an energy source because there are sawmills in Kelowna. Harnessing solar energy for both heat and electricity warrants further investigation, especially solar hot water heating. Wind power is likely not very feasible at UBC-V or UBC-O but may be at Bamfield Marine Station. Tidal or wave power might be worth looking into for the Bamfield Marine Station as well.

By considering appropriate technology and focusing on reducing energy demand UBC will be able to significantly reduce its climate footprint.

7.0 Recommendations

1. Produce renewable electricity and heat on campus and at research facilities

Producing electricity on campus and at research facilities will decrease UBC's dependence on grid power which has high energy losses from transmission. On campus renewable power could generate interest in renewable power. Wind and possibly wave power at the Bamfield Marine Station warrants further investigation.

Heat is the largest source of GHGs for UBC- V, therefore developing cleaner heating systems is crucial for GHG reductions. The steam plant heating system at UBC-V should not be expanded. Instead GSHP should be utilized in new infrastructure. Feasibility studies should be carried out on solar heating and heat pumps including ground, water, air and waste heat sourced. Integrating waste streams into energy systems could provide significant social and environmental benefits in additions to GHG reductions. Energy could be produced from bio materials such as sewage and compost. UBC's waste cooking oil should be used for biodiesel for campus equipment.

2. Purchase Green Power Certificates

Green Power Certificates can also significantly reduce UBC's climate footprint and overall Ecological Footprint. Purchasing GPCs creates demand for cleaner energy. Purchasing 100% green power would be an effective way for UBC to reduce its GHG emissions by nearly 14%.

3. Expand upon existing energy reduction programs

Reducing energy consumption is the best way to reduce GHG emissions. Energy conservation projects and efficiency upgrade projects can be funded with the energy savings produced and also with the carbon tax and offsets avoided. CBSM is a highly effective tool to get people to adopt more sustainable practices. Such programs may also consider including financial incentives. One idea worth exploring is for UBC to get each department to pay for their energy use from their yearly budget. Introducing policies for energy reduction is a very important measure for GHG reduction.

To be effective GHG reductions need to be looked at in a holistic manner. Efficiency gains coupled with an intensive community based social marketing campaign which would likely include financial incentives could play an important role in reducing emissions.

The successes of ECOTrek should be extended to areas of campus that it did not cover. One example is the Empire pool, covering this would save large amounts of energy and has been recommended by MCW.

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Appendix A: Questions for UBC's Energy Round Table

- How can UBC purchase green power certificates to account for 100% of the institutions total power consumption?
- How can UBC produce emission free electricity on its campuses, properties and at its research facilities?
- What are the best sources of electricity available to UBC?
- How can waste streams be utilized for energy demands?
- How can the university lead social changes towards sustainable living?
- How can we drastically reduce individual energy consumption?
- What are the perceived barriers to individual energy consumption?
- How can UBC use electricity more efficiently?
- How can UBC heat the campus more efficiently?
- How could UBC (Vancouver) make the central heating plant (the steam plant) become climate neutral over the long term? Or reduce its carbon footprint in the short term?
- Is the steam plant necessary for heating on campus or could it be replaced with renewable energy systems?