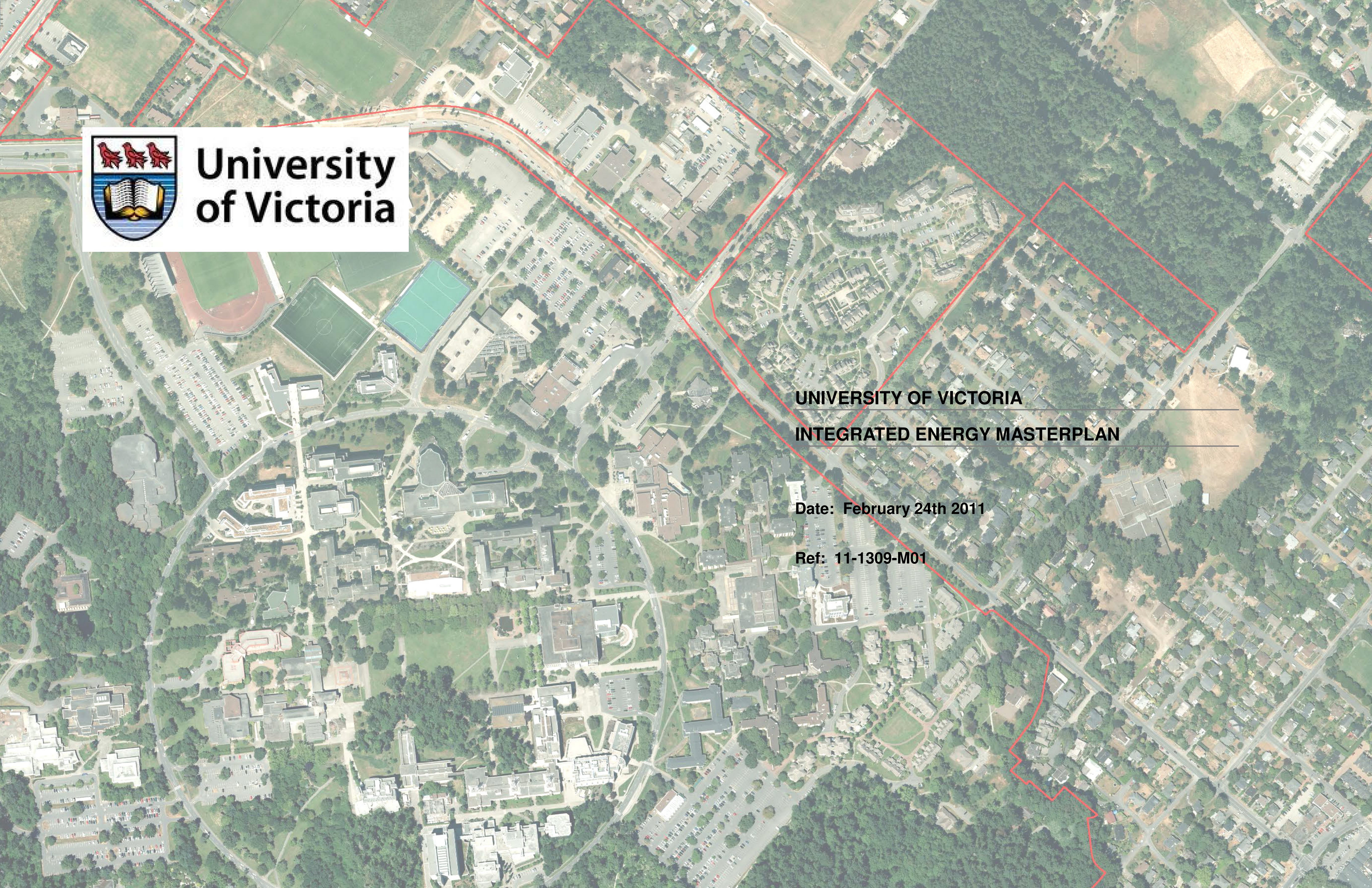

University of Victoria

UNIVERSITY OF VICTORIA

INTEGRATED ENERGY MASTERPLAN

Date: February 24th 2011

Ref: 11-1309-M01

1 EXECUTIVE SUMMARY

1.1 Scope and Objectives

The 2007 University of Victoria Strategic Plan "A Vision for the Future – Building on Strength" identified sustainability as a strategic priority for the institution.

The University's Sustainability Action Plan has identified a number of objectives, including the creation of a campus that utilizes renewable energy sources for its energy needs, and where facilities are built or renovated to meet current green building standards, and act as physical tools of education for both the campus and broader community. UVic's Sustainability Action Plan also sets out its sustainability goals using 2009/10 energy consumption as the baseline.

While the Sustainability Action Plan did set measurable energy and carbon goals, UVic realized the need for a definitive master plan that would define a clear strategy for reaching their goals. In addition, the BC Provincial Government directive for all public institutions to reduce their carbon emissions from a 2009 baseline, further drove the need for setting clear quantifiable goals for energy and carbon emission reductions.

The objective of this study is to devise an Integrated Energy Master Plan to serve as a road map to support UVic in meeting their targets for energy, carbon and costs.

1.2 Energy Targets

The University of Victoria has established stringent overall energy use reduction targets and carbon emission reduction policy as part of their Sustainability Action Plan, and has the ambition to be ahead of its peers in terms of energy efficient building design. This integrated energy master plan has been developed to act as a road map and support UVic in meeting these targets.

The proposed energy use of new buildings at UVic are expected to meet the minimum energy performance criteria defined in the BC Building Code, ASHRAE 90.1 2004. Project specific goals are sometimes set, e.g. LEED Gold, but this is not applicable to all projects. New Buildings will need to achieve greater energy reductions than required by current and projected Energy Codes, in all new and existing buildings to meet the energy and carbon reduction targets.

1.3 UVic's Current Energy Use

UVic's current energy use is better than many of its peers in BC, approximately 17% lower than the NRCAN BC Universities energy intensity benchmark. However Victoria has one of the mildest climates in BC and so energy use is expected to be lower than many of its peers in areas outside the lower mainland of BC

Individual Buildings at UVic typically perform between standard and good practice when compared with national and international benchmarks. The demand for academic and student accommodation is expected to grow at UVic over the coming years and all new buildings will need to perform with much greater energy efficiency than the current building stock for UVic to achieve its energy and carbon reduction targets.

1.4 New Buildings

For new buildings to consistently achieve Good or Best Practice energy benchmarks, energy efficiency needs to be placed as a key driver of a building's design. Developing a building design guideline document will allow UVic to define mandatory performance and prescriptive requirements for the design, construction and renovation of University owned buildings, helping to support and direct designers in helping UVic achieve their energy targets.

UVic should also consider incorporating many of the construction design approaches presented in Section 8 into the design guideline document to maximize energy efficiency.

1.5 Existing Heating Loop

The vast majority of UVic's natural gas use is by the main boiler plant in ELW serving the campus heating loop. The loop operates at high temperatures, hindering the integration of low-grade energy sources and high efficient technologies. Lowering the loop temperature will be prohibitively expensive due to the number of buildings connected to the loop, and the changes required to the heating systems in each building.

Since the loop must remain in operation, the efficiency of the existing DES system should be improved to maximize energy and carbon savings. Currently the high loop temperature is maintained throughout the year, regardless of the climate and each building's heating demand. The provision of a control feedback loop between each building connected to the loop and the main boiler plant at ELW will allow the flow rate and water temperature to match system's needs more closely, thus saving energy and carbon.

1.6 Existing Building Stock

The vast majority of the floor space that will exist in 2020 has already been built; therefore, reducing existing buildings' energy use is a key element for UVic to meet its carbon and energy reduction targets.

The currently on-going Continual Optimization Program has identified significant energy savings, achievable with relatively short paybacks. UVic's priority should be to complete all three phases of the Continual Optimization Program over the next one to two years.

A key element of this program is the installation of end use energy meters to all buildings connected to the district heating loop. Completing this work will allow UVic to easily identify buildings operating inefficiently, and accurately identify the domestic hot water load separately from the space heating load, so that summertime base load can be accurately tracked. This will allow any solar heating panel option to be optimized.

1.7 Potential Low/Zero Carbon Energy Sources

Replacing the existing mid-efficiency gas fired boilers with low and zero carbon solutions will help UVic achieve its carbon reduction target and increase its renewable energy portfolio.

The feasibility of various solutions were initially assessed and presented in Section 10. Combinations of the most feasible solutions, gas-fired condensing boilers, solar thermal panels, biomass boilers and biomass CoGen were assessed in greater detail, presented in Section 11.

From this detailed analysis, the maximum reduction in carbon emissions is achieved by combining a 13,000m^2 solar thermal array, a 4200kW biomass boiler, and replacing the existing gas fired boiler plant with modern condensing boilers. The gas-fired boilers will be used to supplement the solar thermal and biomass boiler during the peak winter months and act as back-up, should the solar thermal system or biomass boiler fail.

A biomass CoGen plant generating electricity as well as heat could be integrated instead of a biomass boiler, providing further energy and carbon savings. However, biomass CoGen plants required significantly more biomass than standard biomass boilers, making their financial feasibility more sensitive to the price of biomass fuel. Procuring a biomass fuel study will confirm the availability of biomass fuel in the vicinity of UVic and the projected fuel price.

1.8 Key Recommendations

1. Produce a Buildings technical design document, outlining UVic's mandatory performance and prescriptive requirements for the design, construction and renovation of university owned buildings.

2. Complete the Continual Optimization Program Scope of Work to all buildings connected to the Central Heating Loop
3. Upgrade the controls to the central heating loop and provide a feedback loop from each building to the central boiler plant.
4. Once the building energy metering installation has been completed, meter the thermal energy use by end use for one year to redefine the baseline and refine sizing of future energy sources.
5. Procure a biomass fuel study to confirm fuel availability, security and future energy cost
6. Replace the McKinnon and ELW boiler plants at the end of their respective lives with high efficiency condensing boilers.
7. Install the solar thermal array. The installation can be phased over a number of years; coinciding with scheduled roof replacements will help reduce mobilization and construction costs.

1.9 Potential Energy use and Carbon Emission Savings

By implementing all of the above recommendations, UVic will reduce their carbon emissions by approximately 40%-45%. This reduction is primarily achieved through the provision of a biomass Combined Heat and Power (CHP) system connected to the existing campus heating loop to offset the current natural gas use.

The implementation of each recommendation can be scheduled to achieve UVic's carbon emission reduction goals, assuming sufficient capital/financing is available. Campus growth and campus Master Planning must also be considered and coordinated with this Integrated Energy Master Plan.

Completing the upgrading the central heating loop controls and replacing the existing boilers in the McKinnon Boiler room with gas-fired condensing boilers within the next four years, UVic will achieve their short term carbon emission target of a 20% reduction over the University's 2007 baseline, by 2015.

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2 CONTEXT

2.1 Background Information

The University of Victoria has a long history of leadership in sustainability. Over the past few decades the campus has received international attention for the commitment to green campus operations, interdisciplinary research, real life learning opportunities, and innovative community partnerships.

The 2007 University of Victoria Strategic Plan "A Vision for the Future – Building on Strength" identified sustainability as a strategic priority for the institution.

The university recognizes that sustainability is a commitment to future generations and requires the collective action of the university community through long term planning, shared learning, grassroots activities and institutional leadership.

2.2 Provincial GHG Emission Reduction Targets

As per the Province of British Columbia Greenhouse Gas Reductions Target Act, GHGRTA (Bill 44, 2007), the reduction target levels for the Province of British Columbia are:

1. 6% below 2007 levels by 2012
2. 18% below 2007 levels by 2016
3. 33% below 2007 levels by 2020
4. 80% below 2007 levels by 2050

The GHGRTA also requires that all public sector organizations, including UVic, be carbon neutral in their operations beginning in 2010 and thereafter. To become Carbon Neutral, organizations must compile an emissions inventory, reduce emissions with specific reduction measures, and for any remaining emissions, purchase carbon credit offsets. A net zero level of emissions can be achieved by the combination of reductions along with the offsets to eventually reach the overall target of 100% reduction.

As of 2010, UVic is committed to being carbon neutral by minimizing carbon emissions and purchasing carbon offsets when necessary in order to achieve equivalent 100% emissions reduction.

Carbon offsets are generated through projects that reduce carbon emissions or remove carbon from the atmosphere within the Province of BC, as mandated by GHGRTA (Bill 44). These projects must comply with specific criteria, including the requirement that the offset is recognized as being above and beyond standard practices.

2.3 UVic Existing Reduction Targets and Policy

The University's Sustainability Action Plan has identified a number of objectives, including the creation of a campus that utilizes renewable energy sources for its energy needs, and where facilities are built or renovated to meet current green building standards, and act as physical tools of education for both the campus and broader community.

UVic's Sustainability Action Plan also sets out its sustainability goals using 2009/10 energy consumption as the baseline, including the following:

- Become carbon neutral by 2010.
- Reduce overall campus electricity consumption by 20%, by 2015.
- Reduce overall greenhouse gas emissions by 20% over 2007 baseline by 2015
- Increase UVic's renewable energy portfolio
- Reduce campus overall water consumption by 25% by 2015.

The Plan also identifies the anticipated benefits to the university and the wider community of reducing carbon emissions through improved energy efficiency and renewable sources.

2.4 Future Building and Energy Code Requirements

Until recently, BC Building Code did not reference any energy standards/requirements for building energy efficiency. In 2008 BCBC Green Building Code revisions, the Province of BC has adopted ASHRAE 90.1-2004 as the building energy efficiency standard for all new construction. ASHRAE continues to revise the standard, typically every three years, and ASHRAE 90.1 2010 is expected to mandate energy use reductions of 30% from ASHRAE 90.1 2004.

Federal Government of Canada has established a standard known as MNECB (Model National Energy Code for Buildings) which in principle follows the same methodology as ASHRAE 90.1 standard with the only difference that the prescriptive parameters are defined for Canadian climate regions. The last version of MNECB was issued in 1997 and is outdated by current requirements of ASHRAE 90.1-2004 and 2007 standards.

An updated version of the MNECB is due to be published in 2011 and expected to be 30-35% more stringent than MNECB 1997 or 18.5% more stringent than ASHRAE 90.1: 2004. It is intended to address overall energy use irrespective of energy source and will be potentially included in the next BC Building Code in 2012.

The projected savings from both ASHRAE 90.1 and MNECB are graphically presented in Figure 2-1.

NOTE: dashed line represents predicted energy savings.

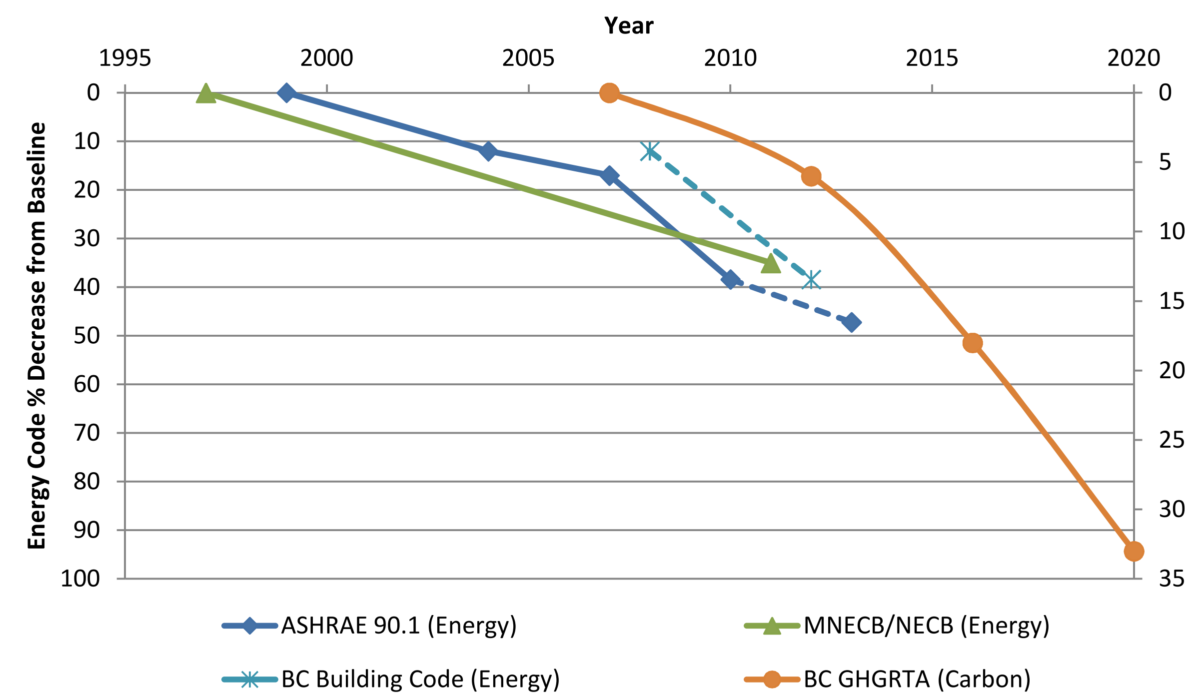


Figure 2-1 ASHRAE 90.1, NECB, BC Building Code and BC GHGRTA Targets

It is unclear, at present, if the 2012 version of the BC Building Code will reference a new energy standard, and if so, which one. It has been assumed that it will adopt the 2010 version.

The Provincial GHG Emission Reduction Targets have been included for information. Although no direct comparison can be made with energy use reduction percentages, the difference in gradient highlights the need for UVic convert to a low or zero carbon energy sources to meet its targets in addition to achieving energy use reductions.

2.5 Future Energy Costs

2.5.1 Natural Gas

Historical natural gas prices have fluctuated over the past 15 year, as shown in Figure 2-2. The 15 year average gas over the 15 year period has remained relatively constant; in recent years, gas prices have been falling.

Whilst it is difficult to predict the future energy cost trend, the continuation of the most recent price reduction trend is likely to be unrealistic. With the recovery of the economy and the growing global demand on the world's fossil fuel resources, prices are likely to increase, as a general trend. Prior to 2001, natural gas had been increasing at 5% per year on average.

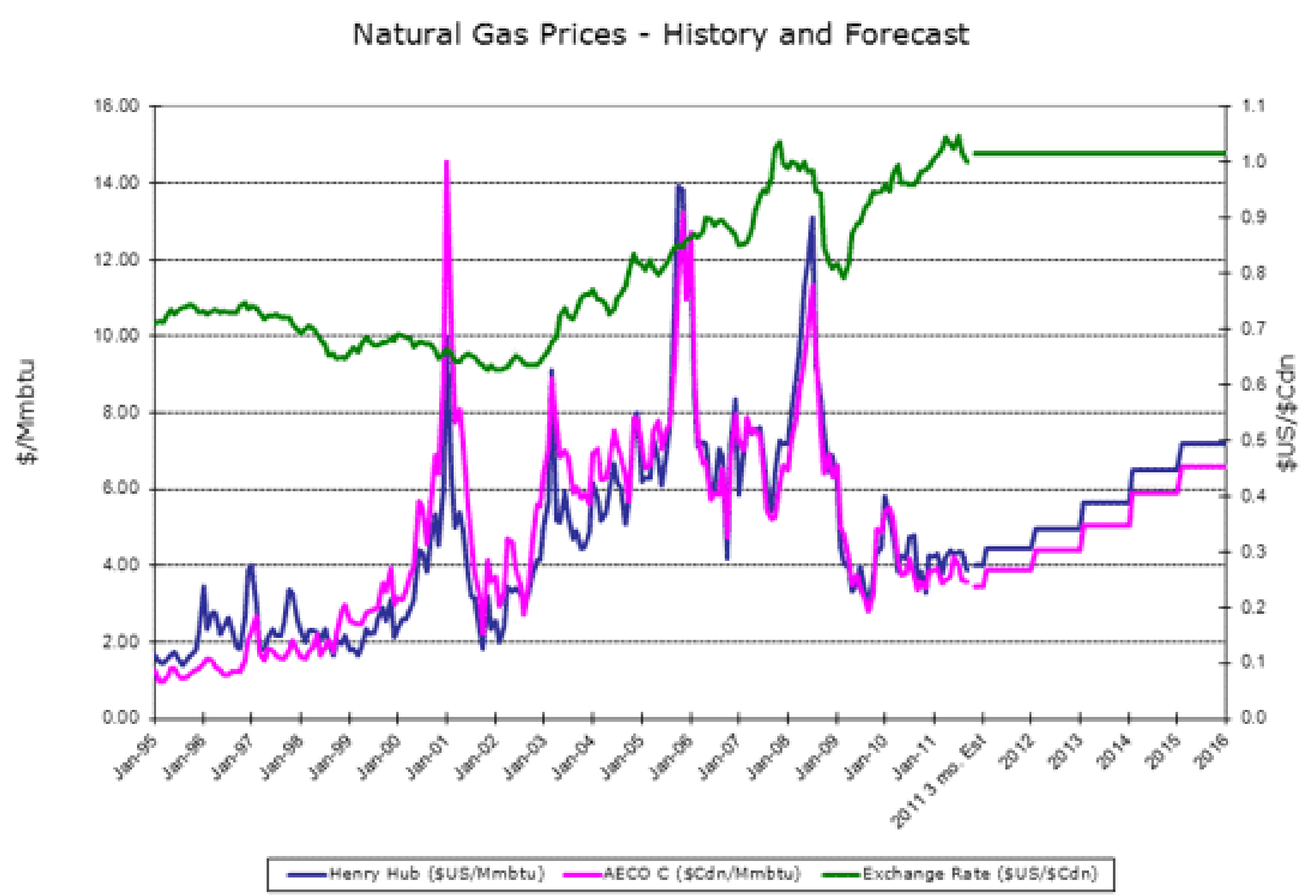


Figure 2-2 Natural Gas Prices - Historical and 5-year Forecast[1]

2.5.2 Electricity

There is very little published information regarding the forecast of electricity prices in BC. However, electricity prices were increased by 8% in BC, in 2011 and were this to continue, could have risen by over 40% during the next 5 years.

It is publicly known that BC Hydro's capacity is being stretched and that the growing future demand will need to be met by a combination of improvements in end use efficiencies to reduce the existing demand and by building new power generation facilities, i.e. site "C".

Also it is known that BC Hydro has been applying for electricity rate increase and that the actual electricity rate increase trend has been curbed by the government.

[1] http://www.sproule.com/Price-Curves#t2 – Natural Gas Forecasts as of January, 2011.

2.6 Local Climate Data

Comprehensive hourly weather data is available for Victoria City Centre, which is located just South West of the University of Victoria. Given the close proximity and geographic similarity the Victoria weather data also accurately represents the local climate of the University of Victoria.

Victoria is located at sea level on the south-eastern tip of the Pacific coast of Vancouver Island, British Columbia. In general, Victoria has a temperate climate with mild temperatures and moderate humidity levels year round. Summers are comfortably warm and dry with large “diurnal” temperatures and winters are relatively mild with high levels of precipitation. This weather pattern is due to the combination of the nearby Pacific Ocean and the protection from the cold continental winter offered by the Coast Mountains rising abruptly from the ocean immediately across the Georgia Strait. The following table shows the average minimum and maximum air temperatures for Victoria during the coldest month (January) and the hottest month (August) using Victoria data.

January		August	
Average Minimum	*Average Maximum*	*Average Minimum*	*Average Maximum*
0.5℃	6.2℃	13.2℃	21.9℃

Table 2-1: Victoria Average Temperatures

Because Victoria is on the Pacific Northwest coast and it rains frequently, common misconception refers to this region as being “humid.” However, only Victoria’s <u>relative</u> humidity is consistently high during winter season, not its absolute humidity. When high relative humidity coincides with low air temperatures, the absolute amount of moisture in the air is still low.

Victoria receives moderate levels of solar radiation during spring, summer and fall making the integration of renewable systems to capture solar energy potentially feasible. The prevailing wind direction is from the west. The peak outdoor design temperatures for Victoria as defined by the BC Building Code and ASHRAE Standard 90.1 are shown in Table 2 below.

Victoria Outdoor Design	BCBC	ASHRAE
Winter Dry Bulb Temperature, 1%	-9℃	-8℃
Summer Dry Bulb Temperature, 1%	26℃	23℃
Summer Wet-Bulb Temperature (max coincident with 23℃ dry-bulb)	19℃	18℃

Table 2-2: Victoria Outdoor Design Temperatures[2]

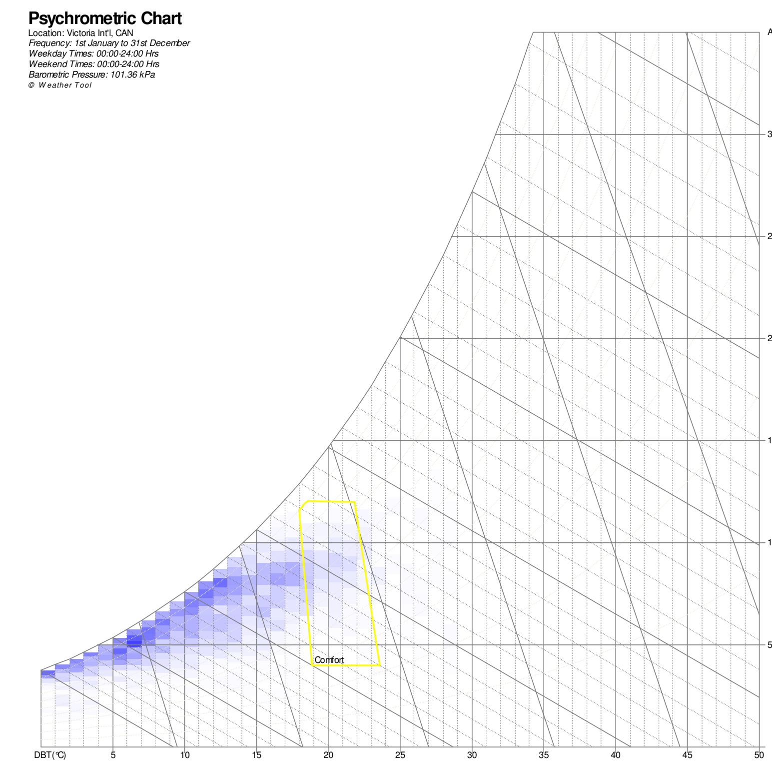


Figure 2-3: Psychometric chart of air temperature and humidity for Victoria

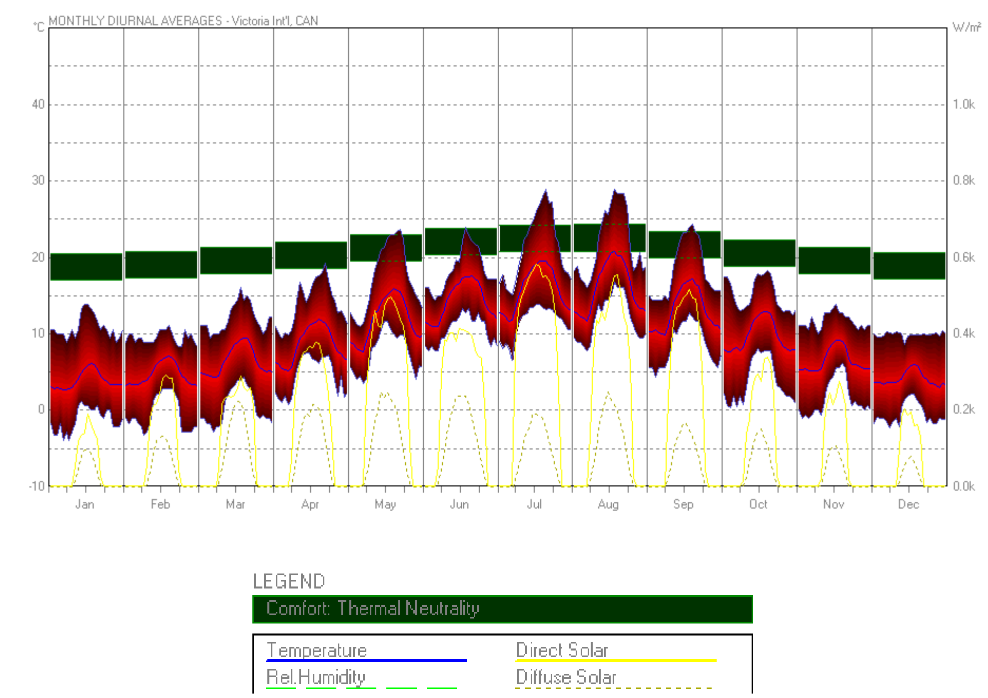


Figure 2-4: Victoria temperature and solar weather profile

2 In general, ASHRAE 90.1 is used in the US, and the Model National Energy Code of Canada for Buildings (MNECB) is used in Canada. However, local Canadian jurisdictions can choose to supersede MNECB, as Vancouver has done by adopting ASHRAE 90.1.

3 UVIC'S VISION

3.1 Energy Goals

In addition to achieving the carbon reduction goals outlined in the Sustainability Action Plan, UVic wants to demonstrate creativity and innovation, and be well known for sustainability and low energy buildings.

UVic also has the ambition to be ahead of its peers in terms of improved building design and reduced energy use, further supporting its leading edge philosophy.

As a comparison, Vancouver Island University have set specific conservation targets for 2010/11, which are to achieve a 10% reduction in electricity, primarily through behavior change, and a 3.3% reduction in natural gas consumption by revising standards and operating protocols.

As a comparison, UBC, considered a leader in sustainability and energy reduction amongst Canadian high education institutions has set targets for GHG reduction at its Vancouver Campus and raising the bar above previously documented goals.

UBC aims to:

- Reduce GHGs to 33 per cent below 2007 levels by 2015
- Reduce GHGs to 67 per cent below 2007 levels by 2020
- Reduce GHGs to 100 per cent below 2007 levels by 2050

They are intending to achieve their targets through the conversion of their campus heating distribution system from steam to hot water with some conversions in many buildings to reduce the return water temperature. They are also introducing a biomass fueled cogeneration system to eventually replace their existing central gas-fired steam boiler plant and carry out continuous improvement and retro-commissioning of existing buildings.

In addition to requiring all buildings on campus to achieve a 42% reduction from a MNECB 1997 performance level, UBC are currently developing a sliding scale of absolute energy density targets, from the maximum energy density allowed to achieve UBC's current requirements to an aggressive target, incorporating national and international best and pioneering practices. These targets will form UBC's future energy requirements and will be set out in their Technical Guidelines.

The majority of these energy conservation approaches are potentially viable at UVic's Gordon Head campus and their feasibility will be assessed as part of this study.

A detailed summary of Canadian universities' sustainability and energy strategies is setout in Appendix A.

3.2 Anticipated future development

UVic's Campus Plan sets out the future land use and infrastructure development.

The demand for academic facilities and student accommodation at UVic is likely to grow over the next twenty years. Student enrolment is anticipated to grow at an average of 2% per year and its envisaged that a further 150,000m^2 of new floor area could be accommodated on campus, based upon the current Campus Plan direction.

A new athletic training facility will be built, with construction starting in 2012, and include a gym and multi-storey parkade. A swimming pool will be added in a subsequent phase. It is proposed to connect this new facility to the existing district energy system.

The University also anticipates the need for the residential area on campus to increase over the next 10 years.

Future growth makes achieving targets harder. Even with these plans for future development, the majority of the floor space existing in 2020 has already been built and highlights the need for existing buildings to be incorporated in any future energy consumption reduction plans.

4 STUDY OBJECTIVES

The objective of this study is to develop an Integrated Energy Master Plan for the University of Victoria, Gordon Head Campus, to help meet or exceed UVic's energy use and greenhouse gas emission reduction goals.

The Master Plan shall be a high level strategic plan for how to incorporate new energy sources, capture waste heat and achieve energy use reductions, evaluate the potential for peak energy demand reductions, and the feasibility of energy supply options.

Appropriate cost/benefit criteria shall be defined and a decision matrix developed to assess each potential option. The viable options shall be assessed in further detail to develop appropriate timelines for their integration and allow investment grade decisions.

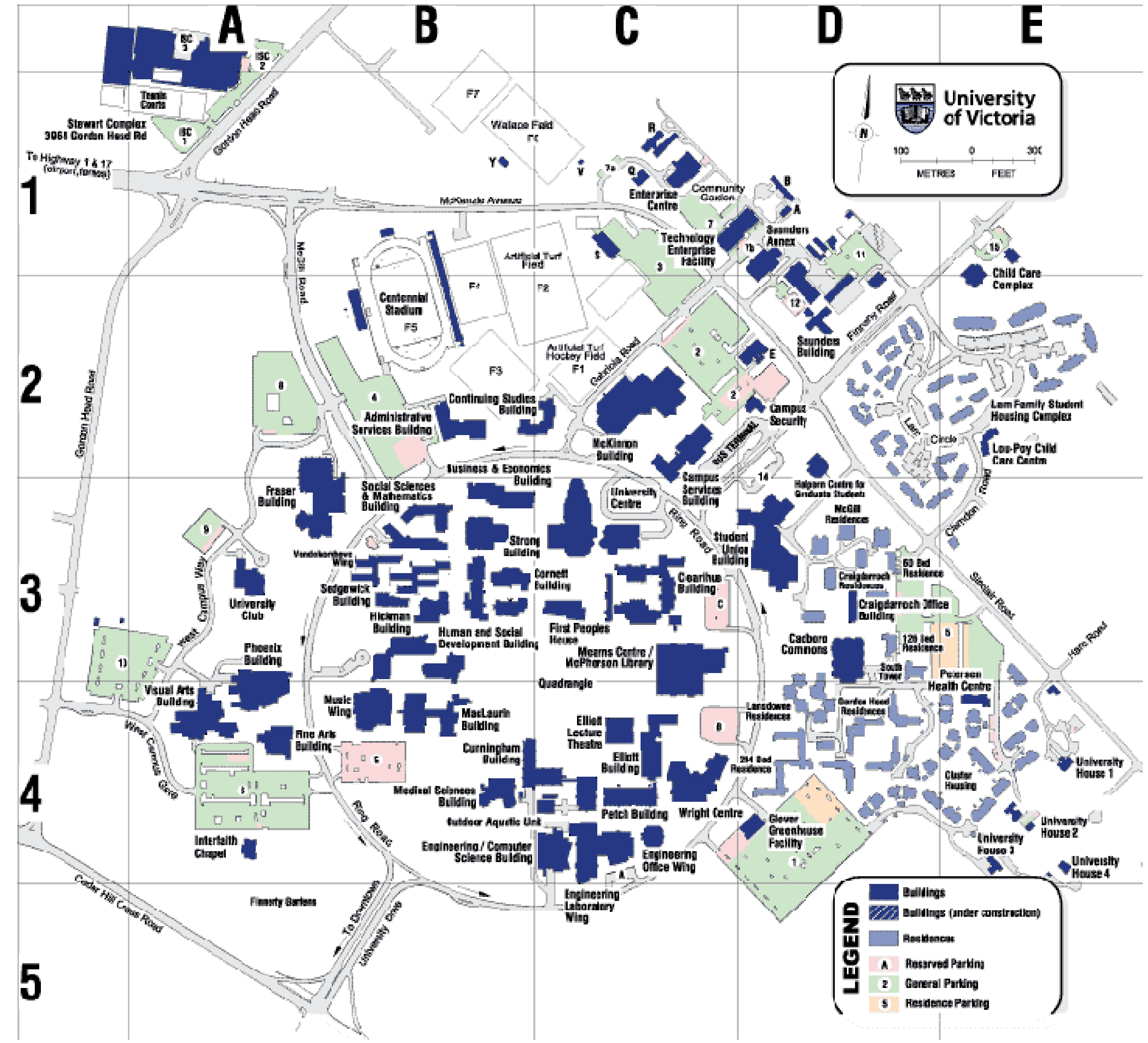


Figure 4-1 University of Victoria's Gordon Head Campus

5 METHODOLOGY

5.1 Overview

Three core elements will be developed in this study to produce a complete, integrated energy master plan for UVic. They are:

1. New Construction and renovation design approach and energy benchmarks (See Section 8)
2. Energy use reduction of existing building stock (See Section 9)
3. Campus wide energy use reduction strategies (See Section 10)

Prior to developing these elements, it is important to gain an understanding of the existing energy situation at UVic, which has been analyzed in the following three sections (Sections 6, 7 and 8)

In summary, the following methodology was used to develop the integrated energy master plan for the University of Victoria:

1. Discovery Phase – Develop an understanding of the status quo at UVic.

2. Confirm the 'business–as-usual' scenario and UVic's future plans and growth projections. Compare UVic's energy consumption to that of its peers. Evaluate the local microclimate as part of the local context research.

3. Develop suitable cost benefit criteria to assess the feasibility of potential option, systems and technologies.

4. Assess potential to reduce energy use of existing buildings and campus wide energy distribution system.

5. Identify effective (optimal) design approaches and tools that can be used by UVic to shift towards energy efficient new construction and renovation design and energy use benchmarks for future buildings.

6. Identify campus wide energy use reduction strategies. These can be split into two main groups:

    i. Recover Energy – assess potential to capture waste energy form buildings and campus to offset demand for heat from central plant or grid electricity.

    ii. Renewable Energy – Identify and investigate technically viable solutions and review their financial feasibility for application at UVic

7. Combine complementary technologies and systems into optimal solution combinations. Assess business case of each combination.

5.2 Cost/Benefit Criteria

Before beginning the assessment process of the options relating to the core options, it is important to define UVic's priorities through the development of suitable cost benefit criteria against which the viability of each option, system and technology can be assessed.

The following criteria have been developed through discussion with the key stakeholders at UVic including Facilities, Finance and Sustainability offices.

In order to make this relatively complex assessment easier to understand and navigate through, we have come up with the following green/yellow/red graphical evaluation:

5.2.1 Commercial Availability

How commercially available is the technology?

Green	The technology is readily available and many installations have been completed. Experience in the industry is high
Yellow	The technology is commercially available but not yet established in local market, with a low number of completed installations. The industry's experience is limited to a number of specialist contractors.
Red	The technology is considered to be pioneering and not yet commercially available in local market, with only showcase projects completed.

5.2.2 Carbon Emission Reduction Potential

How-effective is the technology at reducing carbon emissions at UVic?

The carbon emission reduction potential of each measure or technology can be established by multiplying the potential energy use savings by the carbon intensity of the fuel source. This weight of carbon emissions can then be divided by the total carbon emissions for that fuel type to calculate the expected saving.

Green	Carbon Emission Reduction Potential is greater than 30%
Yellow	Carbon Emission Reduction Potential between 11% and 29%
Red	Carbon Emission Reduction Potential less than 10%

Technologies with low carbon emission reduction potential may still be worth pursuing if their payback period is short, and if they provide educational, social and other non-carbon related benefits to the university.

5.2.3 Payback period

The time taken to recover the initial capital investment is defined as the payback period. The simple payback period of capital cost divided by yearly energy cost savings will be calculated for all technologies. Through discussions with UVic, the following payback period criteria have been developed:

Green	The payback period is less than 7 years
Yellow	The payback period is greater than 7 years, but less than 15 years
Red	The payback is greater than 15 years

Technologies with a payback period greater than 15 years could still be considered as showcase projects if they provide educational, social and other non-energy related benefits to the university.

5.2.4 Retrofit applicability

Can the technology easily be applied as a retrofit to existing buildings?

With at least 80% of the today's buildings expected to remain in existence past 2050, the retrofit applicability and ease of implementation of any technology is an important factor to determine its feasibility for application at UVic. Integrating energy use reduction measures into existing buildings also offers the greatest opportunity for energy use reduction to be realized in the short term.

Green	The technology can easily be applied to existing buildings with only minor disruption to the building's operation and relatively minor cost.
Yellow	The technology can be applied to existing buildings with only moderate disruption to the building's operation and moderate cost.
Red	The technology can be applied to existing buildings but major disruption to the building's operations is likely to be required and significant cost.

5.2.5 Early implementation potential

Can the technology be incorporated in the immediate future?

UVic's sustainability goals include a milestone target for 20% reduction in electricity use and green house gas emissions by 2015. Technologies and strategies which have the potential to be implemented prior to 2015 should be considered as a priority.

(green)	The technology can be implemented prior to 2013
(amber)	The technology can be implemented by 2015
(red)	The technology can only be implemented after 2015

5.2.6 Funding Availability

Is funding available for the technology/system?

Municipal, Provincial, National and private utility (Fortis BC, BC Hydro) funding may potentially be available to support the detailed feasibility analysis and a portion of the capital cost.

(green)	Funding is available for over 25% of the capital cost
(amber)	Funding is available up to and including 25% of the capital cost
(red)	No funding is available

5.2.7 Maintenance, Operation and staffing cost

Is additional maintenance, operation or staffing costs incurred by implementing a technology or strategy, over and above UVic's existing commitments?

(green)	No additional maintenance cost
(amber)	Minimal additional maintenance cost
(red)	Significant additional maintenance cost

6 THE CURRENT SITUATION – UVIC'S BASELINE

6.1 UVic's current energy sources and campus distribution

6.1.1 Electricity

The main Gordon Head campus at UVic is served by 11 electrical utility meters with one main electrical meter at the main transformers accounting for approximately 93% of the campus' total electrical consumption.

In addition to the main revenues meter, the majority of the buildings on campus are independently metered via the Schneider Ion metering system, allowing individual Building Energy Performance Indicators (BEPIs) to be developed.

The campus' electrical use is approaching the limit of the existing BC Hydro feed to the transformers and a second feed is being installed to accommodate future growth on the campus.

UVic have agreed with BC Hydro to reduce their electrical use across the campus, and will incur financial penalties if consumption is higher than a pre-agreed baseline. The peak capacity of the main transformers is 6.5MW.

UVic currently pays the following rates to BC Hydro:

- Basic charge = $0.17160/day

- Energy Cost for first 14800kWh = $0.0815/kWh
- Energy Cost for second remaining use = $0.03930/kWh

- Demand first 35 kW = $0.00/kW
- Demand second 115 kW = $4.18/kW
- Demand remaining kW = $8.02/kW

A rate rider cost of 2.5% is applied to the total of all charges before tax, and sales tax at 12% (HST) is applied to the final amount.

In 2010/11 UVic were charged a total average $0.056/kWh for electricity

6.1.2 Natural Gas

There are over sixty natural gas meters on campus, but 80% of the campus' gas is consumed by the heating plant serving the district heating system, which consists of four main boiler rooms, each with their own gas meter. The remainder of the meters is typically for small gas connections serving stand-alone building heating systems, residences, domestic heating water, labs, and cooking.

UVic is currently charged by Fortis BC at a rate of $12.015 per Gigajoule (GJ) of natural gas use ($0.043/kWh) and a carbon tax at $0.9932/GJ of use ($0.003/kWh). Sales tax at 12% (HST) is applied to both rates.

In 2010/11 UVic were charged a total average of $13.9/GJ ($0.05/kWh) for gas.

6.1.3 District Heating System

Space heating and domestic hot water heating are primarily provided to the Gordon Head campus via a campus hot water heating loop. The loop is fed from one large central heating plant and is supplemented by three smaller ancillary plants also contacted to the campus heating loop. The remaining demand use is further broken down into categories of stand-alone building heating systems, residences, domestic heating water, labs, cooking and external properties.

There are four gas fired boiler plants linked to UVic's Campus "District Energy System" (DES); the main plant, and newest (installed in 1995, approximately 16 years old) is located in the Engineering Laboratory Wing (ELW) building, and smaller ancillary plants in the Clearihue, McKinnon, and Commons.

The ELW boiler room contains four 4100kW Volcano gas-fired boilers (Total capacity = 16MW) and can meet the majority of the campus' heat demand throughout the year. The boilers and corresponding pumps are connected in parallel, and all pump motors have variable speed drives. The boilers have remaining an anticipated life expectancy of approximately 10 years.

During the peak heating season, the McKinnon boiler supports the ELW plant to maintain the heating loop temperatures. The remaining two boiler plants have not been needed during recent winters but are kept on standby at approximately 90^{o}C (200 ^{o}F) through the year. The overall boiler efficiency has been assumed to be approximately 70%.

Heating water is distributed across campus via 300mm diameter supply and return loops.

Heat exchangers within each building interface with the DES and transfer heat to secondary piping loops within the building.

During a tour of the site on April 11th, 2011, the heating loop temperatures were recorded at 105^{o}C - 115^{o}C (200^{o}F – 240^{o}F). It was originally thought that the high loop temperatures were required to eliminate a flue gas condensation issue but this has since been clarified. Certain buildings' uses on campus require high temperature water year round and building heat exchangers have been sized accordingly.

The DES was reportedly designed to operate at a 22^{o}C temperature difference between the supply and return. Initially the corresponding flow rate was found to be too low for effective heat transfer within the boilers and so the temperature difference was reduced to 9^{o}C to provide the required flow rate through the boilers. The issue was identified as water bypassing the boilers through the down-comer tubes on the boilers. This has now been fixed.

Flue gas heat recovery is currently not provided on any of the boilers. The flue gas temperature was recorded at 220 ^{o}C (430 ^{o}F) and is a significant source of waste heat that has the potential to be recovered. However, due to the short life expectancy of the boilers, flue gas heat recovery has not been investigated due to being economically unviable.

There are known issues with lack of individual control and heat energy metering of certain buildings. The secondary pumps and valves serving a number of buildings do not communicate back to the main DDC controls serving the boiler plant. Due to the lack of individual building heat meters, it has, until recently, been impossible to provide accurate picture of the thermal consumption on campus and provide Building Energy Performance Indices. Installation of heat meters to 29 of the campus' major buildings has been progressing as part of BC Hydro's Multi Building Continuing Optimization Program.

6.1.4 Water/Sewer

There are fourteen metered incoming water mains serving the campus, typically coordinated with the main road access points, with two meters (Gordon Head - Midgard and Sinclair Clarndon) providing 82% of all water entering the campus. The majority of buildings are currently not sub-metered and therefore, water consumption for a per building basis cannot be determined.

UVic is currently charged by the Oak Bay and Saanich at a rate of $1.153 per m^3 of potable consumption.

The sanitary drains from the buildings on the west side of campus by gravity, to the west, and collect at a sewer pumping station near Midgard Avenue. From the pumping station, the sewage is pumped to the east and exits the campus along Haro Road. On the east side of campus a single gravity sanitary main serves the buildings and exits the campus to east along Finnerty Road.

UVic is currently charged by Saanich at a rate of \$0.665 per m^3 for sewer discharge and \$0.394 per m^3 for sewage treatment. Sales tax at 12% (HST) is applied to both rates.

6.2 UVic's Energy Use and Carbon Emission Status Quo

UVic has achieved its target to be carbon emission neutral by 2010 through the purchase of carbon offsets. Based on a rate of \$25/tonne, in 2010, UVic's carbon offset cost was approximately \$429,000, based on a rate of \$25/tonne of CO_2 emitted, equating to 17,160 tonnes of CO_2.

As part of implementing their strategic plan, UVic has implemented an Energy Manager Program, providing a full-time staff member whose role is to lead energy and emissions planning and energy project implementation. UVic have also enrolled in BC Hydro's Continuous Optimization Program to undertake retro-commissioning and improve the energy efficiency of key buildings on Campus.

Whilst UVic does not have its own building technical standards, it does require all new buildings to be designed such that mechanical cooling is minimized, apart from specific areas such as computer server rooms.

The following sections present the current energy performance, both campus wide and certain individual buildings.

6.2.1 Campus wide energy and water use

UVic's energy targets are referenced against a base year from April 1st 2009 to March 31st, 2010, known as the 2009 base year. The energy use during this base year was reviewed as part of this study to provide the context for the development of the Integrated Energy Master Plan.

The consumption and utility cost during 2009 is summarized in table 1

Utility		Consumption	Costs	
(Apr 1/09 to Mar 31/10)	Unit			
Electricity	kWh	55,014,558	\$3,104,966	39 %
Natural Gas	GJ	71,595,017	\$3,593,078	47 %
Water	M^3	689,192	\$1,152,480	14 %
Total			\$7,850,524	100%

Table 6-1: 2009/10 utility consumption and cost

From this information, the Building Energy Performance Indices (BEPI) for gas and electricity use can be calculated for the gross building area of the campus, and are approximately 200kWh/m^2.yr of gas and 153 kWh/m^2.yr of electricity. In mild climates like Victoria's, electrical consumption would typically dominate, and since 80% of the gas is used by the campus heating system, heating system efficiency improvements have the potential to achieve the most significant reductions.

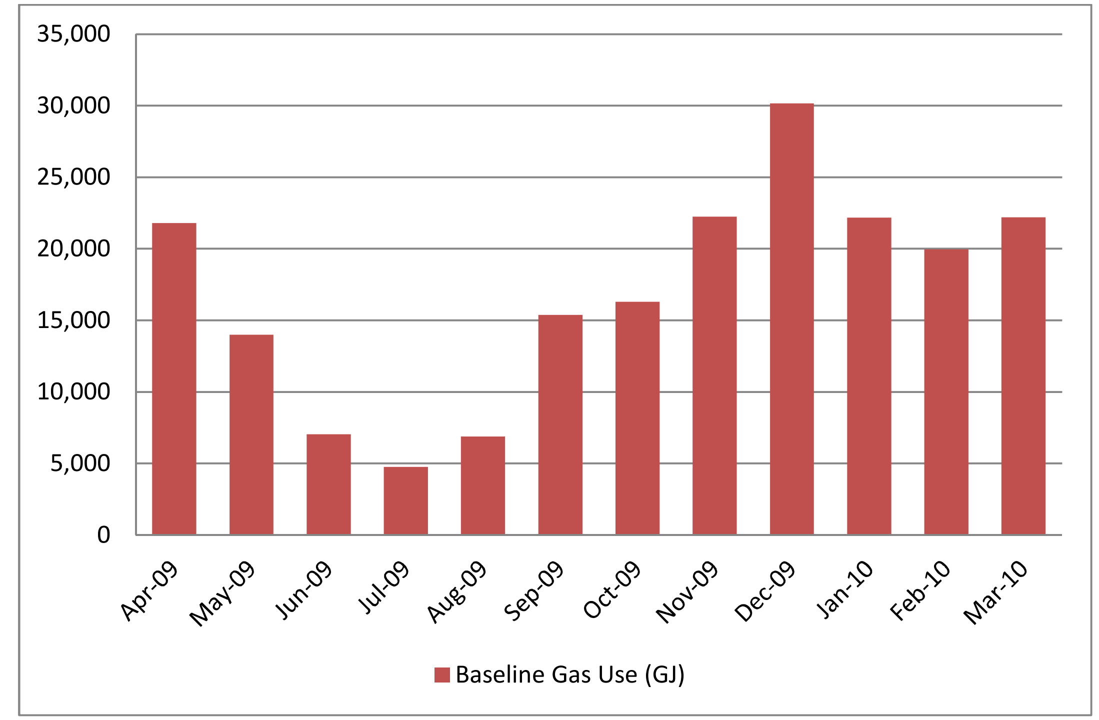


Figure 6-1: UVic's Baseline Natural Gas Use, kWh

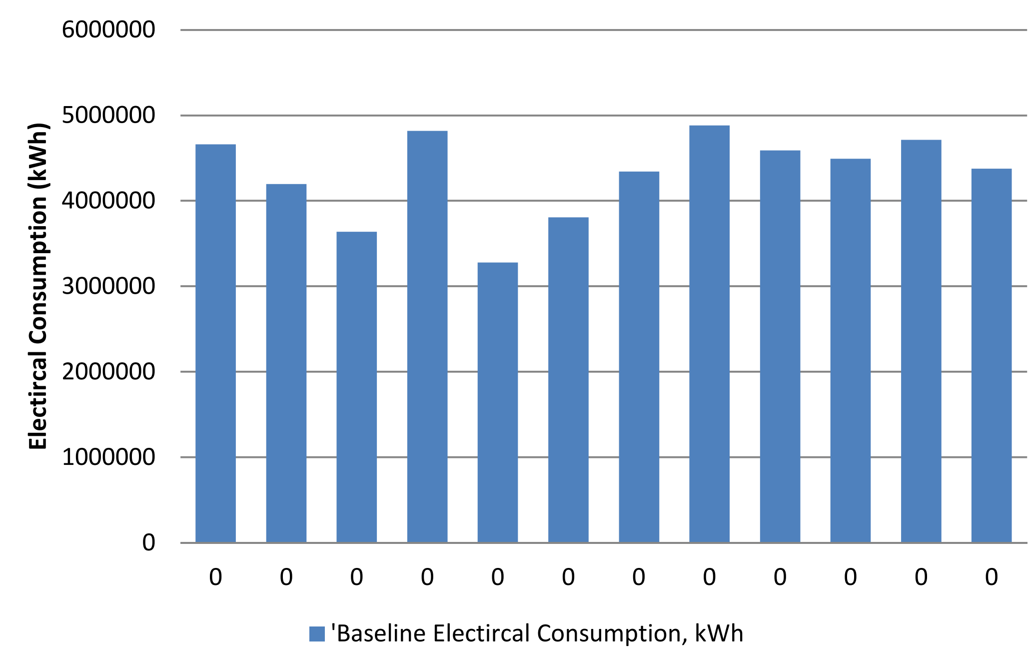


Figure 6-2: UVic's Baseline Electrical COn2009/10 electricity Use

In 2002, Prism Engineering conducted a walk-through Energy Audit to determine energy and water savings potential. As part of this analysis, an estimated breakdown of the gas and electrical consumption by end use was developed illustrated in Figures 1 and 2. Even though the university has expanded during the following years, these breakdowns are likely to still be valid.

A full year on from the base year has only just passed, and the final quarter results are not available at present, but the anticipated trend in energy consumption can be inferred.

Electrical consumption has begun to decline during 2010/11 and is attributed to the implementation of the Energy Manager program, the "turn off the lights" user awareness sticker project, two workplace awareness programs and a Christmas holiday temperature setback initiative.

Gas consumption is also projected to decline during 2010/11, potentially by 9%, again attributed to the energy manager program and temperature setback initiatives.

Implementing the cost effective improvements proposed by the Continuing Optimization Program will help to achieve further reductions over the next few years, and beyond.

Water consumption has been in decline over recent years despite significant growth in student population and building footprint. However, UVic remains the largest consumer of fresh water in the district (CRD). Water consumption has continued to decline since the base year and will continue to decline by operational changes to the Outdoor Aquatic Centre, which consumes water at a rate of 65 US GPM continuously throughout the year, and tempers the water as required.

A recent plumbing fixture audit has been completed and includes recommendations to replace all "once through" Cooling Equipment with air cooled, and replace a third of the toilets with water efficient models.

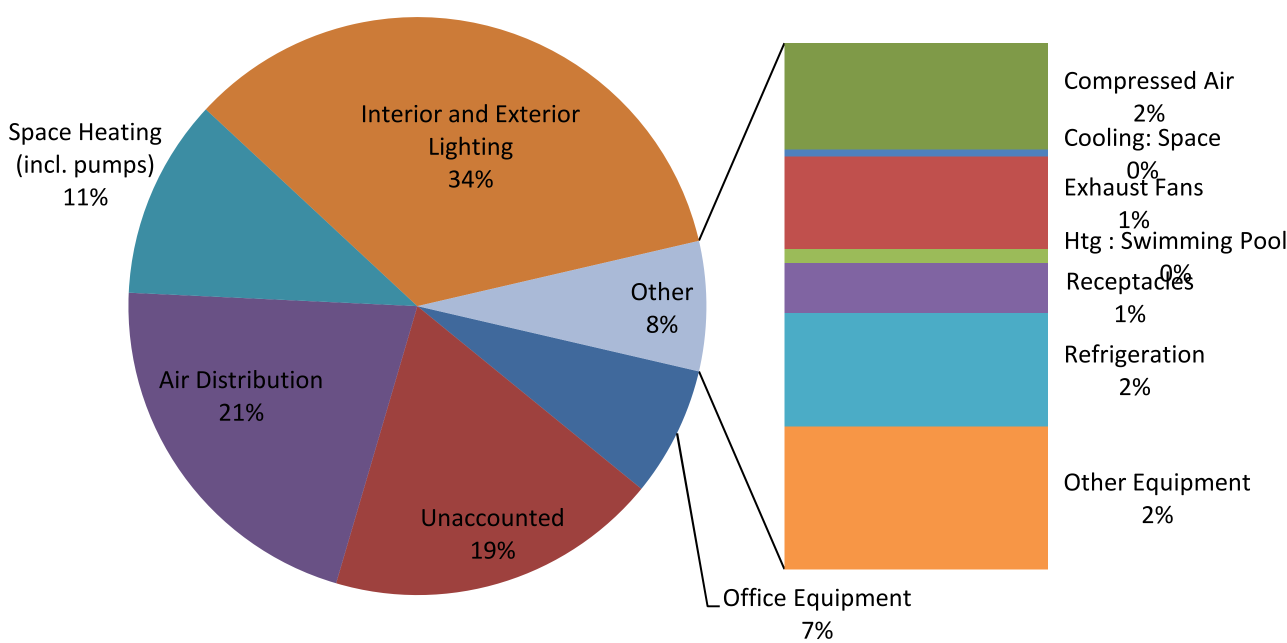


Figure 6-3: Campus Wide Electrical breakdown by end use (2002)[3]

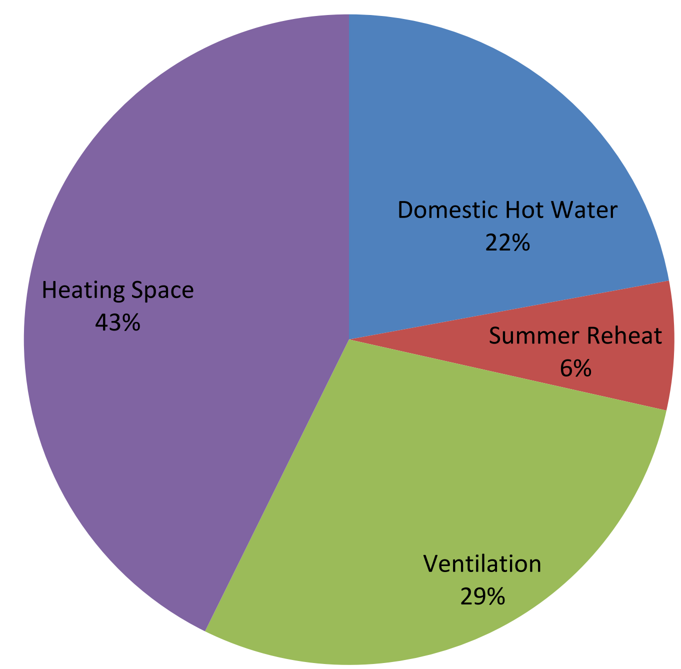


Figure 6-4: Campus Wide Natural Gas breakdown by End use (2002)[4]

[3] Adapted from Prism Engineering's Walk-Through Energy Audit, 2002

[4] Adapted from Prism Engineering's Walk-Through Energy Audit, 2002

6.2.2 Building Specific Energy Use

As discussed above, a lack of operational metering on an individual building basis for thermal energy and water limits the analysis, and comprehensive building specific BEPI figures cannot be calculated. This is being corrected through the Continuous Optimization Program by replacing old, inaccurate heat meters and adding new meters to twenty six of the main buildings on campus.

Heat metering data exists for some buildings as well as electrical meter data from the campus wide Schneider Ion system and is described below. Prism Engineering also developed estimated individual building BEPI figures in 2002; refer to Appendix A. Graphical representations of the meter data for each building discussed below is located in Appendix B.

6.2.2.1 Petch

Built in 1986, the Petch Building is home to department of biochemistry and microbiology, the interdisciplinary centre for biomedical research, the centre for earth and ocean research, and the school of earth and ocean sciences.

Only a snap shot of electrical meter data is available for this building at present.

Petch's peak electricity consumption is 475kW, during occupied hours. The electrical consumption during unoccupied hours gives an indication of the base load, i.e. the amount of electricity constantly used through the whole year. At Petch the base load is approximately 340kW, over 70% of the peak load, indicating that the majority of electrical systems in the building operate on a 24/7 basis, 365 days of the year. The continuous operation of the mechanical ventilation system is likely to be the significant contributor to the high, consistent, electrical use. Any potential changes to the operation schedule of the mechanical system are likely to result in a significant reduction in electricity use.

6.2.2.2 Elliott

The Elliott building houses the departments of physics, astronomy, and chemistry. The three-storey laboratory and four-storey office and research wing was built in 1963, and the Elliott lecture theatre was constructed the following year. The Elliott building was one of the first built on campus and is topped by the Climenhaga observatory.

Again, only a snap shot of electrical meter data is available for this building at present.

At Elliott, The average base electrical load is approximately 98% of the peak during the week, which is very high, even for a building of this type. The noticeable drop in electrical use, albeit by only two kWs, shown on the electrical use profile in Appendix B coincides with the weekend. The operation of the building should be reviewed and any differences between week day and weekend operation should be investigated.

6.2.2.3 Social Sciences and Mathematics

The Social Sciences & Mathematics (SSM) building was completed in 2008 and houses four academic units and a research centre; Geography, Environmental Studies, Political Science, Mathematics and Statistics and the Water & Climate Impact Research Centre (W-CIRC). It mainly consists of classrooms and offices. It was the third campus facility to earn Gold-level status in the Leadership in Energy and Environmental Design (LEED) Green Building Rating Standards program.

The BEPI figure for SSM is 155 kWh/m^2.yr

The base electrical load is approximately 50% of the peak, which is relatively high for a building containing mainly classrooms and offices. A review of the occupancy schedules for the HVAC and lighting should be considered to ascertain to reason for this high base load.

The heating water base load is approximately 10% of the peak and occurs during July and August which is typical for a building of this type and occupancy.

6.2.2.4 Human and Social Development Building

The Human and Social Development Building accommodates the schools of child and youth care, nursing, social work, health information science and public administration, as well as the Indigenous Governance and Studies in Policy and Practice programs.

The HSD building houses three computer labs and a classroom with tele-conferencing capabilities

The BEPI figure for HSD is 192 kWh/m^2.yr

The electrical base load during unoccupied hours is approximately 23% of the peak, and the heating use is approximately 5% of the peak. The electrical profile shows a significant decrease in electrical use during the weekends and unoccupied hours indicating the building is well controlled and appropriate occupancy schedules has been applied.

6.2.2.5 McPherson Library

The McPherson Library (LIB) contains UVic's library holdings. Also located in the McPherson Library building are the university archives, special collections and map library. The McPherson Library was originally constructed in 1964 as a four-storey building, with a major addition in 1974. The original building was used solely as the university library and later additions accommodated audio-visual services and provided temporary space for various academic and administrative units

The BEPI figure for LIB is 202 kWh/m^2.yr

The electrical base load during unoccupied hours is approximately 27% of the peak.

7 PROVINCIAL, NATIONAL AND INTERNATIONAL ENERGY USE DENSITY BENCHMARK COMPARISON

7.1 Introduction

At UVic, a building's expected energy demand must meet the minimum performance criteria defined in the current BC Building Code further referring to the Model National Energy Code of Canada for Buildings (MNECB) and ASHRAE 90.1.

The standards fall short of what is being achieved in other parts of the world and what is possible in Victoria's climate. The methodologies set out in ASHRAE 90.1 and MNECB to define a building's energy performance are essentially identical and have a number of shortcomings. One of their key shortfalls is that they create a "moveable" and "non-specific" energy performance target. Neither of these two standards prescribes building energy performance in clear, straightforward and measurable energy use units. Instead, both of these standards prescribe minimum acceptable building energy performance in indirect, non-energy specific terms such as: thermal performance of building envelope assemblies, minimum equipment efficiencies, lighting and occupant densities, etc. Both standards rely on a comparison between a "proposed" and theoretical "reference" building performance which can only be defined by detailed energy modeling of each specific building. The comparison is also based upon "energy cost" instead of "energy use" and adds an additional layer of complexity by reflecting the building's blend of energy sources, another variable typically inconsistent between different buildings. This makes it impossible to meaningfully compare the energy performance of two different buildings, or determine how the proposed building compares to the "best possible" building energy performance in a given climate.

An alternative to the prescriptive and reference model methodologies is the "energy use intensity" performance target. Establishing a building energy efficiency target for each type of building in a specific climate in clear and measurable terms is a fundamental prerequisite of successful climate adapted design. This alternate methodology of prescribing minimum building energy performance in terms of maximum allowable energy use intensity (e.g. in kWh/m2 year for a specific building type in a specific climate), which has already been implemented in several European countries, including Denmark and France, can actually lead to greater freedom in architecture and system design, while ensuring genuine improvements in energy performance.

Relevant National and International energy use intensity benchmarks have been identified to provide a clear comparison with buildings at UVic summarised in the follow sections. The energy density benchmark figures from each organisation are set out in Appendix D.

The benchmarks are typically based on surveys of existing buildings and analysis of the resulting data, with the lower energy intensities being used to define the Best Practice benchmark to generally reflect buildings that have proven low energy consumption compared to similar buildings. Good and Best Practice buildings are typically designed to exceed Code minimum and consider a building's energy use at the start of the design process.

For the campus and three key building occupancy types (Labs, Classroom and Library, for which UVic historical data was available), UVic's relevant building BEPI data, referenced in Section 7.2 was compared with the national and international benchmarks referenced above. The salient points are summarised in the relevant sections below, and a bar chart is provided at the end of each section for easy reference.

It is important to note that, due to local climate differences, energy cost variations, etc., the primary fuel source mix-used by buildings will differ between regions and countries. To avoid confusion, only the total "purchased" energy of the buildings, irrespective of their fuel type is recommended for comparison (kWhe).

7.2 University Campus Comparison

UVic's Gordon Head Campus energy use intensity is nearly 17% less energy than the NRCAN British Columbia benchmark for Universities, and can be explained by the milder climate in Victoria compared to more northern and eastern part of the Province. UVic's energy use is comparable with its local peers, UBC and SFU, and approximately 12% higher than VIU.

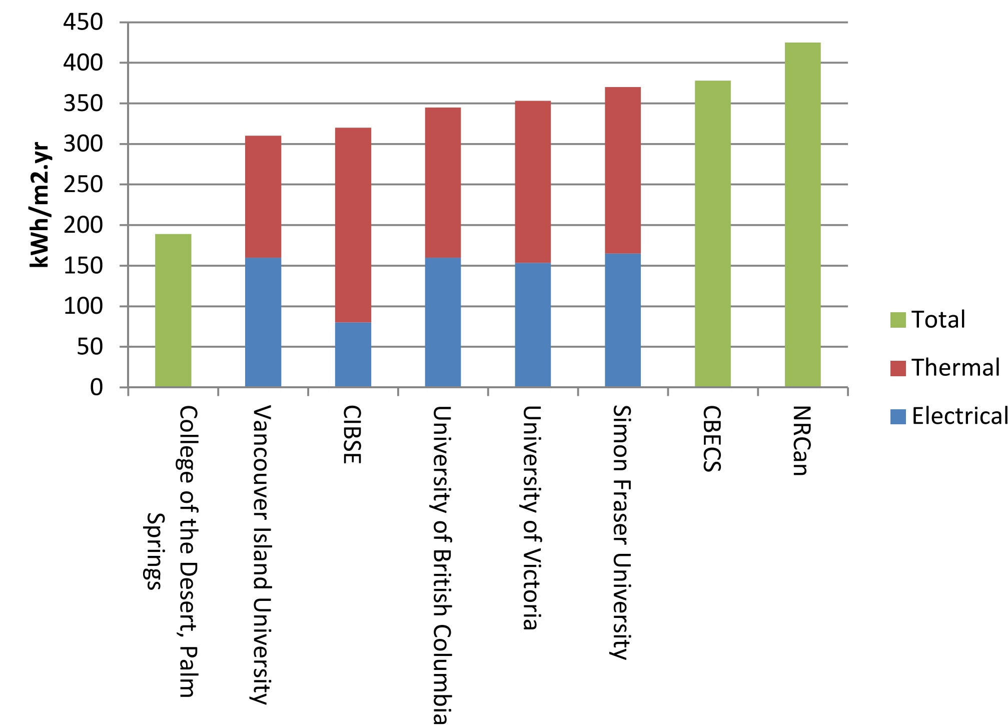
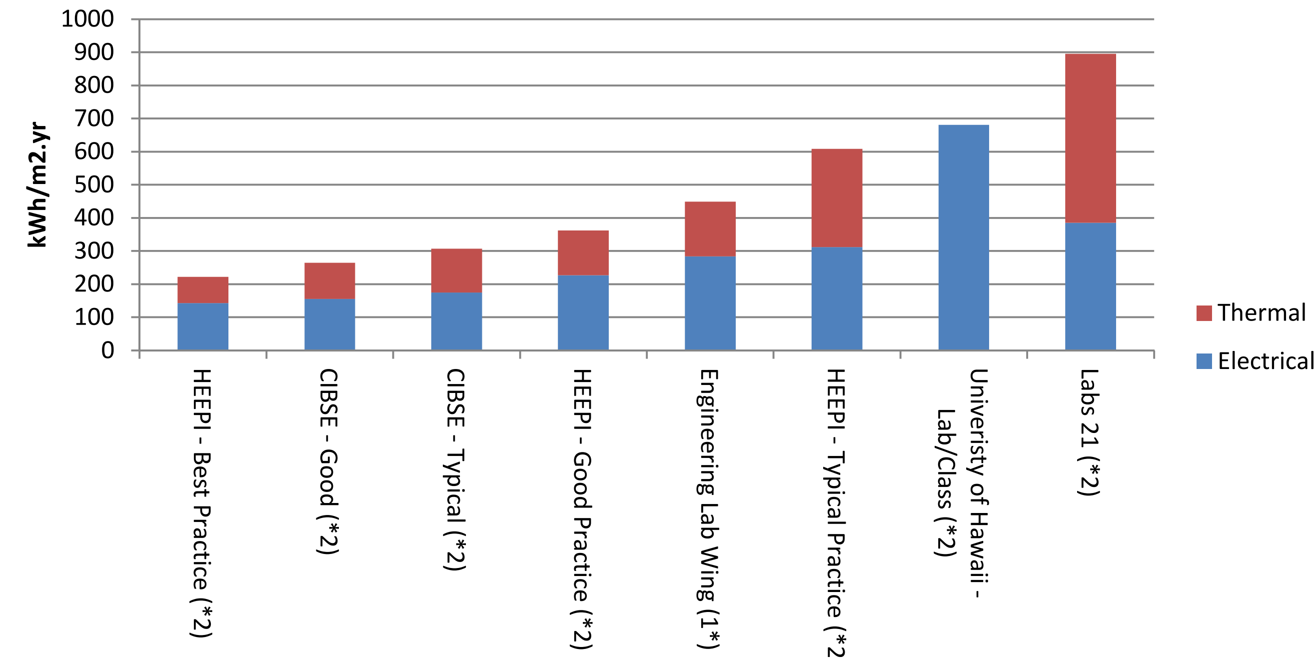


Figure 7-1: Comparison of EUI fro selected University Campuses

7.3 Laboratory Buildings

UVic's Engineering Laboratory Wing uses nearly 50% less energy than Lab 21 buildings and 25% less energy than lab buildings designed to HEEPI's typical practice benchmark. Engineering Laboratory Wing (ELW) consumes over 40% more energy than buildings designed to international 'good and 'best' practice benchmarks.



1* - Actual measured data; 2*-Benchmarks

Figure 7-2: Laboratory Building Energy Use Benchmark Comparison

7.4 Classrooms

While very few buildings at UVic solely contain classrooms, buildings such as Human and Social Development (HSD), and Social Sciences and Mathematics (SSM) containing mostly classroom space, provide an indication of performance and are comparable with international Good Practice. SSM consumes 50% more energy than international Best Practice, and HSD nearly 60% more.

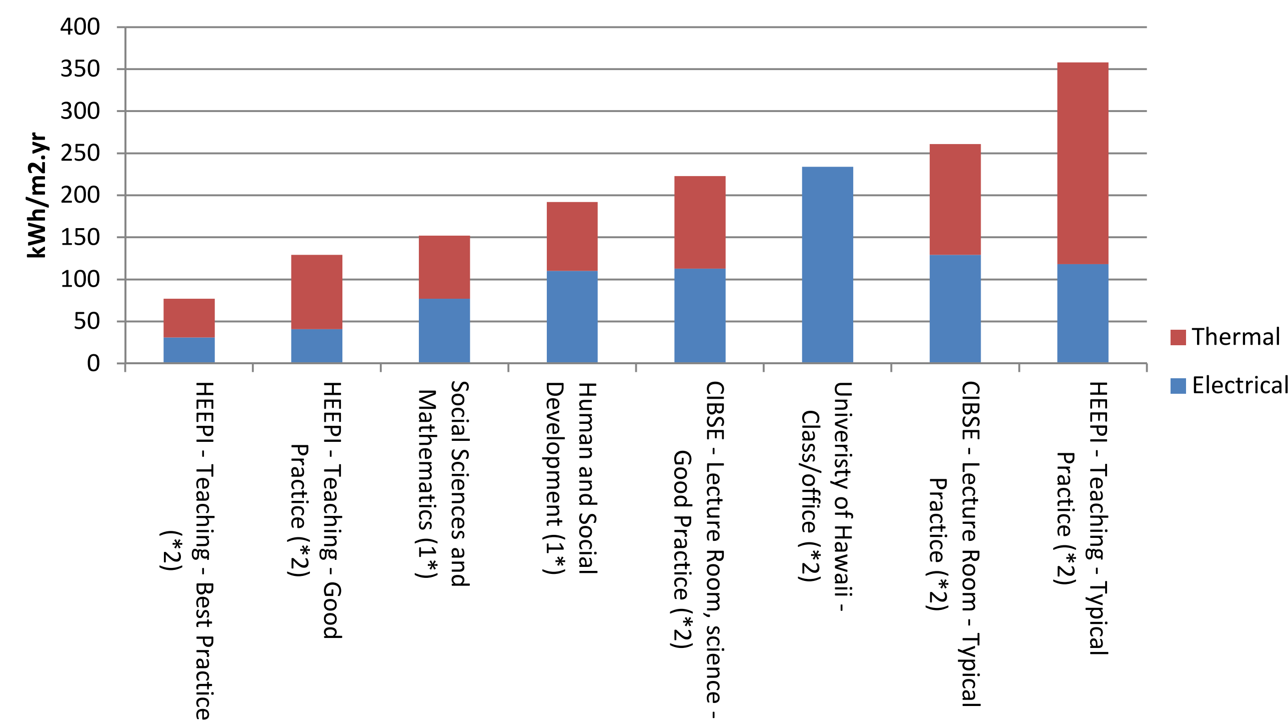


Figure 7-3 Classroom Building Energy Benchmark Comparison

7.5 Libraries

The energy use of the Mearns - McPherson library at UVic is comparable with international 'typical' practice benchmarks for naturally ventilated buildings and nearly 55% better than typical air conditioned libraries in the UK, as indicated by CIBSE benchmarks.

The Mearns-McPheson Library consumes 25% more energy than international Best Practice benchmarks.

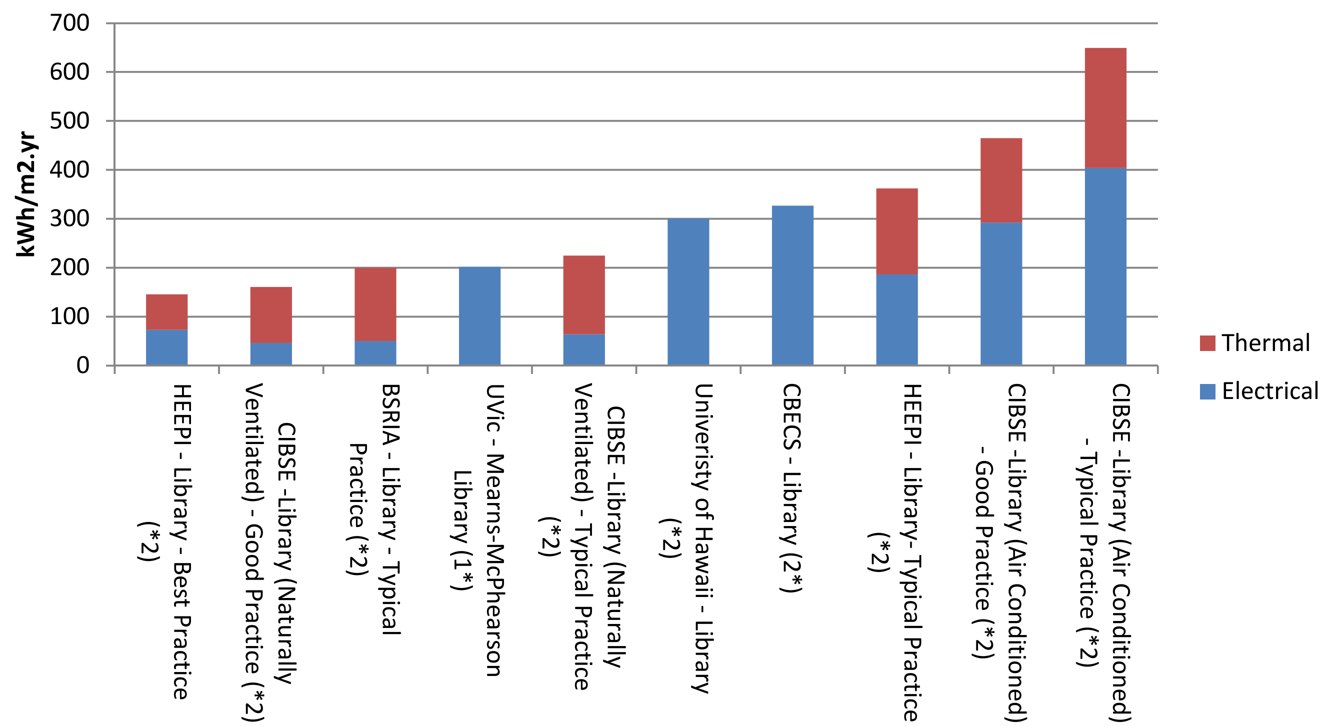


Figure 7-4 Library Building Energy Benchmark Comparison

8 NEW CONSTRUCTION DESIGN APPROACHES AND BENCHMARKS

8.1 Introduction

Buildings use energy to operate systems which provide space heating and cooling, ventilation air tempering, domestic hot water heating, lighting and run various types of electrical equipment from computers to refrigerators.

Reductions in the amount of energy used by new and renovated buildings can be achieved through the use of optimal design approaches and best practice passive design strategies, whilst still providing occupant comfort.

Whilst the special characteristics of each building types will require specific energy use reduction targets, the following generic energy use reduction hierarchy can be applied across all building types:

1 Use less energy – reduce energy demand by applying passive design principles
2 Use energy efficiently – Reduce energy use by incorporating efficient active systems
3 Use of low and zero carbon sources of energy – Reduce dependence on grid based fossil fuel derived energy

A significant of typical building energy use is related to maintaining the building interior at comfortable thermal state and providing ventilation for the building occupants.

Passive design is an approach to building design that uses the building architecture to minimize energy demand and improve thermal comfort. The building form and thermal performance of building elements (including architectural, structural, envelope and passive mechanical) are carefully considered and optimized for interaction with the local microclimate. The ultimate vision of passive design is to fully eliminate requirements for active mechanical systems (and associated fossil fuel-based energy consumption) and to maintain occupant comfort at all times. Where mechanical assistance is required to maintain thermal comfort, energy efficient systems that compliment passive design strategies should be incorporated.

This section presents the design approaches and passive and active strategies which can be used to achieve this vision, describes their application to buildings in Victoria's climate and how they can be incorporated into a new construction building technical guideline.

8.2 Optimal Design Approaches

Through properly applied passive design principles, we can greatly reduce building energy requirements before we even consider mechanical systems. Designs that do not consider passive thermal behavior must rely on extensive and costly mechanical HVAC systems to maintain adequate indoor conditions, which may or may not even be comfortable. Furthermore, even the most efficient technologies will use more energy than is necessary with a poorly designed building. To successfully implement the passive design approach, one must first accomplish the following:

- Understand and define acceptable thermal comfort criteria.
- Understand and analyze the local climate, preferably with site-specific data.
- Understand and establish clear, realistic and measurable energy use performance targets.

This section presents these and other approaches which should be considered when designing energy efficient, sustainable buildings.

8.2.1 Thermal Comfort

Thermal comfort refers specifically to our thermal perception of our surroundings. The topic of thermal comfort is a highly subjective and complex area of study. Through passive design, we can impact four indoor environmental factors that affect thermal comfort:

- Air temperature
- Air humidity
- Air velocity
- Surface temperatures
-

Each factor affects thermal comfort differently. The factors most commonly addressed in the conventional design process, air temperature and air humidity, in fact affect only 6% and 18% of our perception of thermal comfort, respectively. To take a more effective comfort-focused approach, we must also consider the air velocity and the temperature of surrounding surfaces, which account for 26% and 50% of thermal comfort perception, respectively.

The effectiveness of passive strategies at achieving thermal comfort, particularly to avoid overheating during the summer months, depends on the range of acceptable thermal comfort parameters set for the project.

There are two main approaches to specifying the comfort conditions.

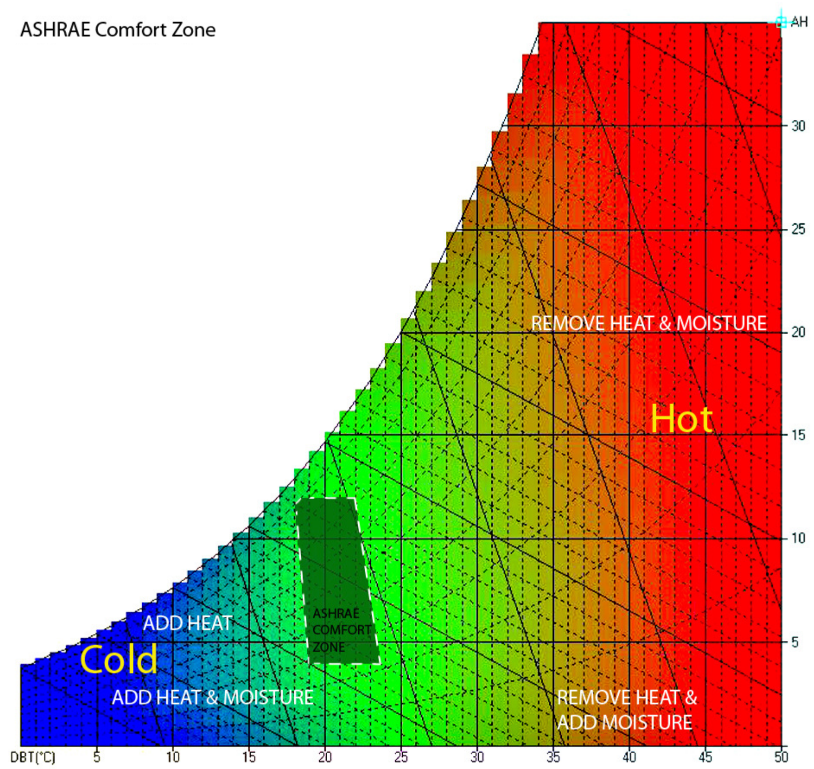
1. Deterministic methods (e.g. Fanger)
2. Adaptive methods (e.g. Brager and de Dear)

The deterministic methods relate given space conditions, such as occupant clothing, temperature to the likely level of space comfort, whereas the adaptive approach relates acceptable space comfort to the outside conditions and uses people's ability to adapt to their surroundings by adjusting their clothing. Both models typically express the level of thermal discomfort as a percentage of persons dissatisfied (PPD).

Deterministic methods, like the Fangar Model, suit the conventional approach well with typical heavy reliance on active mechanical systems regardless of the outdoor climatic conditions. This can also lead to unnecessary energy consumption. Furthermore, this simplification does not account for the temperature of surrounding surfaces which is the dominant factor affecting thermal comfort.

The Adaptive Model correlates variable outdoor conditions with indoor conditions and defines comfort with a wider range of thermal parameters, making it more suited to buildings with passive features and natural ventilation. In the mild Victoria climate, passive buildings can maintain acceptable thermal comfort within the parameters of the Adaptive Model for the majority of the year, with the exception of the coldest outdoor temperatures during winter.

Many adaptive models have been developed to define zones of comfort, combining the effects of all four environmental variables affecting comfort.



8-1 ASHRAE Comfort Zone

8.2.2 Local Climate

Understanding the local climate is the foundation of energy efficient building design. It guides the selection of appropriate passive design strategies and affects the extent to which mechanical systems are needed to maintain comfort.

As discussed earlier in this report, Victoria has a temperate climate with mild temperatures and moderate humidity levels year round. Summers are pleasantly warm and dry and winters are relatively mild with high levels of precipitation. The following table shows the average minimum and maximum air temperatures for Victoria during the coldest month (January) and the hottest month (August).

January		August	
Average Minimum	Average Maximum	Average Minimum	Average Maximum
0.5°C	6.2°C	13.2°C	21.9°C

8.2.3 Energy Performance Targets

Establishing building energy performance targets in clear and measurable terms is a fundamental prerequisite of energy efficient building design. This can be achieved using existing benchmark data and also developing site specific benchmarks through energy modelling.

An energy benchmark range can be developed to allow gradual implementation and give direction to designers.

8.2.4 Integrated Design Process

The integrated design process (IDP) ensures all issues affecting sustainable performance are addressed throughout the building design process, from concept design to occupancy. It is most critical to implement IDP at the early stage of the project when issues can be addressed with minimal disruption through consistent and coordinated collaboration between all the disciplines and the team members.

An experienced design team, who have a coherent understanding of the project targets and design intent, and who place energy performance as a key driver of the design rather than as an add-on will have the best opportunity to meet the financial targets as well as energy targets.

8.2.5 Optimal Space Programming

Most of the buildings include spaces with different occupancy patterns, uses and indoor temperature control requirements. The logical and efficient placement and location of these spaces with respect to their optimal functional arrangement is referred to as Functional Space Programming.

Functional programming is one of the key elements that can also affect the energy performance of every building in addition to the optimal functional arrangement. Locating spaces in their ideal thermal location in the building reduces mechanical heating and cooling energy and reduce glare and improve comfort by taking advantage of the building's natural responses.

In the Victoria climate, optimal space programming typically means:

- Cooling dominated spaces should be located to the north or east or in the centre of the building to reduce or eliminate solar gain.
- Heating dominated spaces should be located on the south and west elevations. However, overexposure should be avoided through the use of effective external shading

The following example will elaborate effects of proper/improper programming on the building energy use.

Almost every Academic building has a requirement for Data/Communication and Electrical rooms. These rooms are typically the location for the servers, AV racks, control panels, MCC panels and Step down transformers. The common characteristic of all these equipment is the heat generation or in other words, these units require considerable amount of cooling energy year round to be maintained at their normal operating temperature (normally less than 30°C).

By locating this cooling dominated space on the north elevation of the building, the cooling energy requirements can be minimized since there will be no adverse solar impact and the heat loss through the exterior walls will reduce the cooling load by a considerable amount. If the room was located at the south or west elevation, all the solar gains would've worked against the load characteristics of the room resulting in excessive cooling energy requirements.

Optimal Space Programming is one of the key no-cost initial best practice strategies for building energy use reduction. By following the simple rules of optimal space programming during the early stages of design, design teams can significantly reduce a building's energy consumption.

8.3 Passive Design Considerations

Passive building elements should be designed to respond to the local climate in ways that reduces the amount of mechanical energy required to provide thermal comfort indoors. Passive features that are well integrated will also reduce the peak thermal demands of building as well. The main variables which influence passive design strategies and typical passive features are described below.

8.3.1 Building Shape and Massing (Form)

The building shape and massing plays a significant role in the overall energy performance and occupant comfort because the envelope surface area affects the amount of heat that is lost or gained through the envelope. The ratio between the envelope area and the useable floor space or volume is the compactness of the building. In climates with extreme hot and cold conditions, a more compact building will have lower rates of heat loss and gain than a building which is more spread out, in winter and summer respectively. The result is lower annual energy consumption for both space heating and space cooling.

However, as with many passive features there is a tradeoff, and in this case the compact building form has a negative effect on availability of day lighting and natural ventilation. Natural ventilation strategies depend on adequate cross ventilation through the space, which functions more effectively in a narrower building profile, which is a often a less compact building form. These impacts can be mitigated through design by using skylights, for example, or atriums to promote adequate air circulation.

8.3.2 High Performance Facades and Glazing Areas

Effective thermal insulation is the most critical design parameter of building envelope. It reduces the rate of heat losses and gains to and from the outside. The rate of heat losses and gains through the envelope is a function of the thermal resistance, R-Value, and the overall heat transfer coefficient, U-Value of the envelope. Minimum R-Values and maximum U-values are prescribed by the ASHRAE 90.1 and MNECB energy standard for buildings.
Thermal insulation also impacts the surface temperature on the envelope interior, which directly Impacts thermal comfort by both radiant and convective heat transfer. In addition to their impact on comfort, interior envelope surface temperatures must remain high enough during winter to avoid condensation and maintain the integrity of the assembly and materials over time.

The glazing to wall area ratio is the ratio of transparent glazing to the total wall area of the envelope. The amount of glazing affects the building in two ways:

- Solar radiation is transmitted directly to the space through glazing where it gets trapped inside, heating the interior surfaces of the space. This is beneficial and desirable during winter (heating season) and undesirable during summer (cooling season), when it results in overheated spaces.
- The insulating value of glazing is poor compared to opaque assemblies and the amount and quality of glazing affects the amount of heat that escapes from or is trapped inside the building.

As such, the size and location of windows affects the heating and cooling necessary in the spaces. As the sun travels across the sky during the day, different building exposures are affected by the changing solar gains differently.

Architecturally, windows must be placed to enhance occupant comfort and aesthetics and provide daylighting by diffusing light with minimal glare.

Typically the requirements of heating and cooling, aesthetics and daylighting are in conflict; energy model simulations help us to strike a balance between them.

8.3.3 Solar Shading

External solar shading includes the use of overhangs, blinds, louvers, trellises, or anything else that blocks the sun's rays from entering the building through glazing and heating the building envelope.

Interior solar shading features, typically internal blinds, are any material that is used to block the sun's rays on the interior side of the windows. They are effective at reducing glare in the space but ineffective at eliminating solar heat gains reaching the space.

The distinction between internal and external shading is important because although both systems block solar radiation, they have different effects on the building thermal load, aesthetic, day lighting, comfort, and mechanical system performance.

When used on transparent envelope assemblies (i.e., glazing), shading reduces the amount of direct solar gain in the space, reduces both the external and internal surface temperatures of affected windows, floors and walls, and reduces glare in the space, while still allowing adequate daylighting.

Interior shading also blocks the sun from penetrating into the conditioned space; however the heat energy is still transmitted through the window assembly. Once within the building envelope, this energy heats the internal surface of the glass and the interior shade. The warm surfaces will heat occupants through radiant and convective heat transfer and if mechanical cooling is used, this heat energy needs to be removed by the system.

Effective shading design requires a balance between admitting desirable solar gains in the winter and blocking off undesirable solar gains in the summer. The optimal shading strategy would be adjustable for different times of the year.

Fixed external shading features should be designed to admit low-angle winter sun and block high angle summer sun.

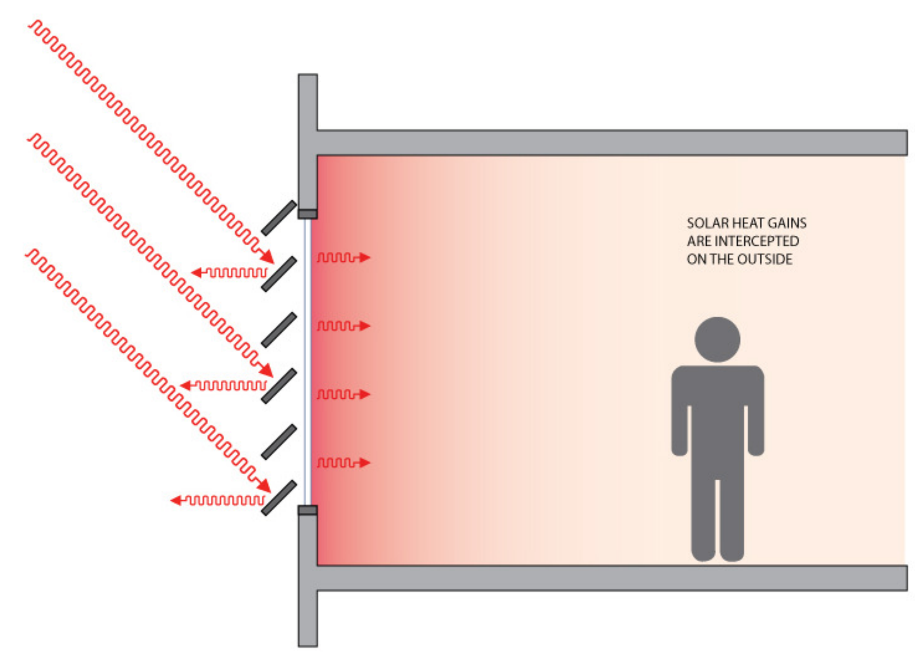


Figure 8-2 Benefits of solar shading

8.3.4 Thermal Mass

All matter has thermal mass, however when used in reference to a building, thermal mass generally means materials capable of absorbing, holding and gradually releasing heat (thermal energy). Thermally massive materials absorb heat and slowly release it when there is a temperature difference between the mass and the surrounding space. When incorporated in a wall, for example, the mass acts as a heat sink, absorbing the heat and slowing its transfer through the wall.

Heavy, dense building materials with high specific heat capacity like stone, concrete or brick have high thermal mass. Lightweight porous materials such as wood, insulation, and glass have low thermal mass. During summer, thermal mass exposed to the interior absorbs heat from the space, including solar gains and lowers the load on the mechanical cooling system. The natural energy conservation benefits of a building's thermal mass can be further extended by appropriate combination with other passive or active strategies such as nocturnal cooling by natural ventilation or low intensity radiant slab heating/cooling systems, respectively.

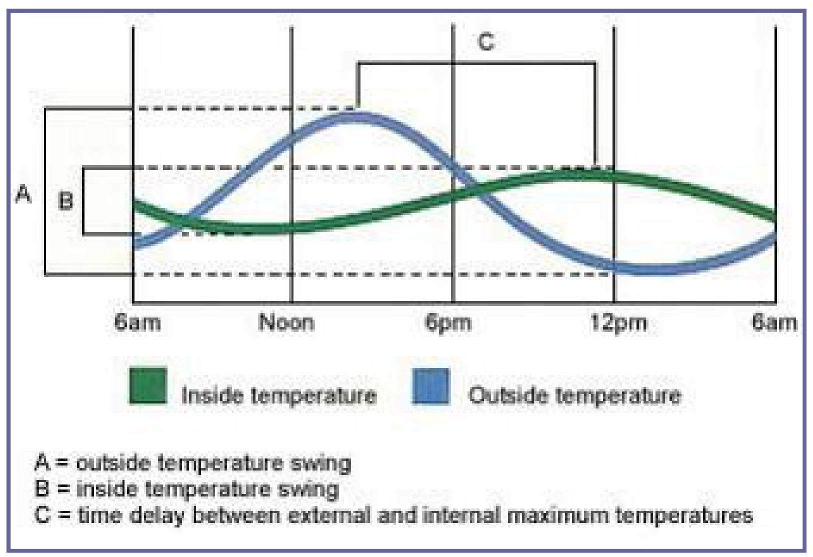


Figure 8-3 Effect of Thermal Mass on Building's Indoor Thermal State

8.3.5 Nocturnal Cooling by Natural Ventilation

In Victoria's mild climate, summers are characterized with sufficiently large "diurnal" temperature fluctuations that present an opportunity for passive nocturnal cooling by natural ventilation. This passive cooling strategy works best in combination with high mass buildings, where the mass can be cooled overnight and then act as a heat sink to absorb heat during the day.

Natural ventilation is encouraged overnight to remove heat accumulated in the building mass during the day. The cooler night-time air flushes and cools the warm building structure/mass. The natural ventilation can be mechanically assisted with exhaust fans. In the morning, the occupants come into a building that is already pre-cooled. This system is best applied to buildings with high daytime use and low night time use.

Ideally, the cool night-time air will be introduced at low level with the relief/exhaust high in the building to allow the hot air to rise as cool air replaces it below.

8.4 Active Building Systems Considerations

Active building systems are the in-building systems with the primary role of maintaining space conditions within the design and comfort parameters. The design and application of highly efficient active systems is linked to the passive measures incorporated and the available sources of energy. Active system selection is relevant to individual building systems and campus wide energy systems. There are also several key choices related to identifying the most appropriate active system configuration, for both individual building systems and campus wide energy applications, as follows:

8.4.1 Heating Only vs. Heating and Cooling

UVic have a preference for heating only within buildings, but also expect internal thermal comfort conditions to be achieved. For spaces with high internal gains, the narrow range defined in ASHRAE will typically require the use of active mechanical cooling which in turn uses additional energy.

The intent to restrict mechanical cooling to those spaces where the need has been demonstrated, such as lecture theatres, should be explicitly defined in all tender documentation so designers of future buildings have a clear brief from the beginning.

By accepting a wider range thermal comfort temperatures (refer to 8.2.1 above for information) the need for mechanical cooling may be eliminated from the majority of building occupancy types as per UVic's intent, and reduce the cooling load in buildings where cooling is deemed required.

8.4.2 Forced-Air vs. Hydronic

Forced-air systems represent the most conventional HVAC system choice in North America. They provide a combination of space heating; cooling and ventilation function in a single package and rely on recirculation of relatively large air volumes to function properly.

Hydronic systems use water to transfer energy from the heating/cooling source to the space heating/cooling emitter. Hydronic systems are more energy efficient at transferring energy from source to point of use since water (liquid) has significantly higher density and volumetric heat capacity than air (gas). Because of this better heat capacity, the volumetric flow of water required to transfer a given amount of energy is significantly less than air, resulting in smaller pipes which allow easier integration into complex buildings, and reduce pumping energy providing energy savings when compared with fan energy used by a forced-air system of equivalent capacity.

Therefore, energy can me moved over long distances using water with greater efficiency, providing opportunities to deliver energy to buildings form outside the building's footprint.

Hydronic systems should be chosen above forced air systems for heating/cooling purposes where possible.

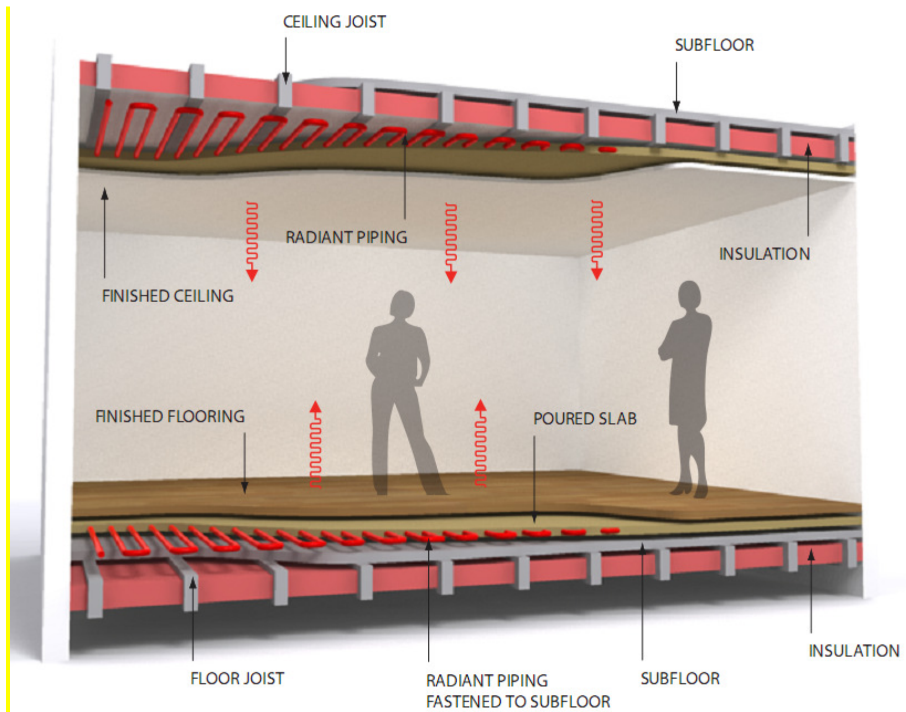
8.4.3 Space Heating/Cooling "Emitter" Choice

The selection of the heating/cooling emitter is dependent on a number of factors including the proposed use of the space, the system type and the exergy (Energy quality) of the available energy.

Convection emitters (relying on natural convection, such as baseboard heating element, or forced convection such as fan coil) rely on the tempering of air to deliver heat to a space. The convection based heating and cooling systems are affected by natural air stratification or sudden pressure gradients caused by opening doors, windows, etc. potentially producing an uneven temperature pattern across a room.

Convection systems typically require medium to high grade heat, i.e. higher heating water temperature which requires the use of more conventional and less efficient heating/cooling sources such as boilers or chillers. The use of electricity for resistance heating is highly undesirable. Electricity is the highest grade (form) of energy available, and demand grows faster than sustainable production capacity (i.e. majority of new power generation plants are fossil fuel based) and an increasingly larger proportion of complex technologies depends on it. Therefore, the use of electricity for resistance heating is not compatible with a modern sustainable perspective and should not be considered for new construction or renovation.

Radiant emitters, such as radiant floor or ceiling heating/cooling rely on actively tempered (heated or cooled) surface to deliver the heating or cooling to the space by radiant heat transfer. Radiant emitters required low grade heat i.e. lower water temperature which can be generated with higher efficiency and/or by low grade waste or renewable energy sources.



8.4.4 Ventilation System Choice

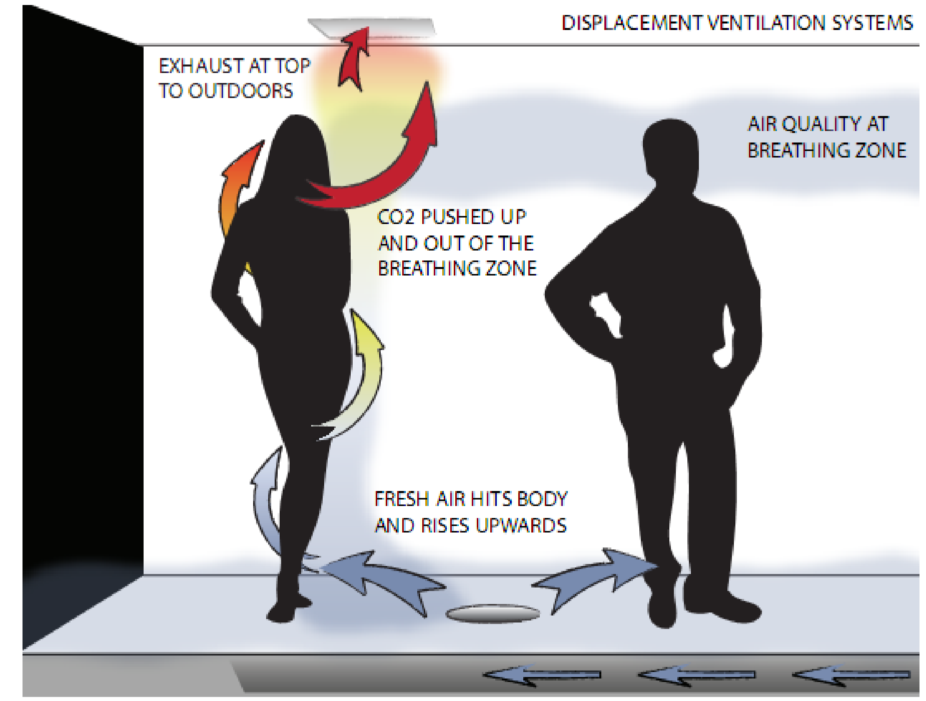
The conventional 'dilution' type ventilation associated with forced air HVAC systems typically provides large volumes of air with the combined function of room temperature (comfort) control and the supply of fresh air for ventilation. In these systems only a relatively small fraction of the overall air flow is fresh outdoor. As described above, the use of air to heat a space is less efficient that hydronic. A large amount of fan energy is required to move the air volume around the building.

An alternative system is a dedicated outdoor air system 'DOAS', which supplies only the relatively small volume of fresh air from outside to meet ventilation requirements, and is installed in parallel with some other space heating/cooling system. The size of the system is kept to the code minimum, 10l/s per person or less, so spaces are not over ventilated. A DOAS system does not provide space heating but has the ability to provide supplementary free cooling when external air temperatures allow, potentially reducing the need for a dedicated cooling system. A version of DOAS where ventilation air is supplied at low level, low velocity and temperature and exhausted at high level is termed displacement ventilation.

The inclusion of energy recovery systems at the point of air exhaust such as plate heat exchangers and run-around coils can further reduce energy use, see section 8.9.6 below.

Reducing a ventilation system's pressure loss can offer energy savings through reduced fan power and greater heat exchanger efficiency. This can offer significant savings in laboratories due to the high ventilation rates. The corresponding increase in ductwork size and air handling unit (AHU) elements will have a cost impact but experience has shown the payback is within 3-5 years[5].

The zoning and control of any ventilation system should be considered during the design process. Providing zone control (demand ventilation) and variable speed drives on the fans can help to reduce energy when sections of buildings are unoccupied.



8-4 Effects of Displacement Ventilation

8.4.5 System Operating Temperatures

Systems should be designed to operate at temperatures as close to the specified internal conditions as possible to maximize system operating efficiency. This also promotes the use of low grade energy sources which offer further opportunities to improve overall building energy performance.

8.4.6 System Energy Recovery Ability

Systems which can recover otherwise wasted/exhausted energy from within a building or neighbouring building will reduce a building's energy demand. The ability of a hydronic system to efficiently transfer energy over large distances with minimal spatial requirements provides great flexibility in recovering and re-distributing energy throughout a building and even a campus.
Another example of recovering energy is the provision of heat recovery in a ventilation system, for example, can significantly reduce the heating demand required to preheat incoming air, with typical efficiencies of 55%-75%. Energy recovery should therefore be incorporated where high ventilation rates

[5] Lab21 Design guide : http://ateam.lbl.gov/Design-Guide/DGHtm/reducingahupressuredrop.htm

are required for other purposes. Certain types of heating/cooling systems cannot incorporate energy recovery mechanisms which may influence their selection.

8.4.7 System Level Expandability and Integration

The ease with which a system can be expanded and adapted will be an important factor for building types and uses. Most hydronic systems typically provide more flexibility and better opportunity for expansion than forced air systems.
A system's ability to accommodate different sources of energy should also be considered. Hydronic systems offer a high degree of source flexibility, from central plants consisting of boilers and chillers to heat pumps, and combined heat and power units. Packaged systems, such as refrigerant based DX or VRF systems, can only accommodate the refrigerant and controls systems they have been designed to use.

8.4.8 Low grade Renewable Energy Sources

The available on-site, low-grade renewable energy sources and/or waste streams of energy should be assessed and harnessed to minimize the need for fossil fuel and electricity as much as possible. A need to apply appropriate energy efficient heating and cooling systems which are well matched with the identified renewable energy sources is required.

8.4.9 Controls

Optimized design and integration of control systems can further enhance the energy reduction capabilities of passive and active systems. For example, CO_2 detectors can effectively track the actual building occupancy levels control the ventilation system to suit. An efficient controls strategy is very important when energy recovery features are being integrated into buildings to maximize the potential savings.

8.4.10 Measurement and Verification (M&V)

Providing proper Measurement and Verification (M&V) systems for building mechanical, electrical and plumbing systems will help to reduce operating costs, air and water pollution and resource depletion through constant feedback of the building systems operation. Heating and ventilation system will also assist with optimizing energy performance and the re-commissioning and preventative maintenance efforts.

Work is currently under way to add measurement and verification retrospectively to all existing buildings linked to the existing heating loop but it is important that metering is integrated into all new and renovated buildings as the Business as usual scenario. This will allow future benchmarking of individual building's energy consumption, help indentify energy pigs quickly, and allow swift identification of building's operating outside of their energy consumption tolerance.

8.4.11 Electrical and Lighting Systems

A building's lighting and plug load electrical energy use will begin to dominate as the heating load and energy use is decreased. The integration of efficient electrical equipment and controls will therefore become increasingly influential.

The provision of occupancy and daylight sensors will reduce the lighting hours of operation by responding to how the building is used and external daylight levels. Efficient lighting fixtures will further reduce the lighting load.

Eliminating 'parasitic' plug loads will reduce the electrical load of a building and can be achieved through the use of "kill" switches and changing human behaviour. The use of efficient equipment such as laptops will further contribute to reducing the plug load in a building.

8.5 New Construction and Renovation Technical Guidelines

8.5.1 Introduction

Producing a design guideline document will allow UVic to define mandatory performance and prescriptive requirements for the design, construction and renovation of University-owned institutional buildings, incorporate many of the design principles stated above, and support and direct designers to meet UVic's requirements. The document can be applicable to all building types on UVic's campus including housing, athletics and institutional buildings, along with landscape and infrastructure.

A guidelines document can also outline the principles behind the requirements, and include: performance objectives, technical requirements, and other UVic-specific requirements for all campus buildings, recommended practices based on the experience of UVic professionals, project documentation requirements, UVic code-related issues, sample front-end documentation, plus steps to follow to expedite completion of UVic projects.

Requirements for LEED certification and energy performance will be a key element of any guideline document for UVic and could be incorporated into a dedicated "Sustainability Section". The Province of British Columbia's Energy Efficient Building Strategy (2008) requires all new government buildings and facilities, and major renovations, to achieve and certify to LEED Gold Performance or equivalent certification. UVic may wish to require a minimum number of points for certain credit and a guideline document will provide the ideal document in which to describe this requirement.

A number of key design approaches and strategies that can be incorporated into a future technical guideline style document are described in the following sections. This is not an exhaustive list but provides examples of how the key design approaches and strategies described earlier can be incorporated into a guideline document for application to new and renovated building design at UVic.

8.5.2 Reference to Best Practice Strategies

The guideline document should promote the reduction of a building's energy demand through the following generic energy hierarchy, which can be applied across all building types.

1. Use less energy – apply passive design principles
2. Use energy efficiently – incorporate efficient active systems
3. Use of low and zero carbon sources of energy

The best practice strategies and design approaches described above should be referenced in the technical guideline for consideration by designers. Any specific sustainability guideline should be explicitly referenced in the Technical Guidelines for designers to refer regarding applicable passive design systems.

8.5.3 Functional Space Programming

An important strategy that is highly relevant for buildings at UVic is functional space programming, and should be highlighted in the Technical Guidelines.

Locating spaces in their ideal thermal location in the building reduces mechanical heating and cooling energy by taking advantage of the building's natural responses. Functional space planning can also reduce glare and improve comfort.

In Victoria's climate, functional space programming typically means:

i. Cooling dominated spaces are located to the north or in the centre of the building to reduce or eliminate solar gain.
ii. Heating dominated spaces are located are located on the south and west elevations. However, overexposure should be avoided through the use of external shading

Functional space programming should be considered by designers during the initial stage of design of all building types at UVic.

8.5.4 Adaptive Thermal Comfort

Designing buildings to achieve adaptive thermal comfort criteria is a key element to realizing significant energy savings and should be clearly defined for designers in the Technical Guidelines.

UVic buildings are generally not air conditioned; however, thermal comfort still needs to be achieved and maintained.

The four main environmental thermal comfort factors that can be affected by implementing passive design strategies in a building are:

i. Air temperature
ii. Air humidity
iii. Air velocity
iv. Surface temperatures

Designers shall take all factors into consideration during the design process.

Adaptive thermal comfort principles, set out in ASHRAE 55-2004, shall be applied to achieve thermal comfort, and particularly to manage the risk of a building's occupants overheating. The table below defines the internal temperature criteria to be used in the design process.

Victoria's temperate climate, with mild temperatures and moderate humidity levels year round, allows the humidity in a space to be uncontrolled, unless specific humidity conditions are required for the proposed space use, such as laboratories.

Certain spaces may require mechanical cooling such as large classrooms, lecture theatres and IT suites where design indicates that internal heat gain will result in unacceptable conditions, i.e. the passive cooling internal temperature defined in the table below **cannot** be achieved. The mechanical cooling system shall be designed to meet the criteria set out in the table below.

Laboratory spaces shall be maintained at room temperature (23°C - 25°C) and must generally satisfy the criteria in table below unless the functionality of the space dictates otherwise. During the shoulder seasons cooling can generally be achieved through the high ventilation rates required by Code.

	Space Type			
	Offices	**Classrooms**	**Large Classrooms+**	**Laboratories**
Heating	20°C - 23°C	20°C - 23°C	20°C - 23°C	23°C ± 2°C
Passive Cooling	Internal temperatures to not exceed: - 25°C for 5% of occupied hours - 28°C for 1% of occupied hours	Internal temperatures to not exceed: - 25°C for 5% of occupied hours - 28°C for 1% of occupied hours	Free cooling	Free cooling
Mechanical Cooling	N/A	N/A	$Ti \leq To - 5℃$	$Ti \leq To - 5℃$

+ Large classrooms and lecture theatres typically accommodate >70 people.

Table 8-1 : Recommended internal temperature conditions to achieve thermal comfort

Where conditions require air-conditioning (apart from those defined above), the design team shout be requested to submit for variance from this guideline as part of the initial submission of project design philosophy.

8.5.5 Building Envelope

Significant reductions in thermal energy use can be achieved by improving the performance of the building envelope. To realize these potential energy savings, a minimum prescriptive performance should be defined by UVic.

Consideration should be given to asking designers to incorporate building envelopes that perform better than the 'Code Minimum Envelope Performance' at the time of design. To support UVic's desire to achieve energy intensity equivalent to international Best Practice Benchmarks, the initial target for building envelope performance should be set at a minimum of he building's envelope performance shall be 25% better than the minimum performance defined in the current Building Code. The code reference to be used as the baseline should be continuously updated with the most onerous version. For example, the reference to Building Code should be replaced with MNECB 2011 once it is published.

8.5.6 Low Flow Fume Hoods and occupancy controlled ventilation.

Laboratory spaces at UVic have been identified as high energy consumers due to the high ventilation load serving the fume hoods and the minimum ventilation rate required in labs.

Specification of low flow fume hoods can significantly reduce the energy use of laboratory spaces and should be considered on all future laboratory building projects at UVic.

Low flow fume hoods are designed to use a lower face velocity, typically 0.3 m/s (60 fpm), and still meet all safety legislation. UVic policy should be to use of modern fume hoods and initiate dialogue with WorkSafe BC to understand how the specification of low flow fume hoods can meet current safety legislation.

The second element relates to the control the minimum ventilation rate in labs based on occupancy. When labs are unoccupied the background, the ventilation rate should be reduced by 50%, provided the current safety legislation can be met.

8.5.7 Indoor Light levels

Reducing electrical energy consumption by not over-illuminating spaces beyond what is required for the task is a key strategy for new and renovated buildings. Currently, UVic do not specify specific lighting levels for their buildings but could be explicit to designers through a guideline document.

As a general rule, the following task lighting levels shall be used:

1. Offices 300-500 lux maintained.
2. Classrooms and Seminar Rooms 300-500 lux maintained.
3. Corridors 100 lux maintained.
4. Washrooms 150 lux maintained.

A second method to reducing the electrical energy consumption relating to lighting is to promote the use of daylighting and individual task lighting which is locally controlled by the user, allowing the remaining space to be designed to achieve a lower ‘background’ level of lighting. E.G. provide background lighting at 200 lux and individual task lighting for each user to supplement the background light level.

8.5.8 Reducing Plug Load

It is relatively easy and cost effective to achieve significant reductions in heating energy in climates such as Victoria’s using current construction methods and materials. In buildings where the heating load has been reduced, the plug load typically becomes the dominant factor. Potential strategies could be highlighted in a guideline document for consideration and implementation by designers such as:

1. Users should be encouraged to switch off PCs overnight
2. Provide ‘Kill switches’ for non essential peripherals
3. Install local metering to monitor electrical use within departments – allows incentives to be introduced
4. Hot desking, remote working and 24-hour use restricted to small areas
5. IT strategy to allow servers to ramp down under part load
6. Consider the use of laptops throughout offices and classrooms
7. Off-site internet based cloud computing systems
8. Renewable systems that generate on-site electricity, such as photovoltaics, should be considered to offset the electrical equipment and plug loads.

8.6 Summary

Future growth at UVic's Gordon Head Campus will make achieving carbon reduction targets much harder; therefore, the goal should be for all new buildings to be as energy efficient as possible.

Defining UVic's mandatory performance and prescriptive requirements for the design, construction and renovation of University-owned institutional buildings in a clear and concise document will help designers place building energy reduction as a key project requirement, and help UVic achieve their future carbon reduction goals.

Analysis of the development of a "technical guidelines" document is presented in Table 8-2.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Figure 8-5 Technical Guidelines Document Assessment

8.7 Recommendations

- Develop a clear and concise document comprising or prescriptive requirements and mandatory performance.
- Develop energy use intensity benchmarks for key building types at UVic to act as energy targets for designers of all new and refurbishment projects at UVic.

9 ENERGY REDUCTION OF EXISTING BUILDING STOCK AND CAMPUS HEATING SYSTEM

9.1 Introduction

Even with UVic's plans for future development, the vast majority of the floor space existing in 2020 has already been built. Therefore, it is critical for the energy consumption of UVic's existing buildings to be reduced, and the efficiency of the existing district heating system be improved.

As per the methodology defined in Section 5, this step should be completed prior to considering potential energy sources, since a smaller building load requires a smaller plant, which in turn reduces capital cost and improved efficiency.

9.2 Continual Optimization

UVic are currently conducting a Continuing Optimization Program, a BC Hydro initiative, with a primary focus to implement low cost operational improvements to buildings HVAC and lighting control systems. The program allows for a re-commissioning of buildings coupled with a detailed energy audit, sub meter monitoring/archiving and software data base analysis.

BC Hydro provides funding to conduct an audit to determine the most cost-effective measures to bring our building's operation up to optimal energy efficiency levels. A list of recommended energy efficiency measures, the implementation costs, the resulting energy savings and the paybacks. Typical annual energy use reductions are in the order of 10% combined from electrical and natural gas.

The University of Victoria's obligation and financial commitment is to complete energy use reduction measures identified that have a simple payback of two years or less. A time frame of over a year will be provided to implement the strategies outlined. A maximum cost of $0.25/ ft2 of the building total gross area has been set by BC Hydro for the available financial incentive cost limit.

An important second component of the program is the utility monitoring for long term sustainability and this monitoring of our electrical and heating systems energy consumption will be included and is a key component of the initiative. BC Hydro will fund the inclusion of a monitoring interface to the existing building electrical and heating systems. The metering data will be key going forward to support the detailed design and integration of new energy efficient systems and energy sources and it is recommended to complete this element as soon as is reasonably practicable.

Phase 1 of the program has recently been completed, and the anticipated energy savings and associated capital costs calculated by SES Consulting are set out in Table 9-1, below. Potential thermal energy use savings of up to 30% have been calculated per building surveyed, and with a very short payback, typically less than three years.

The total reduction of 9,357GJ equates to approximately 5% of the main boiler plant's yearly gas consumption. UVic will be implementing the recommendations over the coming year. Phases 2 and 3 are expected to produce similar results and such significant energy savings across 18 buildings will influence the feasibility of potential campus wide energy sources.

Building	Implementation Cap	Capital Cost	Payback	Estimated Power Smart	Revised Capital Cost	Revised Payback	Project Savings				
							$	GJ	kW	kWh	GHG
SCI	$35,000	$200,023	1.6				$124,026	2,389	330	1,238,500	254
ECS	$24,000	$86,900	2.0				$44,200	1,280	200	341,135	93
DSB	$19,600	$85,127	1.6				$54,553	1,729	238	354,373	125
ELW	$32,000	$131,500	1.3				$101,500	2,860		847,100	212
SSM	$25,000	$35,334	2.4				$14,445	337	156	128,139	26
HSD	$21,300	$69,788	2.5				$28,267	762	201	229,520	56
Total	$156,900	$608,672	1.7	$175,000	$433,672	1.2yrs	$366,991	9,357	1125	3,138,767	766

Table 9-1 Phase 1 - Continuous Optimization Strategy[6]

[6] Recreated from SES Phase 1 Continuous Optimization Strategy, 2011

9.3 Existing High Temperature Heating Loop

The high operating temperature of the existing campus heating loop will hinder the integration of high efficiency technologies and low or zero carbon energy sources. The relatively high number of buildings connected to the loop means lowering the heating supply water temperature will be prohibitively expensive due to the changes required to each building's heating system.

Since the loop will therefore be required to operate at high temperature during the winter months to meet the peak heating demand, the efficiency of the existing boiler plant equipment and the system as a whole should be improved achieve energy savings.

9.3.1 Controls

Whilst the majority of the boiler plant, pumps and valves are connected to some form of direct digital control, there is no feedback loop between a building's heating demand and the heat out put form the main boiler plant at ELW. This was identified in Hirschfield Williams Timmons's Campus Central heating Report, March 2009 and a scope of work outlined to improve efficiency.

The main thrust of the work is for the ELW main heating pumps to be controlled by the building control valves, conserving pumping energy by only providing the minimum flow rate that satisfies all heating demands.

To achieve the required degree of control and potential energy use reduction, a single DDC controls program for the DES would be required, linked to the following control points.

- input of the DES temperature in and out of each building heat exchanger
- input of the DES flow to each building heat exchanger
- input of the supply water temperature to each building from its heat exchanger
- input of each building's supply water set point temperature
- output to modulate the DES control valve to each building heat exchanger
- operating status, temperatures, flow pressure and for each of the ten DES boilers
- operating status for the DES pumps at each boiler plant
- output to control (ON/OFF and speed control) for the DES pumps at each boiler plant
- output to control operating set point temperature for each boiler
- output to control operating set point temperature for supply water from each boiler plant
- controls program to optimize the operation of the DES

Completing the feedback loop between the thermal energy demands of each building the main boiler plant will allow a temperature compensation sequence to be introduced, allowing the loop temperature to be lowered during the shoulder seasons.

There is the potential for the meters being installed as part of the Continual Optimization Program could be used as the flow and temperature inputs, eliminating the need for two sets of energy meters per building, and reducing the capital cost.

The capital cost has been estimated at $150,000 to $200,000, based on a cost of $5,000 - $6,000 per building for the 30 buildings currently connected to the loop. This cost covers the cost of connect new energy meters to an existing Building Management System and refining the control logic.

The provision of local domestic hot water heaters in buildings with high temperature needs (e.g. Lab buildings) and high demand (residential) will allow the loop temperature to be lowered on a more regular basis. The following buildings have been identified as potentially requiring local hot water heaters. The provision of end use energy metering through the Continual Optimization Program discussed in section 9.2 will help to highlight additional buildings with high domestic hot water demands.

Building	DHW requirement
Landsdowne Residential	High DHW Load
Craigdarroch	High DHW Load
Commons	High DHW Load
University Centre	High DHW Load
McKinnon Building	High DHW Load
Petch Building	High DHW temperature required

Table 9-2: Known buildings with specific hot water demand

9.3.2 Central Plant Pumping

Presently the ELW boiler plant handles almost all of the annual campus heating demand. The ELW DES pumps have VFD drives. For various reasons (which have been addressed and resolved) the pumps were not operated as variable speed. This consumed a lot of electrical power. Modifying the control to take advantage of the VFD's should be considered. However, this must be balanced with the advantages of any strategy that reduces the operating DES supply water temperature. This would need to be part of a new central heating controls program

As the other boiler plants provide little annual heating energy, provision of variable speed control to their pumps would save very little electricity.

9.3.3 Boiler Seasonal Shut-Down

By not having to operate the boilers for low demand periods (summer) through offsetting the campus' heating demand using alternative low/zero carbon energy sources is an attractive proposition. Significantly lowering the DES temperatures when the boilers are operating at low demand will likely cause flue gas condensation, which will significantly shorten the service life span of the boilers and potentially cause piping expansion/contraction issues.

Provision of alternate heating for DHW should be considered. However, some science buildings (Cunningham, Petch, Elliott, Bob Wright) have large outdoor air demands that could require heat at least some times in summer. So, removal of the DHW demand alone may not be sufficient to allow shutting down the boilers.

If heat pumps are provided at the central plants or at the buildings then with DHW removed they could provide sufficient "summer" heating capacity at lower supply water temperature.

Some buildings need DHW for cooking or showers so their DHW demand is high. These Buildings are the University Centre, Commons, SUB, McKinnon Gym and Lansdowne and Craigdarroch Residences. Petch uses 80℃ DHW for central lab containers cleaning. For these buildings local condensing boilers and/or solar panels and/or air-to-water heat pumps and/or electric resistance heat could be considered for DHW heating. To keep the capacity of the alternate heaters smaller, larger storage capacity for the DHW should be considered.

For the other buildings the demand for DHW is probably very small – janitorial, hand-washing, science building wash-up. Electric resistance DHW heating could be used where it is not already in use for this.

These options are considered individually in further detail in the following sections.

9.4 Summary

The existing campus heating loop at UVic will provide will remain in operation and operate at high temperature during the winter month. The performance and efficiency of the heating loop can be improved by providing a control feedback loop between all buildings connected to the loop and the central boiler plant. This will help to reduce gas consumption, and reduce the size of any future boiler plant.

Analysis of the heating loop improvements is presented in Table 8-2.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 9-3 Existing Heating Loop Modifications Assessment

9.5 Recommendations

- Install Energy Metering to all buildings connected to the district heating loop. The energy flow meter specification should allow connection to a central building management system.
- Complete all three phases of the Continual Optimization Program
- Provide a feedback loop between all buildings served by the district heating loop eating demand main boiler plant at ELW. Control the heat output from the main boiler plant based on the buildings’ heating demand.
- Provide local heating for domestic hot water for use during summer to allow seasonal shutdown of central boiler plant.

10 ENERGY GENERATION SYSTEMS

10.1 Introduction

The following section describes potential energy saving strategies, their applicability to UVic's Gordon Head Campus, budget cost information, maintenance considerations simple payback calculations. The most feasible solutions will be explored in greater detail in Section 11.

10.2 Revised Baseline

In Sections 9 and 10, it is recommended for all three phases of the continual optimization Program to be completed and the existing heating loop control to be upgraded prior to changing the fuel source at UVic's campus.

The energy savings achieved by making these improvements will help reduce the size of heating plant, reduce the capital cost of replacement, and improve the feasibility. As discussed in Section 9, Phase 1 of the Continual Optimization Program is expected to reduce the central loop's heating demand by approximately 5%, with Phases 2 and 3 expected to produce similar savings.

To account for the energy reduction achieved by implementing the above recommendations in the feasibility analysis of each fuel source, a conservative 10% reduction has been applied to the "baseline" thermal energy consumption of 2009/2010, See Table 10-1 and Figure 10-1

	Baseline Natural Gas Consumption		Adjusted Natural Gas Consumption	
	(GJ)	(kWh)	(GJ)	(kWh)
Apr-09	21,806	6,057,298	19,625	5,451,569
May-09	13,985	3,884,892	12,587	3,496,403
Jun-09	7,050	1,958,405	6,345	1,762,564
Jul-09	4,764	1,323,372	4,288	1,191,035
Aug-09	6,877	1,910,376	6,190	1,719,339
Sep-09	15,381	4,272,784	13,844	3,845,506
Oct-09	16,299	4,527,703	14,670	4,074,933
Nov-09	22,252	6,181,272	20,027	5,563,145
Dec-09	30,156	8,376,817	27,141	7,539,135
Jan-10	22,187	6,163,355	19,969	5,547,019
Feb-10	19,955	5,543,211	17,960	4,988,890
Mar-10	22,207	6,168,660	19,986	5,551,794
Total	202,923	56,368,145	182,631	50,731,331

Table 10-1Revised Natural Gas Consumption Baseline

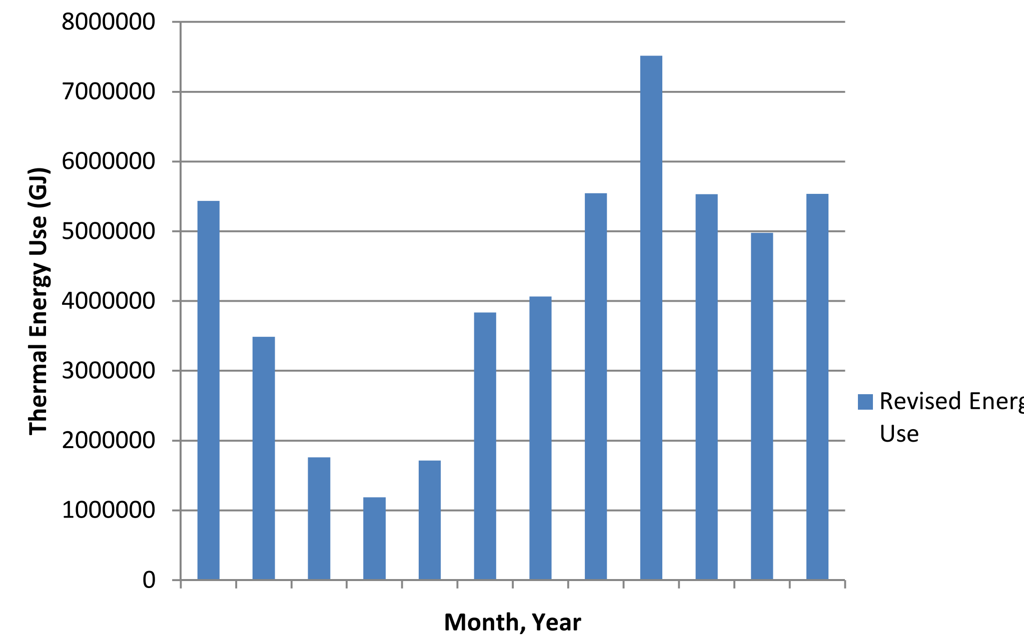


Figure 10-1 Revised Thermal Energy Baseline Use Profile

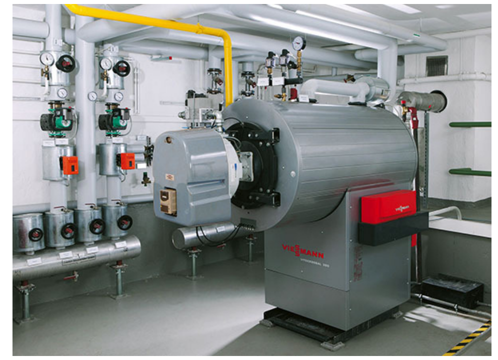
10.3 Assumptions

A set of general assumptions for energy cost and fuel source carbon intensity have been used in the assessment of each technology, unless otherwise stated. The general assumptions are as follows:

Natural Gas Cost = \$0.05/kWh
Electricity Cost = \$0.056/kWh
Carbon Credit Cost = \$25/tonne

Fortis BC Natural Gas Carbon Emission Density = 0.183 tonnes/MWh
BC Hydro Electricity Carbon Emission Density = 0.028 tonnes/MWh

10.4 Central Natural Gas-Fired Condensing Boilers



Description

- Condensing boilers are designed to extract maximum possible amount of heat contained in the natural gas by cooling the flue gases to ambient temperature and capturing the latent heat in condensed flue gases.
- Efficiencies of condensing boilers reaching 95-97% are typically 10-12% higher than conventional, non-condensing boilers, when operated with low heating hot water return temps.
- The efficiency varies depending upon the temperature of the water returning to the boiler; the lower the temperature, the higher the heat recovery potential. Condensing boilers are no less efficient than conventional boilers, when operating with heating water return temperatures above 73^{o}C (165^{o}F)

Benefits

- Allows inefficient, non-condensing, boiler plant to be switched off during summer
- No changes to existing primary heating pump system required
- Would provide backup and peak winter coverage allowing older boiler plants to be decommissioned

Limitations

- capital cost
- Additional gas service, metering and controls
- Heat exchanger arrangements vary between buildings

Feasibility at UVic

- The majority of buildings connected to the existing campus heating loop rely on the loop to generate domestic hot water via separate heat exchangers.
- The existing high temperature loop currently operates at 105 – 115^{o}C throughout the year to meet the campus' domestic hot water load, which is highly inefficient.
- Approximately 4150kW of condensing boiler plant capacity is required to meet summertime heating and domestic hot water load.
- This new boiler plant consisting of a bank of smaller capacity condensing boilers in parallel can replace an existing satellite boiler installation such as Clearihue, as and when require; eliminates the need for new building.
- The new boiler plant can become the lead boiler plant capacity, supported by existing boiler at ELW during peak winter months.
- Each building's heat exchanger controls will require automation, linked to common HWS scheduling
- Local additional domestic hot water heaters to do the final temperature boost will be required in buildings where high temperature DHWS is required. For example, the Petch building has two domestic hot water connections to the loop; one for high temperature and the other for low temperature domestic hot water.
- The business as usual case of replacing the current Clearihue boilers with like for like shall be included in the payback analysis.

Summary

The integration of gas-fired boilers offers the potential to save energy and reduce carbon emissions with a relatively low payback.

FEASIBILITY SUMMARY	
Annual Energy Production =	26,400 MWh/year
Annual energy savings =	3,600 MWh/year
Annual Carbon Savings =	660 tonnes Co_2/year (0.183 tonnes/MWh)
Annual Energy Cost savings =	$165,600/year
Capital Cost =	$1.2M-1.6M
Business as Usual Capital Cost	$0.6M-0.9M
Carbon Credit "refund"	$16,500/year
Simple Payback	3 - 4 years (6-9 years direct payback)

Recommendation

	FURTHER STUDY

10.6 Local Domestic Hot Water Heaters

Description

- An alternative to centralized condensing boilers is the provision of local gas-fired condensing domestic water heaters in each building.
- Local generation of hot water will allow the high temperature loop to be turned off.
- Operate in a similar manner as condensing boilers with efficiencies typically 10-12% higher than conventional, non-condensing boilers.

Benefits

- Allows inefficient, non-condensing, boiler plant to be switched off during summer
- No changes to existing primary heating pump system required
- Would provide backup and peak winter coverage allowing older boiler plants to be decommissioned

Limitations

- capital cost
- Additional gas service, metering and controls
- HEX arrangement varies between buildings

Feasibility at UVic

- Approximately, thirty 140kW gas-fired condensing domestic water heaters provide; one in each building currently connected to the high temperature loop to meet summertime domestic hot water load only.
- Buildings with large ventilation volumes may still require heating during the shoulder seasons. Window of opportunity to turn loop off limited to July and August.
- Space will need to be found in each building's mechanical room.
- Each building's heat exchanger controls will require automation, to allow complete isolation from the loop.
- The capital cost of the domestic hot water heaters is in addition to the business as usual case.

Summary

The payback is excessive for the provision of local domestic hot water heaters to all buildings connected to the heating loop. However, they will remain as a cost effective solution in certain situations, e.g. locally in laboratory buildings to generate high temperature domestic hot water if the district heating loop temperature is lowered or in combination with solar thermal system to act as storage and backup.

FEASIBILITY SUMMARY	
Annual Energy Production =	2500 MWh/year
Annual energy savings =	340 MWh/year
Annual Carbon Savings =	60 tonnes Co_2/year
Annual Energy Cost savings =	$16,000/year
Capital Cost =	$500,000 - $600,000 ($16K - $20k each)
Carbon Credit "refund"	$1,500/year
Payback =	28 - 35 years

Recommendation

	FEASIBLE IN CERTAIN LOCATIONS

10.8 CRD Sewerage Heat Recovery

Description

- A sewer heat recovery system extracts low-grade heat contained in the grey-water and waste water flowing down the sewer system. Heat exchange can be done at the individual building or on a district level.
- On a district level and exchange heat with the water flowing down the underground sewer mains at the development. A system similar to the horizontal ground loop heat exchanger could be installed around the sewer mains and heat pumps would be used to transfer heat between the building systems and the heat exchangers.
- The effluent temperature does not fluctuate significantly on an annual basis. The temperature of the distribution fluid contained in the DES piping would be always lower than the effluent and could be used to draw heat from the effluent stream via a simple heat exchanger.

Benefits

- Large heat harnessing capacity and reliable source of energy
- Provides a cost-effective source of low-grade thermal energy for seasonal thermal energy storage

Limitations

- Capital cost
- Distances from heat source to end use can be long
- Requires buildings to be designed with low temperature heating systems to maximize efficiencies.

Feasibility at UVic

- The Capital Regional District (CRD) is planning the construction of a wastewater treatment facility in the Saanich East-North Oak Bay (SENOB) area, near Arbutus road.
- The CRD retained KWL and Compass to assess sewer heat recovery opportunities. Four opportunities in the Region were screened – UVic and surrounding area determined as leading opportunity. The heat recovery concept described in this section has been developed by CRD and their consultants, including the indicative cost estimate.
- The CRD's analysis is based on real levelized energy costs per end-use MW.h. Levelization is analogous to comparing the net present value of different energy system configurations and has been used as a metric to determine both business-as-usual costs as well as district energy system costs and make fair comparison based on end-use MW.h of thermal energy demand. The assumptions used to create the levelized cost are set out in Appendix XX
- The feasibility of the sewage heat recovery systems also assumes connection to existing UVic Student residences (see figure 10-2) and future growth in the surrounding area. Two scenarios have been assessed; a base scenario and an expanded scenario which assumes significant future growth in the area.
- Both base and expanded scenarios will only offset a small portion of UVic's current gas use; 11% and 16% respectively.
- The indicative cost estimates for each scenario are as follows:
  - Base scenario = $8.9 Million
  - Expanded scenario = $11.6 Million
- The proposed connection of existing buildings on the UVic campus to the sewage heat recovery system will require the buildings to be isolated from the existing central heating plant, although provisions should be made to allow for switch-back on an as-needed basis. Plate-and-frame heat exchangers should be added in parallel with the existing shell/tube heat exchangers in the energy transfer stations to facilitate the lower primary supply temperature. A provisional budget of $100,000 per building for this work was included in the indicative cost estimate.
- The provision of a sewage heat recovery DES has a cost premium vs. BAU assuming no grants,

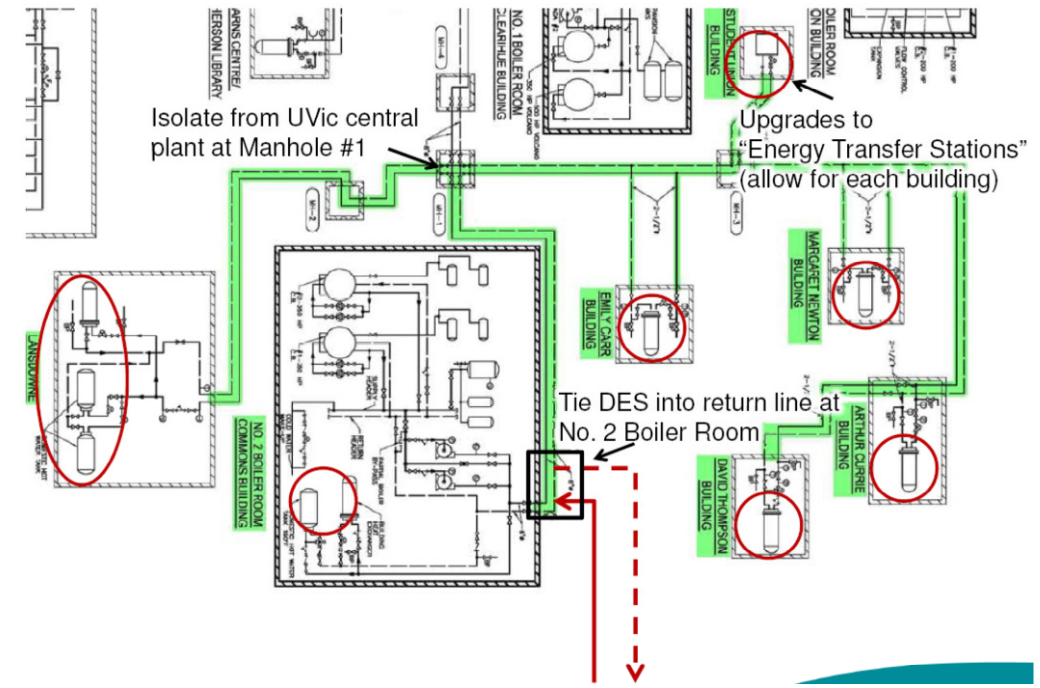


Figure 10-2 Proposed Student residence to be connected to sewage heat recovery system. From KWL/Compass/CRD presentation

FEASIBILITY SUMMARY – Provided by CRD and KWL/Compass		
Scenario	**Levelized Cost per MW.h**	**Comparison to BAU**
Business as Usual	$97	Nil
DES Base Case Without Grants	$118	+22%
DES Base Case With 100% Grant	$54	-44%
DES Base Case With: 67% Grant from Provincial & Federal Gov'ts 33% CRD Debt	$75	-23%
DES Base Case with Grants to match BAU	$97	Nil

Recommendation

	Significant additional cost without grants, only offsets a small portion

10.9 Heat Recovery from Enterprise Data Centre

Description

- Data Centers typically have high cooling loads due to the high electrical consumption and density of the installed servers. They are therefore a potential source of low-grade waste heat.
- Historically, heat from the servers is rejected to atmosphere using air cooled chillers, making it difficult to capture the waste heat.
- The inclusion of water cooled chillers allows the waste heat to be recovered and serve nearby buildings.
- Power Usage Effectiveness (PUE) is the ratio of total amount of power used by a computer data center facility to the power delivered to computing equipment. An efficient data centre has PUE of 1.2-1.5. EDC2 currently has a PUE of 2.

Benefits

- Recovers heat that would otherwise be rejected to the atmosphere.
- A good, continuous source of heat for an ambient district heating loop.

Limitations

- Heat is of a low grade quality
- Requires separate low-temperature or ambient district heating loop

Feasibility at UVic

- The Enterprise Data Centre (EDC2) provides additional server and data processing capacity to support research and administrative functions for the University of Victoria.
- The new facility can accommodate up to 1260 kW of additional server capacity, or 3000 standard servers.
- It is anticipated that the server load will increase over time. UVic are currently reviewing ways to improve the efficiency of EDC2. The following assumptions have been made:
  - Server load = 700kW (future prediction)
  - PUE = 1.5
- Approximately 300kW of low grade waste heat available, continuously.
- Heat is used for source side of heat pump, at coefficient of performance (COP) of 2.5, therefore 750kW of heat produced, every hour, continuously.
- Based on thermal energy benchmark for student accommodation at 253 kWh/m^2.yr, the yearly heat demand of approximately 26,000m^2 of student residences can be met using waste heat from EDC2.
- To maximize the recovery of heat from EDC2 the existing air cooled chillers will need to be replaced with water cooled versions. This has a significant impact to the capital cost of this option
- IF the PUE improves the available heat will reduce.

Summary

Significant energy and carbon savings can be achieved by capturing the low grade waste heat from UVic's data centre, EDC2. However, the thermal energy recovered will be low grade and cannot be used to serve existing buildings connected to the district heating loop.

If new buildings were designed to use low grade thermal energy, e.g. by integrating hydronic radiant slabs instead of electric baseboard, the energy can be captured and used, helping to offset the carbon emissions incurred from growth on the campus.

FEASIBILITY SUMMARY	
Annual Energy Production (waste heat) =	6500 MWh/year (low grade heat)
Annual Carbon Savings =	1200 tonnes Co_2/year
Annual Energy Cost savings =	300,000 $/year
Capital Cost = (Assumes the majority of the ambient district heating cost will be included in this option)	$4M-$5M
Carbon Credit "refund"	$ 27,500
Payback =	12-15years

Recommendation

	TO OFFSET CARBON EMISSIONS FROM NEW BUILDINGS

10.10 Energy from Solid Organic Waste

- Properly managed decomposing organic waste with high energy content (i.e. proteins, fats, sugars) produces useable gas called biogas.
- Comprised of roughly 50% methane CH_4, biogas gas can be burned to create thermal energy or power a turbine generator with waste heat recovered for space heating.
- Biogas is considered a renewable energy source as conventional practice is to flame the gas, reducing methane to less potent green house gases but wasting useable heat energy.
- Solid municipal waste of organic origins can also be incinerated to generate high grade heat.

Benefits
- reduce methane emissions, high impact greenhouse gas, to less harmful greenhouse gas emissions
- harness unused energy source
- less waste to landfill

Limitations
- requires high volume of solid organic waste/year
- space requirements
- turbine size, noise and vibration
- low efficiency of fossil fuel to electrical energy conversion

Application Feasibility at UVic

- UVic currently generates approximately 480 Tonnes of organic and food waste per year.
- Solid municipal needs to undergo pre-treatment or organic elements separated before it can be used to create biogas.
- Food waste typically produces 50-85m^3 of biogas per tonne. Biogas typically produces 0.02GJ/m^3 (6kWh/m^3)
- UVic's organic waste stream will be able to produce 816 GJ/year, equivalent to <0.4% of the yearly thermal energy demand.
- The calorific value of solid municipal waste is approximately 2800kWh (10 GJ) per tonne. UVic's solid municipal waste stream at 660 tonnes per year will provide 1,800,000 kWh (6600 GJ) of thermal energy, equivalent to 3% of UVic's thermal energy demand.
- The CRD produces 160,000 tonnes of municipal waste every year, 30% of which is organic waste. Some of this waste could be diverted to UVic's campus; however the CRD's landfill site at Hartland already converts the landfill gas generated from the region's waste into electricity.

Recommendation

	SHOWCASE

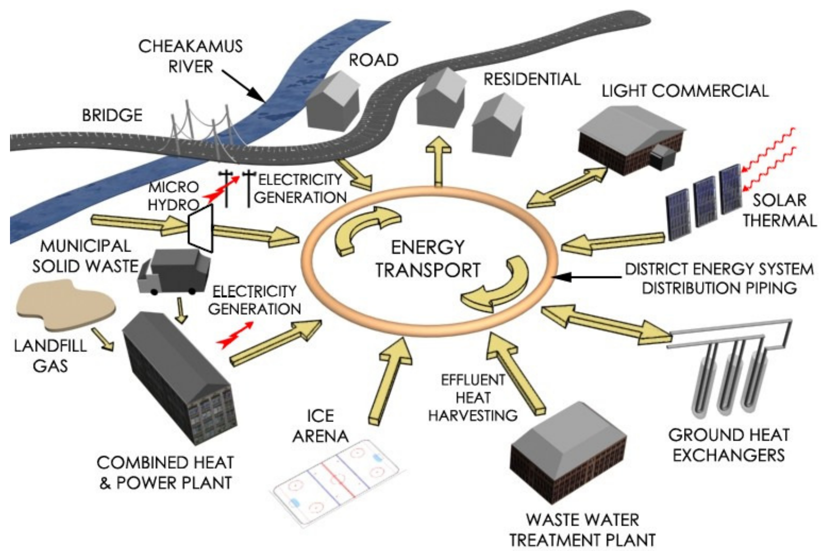
UVIC AVERAGE MONTHLY WASTE/RECYCLING COMPOSTITION AND COST

	Average Monthly Tonnage*	Average Hauling Rate (per tonne)*	Tipping Fee (per tonne)	Notes
Waste (Landfill) - Compactor	45	$ 34.00	$ 107.00	Hauling rate includes compactor and bin rental - $142.50 per load
Waste (Landfill) - Open Top (large items)	1.75	$ 149.00	$ 107.00	Hauling rate includes bin rental - $213.75 per load
Waste (Landfill) - Front Load Bins	8		$ 600.00	Hauling and tipping fee rolled into one rate (price per bin pick up)
Glass/Plastic/Tin	3	$ 181.00	$ 175.00	Hauling rate includes bin rental - $213.75 per load
Cardboard	9	$ 131.00	-$ 113.00	Hauling rate includes bin rental - $213.75 per load - there are also rebates for cardboard (no tipping fee)
Paper	16.5	$ 65.00	-$ 53.00	Hauling rate includes bin rental - $213.75 per load - there are also rebates for paper (no tipping fee)
Food Waste	31		$ 129.74	Hauling and tipping fee rolled into one rate
Metal	5.2	$ 94.00	-$ 100.00	Hauling rate includes bin rental - $213.75 per load - there are also rebates for metal (no tipping fee)
Wood	5	$ 99.00	$ 80.00	Hauling rate includes bin rental - $213.75 per load
Mattresses	2	$ 290.75	$ 189.00	Hauling rate includes bin rental - $213.75 per load
Concrete	0.9	$ 142.00	$ 9.50	Hauling rate includes bin rental - $213.75 per load
Drywall	2	$ 140.00	$ -	Hauling rate includes bin rental - $213.75 per load
Yard & Garden Waste	9	$ 22.00	$ 28.75	Hauling rate includes bin rental - $150.00 per load

**All Average Monthly Numbers based on the last 9 months of data*

FEASIBILITY SUMMARY	
Annual Energy Production (waste heat) =	1800 MWh/year (low grade heat)
Annual Carbon Savings =	330 tonnes CO_2/year
Annual Energy Cost savings =	90,000 $/year
Capital Cost =	Not Commercially Available Estimated at $0.5M-$1M for system to deal with UVic's solid waste stream
Carbon Credit "refund"	$ 8,000
Payback =	>25 years

10.11 Ambient District Energy Systems (DES)



- Although ambient DES loops are not a low or zero carbon energy source in their own right, it provides an infrastructure that can be connected to a number of low-grade decentralized energy sources anywhere on the loop.
- An alternative to UVic's conventional high temperature DES is the use of an "ambient temperature" system featuring a single large volume, non insulated pipe loop maintained at a moderate temperature (i.e. 5-20°C).
- This system is much simpler, more flexible, and more robust than the conventional high temperature DES. However, it requires the use of heat pump technology typically at each building.
- A large development application could include a flexible and expandable distribution loop tied to multiple low grade energy sources and interconnected via heat exchangers.

Benefits

-simpler, more flexible, more reliable and more robust than conventional dual-temperature level DES

- Provides flexibility for DES growth in both its physical size and H&C capacity; ideal for developments with anticipated future growth

Limitations

- High capital cost to install DES loop;

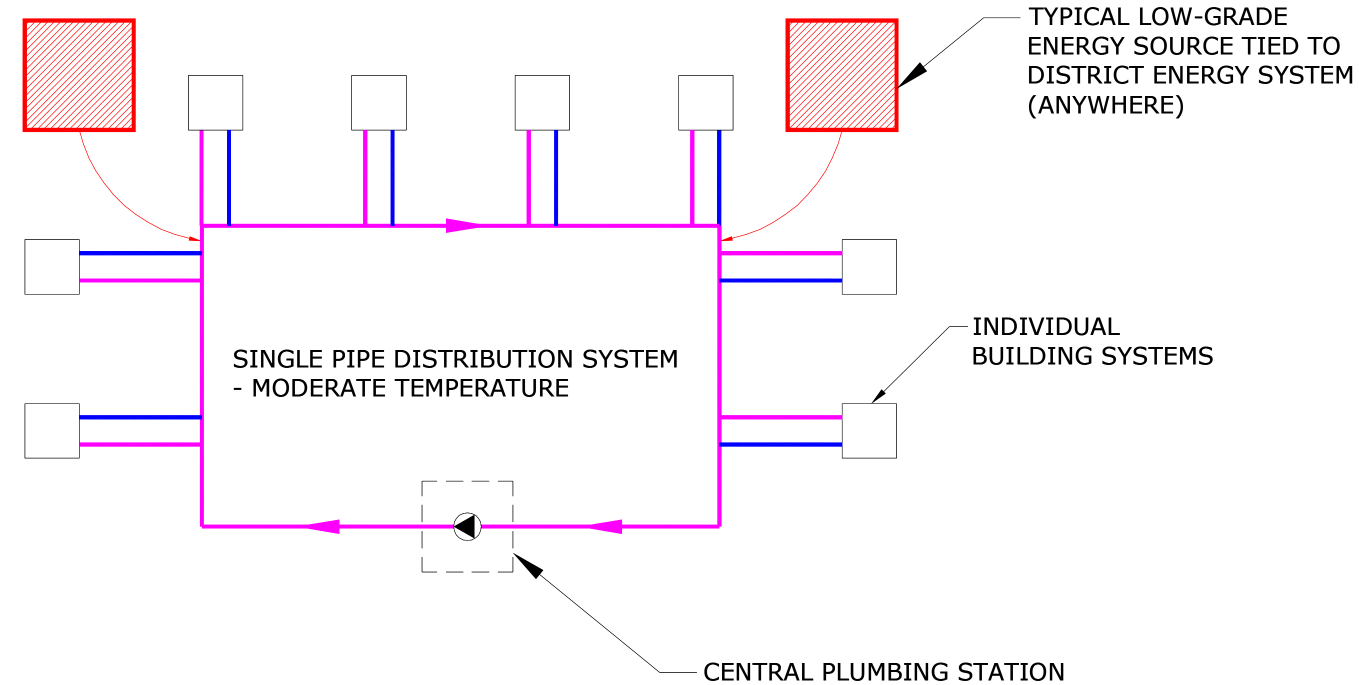
- Relocation and disruption of underground systems likely to be required.

Application Feasibility for UVic

- For UVic a modular, single-temperature, low-temperature DES with distributed heat pumps will enable phased development, efficient operation, and the flexibility to use multiple low-grade thermal energy sources.
- Compliments capture of waste heat from EDC2 and potential future sewage heat recovery.
- Can be developed to serve areas of new construction at UVic's campus.

Maintenance

Typical maintenance – no more onerous than existing high temperature loop.

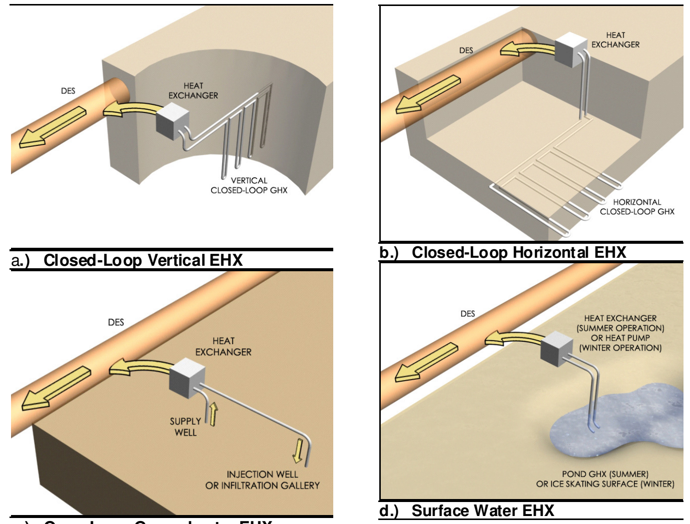


Simplified Schematic of Single Temperature Level DES

Recommendation

	CAN POTENTIALLY SERVE AREA OF NEW CONSTRUCTION

10.12 Geoexchange



a.) Closed-Loop Vertical EHX b.) Closed-Loop Horizontal EHX c.) Open-Loop Groundwater EHX d.) Surface Water EHX

- Solar energy is absorbed by the earth and below a certain depth (2m) the earth is a constant, site specific, temperature year round.
- Earth source energy systems make use of this constant temperature as a source or sink for low grade thermal energy.
- The many earth source heat exchange configurations range from open loop ground water wells to closed loop bore holes.
- All systems use heat pumps and a circulating fluid (water, or a water-glycol mixture as a heat transfer medium). The configuration and size of an earth energy system depends on the underlying geology of the site and annual energy requirements of the building(s) it will serve.

Benefits

-renewable source for low temperature heating and cooling energy

-displaces heating and cooling energy otherwise produced with fossil fuel combustion

-low temperature source well suited to radiant space heating and cooling system

Limitations

-space restrictions on campus may restrict size of geoexchange field

-electrically driven technology

- Produces low temperature thermal energy which is incompatible with the existing high-temperature heating loop

Application Feasibility for UVic

- Earth energy system technology is well established and effective with proper design and commissioning.
- The campus' thermal base load can be met with a geo-exchange system:
  - Assuming a peak load of 4000kW, Coefficient of performance = 4
  - 830, 130m deep boreholes required – 20,000m^2 required
- The size of such a system may not be technically or economically viable for the campus.
- An assessment of the specific site conditions must be conducted by an experienced hydro-geologist to determine the size and configuration of the geo-exchange loop. If this study proves the applicability of the site, a centralized plant with heat pumps would be required to use this low-grade energy source.
- Although the heat pump achieves its highest efficiencies at temperatures closer to ambient.
- Likely to be better suited to potential new ambient loop system serving the east side of campus rather than existing system

Maintenance

Typical maintenance – Assuming W-W Heat Pump, lubrication and filter every 3 months and inspection of refrigeration circuit every year

FEASIBILITY SUMMARY	
Annual Energy Production (Thermal) =	16,000 MWh/year (low grade heat)
Annual Energy Consumption (Electrical) =	4000 MWh/year
Annual Carbon Savings	2800 tonnes CO_2/year
Annual Energy Cost savings =	90,000 $/year
Capital Cost =	Geoexchange loop costs are dependent on ground conditions and type of loop installed. Estimated at $1M-$4M
Carbon Credit "refund"	$ 70,000
Payback =	11- 45 years

Recommendation

	POTENTIALLY CONNECT TO AMBIENT LOOP TO OFFSET FUTURE LOADS

10.13 Biomass Heating only Plant

- Biomass is a renewable energy source created from living organisms such as wood, etc., and is considered to be "carbon neutral"
- Biomass is commonly plant matter grown to generate electricity or produce heat.
- There are a number of technological options available to make use of a wide variety of biomass types as a renewable energy source. Conversion technologies may release the energy directly, in the form of heat or electricity by connecting a CHP engine.
- The technology is simple, and proven, and can be applied on a small modular basis up to large scale.
- Small-scale plants can be designed to grow with UVic's campus site development.
- Clean scrubbers are available to insure that emissions particulates are removed from flue gases.
-

Biomass Plant

Benefits

- "Carbon Neutral" source of heat
- Proven technology available from a number of vendors
- Potentially unlimited renewable fuel

Limitations

- capital cost
- flue stack still required to disperse combustion gases
- Ash produced as waste product and requires removal
- Addition road traffic during peak heating season

FEASIBILITY SUMMARY	
Annual Thermal Energy Production =	36000 MWh/year
Annual Carbon Savings =	6,500 tonnes Co_2/year
Annual Energy Cost savings =	$650k – 750k/year
Capital Cost = (highly dependent on type of boiler and procurement method	$10M - $15M
Carbon Credit "refund"	$230,000
Payback =	15 - 20 years

Recommendation

	SIGNIFICANT CARBON REDUCTION POTENTIAL WITHIN PAYBACK PERIOD

Application Feasibility at UVic

- Biomass plant sized to meet up to 80% of thermal energy demand of the campus, therefore boiler size is 4200 kW (15GJ/ hour). Gas-fired condensing boilers required as back up and to meet peak load
- Based on a calorific value of 11GJ/tonne of biomass (hardwood) approximately 2600 tons of fuel required per month during winter to match peak demand.
- Cost of biomass fuel in BC is typically 50-60% cheaper than gas, approximately $5-$8/GJ
- Sufficient storage will be required to provide at least 24 hours worth of fuel during peak winter conditions.
- Biomass delivered by truck, approximately 50m^3 per truck. Approximately 30 deliveries per week during peak winter conditions.
- Car park #1 offers sufficient space for biomass plant, storage, and is in close proximity to the existing heating loop.
- UVic generates a very low quantity of wood fuel (approximately 60 tonnes of waste wood, every year)
- There is an opportunity to harvest some of the carbon dioxide emissions form the flue gases for use in local greenhouses and algae production plants as research opportunities.

Maintenance and Operation

- Dedicated staff members likely to be required to maintain and operate a plant of this size

10.14 Biomass Combined Heat and Power plant

- Similar process to biomass heating above but addition of turbine allows generation of electricity.
- Eqipment sizing can be thermally or electrically led.
- Small-scale plants can be designed to grow with UVic's campus site development.
- There are a number of technological options available to make use of a wide variety of biomass types as a renewable energy source. Conversion technologies may release the energy directly, in the form of heat or electricity by connecting a CHP engine.

Benefits

- onsite electricity generation displaces dependence on grid
- promotion of renewable energy generation
- Depending on the CHP system chosen, high thermal to electricity ratios can be achieved – 1.5kW$_{th}$:1 kW$_e$ possible using gas turbines.

Limitations

- Capital cost
- Fossil fuel typically used to deliver fuel to site.
- flue stack still required to disperse combustion gases
- Ash produced as waste product and requires removal

Application Feasibility at UVic

- Biomass CHP plant sized to meet 80% thermal energy demand of the campus, and to provide supplemental electrical energy as a result of thermal load priority.
- Graph opposite shows both thermally and electrically led equipment sizing. Option 1 – 15 MMBtu/hour +1MWe (thermally led), Option 2 – 24MMBtu/hr + 4MW$_e$ (Electrically led)
- Boiler size equivalent to thermal only option above. Based on a calorific value of 11GJ/tonne of biomass (hardwood), approximately 4000 tons of fuel required per month during winter to match peak demand.
- Cost of biomass fuel in BC is typically 50-60% cheaper than gas, approximately $9/GJ
- Sufficient storage will be required to provide at least 12hours worth of fuel during peak winter conditions.
- Biomass delivered by truck, approximately 50m^3 per truck. Up to 50 deliveries per week during peak winter conditions.
- Car park #1 offers sufficient space for biomass plant, storage, and is in close proximity to the existing heating loop.
- Again, there is an opportunity to harvest some of the carbon dioxide emissions form the flue gases for use in local greenhouses and algae production plants as research opportunities.
- The feasibility assumes

.

Maintenance and Operation

- Dedicated staff members likely to be required to maintain and operate a plant of this size

FEASIBILITY SUMMARY	
Annual Thermal Energy Production =	36,000 MWh/year
Annual Electrical Energy Production =	9000 MWh/year
Fuel requirement	54,000 MWh/ year
Annual Carbon Savings (assumes fuel is zero carbon) =	6725 tonnes Co$_2$/year
Annual Energy Cost savings =	$300k - $400k /year
Capital Cost =	$10M - $20M
Carbon Credit "refund"	$160,000-$170,000/year
Payback =	22- 28 Years

Recommendation

	FURTHER STUDY REQUIRED TO REFINE POTENTIAL PAYBACK

10.15 Wind

- Wind turbines, or wind mills, have been used for centuries to pump water.
- In recent years the technology has improved making wind turbines an efficient producer of electricity.
- Turbines come in all sizes and are typically mounted on an independent tower.

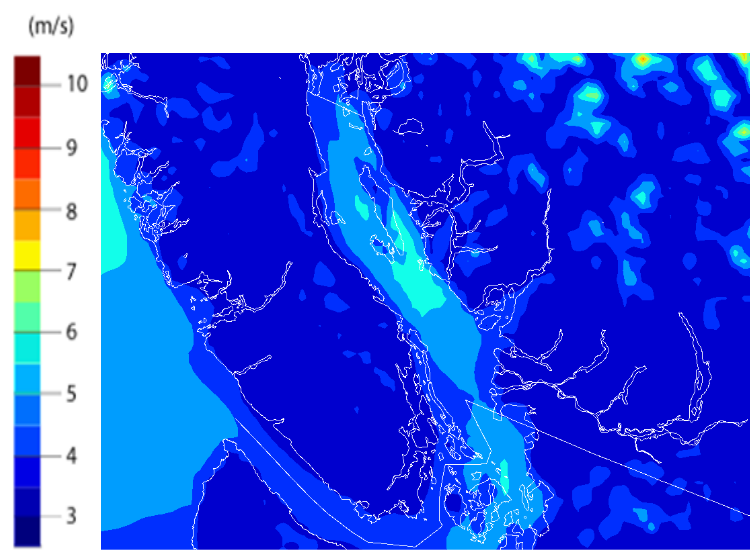
Benefits

- onsite electricity generation displaces dependence on grid
- promotion of renewable energy generation

Limitations

- capital cost
- location requirements
- power generation ability depends on availability of wind speeds within suitable velocity range

Application Feasibility at UVic

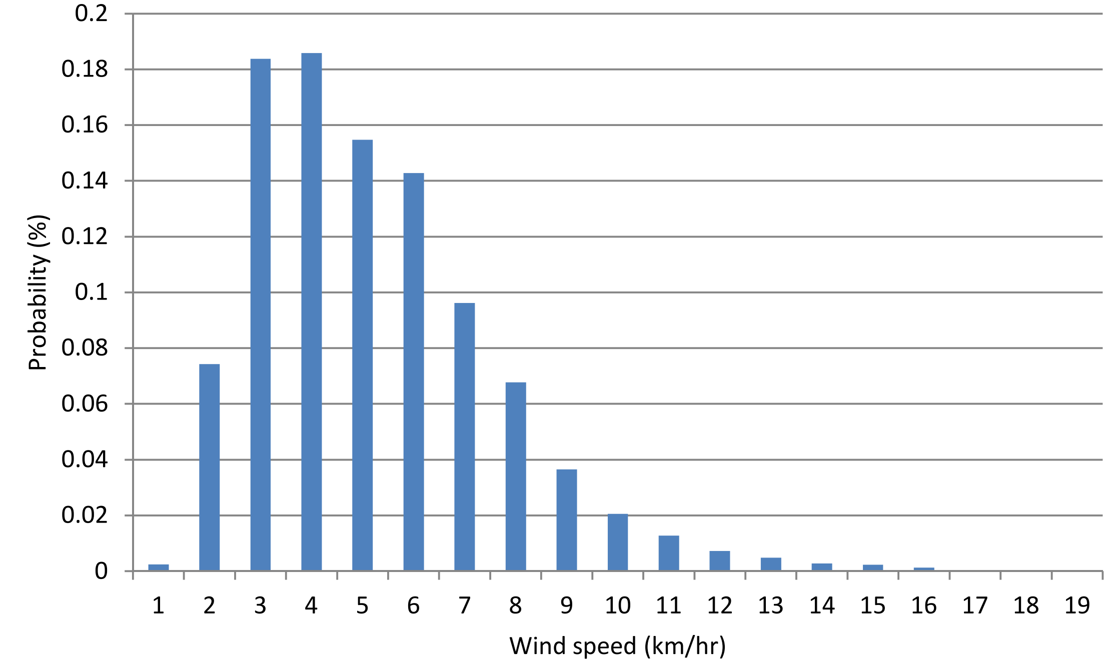


- Wind turbines are most efficient at generating electricity when the average wind speed is above 5m/s.
- The average wind speed typically increase with height, especially in urban environments as friction from buildings, etc are reduced.
- At UVic, the average wind speed up to a height of 30m is approximately 4m/s, based on data from the Canadian Wind Energy Atlas website and the weather station on top of the Social Sciences and Mathematics building on the UVic campus.
- The tree density and buildings surrounding the UVic campus will also create a boundary layer of slower moving air which would reduce the effectiveness of a wind turbine or require a very tall tower.
- Another option would be to install the tower off campus where wind conditions are more favorable. An offsite wind turbine would feed electricity to the grid indirectly reducing the electrical load at the site.

Maintenance and Operation

- Wind turbines require yearly maintenance

The cost and energy production depends entirely on the turbine location and size. The estimates stated here were produced assuming averaged UVic wind conditions and a 250 kW turbine, with a 30m hub height and 30 m rotor diameter.



Social Science wind speed measurements

NOTE: The cost and energy production depends entirely on the turbine location and size. The estimates stated here were produced assuming averaged UVic wind conditions and a 250 kW turbine, with a 30m hub height and 30 m rotor diameter.

FEASIBILITY SUMMARY	
Annual Energy Production =	96 MWh/year (per turbine)
Annual Carbon Savings =	2688 Kg Co_2/year
Annual Energy Cost savings =	$4,783/year
Capital Cost (Unit and delivery) =	$250,000 @ $1000/kW
Payback =	52 years

Recommendation

	EXCESSIVE PAYBACK

10.16 Solar Thermal

- The numerous solar thermal collector technologies include water based flat plate collectors and heat pipe[7] type evacuated tube collectors.
- Collectors are typical mounted on a south-facing exposure and connected to a heat storage device.
- Dark, reflective surfaces absorb direct and/or indirect sunlight and transfer the heat via a heat transfer fluid.
- The fluid is pumped through or across the collector and circulated to a heat exchanger which transfers the energy to a storage medium, such as water in a tank.
- Experience has shown Solar thermal can typically offset 10% of a building's energy demand.

Benefits

- heat energy from the sun displaces conventional boiler energy (either gas or electric)
- reduced CO, SO_x, NO_x, CO_2 and GHG emissions
- reduced dependence on fossil fuels

Limitations

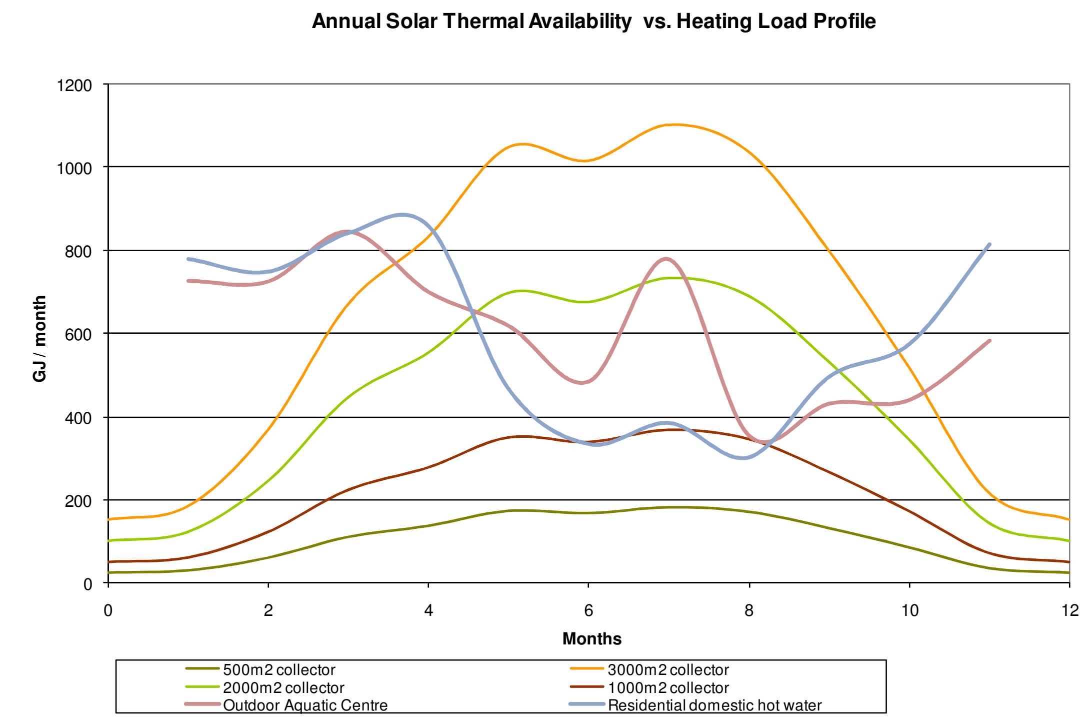
- capital cost
- evacuated tubes may contain refrigerants
- Thermal energy generation is dependent on the availability of sufficient solar radiation

Application Feasibility at UVic

- Solar hot water heating is widely used throughout Canada and the world
- Ideal collector location requires south to west facing exposure, angled between 15 and 45 degrees
- Significant large, un-shaded areas on campus provide ideal location for solar thermal e.g. parking lots. Approximately 40,000m^2 of parking lot available
- Approximately 8000 m^2 - 1000m^2 of suitable roof area on key buildings, in vicinity to existing heating loop. The addition of thermal storage (e.g. the existing heating loop) can extend the usefulness.
- A solar access By-Law may be required to protect any solar thermal installation from over-shadowing by nearby high-rise developments.
- 18,000m^2 of solar thermal panel required to meet UVic's hot water base load during July and August

Maintenance and Operation

- Has a lifespan of up to 25 years and requires very little preventative maintenance.
- Collector surface must be kept clean. Can be part of yearly maintenance strategy



FEASIBILITY SUMMARY	
Annual Energy Production =	720 kWh/m^2
Annual Carbon Savings =	131 Kg CO_2/m^2. year
Annual Energy Cost savings =	40 \$/m^2.yr
Capital Cost (Unit and delivery) =	500 - 1000 \$/m^2
Payback =	14 - 25 years

Recommendation

	FURTHER STUDY REQUIRED TO REFINE POTENTIAL PAYBACK AND BUSINESS CASE

10.17 Solar Photovoltaic Cells

- Photovoltaic (PV) Cells consisting of crystalline material "convert" photons from the sun into direct current electricity. An inverter converts the DC into alternating current which can be used by buildings or fed into the local electricity gird.
- Solar Photovoltaic cells can be integrated with building envelope or mounted in arrays independent from the building

Photovoltaic Panels

Benefits

- Onsite electricity generation displaces dependence on grid
- Can be integrated with building envelope displacing envelope costs

Limitations

- PV. Capacity degrades over time and made of toxic materials
- Low conversion efficiency
- Requires adequate solar exposure
- Electrical power generation dependent on the availability of sufficient solar radiation

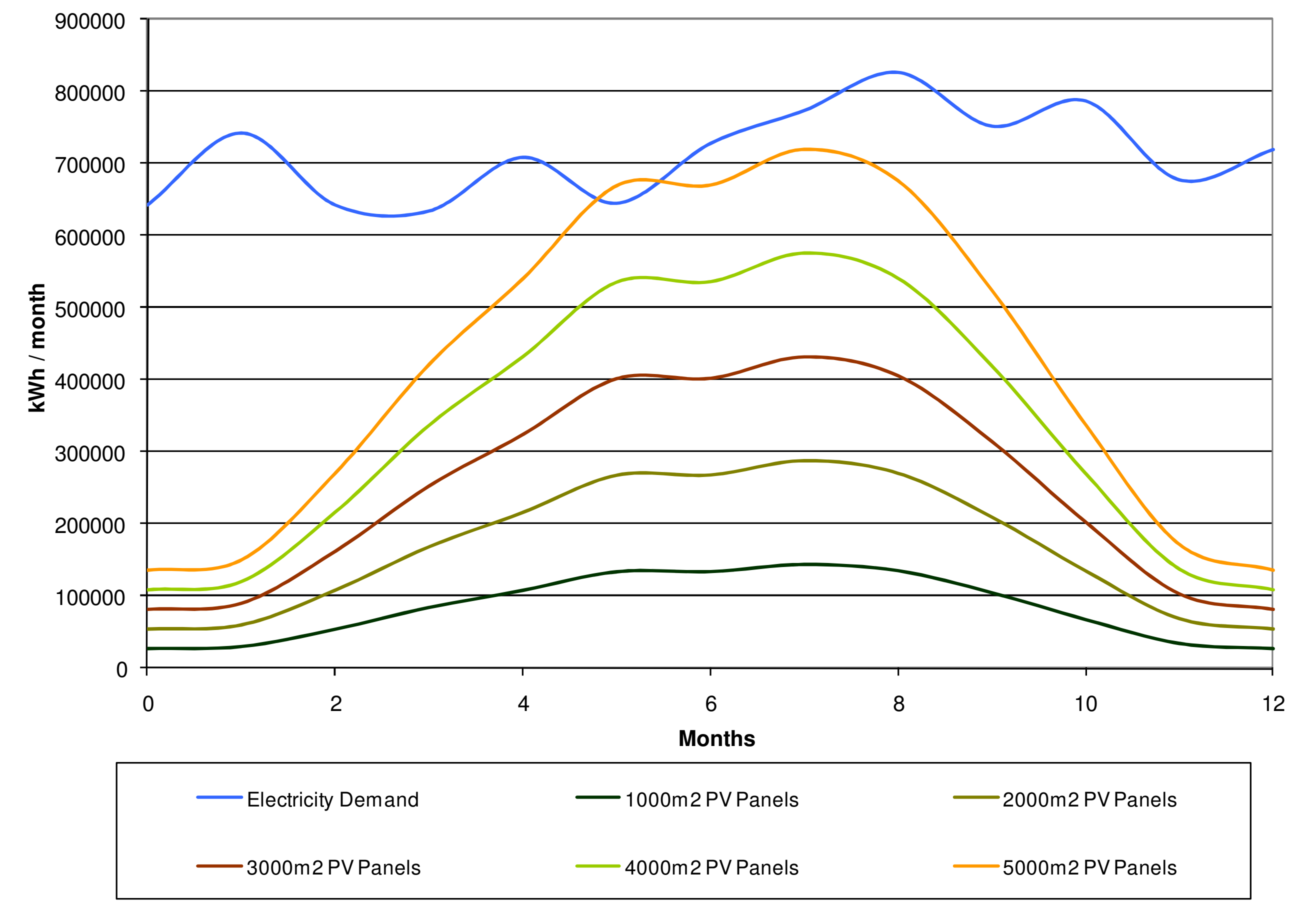
Application Feasibility at UVic

- Ideal solar PV location requires south to west facing exposure, angled between 15 and 45 degrees ideally at an angle equal to the latitude of the site.
- Significant large, un-shaded areas on campus provide ideal location for photovoltaic panels e.g. parking lots. Approximately 40,000m^2 of parking lot available
- Approximately 11000m^2 of suitable roof area on key buildings, in vicinity to existing heating loop. The addition of thermal storage (e.g. the existing heating loop) can extend the usefulness.
- A solar access By-Law may be required to protect any solar thermal installation from over-shadowing by nearby high-rise developments.

Maintenance and Operation

- Has a lifespan of up to 20 years and requires very little preventative maintenance.
- Collector surface must be kept clean. Can be part of yearly maintenance strategy

Annual Solar Electricity Availability vs. Electrical Load Profile



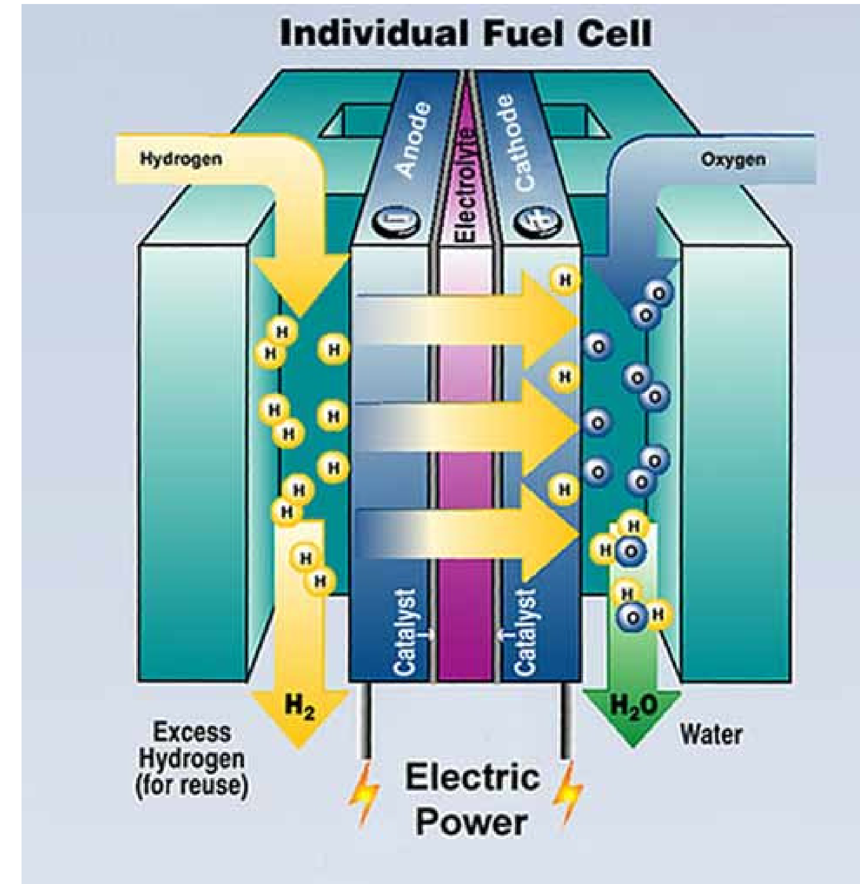
FEASIBILITY SUMMARY	
Annual Energy Production =	150 kWh/m^2
Annual Carbon Savings =	4-5 Kg CO_2/m^2. year
Annual Energy Cost savings =	7.5-10 \$/m^2.yr
Capital Cost =	\$1000-1400/m^2.yr
Payback =	100 years

Recommendation

	EXCESSIVE PAYBACK

10.18 Hydrogen Fuel Cell

- Fuel cell technology is often promoted as one of the most promising sustainable solutions using “clean” energy from hydrogen (H_2) ending our dependence on fossil fuels. The technology uses H_2 as “fuel” and converts it to electricity and water.
- H_2 however is not naturally available in a useable state and must be extracted from other sources through energy intensive processes. In this sense, H_2 is an “energy carrier” similar to electricity. Hydrogen fuel cells require pure H_2 gas; the most common source of H_2 is fossil fuel, typically natural gas. When H_2 is made from natural gas nitrogen oxides are released that are 58 times more potent green house gases than CO_2.
- H_2 use in a fuel cell is a “clean” process; H_2 production is not a clean process. Furthermore, due to the extremely low volumetric energy density at standard temperature and pressure conditions, H_2 needs to be compressed to high pressure (2,000 psig) and cooled to low temperatures (-253 ^{o}C) for storage and transport.
- The overall external energy input required for generation and compression process results in an energy conversion ratio of 6 units in to 1 unit out.
- Though hydrogen can be extracted from water, electrolysis uses more energy to produce the hydrogen than the yield of the fuel cell, which turns it into a net energy sink. Electricity for electrolysis can be generated by using solar power.



Benefits

- no combustion
- combined heat and power potential
- low emissions, just water vapour and heat

Limitations

- hydrogen source from conventional fuels
- electrolysis from H_2O is energy intensive
- energy storage, not source
- high manufacturing costs
- net energy sink

Application Feasibility at UVic

- Fuel cells are able to function as stand-alone generating systems; they can be placed within a distributed power network with each system serving its own building or development while supplying the excess to the grid.
- In spite of above mentioned serious thermodynamic limitations, fuel cells have a high potential to receive funding and attention and may be worth a demonstration project. For example on February 21, 2005, Energy and Mines Minister Richard Neufeld announced $2 million in funding to Fuel Cells Canada to support hydrogen and fuel cell innovation.
- Fuel cell technology does not have a bright future as a replacement for fossil fuels. Producing H2 from water by electrolysis is a net energy sink. There is a certain amount of “wishful thinking” surrounding this technology and an unwise dependence on the hope that future technology will fill the gaps in our currently flawed logic.

Maintenance and Operation

- Fuel Cells require little maintenance.
- On-site hydrogen generation or storage and piping distribution infrasturcutre requires ertaordinary safety measures due to highly explosive nature of hydrogen.

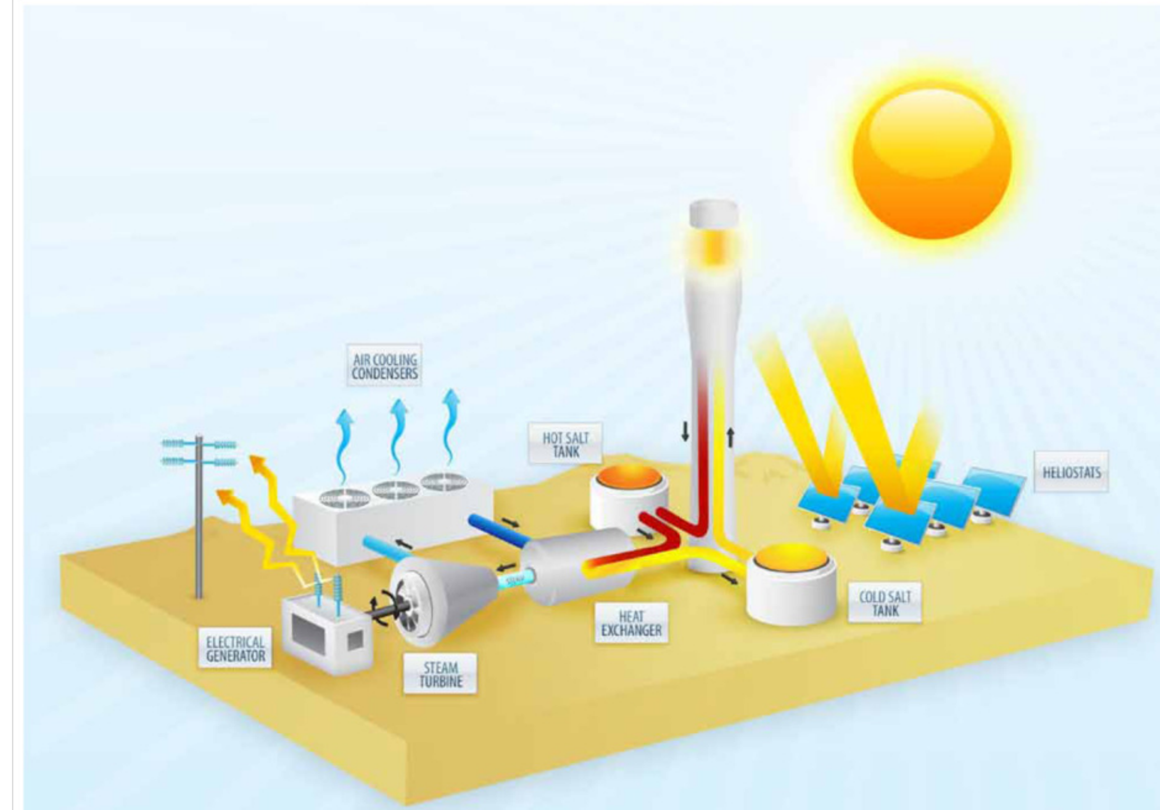
FEASIBILITY SUMMARY	
Annual Energy Production =	Not Commercially Available-
Annual Carbon Savings =	Unknown
Annual Energy Cost savings =	Unknown
Estimated Capital Cost =	$5000-7000/kW
Payback =	Unknown at present

Recommendation

	EXPERIMENTAL AND UNKNOWN PAYBACK. POTENTIAL RESEARCH PROJECT/SHOWCASE

10.19 Concentrated Solar Electric Generation

- Concentrated solar-electric systems generally consist of parabolic reflectors arranged to heat thermal heat transfer fluid, which then can be used to operate an Organic Rankine Cycle (ORC) turbine to generate electricity. They can also be used to generate steam to power a steam turbine and electrical generator.
- A current example of this type of technology is being planned and designed for an installation in Medicine Hat, Alberta, consisting of 1.3 MW generating capacity, using a collector field approximately 100m x 100m (10,000 sq.M). Capital cost = $9M



Benefits

- Renewable energy source
- no combustion
- combined heat and power potential

Limitations

- no night-time utilization
- Low/nil utilization during non-sunshine hours of the day.
- capital cost & Space requirements
- solar to electricity efficiency = 11%
- solar hours and climate create challenges for more than summertime supplemental operation

Application Feasibility at UVic

- A 2 MW electrical load would require approximately 20,000 sq.M of the site area, and that would only satisfy the baseline electrical load during full sunshine daytime hours only. (Based on the Medicine Hat plant being designed)
- Yearly electrical consumption at UVic = 55,000 MWh. Assume Concentrated solar sized to meet 25% of the yearly electrical demand = 13,750 MWh.
- At a capital cost of $800k/MWh, total capital cost = $11 Billion to meet 25% of the Campus' electrical consumption

FEASIBILITY SUMMARY	
Annual Energy Production =	13,750 MWH (25% of UVic's Electrical Consumption)
Annual Carbon Savings =	385 Tonnes
Annual Energy Cost savings =	$770,000
Estimated Capital Cost =	$800k/MWH = $11 Billion (Experimental) Technology not commercially available
Payback =	Excessive

Recommendation

	EXPERIMENTAL AND EXCESSIVE CAPITAL COST AND PAYBACK.

10.20 Summary

The following matrix summarizes the feasibility of the thirteen energy generation systems presented in the above sections using the cost/benefit criteria outlined in Section 5.2. The traffic light colour scheme has been used to reflect the appropriateness of each of the criteria; red reflects “Less Appropriate”, green represents “More Appropriate”.

	Energy Generation System	Commercial Availability	Carbon Reduction Potential	Payback Period	Retrofit Applicability	Early Implementation Potential	Funding Availability	Maintenance, Operation and Staffing Cost	Recommendation
Energy Reduction Strategies	Condensing Boilers	Green	Yellow	Green	Green	Green	Red	Green	Green
	Local Domestic Hot Water Heaters	Green	Red	Red	Green	Green	Red	Green	Yellow
Energy Recovery Strategies	CRD Sewage Heat Recovery	Yellow	Yellow	Yellow	Yellow	Green	Yellow	Yellow	Red
	Heat Recovery From Enterprise Centre	Yellow	Yellow	Green	Yellow	Red	Red	Yellow	Green
	Energy from Solid Organic Waste	Yellow	Red	Red	Red	Red	Red	Yellow	Red
Low/Zero Carbon Solutions	Geoexchange Heat Pump	Green	Yellow	Yellow	Red	Yellow	Red	Yellow	Yellow
	Biomass Heating	Green	Green	Green	Red	Yellow	Yellow	Yellow	Green
	Biomass Cogeneration	Yellow	Green	Green	Red	Yellow	Yellow	Yellow	Green
	Wind	Green	Yellow	Red	Red	Yellow	Red	Green	Red
	Solar Thermal	Green	Green	Yellow	Green	Green	Red	Green	Green
	Solar Photovoltaic Cells	Green	Yellow	Red	Green	Green	Red	Green	Red
	Hydrogen Fuel Cell	Red	Red	Red	Red	Red	Red	Red	Red
	Concentrated Solar	Red	Yellow	Red	Red	Red	Red	Red	Red

Less Appropriate (Red) — (Yellow) — (Green) **More Appropriate**

11 ENERGY GENERATION COMBINATIONS

11.1 Introduction

Various combinations of the five most feasible technologies have been analyzed in the following sub-sections in order to identify the preferred solution for integration at UVic; one which maximizes energy savings and carbon reduction is financially feasible.

The results have been presented under key sub-headings to allow comparison between combinations. For all combinations standard assumptions have been made and are described under the relevant sub-heading below. Combination specific sub-headings, such as those relating to biomass fuel, are provided, as required.

11.1.1 System Size

For each combination, the revised energy baseline for UVic presented in Section 10.2 has been used to approximate the size of each system.

Assumptions regarding the output of the various energy sources are been defined in the relevant sub-section

11.1.2 Capital Cost

A breakdown of the estimated capital cost has been presented for the main elements of each combination. The costing information referenced from local suppliers, published cost data, and Cobalt's experience of the market. Where a cost range has been provided for an element, the mid-point of the range has been used estimate the capital cost required. The margin of error applicable to the total cost is typically ± 15%.

11.1.3 Energy and Carbon Savings

The energy and carbon savings have been estimated for each potential solution in terms of kWh and tonnes, respectively.

The results have also been presented as a percentage of UVic's revised energy baseline following the completion of the Continual Optimization Program, as discussed in Section 10.1.

As a reminder, the revised baseline assumptions for natural gas, electricity, and carbon emissions are set out below

- Revised Natural Gas Consumption = 64,400,000 kWh
- Revised Electrical Consumption = 55,000,000 kWh
- Revised Carbon Emissions = 15,850 Tonnes

11.1.4 Maintenance

A description of the maintenance burden of each combination, relative to UVic's current maintenance regime has been provided in this subsection.

Where there is considered to be an additional maintenance burden, maintenance costs have been estimated at 1% - 2% of the capital cost

11.1.5 Energy Cost Savings and Payback

The energy cost savings and simple payback have been estimated for each potential solution. The energy cost savings applies UVic's current energy costs ($0.056/kWh for electricity and $0.05/kWh for gas) to the estimated energy savings and includes an estimation of the carbon credit cost UVic would no longer pay due to the anticipated carbon savings.

The simple payback has been calculated by dividing the total Capital cost by the energy cost savings.

A sensitivity analysis of the Net Present Value for each combination has also been presented. A Net Present Value (NPV) calculation compares the value of a dollar today to the value of that same dollar in the future, taking inflation and anticipated returns on investment into account. If the NPV of a prospective project is positive, it should be accepted. Return on Investment scenarios of 5% and 7% have been applied to reflect UVic's cost of borrowing and long term asset return expectations.

A set of general assumptions for energy cost and energy cost inflation have been used for all combinations, unless otherwise stated. The general assumptions are as follows:

Natural Gas Cost (Year 1)	= $0.05/kWh
Natural Gas Inflation	= 5% year on year (based on projected energy costs, see Section 2.5.)
Electricity Cost (Year 1)	= $0.056/kWh
Electricity Inflation	= 5% year on year (based on projected energy costs, see Section 2.5.)
Carbon Credit Cost (Year 1)	= $25/tonne
Carbon Credit Inflation	= 2% year on year.
Maintenance Cost	= 2% of capital costs, year on year (where applicable)

The sensitivity analysis has been generated by adjusting a single a single variable, such as gas price or biomass fuel price; the chosen variable will be specific to each combination.

11.1.6 Funding Procurement Options

A brief description of the main method of procurement for each combination has been provided in this subsection. Other funding and procurement options may be available, depending on project cost and the University's financing options. Some procurement options offer a turnkey solution, requiring no capital investment form UVic.

Currently there is no specific funding available from Provincial or Federal Governments for the integration of low or zero carbon technologies into buildings. Independent negotiations between UVic and the Federal or Provincial Governments may result in specific funding for UVic but the feasibility of this is unknown at this time.

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11.1.7 Summary

The results of the feasibility analysis are summarized in this section. A summary table of the feasibility assessment of each combination using the cost/benefit criteria is provided as a quick reference highlight.

11.2 Solar Thermal

11.2.1 System Size

Solar thermal systems are generally sized to meet the base thermal load of a building(s), typically the domestic hot water load since it remains constant for the majority of the year. At UVic, the base load occurs in July and is likely to consist of a small amount of space heating load, in addition to domestic hot water load, because of the building types and energy demands.

The solar thermal array has been sized to meet the existing thermal base load of the central heating loop, and based on the daylight hours experienced in Victoria across the year, an average panel output of 700 kWh/m^2.yr has been assumed; a 13,000m^2 array is required. This array size will allow the central boilers to be turned off in July and their run-time minimized in June and August.

Connecting the solar thermal panels to the district heating loop will allow summertime space heating load, in addition to domestic hot water load, to be met. The loop will distribute thermal energy from locations of low demand and large building footprint (non lab buildings with large roof areas) to locations with high demand and small building footprint (i.e. high-rise residential buildings).

Local hot water generation will be required to boost the domestic hot water temperature in certain buildings and act as back up during cloudy days, allowing the central boiler plant to remain switched off. Buildings with high thermal loads during summer months have been identified in Table 11-3. Following completion of the Continual Optimization Program and installation of local energy meter to each building, the domestic hot water loads can be refined.

11.2.2 Capital Costs

From discussions with a number of solar thermal providers, the capital expenditure required to install a complete solar thermal system based on "vacuum tube" or "flat plate" solar collection, including the necessary storage, is currently in the range of \$700/m^2 to \$900/m^2 of panel for large scale arrays.

A breakdown of the cost involved to install an array of this size at UVic is presented in Table 11-1.

11.2.3 Energy and Carbon Savings

The estimated energy savings are 9.1M kWh per year, a 14% reduction in UVic's thermal demand

The estimated carbon savings are 1,655 tonnes per year; an 11% reduction in UVic's carbon emissions

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3.

11.2.4 Maintenance

Solar Thermal panels require very little maintenance; yearly cleaning is all that is typically required. The typical lifespan of the panels is 20 – 25 years.

11.2.5 Energy Cost savings and Payback

Table 11-3 summarizes the cost savings for the system, in year one. The low cost of energy in Canada means the simple payback period is relatively long at 22 years. This can be reduced by assuming gas prices will rise. A sensitivity analysis of gas prices for Returns on Investment of 5% and 7% are presented in Figure 11-1 and Figure 11-2.

Solar Thermal Cost Breakdown

Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Solar Thermal	13,000	kW	800	10,400,000	Includes Installation Cost	
Mechanical Room pipework, pumps, etc.	400	m	150	60,000	20m of new pipe per mechanical room	RS Means
Heating distribution pipework	100	m	400	40,000	Connect parkade solar thermal to loop	RS Means
Trenching	100	m	150	15,000	Connect parkade solar thermal to loop	RS Means
Solar Thermal Connection Points	20	#	5000	100,000	Connects solar thermal arrays to loop	
Supplementary DHW heaters	24	#	10000	240,000	Provides backup to guarantee sufficient hot water	
Total				**10,870,000**		

Table 11-1 Breakdown of Solar Thermal costs

11.2.6 Procurement and Funding Options

End user customer typically buys direct and self-finances the procurement and installation of a solar thermal system from local suppliers. In the University's situation, an ideal approach would be to procure the capital funding to design and install the entire system as one project, requiring at least \$11 Million. Another option would be to break this project down into phases, not more than five, to meet smaller portions of financing. This would cost more than a single large project approach.

11.2.7 Summary

The integration of a solar thermal system sized to meet the summertime thermal base load will achieve moderate reductions in energy and carbon; 13% and 10%, respectively. Due to the high capital cost and current low energy cost the simple payback is estimated to be 22 years. If gas prices were to increase by 10% a year, and based on a Return on Investment (ROI) of 5%, the payback period reduces to 17 years.

An assessment of feasibility to integrate a solar thermal array at UVic using the cost/benefit criteria is summarized in Table 11-2, below.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-2 Solar Thermal Cost/Benefit Summary

Location	Potential Useable Roof area	Potential Thermal Collection Area	Number of connections points to existing heating loop	Panel cost	Loop Connection Cost	Supplementary DHW generator	Supplementary DHW generator Cost	Energy Output	Energy Cost offset	Carbon savings	Carbon Credit "refund"	Total Cost Saving
	m2	m2	#	$	$	#	$	kWh/yr	$	Tonnes	$	$
Petch	1,750	875	1	$700,000	$5,000	2	20,000	612,500	$30,625	112	2,802	33,427
Elliott	2,000	1,000	1	$800,000	$5,000	1	10,000	700,000	$35,000	128	3,203	38,203
Cunningham	1,000	500	1	$400,000	$5,000	1	10,000	350,000	$17,500	64	1,601	19,101
Bob Wright	1,500	750	1	$600,000	$5,000	1	10,000	525,000	$26,250	96	2,402	28,652
Commons	1,250	625	1	$500,000	$5,000	1	10,000	437,500	$21,875	80	2,002	23,877
University Centre	1,900	950	1	$760,000	$5,000	1	10,000	665,000	$33,250	122	3,042	36,292
McKinnon Gym	1,500	750	1	$600,000	$5,000	2	20,000	525,000	$26,250	96	2,402	28,652
Landsdowne Residences	450	225	1	$180,000	$5,000	2	20,000	157,500	$7,875	29	721	8,596
Craigdarroch Residences	800	400	1	$320,000	$5,000	2	20,000	280,000	$14,000	51	1,281	15,281
ELW	1,500	750	1	$600,000	$5,000	1	10,000	525,000	$26,250	96	2,402	28,652
MacLaurin	1,200	600	1	$480,000	$5,000	1	10,000	420,000	$21,000	77	1,922	22,922
McPherson	1,600	800	1	$640,000	$5,000	1	10,000	560,000	$28,000	102	2,562	30,562
Cornett	1,000	500	1	$400,000	$5,000	1	10,000	350,000	$17,500	64	1,601	19,101
David Strong	500	250	1	$200,000	$5,000	1	10,000	175,000	$8,750	32	801	9,551
Business + Economics	1,000	500	1	$400,000	$5,000	1	10,000	350,000	$17,500	64	1,601	19,101
Clearihue	250	125	4	$100,000	$20,000	4	40,000	87,500	$4,375	16	400	4,775
Human + Social Development	500	250	1	$200,000	$5,000	1	10,000	175,000	$8,750	32	801	9,551
Building Integrated Total		9850	20	$7,880,000	$100,000	24	$240,000	6,895,000	$344,750	1,262	$31,545	$376,295
Parkade		3,150	1	$2,520,000	$5,000			2,205,000	$110,250	404	$10,088	$120,338
TOTAL		13,000		$10,400,000	$105,000		$240,000	9,100,000	$455,000	1,665	$41,633	$496,633

Table 11-3 Solar Thermal Energy, Carbon and Cost Savings

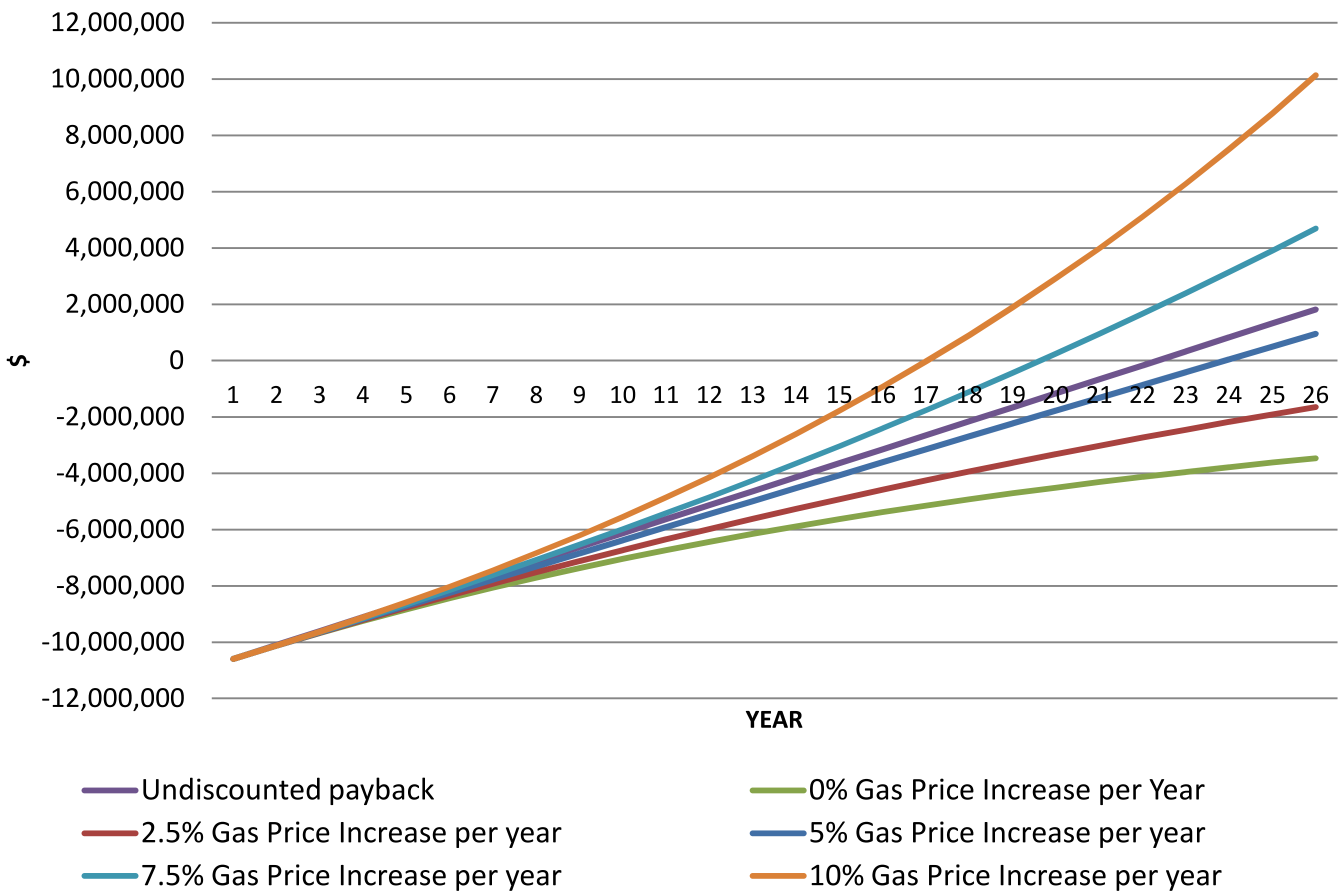


Figure 11-1 Solar Thermal Payback, 5% Return on Investment

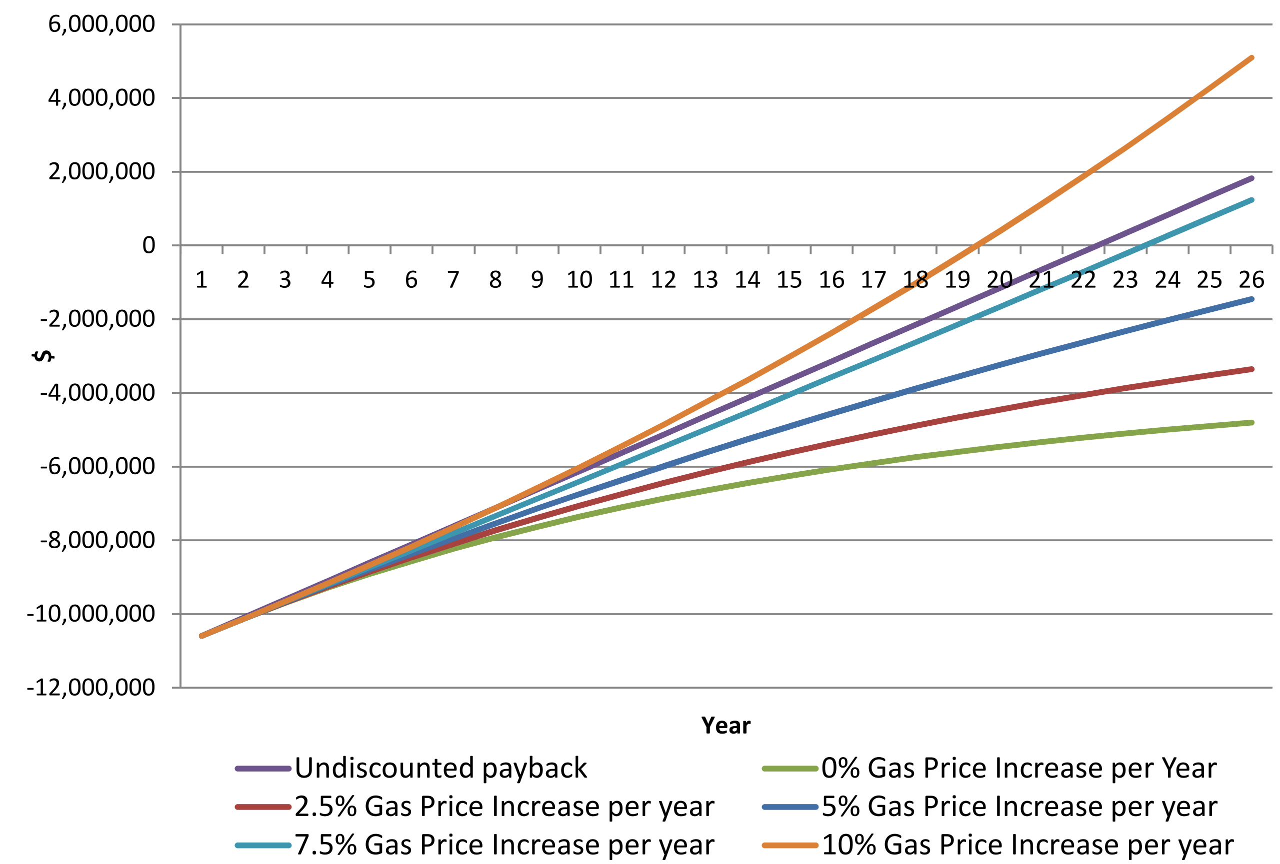


Figure 11-2 Solar Thermal Payback, 7% Return on Investment

11.3 Solar Thermal + Condensing Boilers

The existing primary gas-fired boilers (Volcano Flexible Tube Boilers) serving the central heating loop are due for replacement in the next 10-15 years. Replacing the standard efficiency boilers with gas-fired condensing boilers will provide energy savings, but, the savings will only be realized if the loop temperature can be lowered in the summer months. High efficient gas-fired condensing boilers and a solar thermal array complement each other well, and the feasibility of this combination has been assessed in this option.

11.3.1 System Size

For this combination the solar thermal array from Section 13.2 has been combined with gas-fired condensing boilers sized to meet UVic's current peak thermal load of 16,000kW.

The gas-fired boilers will supplement the thermal output from the solar thermal array for domestic hot water consumption during peak winter times, and act as back-up should any part of the solar thermal system fail.

11.3.2 Capital Costs

The solar thermal array size and costs from section 13.2 have been assumed.

For the gas-fired condensing boilers, it has been assumed that the cost of replacing the existing boiler plants at ELW and McKinnon with standard gas-fired boilers can be deducted since the boilers will require replacement within the next 10 years, regardless. The additional capital cost for the provision of gas-fired condensing boilers over and above standard boilers has been assumed to be $40/kW.

A breakdown of the capital costs involved to install combination of technologies at UVic is presented in Table 11-4 below.

11.3.1 Energy and Carbon Savings

The estimated energy savings are 10.8M kWh per year, a 17% reduction in UVic's thermal energy demand

The estimated carbon savings is nearly 2,000 tonnes per year, a 13% reduction in UVic's carbon emissions

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3.

To calculate the energy savings attributed to the gas-fired condensing boilers, an assessment of when the loop temperature is likely to be low enough for condensing (and therefore energy savings to be achieved) has been made using UVic's gas consumption data and the heating degree days experienced in Victoria.

For months when condensing can occur, an efficiency factor has been applied to supplementary heating demand to calculate the energy savings. If the loop temperature can be low enough for the whole month, an efficiency factor of 0.88 has been applied to reflect the 12% efficiency improvement of gas-fired condensing boilers over standard boilers. Where condensing can only occur for a portion of a month, the efficiency factor has been prorated accordingly.

During the peak winter months, the loop temperature will need to operate at its existing high temperature to provide sufficient heat to each building, therefore no condensing will be possible. In this situation, the efficiency of the gas-fired condensing boiler will assumed to be equal to standard boilers, i.e. efficiency improvement of 1. See "efficiency improvements due to condensing boilers" column in Table 11-6.

11.3.2 Maintenance

Solar Thermal panels require very little maintenance; yearly cleaning is all that is typically required. The typical lifespan of the panels is 20 – 25 years.

Gas-fired condensing boilers will be no more onerous in terms of maintenance than UVic's existing boiler installation.

11.3.3 Cost savings and Payback

Table 11-3 summarizes the cost savings for the system, in year one.

The simple payback period has reduced to 20 years with the inclusion of gas-fired condensing boilers. A sensitivity analysis of gas prices for Returns on Investment of 5% and 7% are presented in Figure 11-13 and Figure 11-24, respectively. At a ROI of 5%, gas prices need to increase by at least 5%, year on year for the investment to be worthwhile, based on a 25 year period. At a ROI of 7% gas prices will need to increase by at least 7.5% year on year.

Solar Thermal + Condensing Boilers						
Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Solar Thermal	13000	kW	800	10,400,000	Includes Installation Cost	
Gas-fired Condensing Boilers	16000	kW	70	1,120,000	Incremental cost	
Mechanical Room pipework, pumps, etc.	500	m	150	75,000	20m of new pipe per mechanical room	RS Means
Heating distribution pipework	100	m	400	40,000	Connect parkade solar thermal to loop	RS Means
Trenching	100	m	150	15,000	Connect parkade solar thermal to loop	RS Means
Solar Thermal Connection Points	20	#	5000	100,000	Connects solar thermal arrays to loop	
Supplementary DHW heaters	24	#	10000	240,000	Provides backup to guarantee sufficient hot water	
Total				**11,990,000**		

Table 11-4 Breakdown of Costs for Solar Thermal + Condensing Boilers

11.3.1 Procurement and Funding Options

End user customer typically buys direct and self-finances the procurement and installation of a solar thermal system from local suppliers. In the University's situation, an ideal approach would be to procure the capital funding to design and install the entire system as one project, requiring at least $11 Million. Another option would be to break this project down into phases, not more than five, to meet smaller portions of financing. This would cost more than a single large project approach.

11.3.2 Summary

The integration of a solar thermal system sized to meet the summertime thermal base load will achieve moderate reductions in energy and carbon; 13% and 10%, respectively. Due to the high capital cost and current low energy cost the simple payback is estimated to be 22 years. If gas prices were to increase by 10% a year, and based on a Return on Investment (ROI) of 5%, the payback period reduces to 17 years.

An assessment of feasibility to integrate a biomass boiler plant at UVic using the cost/benefit criteria is summarized in Table 11-2, below.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-5 Solar Thermal + Condensing Boiler Cost/Benefit Summary

		Solar Thermal				Gas Fired Condesing Boilers - Supplementary Boiler							Total			
Month	Central Heating Loop Demand	Solar Thermal output	Carbon savings from Solar Thermal	Carbon Credit 'Refund'	Displaced energy cost	Supplemntary Heating Load	Condensing Boiler Efficiency compared with a Standard Boiler	Gas-Fired Condensing Boiler Output	Energy Savings achieved using Condensing Boilers	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Total Energy Savings	Total Carbon Savings	Total Carbon Credit Refund	Total Energy Cost Savings
	kWh	kWh	tonnes	$	$	kWh	(less than 1 = more efficient)	kWh	kWh	tonnes	$	$	kWh	tonnes	$	$
Jan	5,547,019	293,552	54	1,343	14,678	5,253,468	1	5,253,468	0	0	$0	$0	293,552	54	$1,343	$14,678
Feb	4,988,890	472,016	86	2,159	23,601	4,516,874	1	4,516,874	0	0	$0	$0	472,016	86	$2,159	$23,601
Mar	5,551,794	754,765	138	3,453	37,738	4,797,029	1	4,797,029	0	0	$0	$0	754,765	138	$3,453	$37,738
April	5,451,569	1,018,946	186	4,662	50,947	4,432,622	0.95	4,210,991	221631	41	$1,014	$11,082	1,240,577	227	$5,676	$62,029
May	3,496,403	1,134,746	208	5,191	56,737	2,361,657	0.88	2,078,258	283399	52	$1,297	$14,170	1,418,145	260	$6,488	$70,907
June	1,762,564	1,225,631	224	5,607	61,282	536,933	0.88	472,501	64432	12	$295	$3,222	1,290,063	236	$5,902	$64,503
July	1,191,035	1,308,948	240	5,988	65,447	0	0	0	0	0	$0	$0	1,308,948	240	$5,988	$65,447
Aug	1,719,339	1,249,240	229	5,715	62,462	470,098	0.88	413,687	56412	10	$258	$2,821	1,305,652	239	$5,973	$65,283
Sept	3,845,506	1,059,501	194	4,847	52,975	2,786,005	0.88	2,451,684	334321	61	$1,530	$16,716	1,393,821	255	$6,377	$69,691
Oct	4,074,933	679,686	124	3,110	33,984	3,395,246	0.95	3,225,484	169762	31	$777	$8,488	849,449	155	$3,886	$42,472
Nov	5,563,145	353,985	65	1,619	17,699	5,209,159	1	5,209,159	0	0	$0	$0	353,985	65	$1,619	$17,699
Dec	7,539,135	245,832	45	1,125	12,292	7,293,304	1	7,293,304	0	0	$0	$0	245,832	45	$1,125	$12,292
	50,731,331	9,796,849	1,793	44,821	489,842	41,052,396		39,922,439	1,129,957	207	$5,170	$56,498	$10,926,806	2,000	$49,990	$546,340

Table 11-6 Solar Thermal + Condensing Boilers- Breakdown of Carbon and Energy Cost Savings

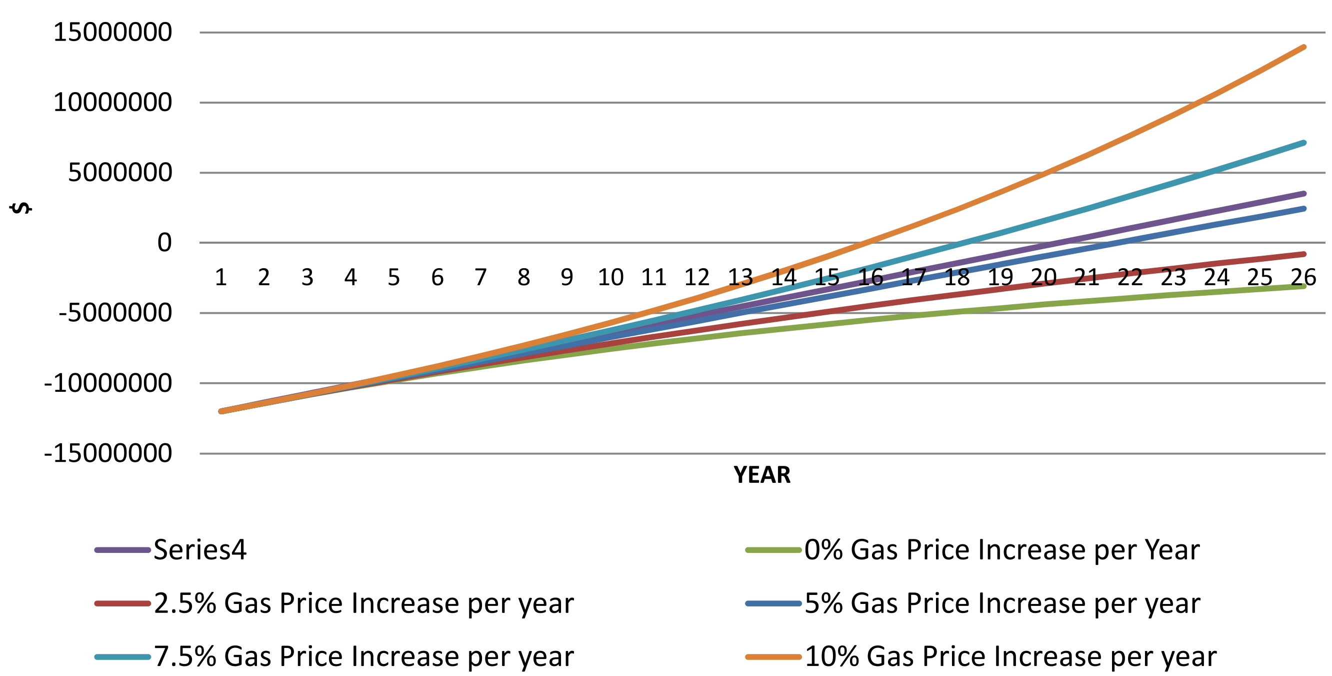


Figure 11-3 Solar Thermal + Condensing Boilers Payback, 5% ROI

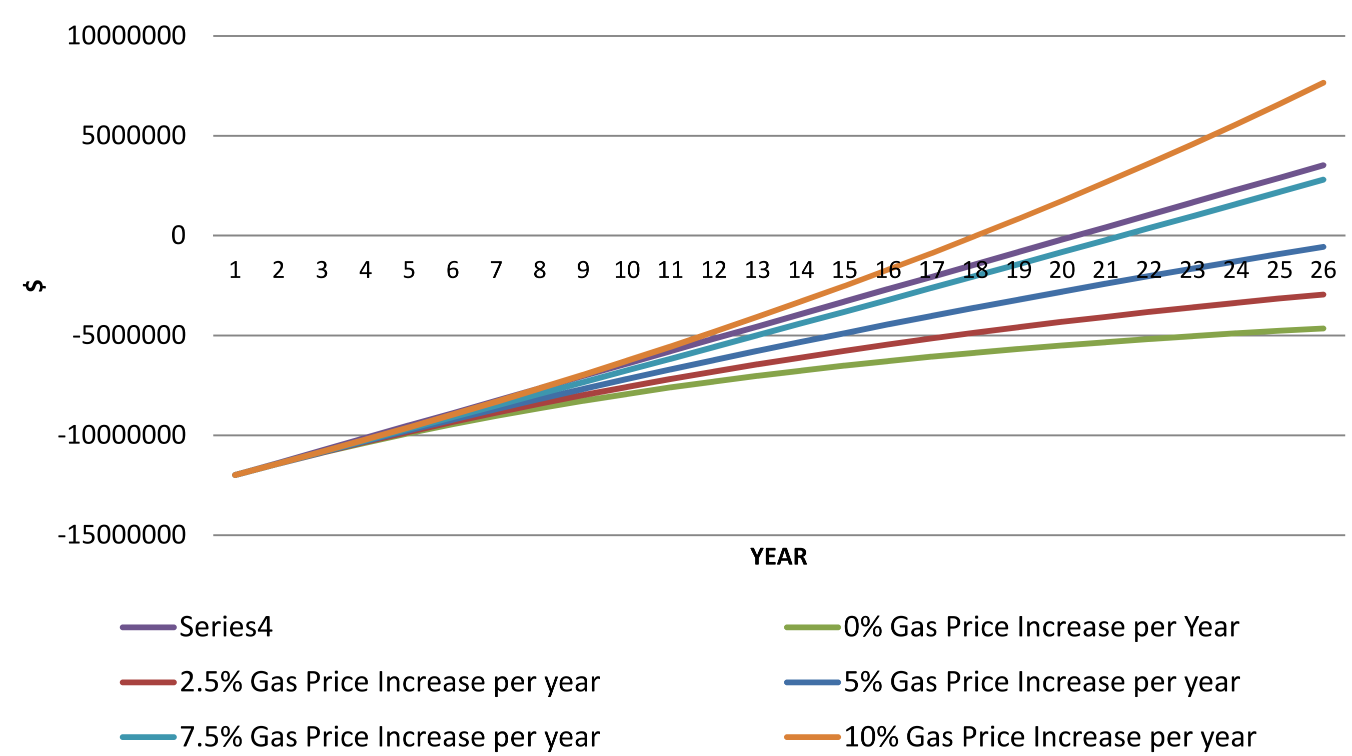


Figure 11-4 Solar Thermal + Condensing Boilers Payback, 7% ROI

11.4 Biomass Boiler + Gas-fired Condensing Boilers

11.4.1 System Size

A biomass boiler size of 4,200kW capacity is proposed to maximize the run-time at 100% load, which helps to maximize efficiency of the system, and limit the necessary turndown to approximately 50% during the summer months. A biomass boiler of this size will provide 65% of the yearly heating demand at UVic, see Figure 11-5. Following completion of the Continual Optimization Program, availability of hourly meter data for the consumption of thermal energy at each building should be used to refine the biomass boiler size.

A boiler of this size will be meet 25% of the peak heating load, with the remainder being met through the use of gas-fired condensing boilers. Note that the peak heating load is estimated to occur for less than 20% of the total heating plant operating hours. A sketch of a typical biomass boiler layout is presented in Figure 11-8

It has been assumed that the supplementary peak heat capacity is provided by new gas-fired condensing boilers, sized to meet peak heating load of 16,000 kW and provide back-up to the biomass boiler.

11.4.2 Capital Costs

The capital cost of a biomass boiler system is highly dependant on system configuration, scope definition and project delivery model. Based on discussions with a number of biomass boiler providers, the capital expenditure required is currently in the range of $1,650/kW to $2,500/kW to supply and install a biomass heating only plant.

For the gas-fired condensing boilers, it has been assumed that the cost of replacing the existing boiler plants at ELW and McKinnon with standard gas-fired boilers can be deducted from this capital cost since the boilers will require replacement within the next 10 years regardless. The additional cost for the provision of gas-fired condensing boilers over standard boilers has been assumed at $40/kW.

A breakdown of the cost involved to install an array of this size at UVic is presented in Table 11-1

11.4.1 Fuel

There are currently no regulated utility providers that supply scrap wood or bio-mass fuel feedstock so fuel costs are potentially un-regulated and volatile.

From discussions with leading biomass providers and industry experts, there is confidence of sufficient fuel being available on Vancouver Island, in the long term. The price of biomass fuel is currently increasing and long term pricing of $40-$80 per Oven Dried Tonne (ODT) for long term supply contracts are currently being quoted.

Based on a calorific value of 15-18 GJ of per ODT of biomass, the energy cost of biomass will potentially be $3- $6 per GJ ($0.01/kWh – $0.022/kWh), over 50% lower than UVic's current natural gas cost.

During the peak winter months, approximately 5-6 deliveries of biomass will be required per day. On-site fuel storage is typically provided for up to 48 hours.

The next step is to complete a detailed fuel study, prior to beginning the design phase of the biomass system.

The risks relating to fuel source, delivery and cost can be mitigated by procuring a turnkey operation form a Utility or ESCo.

11.4.1 Emissions

There are currently no set Provincial emission thresholds for biomass-fuelled energy plants in BC, apart from boilers used for agricultural applications, such as Greenhouses.

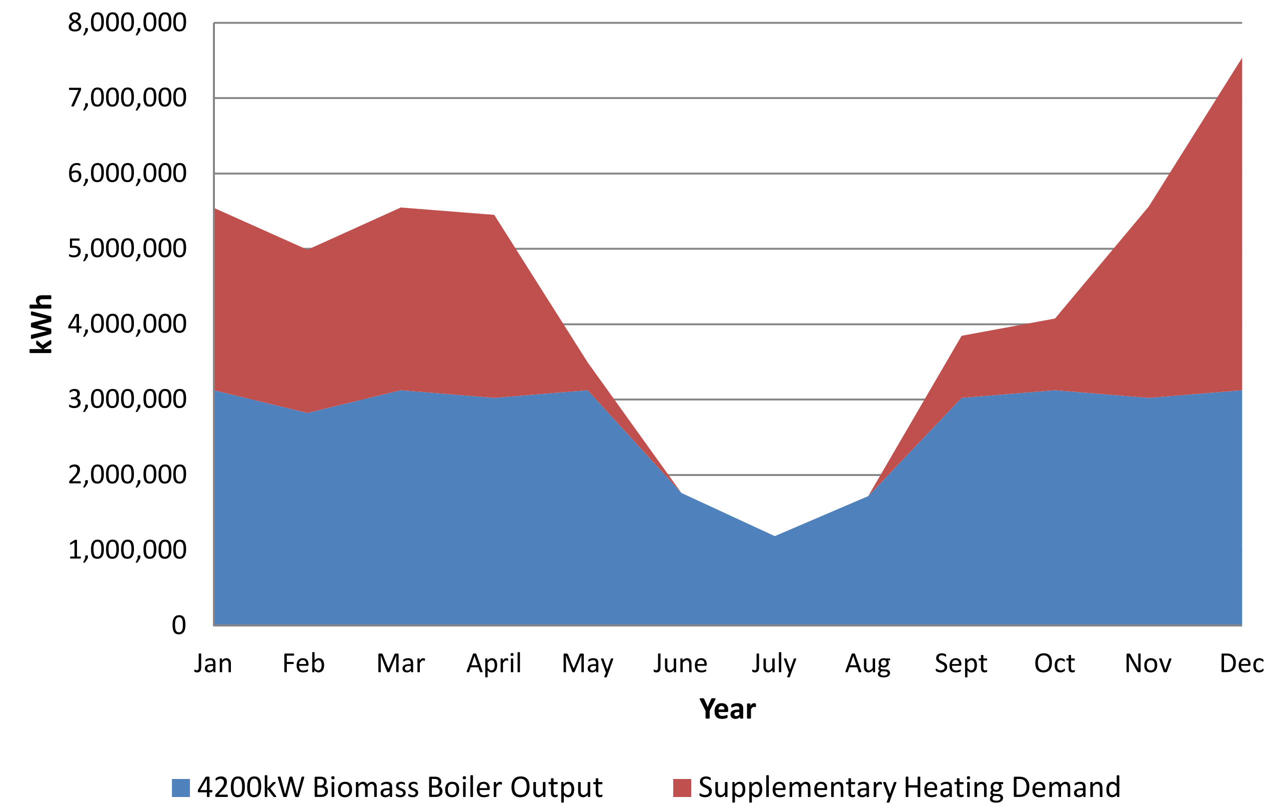


Figure 11-5 Monthly Profile of Biomass boilers output and Supplementary Heating Requirement

Ministry of Environment (MoE) regulates the emissions from agricultural biomass boilers using a standard. All other applications require a permit, which is negotiated on an individual basis with the relevant regional department of the MoE. MoE staff usually applies the agricultural boiler standard, see below.

Item	Capacity of Boiler or Heater	Emission Standards (effective September 1, 2010)	
		Particulate Matter Limit	Opacity Limit
1	Exceeding 3 MW	35 mg/m^3	10%
2	Exceeding 1 MW but not exceeding 3 MW	50 mg/m^3	10%
3	Not exceeding 1 MW	120 mg/m^3	20%

Source: Agricultural Waste Control Regulation, Part 6, Section 18.1, see http://www.bclaws.ca/EPLibraries/bclaws_new/document/ID/freeside/10_131_92

In Metro Vancouver, particulate emission thresholds have been set at 18mg/m^3 with opacity not exceeding 5%. Modern biomass boiler plants typically achieve particulate levels lower than the 18mg/m^3 threshold, and with opacity of only 1%.

Biomass plants also operate in certain States in America where Carbon Monoxide (CO), Volatile Organic Compounds (VOC) and Nitrogen Oxide (NO_x) limits have been set. CO and VOC emissions from burning biomass are typically lower than natural gas; Reductions in NO_x emissions are more difficult but can be achieved using the Selective Non-Catalytic Reduction (NCR) and continuously achieve reductions of 40%-70%.

Biomass Boiler + Condensing Boilers						
Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Biomass Boiler - Heating Only	4200	kW	2000	8,400,000	Average estimated cost	Biomass Boiler Suppliers
Gas Fired Condensing Boilers	16000	kW	40	640,000	Extra over cost for condensing in place of standard	Boiler supplier
New Energy hub building	1000	m2	2500	2,500,000		RS Means
Plantroom pipework, pumps, etc.	100	m	150	15,000		RS Means
Heating distribution pipework	100	m	400	40,000		RS Means
Trenching	100	m	150	15,000		RS Means
Building heat exchangers	2	#	20000	40,000	Connect new energy centre to loop	
Total				**11,650,000**		

Table 11-6 Biomass Boiler + Condensing Boiler Cost Breakdown

11.4.2 Energy and Carbon Savings

The estimated purchased energy savings are 32.5M kWh per year; a 50% reduction in UVic's thermal energy demand.

The estimated carbon savings is nearly 6000 tonnes per year; a 38% reduction in UVic's carbon emissions.

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3

11.4.3 Maintenance

Biomass boilers typically require twice yearly shutdowns for maintenance. They are a higher maintenance burden than gas-fired boilers, and typically require a, a dedicated team of 1-2 staff members will be required to maintain and operate a plant of this size. The biomass boiler output reduction noted during the summer, in Figure 11-5, reflects an amount of days of downtime for maintenance.

Gas-fired condensing boilers will be no more onerous in terms of maintenance than UVic's existing boiler installation.

11.4.4 Energy Cost savings and Payback

In addition to the assumptions set out in section 13.1, a biomass plant capital cost of $2000/kW and a biomass fuel cost of $6/GJ have been used to calculate the energy costs and payback. Table 11-8 summarizes the cost savings for the system in year one.

Based on the above assumptions, the estimated simple payback has been calculated to be 12 years.

Figure 11-6 and

Figure 11-6 provides a net present value calculation and associated sensitivity analysis for return on investment scenarios of 5% and 7%, reflecting UVic's cost of borrowing and long term asset return expectations.

Even with an 8% yearly increase in biomass fuel costs from $6/GJ, the payback period only increase to 10-12 years.

11.4.5 Procurement and Funding Options

There are three main methods through which to procure a biomass heating plant, summarized below, from direct ownership to turn-key operation. All three are valid for implementation at UVic.

1. Direct Sale – End user customer buys direct and self-finances the project based on internal capital hurdle rates. Typical for industrial customers, select federal agencies, municipalities and universities. Typically has the longest procurement timelines.

2. Utilities (Build-Own-Operate-Maintain) – A 3rd party utility finances, owns, operates and sells energy to multiple/single end users. Regulated utilities work energy costs into a rate base for the customer(s), increasingly common for fiscally constrained universities, hospital, military bases.

3. ESCO (Energy Services Companies) – ESCO installs energy equipment, guarantees savings/ energy displacement for end user. 3rd party debt finances the project. End users own the asset at the end of the ESCO term.

Options 2 and 3 eliminate the need for UVic to provide the required capital funding and the Utility or ESCO will the risks relating to biomass fuel provision and cost.

11.4.6 Summary

The introduction of biomass boilers offers the potential to significantly reduce the thermal energy consumption and corresponding carbon emissions from UVic's Gordon Head Campus.

The associated energy cost reductions are sufficient to offset the high capital costs; the simple payback is estimated to be 12 years. Even if the price of biomass was to increase by 8% per year, the payback would only increase to 18 years, based on a ROI of 5%.

An assessment of feasibility to integrate a biomass boiler plant at UVic using the cost/benefit criteria is summarized in Table 11-7, below.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-7 Biomass Boiler + Condensing Boiler Cost/Benefit Summary

	Biomass - Primary Boiler						Gas Fired Condesing Boilers - Supplementary Boiler							Total			
Monthly Hot water load	Biomass boiler output	Carbon savings from Biomass Boiler	Carbon 'Credit' Reduction	Displaced energy cost (Nat. Gas)	Biomass cost	Energy cost saving	Supplemntary Heating Load	Condensing Boiler Efficiency compared with a Standard Boiler	Gas-Fired Condensing Boiler Output	Energy Savings achieved using Condensing Boilers	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Total Energy Savings	Total Carbon Savings	Total Carbon Credit Refund	Total Energy Cost Savings
kWh	kWh	tonnes	$	$	$	$	kWh		kWh	kWh	tonnes	$	$	kWh	tonnes	$	$
5,547,019	3,124,800	572	$14,296	$156,240	$78,120	$78,120	2,422,219	1	2,422,219	0	0	$0	$0	3,124,800	572	$14,296	$78,120
4,988,890	2,822,400	516	$12,912	$141,120	$70,560	$70,560	2,166,490	1	2,166,490	0	0	$0	$0	2,822,400	516	$12,912	$70,560
5,551,794	3,124,800	572	$14,296	$156,240	$78,120	$78,120	2,426,994	1	2,426,994	0	0	$0	$0	3,124,800	572	$14,296	$78,120
5,451,569	3,024,000	553	$13,835	$151,200	$75,600	$75,600	2,427,569	0.95	2,306,190	121378	22	$555	$6,069	3,145,378	576	$14,390	$81,669
3,496,403	3,124,800	572	$14,296	$156,240	$78,120	$78,120	371,603	0.88	327,011	44592	8	$204	$2,230	3,169,392	580	$14,500	$80,350
1,762,564	1,762,564	323	$8,064	$88,128	$44,064	$44,064	0	0	0	0	0	$0	$0	1,762,564	323	$8,064	$44,064
1,191,035	1,191,035	218	$5,449	$59,552	$29,776	$29,776	0	0	0	0	0	$0	$0	1,191,035	218	$5,449	$29,776
1,719,339	1,719,339	315	$7,866	$85,967	$42,983	$42,983	0	0	0	0	0	$0	$0	1,719,339	315	$7,866	$42,983
3,845,506	3,024,000	553	$13,835	$151,200	$75,600	$75,600	821,506	0.88	722,925	98581	18	$451	$4,929	3,122,581	571	$14,286	$80,529
4,074,933	3,124,800	572	$14,296	$156,240	$78,120	$78,120	950,133	0.95	902,626	47507	9	$217	$2,375	3,172,307	581	$14,513	$80,495
5,563,145	3,024,000	553	$13,835	$151,200	$75,600	$75,600	2,539,145	1	2,539,145	0	0	$0	$0	3,024,000	553	$13,835	$75,600
7,539,135	3,124,800	572	$14,296	$156,240	$78,120	$78,120	4,414,335	1	4,414,335	0	0	$0	$0	3,124,800	572	$14,296	$78,120
50,731,331	32,191,337	5,891	$147,275	$1,609,567	$804,783	$804,783	18,539,993		18,227,935	312,058	57	$1,428	$15,603	$32,503,395	5,948	$148,703	$820,386

Table 11-8 Biomass Boiler + Condensing Boiler - Energy, Carbon and Energy Cost Savings

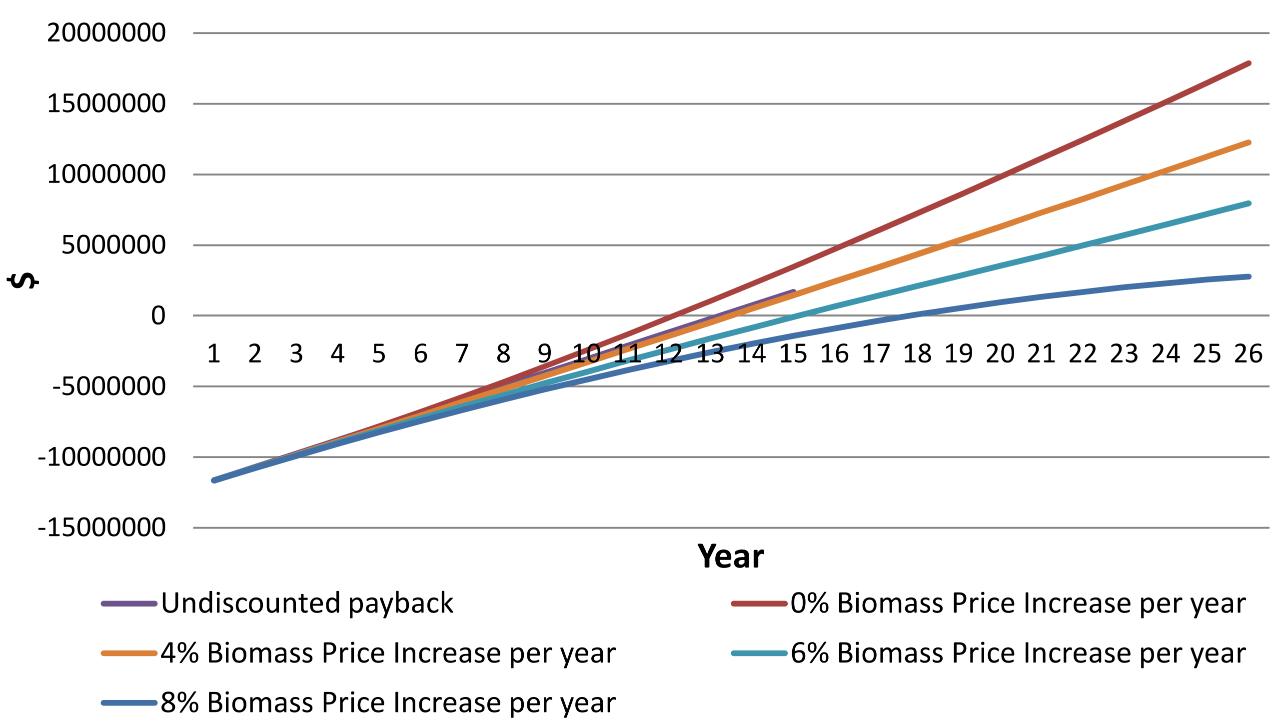


Figure 11-6 Biomass + Condensing Boilers Payback, 5% ROI

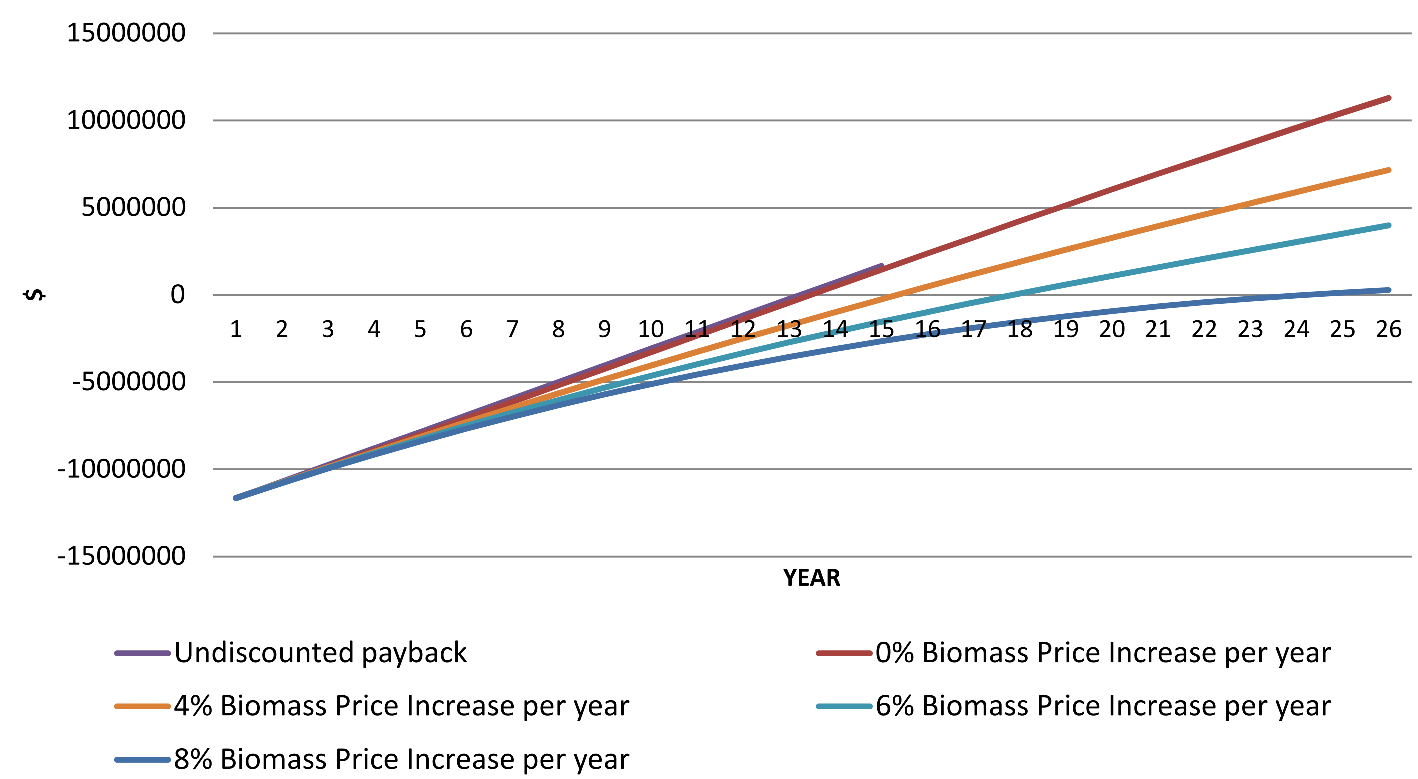


Figure 11-7 Biomass + Condensing Boilers Payback, 7% ROI

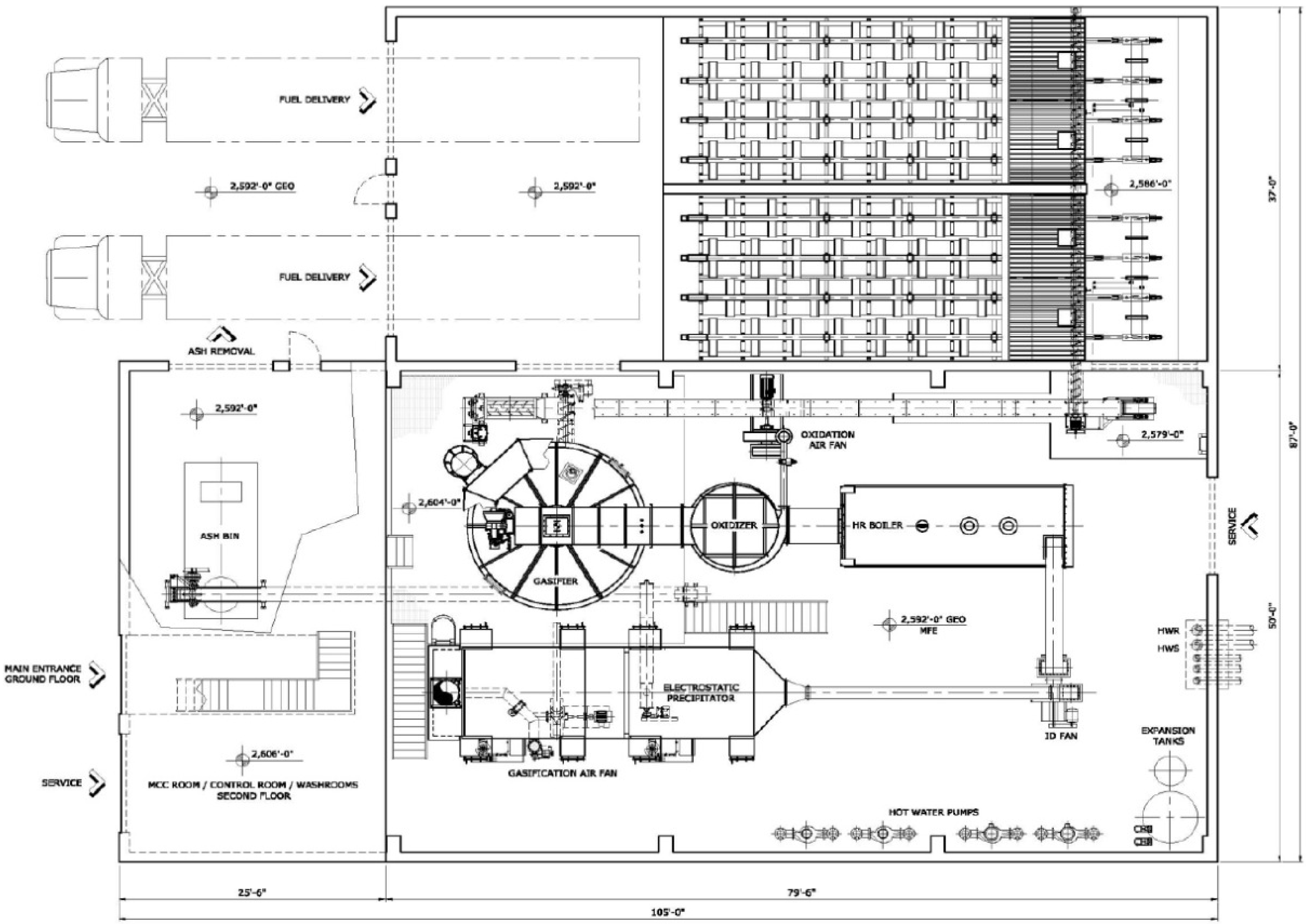


Figure 11-8 Typical Biomass Boiler Equipment Size. Gasification plant shown but other types will be similar in size

11.5 Biomass + Solar Thermal + Condensing gas-fired boilers (Back-up)

Combining a Biomass boiler and solar thermal array will potentially offer significant savings in energy costs and carbon. However, both technologies serve the same load

11.5.1 System Size

The solar thermal array from Section 13.2 (13000m^2) and biomass boiler size defined in section 13.4 (4200kW) have been used in this combination; see Figure 11-9.

The gas-fired condensing boilers and biomass heating plant have been sized to meet UVic's peak thermal load of 16000kW in order to supplement the thermal output from the solar thermal array during peak winter times, and to act as a full back-up should any part of the solar thermal system or the biomass boiler fail.

11.5.2 Capital Costs

The capital cost of a biomass boiler system is highly dependant on system configuration, scope split, project delivery model. Based on discussions with a number of biomass boiler providers, the capital expenditure required is currently in the range of $1650/kW to $2500/kW.

For the gas-fired condensing boilers, it has been assumed that the cost of replacing the existing boiler plants at ELW and McKinnon with standard gas-fired boilers can be deducted from this capital cost since the boilers will require replacement within the next 10 years regardless. The additional cost for the provision of gas-fired condensing boilers over standard boilers has been assumed at $40/kW.

A breakdown of the combined capital cost of all three elements is presented in Table 11-1; nearly 50% of the cost is attributed to the solar thermal system.

11.5.3 Biomass Fuel

The fuel cost assumptions in Section 13.3 remain valid for this option.

The biomass boiler remains the dominant source of thermal energy during the winter and will still require approximately 5-6 deliveries of biomass per day. On-site fuel storage should remain at 48 hours worth, as a minimum requirement.

The next step is to complete a detailed fuel study, prior to beginning the design phase of the biomass system.

The risks relating to fuel source, delivery and cost can be mitigated by procuring a turnkey operation form a Utility or ESCo.

11.5.4 Biomass Emissions

As discussed in Section 13.3, there are currently no set Provincial emission thresholds for biomass-fuelled energy plants in B, apart from boilers used for agricultural applications, such as Greenhouses.

The thresholds discussed in 13.3 will also be valid for this solution.

11.5.1 Energy and Carbon Savings

The estimated energy savings are 37.4M kWh per year; a 58% reduction in UVic's thermal energy cost demand.

The estimated carbon savings is nearly 6845 tonnes per year; a 43% reduction in UVic's carbon emissions.

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3

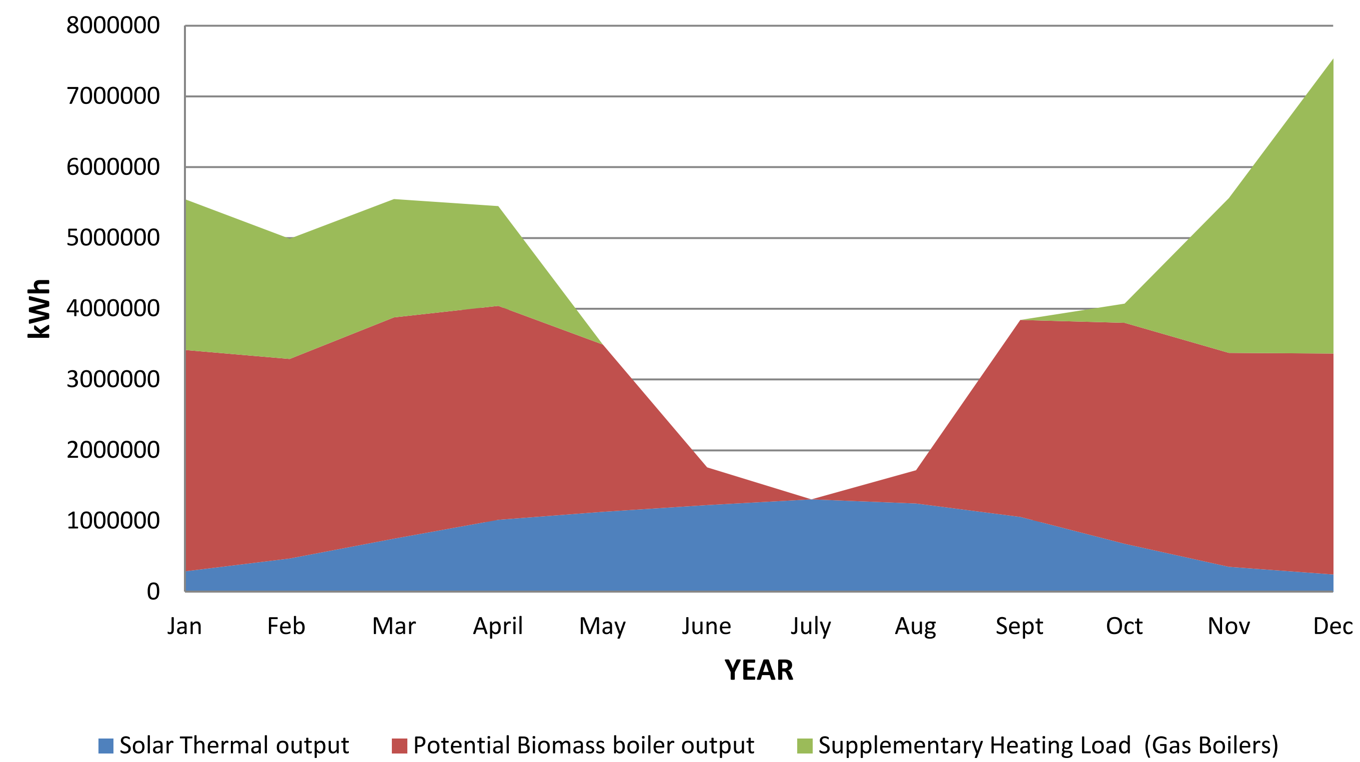


Figure 11-9 Monthly Profile of Solar Thermal output, Biomass boilers output and Supplementary Heating Requirement

11.5.2 Maintenance

Solar Thermal panels require very little maintenance; yearly cleaning is all that is typically required. The typical lifespan of the panels is 20 – 25 years.

The biomass boiler will be shut down during the month of July when the solar thermal output is sufficient to meet the heating demand providing a good opportunity to carry out maintenance. A dedicated team of 1-2 staff members will still be required to maintain and operate a plant of this size. For turnkey operations, the maintenance staffing is typically the responsibility of the provider.

Gas-fired condensing boilers are no more onerous to maintain than UVic's existing boiler installation.

11.5.3 Energy Cost savings and Payback

Table 11-11 summarizes the cost savings for the system in year one and is based on assumptions set out for each of the systems in previous sections.

Based on the above assumptions, the estimated simple payback has been calculated to be 19 years.

Figure 11-6 and

Figure 11-6 present a net present value calculation as associated sensitivity analysis for return on investment scenarios of 5% and 7%, reflecting UVic's cost of borrowing and long term asset return expectations.

Only when biomass fuel costs increase at 8% every year from $6/GJ does the payback extend beyond 25 years. This is unlikely, but still a risk to be considered if other large heating plants convert to biomass fuel and a supply and demand impact is felt.

11.5.4 Procurement and Funding Options

There are three main methods through which to procure a biomass heating plant, summarized below, from direct ownership to turn-key operation. All three are valid for implementation at UVic.

1. Direct Sale – End user customer buys direct and self-finances the project based on internal capital hurdle rates. Typical for industrial customers, select federal agencies, municipalities and universities. Typically has the longest procurement timelines.

2. Utilities (Build-Own-Operate-Maintain) – A 3rd party utility finances, owns, operates and sells energy to multiple/single end users. Regulated utilities work energy costs into a rate base for the customer(s), increasingly common for fiscally constrained universities, hospital, military bases.

3. ESCO (Energy Services Companies) – ESCO installs energy equipment, guarantees savings/ energy displacement for end user. 3rd party debt finances the project. End users own the asset at the end of the ESCO term.

Options 2 and 3 eliminate the need for UVic to provide the required capital funding and the Utility or ESCO will the risks relating to biomass fuel provision and cost.

The end user customer typically buys direct and self-finances the procurement and installation of a solar thermal system from local suppliers. In the University's situation, an ideal approach would be to procure the capital funding to design and install the entire system as one project, requiring at least $11 Million. Another option would be to break this project down into phases, not more than five, to meet smaller portions of financing. This would cost more than a single large project approach.

Biomass Boiler (Heating Only) + Solar Thermal + Condensing Boilers						
Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Biomass Boiler - Heating Only	4200	kW	2000	8,400,000	Average estimated cost	Biomass Boiler Suppliers
Gas Fired Condensing Boilers	16000	kW	40	640,000	Extra over cost for condensing in place of standard	Boiler supplier
Solar Thermal	13000	kW	800	10,400,000		
New Energy hub building	1000	m2	2500	2,500,000		RS Means
Plantroom pipework, pumps, etc.	300	m	150	45,000	All Mechanical rooms, inc. new energy hub	RS Means
Heating distribution pipework	100	m	400	40,000		RS Means
Trenching	100	m	150	15,000		RS Means
Building heat exchangers	2	#	20000	40,000	Connect new energy centre to loop	
Solar Thermal Connection Points	20	#	5000	100,000	Connects solar thermal arrays to loop	
Supplementary DHW heaters						
Total				**22,180,000**		

Table 11-9 Solar Thermal + Biomass Boiler + Condensing Boiler Cost Breakdown

11.5.5 Summary

The combination of biomass boiler and solar thermal panels offers the potential to maximize energy and carbon savings at UVic.

The high capital cost and comparably low energy savings of the solar thermal system increases the payback period compared with solely installing a biomass boiler.

An assessment of feasibility to integrate a combined solar thermal and biomass boiler plant at UVic using the cost/benefit criteria is summarized in Table 11-7, below.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-10 Biomass Boiler + Solar Thermal + Condensing Boiler Cost/Benefit Summary

		Solar Thermal				Biomass - Primary Boiler						Gas Fired Condesing Boilers - Supplementary Boiler							Total			
Month	Central Heating Loop Demand	Solar Thermal output	Carbon savings from Solar Thermal Boiler	Carbon Credit 'Refund'	Displaced energy cost	Biomass boiler output	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Biomass cost	Energy cost saving	Supplemntary Heating Load	Condensing Boiler Efficiency compared with a Standard Boiler	Gas-Fired Condensing Boiler Output	Energy Savings achieved using Condensing Boilers	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Total Energy Savings	Total Carbon Savings	Total Carbon Credit Refund	Total Energy Cost Savings
	kWh	kWh	tonnes	$	$	kWh	tonnes	$	$	$	$	kWh		kWh	kWh	tonnes	$	$	kWh	tonnes	$	$
Jan	5,547,019	293,552	54	1,343	14,678	3,124,800	572	$14,296	$156,240	$93,744	$62,496	2,128,668	1	2,128,668	0	0	$0	$0	3,418,352	626	$15,639	$77,174
Feb	4,988,890	472,016	86	2,159	23,601	2,822,400	516	$12,912	$141,120	$84,672	$56,448	1,694,474	1	1,694,474	0	0	$0	$0	3,294,416	603	$15,072	$80,049
Mar	5,551,794	754,765	138	3,453	37,738	3,124,800	572	$14,296	$156,240	$93,744	$62,496	1,672,229	1	1,672,229	0	0	$0	$0	3,879,565	710	$17,749	$100,234
April	5,451,569	1,018,946	186	4,662	50,947	3,024,000	553	$13,835	$151,200	$90,720	$60,480	1,408,622	0.95	1,338,191	70431	13	$322	$3,522	4,113,377	753	$18,819	$114,949
May	3,496,403	1,134,746	208	5,191	56,737	2,361,657	432	$10,805	$118,083	$70,850	$47,233	0	0.88	0	0	0	$0	$0	3,496,403	640	$15,996	$103,970
June	1,762,564	1,225,631	224	5,607	61,282	536,933	98	$2,456	$26,847	$16,108	$10,739	0	0.88	0	0	0	$0	$0	1,762,564	323	$8,064	$72,020
July	1,191,035	1,308,948	240	5,988	65,447	0	0	$0	$0	$0	$0	0	0.88	0	0	0	$0	$0	1,308,948	240	$5,988	$65,447
Aug	1,719,339	1,249,240	229	5,715	62,462	470,098	86	$2,151	$23,505	$14,103	$9,402	0	0.88	0	0	0	$0	$0	1,719,339	315	$7,866	$71,864
Sept	3,845,506	1,059,501	194	4,847	52,975	2,786,005	510	$12,746	$139,300	$83,580	$55,720	0	0.88	0	0	0	$0	$0	3,845,506	704	$17,593	$108,695
Oct	4,074,933	679,686	124	3,110	33,984	3,124,800	572	$14,296	$156,240	$93,744	$62,496	270,446	0.95	256,924	13522	2	$62	$676	3,818,009	699	$17,467	$97,156
Nov	5,563,145	353,985	65	1,619	17,699	3,024,000	553	$13,835	$151,200	$90,720	$60,480	2,185,159	1	2,185,159	0	0	$0	$0	3,377,985	618	$15,454	$78,179
Dec	7,539,135	245,832	45	1,125	12,292	3,124,800	572	$14,296	$156,240	$93,744	$62,496	4,168,504	1	4,168,504	0	0	$0	$0	3,370,632	617	$15,421	$74,788
	50,731,331	9,796,849	1,793	44,821	489,842	27,524,294	5,037	$125,924	$1,376,215	$825,729	$550,486	13,528,102		13,444,149	83,953	15	$384	$4,198	37,405,096	6,845	$171,128	$1,044,526

Table 11-11 Biomass Boiler + Solar Thermal + Condensing Boiler - Energy, Carbon and Energy Cost Savings

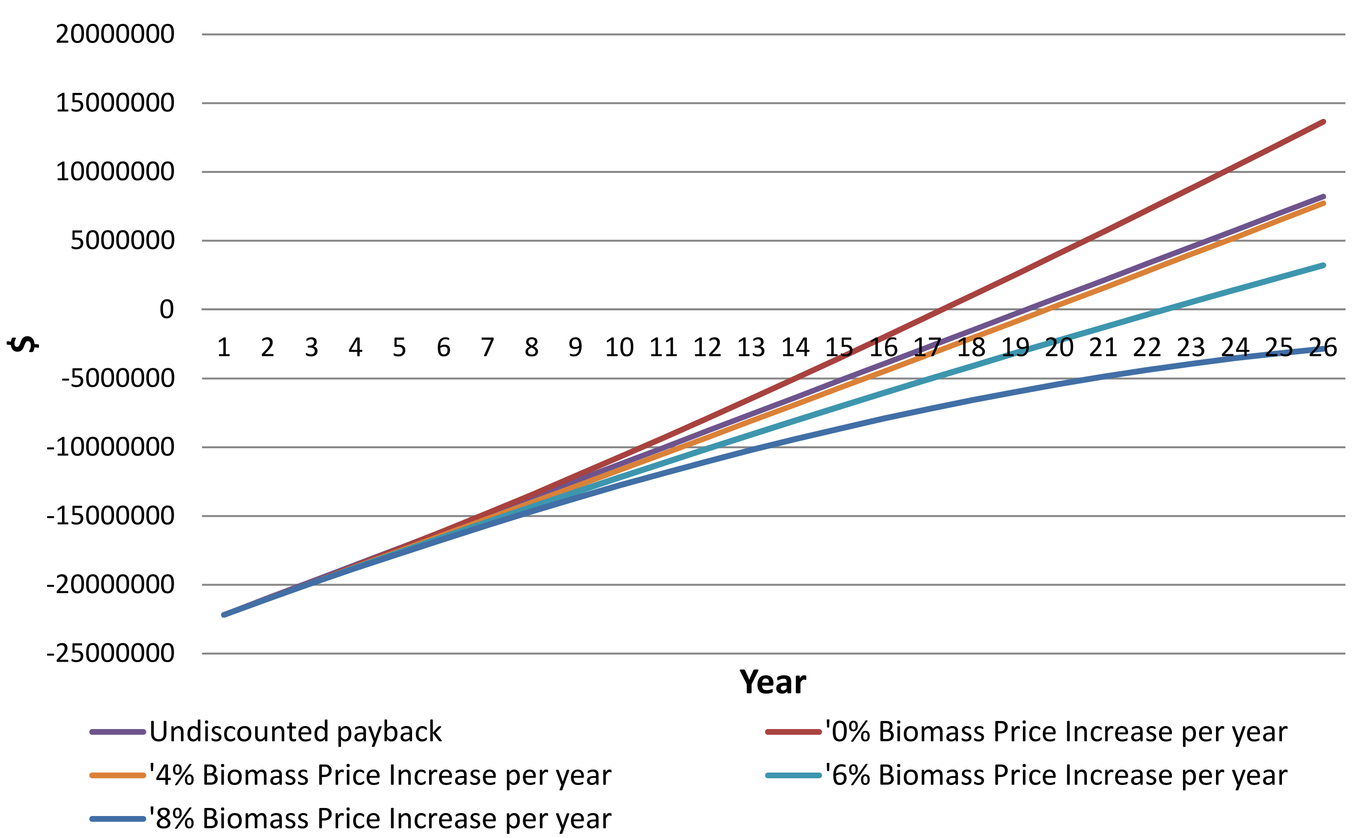


Figure 11-10 Biomass + Solar Thermal + Condensing Boilers Payback, 5% ROI

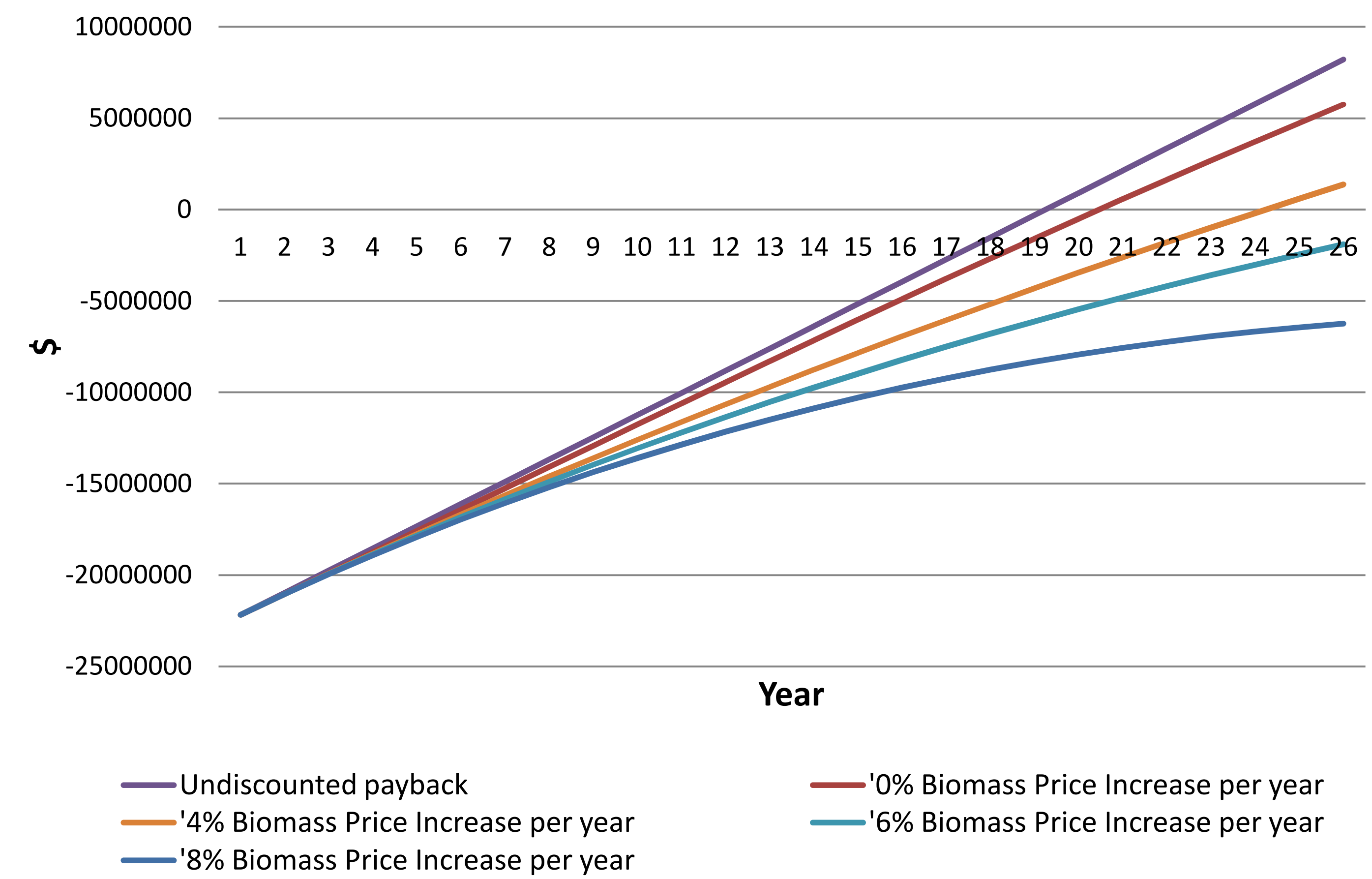


Figure 11-11 Biomass + Solar Thermal + Condensing Boilers Payback, 7% ROI

11.6 Biomass (CoGen) + Condensing Boilers

11.6.1 System Size

The biomass CoGen plant option has been sized based on the thermal load at UVic as the primary sizing constraint, in order to make use of the thermal heat demand from generating a supplemental amount of electricity to avoid the need to reject waste heat. Since the thermal efficiency of the biomass CoGen plant is reduced, compared to a straight heating plant configuration due to the generation of electricity, the boiler capacity will be greater than a straight biomass heating only boiler; however, the thermal output from a CoGen plant configuration shall remain 4200kW, as defined in section 13.4

The electrical output depends on the type of biomass boiler that is used and the electrical output ration can vary from 2:1 to 4:1.interms of heat available vs. electricity generated. For this analysis the worst case has been assumed and the electrical output assumed to 1MWe

The gas-fired condensing boilers have been sized to meet UVic's peak thermal load of 16MW in order to supplement the thermal output from the biomass CoGen plant during peak winter times, and act as back-up should the biomass CoGen plant fail.

A monthly profile of the thermal and electrical energy generation from a biomass CoGen plant of this size is presented in Figure 11-12.

11.6.2 Capital Costs

The capital cost of a biomass boiler system is highly dependant on the system's configuration, scope split, project delivery model. Based on discussions with a number of biomass boiler providers, the capital expenditure required is currently in the range of $1650/kW to $2500/kW.

For the gas-fired condensing boilers, it has been assumed that the cost of replacing the existing boiler plants at ELW and McKinnon with standard gas-fired boilers can be deducted from this capital cost since the boilers will require replacement within the next 10 years regardless. The additional cost for the provision of gas-fired condensing boilers over standard boilers has been assumed at $40/kW.

A breakdown of the combined capital cost of all three elements is presented in Table 11-1.

11.6.3 Biomass Fuel

The fuel cost assumptions in Section 13.3 remain valid for this option.

Due to the lower thermal efficiency of the biomass CoGen boiler, additional fuel is required to maintain the thermal output at 4200 kW. Approximately 6-7 deliveries of biomass will be required, per day, during peak winter periods. On-site fuel storage should remain at 48 hours worth as a minimum requirement.

The next step is to complete a detailed fuel study, prior to beginning the design phase of the biomass system.

The risks relating to fuel source, delivery and cost can be mitigated by procuring a turnkey operation form a Utility or ESCo.

11.6.4 Biomass Emissions

As discussed in Section 13.3, there are currently no set Provincial emission thresholds for biomass-fuelled energy plants in BC, apart from boilers used for agricultural applications, such as Greenhouses.

The Ministry of Environment (MoE) also regulates the emissions from biomass fueled electrical power generation using a separate standard to that for heating only agricultural biomass boilers, see below. As discussed earlier, any biomass CoGen facilities require a permit, which is negotiated on an individual basis with the relevant regional department of the MoE. MoE staff usually applies the appropriate standard.

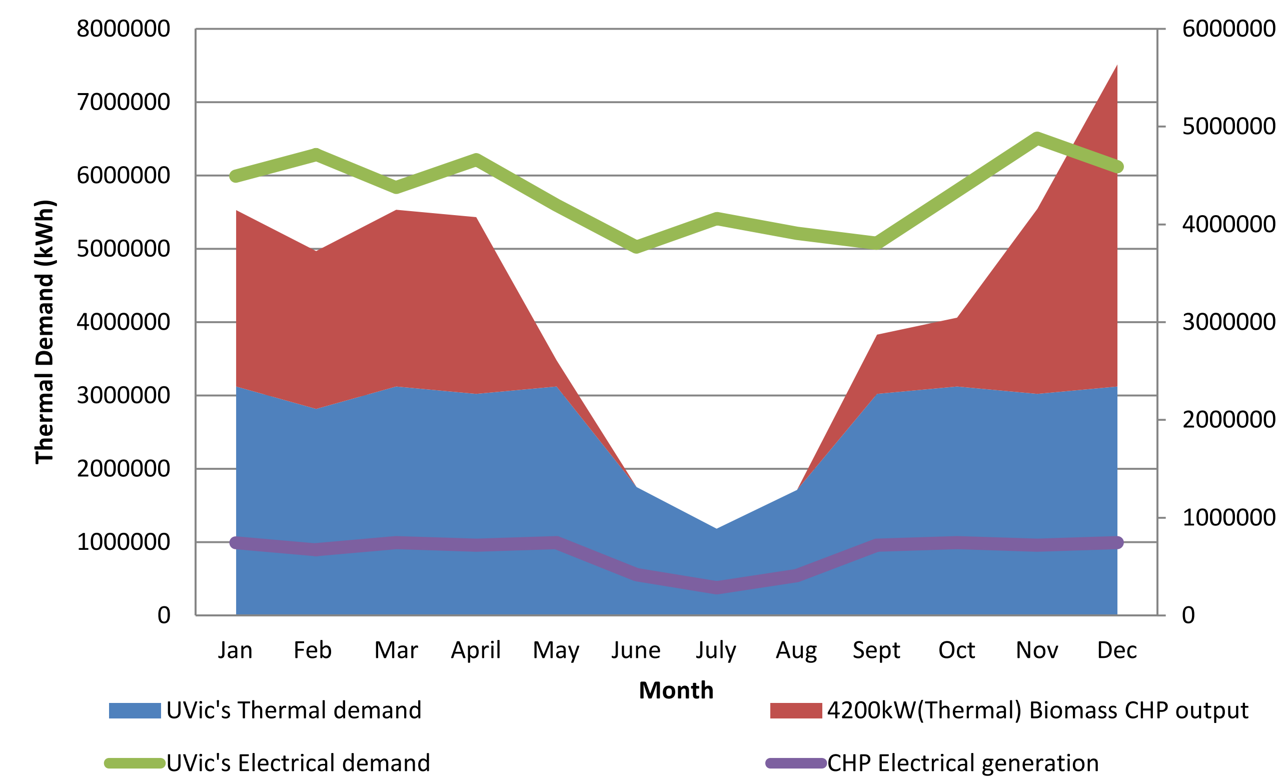


Figure 11-12 Monthly Profile of Biomass CoGen output and Supplementary Heating Requirement

Table 2: Emission Limits for Biomass-fired Electrical Power Generation

Size[a]	Parameter	Limit	Units[b]	Monitoring [e,f,g]
<25 MW (megawatt of electrical output)	Total particulate[c] Opacity Dioxin/Furan Teq[h]	50 - 100	mg/m³ % opacity picograms/m³	Annual Daily Annual
≥25 MW	Total particulate[d] In-stack Opacity Dioxin/Furan Teq[h]	20 - 100	mg/m³ % opacity picograms/m³	2 times/year Continuous Annual

11.6.5 Energy and Carbon Savings

The estimated energy savings are as follows:

- Thermal Energy: 32.5M kWh per year; a 50% reduction in UVic's thermal energy cost demand.
- Electrical Energy: 7.6M kWh; a 14% reduction in UVic's purchased electrical energy demand

The estimated carbon savings is nearly 6160 tonnes per year; a 36% reduction in UVic's carbon emissions.

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3

It has been assumed that electricity is sold back to the Utility, rather than used directly on site, at a rate equal UVic's purchase price. It may be possible to negotiate with BC Hydro to increase the tariff for energy sold due to the carbon neutral quality of the electricity. Selling the electricity directly to the local utility eliminates the high capital cost of providing a private utility and wire network and utility storage on campus.

11.6.6 Maintenance

The biomass CoGen boiler will be shut down during the month of July when the solar thermal output is sufficient to meet the heating demand providing a good opportunity to carry out maintenance. A dedicated team of 1-2 staff members will still be required to maintain and operate a plant of this size. For turnkey operations, the maintenance staffing is typically the responsibility of the provider.

Gas-fired condensing boilers are no more onerous than UVic's existing boiler installation.

11.6.7 Energy Cost savings and Payback

Table 11-11 summarizes the cost savings for the system in year one.

Based on the above assumptions, the estimated simple payback has been calculated to be 26 years.

Figure 11-6 and

Figure 11-6 present a net present value calculation as associated sensitivity analysis for return on investment scenarios of 5% and 7%, reflecting UVic's cost of borrowing and long term asset return expectations.

The increased biomass requirement makes the financial feasibility of biomass CoGen more sensitive to the biomass price increases. If biomass prices did not increase, and gas and electricity prices continued to increase at 5% per year, the payback can be reduced to 14 years based on an ROI of 5%.

11.6.8 Procurement and Funding Options

There are three main methods through which to procure a biomass heating plant, summarized below, from direct ownership to turn-key operation. All three are valid for implementation at UVic.

1. Direct Sale – End user customer buys direct and self-finances the project based on internal capital hurdle rates. Typical for industrial customers, select federal agencies, municipalities and universities. Typically has the longest procurement timelines.

2. Utilities (Build-Own-Operate-Maintain) – A 3rd party utility finances, owns, operates and sells energy to multiple/single end users. Regulated utilities work energy costs into a rate base for the customer(s), increasingly common for fiscally constrained universities, hospital, military bases.

3. ESCO (Energy Services Companies) – ESCO installs energy equipment, guarantees savings/ energy displacement for end user. 3rd party debt finances the project. End users own the asset at the end of the ESCO term.

The ability to sell electricity improves the financial feasibility of a biomass CoGen plant and will likely generate additional interest from Utility providers and ESCo to provide UVic with a turnkey operation.

Options 2 and 3 eliminate the need for UVic to provide the required capital funding and the Utility or ESCO will the risks relating to biomass fuel provision and cost

.

Biomass Boiler (CoGen) + Condensing Boilers						
Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Biomass Boiler - CoGen	4200	kW	4250	17,850,000	Average estimated cost, ± 20%	Biomass Boiler Suppliers
Gas Fired Condensing Boilers	16000	kW	40	640,000	Extra over cost for condensing in place of standard	Boiler supplier
New Energy hub building	1300	m2	2500	3,250,000		RS Means
Mechanical Room pipework, pumps, etc.	100	m	150	15,000	All Mechanical rooms, inc. new energy hub	RS Means
Heating distribution pipework	100	m	400	40,000		RS Means
Trenching	100	m	150	15,000		
Building heat exchangers	2	#	20000	40,000	Connect new energy centre to loop	
				0		
Electrical Connection to grid	1	#	25000	25,000		
Total				**21,875,000**	± 20%	

Table 11-12 Solar Thermal + Biomass Boiler + Condensing Boiler Cost Breakdown

11.6.9 Summary

The combination of biomass boiler CoGen plant with gas fired boilers offers the potential to achieve significant energy and carbon savings at UVic.

The simple payback period is longer than for a heating only biomass boiler due to the additional capital cost, and increased biomass fuel cost. A biomass CoGen plant could replace the heating only biomass boiler in Section 11.5 and be combined with solar thermal to maximize savings, but a the fuel study will be required to confirm the potential fuel cost so payback can be confirmed.

An assessment of feasibility to integrate a combined solar thermal and biomass boiler plant at UVic using the cost/benefit criteria is summarized in Table 11-7, below.

Criteria	Assessment
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-13 Biomass Boiler + Solar Thermal + Condensing Boiler Cost/Benefit Summary

		Biomass CoGen - Primary Boiler								Gas Fired Condesing Boilers - Supplementary Boiler							Total				
Month	Central Heating Loop Demand	Biomass boiler output	Displaced Electricity	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Biomass cost	Energy cost saving	Supplemntary Heating Load	Condensing Boiler Efficiency compared with a Standard Boiler	Gas-Fired Condensing Boiler Output	Energy Savings achieved using Condensing Boilers	Carbon savings from Biomass Boiler	Carbon 'Credit' Refund	Displaced energy cost	Total Thermal Energy Savings	Total Electrical Energy Savings	Total Carbon Savings	Total Carbon Credit Refund	Total Energy Cost Savings
	kWh	kWh	kWh	tonnes	$	$	$	$	kWh	(less than 1 = more efficient)	kWh	kWh	tonnes	$	$	kWh	kWh	tonnes	$	$
Jan	5,547,019	3,124,800	744,000	593	$14,817	$197,904	$131,242	$66,662	2,406,643	1	2,406,643	0	0	$0	$0	3,124,800	744,000	593	$14,817	$81,479
Feb	4,988,890	2,822,400	672,000	535	$13,383	$178,752	$118,541	$60,211	2,152,481	1	2,152,481	0	0	$0	$0	2,822,400	672,000	535	$13,383	$73,594
Mar	5,551,794	3,124,800	744,000	593	$14,817	$197,904	$131,242	$66,662	2,411,405	1	2,411,405	0	0	$0	$0	3,124,800	744,000	593	$14,817	$81,479
April	5,451,569	3,024,000	720,000	574	$14,339	$191,520	$127,008	$64,512	2,412,261	0.95	2,291,648	120613	22	$552	$6,031	3,144,613	720,000	596	$14,891	$85,433
May	3,496,403	3,124,800	744,000	593	$14,817	$197,904	$131,242	$66,662	361,785	0.88	318,371	43414	8	$199	$2,171	3,168,214	744,000	601	$15,015	$83,848
June	1,762,564	1,757,615	418,480	333	$8,334	$111,316	$73,820	$37,496	0	0	0	0	0	$0	$0	1,757,615	418,480	333	$8,334	$45,830
July	1,191,035	1,187,690	282,783	225	$5,632	$75,220	$49,883	$25,337	0	0	0	0	0	$0	$0	1,187,690	282,783	225	$5,632	$30,969
Aug	1,719,339	1,714,511	408,217	325	$8,130	$108,586	$72,009	$36,576	0	0	0	0	0	$0	$0	1,714,511	408,217	325	$8,130	$44,706
Sept	3,845,506	3,024,000	720,000	574	$14,339	$191,520	$127,008	$64,512	810,708	0.88	713,423	97285	18	$445	$4,864	3,121,285	720,000	591	$14,784	$84,160
Oct	4,074,933	3,124,800	744,000	593	$14,817	$197,904	$131,242	$66,662	938,690	0.95	891,756	46935	9	$215	$2,347	3,171,735	744,000	601	$15,031	$84,041
Nov	5,563,145	3,024,000	720,000	574	$14,339	$191,520	$127,008	$64,512	2,523,523	1	2,523,523	0	0	$0	$0	3,024,000	720,000	574	$14,339	$78,851
Dec	7,539,135	3,124,800	744,000	593	$14,817	$197,904	$131,242	$66,662	4,393,166	1	4,393,166	0	0	$0	$0	3,124,800	744,000	593	$14,817	$81,479
Total	50,731,331	32,178,216	7,661,480	6,103	$152,578	$2,037,954	$1,351,485	$686,469	18,410,663		18,102,416	308,247	56	$1,410	$15,412	32,486,463	7,661,480	6,160	$153,989	$855,870

Table 11-14 Biomass CoGen Boiler + Condensing Boiler - Energy, Carbon and Energy Cost Savings

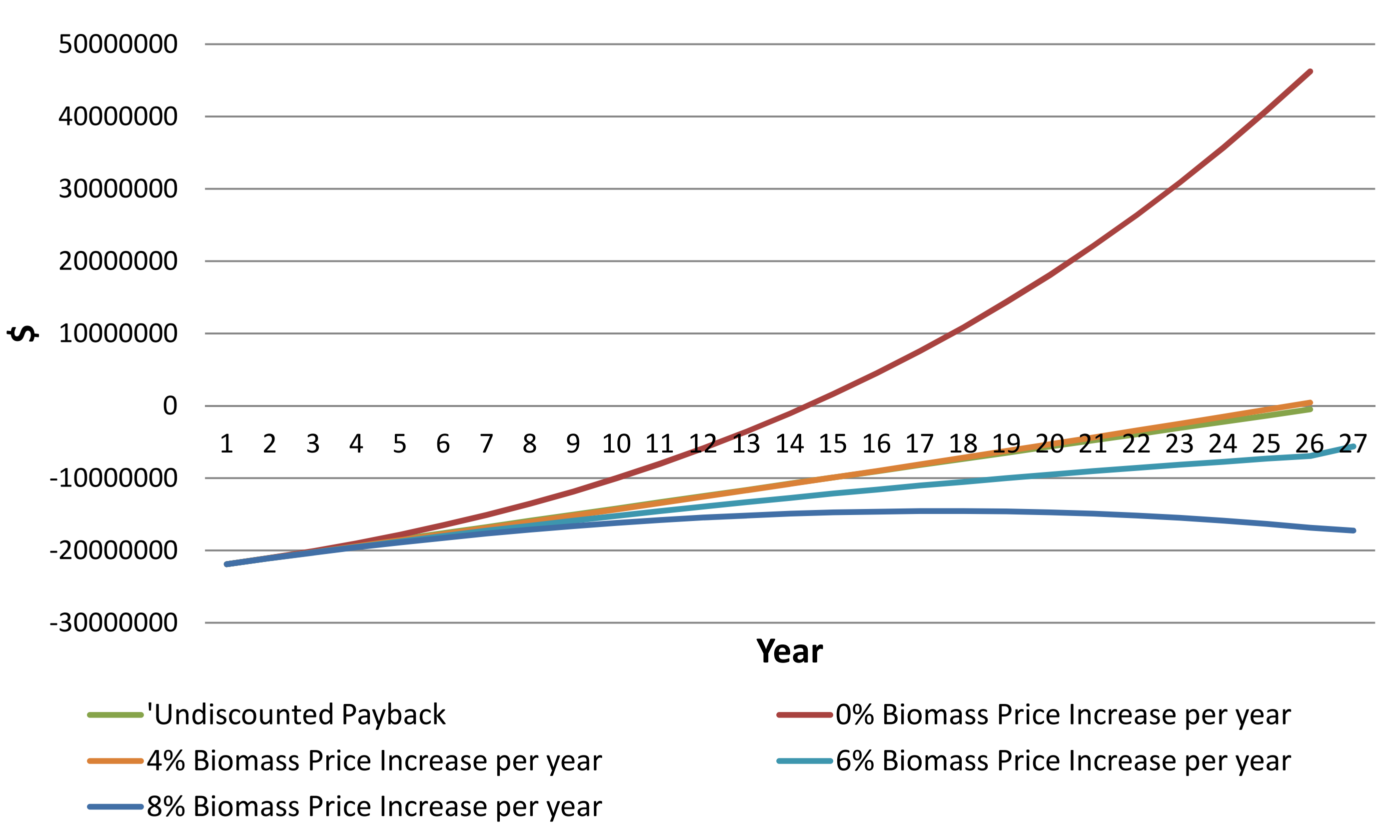


Figure 11-13 Biomass CoGen + Condensing Boilers Payback, 5% ROI

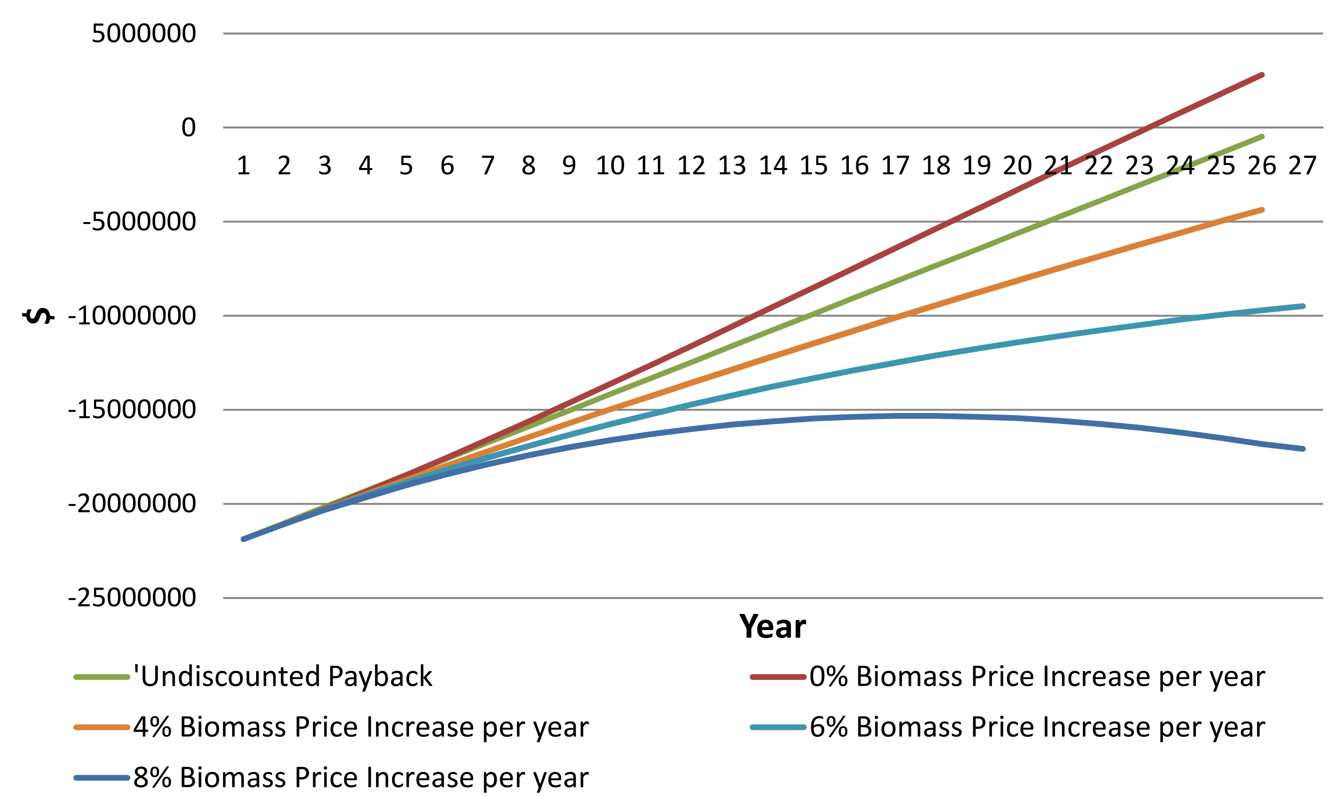


Figure 11-14 Biomass CoGen + Condensing Boilers Payback, 7% ROI

11.7 Ambient Heating Loop with Water to Water Heat Pumps

An ambient temperature loop should be considered at UVic to serve campus building developments that are outside of the “connection boundary” to the high temperature DES loop. The feasibility of implementing the loop will be improved further if the available waste heat from the data centre on campus, EDC2.

11.7.1 System Size

The initial size of system shall be based on the available heat from EDC2 and a loop length that stretches from EDC2 to the nearby residential developments. The loop can be expanded as, and when required and additional low grade heat sources connected, e.g. geoexchange heat pumps.

The amount of heat available fro EDC2 is dependent on two main factors; the electrical consumption (and therefore heat output) of the installed servers and the Power Usage Effectiveness (PUE) of the building.

The existing air-cooled chillers will be replaced with water to water heat pumps to capture the waste heat in a useful form and increase the “grade” (temperature) of the waste heat. It has been assumed the system will operate 24hrs/day.

From discussions with the IT department at UVic, the following assumptions have been made regarding the future installed capacity and expected PUE.

ASSUMPTIONS		Units	Notes
Installed Server Capacity	700	kW	
Power Usage Effectiveness	1.5		
Cooling percentage of non-server building load	75%		
W-W Chiller efficiency	95%		
Potential Waste heat	249	kW	
Heat Pump COP	2.5		
Low grade heat availability to DES	623	kW	
Run hours	8,760	hrs	(assumed continuous)
Total heat available per year	5,461,313	kWh	(displaced gas)

Table 11-15 Ambient Heating Loop Cost Breakdown

The ambient loop can be expanded as new buildings are brought on line and alternative energy sources such as geoexchange heat pumps can be added, as and when required. The space heating system will need to be a low temperature hydronic based system, such as radiant slabs, panel radiators or other similar low temperature heating terminals to utilize the low temperature waste heat efficiently.

11.7.2 Capital Costs

The existing air cooled chillers will need to be replaced to allow the waste heat to be captured. A breakdown of the combined capital cost of all three elements is presented in Table 11-117.

It has been assumed that the cost to provide the required low temperature hydronic heating system, over and above that for electric baseboard, will be incorporated into the construction budget of each building.

Ambient 'District' Heating Loop - To serve New Construction						
Description	Quantity	Unit	Cost/unit $	Total Cost $	Notes	Source
Water Cooled Heat Pumps	250	kW	350	87,500		
Plantroom pipework, pumps, etc.	100	m	150	15,000		
Heat pump	2		50000	100,000	Increases exergy of waste heat	
Energy hub building	200	m2	2500	500,000		
Heating distribution pipework	2000	m	400	800,000		
Trenching	2000	m	150	300,000		
Building heat exchangers	15	#	20000	300,000	Estimated number of new buildings	
Geoexchange heat pump		#	50000	0		
Geo-exchange field						
				0		
Total				2,102,500		

Table 11-16 Ambient Heating Loop Cost Breakdown

11.7.3 **Energy and Carbon Savings**

The estimated amount of thermal energy that can be displaced is 5.4M kWh per year; equivalent to space heating demand of 40,000m^2 of student residences.

Installing an ambient loop to recover and utilize waste heat from EDC2 can potentially offset nearly 1000 tonnes per year of baseline carbon emissions.

A detailed breakdown of the estimated energy and carbon savings for the proposed system is set out in Table 11-3

ASSUMPTIONS		Units	Notes
Total heat available per year	5,461,313	kWh	(displaced gas)
Assumed Gas cost	0.05	$/kWh	
Displaced gas cost	$273,066		
Carbon saving	999	tonnes	
Carbon credit 'Refund'	$24,986		
Total energy cost savings	$298,051		
Capital cost	$2,102,281	$	
Simple Payback	7	years	

Table 11-17 Energy And Carbon offset estimate for Ambient Heating Loop

11.7.4 **Maintenance**

The ambient loop will be no more onerous than UVic's existing heating loop. The new water-to-water heat pumps will be replacing existing chiller unit, and have a similar maintenance regime, therefore no additional maintenance is required; the maintenance regime of water to water heat pump will be no more onerous than a typical gas-fired boiler.

11.7.5 **Energy Cost savings and Payback**

Table 11-11 summarizes the cost savings for the system in year one and is based on assumptions defined above.

The estimated simple payback has been calculated to be 6-8 years.

11.7.6 **Procurement Options**

The end user customer typically buys direct and self-finances the procurement and installation of an ambient heating loop.

11.7.7 **Summary**

The integration of a new ambient temperature loop utilizing waste heat already available on campus to serve new buildings will help reduce the energy impact of population and campus building growth at UVic's Gordon Head Campus. The ambient loop system is recommended for new campus growth that is beyond the current high temperature heating district energy system.

An assessment of feasibility to integrate an ambient heating loop plant at UVic using the cost/benefit criteria is summarized in Table 11-18, below.

Criteria	
Commercial Availability	
Carbon Reduction Potential	
Payback Period	
Retrofit Applicability	
Early Implementation Potential	
Funding Availability	
Maintenance, Operation and Staffing Cost	

Table 11-18 Ambient Loop Cost/Benefit Summary

11.8 Options Matrix

						<---------Reduces Existing Energy Consumption		Offsets Campus Growth carbon emissions ----->
Criteria		**Units**	**Option 1**	**Option 1A**	**Option 2**	**Option 2A**	**Option 3**	**Option 4**
			Solar Thermal	Solar Thermal + Condensing Boilers	Biomass (Heating Only) + Condensing Boilers	Biomass (Heating Only) + Solar Thermal Panels + Condensing Boilers	Biomass CHP + Condensing Boilers	Ambient heating Loop
Features	System Description		Evacuated Tube Solar panels located on roofs of buildings around campus Exisiting heating loop used to move thermal energy around campus. Panels connect directly into return of district heating loop. Local DHW heaters (Electric) used to meet specific needs, e.g. high temperature water in Petch	Evacuated Tube Solar panels located on roofs of buildings around campus Exisiting heating loop used to move thermal energy around campus. Panels connect directly into return of district heating loop. Gas-fired condensing boilers used as supplementary during peak heating requirements	New Biomass boiler connected to exisitng heating loop Exisiting heating loop used to move thermal energy around campus. Panels connect directly into return of district heating loop. Gas-fired boilers used as supplementary. Either existing Volcano boiler plant or phased requirement with condensing boilers	Evacuated Tube Solar panels located on roofs of buildings around campus, connected to existing heating loop New Biomass boiler connected to exisitng heating loop Biomass boiler shut down during June, July and August	Biomass gassification sytem + turbine or ORC Non- Condensing boilers used as supplementary heating energy source	A single, large-volume, non-insulated pipe loop maintained at a moderate temperature level, can be connected to a number of different low-grade energy sources anywhere on the loop simpler, more flexible, more reliable and more robust than the conventional dual-temperature level DES A large development can be covered by an unlimited number of small, manageable, independent loops tied to the closest low-grade energy source and simply "daisy-chained" together via heat exchangers Connects to EDC2 To serve potential future developments on east side of campus Waste Heat from EDC2 In future, geoexchange heatpumps or sewer heat recovery
	Energy Sources		Solar	Solar + Natural Gas	Biomass + Natural Gas	Biomass + Solar+ Natural Gas	Biomass + Natural Gas	
	Displaced Energy Sources		Natural Gas	Natural Gas	Natural Gas	Natural Gas	Natural Gas + Grid Electricity	Natural Gas
	Energy Distribution		Exisitng District Heating Loop	Exisitng District Heating Loop	Existing District Heating Loop	Existing District Heating Loop	Existing District Heating Loop	New Ambient, single temperature district heating loop
Assumptions	Displaced Energy cost inflation		5% per year	5% per year	5% per year	5% per year	5% per year	5% per year
	Carbon Credit Inflation		2% per year	2% per year	2% per year	2% per year	2% per year	2% per year
Energy	System output		700 kWh/m2.yr (of panel area)	700 kWh/m2.yr (of panel area)	3000kW/Tonne of Biomass	700 kWh/m2.yr (of panel area) 3000kW/Tonne of Biomass	3000kW/Tonne of Biomass	-
	System size	(As noted)	Panel Area = 13,500 m2	Panel Area = 13,500 m2 16000 kW of Condensing Boiler	4200kW biomass boiler	3250kW biomass boiler Solar Thermal Panel Area = 13,500 m2	4200kW (Thermal) biomass boiler	Waste heat output from EDC2 = 650kW
	Energy savings	kWh	9,100,000	10,800,000	32,500,000	37,400,000	Thermal = 32,000,000 Electricity = 7,600,000	5,461,313
		%	14%	16%	50%	58%	Thermal = 50% Electricity = 14%	N/A
Carbon	Carbon intensity of displaced energy source	Tonnes CO2/kWh	0.183	0.183	0.183	0.183	Gas = 0.183 Electricity = 0.028	0.183
	Carbon savings	Tonnes	1,655	2,000	6,000	6,845	6,160	999
		% of total	14%	11%	38%	43%	39%	N/A*
Cost	Capital Cost	$	$9M - $12M	$10.8M - $13.2M	$10.5M - $12.8M	$19.5M - $24.5M	$20M - $24M	
	Unit cost	$/unit	$750/m2	$750/m2 of solar thermal panel $40/kW of condensing boiler	$1650/kW(thermal)	$1650/kW(thermal) of biomass boiler	$3750/kW(thermal) of biomass CHP	
	Energy cost savings	$/year	$500,000	$540,000	$820,000	$1,000,000	$700,000	
	Carbon Credit savings	$/year	$40,000	$50,000	$150,000	$170,000	$150,000	
	Simple Payback	Years	20-24	18-22	12 -15	17 - 22	19-25	7-12

						<---------Reduces Existing Energy Consumption		Offsets Campus Growth carbon emissions ----->
Criteria		**Units**	**Option 1**	**Option 1A**	**Option 2**	**Option 2A**	**Option 3**	**Option 4**
			Solar Thermal	Solar Thermal + Condensing Boilers	Biomass (Heating Only)	Biomass (Heating Only) + Solar Thermal Panels	Biomass CHP	Ambient heating Loop
Maintenance and Operation	Maintenance Cost		No additional maintenance above baseline, yearly panel cleaning	Same as option 1	Twice yearly shut down for maintenance	Twice yearly shut down for maintenance. Can be carried out during summer month shutdown	Same as Option 2	Maintenance burden no greater than exsiting heating loop
	Staff Requirement		No additional staff requirement	No additional staff requirement	1-2 dedicated staff memebers likely to be required to maintain and operate a plant of this size	Same as Option 2	Same as Option 2	Same as Option 1
	Reliability		Very reliable system, any issues are well known	Very reliable system, any issues are well known	Known technology, commercially available, reliable	Established technology with proven reliability records	Cutting edge technology, reliability currently not guaranteed	
	Building/System Control		Control is simple, and easy to optimize	Control is simple, and easy to optimize				
	Fuel Deliveries	#/day during peak winter conditions	N/A	N/A	4-5	3-4	6-7	N/A
Integration	Existing Building Impacts		Local electric DHW tank, to be located in each existing Mechanical room	Same as Option 1	None	Same as Option 1	None	N/A
	Roof/Wall/Slab penetrations/ integration		Shafts and planning for piping needs	Same as option 1	None	Same as option 1	None	
	Design and Construction		This technology is commonly used and it is well understood by the designers and contractors	Exisitng boiler room in Clearihue will need to be reconfigured	New energy hub will be required, approximately 1000m^2. Includes 48 hours of storage. Parking #1 provides ideal location	Same as Option 2	Same as Option 2	Energy hub building required, locate near EDC2
Implementation	Delivery Vehicle Options				**1. Direct Sale** – End user customer buys direct and self-finances the project based on internal capital hurdle rates. Typical for industrial customers, select federal agencies, municipalities and universities. Typically the longest procurement timelines. **2. Utilities (Build-Own-Operate-Maintain)** – A 3rd party utility finances, owns, operates and sells energy to multiple/single end users. Regulated utilities work energy costs into a rate base for the customer(s) Increasingly common for fiscally constrained universities, hospital, military bases. **3. ESCO (Energy Services Companies)** – ESCO installs energy equipment, guarantees savings/ energy displacement for end user. 3rd party debt finances the project. End users owns the asset. Typical for all US public sector verticals.			
	Timescales/phasing		Can be installed in phases, as part of building or infrasturcutre upgrades	Can be installed in phases, as part of building or infrasturcutre upgrades	Typically built in a single phase.	Typically built in a single phase. Can be installed in smaller phases but costs will increase	Typically built in a single phase.	Modular, single-temperature, low-temperature DES with distributed heat pumps will enable phased development. Loop can be expanded inline with phasing of buildings
	Funding							
	Further Study Requirements				A detailed study into the local biomass fuel availability should be	A detailed study into the local biomass fuel availability should be	A detailed study into the local biomass fuel availability should be	Define future growth potential and timescale
Notes				Assumes exisitng boiler plant will be replaced; capital cost reflects only the additional cost for condeining boilers, over and above traditional boilers			Sizing of CHP was thermally led Capital costs do not include savings by avoiding BC Hydro upgrade	Proposed for future developments Capital cost assumes a single pipe, ambient loop length of 2000m and individual building heat exchangers * Offsets future growth. No present savings from current baseline

12 CONCLUSIONS

12.1 Energy Targets

The University of Victoria has established stringent overall energy use reduction targets and carbon emission reduction policy as part of their Sustainability Action Plan, and has the ambition to be ahead of its peers in terms of energy efficient building design. This integrated energy master plan has been developed to act as a road map and support UVic in meeting these targets.

The proposed energy use of new buildings at UVic are expected to meet the minimum energy performance criteria defined in the BC Building Code, ASHRAE 90.1 2004. Project specific goals are sometimes set, e.g. LEED Gold, but this is not applicable to all projects. New Buildings will need to achieve greater energy reductions than required by current and projected Energy Codes, in all new and existing buildings to meet the energy and carbon reduction targets.

12.2 UVic's Current Energy Use

UVic's current energy use is better than many of its peers in BC, approximately 17% lower than the NRCAN BC Universities energy intensity benchmark. However Victoria has one of the mildest climates in BC and so energy use is expected to be lower than many of its peers in areas outside the lower mainland of BC

Individual Buildings at UVic typically perform between standard and good practice when compared with national and international benchmarks. The demand for academic and student accommodation is expected to grow at UVic over the coming years and all new buildings will need to perform with much greater energy efficiency than the current building stock for UVic to achieve its energy and carbon reduction targets.

12.3 New Buildings

For new buildings to consistently achieve Good or Best Practice energy benchmarks, energy efficiency needs to be placed as a key driver of a building's design. Developing a building design guideline document will allow UVic to define mandatory performance and prescriptive requirements for the design, construction and renovation of University owned buildings, helping to support and direct designers in helping UVic achieve their energy targets.

UVic should also consider incorporating many of the construction design approaches presented in Section 8 into the design guideline document to maximize energy efficiency.

12.4 Existing Heating Loop

The vast majority of UVic's natural gas use is by the main boiler plant in ELW serving the campus heating loop. The loop operates at high temperatures, hindering the integration of low-grade energy sources and high efficient technologies. Lowering the loop temperature will be prohibitively expensive due to the number of buildings connected to the loop, and the changes required to the heating systems in each building.

Since the loop must remain in operation, the efficiency of the existing DES system should be improved to maximize energy and carbon savings. Currently the high loop temperature is maintained throughout the year, regardless of the climate and each building's heating demand. The provision of a control feedback loop between each building connected to the loop and the main boiler plant at ELW will allow the flow rate and water temperature to match system's needs more closely, thus saving energy and carbon.

12.5 Existing Building Stock

The vast majority of the floor space that will exist in 2020 has already been built; therefore, reducing existing buildings' energy use is a key element for UVic to meet its carbon and energy reduction targets.

The currently on-going Continual Optimization Program has identified significant energy savings, achievable with relatively short paybacks.

UVic's priority should be to complete all three phases of the Continual Optimization Program over the next one to two years.

A key element of this program is the installation of end use energy meters to all buildings connected to the district heating loop. Completing this work will allow UVic to easily identify buildings operating inefficiently, and accurately identify the domestic hot water load separately from the space heating load, so that summertime base load can be accurately tracked. This will allow any solar heating panel option to be optimized.

12.6 Potential Low/Zero Carbon Energy Sources

Replacing the existing mid-efficiency gas fired boilers with low and zero carbon solutions will help UVic achieve its carbon reduction target and increase its renewable energy portfolio.

The feasibility of various solutions were initially assessed and presented in Section 10. Combinations of the most feasible solutions, gas-fired condensing boilers, solar thermal panels, biomass boilers and biomass CoGen were assessed in greater detail, presented in Section 11.

From this detailed analysis, the maximum reduction in carbon emissions is achieved by combining a 13,000m^2 solar thermal array, a 4200kW biomass boiler, and replacing the existing gas fired boiler plant with modern condensing boilers. The gas-fired boilers will be used to supplement the solar thermal and biomass boiler during the peak winter months and act as back-up, should the solar thermal system or biomass boiler fail.

A biomass CoGen plant generating electricity as well as heat could be integrated instead of a biomass boiler, providing further energy and carbon savings. However, biomass CoGen plants required significantly more biomass than standard biomass boilers, making their financial feasibility more sensitive to the price of biomass fuel. Procuring a biomass fuel study will confirm the availability of biomass fuel in the vicinity of UVic and the projected fuel price.

12.7 Key Recommendations

1. Produce a Buildings technical design document, outlining UVic's mandatory performance and prescriptive requirements for the design, construction and renovation of university owned buildings.
2. Complete the Continual Optimization Program Scope of Work to all buildings connected to the Central Heating Loop
3. Upgrade the controls to the central heating loop and provide a feedback loop from each building to the central boiler plant.
4. Once the building energy metering installation has been completed, meter the thermal energy use by end use for one year to redefine the baseline and refine sizing of future energy sources.
5. Procure a biomass fuel study to confirm fuel availability, security and future energy cost
6. Replace the McKinnon and ELW boiler plants at the end of their respective lives with high efficiency condensing boilers.
7. Install the solar thermal array. The installation can be phased over a number of years; coinciding with scheduled roof replacements will help reduce mobilization and construction costs.

8. Procure the design and construction of a biomass boiler/ biomass CoGen plant. The outcome of the biomass fuel study will influence the decision.

12.8 Implementation Schedule

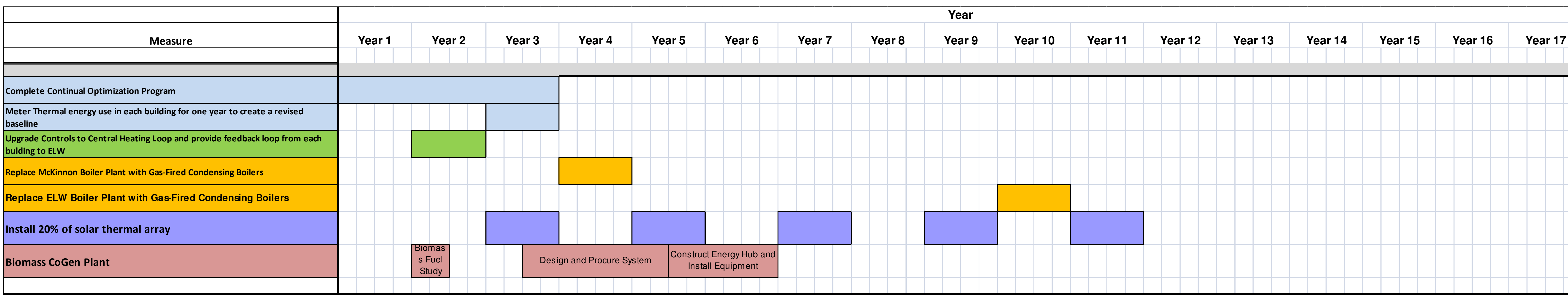
The following schedule is an example of how the above recommendations could be implemented at UVic. It is based on the initial goals of UVic to reduce Carbon at a rate similar to its peers.

UVic's first priority should be to complete the Continual Optimization Program, including the individual building metering. In parallel with this, the controls upgrade to the campus heating loop can occur to maximize the efficiency of the existing loop as soon as possible.

The installation of the solar thermal array has been separated into arbitrary 20% portions based on panel area, with a portion scheduled to be installed every two years. A portion of the solar array could just as easily be installed as and when budgets allow or building renovation programs are scheduled to occur.

By upgrading the central heating loop controls and replacing the existing boilers in the McKinnon Boiler room with gas-fired condensing boilers within the next four years, UVic will achieve their short term carbon emission target of a 20% reduction over the University's 2007 baseline, by 2015.

This implementation schedule example could be used to plan capital financing timing/milestones, or, if capital and financial milestones are found to be different than the suggested timetable, the carbon reduction implementation schedule can be revised to suit when capital/financing can be procured. Campus growth and campus Master Planning must also be considered and coordinated with this Integrated Energy Master Plan.



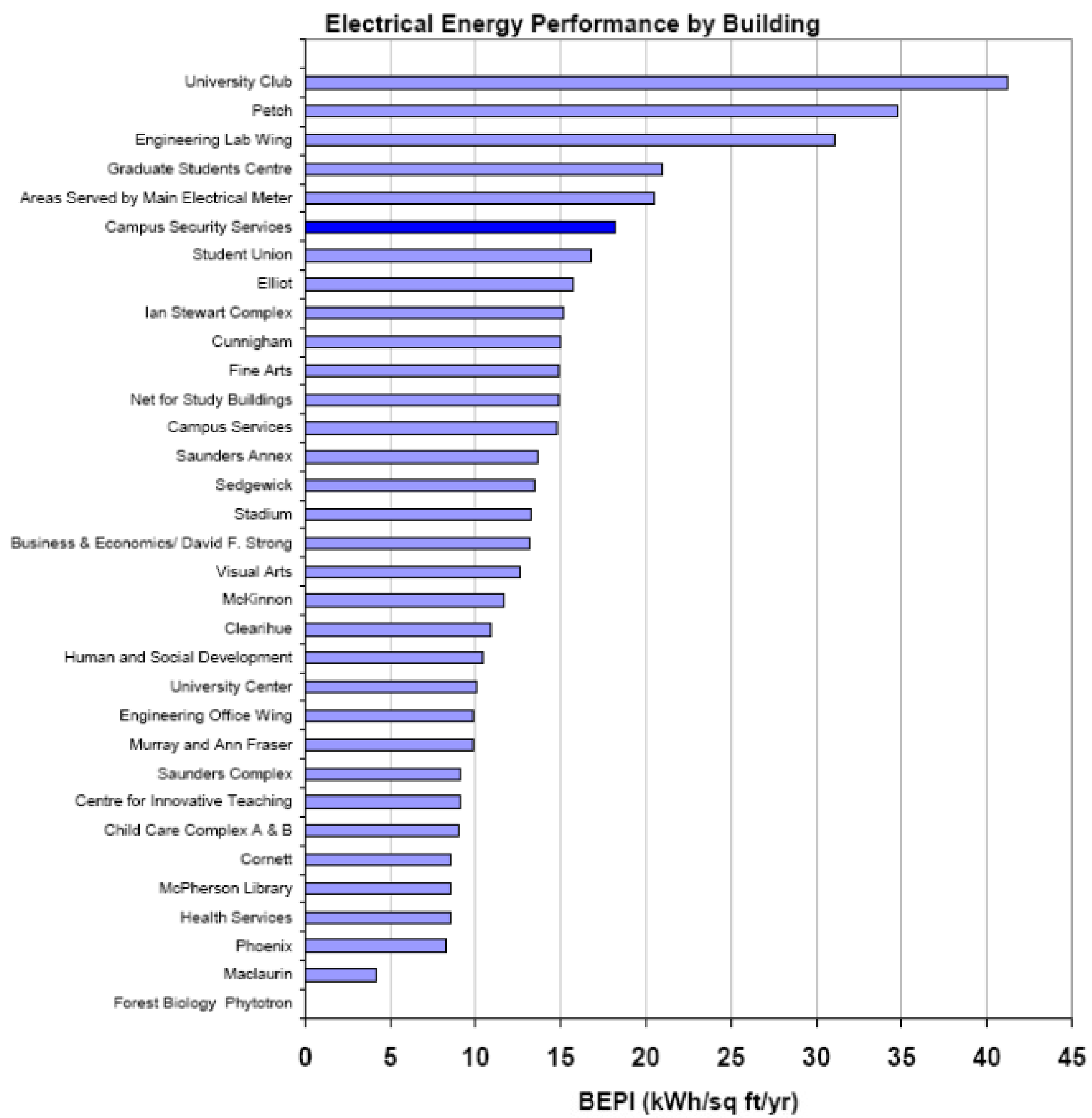
13 APPENDIX A

13.1 Summary of Canadian University's Sustainability and Energy Plans

INSTITUTION	SUSTAINABILITY PLAN	ENERGY PLAN	ENERGY TARGETS
Dalhousie University	Yes- Climate action plan 2010	Yes, part of Climate Action Plan	Baseline 2009 GHG Reduce GHG by 15% by 2013 Reduce GHG by 20% by 2016 Reduce GHG by 50% by 2020
Queens University, Ontario	Yes, November 2010		Plan only, no set targets
University of Toronto, Ontario	Yes- October 2008		Plan only, no set targets
University of Guelph, Ontario		Yes- 2009/2010	General small projects with general goal to reduce overall energy use approx. 3% per year
Wilfrid Laurier University, Ontario		December 2009	75% GHG reduction per square foot relative to other institutions by 2020 25% energy reduction by 2012 from 2009 baseline.
McGill University, Quebec		Yes- 2010-2015 Plan dated May 4, 2010	70,000 tonnes GHG saving from 2003 level Energy reduction of 11.4% from 2011 level by 2015
Red River College Manitoba		January 2004 GHG Reduction Plan	Plan only, no specific end goals, just yearly reduction strategies.
University of Calgary, Alberta	Yes, April 2011 2010 Sustainability Plan	Part of Sustainability Plan	Reduce overall Campus energy intensity as follows: 2012 1.6 GJ/sq.M/year 2015 1.4 GJ/sq.M/yr 2020 1.3 GJ/sq.M/yr Using 2008-2009 Baseline: 45% GHG reduction by 2015 60% GHG reduction by 2020 80% GHG reduction by 2050
University of Alberta, Alberta	January 2011 Initiatives and Measures (DRAFT)		Summary of results to date and a plan for future actions, no specific reduction goals listed
SAIT and NAIT, Alberta	October 2009 Update		Base-lining and series of capital improvements, no specific targets listed
BRITISH COLUMBIA COMPARABLES			
BCIT Burnaby	Last Updated 2006 as part of Campus Master Plan	Last Updated 2006	General incremental goals per year, and upgrading existing Buildings. New Buildings are to be built to LEED Gold. Master Plans still being developed.
Emily Carr University of Art and Design		2009 Carbon Neutral Report	Carbon Neutral by 2010 and then follow BC Provincial Carbon Reductions through continual existing building systems optimizations and carbon credits.
Kwantlen Polytechnic University		Energy Management Action Plan 2010	Reducing electricity 5% by 2011 from 2006 levels Reducing electricity by 14% by 2016 from 2006 levels Reducing electricity by 20% by 2020 from 2006 levels Carbon Reduction to follow Provincial Goals
UNBC	Green Strategy March 2009		No specific energy or carbon goals found. Likely following Provincial carbon reduction targets. UNBC Currently installing pilot projects for wood pellet heating and biomass boiler plant
University of the Fraser Valley		Strategic Energy Master Plan April 2011	Reduce Energy Intensity by 10% by 2015 from 2009/2010 Base case. Continuous Building optimization program. Carbon reduction to follow Provincial targets through energy reduction and carbon credits.
Vancouver Island University		Vancouver Island University Carbon Neutral Action Plan Report, March 2010	Carbon Neutral by 2010 and then follow BC Provincial Carbon Reductions through continual existing building systems optimizations and carbon credits.
Capilano University		2009 Carbon Neutral Action Report	Meet Province of BC GHG reduction goals as minimum, no specific targets over and above those. »» By 2012: 6% below 2007 levels

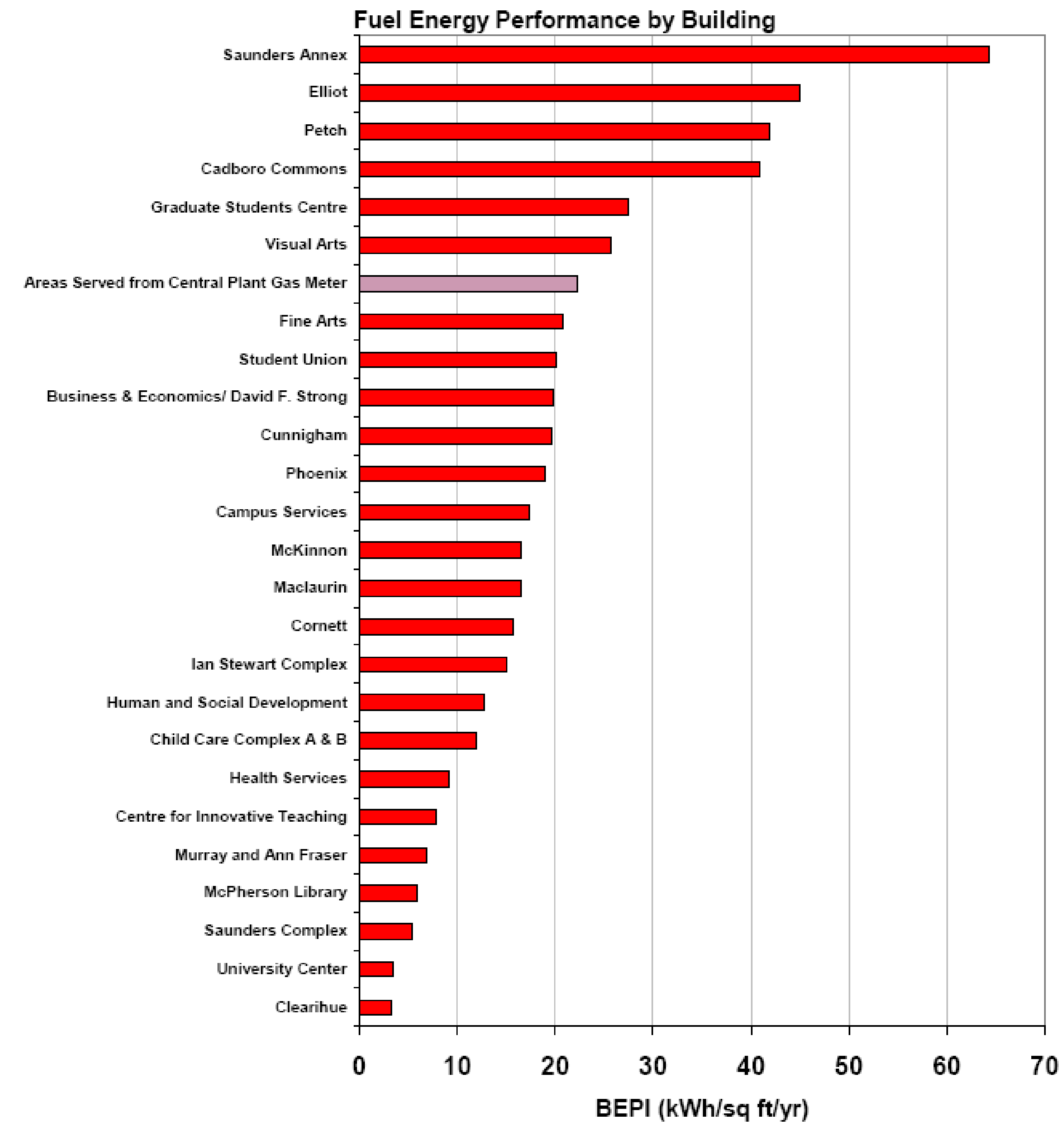
			»» By 2016: 18% below 2007 levels »» By 2020: 33% below 2007 levels »» By 2050: 80% below 2007 levels
Thompson Rivers University	Campus Sustainability Action Plan 2010-2012		Meet Province of BC GHG reduction goals as minimum, no specific targets over and above those. »» By 2012: 6% below 2007 levels »» By 2016: 18% below 2007 levels »» By 2020: 33% below 2007 levels »» By 2050: 80% below 2007 levels
UBC	Yes- see UBC Website	Climate Action Plan 2010-2015	Become net positive energy producer by 2050 33% GHG reduction from 2007 levels by 2015 66% GHG reduction from 2007 levels by 2020 All new buildings to achieve 42% below 1997 MNECB
SFU Burnaby	General Sustainability Plan	Energy Management Plan July 2010	Reduce energy consumption by 2% per year Reduce GHG from 2007 levels by 33% by 2020 with 80% reduction by 2050
Royal Roads University	Yes, 2009 Sustainability Plan	To be off grid by 2018	Reduce GHG by 50% by 2020 from 2007 Baseline
Camosun College		Carbon Neutral Action Report 2009	• To achieve a cost savings of 10% of 2005 levels ($98,750/yr) by the year 2012. • To reduce electrical and natural gas energy consumption intensity in both campuses by 10% of 2005 levels by the year 2012. • To reduce greenhouse gas emission intensity of 8.5% (200 tonnes/yr) from its 2005 levels by the year 2012. Camosun College will endeavor to reduce electrical and natural gas energy Consumption intensity (usage per square foot) in both campuses by 10% of 2005 levels by the year 2012. Camosun College targets greenhouse gas emission intensity reductions of 8.5% (200 tonnes/yr) from its 2005 levels by the year 2012.
Langara College	Langara College Strategic Plan 2010-2013	Energy Management Plan "Coming Soon"	Continue to build new buildings to LEED Gold Standards Minimizing Campus energy use through continuous optimization No specific targets/goals found, other than following Provincial Carbon Reduction targets.
North Island College	Environmental Scan May 2010		Minimizing Campus energy use through continuous optimization No specific targets/goals found, other than following Provincial Carbon Reduction targets.
Okanagan College	Environmental Scan November 2010		Minimizing Campus energy use through continuous optimization No specific targets/goals found, other than following Provincial Carbon Reduction targets.
Vancouver Community College			Minimizing Campus energy use to follow BC Provincial Carbon Reductions through continual existing building systems optimizations and carbon credits.

14 APPENDIX B



Prism

Engineering - UVic Walk-Through Energy Audit Report, 2002



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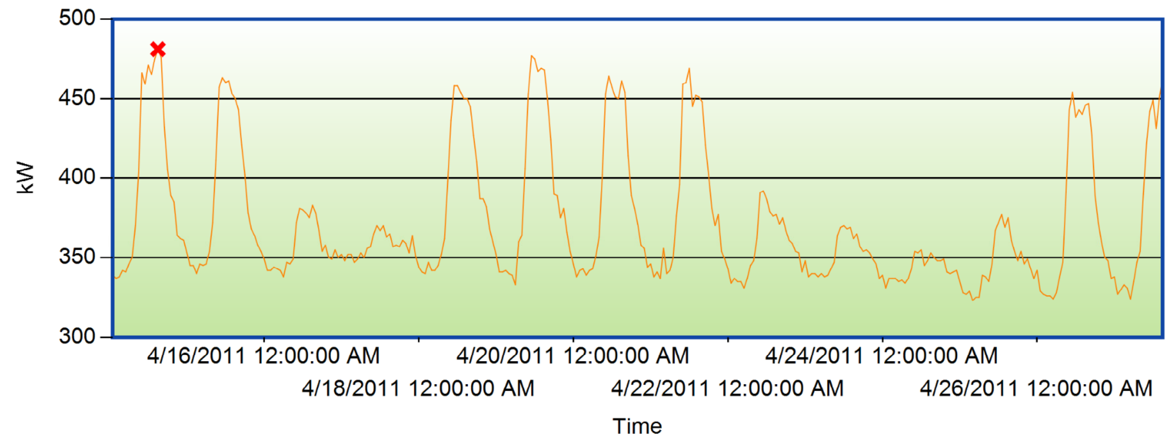
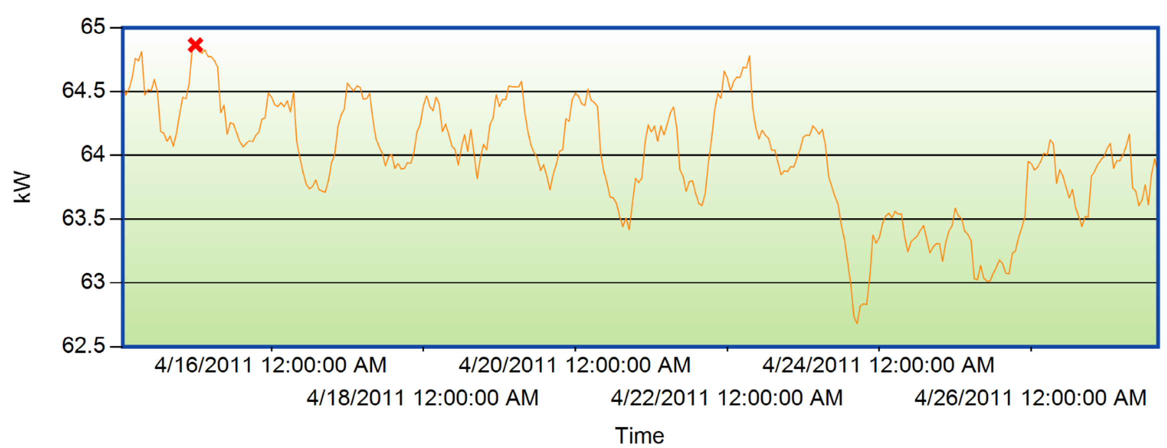
Engineering - UVic Walk-Through Energy Audit Report, 2002

15 APPENDIX C

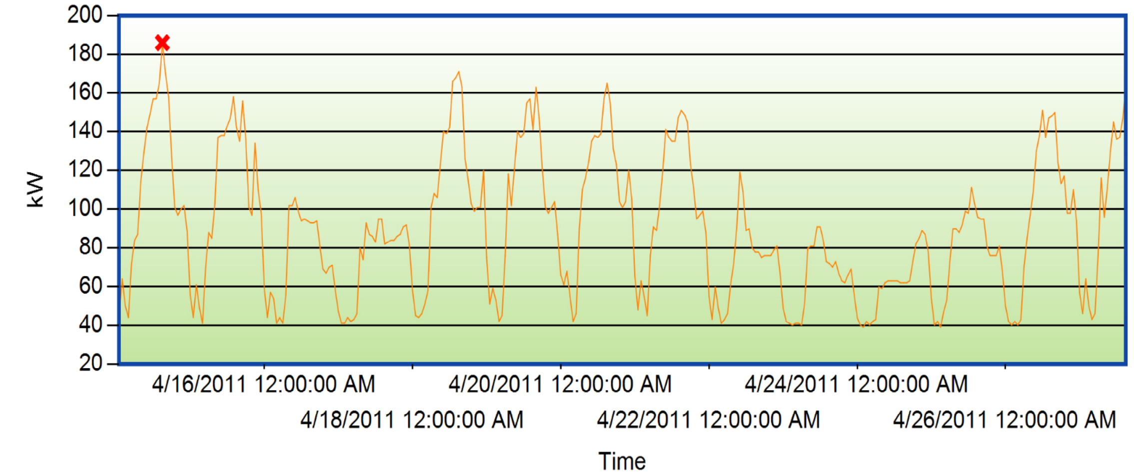
15.1.1 Petch

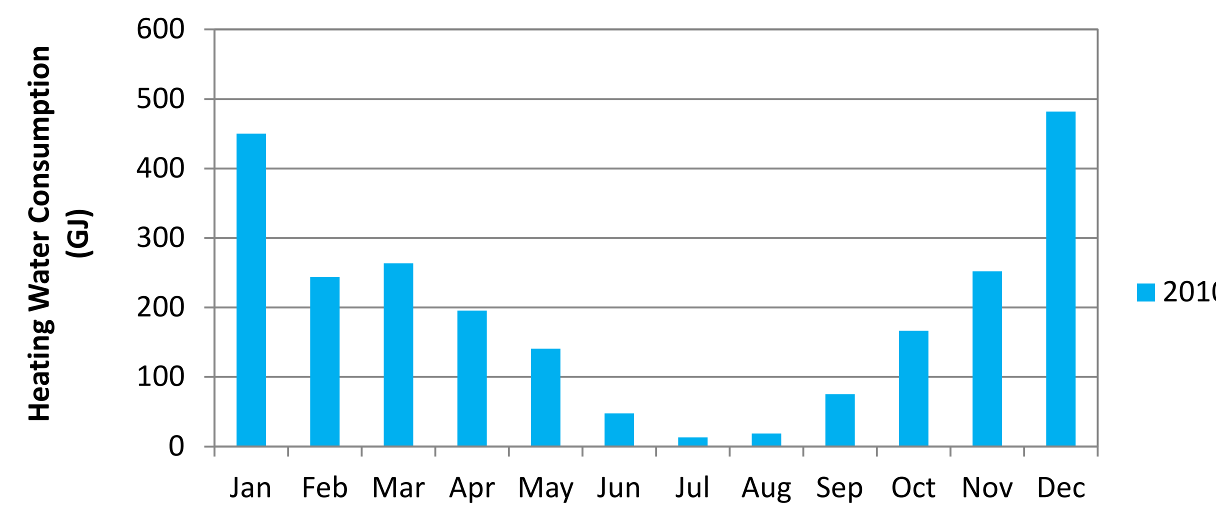


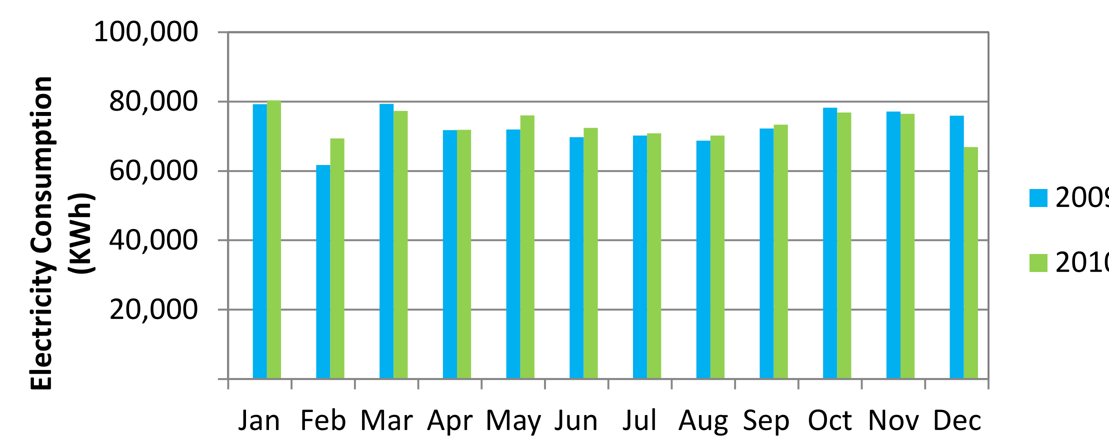
15.1.2 Elliott



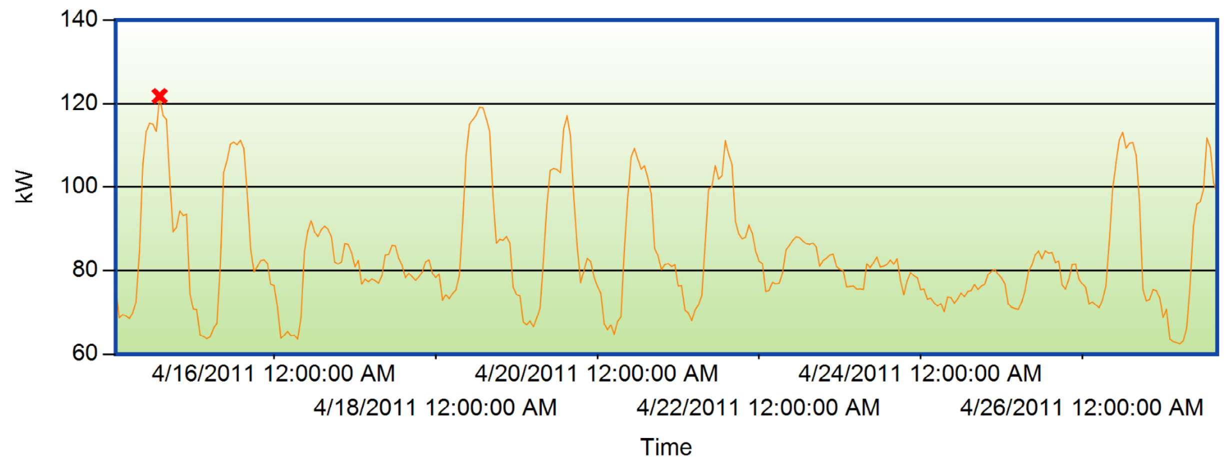
15.1.3 Human and Social Development

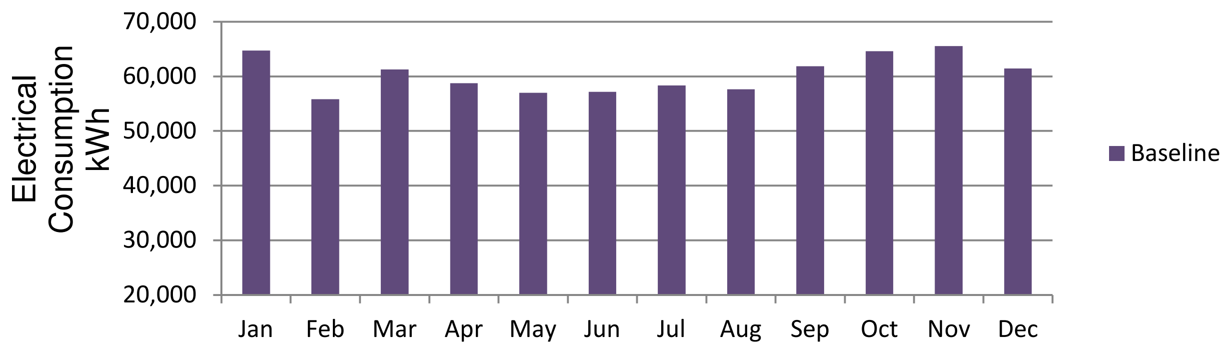


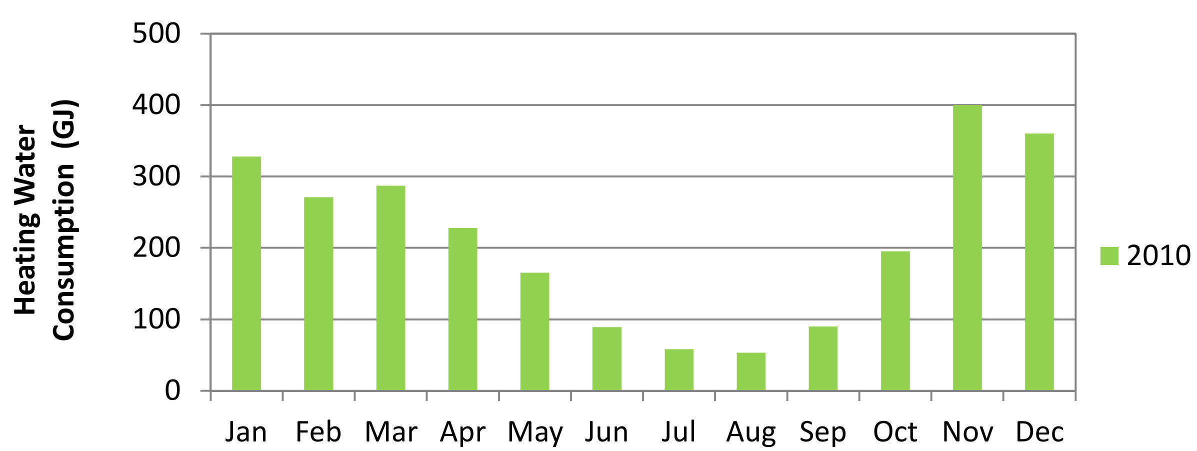




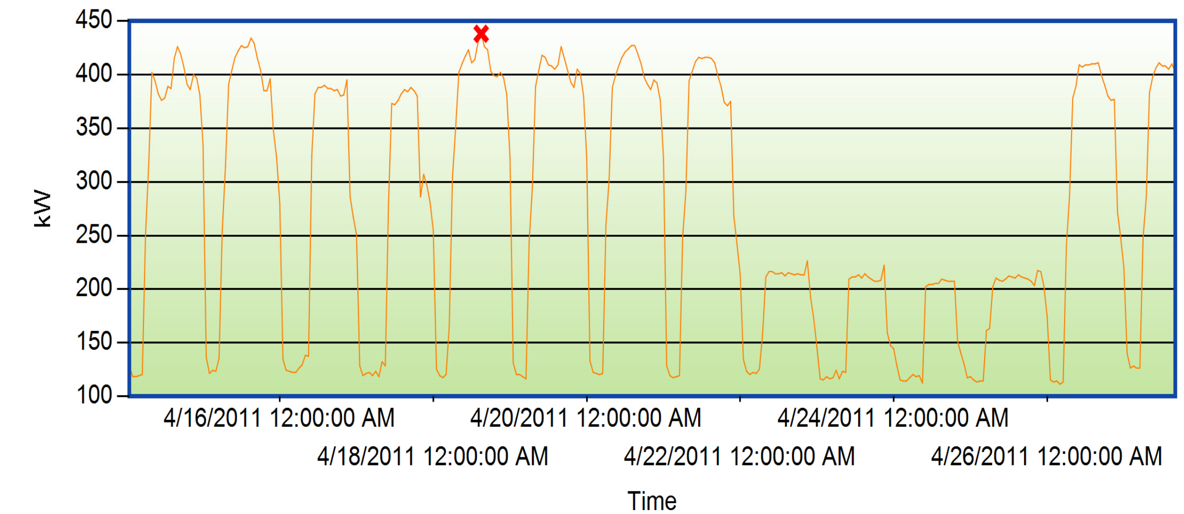
15.1.4 **Social Sciences and Mathematics**







15.1.5 **McPherson Library**



16 APPENDIX D – NATIONAL AND INTERNATIONAL ENERGY BENCHMARKS

Relevant National and International energy density benchmarks have been identified and defined below

16.1 United States

16.1.1 Laboratories for the 21st Century Energy Benchmark

A series of case studies published by the Laboratories for the 21st Century group, highlighted sustainable features in engineering, and architecture and facilities management for a number of US based facilities. The following tables in provide data for different laboratory types and a detailed breakdown of how the energy is used for some case studies. Table 16-1: Laboratories for the 21st Century – Energy Benchmarks

*Energy data extracted from a series of case studies published on the Labs 21 website, www.labs21centry.gov highlighting sustainable features in both engineering, architecture and facilities management.

**Energy data predicted by project consulting engineers, Hully and Kirkwood.

***Climate Zone based on Briggs, Lucas and Taylor 2002 "Climate Classification for Building Energy Codes Standards". http://www.energycodes.gov/implement/pdfs/climate_paper_review_draft_rev.pdf.

****24 hour operation is assumed for labs where energy data is predicted.

Facility Name	Location	Climate Zone***	Type	Total Gross Floor Area m^2	Measured (M)/ Predicted (P)	Total Annual Thermal Energy $kWh/m^2/yr$	Total Annual Electrical Energy $kWh/m^2/yr$	Total Annual Ventilation Energy $kWh/m^2/yr$	Total Annual Cooling Plant Energy $kWh/m^2/yr$	Total Annual Lighting Energy $kWh/m^2/yr$	Total Annual Small Power Energy $kWh/m^2/yr$
Donald Bren Hall	California	Warm, Marine	Research	7,866	M	148	188	31	21	93	47
Cardiovascular & Biomedical Research Center	Glasgow	Cool, Dry/Marine	Research	12,000	P**	360	455	N/A	N/A	N/A	N/A
Fred Hutchinson Cancer Research Center	Washington	Mixed, Humid	Research	49,480	M	590	524	N/A	N/A	N/A	N/A
Marian E Koshland Integrated Natural Science Center	Pennsylvania	Cool, Humid	Research	17,226	P	102	239	57	24	23	136
Pharmacia Building Q	Illinois	Cool, Humid	Research	16,351	M	N/A	473	307	57	33	75
Whitehead Biomedical Research Building	Georgia	Warm, Humid	Research	30,194	M	682	681	N/A	N/A	N/A	N/A
Louis Stokes Laboratories	Maryland	Mixed, Humid	Biological	27,363	P	N/A	726	323	161	78	164
Nidus Centre	Missouri	Mixed, Humid	Biological	3,831	M	463	476	173	161	40	117
Process and Environmental Technology Laboratory	New Mexico	Warm, Dry	Instrumentation	14,069	M	385	463	N/A	71	N/A	60
The US EPA's National Vehicle and Fuel Emissions Lab	Michigan	Cool, Humid	Instrumentation	12,542	M	746	311	N/A	N/A	N/A	N/A

16.1.2 CBECS Energy Use Comparisons- United States

Commercial Building Energy Consumption Survey (CBECS), conducted in 2003, was used to calculate values presented in this table. The data is gathered from the US. Dept. of Energy's – Energy Information Administration (EIA) to show the national average building energy use in the United States.

The table below summarizes the results published in 2003:

Building Use	Average Source Energy Use Intensity kWhr/m^2-yr	Average Percentage Electric	Average Site Energy Use Intensity kWhr/m^2-yr
Education - College University (campus level)	882	63%	378
Restaurant/Cafeteria	1925	53%	952
Nursing Homes	803	54%	390
Public Assembly - Library	775	59%	327
- Recreation	428	55%	205
- Social / Meeting	321	57%	164

Table 2: CBECS National Average Source Energy Use Comparison

Source Energy is a measure that accounts for the energy consumed on sire in addition to energy consumed during generation and transmission in supplying energy to the site.

16.1.3 University Of Hawaii Energy Use Comparisons

In 2001, HECO (Hawaiian Electric Company) supported a building by building audit of the Manoa University campus to assess each building's energy consumption and potential for energy conservation measures.

The following summarizes the results last published in 2007:

Building Occupancy	kWh/year	kWh/m2-yr	% of Total Energy Use
Lab/Class	5,964,206	681	4.3
Lab/Class/Office	38,263,645	481	27.4
Office/Lab	16,487,311	372	11.8
Class/Office	30,277,375	234	21.7
Office	10,111,205	254	7.2
Library	15,097,136	301	10.8
Food/Facility/Office	8,376,420	453	6.0
Dormitory	5,096,752	55	3.6
Storage	496,084	102	0.35
Other (Clinic/Arena/Residential)	9,632,147	94	6.9
Total	139,765,181	246	100

Table 3: University of Hawaii at Manoa Energy Use Breakdown Building Occupancy Type

16.2 European Countries

16.2.1 HEEPI Benchmarks

Higher Education Environment Performance Improvement, known as HEEPI, is an organization that is financed by the Higher Education Funding Council for England and managed by the University of Bradford, in collaboration with the:

- *Association of University Directors of Estates*
- *Building Research Establishment (funded by Action Energy)*
- *Environmental Association for Universities and Colleges*
- *Standing Conference of Principals.*

HEEPI aims to improve the environmental performance of universities and colleges by:

- **Developing environmental benchmarking within further and higher education**
- **Running events to share best practice and build networks**
- **Providing an information resource**

HEEPI published a summary of benchmarking results in August 2006, which can be found below.

The main points to note from these tables include:

The high energy consumption of chemical science labs, largely due to the high levels of ventilation associated with fume cupboards (Fume Hoods) and related occupant safety requirements.

16.2.1.1.1.1 The presence of a secure facility greatly increases the energy consumption of medical/bioscience laboratories

16.2.1.1.1.2 The generally lower total energy consumption figures associated with physical engineering laboratories compares to other laboratory types, though electricity consumption is proportionately higher.

For more information refer to www.heepi.org.uk

Laboratory Type	Typical Practice Energy Performance (kWh/m2-yr)		Good Practice Energy Performance (kWh/m2-yr)		Best Practice Energy Performance (kWh/m2-yr)	
	Fossil Fuel	Electricity	Fossil Fuel	Electricity	Fossil Fuel	Electricity
All Labs	296	312	135	227	79	143
Medical/Bioscience (with secure facility)	397	362	198	227	100	245
Medical/Bioscience (w/o secure facility)	289	300	196	242	130	109
Chemical Science	353	367	244	333	177	327
Physical Engineering	177	196	104	86	119	52

Admin/Support	166	90	107	46	88	28
Sports Centers	325	199	-	-	138	88
Libraries	176	186	-	-	73	73
Residences	240	57	198	47	126	35
Teaching	240	118	88	41	46	31

Table 4: HEEPI Benchmarking Table

16.2.1.2 CIBSE Benchmarks

CIBSE, The Chartered Institute of Building Services Engineers, is the professional body, standard setter and authority on building services engineering. It publishes Guidance and Codes which are internationally recognized as authoritative, and sets the criteria for best practice in the profession. It is represented on major bodies and organizations which govern construction and engineering occupations in the UK, Europe and worldwide.

The table in Appendix D summarizes the benchmarking results published in December 2003 and 2008. The benchmarks are from 2003 unless stated otherwise. The benchmarks are for each space type and offer a direct comparison with the modeled benchmarks.

Building Type	Electricity kWh/m2-yr		Fossil Fuel kWh/m2-yr	
	Good	Typical	Good	Typical
Education - Catering, Bar, Restaurant	137	149	182	257
Lecture room, arts	67	76	100	120
Lecture room, science	113	129	110	132
Library, air-conditioned	292	404	173	245
Library, naturally ventilated	46	64	115	161
Science Lab	155	175	110	132
residential, halls of residence	65*	100		420*
Residential, flats	45	54	200	240
Offices - Air-conditioned (standard)	120*	226	95*	178
Naturally ventilated, cellular	33	54	79	151
Naturally ventilated, open plan	54	85	79	151
Sport and Recreation - Fitness Center	127	194	201	449
Combined center	96	152	264	598

Table 5: CIBSE Building Benchmarks

* Benchmark from 2008

16.2.1.3 BSRIA Benchmarks

British Standards Research Institute Association (BSRIA) is a research, consultancy and test organization helping companies in the built environment.

The BSRIA benchmarking results in the following table were published as the Rules of Thumb Guidelines for Building Services in August 2003. There is very little difference between the Good Practice BSRIA benchmarks, published in 2003, and the Good Practice benchmarks published in 2008. This indicates that energy reduction strategies in 2003 are still valid solutions today.

Building Type	Electricity kWh/m2-yr		Fossil Fuel kWh/m2-yr	
	Good Practice	Typical	Good Practice	Typical
Higher Education - Teaching	-	22	-	151
Research	-	105	-	150
Lecture hall	-	108	-	412
Office	-	36	-	95
Library	-	50	-	150
Catering	-	650	-	1100
Recreation	-	150	-	360
Offices - Air-conditioned (standard)	128	226	97	178
Naturally ventilated, cellular	33	54	79	151
Naturally ventilated, open plan	54	85	79	151
Residential - Care Homes	59	75	310	390

Table 6: BSIRA Benchmarks

17 APPENDIX E – SUPPORTING INFORMATION REALTING TO CRD'S SEWAGE HEAT RECOVERY FEASIBILITY STUDY

KERR WOOD LEIDAL
consulting engineers
compass
Greater Vancouver
200 - 4185A Still Creek Drive
Burnaby, BC V5C 6G9
T 604 294 2088
F 604 294 2090

December 21, 2011

Mr. Dan Telford, P.Eng.
Environmental Sustainability Department
Capital Regional District
625 Fisgard Street, P.O. Box 1000
Victoria, BC V8W 2S6

Dear Mr. Telford:

RE: RESOURCE RECOVERY AND USE PLAN – BUSINESS CASE DEVELOPMENT
Follow-Up Communication to UVic from December 14 Workshop
283.330-200

This letter provides some additional background information as a follow-up to our presentation to the University of Victoria on December 14, 2011. This information is in response to questions raised during and after the presentation. Topics covered are:

1) Additional detail on business-as-usual (BAU) costs for existing buildings connected to the UVic heating loop.
2) Additional detail on connection cost assumptions for buildings connected to the UVic heating loop.
3) A recap of our levelized costs and other results presented in our attached slide deck.
4) Additional detail on the amount of connected UVic floor area included under each scenario.
5) Next steps for this project.

We have also provided a copy of the presentation prepared for the December 14 meeting. We understand that this presentation is potentially sensitive, and should not be provided to any parties other than UVic staff.

The analysis prepared for our final report and included in the attached presentation is based on real levelized energy costs per end-use MW.h. Levelization is analogous to comparing the net present value of different energy system configurations. We have used levelization as a metric to determine both business-as-usual costs as well as district energy system costs, so we are making an 'apples to apples' comparison based on end-use MW.h of thermal energy demand.

For existing UVic campus space, connected to the campus heating loop, we are projecting a real levelized cost per end-use MW.h of $81 over the 30 year analysis period (2014 – 2043). This is based on the following assumptions:

- The overall efficiency of the heating loop, from gas input to thermal energy extracted at the building, is 75%. This includes losses at the boiler plant, as well as losses at the distribution system.
- Current gas commodity and delivery charges are ~$12 per GJ or $43 per MW.h of fuel input. This natural gas cost consists of a commodity component ($3.80 per GJ or $14 per MW.h) and a midstream and delivery component ($8.20 per GJ or $30 per MW.h). Carbon taxes and PCT offsets add another $2.60 per GJ or $9.20 per MW.h for an overall total cost of $14.60 per GJ / $53 per MW.h.
- Adjusted for 75% system efficiency, this is equivalent to $70 per MW.h at the building interface, based on current gas prices and carbon taxes.

- Current industry projections of future natural gas prices show an increase in the commodity cost component of gas prices from $3.80 per GJ ($14 per MW.h) to $6.70 per GJ ($24 per MW.h) in nominal dollars by 2015, with escalation at inflation only thereafter.
- Carbon taxes will escalate from $1.25 per GJ to $1.50 per GJ in 2012, and will escalate at inflation thereafter.
- Midstream and delivery charges, and PCT offset costs are expected to escalate at inflation over the analysis period.

There was some concern expressed in regard to the extent of modifications required for existing UVic residences. AME Group were retained to provide a review of the connection requirements on the existing UVic buildings, and offered the following recommendations:

- The heating system will need to provide a minimum 180ºF (82ºC) primary hot water supply temperature during normal conditions (currently 240ºF / 116ºC), and up to 200ºF (93ºC) during peak conditions, which will require the continued use of on-site boilers on the UVic campus;
- The existing residence buildings need to be isolated from the existing central heating plant, although provisions should be made to allow for switch-back on an as-needed basis;
- A 40ºF (20ºC) differential temperature is required between the supply and return to maintain the current hydraulic conditions;
- Plate-and-frame heat exchangers should be added in parallel with the existing shell/tube heat exchangers in the energy transfer stations to facilitate the lower primary supply temperature;
- If space is a concern, the existing shell/tube heat exchangers may potentially be removed, subject to further engineering work;
- A provisional budget of $100,000 per building should be included, which was the case for the cost estimates prepared in the business case analysis.

As shown in the attached slide deck, levelized BAU and DES costs under the Base Case and Expanded Case are as per the following table.

Table 1: Levelized Cost Results for Base Case and Expanded Case

	Base Case	Expanded Case
DES Costs per MW.h	$118	$105
BAU Costs per MW.h	$97	$97

Further to the above table, it is also of interest to examine the effect of potentially available grant funding upon the overall cost of energy. This is shown in Table 2.

Table 2: Effect of Grant Funding on Levelized Energy Costs

Scenario	Levelized Cost per MW.h	Comparison to BAU
BAU	$97	Nil
DES Base Case Without Grants	$118	+22%
DES Base Case With 100% Grant	$54	-44%
DES Base Case With: 67% Grant from Provincial & Federal Gov'ts 33% CRD Debt	$75	-23%
DES Base Case With Grant to match BAU	$97	Nil

High-level information on capital costs and some operating costs parameters is included in the attached presentation.

Table 3 shows the end-use MW.h of thermal energy demand associated with each sub-area connected to the DES, as well as the projected connection date for our Base Case and Expanded Case. For new campus space, we have assumed that all development is pushed out to 2020. For new space built at Queenswood, we have assumed that new space is built and connected to the DES between 2016 and 2020. As noted below, the combined end-use thermal energy load for existing campus space, new campus space, and new Queenswood space used in our Base Case analysis is 7,900 MW.h. For the Expanded Case, it is 13,600 MW.h.

We have also estimated the equivalent alternate floor space required to satisfy the conditions in the business case analysis should our initial estimates require adjustment due to UVic's plans for existing and future buildings. We wish to determine whether the projected floor space requirements are attainable from an alternate set of buildings from those proposed for the business case. The following table shows our estimates of demand as per the draft business case analysis, as well as the equivalent replacement floor area for alternate sets of buildings.

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Table 3: Estimates of Annual Energy and Floor Area for Draft Business Case

	Base Case	Expanded Case	Maximum Heat Recovery	Anticipated Timeline
Annual Energy Demand (MWh)				
Non-UVic	2,900	2,900	2,900	2014
UVic Campus	5,500	8,800	29,800	2014-2020
Future Off-Site	2,400	4,800	4,800	2016-2020
Total	**10,800**	**16,500**	**37,500**	**2014-2020**
Required Floor Area (m^2)				
per Draft Business Case				
Non-UVic	30,000	30,000	-	2014
Existing UVic	28,000	28,000	-	2014
Future UVic	30,000	60,000	-	2020
Future Off-Site	30,000	60,000	-	2016-2020
Total	**118,000**	**178,000**	**-**	**2014-2020**
Alternate				
Non-UVic	30,000	30,000	30,000	2014
100% Existing @ 115 kWh/m^2	69,000	118,000	301,000	TBD
100% Existing @ 107 kWh/m^2	74,000	127,000	323,000	TBD
100% Future @ 80 kWh/m^2	99,000	170,000	433,000	TBD

Based on our meeting with UVic, some further discussion may also be required with UVic to determine appropriate scenarios to include in our final report given the sensitive nature of future development plans. It may be appropriate to exclude the Expanded Scenario from our report if it represents an excessively high estimate of future development in the area. Once our report is finalized, there are several opportunities to further refine this analysis in the event that CRD and UVic elect to move forward on this project.

If you have any questions regarding the above, please do not hesitate to contact the undersigned.

Yours truly,

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