UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Energy & Buildings: Sustainable Strategies for Ponderosa Hub

Raphael Roy-Jauvin, Yael Haar, Hadi Kholeif, Natalia Pisarek

University of British Columbia

APSC 364

March 27, 2012

ENERGY & BUILDINGS: SUSTAINABLE STRATEGIES FOR PONDEROSA HUB

a place of mind

UBC

A synthesis report prepared for:

APSC 364

March 27th, 2012

Raphael Roy-Jauvin

Yael Haar

Hadi Kholeif

Natalia Pisarek

TABLE OF CONTENTS

1.0 BACKGROUND BRIEF

1.1 CURRENT DOMINANT SOURCES OF ENERGY AT UBC

The current dominant sources of energy for the purpose of heating and generating electricity within the UBC Vancouver campus are from Fortis BC, which provides natural gas and BC Hydro, which provides electricity to the campus through electric transmission lines. The natural gas and electricity are then distributed to the core academic, ancillary and tenant buildings. The electricity is used to light, ventilate and air-condition the campus. Natural gas fuels the district energy system, which then generates steam in order to heat the buildings on campus.

1.2 CURRENT INFRASTRUCTURE FOR ENERGY AT UBC

The buildings at UBC are heated through the steam district heating system composed of a comprehensive piping distribution network, in-building energy transfer stations and an energy plant. The steam distribution system is used to distribute the steam through the distribution pipes. The distribution system consists of 8.5km of underground piping and operates at a temperature of approximately 180°C. The equipment in energy transfer stations in each building includes heat exchangers, steam meters and steam to water converters. The energy transfer stations in each building include a steam meter and pressure reducing valve (PRV) assembly in order to reduce system pressure. UBC's buildings use a high-temperature heating system with a supply temperature ranging from 80°C - 93°C. The boiler plant contains four steam boilers installed with a total capacity of 420,000lb/hr and a firm capacity of 270,000lb/hr (Stantec, 2010).

Two BC Hydro transmission circuits feed the electrical distribution network at UBC, 60L56-North with a capacity of 62 MVA and 60L67-South with a capacity of 42 MVA, operating in parallel on the 12kV side of the transformer. Either line has the capability to carry the entire load of the North substation, UNY at which they terminate if the other transmission line is currently out of service. The campus is gradually approaching the limits of the BC Hydro electrical transmission lines that are currently serving the community. The North substation has a capacity of 47 MVA and a peak load of 32 MVA while the south substation has a capacity of 13 MVA and a peak load of 11 MVA. The total combined peak load of both substations is 43 MVA. UBC has a power factor of 0.95 within its electrical transmission lines (Stantec, 2010).

1.3 CURRENT END USERS OF ENERGY AT UBC

An end user is defined as a person who uses product requiring energy consumption. It is important to note that the end user may not necessarily be the purchaser of the device or energy. In the case of UBC residences, end users of energy consist of: Residents, staff and janitorial crew, and visitors. There are currently 8,000 residents and staff living and working in UBC's student housing. The University Neighborhood Association (UNA) has 7,500 residents living on campus. The University is hoping to grow its number of student residents to 14,000 by 2025.

A large number of factors, not necessarily unique to universities, may influence the energy saving behavior of end users. These are identified by Smith and Pett (2005) as follows:

- Employment situation (employed, self-employed, or unemployed)
- Level of knowledge over heating methods and systems
- Proper understanding of thermostat behavior, and placement of thermostats in the household.

1.4 CURRENT INPUTS AND OUTPUTS OF THE SYSTEM

Wasted energy with older systems at UBC amounts to the losses from the distribution networks, operations staff states that 28% of steam that leaves the powerhouse is lost during distribution; 6% of this steam is used internally for de-aerating. Stantec estimates the distribution losses at 25% and deaerator energy use at 4%. Overall system efficiency is 62% when the boiler and distribution efficiencies are combined. It is estimated that these losses of steam are generally consistent throughout the year. A major source of wasted energy by older steam systems is loss from distributions networks.

1.5 CURRENT COST IMPLICATIONS TO UBC AND ADJACENT AREAS

Since the Campus sustainability office was formed in 1998, UBC has achieved savings of upwards of 7 million dollars annually. The energy costs of UBC's residences, as well as their Building Energy Performance Index as compiled by Storey (2011) are shown in appendix A.

1.6 CURRENT ENVIRONMENTAL IMPACTS OF SYSTEMS

The current environmental impacts of UBC's housing and energy accounts for over 95% of UBC's greenhouse gas emissions (UBC 2010b). UBC plans to identify strategies to transform the existing energy system from a GHG intensive system to one that is GHG neutral to achieve its goal of becoming the first carbon neutral campus in North America. UBC plans on attaining to this goal by completing the following steps:

1. Building enclosure retrofits and mechanical system upgrades to reduce heating consumption
2. Replacing the existing steam based district-heating system with medium temperature hot water to reduce thermal losses and replacing the aging natural gas boilers with alternative technology.
3. Electrical demand side management to extend the service life of the existing distribution network, and potentially eliminate the need for increased distribution system capacity.

A plan to move from high to medium temperature steam is presently being created, which will lead to a 40% reduction in GHG emissions. UBC has introduced a process to implement a biomass gasification plant is currently under construction. Lastly, the building retrofits are being expanded which are expected to reduce emissions by an additional 30%.

1.7 CURRENT SOCIAL IMPACT CONSIDERATIONS

Since the 1990s UBC has promoted sustainable community planning as they envisioned a vibrant university community. "The University Neighborhoods' Association was established in 2002 to support the growth of a vibrant and sustainable community and provide municipal-like services for residents. This act is integrated under British Columbia's Societies Act and governed by a board of seven members. To this day the UNA has 2,000 members and represents approximately 7,500 residents in 5 different neighborhoods. Local regulations are made—noise, parking, animal control, etc.—by the UNA in addition to recreation, community programs, elections and landscaping. Another social impact program is UBC REAP (Residential Environmental Assessment Program) which is a green building rating system which was developed to provide residents with a rating system based on the LEED certification system. REAP is a prescriptive assessment system that takes the much of the guesswork out of sustainable building practices for residential developers, which are typically not as familiar with green buildings.

1.8 JURISDICTIONS THAT CONROL ENERGY AND SYSTEMS

UBC is responsible for securing its own energy needs. Electricity and natural gas is distributed to academic, ancillary and residential buildings on campus. In this context UBC is both a utility customer and a utility supplier. Since UBC is a separate jurisdiction within the GVRD this raises responsibilities but also opportunities. UBC is able to set its own trajectory for energy management and has opted for a platform of sustainability in recent years. UBC has created several key projects and mandates, which guide energy use and energy planning decisions on campus. For example, UBC has created a program for residential housing on campus called Residential Environmental Assessment Program (REAP), which directs decisions regarding tenant buildings on campus. Other initiatives include:

· Campus Sustainability Office, which informs campus operations from a sustainability perspective;
· Energy Optimization Program partnership with BC Hydro to reduce energy use and greenhouse gas emissions by 10 percent by 2015;
· Energy retrofit via ELECTrek II: Reductions of energy use through lighting re-design;
· Alternative Energy Sources Project (AESP) to examine the feasibility of low-carbon and carbon-neutral energy alternatives;
· Energy management via energy dashboards and energy meters;
· Focus on behavior change: "A key source of energy conservation for the future is not in the ground or the air, but in what we reduce through our behavior. We need to rewire ourselves to consume less and reuse what we waste…we all have a responsibility to power a sustainable world" (UBC 2012).

2.0 SUMMARY OF THE FOUR OPTIONS

2.1 BUILDING MANAGEMENT SYSTEMS

Description

A building management system (BMS) is a computer-based control system connected in buildings which controls and monitors the building's electrical and mechanical apparatus. A BMS comprises of hardware and software used to control a building's power systems, lighting, security and HVAC systems. The three basic functions of a BMS are controlling, monitoring and optimizing the building's energy performance for efficiency.

High-level cost implications

High-level cost implications including capital costs and projected operating costs may vary significantly. The capital cost of the anticipated system at Ponderosa Hub is $160,000 and is expected to cost approximately in the range $0.50-$1 per sq.ft to operate. It is expected that such a system will introduce annual savings of up to 30% depending on the condition of the building.

Environmental impacts

The building management system will result in positive environmental impacts, it will help cut greenhouse emissions into the atmosphere and decrease the life-cycle energy requirements through less demand of natural resources.

Social Impacts

BMS systems generally work well on the macro-scale but are not as commonly applied at the micro-scale since residents desire a degree of temperature control in their living space.

Co-benefits to UBC and the community

There are multiple benefits that a building management system may provide to UBC and the campus community. Building occupants may enjoy steady control of internal comfort conditions. Other benefits include effective monitoring of building performance, reduction of energy consumption through performance optimization, increased plant operational lifetime and reliability. UBC may enjoy a higher value to the buildings, central control and monitoring of building and lower costs of maintenance.

Research and academic potential of this project

The BMS has an academic research potential as groups of scientists may study and analyze the performance data of the building in order to determine the optimum performance characteristics. There is also research potential into the relationship between BMS and resident comfort.

Potential controversy

Although are multiple benefits as a result of using this technology, it is possible to introduce a potential controversy since residents may desire greater autonomy.

Implicated stakeholders

UBC, Fortis and BC Hydro are all stakeholders. Residents are also important to consider since an automated system might reduce their level of thermal control in their living space.

2.2 ECO-FEEDBACK SYSTEMS

Description

In most cases residents of buildings are unaware of how much energy they consume on a day-to-day basis. Eco-feedback systems can help occupants have a more interactive relationship with their use patterns. These systems can provide occupants with information on the amount of energy consumption that is occurring while encouraging energy efficient behavior. There is a "user interface" between a computerized system and building occupants that allows display of usage; which may prompt energy savings. There are several major design components which are described below:

Table 1
Summary of design components and prototype interface functionality.

Design component	Corresponding functionality in prototype eco-feedback web interface	Functionality description
Historical comparison	Ability to view three historical electricity utilization graphic modes (*24 h, to date, last week*)	Users have the ability to view their consumption on three different historical graphs: line graphs showing *24 h* and *to date* consumption and a bar graph showing the *last week* consumption snapshot
Normative comparison	Ability to view friends' average electricity utilization and building average electricity utilization	Users can add or remove designated friends from their peer network on their consumption graphs and their network consumption average
Rewards and penalization	Ability to earn positive and negative reward points based on consumption	Users are credited with points for reducing consumption from their baseline (pre-study level), completing audits, or answering surveys. However, users are deducted points for increasing consumption and are shown if they have negative points to reinforce penalization
Incentives	Ability to redeem reward points for prizes	Rewards points can be redeemed for prizes (i.e. gift certificates to local restaurants, energy efficient power strips) on the redemption page of the interface
Disaggregation	Ability to audit the consumption of specific appliances and devices by using an energy audit tool	Users receive an approximation of the energy usage of a given appliance by designating a time that the appliance was on and a time that it was off. Users are asked to minimize the change in other electrical devices to achieve maximum accuracy

High level cost implications

The costs of an eco-feedback system range from $264-396 not including the costs of installation (Berges, Nunes, et al, Ocneaunu, and Quintal). It is important to note that these figures were converted from Euros. Potential savings ranged from 5% to 55% throughout three studies. One residential eco-feedback study was found a reduction in energy consumption by 10% by providing users with historical consumption information (Jain, Taylor, Peschiera 2012). Another residential study observed savings of up to 26% by providing historical and normative consumption information to 80 users. (Jain, Taylor, Peschiera 2012). A third residential study which provided users with historical and detailed appliance-specific consumption information yielded savings of 5.8% (Jain, Taylor, Peschiera 2012).These three studies illustrate the variability in observed savings and constituting interface components across eco-feedback studies (Jain, Taylor, Peschiera 2012).

Environmental impacts

Researchers have concluded that reasonably achievable emissions reduction can be approximately 20% in the household sector within 10 years if the most effective interventions are used. (T. Dietz, Gardner, Gilligan, Stern, Vandenbergh).

Co-beneficiaries

A list of co-benefits consists of saving energy and money, having residents interact with and promote sustainable energy use. Moreover, residents can be given rewards which generate an additional incentive to conserve.

Research potential of this project

There is high research potential including psychological research to see how eco-feedback systems affect the behaviour of residents. Also a comparative study with and without eco-feedback systems could also be a potential study.

Potential controversy

The debate over the accuracy of energy monitoring devices may be one controversy. Overlap in functionality between the components (e.g. “network average” on historical comparison graphs) is another potential issue.

2.3 ENERGY COMPETITION

Description

Residence-wide competitions whose goals are to reduce energy consumption at the demand level promote energy literacy and foster residence community development at UBC. First year dormitories at UBC have already participated in the so called *Do it in the Dark* competition, which was a BC wide inter-university competition between dorms to engage first year students in sustainability; Totem Park and Place Vanier earned first place among many schools (UBC Campus and Community Planning, 2011).

The fact that this competition has already occurred on campus provides a good first step in helping design one, which could include Ponderosa hub. *Do it in the Dark* employed awards and a Facebook page to inform students of the competition and of their standings, as well as taking advantage of community settings like the dining hall to inform students. Ponderosa hub has a different design, it is less focused on communal living, and thus a different design approach to engage and inform residents should be employed.

An excellent study by Brewer and Lee (Hawaii 2011) laid out a plan for a similar competition (The Kukui Cup) at the University of Hawaii whose central strengths lay in the implementation of power meters in the electrical panels to monitor energy usage per floor. This was accompanied by an open source monitoring website which can monitor energy consumption in real time. This application, available at: https://github.com/keokilee/makahiki, is modeled to be usable by any University wishing to implement its own residence wide competition.

A successful study would engage participants through information, constant feedback through the above website, and a points and awards system designed to reward floors with the most savings.

High level cost implications

One of the biggest strengths of this option is its cost affordability. The only major cost involved would be the hiring of a part time employee to manage and ensure the quality of the competition, as well as prizes for remuneration.

State of development of technology

Technology is readily available and proven to be effective. UBC's own competition has demonstrated a willingness to participate and be engaged on the part of the students. Also, dorm competitions in general have been shown to be reliably successful at reducing energy usage (Brewer and Lee 2010). Finally, the software for feedback is already in place.

Environmental impacts/ Resource use

The positive environmental impacts of the contest would be reducing energy consumption and decreasing the carbon footprint.

Co-beneficiaries

The main co-beneficiaries are UBC who stands to save money from this competition through reductions in energy use, all the participants who stand to learn about sustainability and energy conservation, and the academic community who, if involved, can study and learn about non-financial incentives of energy conservation, and what motivates individuals to change their own actions for a communal good.

Research potential

As stated above, the unique social conditions of a residence setting and its location in the heart of Academia provide great research opportunities for those studying behavior.

Controversy

Brewer and Lee (2011) have noted that little is known about post-competition changes in participant behavior due to lack of research. Additionally, Sintov *et al.* (2010) attempted a similar competition based on self-completed surveys about behavior, which could be filled out online but found that of thousands of potential student participants, only six registered to participate. Thus, as the Ponderosa hub is built in a much less social nature than first year residences, the probability of low participation is a potential weakness in this proposed option.

2.4 PHASE CHANGE MATERIALS

Description

A phase change material (PCM) is a material with a high capacity of storing and releasing large amounts of energy. PCMs can be used in building design to achieve thermal stability, thereby reducing energy heating (and cooling) load. PCMs are latent heat storage materials which use chemical bonds to store and release heat. This technology is not new and is well researched regarding its energy savings potential. PCMs are not as well developed in the commercial sense but there are several market-available PCM products for residential use in building envelopes. PCM products are often blended with conventional insulation but there are also separate products meant to be installed in addition to insulation.

High level cost implications

Costs are borne during the initial stage of application. Once PCMs are installed as wall insulation there are no further costs associated with maintenance or monitoring. In other terms, PCMs are a passive strategy. Some PCM companies provide consulting services such as feasibility studies at costs ranging from $1,500 to $3,000. More specifically, two PCM products have been identified: Apple Blossom Energy PCM-blended cellulose insulation and Phase Change Energy Solutions BioPCM mats. The former is insulation, the latter is a PCM product meant to be installed together with conventional insulation. The cost of the BioPCM mat is $2.00 per sq.ft; it should be noted that this product does not need to cover the entire wall space to effective (Phase Change Energy 2012). However, we must also keep in mind that the cost of BioPCM mat is on top of the cost of conventional insulation since it does not replace insulation. The cost for the PCM cellulose insulation is between $2 and $5/lb (ORNL 2008).

Environmental impacts/ Resource Use

The environmental impacts of PCMs are dependent on their source material. PCMs today are non-toxic, non-flammable and safe for human handling. However, life cycle analyses indicate that PCMs have impacts (Gracia et.al. 2010). For example, the BioPCM mat is composed of soy and palm oils. This product is 100% recyclable but there are larger-picture implications. Palm oil has received criticism in recent years since commercial crops of palm oil displace local ecosystems.

Significant energy savings are possible with application of phase change materials. Studies have shown that savings of 40% are attainable, however the more conservative estimate of 30% is used in this report. Related to energy savings are cost savings for the university. Other benefits include increased thermal comfort for residents since PCMs enable maintenance of “comfort zone” temperatures inside residences.

Co-Beneficiaries

UBC is a in an excellent position to benefit from this option financially since reduced energy consumption is linked to reduced costs.

Research potential

There is no direct research prospect since the PCM will be inaccessible once installed inside residence walls; monitoring of energy use will affirm the energy reduction potential of this technology. However, there are a number of indirect paths for study of PCM. Examples of research streams include: life cycle analysis and identification of more “sustainable” materials with phase change properties.

Controversy

Potential controversy may arise from the composition of the PCM itself. Use of palm oil products, as mentioned above, can be contentious. There may also be concern by some that UBC is settling for technological “fixes” rather than engaging with sustainability in a more meaningful way. However, the energy saving potential of this strategy is significant. If PCMs are applied in tandem with other programs which stress community participation, open dialogue, social sustainability and consumer responsibility there is a high possibility of success.

3.0 INDICATOR MATRIX

The indicator matrix was developed around these following objectives because they were deemed conducive to UBC's sustainability goals:

1. To help UBC ensure ongoing economic viability
2. To develop realistic and achievable sustainability strategies
3. To help UBC understand and manage project risk
4. To help UBC achieve a major objective in sustainable design - to reduce energy consumption
5. To help the Province of BC meet its objective to reduce the expected increase in electricity demand by 2020 by 66%
6. To help UBC reach its carbon neutral objective
7. To help UBC increase understanding of sustainability inside and outside the university
8. To help UBC integrate research opportunities into the operations branch of UBC (integrating operations, teaching, learning and research)
9. To create strategies which are long-lasting and effective over long timescales

These objectives attempt to integrate environmental, social and economic sustainability and are primarily motivated by UBC'S Inspirations and Aspirations Final Report (2010). Provincial level goals are also taken into consideration for energy reduction targets considering that UBC is supplied by provincial hydro power. A fourth "temporal" category was added to reflect the focus on long-term solutions. Therefore, four categories are identified in the matrix: economic, environmental, social and temporal. Economic indicators primarily address capital and operational costs of the different strategies. Environmental indicators address the energy saving potential of each strategy, including related carbon emission reductions. Social indicators attempt to identify the community participation and education potential of each strategy. Finally, the temporal indicator attempts to assess whether the strategy is effective over the long-term since sustainability at UBC is discussed as a long-term process.

Some of the indicators rely on percentages or calculated estimates, such as the energy savings estimates. Many of the indicators are quantitative and rely on a 1 to 3 scale; 1 being a low score and 3 being the most desirable score. Marine Drive Towers were used as a proxy because it shares some attributes with Ponderosa Hub: it is a relatively new development (compared to Gage for example) and it does not use steam for energy (neither will Ponderosa). The numbers used in these calculations are available in Appendix B.

3.1 Matrix in *APPENDIX A*

4.0 RESULTS OF THE MATRIX

4.1 BUILDING MANAGEMENT SYSTEM

Economic Sustainability

The capital costs would include the retail value of the system and installation of system including all additional devices. The cost of which is approximately determined to be $160,000 by Siemens Canada. Training costs are included in the capital costs, usually provided by the manufacturer, in order to train several personnel in the use of the system which approximately lasts two months. The recommended system is the BMS developed by Siemens as it presents an equal trade-off between the device features, energy-saving efficiency and the capital and operational costs. The cost of operation is low at approximately $0.50-$1.00 per sq.ft. for effective operation and would not require any personnel to monitor the system on a daily basis therefore this duty may assigned to the maintenance team. It would also decrease the carbon tax costs by $30/ton as the system results in decreased greenhouse gas emissions. The implementation of the system results in a low payback period (approximately 5 years) according to the Harvard sustainability initiative and a high return on investment, although to actual data is present.

This system would require extensive planning by the building operators and a cost-benefit analysis of the operation of the system. Engineers/Technologists will be required to be present on-site in order to install and startup system. Complexity of long-term management of the system is extremely minimal as it is completely automated and thus does not require later human inputs. On some scheduled occasions, maintenance teams will need to check the system for any warnings or potential system crashes. Although there is specialized knowledge required to operate the system, this may be overcome through a simple training course that is offered by the manufacturer for technicians. Almost all technicians will be capable of understanding the concepts; good computer skills will also be required.

Environmental Sustainability

The estimated reduction in energy may be up to 30%, according to Siemens Canada, when installed in older buildings, which is not built with a LEED sustainability standard in mind. At the Ponderosa Hub, it is expected that the system will function to increase the energy efficiency within the building environment by reducing the energy approximately 12%-15% in kWh used per year according to Siemens. For an average building of 10 floors, the installation of the Siemens internal system would decrease energy use and result in annual savings of $33,000 according to Harvard University sustainability initiative. Using a BMS system, according to the Harvard sustainability initiative, it results in a decrease in annual greenhouse gas emissions of over 31 metric tons of carbon dioxide equivalent in a commercial building of 10 floors. It is therefore estimated that there will be a reduction of $930 annually in the carbon tax.

Social Sustainability

The project is not highly visible as it runs in the background and may not be noticed by the public. Thus, it is expected that there will be a low degree of participation by the public. This may result in residents not being aware of fundamental sustainability issues. It fails to reflect UBC's active participation vision due to its inactive strategy.

Although the system has been available commercially for multiple customers during the last decade, according to Dr. Atabaki of the UBC Mechanical Engineering Department, the system has not been perfected and there are always opportunities to further tune and enhance the system using formulas developed through scientific research.

Temporal Indicator

It is extremely efficient over-time, building management systems perform extremely well over time. It is a lifelong technology, which produces annual cost savings and reduced greenhouse gas emissions compared to a building without BMS.

The BMS option is a perfect long-term sustainability initiative, due to its low payback period; it is has an excellent return on investment and is the optimum choice for energy reduction in residential and commercial buildings. Although it has high implementation costs and requires extensive knowledge to install and operate, it does not require any further modifications. The option performs poorly on social sustainability as there is no any community participation in the project while it runs in the background with many unaware of its existence therefore there is no opportunity for community education or raising public awareness of this sustainability initiative.

4.2 ECO-FEEDBACK

Economic Sustainability

Eco-feedback systems scored moderately in economic sustainability due to the relative low cost of the systems themselves but high costs of implementation. The cost of the system itself ranges from $264-5000 depending on the complexity of the system. The monitoring systems that will be installed in the Ponderosa building will cost approximately $150K per building. The amount of savings eco-feedback systems can provide range from 5-15% annually. Maintenance check-ups would be the only long-term management required therefore eco-feedback scored highly in technical feasibility. Different types of displays for eco-feedback range from metering systems, to computer screen displays, to televisions. The information displayed also varies: electricity consumption, gas consumption, historic consumption, daily consumption, temperatures, and comparisons with other homes or floors. In addition ambient displays alert householder to the fact that something related to their electricity supply has changed or will do so. For example, a flashing light was used to alert householders to turn off the air-conditioning and open the window when the temperature had dropped (Seligman et al. 1979).

Environmental Sustainability

Eco-feedback systems scored well in environmental sustainability. Reductions from 6%-20% of electricity were seen throughout various types of eco-feedback systems. One example of research conducted in Japan with a complex interactive online display system yielded savings of 18% in electricity and 9% in gas in 10 households where the information was displayed (Ueno et al. 2005). Eco-feedback also did well in the GHG reduction of environmental sustainability—with research concluding a reduction of 20% of over the next 10 years, based off behavioral interventions alone (Dietz, Gardner, Gilligan, Stern, Vandenbergh)

Social Sustainability

Eco-feedback systems scored well in social sustainability and would bring many social benefits to the community. Having residents gain an environmental awareness and become environmentally literate would give them a common reason to practice a environmentally friendly lifestyle. A central communal monitoring system could promote a collective incentive of a community supporting a progressive cause. These systems could provide research potential to see how metering systems affect people's actions and how much of difference they make. Psychological studies could be done in addition to energy reduction research.

Temporal Indicator

The main focuses of eco-feedback systems would be to create long-term permanent reductions of energy use and keeping it at a constant reduced level. Eco-feedback systems have the ability to do this; it only depends on the attitudes and lifestyles of the residents. Mandatory tutorials for residents explaining how to use the systems and the benefits—ecologically and economically—it would bring, would help result in a collective positive awareness for the future.

4.3 ENERGY COMPETITION

Economic Sustainability

Cost would include installation of an energy monitoring system on a per-floor basis. The cost of which is $150,000 per building ($300K total). There are potential additional costs of one part-time employee to support Residence staff and to ensure a quality event. This employee could be remunerated at 10hrs/week at 15.49$ (numbers based on Work Study student positions) at a total cost of 2,168$. The operational costs are minimal to negligible once the single employee and energy monitors are paid for. The following diagram demonstrates the complexity of initiation.
This program would require planning on behalf of residence staff in the form of advertising, gathering participants, utilizing a feedback system and establishing rules and prizes. Although the framework for the competition can be carried from year to year, renewed energy, commitment and time will be required for every competition. To avoid competition fatigue, new prizes every year along with difference energy saving concentrations (one year water conservation is focus another year electricity, etc.) can help to bring more variety each year. Once the system is installed it will only need minor maintenance checkups around the time of the competition. Very little specialized knowledge is required, as energy monitors are simple to use if not already in place, and the suggested Makahiki web application (see Brewer et al. 2011) is free and specifically designed for such events.

Environmental Sustainability

Oberlin College's 2005 competition (Brewer et al. 2011) saw reductions of 32% over a 2-week event, and similar reductions in the two weeks post-competition. UBC's *Do it in the Dark* saw reductions of 27.6% for their winning residence (Totem Park). Using Marine Drive Tower's electrical energy consumption as a proxy for Ponderosa, and using a safe estimate of 20% reduction in energy for 1 month of the year, one expects reductions in the order of 3 kWwh/m2. For greenhouse gas reductions we used MDT as a proxy, the calculations shown above result in a 2% reduction in total energy use, which would equate to a 2% reduction in CO2 equivalent, or approximately 2 t.CO2eq.

Social Sustainability

There are many educational benefits to this competition; the most important is seeing that students become environmentally literate. This will infer that they understand the ecological affects of energy consumption and how their actions and habits affect the environment. For that reason, this competition scored high in this part of the matrix. Due to the feedback system characteristic in this approach and the high degree of participation, all participants and potentially all residents stand to learn about conservation and sustainability. This is a very active strategy, which will require enthusiastic community participation for success. There is a large scope of research potential, as shown in previous research, there is potential here to investigate questions relating to group behavior, non-financial motivators for energy conservation, and research how successful these strategies are at long-term conservation outcomes.

Temporal Indicator

This option may be seen as a shorter term option, but when applied annually can give long-term results. This option demonstrates moderate to excellent economic sustainability due to its very low costs across the board and simplicity to implement. It does however require some sustained energy year after year to remain effective. This energy may have to come from a paid position . Additionally, this strategy demonstrates excellent social sustainability, as it has great learning potential both for the participants and for the academic community at large, as well as fostering engagement and community spirit. This strategy however performs rather poorly on the environmental sustainability sphere, due to its small overall effect on GHG emissions and energy consumption. However, it should be noted that this result is entirely dependent on the ability and incentive of participants to continue a degree of conservation-minded actions after the competition is concluded. These incentives could be supported in the form of permanent feedback systems, which residents will have become familiar with during the competition but will continue to be able to use throughout the year, or monthly prizes to the most energy conscious floor.

4.4 PHASE CHANGE MATERIALS

PCM insulation will reduce the daily flux of energy exchange between inside and outside the building. This reduces the need for heating. Review of the literature shows that PCMs may reduce the total heat flow through a (insulated) wall by up to 40%. The more conservative estimate of 30% is used in this evaluation to prevent overestimation. These figures translate into significant consumption reductions. The concept of PCM insulation is not new, gaining recognition in the 1980s. However, at the time available PCM materials were either toxic or flammable. Today, PCM products for commercial and residential use are non-toxic and non-flammable. Finally, PCMs are a chemical solution with potential environmental costs (like any building material). For example, one manufacturer boasts that their PCM product is environmentally friendly because it is 100% recyclable. This is a positive attribute, but this PCM is also made of palm oil; palm oil has raised criticism in recent years due to habitat destruction in favour of growing industrial palm oil crops. This should at the very least be acknowledged in the context of sustainability at UBC.

Economic Sustainability

PCMs perform very well in this set of indicators. Capital costs for PCM insulation are higher than for conventional insulators. However, payback period is relatively rapid given the annual cost savings and absence of maintenance costs. Costs include purchase of the PCM product and less directly, installation costs (e.g. labour). Two companies have been identified, both based in the U.S. Research has shown that there is currently little interest in this technology in Canada. Manufacturers are found primarily in the U.S.A. and Europe. Cost of the BioPCM mat (one of the two products) is $2 per square foot. This product must be installed in addition to conventional insulation however. It was not possible to receive a direct estimate from Apple Blossom Energy for the PCM-cellulose insulation, but research documents by ORNL (the organization that developed the product) costs could range from $2 to /lb. Finally, manufacturers of this strategy ensure that it can be applied in regular construction. Also, since PCM materials in insulation are non-toxic they are not challenging to handle. PCMs meant for residential use are pre-manufactured products rather than PCMs in the chemical sense. Therefore they require no specialized knowledge to install.

Environmental Sustainability

Review of the literature shows that PCM insulation can reduce energy load by up to 40%. The most common range was between 30% to 40%, therefore the more conservative number of 30% will be used to prevent overestimation. Using Marine Drive Towers as a proxy for one can estimate a reduction of 54 kWh/m2**.** Similarly, one can estimate a reduction of approximately 31 tCO2eq. The current carbon tax in British Columbia is $30/tonne of CO2. Using this number and the above CO2 reduction, one can estimate a reduced expenditure of $930 annually.

Social Sustainability

PCM insulation is a passive technology installed inside walls; therefore it is not visible to residents. There is some potential to educate residents about the presence of the PCM but there is no engagement above this minimum level. Finally, there is some potential for meaningful academic involvement, albeit in indirect ways.

Temporal Indicator

PCM insulation performs very well over time. It is a durable technology which produces cost savings annually compared to an insulation system without PCM (Phase Change Energy 2012).

4.5 CUMULATIVE MATRIX RESULTS:

Criteria	**Indicators**	**Energy Competition**	**Eco-feedback system**	**PCM**	**BMS**
A) Economic Criteria					
Increased Economic Benefits	Estimated capital Costs	$3,000	$264-396	BioPCM $2/sq.ft PCM-Cellulose $2-5/lb.	$160 000
	Estimated operating costs	$3,000/year	--	none	$0.5-1/sq.ft.
2.Technical feasibility/ability to implement	Complexity of initiative (1-3)	2	2	1	3
	Complexity of long-term management (1-3)	2	1	1	1
	Level of specialized knowledge and materials (1-3)	1	1	2	2

B) Environmental Criteria					
Increased Energy efficiency	Estimated % reduction in kWh/m2	3 kWh/m2	20% per year	54kWh/m2	12-15%/year
GHG Emission reductions	Estimated reduction in CO2 (t. CO2.eq.)	2 tCO2eq.	--	31 tCO2 eq.	31 tCO2 eq.
C) Social Criteria					
Educational benefits	Visibility of project (Y/N)	Yes	Yes	No	No
	Communication provided to residents (1-3)	3	3	1	1
Community participation	Is the strategy active (Y) or passive (N)?	Yes	Yes	No	No
Research potential	Academic community involvement potential (Y/N)	Yes	Yes	Yes	Yes
D) Temporal Criteria					
Effectiveness over time	Are benefits long term or short term (1-3)	1	2	3	3

5.0 DISCUSSION

Phase change materials (PCMs) and a residence-wide energy competition were chosen as the best options of the original four identified. Building Automated Systems (BMSs) were rejected because they are not likely to be successful at the unit-level scale. Residents prefer a certain degree of autonomy in regards to heating control in their living space therefore an automated system would dismiss this need for autonomy. The Eco-Feedback option was rejected on the grounds that a similar technology is already integrated into Ponderosa building plans. Plans for Ponderosa Hub indicate that the development will include some form of both building-level and unit-level monitoring systems. Therefore, this option was eliminated. Finally, PCMs and the energy competition were chosen on the grounds of significant energy savings and meaningful social engagement. The first option offers consumption reduction potential and the latter enables behaviour to be examined and discussed. These two options together offer a robust energy reduction strategy which integrates environmental, economic and social sustainability.

5.1 ENERGY COMPETITION

Energy competitions encourage and promote a sense of community in dorms, create educational opportunities, enhance ecological awareness, and are commonly seen as fun and engaging experiences. The option we believe is the most engaging and innovative is an energy competition focused on sustainable behavior change and environmental literacy. The energy competition we based off of is called "The Kukui Cup" which was implemented in the University of Hawaii. It consists of a general web application framework for energy competitions called Makahiki. The exceptional feature of this application is that it is adaptable to support the needs of other universities who want information technology, and can be configured to meet the requirements of their environment. The questions to be answered as to why we chose energy competitions consist of: "To what extent and in what ways does our the energy competition improve the "energy literacy" of participating students? Second, how effective is our use of information technology to support behavioural change tools including goals, commitments, and near real-time energy feedback? Third, to what extent does our approach yield sustained changes in energy behavior, and what factors appear to influence sustained change?" (Brewer, Lee, Johnson 2011)

Students participating in an energy competition must be environmentally literate and able to relate to the foundation of the competition. Brewer, Lee, and Johnson define energy literacy as the understanding of energy concepts as they relate both on the individual level and on the national/global level. People need to understand how energy is being generated and consumed to further reduce their use. Knowledge, attitudes and behaviors are the three components of energy literacy. Students need obtain knowledge, such as understanding that the kilowatt-hour is the basic measure of electrical energy to fully comprehend their effects on the environment. Students must adapt positive and new attitudes towards the environment—for example, favoring renewable energy vs. fossil fuels. The last component, behavior, consists of changing everyday habits to begin the process of consistent energy reduction. The energy competition is designed to test the energy literacy of participants. There will be an assessment of the energy literacy of participants through a questionnaire presented via the contest website, as an activity that can be performed for points. Points are awarded—for the completion of tasks—through the competition website (powered by Makahiki) to increase students' energy literacy and in turn reduce energy usage. At the end of the competition awards will be presented based on points and energy consumption. Many awards will have supplementary prizes to incentivize participation.

To engage residents in the competition, methods will be applied—such as a kick-off meeting at which free T-shirts and buttons will be distributed, in addition to signage on each floor about the competition, and a closing grand prize ceremony. The competition website will log data about participants' actions on the site. All participant actions and events will be logged with a timestamp. Participants can do this by: logging into the website, selecting a goal for floor participation, and submitting text to verify completion of an activity. These events can be used to create a profile of each the participants. The energy literacy surveys from before and after the competition can address the impact of the energy literacy of the participants. Increased scores in post-competition energy literacy would provide an indication that the activities of the competition may increase energy literacy.

One basic way to measure the effectiveness of the information technology will be to examine the website logs to see how many residents actually participate in the competition by logging into the website, how often they log in, and how many tasks they complete. The efficiency of these tasks in improving energy literacy will be assessed by examining the correlation between Kukui Nut points awarded per participant, and their performance on the energy literacy surveys. The relationship between the amount of energy usage amongst different floors and the accumulated “Kukui Nut” points will also provide windows into the effectiveness of the information technology to support behavior change. By using the energy data, it is possible to determine the energy consumption of each floor before, during and after the competition. The amount of energy consumption after the competition ends is most important when looking for sustainable change, and the relationship between energy consumption, Kukui Nut points, website use, and energy literacy can help us see a sustainable change or not.

Some of the cons of an energy competition in the Ponderosa Hub would be that there are no financial incentives. This is because residence hall fees are flat rate and do not change based on energy usage therefore participants would not financially benefit. Another con of the competition is the fact that is a only for a short period of time. This brings up the question: Will these changes last? Will students take what they learned during this competition with them? and will these habits become first nature? These are some questions for further research.

This competition could help UBC attain achievable sustainability strategies by educating students on environmental literacy. Participants will do their part in changing their lifestyles and adapting towards more sustainable behaviors while being rewarded for their actions. Since this energy competition is designed to test the energy literacy of participants that means students must understand the methods of saving energy and why it is important. The competition is aimed towards changing habits to where they become first nature—for example, turning off the lights. Therefore, the energy competition would help UBC with their objectives of reducing energy consumption in addition to reducing the expected increase in electricity demand of 66% by 2020.

The economic incentives for this competition consist of savings ranging from 5-15% annually. This will meet UBC economic incentive of reducing total costs associated with energy. This competition will do an exceptional job at meeting UBCs goal of increasing the understanding of sustainability inside and outside the university. Having students acquire knowledge on environmental literacy, which would consist of proper knowledge and skills about energy—for example, where it comes from, how we extract it, how it affects the environment, alternative approaches to energy. In addition participants will learn that to have positive attitudes and behaviors towards the environment, such as lifestyle changes that can become habits to reduce one’s carbon footprint. This will also be helping UBC work towards their carbon neutral objectives. Creating a strong environmental literacy in students will create a strong progressive outcome for the environment and the University of British Columbia.

5.2 PHASE CHANGE MATERIALS

Phase change materials (PCMs) are materials whose chemical composition allows for storage and steady release of large amounts of energy. PCMs work on the principle of latent heat; PCM materials store and release energy as they change states from say, liquid to solid and back. Since this change of state occurs gradually (following temperature gradients), PCMs maintain comfortable temperatures over long periods. Therefore, heating load is minimized since residence units are not subject to massive temperature drops during the day or night. Studies have shown that PCMs in insulation applications can reduce heating load by up to 40%. Therefore PCM insulation helps UBC achieve both energy reduction targets as well as carbon emission targets (since these are related to energy use). This technology is also relatively inexpensive in the context of expected benefits. PCM insulation products are more expensive than conventional insulation. However, given that insulation of any kind is already an accepted building cost the true economic weight of PCMs should be viewed as the relative cost difference between conventional and PCM insulation (rather than in absolute terms). There are also no associated maintenance costs since PCMs are a passive technology. Therefore PCM insulation is a cost-effective solution to demand-side energy reduction. As explained above, PCMs perform very well in relation to the economic, environmental and temporal indicators introduced in this report. Since these products have a large capacity to reduce energy demand they help UBC meet reduction targets in both kWh and carbon emissions. Similarly, there is an obvious correlation between energy reductions and cost savings therefore this option helps UBC implement sustainability strategies which are economically feasible. Also, since the BioPCM mat is not an insulation replacement it does not need to cover the entire wall space.

It is important to note that there may be some criticism regarding the soy and palm oil source of the BioPCM mat. In recent years commercial palm oil harvesting has received criticism for forest and ecosystem degradation (Obidzinski 2012). At the same time, this PCM is a non-petroleum product and is 100% recyclable. The PCM-cellulose blend is perhaps less contentious since the product is made from 85% recycled newspaper (Apple Blossom Energy 2012). In other terms, should a life cycle analysis be conducted the PCM-cellulose may perform better in terms of source impact. In the context of sustainability the Apple Blossom insulation is a more "local" product since newspaper is available locally whereas palm oil is not. The local/global debate often favours local sourcing, especially in the context of carbon emissions when products are shipped long distances. The Apple Blossom insulation is also very good for sound proofing; this is an additional consideration for a large residence facility like Ponderosa (Apple Blossom 2012).

It is also of interest to note that both the BioPCM mat and the PCM-cellulose insulation are recognized by LEED (Phase Change Energy 2012; Apple Blossom Energy 20120). Finally, an opportunistic argument would be that the currently available BioPCM mats cannot restore the ecosystems that palm oil replaced. It is possible to achieve significant energy savings however and given the inability to revert what has been done BioPCM mats serve an important objective - reduced energy demand. It should be made clear that these are educated speculations inspired by sustainability literature and available manufacturer information. Regardless of immediate certainty these are important issues to consider. The discussion of sustainable building materials is a tricky one since most everything we apply will have an environmental impact. In this case it is important to weigh the costs and benefits; a meaningful discussion of these issues is demanded in the context of sustainability.

In terms of social sustainability objectives PCMs perform poorly. These products are passive technologies and do not allow for meaningful resident participation. However, there is potential to improve PCMs' social sustainability score via open dialogue. For example, residents can be made aware of the PCM insulation at Ponderosa. There is also the opportunity to generate research interest in PCMs; there is currently very little commercial interest in Canada or academic interest at UBC for PCMs. The performance of phase change materials in this category is why we feel coupling PCM insulation with a residence wide energy competition is a meaningful way to integrate all three components of sustainability. Finally, it is fitting that in a sustainability context a single strategy is not sufficient but rather a range of strategies which reflect the complexity of sustainability rhetoric.

Two commercial/residential applications of PCM have been identified. The first product is a PCM "mat" meant to be installed in addition to conventional insulation. The second is a PCM-Cellulose insulation blend meant to replace conventional insulation. The mat is manufactured by Phase Change Energy Solutions and the PCM-cellulose insulation is manufactured by Apple Blossom Energy. Both materials are designed to follow conventional building practices. The University of Washington has employed the BioPCM mat in an academic building (GreenTree 2012), though it was not possible to find high-profile residential applications. However, the BioPCM mat has been tested successfully in many experiments, all of which confirm the 30% energy savings potential (Phase Change Energy 2012). Similarly, the Apple Blossom Energy PCM-cellulose insulation has been tested successfully (Kony et.al. 2012).

Finally it is important to resolve the issue of toxicity. PCMs have been rejected for residential use in the past because the chemicals proposed were either toxic or flammable. Today we have effective

PCM products that are safe to use and have undergone testing to affirm manufacturer claims. Both the BioPCM mat and the PCM-cellulose insulation are non-toxic and non-flammable.

The energy competition described above does offer short-term energy savings. Long-term savings are still uncertain because they are highly dependent on behaviour change. This aspect of behaviour relating to sustainable energy use is why the energy competition is an excellent strategy for UBC's Ponderosa development. The potential for community participation is massive. Moreover, this strategy touches on the often un-tapped resource of changing behaviour. Changing our own behaviour and that of others is challenging but this concept is at the heart of recent sustainability dialogues. Therefore, it is a strong option for the university. In contrast, the PCM solutions offer significant energy saving potential but do not have the capacity to engage the community. The decision to present PCM as a final strategy was a pragmatic one; this technology does deliver energy savings. Together these two options offer a robust energy reduction strategy which reduces the demand load and generates opportunities for meaningful participation and even behaviour change in the long-term.

REFERENCES

2010 Carbon Neutral Action Report. (2010.) Retreived from <http://www.livesmartbc.ca/attachments/carbon_neutral_action_reports/UBC_2010.pdf>

Achieving Energy Savings with Building Automation Systems. 12 Feb 2102. < http://www.automatedbuildings.com/news/apr07/articles/esource/070322105430kamm.htm>.

Apple Blossom Energy. Cellulose Insulation. 27 March 2012. <http://www.appleblossomenergy.com/cellulose-insulation>

Berges, Mario, Nuno J. Nunes, Adrian Ocneanu, Felipe Quintal, and , eds. "SINAIS: Home Consumption Package: a low-cost eco- feedback energy-monitoring research platform." .N.p., n.d. Web. 13 Feb 2012. <http://www.vs.inf.ethz.ch/edu/HS2011/CPS/papers/froehlich10_eco-feedback.pdf>.

Brewer, Johnson, Lee, Xu. *Makahiki: An Open Source Game Engine for Energy Education and Conservation.*
Information and Computer Sciences University of Hawai'i at Mānoa.

Brewer, R.S., Lee, G.E. 2011. The Kukui Cup: a dorm energy competition focused on sustainable behavior change and energy literacy. Proceedings of the 44th Hawaii International Conference on System Sciences.

Doukas, H. (2007). Intelligent building energy management system using rule sets. *Building and environment , 42* (10), 35-62.

Government of British Columbia.University Endowment Lands. URL: http://www.universityendowmentlands.gov.bc.ca/about/structuregovernance.htm. (last accessed January 29, 2012).

GreenTree. BioPCmat adds to natural comfort in University of Washington building. March 27 2012. < http://greentree-products.com/Applications.html>.

Harvard Sustainability Initiative: Building Management Systems. 22 March 2012. < http://www.green.harvard.edu/greening-it>.

Jain R.K., et al., Assessing eco-feedback interface usage and design to drive energy efficiency in buildings, Energy Buildings (2012), doi:10.1016/j.enbuild.2011.12.033

Kosny , J. 2010. Understanding Potential for Phase Change Material Applications in Residential Buildings .". Ed. Fraunhofer Center for Sustainable Energy. Denver, CO. <http://apps1.eere.energy.gov/buildings/publications/pdfs/building_america/ns/b15_phase_change.pdf>.

Kosny, J., Yarbrough, D., Miller, W., Petrie, T., Childs, P., Syed, A.M. 2008. 2006/2007 Field testing of cellulose fiber insulation enhanced with phase change material.

Natural Resources Canada. Comprehensive Energy Use Database, 1990 to 2009. URL: http://oee.nrcan.gc.ca/corporate/statistics/neud/dpa/comprehensive_tables/list.cfm?attr=0. (last accessed January 29, 2012).

Obidzinski, K., R. Andriani, H. Komarudin, and A. Andrianto. 2012. Environmental and social impacts of oil palm plantations and their implications for biofuel production in Indonesia. *Ecology and Society* **17**(1):25.http://dx.doi.org/10.5751/ES-04775-170125

PCM Products Ltd. Phase Change Materials Thermal Management Solutions. 13 Feb 2012. < http://www.pcmproducts.net/home.htm>.

PCM Thermal Solutions Inc. Thermal Management Consulting. 13 Feb 2012. < http://www.pcm-solutions.com/consulting.html>.

Siemens Canada: Building Automation System. 22 March 2012. < http://www.buildingtechnologies.siemens.com/bt/us/Products__and__Systems/Building_automation_and_control/APOGEE_Building_Automation_System/Pages/apogee_building_automation_system.aspx>.

Sintov, N. D., Desario, G., Prescott, C. A. 2010. Effectiveness of a Competition-based intervention in promoting pro-environmental behavior in a university residence. ACEE summer study on energy efficiency in buildings.

Smith, W. and Pett, J. 2005. Energy efficiency refurbishment programmes help, but are the end-users doing their bit?. ECEEE 2005 Summer Study – What Works and Who delivers?

Storey,S. GHG and cost calculations. UBC Sustainability Office

Sustainability at UBC. Energy Management. URL: http://www.sustain.ubc.ca/campus-sustainability/greening-the-campus/energy-management (Last accessed January 29, 2012)

Stantec Consulting. *"Alternative Energy Feasibility Report For University of British Columbia."* (June 2010.) Retreived from http://www.projectservices.lbs.ubc.ca/Links/AESP EoI/Phase_Two_Step_Three_june_11.pdf.

Tyagi V.V., Buddhi D. 2005. PCM thermal storage in buildings: A state of art. Renewable and Sustainable Energy Reviews. 11 (2007). 1146-1166.

UBC.UBC campus alternate energy feasibility study. (2011). Retrieved from http://www.canadianconsultingengineer.com/awards/pdfs/F-2_UBCCampusAlternateEnergy.pdf

UBC Campus and Community Planning. 2010a. UBC takes top honors in BC-wide energy-saving Competition. http://www.planning.ubc.ca/vancouver_home/news_and_events/enewsletter/january_2012/articles564.php (last accessed February 12, 2012).

UBC.2008/2009.*Case study/ green building*. Retrieved from http://www.sustain.ubc.ca/sites/sustain.ubc.ca/files/uploads/pdfs/CaseStudy_GreenBuilding.pdf

UBC. 2010b. UBC Carbon Neutral Action Report. http://www.sustain.ubc.ca/about-us/annual-sustainability-reports

UBC Public Affairs.UBC Facts and Figures 2009/2010. URL: http://www.publicaffairs.ubc.ca/services-for-media/ubc-facts-figures/. (last accessed January 29, 2012).

UBC Student Housing and Hospitality Services. Student Housing Vancouver. URL: http://www.housing.ubc.ca/vancouver. (last accessed January 29, 2012).

UBC Sustainability. Energy. URL: http://sustain.ubc.ca/campus-sustainability/campus-themes/energy. (last accessed January 29, 2012).

University Neighbourhood Association.*About Us.* Retrieved from <http://www.myuna.ca/about-us/>.

Wilcove, D., Koh, L. 2010. Addressing the threats to biodiversity from oil-palm agriculture. Biodiversity and Conservation. 19(4).p.999-1007. DOI: 10.1007/s10531-009-9760-x

APPENDIX A – ENERGY USE COMPOSITION

Type of energy Use	% Share (*apartments)*	% share GHG emissions
Space Heating	54.8 *(35.8)*	65 (*43.2)*
Water Heating	21.6 *(34.4)*	33.9 (*54.8)*
Appliances	16.9 *(25.1)*	1.2 (*2.0)*
Lighting	5.9 *(4.4)*	0.0 (*0.0)*
Space Cooling	0.8 *(0.4)*	0.0 (*0.0)*

APPENDIX B – ENERGY CONSUMPTION AT UBC RESIDENCES

Residential Units	Electricity Cost ($/m2)	Steam Cost ($/m2)	Combined BEPI (kWh/m2)	GHG Emissions (t.CO2.eq.)
Totem Park	3.01	2.92	179.53	785.1
Walter H. Gage	2.74	2.99	176.04	1302.81
Place Vanier	3.52	5.04	272.41	1229.19
Marine Drive Towers	8.10	n/a	180.49	104.4

APPENDIX C – INDICATOR MATRIX

Criteria	**Indicator(s)**	**Objective**	**Justification**
Economic Indicators			
Increased economic benefits	1. Estimated capital costs 2. Estimated operating costs	To help UBC ensure ongoing economic viability. *From Inspirations and Aspirations: UBC Sustainability Strategy 2006-2010; Final Report	• Overconsumption of energy causes unwarranted economic costs to the university. • For sustainability measures to last they must be economically practical.
Technical feasibility/ ability to implement	A. Complexity of initiative 1- simple 2- some complications 3- complex B. Complexity of long-term management 1- simple 2-some complications 3-complex C. Level of specialized knowledge and materials required (e.g. engineering) 1- no specialized knowledge/materials required 2-some degree of specialized knowledge/materials	To develop realistic and achievable sustainability strategies, and to help UBC understand and manage project risk.	• These indicators are necessary to determine the level of effort required to bring the initiative into fruition.

	required 3-high level expertise/materials required		
Environmental Indicators			
Increased energy efficiency	1.Estimated % reduction in kWh/m2 *based on literature and baseline proxy Marine Drive Towers	To help UBC achieve one of its major objectives in sustainable design: to reduce energy consumption. To help the Province of BC meet its objective to reduce the expected increase in electricity demand by 2020 by 66%.	• Energy is finite. • Overconsumption of energy causes faster depletion of natural resources. • Accurate and quantitative description of reduction in energy use.
GHG emission reductions	1.Estimated reduction in C02 (in tonnes) 2.Reduction in carbon tax exposure *based on baseline proxy Marine Drive Towers	To help UBC reach its carbon neutral objective by the timeline set.	• Climate change is a critical global issue
Social Indicators			
Educational benefits	A.Visibility of project Y/N B. Level of communication of information to residents 1-minimal information	To help UBC increase understanding of sustainability inside and outside the university. *From Inspirations and Aspirations: UBC Sustainability Strategy 2006-2010; Final	• Education is a fundamental tool for changing perspectives and behavior toward sustainability. • The indicator garners a sense of how aware residents are of sustainability actions.

	provided 2-substantial amount of information provided 3-comprehensive and meaningful information provided	Report	• Establishment of new modes of behavior.
Community participation	1.Passive vs. active strategy Active – 1 point Passive – 0 points	To help UBC increase understanding of sustainability inside and outside the university. *From Inspirations and Aspirations: UBC Sustainability Strategy 2006-2010; Final Report	• Participation is an effective means for building social capital (e.g. trust and understanding of sustainability issues).
Research potential	1.Can the academic community get involved Yes-1 point No- 0 points	This indicator would specifically integrate learning and research opportunities into the operations branch of UBC. Thus, this criterion helps UBC to further integrate sustainability across operations, teaching, learning and research. *From Inspirations and Aspirations: UBC Sustainability Strategy 2006-2010; Final Report	• UBC is a research institution, with a central mandate to advance sustainability on its campus and beyond through research.

Temporal Indicator			
Effectiveness over time	Are the benefits felt on the long term or short term 1-under a year 2-1 to 5 years 3- greater than 5 years	We aim to create sustainability strategies which are long-lasting and therefore have greater overall effects.	• This is important to maximize the returns of any sustainability strategy undertaken