UBC Social Ecological Economic Development Studies (SEEDS) Student Report

Ponderosa Commons Energy Conservation Studies

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Executive Summary

This report provides an analysis and evaluation of possible demand side management strategies for reducing energy demand in residences in the University of British Columbia with the design of the as-yet un-built Ponderosa Phase 1, 2 and 3 student residences used as a case study. Four options had been initially proposed, analyzed and ranked through the means of a sustainability criteria matrix that had been developed for the purpose of this project. The four proposed options are the use of fabric curtains (as opposed to venetian blinds), 'Nest' Programmable Thermostats, High-resolution Real time Feedback Systems and Power Strips with attached 'Universal Plugs'. While the first three options reduce heating loads in residential buildings, the fourth option of the use of Power Strips with attached 'Universal Plugs' aims to reduce plug loads.

The options, fabric curtains, 'Nest' Programmable Thermostats and High-resolution Real time Feedback Systems performed the best on the whole when assessed using the sustainability criteria matrix that had been generated based on the three defining pillars of sustainability: Environmental, Social and Economic. Consequently, the option of Power Strips with attached 'Universal Plugs' has been excluded from the recommendations as it proved to be economically unfeasible at the moment.

The sustainability criteria matrix consisted of indicators to measure energy usage reductions, occupant engagement, technical and economic feasibility and academic research potential among other things. Points had been assigned to each of the options depending on how well they fared against the indicators, with highest number of points given to the best performing option and so on. Certain indicators such as reduction in energy consumption were more quantifiable than others like those measuring occupant engagement. As such, a survey was carried out among students to gauge the less quantifiable indicators in a reliable manner. Subsequently, the total number of points was added to rank the options.

This conclusions and recommendations proposed in this report have been made after considerable thought and analysis of the information that had been available at the time of writing. While the authors of this report stand by the conclusions and recommendations made in this report, certain limitations of the proposed options have to be also acknowledged. Certain foreseeable challenges in relation to the proposed options are also discussed in this report.

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DISCLAIMER

The survey results presented in Appendix G are meant for internal use only by the staff at UBC Plant Operations. These results should not be published without BREB approval. The survey can be found in Appendix G.

Questions and comments are welcomed. Please contact Marie at limarie90@gmail.com.

Introduction

The basis for the University of British Columbia's Demand Side Management (DSM) Strategy for the Point Grey campus is the need for reducing the energy demand in buildings. In order to comply with its Climate Action Plan, UBC has adopted a series of initiatives including the Continuous Optimization program and mandatory LEED Gold Standards to ensure that both existing buildings and new constructions on campus are reducing their energy usage and carbon emissions quite substantially.

While green building designs and energy-efficiency technologies are well-developed and researched, less is known about the role of occupant behaviour for energy demand management. However, studies showing that occupant behaviour can significantly amplify or dampen the effectiveness of energy-efficiency technologies used on buildings are emerging in recent times. Therefore, the Student Housing and Hospitality Services (SHHS) and the UBC Campus Sustainability Office are keen on engaging and enabling the current and future building occupants to adopt energy efficient behaviour.

This report will discuss both passive and active (i.e. requires occupant engagement) strategies for energy-efficient indoor comfort provision in buildings and put forward several recommendations to SHHS and the Campus Sustainability Office with regards to future residential buildings. This project used the design of the as-yet un-built Ponderosa Phase 1, 2 and 3 student residences as a case study.

Background

The project was initiated through reviewing general energy infrastructures at residential buildings in UBC. The findings were that most of the energy and electricity needed for lighting, heating and ventilating the buildings came either in the form of hydroelectricity supplied by BC Hydro or from natural gas supplied by Terasen Gas. Heating was identified to be a major source of energy consumption in residential buildings on campus.

Four strategies to engage and promote energy-efficient occupant behaviour were proposed and analysed. The summarised descriptions of the four strategies are as follows.

Option Study

Option 1 Fabric Curtains

Curtains are a popular household feature and an established one. Replacing the venetian blinds traditionally used at UBC would create warmer rooms, while still allowing for the movement of fresh air through the room. This is because curtains insulate cold windows due to their solid (not slatted) material. Blackout curtains have an R-Value (insulation value) of 3.8 (Galt Home, 2012), which is more insulation than wooden blinds (3.17 – The Blind Spot, 2012). This relative additional insulation will act in helping reduce energy consumption.

Option 2 NEST Programmable Thermostats

Heating (and cooling) in a home is one of the most energy consuming domestic processes – "In 2005, 49.1% of energy consumed by residential buildings was used for space heating and cooling…" (Moon & Han, 2011) A programmable thermostat can help reduce consumption by automatically turning down the heating during time periods pre-set by the owner, such as at night when occupants are asleep, or when occupants are away from home. In particular, the use of NEST (NEST Lab, 2012) programmable thermostat is proposed. The added advantage of NEST is that it automatically programs itself as you teach it energy saving habits and thus, eliminating the need to adjust the thermostat yourself.

Option 3 High-resolution Real-time Feedback Systems

Energy feedback systems in general, inform the occupant how much energy is being consumed. A high-resolution real-time feedback system will involve installing separate meters that track energy consumption for a defined space, such as a suite or a floor. Students will then be able to view suite-specific or floor-specific energy consumption data from public displays or from a personal computer.

Categories of feedback systems include direct and indirect feedback systems (Darby, 2006; Appendix A); direct feedback systems are further categorised into low and high-resolution systems. A low resolution system involves manual meter reading and data entry while a high resolution system automatically feeds meter readings into the database at much shorter time intervals (Appendix B). Compared to the other types of feedback systems, high-resolution real-time feedback systems achieved the highest reductions in energy consumption with an average of 55% (Petersen, Shunturov, Janda, Platt, & Weinberger, 2007). Thus, they were considered as a highly effective option for engaging occupants to adopt a more energy-efficient behaviour.

Option 4 Use of Power Strips with 'Universal Plug'

This option looked into making unplugging easier so as to incentivise occupants to unplug their appliances after use in order to reduce plug loads in residential buildings. It involves using power strips with plugs designed like the Universal Plug (a hollowed-out plug) attached to them. The Universal Plug has a circular cut-out that allows people to pull out the plugs easily with minimum effort. The plug also has a built-in reminder in the form of a glowing inner surface that becomes more prominent when the room lights are switched off and the room gets dark. (Domestic Aid: Universal Plug, n.d.) The hollowed centre and the glowing halos intuitively remind users to yank out the plug after use. When attached to a single power strip, multiple appliances can be unplugged with ease with the universal plug (Appendix C).

Evaluation

Methodology for Developing Indicators

In developing a framework to assess the options, criteria were generated based on the three categories that define sustainability: Environmental, Social and Economic.

Environmental

- ***Energy Conservation:*** Percentage reduction in electricity consumption is the indicator here. Most of the figures were either estimates provided by the manufacturer or actual results taken from precedents. The percentages and options were ranked; the option that conserves the most electricity was awarded four points and the option that conserves the least was awarded one point.
- ***Additional Material Input Required:*** Resources consumed to implement these options is also important. The scope of this project did not allow for thorough life cycle assessment on each of the options. Instead, "likelihood of being recyclable" was incorporated into the criteria as a proxy to see how likely inputs can be reused. Options were rated using as scale of 1-3, 1 point for "Not Likely" and 3 points for "Recyclable".

Social

- ***Occupant Engagement:*** Ideally, we hope to influence occupants' behaviour and lead them into permanently adopting energy conservation practices. This criterion is broken down into three indicators: **awareness**, **attitude** and **action**. Through a survey (Appendix D), students were asked to answer the following questions:

	Scale of 1-5	
Questions	1 Point	5 Points
Awareness How will it affect your awareness for conserving energy?	Significantly less aware	Significantly more aware
Attitude How will it affect your attitude towards energy conservation?	Want to make an effort to waste energy	Want to make an effort to conserve energy
Action How likely do you think it will change your behaviour in the long-term with regards to energy conservation?	Not at all likely to change my behaviour	Very likely to change my behaviour

Table 1 Occupant engagement evaluation criteria

The results computed in the relevant fields of Table 3 consist of weighted averages of the survey responses according to the rating scheme above. In addition, the options are classified as passive or active. Passive options are awarded 1 point whereas active options are awarded 2 points; preference is given to active options because they are more likely to induce occupants into adopting energy conservation practices. This is also in alignment with one of UBC's goals for sustainability.

- ***Comfort Level:*** A university residence must also provide a level of comfort to the students. Again through a survey, students were asked to evaluate each option (on scale of 1-5) with regards to the perceived change in comfort level.
- ***Community Sustainability:*** Establishing local business partnerships is an essential part of maintaining local economic sustainability. This qualitative indicator seeks to examine the potential of setting up local partnerships or sourcing material from local supplier.

Economic

- ***Research Potential:*** In alignment with the objectives of UBC as a Living Lab, research potential is evaluated on scale of 1-3, with 1 point being no research potential and 3 points being "will advance university as an academic leader in this field". Research potential includes:
    - Developing further applications for the technologies related to the options (e.g. extending high resolution feedback to mobile devices)
    - Providing a good basis to conduct new research projects (e.g. determining whether installing thermostats per floor or per suite will be most effective for changing occupants behaviour).
- ***Economic Feasibility:*** Three factors are considered under economic feasibility – cost of the option, payback period, and % reduction in energy costs.
    - Cost of the option: each option is ranked; the least expensive option is given 4 points and the most expensive option is given 1 point.
    - Payback period: total cost is divided by the amount of annual energy cost savings to see how many years it would take to recover the entire cost. The option with the shortest payback period is given 4 points and the option with the longest period is given 1 point.
    - % reduction in energy costs: the figures are taken from manufacturer's estimates or actual savings from precedents. The option with the most reduction in energy cost is given 4 points and the option with the least reduction in energy cost is given 1 point.
- ***Technical Feasibility:*** Two dimensions were considered in evaluating technical feasibility:
    - Evidence of precedents: if other institutions have successfully implemented a particular option in the past, it will greatly increase feasibility. The option is awarded 3 points if there is evidence of precedents, and is awarded 0 points if otherwise.
    - Evidence of existing products: some energy conservation solutions may be theoretical and prototypes of the hardware may not exist yet. If prototypes or final products are available, feasibility will be greatly increased. The option is awarded 3 points if there is evidence of existing prototypes or commercial products on the market, and is awarded 0 points otherwise.

A Note on the Weighting of Indicators

The environmental, social and economic criteria are all equally important in defining sustainability. All indicators were given equal weights with the exception of technical feasibility. A technically unfeasible option will likely to incur more costs than to generate benefits. As mentioned above, each option deemed to be technically feasible will be awarded 3 points.

Indicator Matrix

Category	Criteria	Indicator(s)	Objective(s)	Justification
Environmental	Energy Conservation	% reduction of electricity consumed by residential spaces in Ponderosa Commons	To reduce absolute levels of electricity consumption in residential spaces in Ponderosa	In line with UBC objectives to conserve resources and reduce non-renewable energy consumption (Inspirations and Aspirations Final Report, 2011)
	Additional Material Input Required	Additional input and input material recyclability (3: Recyclable; 2: Partially Recyclable; 1: Not Likely recyclable)	Minimize consumption of additional materials and resources.	Aiming to minimize resource footprint (including embodied energy of implementing proposed solutions) by managing the kinds of materials i.e. local/recyclable. This fits with the goals for the Materials and Resources prerequisites for (LEED, 2009)
Social	Occupant Engagement	Perceived positive change in energy literacy (awareness)	To cultivate positive energy-related habits through active user engagement	In line with UBC objective to "support and engage staff, faculty and students in sustainability learning, practice and leadership development". (UBC Annual Operational Sustainability Report Vancouver Campus, 2011)
		Perceived positive change in energy conservation behaviour (attitude)		
		Perceived positive change in energy conservation behaviour (action)		
		Passive or Active (2: Active; 1: Passive)		
	Comfort Level	Perceived level of comfort	To provide optimal comfort levels to occupants while in residence	In alignment with the UBC Department of Student Housing and Hospitality Services' goal of providing an environment that helps students succeed both academically and socially (UBC Student Housing, 2012). In alignment with LEED's criteria of "[... to] promote [occupants'] productivity, comfort and well-being," (LEED, 2009)
	Community Sustainability	Potential of setting up local business partnerships or sourcing from local supplier (3: High; 2: Possible; 1: Low)	Aim to create sustainable community by supporting local businesses	Local partnerships will create positive externalities for local community such as research and development partnerships, and opportunities to implement similar solutions at a city-level
Economic	Research Potential (Educational and Economic Value)	Research Potential (3: Will advance university as an academic leader in this field; 2: Research connections exist or have a potential to be established, 1: No foreseeable research potential)	To evaluate the educational and instructive ability of proposed options through the means of their expected research potential	Fits with UBC as a living laboratory, using the university as a space to explore possibilities of new ways of doing things through implementation and monitoring
	Economic Feasibility	Cost of option	To ensure the project is in alignment with UBC's budget	Must consider financial constraints such as incremental costs, opportunity costs, and financing (debt vs. equity)
		Payback period	To provide a time frame for the option to sustain itself	Shorter payback periods are desired as resources can be devoted other valuable projects; also to ensure that payback periods are within the lifespan of both the product and the Ponderosa building itself
		% reduction in energy costs	To measure cost savings	With limited resources, solutions with higher cost savings are preferred
	Technical Feasibility	Evidence of precedents at other institutions? Y/N	To evaluate feasibility of implementing solutions within UBC's abilities.	Precedents will greatly accelerate feasibility studies and opens up opportunities for collaboration
		Evidence of existing products (e.g. NEST thermostat) Y/N		Relevant existing products/prototypes (especially those available on the market already) will provide insight to whether the solution is feasible at UBC

Table 2 Rationale and justification for chosen indicators

Options Evaluation Summary

Category	Criteria	Indicator(s)	Best Performing Option
Environmental	Energy Conservation	% reduction of electricity consumed by residential spaces in Ponderosa Commons	Thermostat
	Additional Material Input Required	Additional input and input material recyclability (3: Recyclable; 2: Partially Recyclable; 1: Not Likely recyclable)	Curtains, Thermostat, Universal Plug
Social	Occupant Engagement	Perceived positive change in energy literacy (awareness)	High Resolution Feedback
		Perceived positive change in energy conservation behaviour (attitude)	
		Perceived positive change in energy conservation behaviour (action)	
		Passive or Active (2: Active; 1: Passive)	Thermostat, High Resolution Feedback, Universal Plug
	Comfort Level	Perceived level of comfort	Thermostat
	Community Sustainability	Potential of setting up local business partnerships or sourcing from local supplier (3: High; 2: Possible; 1: Low)	Curtains
Economic	Research Potential (Educational and Economic Value)	Research Potential (3: Will advance university as an academic leader in this field; 2: Research connections exist or have a potential to be established, 1: No foreseeable research potential)	High Resolution Feedback
	Economic Feasibility	Cost of option	Curtains
		Payback period	Thermostats
		% reduction in energy costs	Thermostats
	Technical Feasibility	Evidence of precedents at other institutions? Y/N	Curtains, Thermostat, High Resolution Feedback
		Evidence of existing products (e.g. NEST thermostat) Y/N	Curtains, Thermostat, High Resolution Feedback, Universal Plug

Table 3 Best performing options for each indicator

Evaluation Results[1]

Category	Criteria	Indicator(s)	Fabric Curtains	Thermostat	High Resolution Feedback	Universal Plug
Environmental	Energy Conservation	% reduction of electricity consumed by residential spaces in Ponderosa Commons	Unknown (0)[2]	~33% (4)	10% (3)	5-10% (2)
	Additional Material Input Required	Additional input and input material recyclability (3: Recyclable; 2: Partially Recyclable; 1: Not Likely recyclable)	3	3	1	3
Social	Occupant Engagement	Perceived positive change in energy literacy (awareness)	2.9	3.6	4.6	3.5
		Perceived positive change in energy conservation behaviour (attitude)	3.1	3.7	4.1	3.5
		Perceived positive change in energy conservation behaviour (action)	2.7	3.6	3.9	3.4
		Passive or Active (2: Active; 1: Passive)	1	2	2	2
	Comfort Level	Perceived level of comfort	3.6	3.7	3.2	3.1
	Community Sustainability	Potential of setting up local business partnerships or sourcing from local supplier (3: High; 2: Possible; 1: Low)	3	1	2	1
Economic	Research Potential (Educational and Economic Value)	Research Potential (3: Will advance university as an academic leader in this field; 2: Research connections exist or have a potential to be established, 1: No foreseeable research potential)	2	2	3	2
	Economic Feasibility	Cost of option	CAD$16,728.84 (4)	USD $277,884 (1)	USD $120,192.31 (2)	CAD $33,480 (3)
		Payback period	3 years (3)	0.5-2 years (4)	8 years (1)	6 years (2)
		% reduction in energy costs	29% (3)	~30% (4)	5% (1)	5-10% (2)
	Technical Feasibility	Evidence of precedents at other institutions? Y/N	Yes (3)	Yes (3)	Yes (3)	No (0)
		Evidence of existing products (e.g. NEST thermostat) Y/N	Yes (3)	Yes (3)	Yes (3)	Yes (3)
Total			**37.2**	**41.6**	**36.8**	**33.4**

Table 4 Evaluation results

[1] Justifications for the calculations can be found in Appendix E and F

[2] According to the Eclipse Curtains, their blackout curtains can reduce thermal loss by up to 25% (Eclipsecurtains.com, 2012). Since an estimate of actual energy savings cannot be found, the option of Fabric Curtains is awarded 0 points to be conservative.

Recommendations

Based on the results of the sustainability criteria matrix, input from operational staff and residents, the three options of using **fabric curtains**, **high resolution real-time feedback systems** and **programmable thermostats** are recommended as strategies for engaging and enabling current and future building occupants to adopt energy efficient behaviour. The option of attaching 'universal plugs' to power strips was excluded from the recommendations, on the basis of complex logistics and lack of precedents (which makes it unreliable). The rationale for the recommendation of the three aforementioned options and the exclusion of the fourth option is discussed in greater detail below.

The three options of using fabric curtains**,** high resolution real-time feedback systems and programmable thermostats can be seen as an integrated way of tackling the problem of reducing heating loads in residences. It is hoped that the integration of one or all of the options in tandem would help to reinforce and amplify the effectiveness of each of the three proposed options.

Rationales behind the recommendations are classified into the following: High-level Cost Implications, Environmental impact, Social Impact, Co-benefits and Academic Research Potential.

In addition, the recommendations of the three options are also based on the fact that they performed well when judged against the indicators discussed earlier in the sustainability criteria matrix. While all four options were successful in achieving positive environmental impacts of energy reductions, the indicators measuring economic (i.e. cost implications) and technical feasibility were given greater weight in deciding our final recommendations (with the exception of high-resolution real-time feedback; please see page 16 for justification). This is because ultimately economic and technical feasibility will be the constraining factors in deciding whether or not to implement these proposed options. As shown in Table 2, the options of fabric curtains and NEST thermostats were the best performers in the economic and technical feasibility criteria.

Fabric Curtains

High-level Cost Implications

Blackout curtains are cheaper than aluminum Venetian blinds. Blackout curtains are easier to repair and replace, as well as being more economical to clean in terms of time and money (Cooper, 2012). The blackout curtains in question would ideally be similar to Eclipse curtains (eclipsecurtains.ca, 2012) and the venetian blinds similar to standard aluminum blinds from Blinds.ca (blinds.ca, 2012).

Environmental Impacts

Curtains insulate warmth of the room and allow less heat to escape through the windows; this will reduce GHG emissions due to the reduction of heating required within rooms (Nicol, 2001). There will also be less light pollution in the surrounding area (Harder, 2004) outside the buildings, as with curtains, less light is likely to be seen from the outside due to the thick and continuous window covering.

Social Impacts

Students are more likely to acquire better sleep with the curtain's blackout quality, as much light is let in through the slats of venetian blinds light in a room. Blackout blinds are recommended to combat this, as well as help to improve students' concentration and cognitive function, which is critical in studying (Pilcher & Huffcutt, 1996). There will also be less frustration dealing with broken, bent, tangled or lopsided blinds (Rubin et al, 1978). Using curtains is very straightforward and no additional resource needs to be spent to train students on how to use them.

Co-benefits

Well rested students will be happier and more productive (Brown, n.d.). We expect there will be less maintenance call-outs compared to that of blinds repairs. Curtains can be easily removed and cleaned – which will improve health among students due to the increased opportunity to eliminate settled dust and subsequent dust mites from the room (Khatri et al, 2011).

Academic Research Potential

Potential academic research areas arising from this technology could include psychology tests to measure the difference in sleep between the different window covers. Practical research could include the identification of the best blackout/environmentally friendly/durable fabric to use for the curtain material.

NEST Programmable Thermostats

High-level Cost Implications

The cost for providing a NEST thermostats for all 'beds' in Ponderosa would be approximately USD $278,000 (NEST Lab, 2012). According to NEST's website the money saved would mean payback period of less than two years (based on an energy bill of $2,200 per year). USD $277,884 may seem like a substantial cost over more conventional programmable thermostat cost to Ponderosa (USD $33,920-$80,352). NEST has a motion detector, provides feedback on how much energy the user has saved, and informs the user the impact of his/her behaviour. It is also connected to the internet and will inform the user about how the weather affects the user's heating/cooling choices. The features that NEST provides are unique and address the problems of programmable thermostats found in the literature (Karjalainen 2011, Gao & Whitehouse, 2010, Meier et al. 2011).

Environmental Impacts

A life cycle analysis would allow transparency on the overall environmental impacts of the NEST thermostat. However, like many products today, they do not have life cycle analysis, which requires further research. With an expected life span of at least of at least 25 years (for the electric base board heating) (Stantec, 2010) these energy savings could be substantial. However, it is unclear whether these energy savings is enough to offset the environmental impacts resulted from the manufacturing of (the NEST) programmable thermostats. There are facilities in the Vancouver area for the recycling of thermostats (City of Richmond, 2009).

Social Impacts

Studies have found that over 40% of programmable thermostats owners don't programme them (Koehler, Dey K., Mankoff, & Oakley, 2010). This seems to be mainly due to a lack of understanding and misconceptions about how heating systems work (Peffer, et al. 2011). One of the features of NEST is that it tells you the estimated time it will take to reach the new temperature. This should help stop people using thermostats like a 'valve' (Meier et al. 2011). People like to have control over the temperature of the environment and it is beneficial to their well-being when they do (Karjalainen, 2011). Although the NEST thermostat will start automatically adjusting itself after a week you can still change its settings if you wish. You can control it when away from home using a laptop or a smart phone so your home is the right temperature when you return. NEST helps you teach it sustainable behaviour by giving feedback as to whether your actions are 'green' by changing its display.

Academic Research Potential

It appears there have been no studies looking at how people use one particular type of programmable thermostat as would be the case in residence. In addition "…there have been few careful studies of the energy savings attributed to these [programmable] thermostats."(Meier et al, 2011). The NEST thermostat in particular provides research opportunities as it is a new product and a new concept. Occupants' use of this thermostat may potentially be very different than 'traditional' thermostats.

High-resolution Real-time Feedback Systems

High-level Cost implications

Based on Oberlin College's case, the installation cost per student is $109.27, which translates to a total estimated installation cost of $120,191.31 for both Phase 1 and Phase 2 of the Ponderosa hub (Appendix C). Oberlin College achieved a total 20% of monetary savings for combined utilities under a competition environment. (Petersen et al., 2007). Using 5% as a conservative estimate for maintainable savings, the payback period would be 8 years (Petersen et al., 2007).

Environmental Impacts

The two week competition period at Oberlin College saved 68,300kWH of electricity which translates to a reduction of 148,000lbs of CO_2, 1,360lbs of SO_2 and 520lbs of NO_x in emissions (Petersen et al., 2007). The electric power needed to run all parts of the feedback system was less than 600W by direct measurement (Petersen et al., 2007).

Social Impacts

In addition to the successful results achieved by Oberlin College, a literature review across various studies shows that feedback does lead to substantial reduction in energy consumption (Fischer, 2008). Students at Oberlin College have also expressed that they were "engaged by the accessibility of data and were inspired to think about their personal and collective resource use" and would intend to continue to adopt better energy conservation practices (Petersen et al., 2007). Both Fischer and Darby emphasize that an intrinsic or extrinsic motivation to conserve energy is necessary in order for feedback to be effective (Fischer, 2008; Darby, 2006). Although there is no significant evidence for post-study persistent behavioural change, a new type of behavior that lasts three-month or longer seems likely to persist (Darby, 2006); continued feedback would likely to facilitate this process.

Co-Benefits

The feedback system will provide opportunity for UBC faculties and students to participate and improve the system's design. The system will also provide solid infrastructure for energy rebate programs to increase incentives for energy conservation.

Academic Research Potential

Open-source and Application Program Interface (API) provides flexibility to expand data accessibility to other devices such as mobile handsets (Brewer et al., 2011) in the future.

Rationale for Exclusion of Option 4: Use of Power Strips with Universal Plugs

Academic Research Potential

While the design of the Universal Plug itself does not warrant further research, it is becoming increasingly imperative to look into more intuitive forms of reminders and prompts if energy-users are expected to be engaged into developing lifelong energy-efficient behaviours. And, the fact that a notable aspect of the design of the Universal Plug is that it intuitively reminds users to yank out the plug after use makes it a stepping stone for future designers and researchers looking into inducing positive behavioural changes among energy users. In terms of its research potential, the Universal Plug acts as a precedent to research into more intuitive forms of prompts and reminders that encourage best-practice behaviour among users. However, this type of research is more suitable for private designers and does not fall within the scope of research conducted by academic institutions like UBC. Having said that, phantom plug load is an issue that needs to be addressed as it consumes energy without benefit to anyone. Thus, research into reducing phantom load is called for.

Challenges and Implicated Stakeholders

However, foreseeable challenges come in the form of resistance from incumbent electrical equipment manufacturers to incorporate the Universal Plug into their existing designs of power strips. As they are one of the most important stakeholders in the implementation of this recommendation, attaining their support is critical. Alternatively, the challenge may be overcome by seeking small-scale, local manufacturers who may be more receptive to incorporating new design ideas. Another important barrier to the adoption of the Universal Plug was the lack of adequate precedents to verify and validate its reliability and scalability. On the whole, the uncertainties involved in the implementation of this option and the administrative costs involved in the provision and the re-collection of the power strips made this option less desirable compared to the other option. Thus, it was not recommended as an ideal demand-side management strategy to be used for the Ponderosa Commons.

Discussion

While the three options of fabric curtains**,** high-resolution real-time feedback systems and programmable thermostats are recommended on the basis of their potential social and environmental benefits, cost implications and future research potential, there are some challenges associated with them.

Fabric Curtains

Possible concerns with curtains include claims that curtains could pose as a fire hazard if positioned over heaters in the room – which they should not if installed correctly with the right length and material. Implicated stakeholders could include, but are not limited to, UBC students, Student Housing and Hospitality Services, the contractor for the provision and maintenance of the curtains, and the manufacturers of the curtains themselves. These stakeholders would need to be actively engaged in order to ensure the successful implementation of the proposed option.

NEST Programmable Thermostat

As NEST is a relatively new technology there has not been any independent and reliable research done on it to validate its performance claims. It is important to consider the incentives of different stakeholders, that is, who consumes the energy and who pays the bills. People who pay for their heating are 13% more likely to turn down their thermostats than those who don't pay (Gillinghamy, Harding, & Rapso, 2012). In campus residence where energy bills are included in the rent, students may not see an incentive to reduce energy use. A reward scheme can effectively address this issue. The design and aesthetics can make a significant difference in the usability and therefore use of a product (Tractinsky et al. 2000 as cited in Karjalainen, 2011). NEST has been designed to blend into any wall "chameleon design" and be user friendly.

High-resolution Real-time Feedback System

The poor performance of this option under the economic feasibility criteria indeed undermines the recommendation's rationale. However, given that Ponderosa Commons will have separate metering for each suite and for each floor, the meter installation cost is already a sunk cost. The incremental cost of installing sensors, a server, and software should not be as significant. In this case, the academic research potential of this option may very likely outweigh the cost. It will also provide a solid infrastructure for future energy incentive programs.

UBC Plant Operations will need to devote extra resources into both software and hardware maintenance. For example, providing high-resolution feedback on a per suite basis requires separate meters to be installed, which will increase workload on UBC Plant Ops staff.

Appendices

Appendix A

Direct feedback: available on demand. Learning by looking or paying.

- Self-meter-reading
- Direct displays
- Interactive feedback via a PC
- Pay-as-you-go/keypad meters
- ‘Ambient’ devices
- Meter reading with an adviser, as part of energy advice
- Cost plugs or similar devices on appliances

Indirect feedback – raw data processed by the utility and sent out to customers.

- Learning by reading and reflecting
- More frequent bills
- Frequent bills based on readings plus historical feedback
- Frequent bills based on readings plus comparative/normative feedback
- Frequent bills plus disaggregated feedback.
- Frequent bills plus detailed annual or quarterly energy reports.
- Inadvertent feedback – learning by association
- With the advent of microgeneration, the home becomes a site for generation as well as consumption of power.
- Community energy conservation projects such as the Dutch ‘Eco-teams’.

(Darby, 2006)

Appendix B

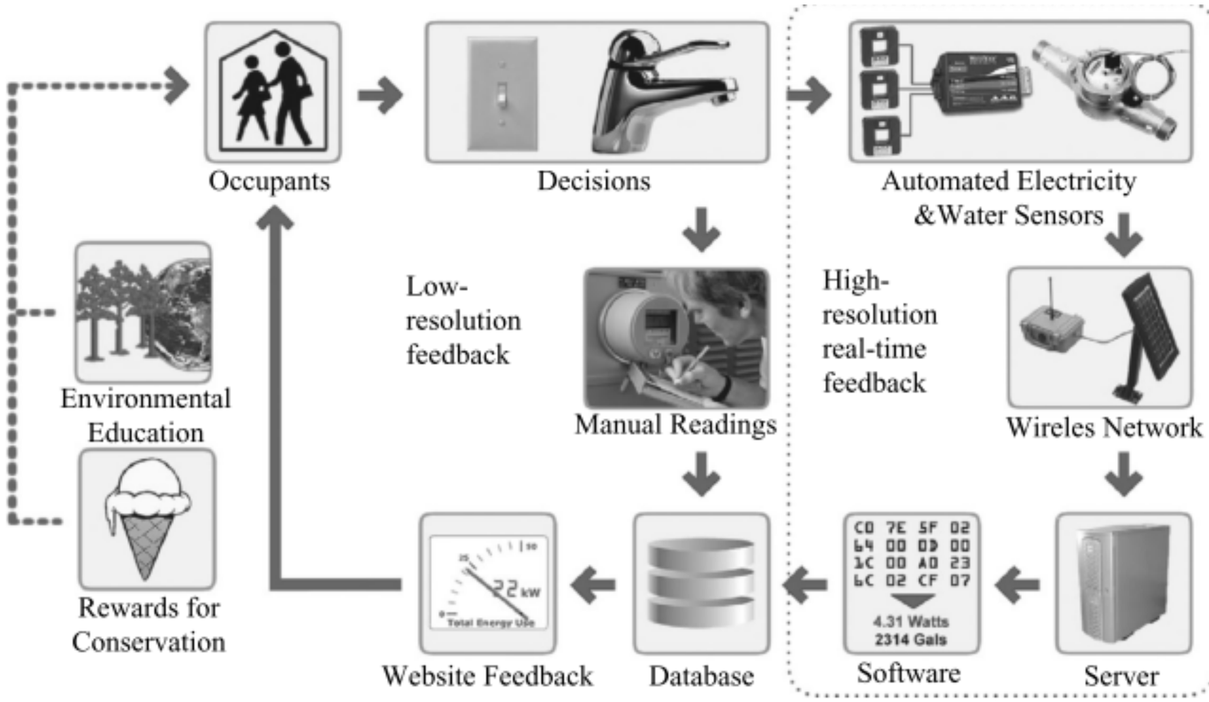

Figure 1 High-resolution Feedback versus low-resolution feedback at Oberlin College (Petersen et al., 2007)

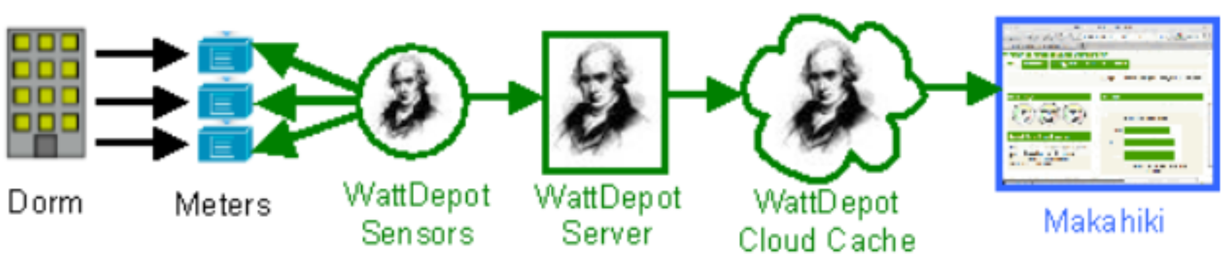

Figure 2 Feedback System Design at University of Hawaii Manoa Campus (Brewer et al., 2011)

“Dorm energy usage is captured by one or more meters, which are queried by WattDepot sensors and the raw data sent to the WattDepot server. Analyses are computed and stored in cloud-based services for ease of retrieval and display in the Makahiki web application” (Brewer et al., 2011).

Appendix C

The Universal Plug

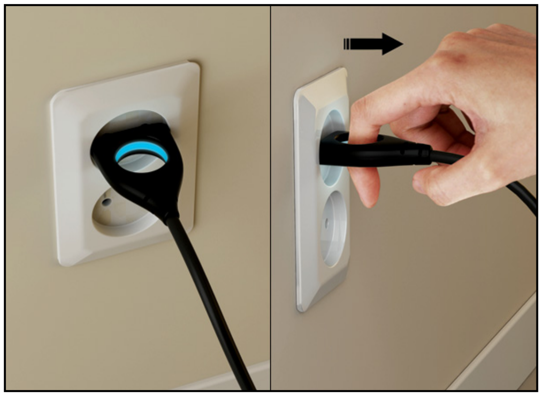

Figure 3 Universal Plug's circular cut-out that allows people to pull out the plugs

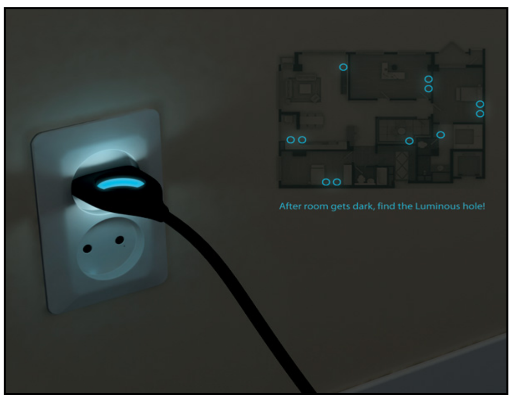

Figure 4 The plug also has a built-in reminder in the form of a glowing inner surface

Appendix D

Oberlin University					UBC		
Total Students[3]	*Total Dormitories*[4]	*Student per Dormitory*	*Installation Cost per Dormitory*[5]	*Installation Cost per student*	*Ponderosa Phase 1 (bed)*[6]	*Ponderosa Phase 2 (beds)*	*Estimated Total Installation Cost*
2288	25	91.52	$10,000	$109.27	577	523	$120,192.31

Table 5 High resolution feedback installation cost estimate

[3] http://www.parchment.com/c/college/college-959-Oberlin-College.html
[4] (Petersen et al., 2007)
[5] (Petersen et al., 2007)
[6] http://www.planning.ubc.ca/vancouver_home/consultations/current_projects/academic_lands/articles460.php

Appendix E

Category	Criteria	Indicator(s)	Option 1 - Curtains	Option 2 - Thermostat
Environmental	Energy Conservation	% reduction of electricity consumed by residential spaces in Ponderosa Commons	Not Enough Data	If manufacturing recommendations are followed, there is the potential to save 33% (Honeywell, 2012).
	Additional Material Input Required	Additional input and input material recyclability	Patent for recycling polyester (Oakley, 1993)	Thermostats can be recycled (City of Richmond, 2009).
Social	Occupant Engagement	Perceived positive change in energy literacy (awareness)	Survey Results	
		Perceived positive change in energy conservation behaviour (attitude)		
		Perceived positive change in energy conservation behaviour (action)		
		Passive or Active (2: Active; 1: Passive)	Passive	Active
	Comfort Level	Perceived level of comfort	Survey Results	
	Community Sustainability	Potential of setting up local business partnerships or sourcing from local supplier (3: High; 2: Possible; 1: Low)	Google search reveals several Canadian suppliers of Eclipse curtains	Ordering thermostats online is probably the most cost effective, which means bypassing any local supplier. Possibility of creating additional hours of employment for local electricians.
Economic	Research Potential (Educational and Economic Value)	Research Potential (3: Will advance university as an academic leader in this field; 2: Research connections exist or have a potential to be established, 1: No foreseeable research potential)	The basis of curtains being more energy saving in a university setting has been proven (otherwise they wouldn't be used), however research potential lies in developing more sustainable/cheaper curtains.	Extensive papers and studies already on programmable thermostats; most studies are for individual home owners and few are for university type residence. The context in UBC residence and sustainability will contribute to original research.
	Economic Feasibility	Cost of option	$14.99 x 1116 = CAD$16,728.84 (Amazon.com, 2012)	Nest USD $249 per thermostat (Nest Labs, 2012); other options USD $72-$120 per thermostat (Prothermostat.com,2008). Maximum USD $277,884 (Nest), USD $33,920-$80,352 (other options)
		Payback period	2.9 years (Petersen et al, 2007)	"Through proper use of pre-programmed settings, a programmable thermostat can save you about $180 every year in energy costs" (Energy Star, 2009). Plus additional labour costs for installation.
		% reduction in energy costs	29% - cost savings, comparing the curtains with blinds (Blinds.ca, 2012)	If manufacturing recommendations are followed there is the potential to save 33% (Honeywell, 2012). (Variable for thermostat type 15 - 33%)
	Technical Feasibility	Evidence of precedents at other institutions? Y/N	UBC, University of Manchester, University of Edinburgh	Google search reveals various studies on programmable thermostats. Examples: "Programmable thermostats as means of generating energy savings: some pros and cons" by André Pourde from the University fo Alberta (Plourde, 2003).
		Evidence of existing products (e.g. NEST thermostat) Y/N	Curtains are very easily available and widely used. Currently, the specific curtains in question are out of stock online, however with business ties this can be accommodated / remedied quickly	At the moment NEST is out of stock. However even when it is in stock it is only available in the US through purchasing with a US credit card. Other programmable thermostats are easily available in Vancouver.

Table 6 Indicators matrix calculation for Option 1 and 2

Appendix F

Category	Criteria	Indicator(s)	Option 3 - High Resolution Feedback	Option 4 - Universal Plug
Environmental	Energy Conservation	% reduction of electricity consumed by residential spaces in Ponderosa Commons	Conservative estimate of 10% from precedents (Petersen et al., 2007)	Under the assumption that the use of the Universal Plug eliminates phantom load completely, energy savings of approximately 10% can be expected. Phantom loads account for 5-10% of residential electricity use. (Dawson et al., n.d.)
	Additional Material Input Required	Additional input and input material recyclability	Not enough information. Assumed % of recycle material to be low. Also, instead of one meter for the entire building, depending on if the feedback is per floor or per suite, many meters will need to be installed, which will consume more material.	Currently a design idea; recyclability unknown. Some manufacturers (e.g. BITS Limited) are known for accepting broken or spent power strips for recycling. BITS also focuses on reducing and reusing input material (Smart Plugs: A Buyer's Review, 2011).
Social	Occupant Engagement	Perceived positive change in energy literacy (awareness)	Survey Results	
		Perceived positive change in energy conservation behaviour (attitude)		
		Perceived positive change in energy conservation behaviour (action)		
		Passive or Active (2: Active; 1: Passive)	Active	Active
	Comfort Level	Perceived level of comfort	Survey Results	
	Community Sustainability	Potential of setting up local business partnerships or sourcing from local supplier (3: High; 2: Possible; 1: Low)	BC Hydro offers smart meters and feedback displays (BC Hydro, 2011)	The Assist Plug, installed on small kitchen appliances manufactured by Breville is similar to the Universal Plug in design (hollow cut-out in the plug and allows plug to be pulled out with minimal effort). However, manufacturers are mostly located in China. Unlikely that the Universal Plug can be made locally at the required scale and cost.
Economic	Research Potential (Educational and Economic Value)	Research Potential (3: Will advance university as an academic leader in this field; 2: Research connections exist or have a potential to be established, 1: No foreseeable research potential)	Many possible research projects such as extending feedback to mobile devices, developing intelligent feedback meters, and developing energy rebate schemes	Design of Universal Plug itself has little research potential. May add value to cognitive behaviour studies (for example, what kind of reminders and prompts are more effective at engaging energy-users into developing long-term energy conservation practices).
	Economic Feasibility	Cost of option	Estimated installation cost per student: $109.27 (see Appendix D for detailed calculation); $109.27 × Total Students in Ponderosa = $109.27 × 1100 beds = $120,192.31	A typical configuration of a power strip with the universal plug would cost approximately $30. If such a power strip is to be provided to each resident (UBC, 2011), the total costs may be expected to be 1116 × $30 = $33480
		Payback period	8 years (Petersen et al., 2007)	The power strips can be collected from occupants by UBC residence office at the end of each term, thus avoiding repurchase costs. The expected annual cost savings of eliminating standby power are $6975 (see cell below). Initial costs of purchasing these power strips are covered through cost savings from reduced energy wastage in 33480/6975 = 4.8 years. Taking into account, repair, replacement and maintenance costs, a conservative estimate of the payback period can be taken to be 6 years.

		% reduction in energy costs	5% - conservative estimate taken from precedent (Petersen et al., 2007)	Potential annual cost savings of up to $25 per household can be expected by reducing standby power (based on annual residential energy consumption per household in B.C). 1116 student beds are expected to be added in the Ponderosa Commons. Taking 4 beds to be using an equivalent amount of energy to a typical household, the potential annual cost savings are (1116/4) × 4 × $25 = $6975
	Technical Feasibility	Evidence of precedents at other institutions? Y/N	University of Hawaii (Petersen et al., 2007)	No such precedent at institutions
		Evidence of existing products (e.g. NEST thermostat) Y/N	WattDepot (Brewer et al., 2007)	The Assist Plug has received positive customer feedback and is now applied to Breville products worldwide (Clay, 2012).

Table 7 Indicators matrix calculation for Option 3 and 4

Appendix G

Survey

Have you ever lived in a university residence before (duration greater than two weeks)?

Yes/No

If you have answered yes to the previous question, please mark all the seasons during which you have stayed at the residence.

Spring (March - May)

Summer (June - July)

Autumn (September - November)

Winter (December - February)

Please rate each option regarding the following:

How will it affect your awareness for conserving energy?
(1: Significantly less aware; 5: Significantly more aware)

How will it affect your attitude towards energy conservation?
(1: Want to make an effort to waste energy; 5: Want to make an effort to conserve energy)

How likely do you think it will change your behaviour in the long-term with regards to energy conservation?
(1: Not at all likely to change my behaviour; 5: Very likely to change my behaviour)

Please rate how the energy conservation measure will affect your perceived comfort level?
(1: Significantly decrease my comfort level; 5: Significantly increase comfort level)

The survey results cannot be directly published due to lack of BREB approval. Please contact Marie at limarie90@gmail.com for more information, comments or questions.

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