FOSTERING SUSTAINED ENERGY BEHAVIOR CHANGE AND INCREASING ENERGY LITERACY IN A STUDENT HOUSING ENERGY CHALLENGE

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To Yuka: thanks for all the love, support, and patience you have shown me while I worked on my Ph.D. It is most deeply appreciated.

♡

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ABSTRACT

We designed the Kukui Cup challenge to foster energy conservation and increase energy literacy. Based on a review of the literature, the challenge combined a variety of elements into an overall game experience, including: real-time energy feedback, goals, commitments, competition, and prizes.

We designed a software system called Makahiki to provide the online portion of the Kukui Cup challenge. Energy use was monitored by smart meters installed on each floor of the Hale Aloha residence halls on the University of Hawaiʻi at Mānoa campus.

In October 2011, we ran the UH Kukui Cup challenge for the over 1000 residents of the Hale Aloha towers. To evaluate the Kukui Cup challenge, I conducted three experiments: challenge participation, energy literacy, and energy use.

Many residents participated in the challenge, as measured by points earned and actions completed through the challenge website. I measured the energy literacy of a random sample of Hale Aloha residents using an online energy literacy questionnaire administered before and after the challenge. I found that challenge participants' energy knowledge increased significantly compared to non-challenge participants. Positive self-reported energy behaviors increased after the challenge for both challenge participants and non-participants, leading to the possibility of passive participation by the non-challenge participants.

I found that energy use varied substantially between and within lounges over time. Variations in energy use over time complicated the selection of a baseline of energy use to compare the levels during and after the challenge. The best team reduced its energy use during the challenge by 16%. However, team energy conservation did not appear to correlate to participation in the challenge, and there was no evidence of sustained energy conservation after the challenge. The problems inherent in assessing energy conservation using a baseline call into question this common practice.

My research has generated several contributions, including: a demonstration of increased energy literacy as a result of the challenge, the discovery of fundamental problems with the use of baselines for assessing energy competitions, the creation of two open source software systems, and the creation of an energy literacy assessment instrument.

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CHAPTER 1
INTRODUCTION

In this dissertation, I describe the Kukui Cup research project, which explores how to use information technology to educate individuals about energy and foster sustained, positive changes in energy use behavior. To investigate our approach to energy education and sustained behavior change, we held the 2011 UH Kukui Cup: a student housing energy challenge held at the University of Hawaiʻi at Mānoa that combined education, game mechanics, real-time energy feedback, and incentives. In this chapter I explain the motivation for the research, briefly describe the system, and the contributions of this research project.

The Kukui Cup project is large and could not have been accomplished by one person. Research from the project is the subject of this Ph.D. dissertation, a Computer Science Master's thesis, and two additional Ph.D. dissertation proposals. The 2011 UH Kukui Cup team had ten members, and the planning and execution of the challenge required extensive collaboration with UH Mānoa Student Housing. Therefore, in this dissertation I use the word "we" to describe work or results that were obtained as part of the collaboration of the Kukui Cup team (of which I was a very active core member), and I use the word "I" for work that was mine alone.

1.1 Motivation

The economies of the industrialized nations of the world run on fossil fuels: oil, coal, and natural gas. The worldwide demand for energy is increasing as more countries industrialize. However, the use of fossil fuels for energy must be curtailed for a variety of reasons:

- Fossil fuels are a finite resource that will eventually run out. As supplies are drained, they will become increasingly expensive due to the costs of extraction [88].
- Many countries (such as the United States) use much more fossil fuel than they can extract from domestic sources, so they must rely on imported fuels. This dependence leads to *energy insecurity*.
- The extraction of fossil fuels can be very damaging to the environment, such as the practice of mountaintop removal to extract coal deposits.
- Burning fossil fuels results in serious environmental impacts including climate change [20] from greenhouse gas (GHG) emissions and other air pollution.

We must develop renewable energy sources that can replace the current fossil fuel sources. However, the switch to renewable energy can be eased by reducing energy use, which I discuss in the next section.

1.2 Energy Conservation

One way fossil fuel use can be decreased is by decreasing the total amount of energy consumed. Socolow and Pacala have proposed a plan for reducing global GHG emissions to acceptable levels through the implementation of a series of 'wedges', where each wedge represents a reduction of 25 billion tons of CO_2 emissions over 50 years [112]. One of the 15 wedges they proposed is to cut electricity use in homes, offices, and stores by 25%.

On a more local level, the state of Hawai'i has created the Hawaii Clean Energy Initiative, which seeks to reduce Hawai'i's fossil fuel use by 70% by 2030 through increasing the use local, renewable energy sources (for electricity and transportation fuel) to 40% of demand and reducing demand by 30% through efficiency and conservation [90].

Amory Lovins coined the term *negawatt* to refer to power that has been conserved, and therefore, does not need to be generated [66]. Negawatts can be 'generated' in two basic ways: by increasing the efficiency of devices that consume energy, and by changing people's behavior to reduce energy use.

Changing people's behavior with respect to energy holds significant promise in reducing energy use. Darby's survey of energy consumption research found that identical homes could differ in energy use by a factor of two or more [24]. Data from a military housing community on Oahu show energy usage for similar homes can differ by a factor of 4 [91].

There are other approaches to achieving energy conservation beyond behavior change. *Demand response* (DR) is a method of reducing electricity use during peak times through automated control of electricity-using devices such as appliances [25, 15]. For example, one possible DR program would allow a utility to turn off clothes dryers in participating homes during periods of peak demand in return for a monetary incentive. DR can also be used to shift electricity use from peak periods to off-peak periods through the use of timers for non-time-sensitive loads such as dishwashers. Reduction of peak load can eliminate the need for utilities to use less efficient "peaker" power plants, thereby reducing greenhouse gas emissions. Successful use of demand response can also reduce the need for additional non-renewable generation capacity, or make better use of renewable energy, which may be more available during off-peak periods (such as wind power at night).

Variable pricing for electricity represents another related method for encouraging energy conservation [53]. Most electricity consumers pay a fixed price per kilowatt-hour over the course of a billing period, which does not reflect the fact that electricity produced at peak periods costs much more to generate than electricity produced during off-peak periods. Variable pricing provides a way to make those cost differences visible to consumers, enabling them to potentially change their behavior, such as shifting use to off-peak periods, or forgoing some non-essential electricity use to save money.

While both demand response and variable pricing are promising methods for energy conservation, my research does not make use of them due to the particular setting I have chosen to explore:

university residence halls (see Section 1.4). Occupants of residence halls have no ability to make decisions about the type of appliances that DR typically targets, and they are usually not billed for the amount of electricity they use.

1.3 Energy Literacy

Energy literacy is the understanding of energy concepts necessary to make informed decisions on energy use at both individual and societal levels. Increasing energy conservation is difficult when people do not understand energy fundamentals, or how energy is used in their homes and workplaces. At the level of public policy, there will be many decisions that will need to be made about exactly what path we choose to reduce fossil fuel use.

Some examples of energy literacy are:

- Understanding the difference between power and energy (see Appendix B).
- Knowing that a microwave uses much more power than a refrigerator, but that the refrigerator will use much more energy over time.
- Knowing how electricity is generated in one's community.

There is a proposed renewable energy project in Hawaiʻi called "Big Wind" that would generate as much as 400 MW from wind farms covering substantial portions of two more rural islands (Molokaʻi and Lānaʻi) with excellent wind resources [73]. The power would be transmitted via a new undersea cable to Oahu, which has the majority of the state's population, but with inferior wind resources. There are advocates both for and against Big Wind. To make an informed decision one should understand how Oahu's electricity is generated now, and the characteristics and challenges of wind energy.

1.4 The 2011 UH Kukui Cup

To investigate ways to foster energy conservation through behavior change and increase energy literacy, we designed and implemented the Kukui Cup Challenge. The challenge is named after the kukui nut (also known as candlenut), which was burned by Native Hawaiians to provide light, making it an early form of stored energy in Hawaiʻi. The 2011 Kukui Cup took place in the Hale Aloha student residence halls on the University of Hawaiʻi at Mānoa campus. My dissertation is limited in scope to this inaugural 2011 UH Kukui Cup.

Energy competitions have become increasingly common on college and university campuses. In these competitions, buildings compete to see which residence hall can use the least energy over some period of time, often with prizes for the winning hall. Unfortunately, there is some evidence that participants engage in unsustainable behaviors (such as keeping hallway lights off at night) in order to win the competition, but return to previous behaviors after the competition is over [101]. In addition, most college competitions are intended primarily to raise awareness and conserve energy, not to conduct research on how best to achieve these goals.

The 2011 UH Kukui Cup took place over 3 weeks starting in October 2011 in four residence halls for first-year students on the UHM campus containing a total of approximately 1070 residents. Each residence hall is further broken into five pairs of floors, each of which share a common lounge area. These pairs of floors are referred to as *lounges*, and were the team unit in the challenge.

The Kukui Cup combines four important features in an effort to foster energy conservation and increase energy literacy:

- Near real-time feedback on energy use in each lounge. A variety of research has shown that energy feedback can be helpful in fostering energy conservation (see Section 2.1).
- Incentives in the form of prizes that can be won during the challenge both through merit and through chance.
- Educational activities and events designed to increase energy literacy, taking place both online and in the real world.
- A gameful design intended to engage participants and make the challenge fun and worthwhile.

There were two parallel competitions during the Kukui Cup: an energy competition where lounges competed to use the least electricity, and a point competition where individuals competed to earn the most points by taking actions mediated by the challenge website. To support the energy competition, we installed energy meters on each floor of each building, allowing us to record power and energy data every 15 seconds. The challenge website provided each participant with a personalized data such as his or her lounges's power usage in near-realtime, their lounge's cumulative energy usage for the challenge, and their lounge's ranking in the challenge.

The other major feature of the challenge website is to provide participants the ability to take a variety of educational actions to earn points. The actions are designed to either increase the energy literacy of the participant, or help reduce the energy consumption of the lounge, or both. The actions are divided into three different categories: activities, commitments, and events. Activities are one-time actions that are verified through the website, such as watching a short YouTube video about energy intuition and correctly answering a question about the content. Commitments are intentions to conserve energy in the future in ways that cannot be verified through the website, such as turning off the lights when leaving a room. Events are scheduled, real world gatherings intended to increase energy literacy, such as a tour of a wind farm.

Associated with each action is a number of points. When a participant performs an action, such as determining the amount of power each device in their room consumes, they can submit information on the website verifying their completion of the action. In the case of the power audit, the information might be the list of devices in their room and the power consumption of each device. Once a website administrator verifies the information, the participant is awarded the points assigned to the completed action.

1.5 Research Questions

The research questions that I have investigated are:

1. *To what extent did residents participate in the challenge?* I ask this question because without significant participation in the challenge, there would be insufficient data to answer the rest of the questions.

2. *How did energy literacy change after the challenge?* We designed the challenge to increase the energy literacy of participants, so this question assesses one aspect of the challenge's effectiveness.

3. *How did energy use change during the challenge?* A standard measure for energy competitions, the expected result is that energy is conserved during the competition.

4. *How did energy use change after the challenge?* Understanding changes in energy use after the challenge is over gives insight into whether changes during the challenge were sustainable. Existing research focuses primarily on the challenge itself, not examining the reasons why energy usage might rebound after the challenge is over.

5. *What is the relationship between energy literacy and energy usage?* I hypothesize that more energy literate participants will conserve more energy; therefore, I examined the relationship both during the challenge and afterwards.

6. *How effective were the* actions *available via the website?* Are the actions that players complete during the challenge effective at improving energy literacy?

7. *How appropriate were the point values assigned to actions?* The points assigned to actions are intended to motivate participants to perform the actions, but the values were assigned without any participant data.

8. *How important was lounge-level near-realtime feedback?* There are good reasons to believe that lounge-level near-realtime feedback will lead to increased energy conservation, but they also greatly increase the challenge budget and logistical complexity. Is the trade-off worth it?

1.6 Contributions

My research has generated the following contributions:

- The design of the Kukui Cup serious game experience
- A demonstration that participation in a Kukui Cup challenge can lead to improvements in energy literacy
- The discovery of serious problems inherent in using a baseline in assessing the effectiveness of an energy competition
- The open source WattDepot energy data management system, which can be used as a platform for research on energy
- The Makahiki sustainable serious game system, which can be used to conduct future Kukui Cup challenges (I was a major contributor to the requirements and design of Makahiki)
- A library of actions, tailored to Hawai‘i, related to energy and sustainability
- An instrument for assessing energy literacy, tailored for Hawai‘i
- A smart meter infrastructure in the Hale Aloha residence halls, allowing future Kukui Cup research at UHM

A detailed description of the contributions can be found in Section 6.2.

1.7 Outline

This dissertation is organized into the following chapters:

- Chapter 2 looks at related research, including student housing energy competitions, energy feedback, and psychological techniques for fostering behavior change.
- Chapter 3 describes all aspects of the 2011 Kukui Cup, including the challenge, the energy data collection, and the challenge web application.
- Chapter 4 lists my research questions and explains how I have evaluated them through three experiments: challenge participation, energy literacy, and energy use.
- Chapter 5 describes the results from the research design in Chapter 4.
- Chapter 6 concludes with a list of the contributions of this research and future directions.

- Appendix A is a list of publications that have come out of the Kukui Cup project that I have authored or co-authored.
- Appendix B covers the definitions of power and energy, and their interrelationship. Understanding these two concepts is critical to understanding the evaluation of energy use and an important part of energy literacy.
- Appendix C lists the set of actions made available to participants through the challenge website to improve their energy literacy.
- Appendix D provides the Hawai‘i-specific questionnaire designed to assess the energy literacy of participants.
- Appendix E contains the questionnaire made available to participants during the final week of the challenge.

CHAPTER 2
RELATED WORK

This chapter examines prior research on changing behavior through information technology and related systems. First I cover research in energy feedback, which forms the foundation for participants understanding of their energy use, followed by a description of the practical methods of recording electricity data. Next, I cover research into motivations for pro-environmental behavior, and techniques that have been demonstrated to foster that behavior. The Kukui Cup uses these techniques to build a persuasive game experience for participants, and the following sections cover the design of environmentally persuasive systems, and game design. An important goal of the Kukui Cup pedagogy is to increase the energy literacy of participants; therefore, the topic of energy literacy is covered next. The final two sections review systems related to the Kukui Cup, and research on dorm energy competitions.

2.1 Energy Feedback

As Lord Kelvin is famously reputed to have said, "If you can not measure it, you can not improve it." In the case of electricity usage, the only feedback most people receive is a monthly bill detailing the number of kilowatt-hours used over the course of the previous month. Ed Lu of Google analogizes this situation as if there were no prices items at the grocery store, and shoppers were just mailed a bill at the end of the month [54]. Office workers or dormitory residents might never see any feedback on how much electricity they are using!

Feedback systems display the consumption of a resource (such as electricity) to the user, usually in real time. Darby provides a detailed survey of studies on electricity feedback systems from the past 3 decades [24]. The survey of 20 studies finds that, on average, the introduction of a direct (real-time) feedback system leads to reductions of energy usage ranging from 5-15%. Feedback systems providing historical data (such as those provided with billing statements) are not as effective (0-10% reductions), but can be useful for assessing the impact of efficiency measures such as improved insulation or a more energy efficient appliance, since those savings accumulate over time.

Darby found that "consumption in identical homes, even those designed to be low-energy dwellings, can easily differ by a factor of two or more depending on the behaviour of the inhabitants." This finding demonstrates the significant potential to curb energy usage through changes in individual's behavior.

Another survey of energy feedback was conducted Faruqui et al., which looked at 12 utility pilot programs that installed in-home displays with near-realtime feedback [41]. They found that customers that actively used the display averaged a 7% reduction in energy usage, while those pilot programs that included pre-paid electrical services reduced their energy usage by 14%. The sustainability of the energy reduction is unclear based on the pilot studies since they were of limited length.

The authors believe it is unknown whether the residents of homes with displays will acclimate to the display and cease to use it to reduce their energy usage.

Foster and Mazur-Stommen surveyed nine large-scale, real-time feedback pilot studies conducted recently in the US, UK, and Ireland [42]. Energy savings in the studies ranged from 0–19.5%. The 19.5% savings occurred in a multi-year study in Northern Ireland that combined real-time feedback with pre-payment of electrical service. The addition of pre-payment (which is uncommon in other areas) is likely the factor that increased the conservation. The average energy savings was 3.8% (excluding the Northern Ireland pilot), with two studies finding no aggregate effect of real-time feedback. Some studies found that certain households saved up to 25%, and Foster and Mazur-Stommen refer to these as "cybernetically sensitive" households. They postulate that these cybernetically sensitive households are particularly motivated by feedback in energy use. These households appear to cut across demographic lines, so identifying them in advance will require further research. The persistence of savings across the pilots was mixed. Some pilots found that electricity savings increased over time, possibly due to learning about energy consumption habits. Those pilots that tested persistence found that some savings persisted after the pilot, except for one that returned to zero after four weeks. The persistent savings fell from higher initial savings over time. Foster and Mazur-Stommen identify five factors that can affect energy savings from real-time feedback:

- "a 'sensitivity' towards real-time energy consumption feedback;
- the design of and content provided by feedback devices, and the degree to which these facilitate the tasks that consumers want to accomplish through feedback;
- the installation process and reliability of feedback devices;
- engagement with feedback, which is both confounded and encouraged by dynamics within the household; and
- the degree to which learning and habit formation take place."

They found that the infrastructure overhead of obtaining real-time feedback (meter cost, installation) was high compared to other energy conservation techniques, though it would likely go down as more households are served. From a utility perspective, it might not be a good investment outside of the cyber-sensitive households. They also point out that research on the means by which energy is conserved in the household is still very limited, and suggest ethnographic research methods might be helpful in this regard.

Darby also points out that while feedback is critical for energy conservation behaviors, feedback alone is not always enough [23]. Other factors that lead to higher rates of energy conservation include contact with an advisor when needed, and training and social infrastructure.

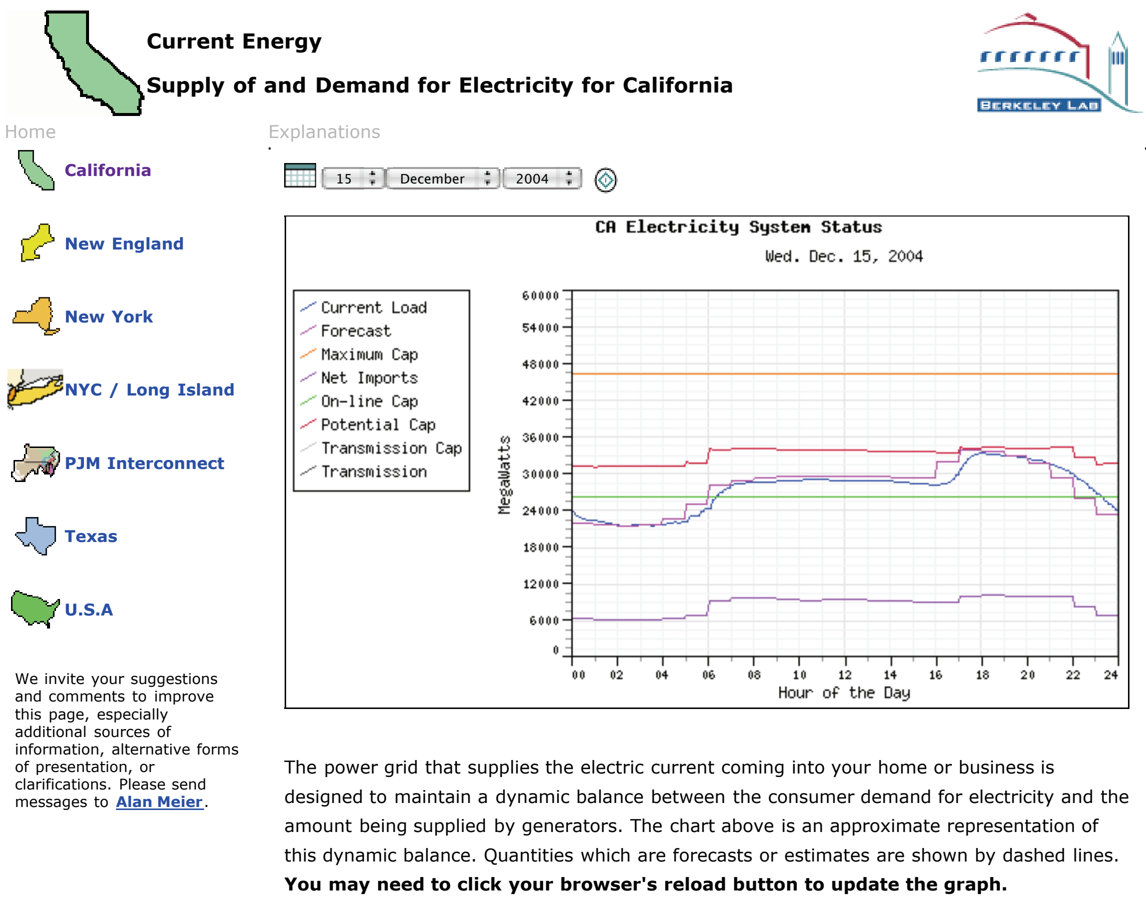


Figure 2.1: View of LBNL's Current Energy Web Site on December 15, 2004

During California's energy crisis in 2000 and 2001, Lawrence Berkeley National Laboratory created a web site that graphed data from utility organizations [4]. The graphs showed consumer demand for electricity (actual and forecast), and the utilities' generation capacity (see Figure 2.1 for an example graph). Darby reports anecdotal evidence that people viewing the graphs changed their electricity usage based on the data [24].

Ecotricity, a renewable energy utility in the UK, has developed a grid-level feedback system. The Ecotricity website provides a real-time dashboard that displays the types of energy sources used to power the UK grid (fossil fuels, nuclear, and renewable) and the overall carbon intensity of the grid in gCO_2 per kWh as shown in Figure 2.2. The carbon intensity display is made actionable through a traffic light visualization that is green when the grid is emitting less carbon and red when it emits more carbon.

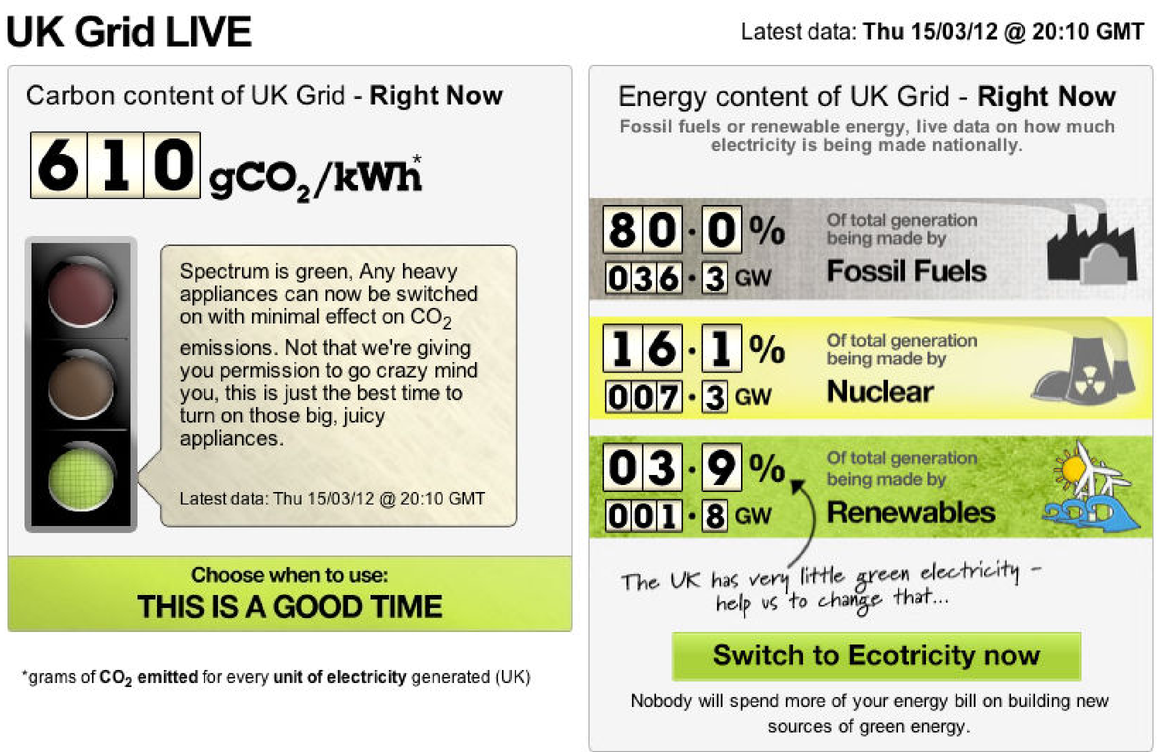
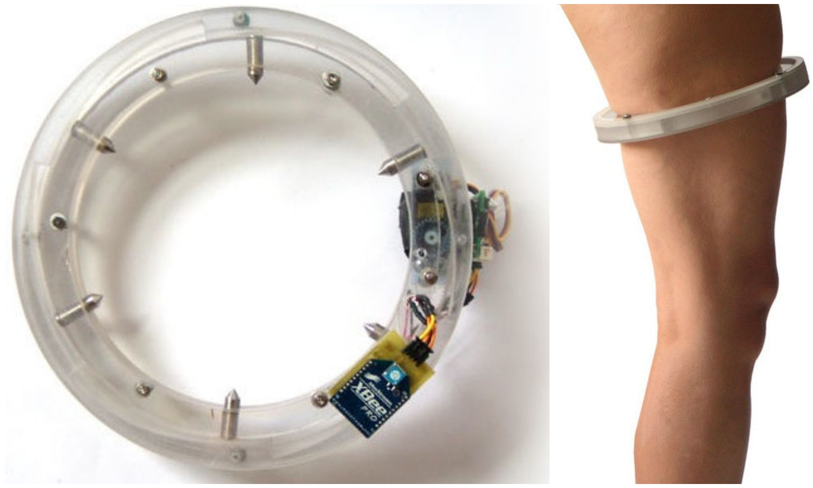


Figure 2.2: Ecotricity's live UK Grid dashboard

There is also evidence that just the knowledge that one is being monitored can cause one to consume fewer resources. A group of researchers simulating a mission to Mars or the Moon in the Canadian Arctic for four months tracked the crew members' water usage [3]. Water usage was monitored via automated meters during the entire mission, but during certain multi-day study periods, crew members were also required to manually log their water usage at the point of use. The authors found that water usage was 10% less during these study periods. The reduced water usage could be due to the knowledge that the usage was being examined more closely, or perhaps the extra effort required to manually record their water usage led to crew members reducing non-essential water use (see Section 2.12.4 for another possible benefit to manual data collection).



(a) Device itself (b) As worn on leg

Figure 2.3: Thighmaster energy feedback mortification device

Rüst has implemented an extreme energy feedback system called the Thighmaster [108]. Inspired by the cilice (a small metal garter with inward facing spikes) worn by some members of the Catholic Opus Dei organization as part of a practice of mortification, the Thighmaster is a "techno-garter" that pokes the wearer with spikes when their actions are not environmentally responsible (as defined by Rüst), see Figure 2.3 for a depiction of the device. Specifically, the Thighmaster communicates wirelessly with electricity usage sensors and a human speech sensor that monitors whether the user speaks with their house plants. While more of a demonstration, the Thighmaster shows the complex emotions involved in people's reactions to climate change. It goes without saying that being pierced by spikes is unlikely to be a viable energy feedback mechanism for most users.

A meta issue for all energy feedback systems is how to ensure that they continue to be "sticky" for users, as a feedback system that users do not look at will be unable to accomplish anything. There are indications that the long-term impact of eco-feedback may be diminished due to habituation. Froehlich suggests that the average user will spend less than one minute per day exploring their energy consumption behaviors [45]. A study by Houde et al. of households using Google PowerMeter found an "immediate decrease in electricity consumption, but in the long term these electricity savings decrease and disappear." [57] This finding suggests that a primary concern for any energy feedback system is ensuring that users continue to interact with it over the long term. Put another way, feedback alone is not enough to accomplish the goals that most feedback systems hope to achieve. One solution to the lack of stickiness of feedback systems is the incorporation of game play. Serious games like the Kukui Cup provide an alternative route to promote both learning and engagement with energy feedback.

Energy feedback was a core element of the Kukui Cup system. Feedback provides awareness of energy use that participants in student housing have likely never experienced before, and provides verification to participants that behavior changes can change energy use. Many studies have shown that providing energy feedback leads to some degree of energy conservation; therefore, feedback is another useful component in the Kukui Cup system. However, feedback alone is not necessarily successful, as shown by the two studies that resulted in 0% energy reduction [42]. Energy data needed to provide feedback to participants are also necessary for both the scoring of the energy competition and as one means of evaluating the impact of the system.

2.2 Energy Baselines

When using energy feedback, goals (Section 2.5.2), and competition (Section 2.4), the concept of a *baseline* can be useful. A baseline is some representation of past energy use. For example, a baseline could be computed by averaging the previous two weeks of electricity use by a residence hall, expressed in kilowatt-hours. Another common way to compute a baseline for a particular period of time, such as the month of January, is to average the energy use for that period in previous years.

Once computed (by whatever means), baselines can be used in several ways. A common problem in energy competitions among buildings is that they are different sizes and have different energy use profiles. The differences between buildings make absolute energy use for each building a poor metric for the competition. The most common solution to this problem is to compute a baseline for each building, and then rank buildings based on how much their energy consumption during the competition has changed as a percentage of the baseline. This normalization by the baseline makes it possible for large buildings to compete against small buildings, or older buildings to compete against newer buildings.

Baselines are also commonly used when setting an energy conservation goal. An appropriate energy conservation goal can be computed by picking a conservation percentage (like 5%) and subtracting the percentage from the baseline. Picking the conservation goal using a baseline ensures that the goal is at least related to past energy use.

A different way of using baselines is as a way to measure the effectiveness of energy behavior change interventions. In this case, the baseline is used as a predictor of future energy use in the absence of the intervention. The assumption being made is that energy would continue to be used at the baseline rate if it were not for the intervention. Researchers using the baseline as a predictor often make claims about the effectiveness of their intervention: if energy use during the intervention was less than the baseline, then the intervention was successful. When energy use is lower during the intervention, the difference between the baseline and the actual energy used is often claimed to be energy “saved” due to the intervention.

Ranking teams in a competition, or setting appropriate energy conservation goals can be thought of as game elements or mechanics. Using baselines as part of a game is distinct from the use of baselines as a means of evaluating interventions [62]. The Kukui Cup uses baselines in both those ways, and as I will show later, the baselines used were actually computed in different ways depending on how they were used.

2.3 Electricity Metering

Electricity metering systems can be broken down into two types: plug load meters that measure the electrical load directly plugged into them, and panel energy meters that measure the electrical usage of an entire distribution panel (which might cover an entire small building, or a floor of a larger building). Both typically provide a real-time display of electricity usage, and some sort of historical total (usually in kilowatt hours).

2.3.1 Plug Load Meters

The Kill-A-Watt is an example of an inexpensive plug load meter [93]. It is designed to be plugged into a wall outlet, and the load is then plugged into the Kill-A-Watt. An LCD display shows the current voltage, current, power, frequency, power factor, and cumulative energy used since the unit was plugged in. The Kill-A-Watt provides an easy way to determine how much electricity a particular appliance (or set of appliances if connected via a power strip) uses. The manufacturer claims the Kill-A-Watt is accurate to within 0.2%. There are several drawbacks to the Kill-A-Watt. Because of its shape, it generally obscures both of the outlets commonly found on a wall outlet in the US, preventing the second outlet from being use while measurement is taking place. The load must be plugged in via the Kill-A-Watt, so that means that the user must disconnect the load from power at least momentarily, which can be inconvenient for some loads (e.g., computers, refrigerators). The Kill-A-Watt also has no facility for exporting the data it collects. Further, if power is lost for any reason, the data collected will be lost as well.

LeBlanc attempted to address the issue of data collection with his work on recording device-level power consumption [69]. He developed a sensor that sits between the load and the wall outlet, like the Kill-A-Watt. The sensor records electricity usage, and transmits the data wirelessly using the ZigBee protocol to a base station. Details on how to construct the wireless power monitor can be found at the author's personal website [70]. This system solves the problem of automated data collection, but still requires the load to be unplugged before monitoring. It also faces the problem of all plug-load meters, which is that it can only monitor what it is connected to; therefore it is unsuitable for providing a comprehensive picture of electricity usage in a building or floor.

2.3.2 Panel Meters

The Energy Detective TED Model 5000 is a panel electricity meter from Energy, Inc [38]. TED consists of three components:

- a Measuring Transmitting Unit (MTU), which is connected directly to the incoming power lines at the circuit breaker box
- a Gateway that receives data from the MTU through the electrical wiring of the home, stores it, and makes the data available via HTTP using an Ethernet connection
- a handheld, wireless display unit that provides a continuously updated display of power usage sent via the Zigbee protocol from the Gateway.

The MTU uses current transformers, which clamp over the incoming power cables, and measure the amount of current being transmitted over them. Because the transformers clamp over the existing cables, there is no need to alter the existing wiring. The instantaneous power consumption can be computed using the current data combined with the utility voltage. These data are transmitted to the display unit through the building's electrical wiring.

The display unit receives the instant power consumption data from the Gateway unit every few seconds. The power consumption data can be displayed in real time in kilowatts or dollars (after the user enters pricing data). It can also track historical consumption, peak usage, and project usage for the rest of the month based on historical usage. The Gateway unit provides a detailed web interface to the power data for computers inside the home, and can be configured to upload data to Google PowerMeter (Section 2.12.6) every 15 minutes. Energy Inc. makes an XML API available for developers who wish to use the data directly. TED appears to be the lowest cost option for whole home electricity monitoring with data recording and Internet accessibility.

While panel energy meters provide only building-wide usage data, users can use the real-time display to figure out the impact of particular uses as air conditioning through trial and error experimentation. Parker et al. describe a protocol for using a household-wide meter and a circuit breaker panel to localize the energy usage in a home [95]. All the breakers are turned off, and then turned on one at a time while recording data from the electrical meter. In 2–4 hours, users were able to generate a spreadsheet mapping the electricity usage in their homes.

2.3.3 Building Energy Displays

Another type of electricity usage monitoring is building energy displays, which monitor electricity usage for an entire building (usually non-residential, such as a school or office building) and display the usage information in some public area such as a lobby. Green TouchScreen [103] and Building Dashboard [74] are examples of this type of product. These devices aim to make building occupants aware of the overall environmental impact of the building, which is something usually invisible to the occupants. Some systems make the displays available via the web so that users can view the information from their desk as well as the lobby. The displays often provide information beyond just electricity usage, such as water or natural gas usage, and may display the usage in units other than kWh, such as number of incandescent light bulbs lit or hours of TV watching. Beyond their potential utility in helping building occupants to reduce their energy usage, informative displays can be used to get points toward Leadership in Energy and Environmental Design (LEED) certification for a building.

2.3.4 Metering Summary

While plug load meters are helpful since they can provide power and energy data about a single device, using them for energy metering in the 2011 Kukui Cup is not appropriate for several reasons: it would require approximately 2800 meters to cover all in-room outlets, plug load meters cannot track overhead lighting use, they would be easy to circumvent to reduce reported energy use, and per-outlet energy data raise important privacy issues that would complicate the challenge. However, we did make use of plug load meters for the room energy audit activity, where participants used the meters to determine the power use of each devices in their room.

The Kukui Cup used panel meters installed on each floor of the residence halls for energy data collection (as will be discussed in Section 3.4.2). No building energy displays were deployed as part of the 2011 Kukui Cup, due to the cost of displays and the logistics of installing displays in a vandal and theft-proof manner.

2.4 Dormitory Energy Competitions

Residence hall energy competitions are events where residence halls or floors within a residence hall compete to see which building will use the least energy over a period of time. Some competitions pull in other aspects of environmental sustainability, e.g., reducing water usage, reduced waste production. The competitions tap into both the residents competitive urges, and the interest in environmental issues. However, unlike a home environment, the residents typically do not financially benefit from any reduction in electricity use resulting from their behavior changes, because residence hall fees are flat-rate and do not change based on energy usage. This billing model leads to residents being completely unaware of their energy usage, since they lack even a monthly bill as feedback. Dillahunt et al. describe a similar situation with their investigation of energy usage in low income communities, where individuals may not be billed directly for electricity and may not have the means to upgrade appliances [34]. Despite these differences, Dillahunt et al. found that the residents of low-income housing were still motivated to save energy and came up with diverse energy-saving solutions, which may suggest that dorm residents can be similarly motivated.

Energy competitions in residence halls have become a popular event at colleges and universities: in 2010, a survey by Hodge found 163 colleges that had held a dorm energy competition or planned to during the 2010–2011 academic year [56], with approximately 40% of schools running their first competition in 2008 or later.

The most basic type of energy competition website displays energy data which is updated manually on a periodic basis (such as weekly). The Wellesley College Green Cup [109] is an example of this type of competition. Lee provides a comparison of many different types of dorm energy competitions and the technology they use [72, pp. 6–11].

2.4.1 Oberlin College Energy Competition

Other schools have more complicated and interactive competition websites, such as the early adopter Oberlin College. Petersen et al. describe their experiences deploying a realtime feedback system for an Oberlin College dorm energy competition in 2005 [101, 98]. 22 dormitories were in competition over a two week period, with two dorms having feedback updates every 20 seconds, and the other 20 getting updates every week. The realtime dorms also recorded electricity usage for each of the three floors, but only displayed the data from two of the floors, leaving the third as a control. Web pages were used to provide feedback to students, because they all have computers and Internet access in their rooms. They found a 32% reduction in electricity use across all dormitories, with the two realtime feedback dorms reducing usage the most. Freshman dorms were among the highest electricity reducers, while upperclassman dormitories were quite low (average 2% reduction). During a two week post-competition period, the average electricity usage was similar to consumption levels during the competition. However, the weather was warmer and there was more sunlight during the post-competition period, so it is unclear if the reduction was competition-related.

In terms of participation, Petersen et al. found 46% of residents looked at the competition website at least once (based on web server logs mapping IP addresses to residence halls). 23% of dormitory residents filled out the online post-competition survey. Survey respondents indicated that some behaviors, such as turning off hallway lights at night and unplugging vending machines were not sustainable outside the competition period.

2.4.2 Campus Conservation Nationals

The Campus Conservation Nationals (CCN) is a series of energy and water use reduction competitions run in residence halls on college campuses in North America in 2010 and 2012 [75]. 40 schools participated in the 2010 pilot competition, with a claim of 508,000 kWh saved due to the competition. There are 150 schools participating in the 2012 competition (taking place between February 6 until April 23), with a goal of one gigawatt-hour of energy savings for all schools combined. Both the 2010 and 2012 competitions lasted three weeks. For the 2012 competition, each school could pick which three weeks to run the competition during the 11 week window [76]. Each school was allowed to decide what baseline values to use for each residence hall, with a suggestion to use the average energy and water consumption for the hall over the two weeks prior to the competition. The baselines are not normalized for changes in weather during the competition or between competing schools. The energy and water use data is manually input by each school at least once per week during the competition, but the organizers request that it not be input more frequently than once every two days. Each school can choose to compete in different ways: competitions among residence halls on a single campus, competitions among schools in a geographic region, and competitions among peer institutions. Each school is responsible for providing prizes to the residence hall that conserved the most energy and/or water, while the national sponsors provide prizes to the schools that reduce the most overall. There does not appear to be any measurement of energy or water use after the competition is over. However, there is a web questionnaire for students that schools can direct their participants to. The data from the student questionnaires was collected by researchers at Oberlin College for analysis.

2.4.3 Western Washington University Go for Green Challenge

Western Washington University held a Go for Green Challenge in 2008, described in a Masters thesis by Mauney [79]. The challenge took place in eight of sixteen on-campus residence halls, with the remaining eight halls serving as a comparison group. The competition took place over three months from January 8 to April 1, 2008. A survey of residents in advance of the competition showed low participation rates in residence hall activities: 80% reported that they do not participate at all in such activities. The goals of the challenge were to reduce electricity use by 10%, and increase energy awareness and participation by residents. Energy use was measured using building-level meters that were recorded once per month. Each of the residence halls had different construction and numbers of residents, so the energy use was compared to a baseline for each hall and normalized to kilowatt-hours per resident. Three monthly baselines were computed for the three months of the competition by averaging the number of kilowatt-hours used by the hall for that month in the previous three years (2005–2007). To encourage participation, the challenge each hall earned points by the actions of their residents. Each 1% energy reduction that a hall made from the baseline was worth 20 points, while each resident that made a green pledge, completed a survey, or attended a hall event earned one point for their hall. Prizes donated by local businesses were awarded to the halls that earned the most points. To organize and promote the challenge in each hall, leaders were recruited, including: Resident Advisors (RAs), Resident Directors (RDs), and EcoReps (residents recruited to help run the competition). The leaders were encouraged to take initiative in planning events and promoting the challenge; therefore, the experience of residents in each hall was different. The treatment halls where the challenge ran were not randomly selected: only halls that had EcoReps or involved RDs were selected, leading to a quasi-experimental design.

A survey was administered to residents of all participating halls before, midway through, and after the challenge, to assess attitudes towards conservation, behavior changes, and education. The survey had several sections:

- Classifying fellow hall residents as: conservers, efficient users, unaware, or overly consumptive
- Frequency of six self-reported behaviors around elevator use, turning off devices, and shower use
- Education question (did you learn something as result of challenge): yes or no

The responses between the different surveys were not matched up within participants, and the comparison halls were not surveyed.

Mauney found that treatment halls showed greater energy reduction compared to the baseline than comparison halls. However, seven of the eight comparison halls showed reduction in energy use during the GGC. Average energy reduction in treatment halls was 12.5%, and 6.1% for comparison halls. Since the baseline was computed using three years of historical data, some hall reductions were believed to be caused by renovations that improved the hall's energy efficiency, but other halls had no recent renovations.

The pre-challenge survey had a response rate of 18%, while the post-challenge survey had an 11% response rate. Mauney found that the survey response rate was significantly correlated with the percentage of hall residents that signed the green pledge. Reduction in energy use was significantly correlated with percentage of residents classified as conservers or efficient users. As expected, halls that had interior hallways with more chances for resident interaction reduced more than apartments with exterior hallways. There were small changes in reported behavior pre and post challenge, including more unplugging appliances and lower elevator usage.

In addition to the resident questionnaire, the challenge leaders (RAs, RDs, EcoReps) were surveyed about their experiences after the first month of the competition. Leaders were asked how they communicated about the challenge to residents, and what behavior changes they observed in their residents. The most common promotion strategies were posted materials, and verbal discussion including going door to door in the hall. The largest behavior change in residents noted by leaders was turning out lights when not in use.

Mauney concludes that having RAs or EcoReps in each hall is an important factor for success in the challenge: the best performing hall had an RD who made the challenge the main program focus during the challenge period. RDs also wished to see some of the money saved by the energy reduction returned to halls, but this is complicated by uncertainty in whether the reduction was due to behavior change or other factors.

The Go for Green Challenge has many similarities to the Kukui Cup: a point system to motivate participants, addition of energy education, and pre- and post-challenge surveys of participants.

However, it had several shortcomings: no individual points, monthly energy use feedback, limited program activities, no web interface, and a problematic multi-year baseline calculation. The 2011 Kukui Cup addressed each of these issues.

2.4.4 University of Southern California Ecolympics

Sintov performed a study of the effectiveness of an energy competition in undergraduate dormitories at the University of Southern California [111]. The competition took place in seven buildings in the fall of 2009, and lasted for eight weeks. Each building was exposed to a different set of interventions, including one control building that did not receive any intervention. All intervention buildings received appeals (requests) to reduce energy use, delivered by email and posters in the dorms. The intervention dorms also competed to receive a building-wide pizza party as a group-level incentive, which was awarded to the building that reduced its energy use the most.

A study website provided additional intervention content, including informational modules, real-time energy feedback, and an self-determined energy goal. Each intervention building was provided a different combination of the three additional online interventions. Unfortunately, of the 1,693 residents in the buildings offered the online treatment, only six participants (0.4%) registered to access the study website, so no analysis could be done on the effectiveness of the website interventions.

To analyze the energy use of the buildings, a baseline for each building was computed by averaging the electricity use from the six weeks immediately preceding the competition. During the intervention period, the electricity use across all buildings declined by 0.8%, with the best building decreasing by 7.1% and the worst increasing by 3.1%. Multi-level mixed models that accounted for average temperature, year, and study phase indicated that the intervention buildings used more electricity during the competition than during other time periods.

Sintov also conducted pre- and post-competition surveys of residents regarding their self-reported behavior. Of the 187 survey participants used for analysis, 80 were from the intervention buildings, and 107 were not part of the competition. Sintov used a modified version of the Schultz Pro-Environmental Behavior Scale to measure pro-environmental behaviors (PEB) among participants. Sintov's analysis of the survey data found no significant change in self-reported PEB as a result of the interventions.

Based on the experiences from the competition, Sintov provides several recommendations for future research in dorm energy competitions. One of the biggest issues with the competition was the very small number of residents that actually used the study website, precluding any conclusions about the online interventions. Sintov suggests that studies maintain a physical presence in the dormitories to increase participation, as many residents are accustomed to face-to-face interaction with campus organizations. Sintov also recommends obtaining early buy-in from stakeholders such as resident advisors. Results from a focus group indicated that residents did not identify strongly with their dorm, which may have rendered the group-level incentives ineffective. Survey and focus group participants received individual incentives in the form of money or class credit, which was reported as more motivating. Regarding analysis of building energy use, Sintov suggests using historical energy data to select optimal project dates to avoid a study period where energy use is expected to increase during the challenge.

The USC energy competition is similar to the Kukui Cup in several ways: pre- and post-competition surveys on behavior, energy feedback for participants, a website with intervention content, and group-level incentives for winning teams. However, its biggest shortcoming was the lack of participation in the website, which would be catastrophic for the Kukui Cup.

2.4.5 Dorm Energy Competition Survey

Hodge's survey of dorm energy competitions found a wide range of energy conservation results from the competitions [56]. The median competing building reduced energy use by 9%, but the worst building increased usage by 12%. The median winning building reduced by 22%, but the worst winning building was 0% and the best was 80%! Hodge identifies five core components of dorm energy competitions:

1. Incentives, such as food, parties, and trophies;
2. Team-based competition instead of individual competition;
3. Short competitions lasting approximately one month;
4. Energy feedback, including ranking compared to other dorms; and
5. "Hype", such as dances and cafeteria meals lit by candlelight.

2.4.6 Dorm Energy Competition Summary

The Oberlin energy competitions, with their real-time energy feedback, were a major influence on the design of the 2011 Kukui Cup. The idea of metering floor-by-floor in the Kukui Cup, rather than building-by-building was intended to build more tightly-knit teams, and allow the effects of behavior change to be more apparent since the feedback would occur on a smaller scale. The WWU Go for Green Challenge has several similarities to the Kukui Cup. In both competitions, points could be earned as well as energy conserved, though in the Kukui Cup individuals could earn points and the energy competition was not directly linked to the point competition. The Go for Green challenge also used survey instruments before and after the competition, though participants were not matched across the surveys as they were in the Kukui Cup. Mauney's suggestion that involved RAs and EcoReps are important to the success of the competition is well-heeded, though we did encounter some difficulties in this area (see Section 5.8).

The Kukui Cup attempts to address the lack of website use encountered in the USC energy competition by making the challenge website an integral part of the challenge, and turning the competition into an overall game experience. The Kukui Cup also makes extensive use of individual incentives in addition to group incentives, which is made possible by the energy literacy aspect of the challenge, something that was not possible for the USC competition. The 2011 Kukui Cup incorporated each Hodge's five components for a successful energy competition.

2.5 Fostering Sustainable Behavior

A variety of methods have been employed in an attempt to get people to change their behavior to be environmentally sustainable; McKenzie-Mohr provides a good summary of the area in his online book [82]. One of the most common techniques is the information-based campaign, which relies on providing information to the public through advertisements and documents like pamphlets and brochures. One type of information campaign attempts to shape peoples' attitudes towards an environmental issue, in the hope that those new attitudes will lead to more sustainable behavior. Unfortunately, these campaigns are usually unsuccessful. For example, Geller performed an investigation of the impact of three hour workshops on energy conservation that included a survey before and after the workshop [50]. The results of the survey indicated that the workshop had increased the energy literacy of the attendees and they indicated a willingness to implement energy conservation in their homes. However, followup visits with a selected group of 40 of the attendees found that very few had actually taken action (e.g., insulating their water heater or installing low-flow showerheads that had been given out during the workshops).

The other type of information-based campaign is based on financial incentives. In energy, this would include a utility advertising the rapid return on investment from a solar hot water heater, or promotion of rebates for more efficient appliances. This approach is also problematic, since it assumes that people are purely rational when making financial decisions, when they are not. For example, in 1983 California utilities were spending "200 million dollars annually to promote energy conservation" but with very limited success [21].

To avoid the problems with information-based campaigns, McKenzie-Mohr has developed a process he calls Community-Based Social Marketing (CBSM) [82]. The process consists of several steps:

1. Identifying barriers to the desired behavior, and the benefits of the desired behavior to the individual;

2. Developing a strategy to overcome the barriers using behavior change tools;

3. Piloting the campaign on a small portion of the intended community, and making changes as needed; and

4. Evaluating the effectiveness of the campaign on fostering the desired behavior.

We focus here on the behavior change tools, which are critical to actually getting people to change their behavior: commitments, goals, and norms.

2.5.1 Commitments

Asking an individual to make a commitment has been shown to be an effective tool in changing behavior. In particular, an initial small, innocuous commitment can lead later to a larger commitment. For example, Freedman and Fraser conducted experiments in which participants were asked to perform a small task (such as signing a petition to keep California beautiful) and then later asked to perform a more onerous task (such as placing a large billboard on their lawn that said "Keep California Beautiful") [44]. They found that participants that committed to the small task were much more likely to agree to the second task. The authors call this the "foot-in-the-door" technique. One of the reasons this technique is believed to work is the desire by individuals for self-consistency.

Making commitments public can increase their effectiveness. Pallak et al. studied residents that were asked to make a commitment to conserve electricity and natural gas [94]. Some homes were asked to make a private commitment, while others were asked if their commitment could be publicized, though they were never actually published. Those who made commitments that they thought were public conserved more energy than the private committers, even one year later and after they were told that their names were not actually going to be publicized.

2.5.2 Goals

Goals can be thought of as commitments that can be objectively measured. Because measuring progress toward a goal is useful, goals are often paired with feedback (see Section 2.1). Becker investigated goal setting along with feedback of home electricity use [5]. Half of the participants were given a goal of reducing electricity use by 20% during the summer, the other half were given a goal of 2%. The participants given the higher goal conserved between 13%–15%, while the group with the smaller goal did no better than a control group. Van Houwelingen and van Raaij investigated use of natural gas in homes and compared daily feedback with monthly feedback and self reporting, with all groups having a conservation goal of 10% [120]. The group with daily feedback reduced their energy use by 12.3%, and some reduction continued in the year after the feedback device was removed from their home.

2.5.3 Norms

Social norms are one way in which people's behavior is influenced by the behavior of others. Cialdini et al. make the distinction between descriptive norms (the way things are) and injunctive norms (the way things ought to be) [17]. In a series of experiments on littering, they found that the behavior of confederates of the researchers significantly changed the participants' behavior. For example, participants that viewed a confederate littering were more likely to litter a handbill that had been placed on their car. Also, participants that viewed a confederate littering into a clean environment were less likely to litter than those that observed littering into an environment that already contained a lot of litter.

One problem with descriptive norms is that they can lead to 'boomerang effects' where the norm has the effect of decreasing the desired behavior. Schultz et al. investigated this issue in the context of home energy conservation [110]. 290 homes were divided into two groups: one that would receive a written descriptive norm regarding their energy usage, and one that would receive the descriptive norm plus an injunctive norm. The descriptive norm showed participants whether they were above or below the average energy usage in their neighborhood. The injunctive norm was simply a frowning or smiling emoticon based on whether the participant home was using more or less than the average consumption respectively. They found that homes that only received the descriptive norm led to energy conservation in homes above the average, but led to increased energy usage in homes below the average (the boomerang effect). However, those homes that also received the injunctive emoticon did not have a boomerang effect. Clearly injunctive norms are an important addition to any attempt to use comparative data to foster energy conservation.

Cultural norms can strongly influence what behaviors are non-negotiable. Strengers performed an ethnographic study of 10 households participating in a smart metering trial to examine how their comfort and cleanliness norms affected their energy savings [115]. Participants were provided with metering devices that displayed electricity and water usage, and greenhouse gas emissions in real time. The author was attempting to use feedback to change the participants societal norms for comfort and cleanliness. For example, until relatively recently, bathing weekly was the norm, but now bathing daily is considered normal behavior. Like many people, the participants did not understand the connection between the consumption data and their practices. Participants tended to increase conservation by changing technology (such as using compact florescent lamps (CFLs) instead of incandescent light bulbs), or by minor behavioral changes like "taking shorter showers, doing full loads of laundry".

Strengers states that people act the way they do (in matters of cleanliness and comfort) because "they believe society expects them to" and because many companies and organizations have a vested interest in keeping it that way. Therefore, just providing people information about their consumption is not enough, because individuals are constrained by infrastructures and social norms. She suggests increasing social interaction regarding the feedback system by making placement more prominent and encouraging discussion with household visitors, because people tend to conform to the expectations of their peers. However, it would seem that changing cultural norms is one of the hardest possible means for reducing consumption. It also feeds into many of the negative stereo-types of environmentalism: smelly people living in dark, cold homes. Despite the irrationality of some of these norms, effort may be better spent focusing on areas where the effort will meet less resistance.

2.6 Design of Environmentally Persuasive Systems

There is considerable research on the subject of designing environmentally persuasive systems. Woodruff et al. performed a qualitative study of individuals who are making a significant effort to be green, in an effort to inform future designs by documenting existing green practices and beliefs [123]. The participants were all involved in making their home more sustainable and energy efficient. The authors found that these environmentally inspired people have diverse affiliations. Traditional environmental activism, for example, isn't always central to their interests. 35 homes participated in the study, with 56 people in total. The participants were mostly "bright green environmentalists", that is environmentalists that believe that technology can make the world more sustainable, rather than believing that technology is the root of unsustainable behavior and should be abandoned. The authors divided the participants into three groups based on their motivations: "counterculture bio-centric activism; American frontier self-reliance and rugged independence; and trend-focused utopian optimism." The first group focused on stewardship of the earth, while the second group on frugality, do-it-yourself activities, and patriotism from getting off foreign oil. The third group was focused on trend-setting, and being "eco-chic".

The authors found that the participants were reflective about the positive environmental choices they made, often trying to improve their sustainability through playful analysis of the options, such as buying a product online versus buying it from a store. They found that participants eagerly assessed the performance of their homes, so that they could tune their houses for better energy savings. This assessment included extensive data collection, both manual and automatic. In making their homes more efficient, the participants would work on improving one area at a time, then move on to the next area. However, after living in a house for 1.5 years, their interest in data collection had waned, in part because their routines had been internalized. Participants also wanted to live by example and inspire others, such as by driving a hybrid car.

Based on the interviews, the authors found several implications for design. The participants tended to learn about sustainability in a depth-based manner (focusing on one area at a time) rather than in a breath-based manner. Many popular attempts to encourage environmentally responsible behavior involve short lists of relatively easy actions, which is contrary to how the participants sought information. The authors suggest that advice systems focus on the user's primary motivations in an in-depth manner rather than providing a list of easy actions. The participants found mentorship to be an important part of the learning process, so the authors suggest that systems match mentees with mentors that have already mastered the area of expertise being sought. The authors suggest that users be provided with ways to express their identity and share their green activities to others via social networks. The authors observed that many participants enjoyed the process of determining the most sustainable option among many choices. Woodruff et al., therefore, suggest providing users with modest mental puzzles that help users explore the outcomes of different actions rather than telling them the answer outright.

Darby's review of energy feedback studies yielded some suggestions for design of environmentally persuasive systems [24]. She observed that historical feedback of the user's energy consumption is more effective than feedback that compared usage to others, or feedback that compared usage to normative values. However, users did report finding pie charts of typical breakdowns of home energy use helpful, even though they were averages of all users rather than the user's own data. Although users reported that they liked to see comparative information, it didn't necessarily lead to energy conservation. In addition, if a user is shown comparative data that indicate that their usage is lower than their peers, it could lead to the user feeling less concerned about energy conservation.

Chetty et al. performed a qualitative study of the resource management processes of 15 households in an effort to help ubiquitous computing researchers design better resource feedback systems [16]. They found that participants were unaware of real-time resource consumption for both the entire home and individual appliances. The study examined the participants' usage of natural gas, electricity, and water. Thermostats were a problem for participants. They argued about how the thermostats should be set, and half of the homes with programmable thermostats hadn't actually programmed them. Some participants were in living situations where they paid a flat rate for their utilities, which led to a lack of motivation to conserve resources. Participants wanted real-time information on their resource usage, utility pricing (if there is peak load pricing), and also alerts if there is anomalous usage (such as a broken toilet using an excessive amount of water). The authors report that participants were also aware of potential privacy issues, such as being able to infer other's habits from their resource usage, and being able to detect the wasteful use of resources.

Based on their study, Chetty et al. provide some suggestions for future system designs. In the modern world, infrastructure is invisible: you don't have to know how much energy an appliance uses when you plug it in. Therefore, the authors suggest visualizations "that equate our resource usage with units of production, for example, buckets of water, bags of coal, stacks of wood, as well as a monetary amount." They point out that households are often made up of multiple people with different levels of interest in being green and different responsibilities (some may not have to pay the bills), so system design will have to reflect these differences. The authors also worry about the "green divide" in that lower income households might not be able to afford expensive equipment. They suggest the need to make sure devices supporting resource conservation are affordable to all.

One of the issues raised by Oberlin dormitory energy competitions is how to help residents sustain their interest in conservation principles and transfer their energy-saving behaviors once they leave the dormitory context [97]. The dormitory energy competition is clearly able to reduce energy consumption when students are living in the dorms, but without engagement in larger issues (at the institution, community, or global level) then their long-term behavior may not be environmentally positive.

Surveys by Froehlich et al. [47] and Pierce and Paulos [102], show that a substantial amount of the research in sustainable human-computer interaction (HCI) has revolved around work on electricity consumption feedback. There has also been criticism of the general thrust of this segment of sustainable HCI research. Froehlich et al. point out the lack of communication between HCI researchers and the field of environmental psychology, as well as the relative dearth of long-term field studies in HCI feedback research. Pierce and Paulos point out the general failure of sustainable HCI researchers to address emerging energy systems, such as the smart grid and demand response. Brynjarsdóttir et al. further critique the entire range of recent persuasive sustainability research as overly focusing on optimization of simple metrics and individual action to the detriment of the more complex reality of sustainability [12].

The recommendations from Froehlich et al. [47] match up well with our research. The Kukui Cup is grounded in the extensive work from the environmental psychology, popularized by the Community-Based Social Marketing (CBSM) process [82] including goal setting and public commitments. Froehlich et al. also point out that most eco-feedback systems focus on curtailment behaviors (such as turning off lights when leaving a room) at the expense of efficiency behaviors (such as installing more efficient light bulbs), despite evidence that efficiency behaviors might be much more effective. While a significant portion of the Kukui Cup focuses on curtailment behaviors, there are a number of activities that focus on efficiency behaviors such as replacing an incandescent light bulb with a compact fluorescent lamp, and exploring the relative efficiencies of different vehicles. Froehlich et al. also point towards learning as an important area for energy feedback research, and educational content is an essential part of the Kukui Cup experience.

One recommendation from Pierce and Paulos [102] is the use of "energy metadata" to tag energy with characteristics such as how it was produced. While the Kukui Cup does not provide any metadata, it is highly concerned with the issue of how energy is generated, with a significant portion of the educational content focused on how Hawaiʻi generates its energy. Both Pierce and Paulos and Brynjarsdóttir et al. suggest energy feedback or persuasive sustainability systems need to move beyond their current focus on the individual, and engage users on the complex and less easily measured aspects of sustainability such as community and political issues. The Kukui Cup attempts to take on this challenging issue through the creative, open-ended activities made available to players such as interviewing relevant policymakers, and providing points for attending events held by campus and community environmental organizations.

The 2011 Kukui Cup takes into account the research on environmentally persuasive systems in several ways. The design of the Smart Grid Game that contains the actions that participants can perform (see Section 3.7.2.3) allows participants to explore a topic in depth by selecting activities of increasing difficulty from the same subject column, following Woodruff et al.'s recommendation. To address the concerns raised by the Oberlin dormitory energy competitions about engagement in larger environmental issues, we developed activities and events intended to make participants aware of overarching environmental issues and encourage them to get involved in local environmental organizations. I chose not to follow Chetty et al.'s recommendation to visualize resource usage through units of production, as I feel that an intuitive understanding of a kilowatt-hour is an important part of energy literacy, which is an important goal of this research.

2.7 Games and Game Design

The Kukui Cup challenge consists of a number of smaller games, and as such draws on game design research. The Kukui Cup can be thought of as a *serious game*, which Zyda defines as "a mental contest, played with a computer in accordance with specific rules, that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" [126]. A serious game is a game that has a an educational goal as well as the goal of entertainment. Thus serious games involve pedagogy, though as Zyda notes, pedagogy must be subordinate to the entertainment goal. *Gamification* is another concept being used to describe the use of game mechanics in other contexts. Deterding et al. define gamification as "the use of game design elements in non-game contexts" [28]. Both serious games and gamification use games to further non-game objectives (such as education), the key distinction here is that gamification involves the use of game *elements* (such as scoreboards or badges) as opposed to fully formed games. Since the Kukui Cup is a game first and foremost, it is a serious game and not a educational system that has been "gamified".

Another class of game relevant to the Kukui Cup are *alternate reality games* (ARGs), which McGonigal defines as "games you play to get more out of your real life, as opposed to games you play to escape it" [81, p. 125]. The Kukui Cup's incorporation of real-world activities around energy conservation and energy literacy that earn participants credit (kilowatt-hours or points) in the game qualify it as an ARG. The "alternative" portion of the Kukui Cup involves requiring participants to examine their day-to-day behavior with respect to energy use, something that is novel to many participants.

Gee examined how learning takes place in the world of video games, and contrasted it with the way learning typically takes place in schools [49]. He points out that good games are both deep and complicated, but large numbers of players manage to learn how to play them. Through examination of a series of games, he develops 36 learning principles that are applicable both to game design and learning inside the classroom. One important distinction Gee makes is between *passive learning*, where learners are presented with facts without context, and *active learning*, where learners make active use of new facts and principles by putting them to use. Beyond active learning, he defines *critical learning* as thinking about the game (or other learning situation) at a meta level, and producing novel and unexpected results.

Gee's analysis provides useful ideas about how to make games easy to learn and challenging enough to be worth playing. However, Gee's examples are all from deep, immersive games produced by commercial game developers with large teams and budgets. Given the budget and personnel constraints of the Kukui Cup, many of the positive, in-depth aspects of game learning he describes are out of reach for the Kukui Cup. Gee also sidesteps the issue of how to make games that convey real-world "content" in an engaging manner. While it would be great if the Kukui Cup led players to improve their problem solving skills, an important part of learning goals of the Kukui Cup is to increase energy literacy.

In designing games around learning, Murphy brings together research on learning and principles of game design [87]. He proposes six laws of learning for games: motivation, feedback, practice, positive feelings, intensity, and choice/involvement. He describes seven principles of game design, and finds that they are quite similar to the laws of learning: flow, feedback, simplicity, engagement, choice/involvement, practice and fun. Koster goes as far as to say that "fun is just another word for learning" [67].

Serious games have been used to solve longstanding scientific problems. Khatib et al. describe the use of the protein folding game Foldit to predict the structure of the Mason-Pfizer monkey virus retroviral protease [64]. Foldit players are presented with a three-dimensional model of a protein, and asked to interactively manipulate it to find the model with the lowest energy ("folding" it) and thereby earning the highest score. A team of Foldit players was able to determine the structure of the M-PMV protein, which had eluded researchers for a decade.

McGonigal describes an energy-related alternative reality game called World Without Oil ([81], p. 302). In April 2007, approximately 2,000 players imagined what life would be like without oil, and posted their stories and thoughts via a variety of media including email, blog posts, photos and videos. The central website [36] provided an dashboard with daily updates. The game also encouraged players to try actually living as though oil was not available, and some players reported that after the game they found themselves acting in a more sustainable fashion.

2.8 Energy Literacy

Energy literacy is the understanding of energy concepts as they relate both on the individual level and on the national/global level. Solving the world energy crisis will require everyone to understand how energy is generated and consumed, so that they can make more informed choices in their lives and as informed citizens involved in their communities. Energy literacy is also needed at the individual level, since decisions about how to conserve energy require an understanding of how energy is used and what actions are most helpful for conservation.

Defining and assessing energy literacy are, therefore, key to any attempt to improve energy literacy. DeWaters and Powers of Clarkson University have developed an energy literacy survey instrument for middle and high school students [29, 30]. Guided by research on defining environmental and technological literacy, they define energy literacy as consisting of three components: knowledge, attitudes, and behaviors. An example of energy knowledge would be understanding that the kilowatt-hour is the basic measure of electrical energy. Energy attitudes refers to concepts such as the belief that we should make more use of renewable energy in our power grid. Energy behaviors refer to specific things that can be done to reduce energy use, such as turning off lights when leaving a room.

Their survey consists of one section for each of the components, the knowledge questions using a multiple choice format, and the attitude and behavior questions using a 5-point Likert-style scale from strongly agree to strongly disagree. DeWaters and Powers administered the instrument to 3708 middle and high school students in New York State [31]. DeWaters and Powers found that students are concerned about energy problems, with a mean attitude score of 73%, but that knowledge scores lagged far behind (42% correct). The behavior score fell in-between at 65%, but interestingly high school students scored lower than middle school students, suggesting that as students get older, they engage in fewer energy-conserving behaviors. Based on their findings, they make some recommendations, including: energy curricula be "hands on, inquiry based, experiential, engaging, and real-world problem solving . . . ", and using the campus as a "learning laboratory".

Southwell et al. conducted a nationwide survey of 816 adults on their understanding of energy [113]. Based on their belief that energy literacy is multifaceted, they measured three concepts: perceived understanding of energy, demonstrated energy knowledge, and the ability to interpret an energy bill. Respondents' perceived understanding of energy was high, with 79% believing that energy is a topic "people like me" can understand. However, Southwell et al. found that the average respondent answered fewer than 60% of the energy knowledge questions correctly. Their results suggest a gap between the perceived and actual energy knowledge. The authors recommend future research on whether these facets of energy literacy are predictors of energy use behavior. The specific 11-item energy knowledge instrument used in the survey was drawn from the DeWaters and Powers instrument, and is similarly problematic for use in Hawai'i.

Attari et al. conducted a national online survey of 505 people regarding perceptions of energy consumption and savings [1]. They found when respondents were asked what single thing they could do that conserve the most energy, most responded with curtailment actions rather than efficiency improvements, despite evidence that efficiency improvements are more effective at saving energy. When asked to compare the energy use of various appliances and the effect of various energy efficiency actions, respondents tended to slightly overestimate energy use by small appliances and dramatically underestimate energy use by large appliances. Respondents who scored above average for numeracy or the New Ecological Paradigm scale had more accurate perceptions. Surprisingly, respondents that self-reported positive environmental behaviors actually had less accurate perceptions. Understanding the relative energy consumption of different appliances and behaviors is an important aspect of energy literacy. In the Kukui Cup, we have created activities such as a video on energy intuition and events such as an energy scavenger hunt intended to increase participants' understanding in this area.

Earlier work on assessing energy literacy includes a survey of attitude, knowledge, and intentions by Geller [50] given to participants at energy conservation workshops in the wake of the energy crisis of the 1970s.

2.9 Motivation

In encouraging individuals to change their energy use behaviors, it is worthwhile to examine research on motivations for behavior. This section starts with a discussion on intrinsic versus extrinsic motivations, followed by an alternative multifaceted theory of motivation. Then I cover research on specific motivations for environmentally responsive behaviors, ending with a summary of motivation research as it applies to the Kukui Cup.

2.9.1 Intrinsic and Extrinsic Motivation

One area of research into human motivations characterizes motivations as either intrinsic or extrinsic: intrinsic motivations are those behaviors where the activity is its own reward, whereas extrinsic motivations are external rewards provided for a particular desired behavior. A great deal of research has been conducted on the relationship between these two types of motivation. One particular concern is over the possibility that provision of external rewards (extrinsic motivators) might reduce intrinsic motivation for tasks. For example, participants asked to draw pictures and then rewarded with money or candy might later be less likely to draw pictures in the absence of rewards, which is interpreted as a reduction in intrinsic motivation for drawing. This effect of extrinsic rewards reducing intrinsic motivation is termed *undermining*. There is debate in the research community as to whether undermining is a common effect, or uncommon and of little practical implication. Deci et al. performed a meta-analysis of 128 studies of extrinsic rewards on intrinsic motivation, and found pervasive evidence that extrinsic rewards did in fact reduce intrinsic motivation [27]. Cameron et al. performed a subsequent meta-analysis and found no effect or a positive effect of extrinsic rewards on intrinsic motivation in many cases [13]. Specifically, they found intrinsic motivation towards low-interest tasks (tasks considered boring) was improved by the measure of free choice intrinsic motivation (time spent on the tasks after rewards are removed) and unchanged in self-reported task interest. When rewards are provided for performing better than others, studies showed significant increases in free choice (time spent on tasks after rewards are removed) and participant-reported task interest. Cameron et al. note that the magnitude of the impacts, both positive and negative are generally small.

2.9.2 Multifaceted Motivation

While the intrinsic/extrinsic dichotomy is a popular framework for studying motivation, others find it highly problematic. Reiss critiques the collapsing of all motives into two categories as a gross oversimplification [106]. He finds the use of behavioral measures of intrinsic motivation (such as recording the activities of children playing freely) as inferior to self-reports of motivation, and questions the reliability of such behavioral measures. Reiss instead proposes a multifaceted theory of motivation that he calls the *theory of 16 basic desires* [105]. These 16 desires or human needs are summarized in Table 2.1. While these desires are claimed to be universal, each individual will aim for higher or lower degrees of each type of motivation. The differences in motivation are the significant point of the theory. Reiss and collaborators have developed the Reiss Motivation Profile to assess which areas an individual is most motivated by, which has been validated in areas including sports, careers, and spirituality.

Table 2.1: 16 basic human desires, adapted from Reiss, Table 1 [105]

Motive name	Motive
Power	Desire to influence (including leadership; related to mastery)
Curiosity	Desire for knowledge
Independence	Desire to be autonomous
Status	Desire for social standing (including desire for attention)
Social contact	Desire for peer companionship (desire to play)
Vengeance	Desire to get even (including desire to compete, to win)
Honor	Desire to obey a traditional moral code
Idealism	Desire to improve society (including altruism, justice)
Physical exercise	Desire to exercise muscles
Romance	Desire for sex (including courting)
Family	Desire to raise own children
Order	Desire to organize (including desire for ritual)
Eating	Desire to eat
Acceptance	Desire for approval
Tranquility	Desire to avoid anxiety, fear
Saving	Desire to collect, value of frugality

2.9.3 Motivation of Environmentally Responsible Behaviors

De Young investigated the motives behind individual's environmentally responsible behaviors (ERBs) through a series of surveys [124]. Traditionally, the motives invoked by researchers attempting to promote ERB were constrained to material incentives or disincentives and altruistic reasons. The problem with incentives is that they "needed constant reintroduction to remain effective and they proved to be less reliable than we had hoped". Incentives can initiate ERB, but people's behavior changes back when the incentives end, and even continuing incentives can have low reliability.

De Young also describes some of the pitfalls that can be encountered in motivating ERB, such as psychological reactance, where people do the opposite of the ERB they are being asked to undertake. Even those initiating the behavior changes can be negatively impacted. De Young describes some initiators experiencing feelings of contempt for those whose behavior they are trying to change, and also contempt for themselves.

Self-interest is generally considered the cause of environmental problems: "focusing solely on short-term individual or familial gain to the exclusion of long-term societal or environmental benefits". De Young, however, suggests that self-interest can be a solution to environmental problems. He distinguishes self-interest from selfishness: self-interest meaning each individual is responsible for getting their own needs met. De Young believes that intrinsic satisfaction is a better way to motivate ERB, as people find that "certain patterns of behavior are worth engaging in because of the personal, internal contentment that engaging in these behaviors provides."

Based on 9 different studies of ERB across different populations and environmental focuses, De Young found 3 intrinsic satisfactions:

1. "satisfaction derived from striving for behavioral competence";
2. "frugal, thoughtful consumption"; and
3. "participation in maintaining a community".

Competence involves the enjoyment in completing tasks and solving problems. Frugality is enjoyment from the "careful stewardship of finite resources". Participation is the enjoyment from participating in community activities such as sharing news and collaborating with others toward a shared goal.

While attitudes and norms can lead to behavior change, people also need tools and guidance to realize this change. As De Young puts it, "without considering these variables, we make the error of assuming that once people know what they should do and why they should do it, they will automatically know how to proceed." In the particular case of competence as a motivator, it is important to provide people with the opportunity to utilize their competence or they will grow frustrated. He suggests that motivating through competence be accomplished by providing an environment where information on procedures is available and new behaviors can be tried out in a supportive environment.

Darby's survey of electricity feedback programs found similar results on motivations [24]. She found that energy conservation efforts stopped when incentives were removed. When trying to get people to change their behavior, she found that behavior changes formed over a three month period is more likely to persist than changes made over shorter periods. She also found that internal motivation is most important for continued conservation efforts.

2.9.4 Summary

Concerns about the undermining effect are prevalent in the education and gamification areas, both of which are relevant to the Kukui Cup. Based on the meta-analysis by Cameron et al., it would appear that undermining is not a significant concern for the extrinsic rewards available in the Kukui Cup. In the unfortunate event that the actions that make up the Kukui Cup are considered "low interest" by participants, intrinsic motivation is likely to be increased by extrinsic rewards. In the more likely event that the actions are "high interest", the meta-analysis suggests that extrinsic rewards will increase intrinsic motivation in the context of the competitive nature of the Kukui Cup. Reiss' criticism of the intrinsic/extrinsic dichotomy rings true to me, which makes the possibility of an undermining effect even less likely. I have not explicitly addressed Reiss' taxonomy of 16 human desires in this research, but it provides a potentially interesting area for future study. However, the Reiss Motivation Profile is not freely available so additional instrument development would be required.

De Young's research on motivating ERBs has been integrated into the design of the Kukui Cup. The actions available to participants in the energy literacy portion of the competition are intended to increase in difficulty through the competition, giving participants the opportunity to strive for mastery of the material. The De Young's idea of "frugal, thoughtful consumption" is truly central to the Kukui Cup, through the real-time energy feedback and the energy literacy content intended to explain to participants the aspects of their energy consumption that they have taken for granted.

The 2011 Kukui Cup did not follow Darby's recommendation that habits are formed over a three month period, possibly to the detriment of the challenge. Extending the length of the challenge in a logistically feasible way is an important direction for future research.

2.10 Connection to Nature

Some researchers have proposed that one's degree of emotional connection to nature could lead to environmentally responsible behaviors. Mayer and Frantz investigated this hypothesis through the development and assessment of the Connectedness to Nature Scale (CNS) [80]. They conducted five studies to ensure the internal validity of the scale, and to compare it to other scales and degree of environmentally responsible behavior. They found that the CNS correlates positively with self-reported environmentally responsible behavior. However, their research has not established a causal link between the CNS and environmentally responsible behavior. The New Environmental Paradigm (NEP) scale, which measures cognitive beliefs about the environment as opposed to emotional connection, did not correlate with self-reported environmentally responsible behavior, after controlling for the effect of CNS. Mayer and Frantz found that college students enrolled in an environmental studies class had significantly higher CNS scores compared to those students enrolled in three other subjects, which they take as an indication that CNS can predict real life decisions.

The items that make up the CNS are listed in Section D.5. Frantz has developed a revised and simplified version of the scale intended for use with children, which has been fully validated but not yet published (personal communication, December 8, 2011). A shorter version of the scale, containing only 5 items has also been used, but has not been empirically compared with the longer form.

Perrin and Benassi investigated the CNS by re-analyzing Mayer and Frantz's data and also conducting their own studies [96]. They conclude that the CNS does not measure an *emotional* connection to nature, rather it gauges people's beliefs about their connection to nature. Perrin and Benassi claim that the differences Mayer and Frantz found between the CNS and the NEP scale were due to things like the self-referential wording of the CNS (most items start with "I"), the positivity of the CNS items contrasted with the negativity of the NEP items, and the way in which CNS items were presented along side other measures. Perrin and Benassi conclude that the CNS measures connectedness to nature, but not an emotional connection to nature, which would require development of a new scale.

In presentations at the Behavior, Energy, and Climate Change conferences, researchers at Oberlin College have reported on the relationship between the CNS and energy conservation in the context of dorm energy competitions held at Oberlin. Petersen et al. reports that the CNS (presumably high CNS scores compared to other dorms) was the best predictor of energy use behavior during the competition [99]. Interestingly, the dorms with high CNS scores use less electricity outside of the competition, but they reduce electricity use less during the competitions. One possible explanation for this unintuitive result could be the baselines used for the Oberlin competitions. Before the competition, a baseline of energy usage is established for each dorm. The metric of competition is the reduction in energy use from the baseline, which is crucial because each dorm has different construction so absolute energy use would be an unfair metric. One corollary of this baseline system is that the dorms that are already using energy wisely rarely win the competition, because they have less "fat" to trim, compared to a dorm that starts as a wasteful energy user. It would make sense that high CNS dorms (which use less electricity before the competition) would reduce less during the competition, since their energy behaviors are already geared towards conservation. In a presentation the next year, Petersen et al. report that high CNS dorms also look at the competition website less than other dorms [100], concluding that high CNS dorms may have more intrinsically motivated residents, who are the least responsive to energy feedback and competitions. Frantz et al. report that CNS values are the "single best psychological predictor of electricity use" [43]. Frantz et al. further report that the connection to nature and increases in connection to nature (as measured by pre-post CNS measurements) are associated with increased reductions in energy use during competitions, which seems to be in conflict with the results reported by Petersen et al.

Given the results reported by Petersen and Frantz, further investigation of the role of the CNS in energy competitions is worthwhile. If high CNS residence halls are in fact less responsive to energy feedback and competitions, it might make sense to emphasize other techniques to encourage energy conservation in those buildings. If, on the other hand, high CNS values and increases in CNS post-competition are predictive of increased energy conservation, then the CNS could be used as a tool to determine which residence halls should be targeted for competitions to maximize return on investment in meters and logistics. Further, if connection to nature can be shown to cause energy conservation (a causal rather than correlative relationship), as Frantz and Petersen are pursuing, then investigation into ways to increase participants connection to nature could be beneficial to energy competitions and energy conservation research in general.

2.11 Group Identification

Henry, Arrow, and Carini have developed a three-part model of group identification [55]. They define *group identification* as "member identification with an interacting group", which is a trait of individuals, as opposed to *group identity* as the group-level identity which can be perceived by members and non-members. The three sources of group identification they propose are: cognitive, affective, and behavioral. Arrow and Carini developed an assessment tool called the Arrow-Carini Group Identification Scale 2.0, with subscales for each of the three sources of group identity. Henry, Arrow, and Carini conducted a series of studies to develop and assess the scale. Participants in the studies were asked to complete the scale for a group they belonged to with between 3 and 25 members. They found that the scale worked well overall in distinguishing between the three subscales, and correlated well with a previous unidimensional scale of group identification by Hinkle et al. One limitation with the scale is that it "presumes the existence of a real group that is perceived to exist not only by a researcher but also by its members". The items that make up the Arrow-Carini 2.0 scale are listed in Section D.4.

In the Kukui Cup, teams are formed from the architecture of the residence halls, so one unit of competition is the lounge formed by a pair of floors. The point and energy scores for a lounge are formed from the sum of the points of the members and the aggregate energy use of the members. While it might theoretically be possible for a lounge to win these competitions simply through each team member working diligently on their own, it seems much more likely that a lounge that wants to win will work together as a team. Therefore, it is important to assess the group identification of the residents towards their lounge. One of the studies conducted by Henry et al. had participants complete the Arrow-Carini scale both for an important group and an unimportant group that they belonged to. As expected, the important groups were rated higher (5.93, SD = .93) than the unimportant groups (3.89, SD = 1.07). One of the most common unimportant groups selected by participants were housemates, which is similar to the “lounge-mates” that make up teams in the Kukui Cup. In addition, lounges have more members (usually 54) than the groups investigated by Henry et al. (3–25).

2.12 Related Systems

In this section we examine other systems that have been designed to help users become more aware of their environmental impact, or make environmentally-positive behavior changes.

2.12.1 StepGreen

StepGreen is a web application designed to encourage people to undertake environmentally responsible actions [114]. Mankoff et al. have written about the design and evaluation of the system [78]. As they point out, there has been ample research on means of influencing green behaviors, less is known about how to use social technologies to encourage green behaviors. StepGreen is designed to leverage online social networks to motivate personal change, by providing suggestions for improvement.

The StepGreen system is currently open to the public. Figure 2.4 shows an example of the default page shown when a user logs in. Users create an account on StepGreen, and then are presented with a list of actions with positive environmental consequences (mostly reduced GHG emissions). Example actions are “Turn off the lights when you exit the house in the morning for the day”, “Take the stairs at work”, and “Set your home computer to automatically hibernate/sleep after a short period of inactivity”. Each action is associated with its cost savings and reduction in CO_2 emissions. Users can get more information about the action and how the savings were calculated. For each action, users can indicate whether they are already performing that action, whether they commit to undertaking that action, or whether the action is not applicable to them. Users can create new actions to be added to the list, but because the new actions have not been analyzed by the site maintainers, the financial and CO_2 savings are listed as unknown.

Once users have selected actions that they are either already performing or commit to performing, they can track them on the Reporting page. For one time actions, such as replacing an incandescent light bulb with a compact florescent bulb, users simply check off when they are completed. For recurring actions, users must indicate how many times they have performed the action since their last report in order for the system to track the activities. Based on the user’s self-reporting, StepGreen calculates the amount of money saved, pounds of CO_2 saved (i.e., reduced), and missed pounds of CO_2 saved, and provides a historical graph of these values.

StepGreen also provides links to social networking sites. They provide a MySpace profile widget, and a connection to Twitter. Both of these links provides a way to inform the user’s social network about what actions the user is undertaking. This feature can serve to recruit other people

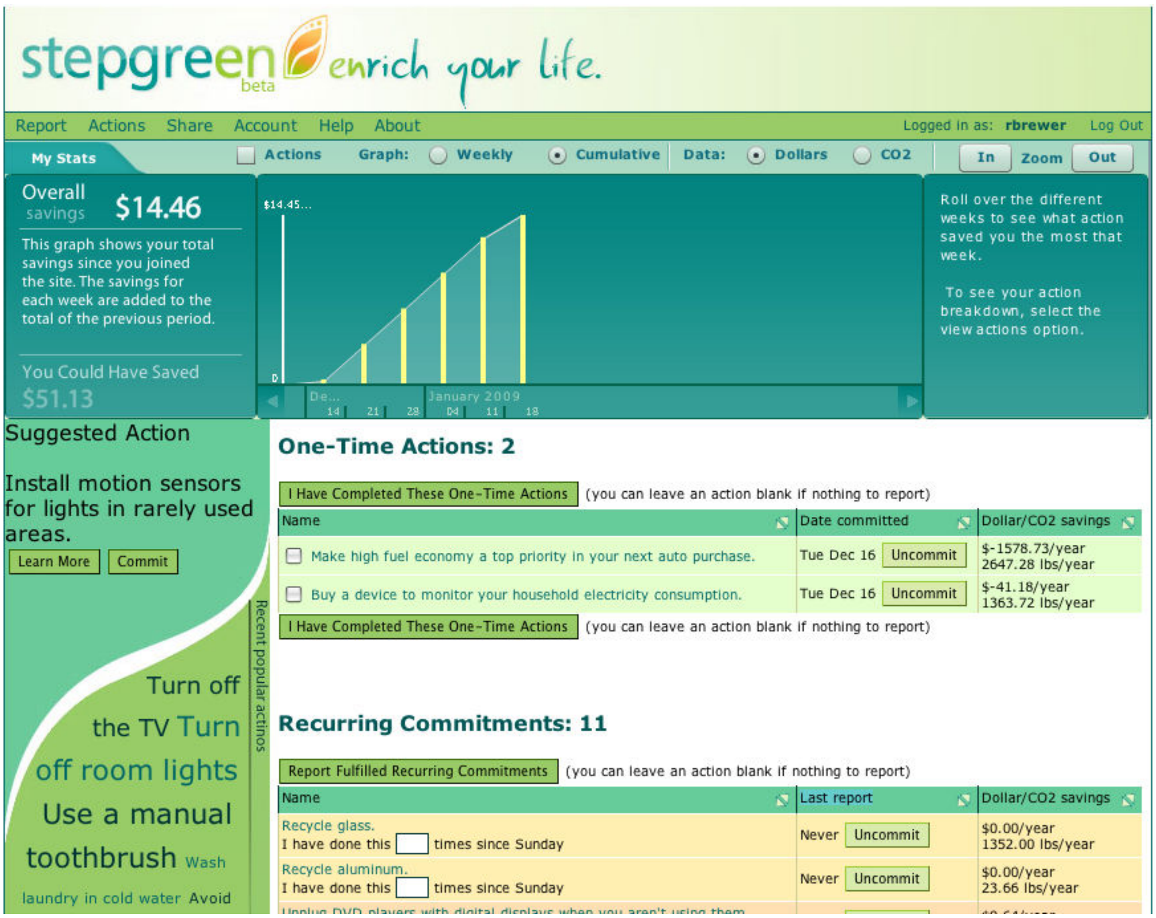


Figure 2.4: Example page from StepGreen website

to use StepGreen, provide comparisons on financial and environmental savings among peers, and encourage users to keep to their StepGreen commitments. Mankoff et al. performed a field evaluation of StepGreen using 32 participants from the local community. Participants were asked to use the system over the three week period, and view their MySpace profile twice a day. The MySpace profile widget showed a graph of recent CO_2 or financial savings, recent commitments, and a new action suggestion. The goal of the evaluation was to analyze the usability of StepGreen, rather than the behavioral impact of the system. Participants committed to an average of 16 actions, and reported completing 88% of the actions they committed to. Most participants reported that they learned about new actions through the evaluation, and almost half indicated that they now realized that household energy use was more of a factor in global warming than they had previously thought.

As a result of their evaluation, Mankoff et al. redesigned StepGreen to include more social features directly in StepGreen (such as comparison of data and discussion groups) rather than just piggybacking on existing social networks like MySpace. Manual reporting of actions was a participant concern, so the reporting page has been improved, and there are plans to support the input of sensor data from the UbiGreen transportation sensing project [46]. To deliver visualizations appropriate to different contexts such as a social media widget and the StepGreen website, StepGreen now supports an API that visualizations can query for data. An example visualization uses a virtual polar bear to motivate users to reduce their carbon footprint (see Section 2.12.2).

Grevet et al. studied social visualizations in StepGreen with a dorm competition at Wellesley College [52]. While the social visualization was received well, participants found that the list of actions in StepGreen was not well suited to their residence hall lifestyle.

StepGreen would be challenging to keep up to date due to the reliance on manual data input. Due to the limitations of manual reporting, StepGreen may report missed savings that are not accurate, annoying users. For example, recycling glass is an action that is listed as having substantial carbon savings. However, if one chooses to drink water from a mug instead of purchasing a beverage and later recycling the glass container, clearly the carbon savings are greater from using the mug, but StepGreen will count the lack of recycling as missed savings.

2.12.2 Virtual Polar Bear

Dillahunt et al. (who are involved with the StepGreen project) have built a system providing a virtual polar bear that is affected by the user's environmental choices as a means to motivate users to reduce their carbon footprint [33]. They note that there are strong emotional bonds between humans and animals, which may help to encourage environmentally-responsible behavior. The authors performed a one week study, with participants divided into two groups: an attachment group and a control group. The attachment group read a story about climate change impacting polar bear habitats, and were asked to name their virtual polar bear. As participants make or decline commitments to environmentally responsible actions, the ice under polar bear either grows or shrinks (see

Figure 2.5 for images of the polar bear). The study had 20 participants (10 for each group), all of whom were surveyed before and after to test for levels of empathy and environmental concern. The participants in the attachment group had more fulfilled environmental commitments, which was a statistically significant difference. The attachment participants also had a greater level of environmental concern after interacting with the polar bear. The authors were unsure whether effects would be sustained in a longer study. They are now working on bringing the system to a mobile platform and creating a polar bear application for Facebook and MySpace.

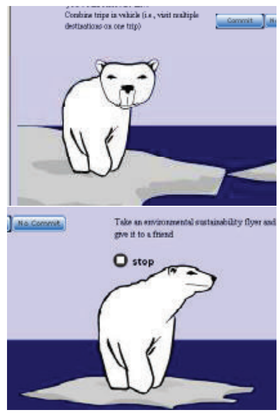


Figure 2.5: Example images of virtual polar bear with lots of ice and with little ice

2.12.3 Personal Kyoto

Personal Kyoto is a web service that tracks the electricity usage of users in the New York area, and compares it to a "Personal Kyoto Goal" for the user [40]. The Personal Kyoto Goal represents the limit of electricity usage that would apply to the user if the Kyoto Protocol (which the USA is not a party to) were administered on an individual basis rather than on a national basis.

The user's electricity usage is retrieved from the local utility's web site (Con Edison) using the user's account number. In addition to the monthly usage (which can vary substantially due to circumstances and the seasons), a 12 month rolling average is computed to remove the seasonal effects. The Personal Kyoto Goal is defined as 75% of the first point of the monthly rolling average when the user signed up with the web site. Figure 2.6 shows an example graph with monthly averages and a personal Kyoto goal.

Personal Kyoto is a cleverly designed system in that it uses the user's real data, but avoids manual data entry by scraping the data from the utility web site. It also gives the user a specific goal for reducing electricity use that has a real justification and ties into the environmental "gravitas" of the Kyoto Protocol.

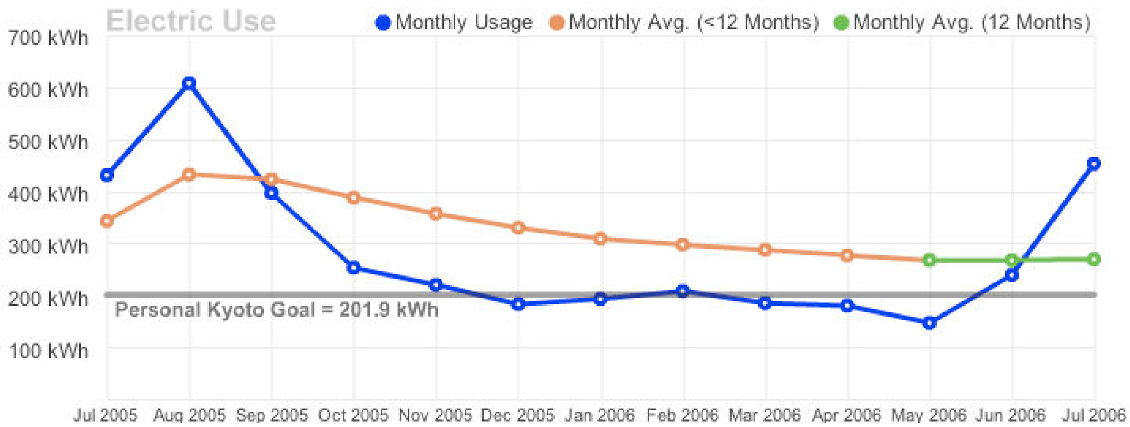


Figure 2.6: Example graph of electricity usage from Personal Kyoto

2.12.4 EcoIsland

Takayama and Lehdonvirta have constructed a system they call EcoIsland, which attempts to "motivate behaviour changes that reduce CO2 emissions" using a background game-like activity, with a centrally installed display in the home [117]. Figure 2.7 shows an example of the user interface. Each family member has an avatar on the virtual island, and they set a family CO_2 emissions target. The family's emissions are tracked via sensors and self-reporting. If the emissions exceed the chosen target level, the water level on the island rises, and if the water level continues to rise it will eventually end the game.

Participants' mobile phones have a list of suggested actions to reduce emissions, and they can self-report their actions using the phone. Participants can see the islands of other participants and they receive a periodic allowance in a virtual currency. The participants can use the virtual currency to buy decorations for their island, or to purchase carbon credits from other users. Participants with low emissions, therefore, can decorate their island, while those with high emissions have to spend their money on carbon credits. EcoIsland provides a metaphor for the users' emissions and makes them aware of the consequences of their actions.

The sensor portion of the system was not yet implemented at the time the authors conducted their study. The authors performed a four week pilot study of EcoIsland with 20 people in six families. During the first week, the baseline electricity usage of each participant's air conditioning system was monitored using a plug load meter (for more information on this type of meter, see Section 2.3.1). During the second week, one participant from each household was asked to use the system, while in the third week all members were asked to use it. In the fourth week, the carbon trading system was introduced to participants. At the conclusion of the study, the participants were surveyed: 17 of 20 participants said "they were more conscious of environmental issues after the experiment than before." However, users indicated that they were motivated by game issues (such as

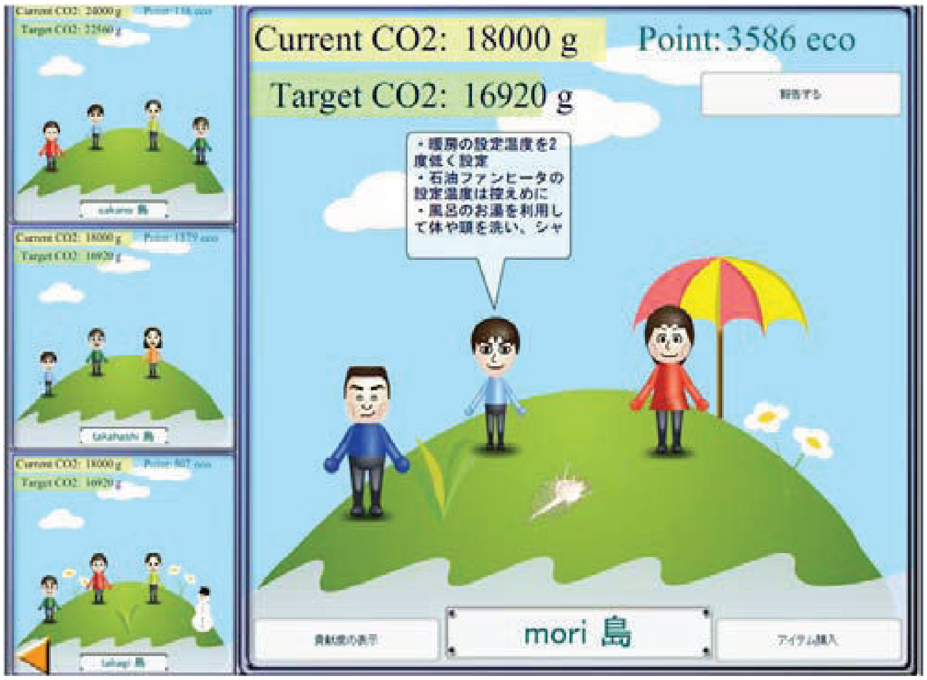


Figure 2.7: Example EcoIsland display, with family avatars

saving the sinking island and buying in-game decorations) rather than saving the environment. Few of the participants used the carbon trading system because their targets were easy enough to achieve without trading. Air conditioner usage in participant homes showed no correlation with game outcome, but the authors believe that the short study may have affected that outcome. The study was conducted in winter, which might seem like an inappropriate time to measure air conditioner use. However, in Japan, many air conditioning units also function as heaters, so it may be this type of air conditioner usage that the authors are referring to. One interesting result is that participants noted that manual reporting contributed to their motivation; therefore, replacing the reporting with sensors could reduce user's motivation to change.

2.12.5 PowerHouse

Reeves et al. have developed an online game called Power House intended to use the engagement of games to encourage players to reduce their energy usage [104]. Power House players import their electricity use data from their utility (recorded by smart meter). The game dashboard shows recent electricity usage, and real-world electricity usage impacts the results of the online games. Multiple online mini-games are provided for players, such as a game where players move around a house, turning on and off appliances to allow their in-game avatars to complete actions such as washing clothes or cooking dinner. Players that have conserved energy in their actual homes are able to turn on more appliances in their virtual home before tripping a circuit breaker, making game play easier. Power House is currently being evaluated, and results are not yet available. Power House is similar to the Kukui Cup in its integration of real-world and online actions, but Power House contains professional-quality mini-games, while the Kukui Cup focuses on educational actions both online and in the real world.

2.12.6 Google PowerMeter

Utilities are starting to install ‘smart meters’ (also called AMI for Advanced Metering Infrastructure) on homes as part of an overall push towards the ‘smart grid’. However, these smart meters are often thought about from the utility’s perspective: eliminating manual meter reading, enabling time-of-day electricity pricing, and monitoring power reliability. While there are many benefits for the utility, frequently updated power data from the meter could be very useful if provided directly to the people being metered, as discussed in Section 2.1.

Google PowerMeter is a web application developed to make smart meter data available to the end users living in smart metered homes [51]. Google partners with utilities that have rolled out smart meters, and collects the power data from the utility. PowerMeter also works with the TED 5000 home energy meter that can be installed by end-users without interaction with the utility (see Section 2.3.2). The data are recorded at 15 minute intervals, and presented in a variety of graphs that show daily usage and home base load levels. Figure 2.8 shows an example display for a home in Hawai‘i. The primary interface for PowerMeter is a web gadget that is installed on the user’s iGoogle home page. PowerMeter allows users to share their data with others, and has added an API to allow users to get access to their raw data. Google decided to shut down the PowerMeter service on September 16, 2011 because “our efforts have not scaled as quickly as we would like” [11].

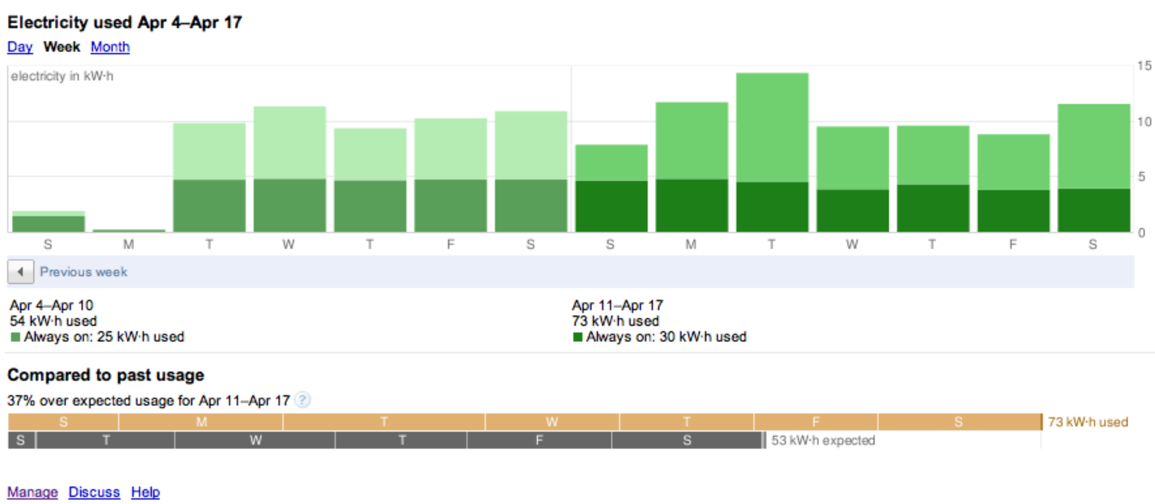


Figure 2.8: Google PowerMeter data for a home in Hawai‘i

2.12.7 Microsoft Hohm

Microsoft Hohm is a web application that allows consumers to view their energy usage (similar to Google PowerMeter) and offers recommendations for energy conservation [84]. Figure 2.9 shows an example display for a home in Hawai'i. For homes that do not have a utility-installed smart meter or a consumer-installed energy monitoring device, Hohm allows users to supply their address and characteristics of their home to estimate their energy use. Unfortunately, the default data Hohm provides for Hawai'i homes is inaccurate, as it assumes that all homes use energy for heating. Based on the energy data and home characteristics entered by the user, Hohm provides detailed suggestions for saving energy, such as lowering the temperature of water heaters, including cost saving and CO_2 emission savings. Like Google PowerMeter, Microsoft decided to discontinue the service "due to the slow overall market adoption of the service" [85]. Hohm was shut down on May 31, 2012.

2.12.8 iamgreen

iamgreen is an application for the Facebook social networking platform that provides an online gathering place for environmentally conscious users [58]. iamgreen provides all of the standard components of Facebook: e.g., a newsfeed of events from members, status updates, news articles. The application provides a list of environmentally responsible statements called "leaves", such as "Most of my lightbulbs are compact fluorescents", "I recycle, even when it is not convenient", and "When I drive, it's over 40mpg baby" (see Figure 2.10 for an example of the leaf selection page). For each statement, users can indicate if they engage in that behavior, they aspire to that behavior, they wish to hide the statement (removing it from the list of choices), or they want to recommend it to a friend. Users can then display the number of leaves they have committed to in their Facebook profiles. Users can also contribute new leaves, which will be displayed as options to other iamgreen users.

While the leaves concept is a simple way to encourage users to make more environmentally positive choices, it suffers from some obvious deficiencies. First, leaves, for the most part, have the same value (though apparently some actions, such as not owning a car, are worth more than one leaf). The leaf system also lacks any quantitative feedback other than the number of leaves, so the user is not provided with real insight into their environmental footprint. Like any system based on manual reporting, users have to spend time reporting any changes to their action list. Without quantitative feedback, it seems likely that many users will make some selection of leaves and then revisit them infrequently or never again.

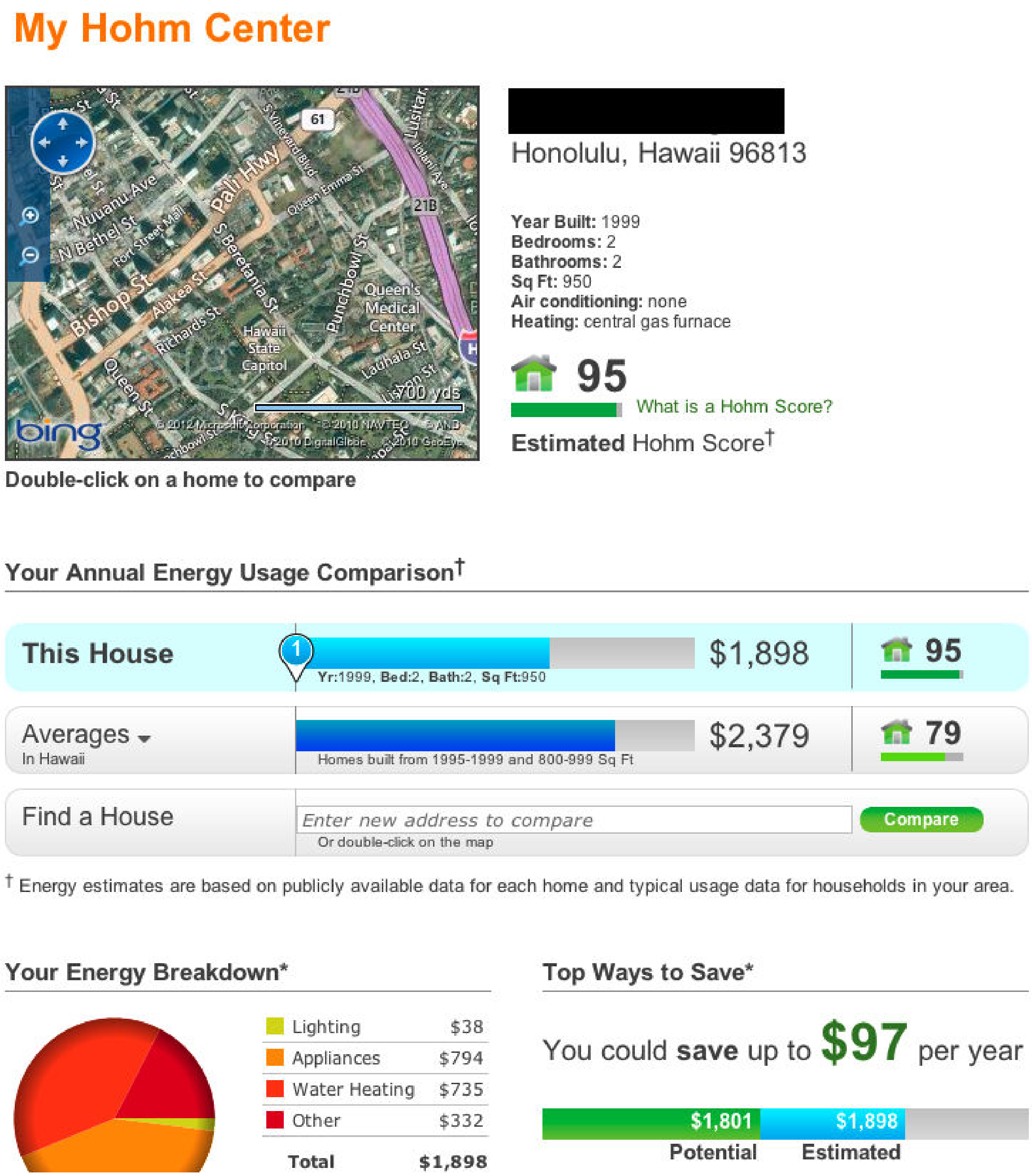


Figure 2.9: Microsoft Hohm data for a home in Hawai‘i

Figure 2.10: Leaf selection page of iamgreen Facebook application

CHAPTER 3
SYSTEM DESCRIPTION

This chapter describes the Kukui Cup system. By system, I mean all aspects of the 2011 UH Kukui Cup: the energy conservation competition, the point competition, the events that took place during the challenge, and the underlying information infrastructure that supported it.

The 2011 Kukui Cup was designed with three goals in mind:

1. Enabling research into fostering sustainable environmental behavior change;

2. Improving the energy literacy of the participants; and

3. Reducing the energy consumption of the residence halls.

The participants competed in two ways: to reduce energy consumption in the participating residence halls, and to accumulate points by performing tasks related to energy literacy and conservation through the challenge website.

3.1 Setting

The 2011 Kukui Cup took place in the Hale Aloha residence halls on the University of Hawaiʻi at Mānoa campus [119]. Hale Aloha consists of four cylindrical towers, named after Hawaiʻian flowers: Lehua, Ilima, Mokihana, and Lokelani. The towers are arranged around a central courtyard that contains benches, trees, and small raised platform that can be used as a stage. Next to the courtyard is a large cafeteria that provides meals for all the on-campus student residents.

The Hale Aloha towers were built in the 1970s. Each tower contains 13 floors with the following composition:

- Floor 1: lobby (front desk, mailboxes, vending machine, TV)
- Floor 2: apartment for a Residence Director or Assistant Residence Director
- Floors 3–12: rooms for student residents
- Floor 13: laundry room, shared kitchen, meeting & study spaces

The student resident floors (3–12) contain 14 inhabited rooms: 13 rooms intended for two residents, and one room designated for the floor's Resident Advisor (RA), who lives alone. There are two bathrooms per floor, each containing multiple individual rooms with a shower, toilet, and sink with a lockable door.

The even floors (4, 6, 8, 10, 12) have a sunken lounge space in the center of the floor with chairs, tables, and benches. The odd floors (3, 5, 7, 9, 11) share the lounge with the even floor above, accessed by a central stairwell. The pairs of floors are called "lounges" after their shared lounge space and labeled by letter: lounge A (3–4), lounge B (5–6), lounge C (7–8), lounge D (9–10), and lounge E (11–12). Hereafter, a lounge (pair of floors) will be specified using the name of the tower and the letter of the lounge, such as Ilima A or Lokelani C. With four towers, each containing five lounges, there are a total of 20 lounges participating in the challenge.

There are two elevators in each tower: one that serves each floor (1–12), and one that goes only to the lounges (A–E and R, the roof lounge that is the 13th floor).

The residents' rooms include a pair of beds, armoires, desks, and chairs with one set arranged along each wall. In Lehua and Ilima, each side of the room has two power outlet boxes (4 outlets), while Mokihana and Lokelani have three power outlet boxes (6 outlets). Each room has two Ethernet jacks that provide Internet access. The student resident floors have have no central air conditioning, relying on windows for climate control (due to Hawai‘i's climate, there is no need for heating). Residents with special needs (such as breathing problems or severe allergies) may request the installation of a room air conditioner at additional cost beyond the standard housing rates. There were three such air conditioning units approved during the Fall 2011 semester. Unapproved air conditioners are not allowed, and residents caught with one must pay a fine for energy consumption based on the number of weeks it was present in the room.

3.2 Participants

The participants of the challenge were the residents of the four Hale Aloha towers. The residents were all first-year students starting at UH Mānoa. Each resident floor was overseen by a Resident Advisor (RA), a paid student employee who was in charge of enforcing rules, organizing activities, and being the first point of contact for residents. The RAs were allowed and encouraged to participate in and promote the challenge.

These first-year student residence halls are specifically targeted for two reasons. First, based on conversations with UH Mānoa undergraduates, residents in the first-year residence halls are more likely to attend floor meetings and events, while upper-class residence halls are more like apartments where residents might not know their neighbors well or be motivated to attend floor meetings. Second, as the goal is to improve energy literacy and foster behavior changes in the participants, the earlier these changes take place in their college experience, the more benefit there will be to the participants and the University.

Each floor of the Hale Aloha towers has an RA and 13 double occupancy rooms, and there are 10 floors of student residents per tower. Therefore, at full occupancy, there are 270 potential participants per tower and 1080 potential participants in total.

The challenge was run by a team of Kukui Cup staff, which included a professor, graduate and undergraduate students. The staff organized and ran events, put up marketing posters, and administered the challenge website.

3.3 Timing

The 2011 Kukui Cup was organized into three rounds, each lasting a week. Two to three week student housing energy competitions are common (such as the one described by Petersen et al. [101]), and provide a balance between sufficient time to get participants involved and waning interest in a longer challenge. The intensive event schedule, need for fresh energy literacy content, and logistical overhead of running the challenge also made a longer challenge infeasible for this inaugural Kukui Cup.

As discussed in Section 3.2, the Kukui Cup took place in first-year residence halls in an attempt to increase participation by students just starting in a new environment, and hopefully thereby more receptive to new experiences. For this same reason, we wanted to hold the challenge in the Fall semester, in the first half of participants' first year. The Fall semester at UH Mānoa starts in late August (August 22 in 2011), and ends in mid-December (December 15 in 2011). We scheduled the challenge in the middle of the semester for two reasons. First, at the beginning of the semester students are settling into their new environment and dealing with their classes. I also needed time to gather baseline data on electricity usage before the challenge started, precluding an early semester start. Second, starting late in the semester is complicated by the Thanksgiving holiday (which took place during the week of November 22 in 2011), and the increasing workload as the semester winds down. The 2011 challenge started at midnight on Sunday October 16, 2011 and ended at midnight on Sunday November 7, 2011.

3.4 Energy Meters

Monitoring the energy use by the residents is a core aspect of this research. This section covers the physical infrastructure needed to monitor energy use. Note that in the Hale Aloha towers, electricity is the only real source of energy in use (there is no natural gas or heating oil use). Therefore the energy monitoring is limited to monitoring of electricity use, and the terms energy and electricity are used interchangeably throughout this document.

3.4.1 Meter Operation Principles

Power meters typically work by sampling the voltage and current passing through a circuit to compute the power being consumed or produced ($Power = Current \times Voltage$). In a building setting, a meter will often measure the power being used by a single electrical distribution panel, which contains circuit breakers for the various loads in the vicinity. While voltages may be measured directly by connecting a voltmeter to one of the breakers, often the current present in home or institutional wiring are too large for convenient measurement by a meter. Current transformers (CTs) are used to step down this higher current to a more useable level. CTs are torus-shaped and typically have two pieces that can be clamped around existing wiring, allowing installation without breaking the existing electrical circuit. In an institutional setting, typically three-phase power will be used since it is a more economical use of conductor for heavy loads compared to single or two-phase power. To measure three-phase power, typically three ammeters (and thereby three CTs) and one voltmeter are required. A digital power meter will sample these four inputs at high frequency to compute power use, and also integrate over time to compute energy use (see Appendix B for an explanation of the difference between power and energy).

3.4.2 Meter Selection

The Kukui Cup energy competition required two uncommon features for the energy metering: monitoring at the level of a floor as opposed to a whole building, and near real-time data collection at approximately 15 second intervals. In addition, we required that the meter provide a documented way to retrieve the energy data so that I could write software to collect and display the data.

Based on these requirements, we selected the Shark 200S meter from Electro Industries/Gauge Tech [37]. The Shark has an Ethernet port for Internet connectivity, and supports the standard Modbus TCP protocol [86] for queries of energy data. In addition to the Shark meter, three appropriately-sized CTs were needed for each meter to measure the current on the three phases of power present at each panel.

3.4.3 Hale Aloha Electrical Infrastructure

I conducted a preliminary walkthrough of the Hale Aloha electrical infrastructure in August 2010. This walkthrough revealed there were two types of electrical distribution panels present on the resident floors:

1. A newly installed panel installed in the telecommunications room present on the even floors, and

2. The original panel installed in the shared lounge area present between even and odd floors.

The first type provides an additional power outlet box on each side of each resident room for the even floor and the odd floor below (e.g., 3 and 4). I refer to these panels as "telco" panels, based on the label used outside of the telecommunications room.

In second type of panel provides power to room outlets, overhead lights, and other circuits on the floors that share the lounge (e.g., 3 and 4 for lounge A). I refer to these panels as “lounge” panels based on their location, however they monitor power use throughout the two floors, not just the small number of circuits used in the shared lounge space.

Energy meters like the Shark are designed to monitor the load from a single panel, by installing the CTs over the power lines coming into the panel. Attaching a meter to a telco panel will provide data on a segment of energy use for two floors (the new outlet boxes in resident rooms), but it is infeasible to break that down to a per-floor level. The lounge panels also monitor circuits spread across the two floors. However, the sum of the power use by the telco and lounge panels provides an accurate measure of the power use of the pair of floors that make up a lounge.

3.4.4 Meter Installation

Getting the meters installed across the four towers proved quite challenging, despite the strong support of everyone involved, including UH Mānoa Student Housing. The Shark meters needed to be ordered through the university procurement process, and required installation by an externally contracted electrician. The telco meters were installed in the same room as the Ethernet switches that supply Internet connectivity to the floor, so those meters could be connected using a short cable. The lounge panels, however, had no nearby Ethernet jacks, so conduit and Ethernet cable had to be installed to connect back to the telco rooms.

Our efforts began in the summer of 2010, with the goal of running the inaugural challenge in October 2010. However, the date was pushed back to February 2011 and then October 2011 due to delays in the meter installation process. Table 3.1 shows the timeline of when I first received valid data from a lounge (which requires both meters serving that lounge to be operating properly). The meters in Lehua were installed at the end of March 2011, while Mokihana and Ilima were not installed until September 2011. The meters in Lokelani were only installed shortly before the challenge began in October 2011. Three meters experienced problems that made their data invalid after installation in Lokelani, and had to be replaced or adjusted. These failures further delayed the receipt of good data necessary for calculating baselines and running the challenge.

3.4.5 Energy Audit

With the meters installed on both the telco and lounge panels, I was able to capture all the electricity use on the resident floors. However, it was not known whether there were additional loads connected to those panels that were not under the control of the residents, or whether these additional loads differed between floors. Any differences could potentially throw off the results of the competition, and add uncertainty to any conclusions about resident behavior based on the energy usage data.

The original goal was to install all the energy meters during the summer 2011 break, when the towers are typically unoccupied. This strategy would have allowed us to gather energy data with no

Table 3.1: Timeline of meter installation

Lounge	First valid data received
Lehua-A	3/30/11
Lehua-C	3/30/11
Lehua-D	3/30/11
Lehua-E	3/30/11
Lehua-B	3/31/11
Ilima-A	9/9/11
Ilima-B	9/9/11
Ilima-C	9/9/11
Ilima-D	9/9/11
Ilima-E	9/9/11
Mokihana-A	9/9/11
Mokihana-B	9/9/11
Mokihana-C	9/9/11
Mokihana-D	9/9/11
Mokihana-E	9/9/11
Lokelani-A	10/6/11
Lokelani-E	10/6/11
Lokelani-D	10/11/11
Lokelani-B	10/14/11
Lokelani C	1/23/2012 *(after challenge)*

residents present, which would have shown any hidden loads present on the floors. Unfortunately, all the meters were installed after residents were already present in the towers. The Lehua installation was completed at the end of March 2011, but Lehua was used to house summer session students, so it was never unoccupied long enough to complete an audit. Meters were installed in Ilima and Mokihana after the residents had moved in for the Fall 2011 semester, and the Lokelani installation was completed only shortly before the challenge began.

To address this issue, a joint team from UH Mānoa Student Housing and the Kukui Cup project conducted an energy audit of the four Hale Aloha towers during the winter break after the Fall 2011 semester [7]. Residents are not required to leave during the winter break, but many residents do leave, providing an opportunity to unplug all devices in resident rooms and examine the power usage recorded by the lounge meters. Other results from the energy audit can be found in Section 5.7.

3.4.5.1 Panel audits

After each room was examined for devices to unplug, the overall power usage from each meter was recorded on a per-panel basis. Table 3.2 shows the power data that was collected.

From Table 3.2, one can see that for all the telco panels, the power measured was roughly the 5 W that our meters appear to consume. This confirms that the new panels in the telecom/IDF rooms only provide power to plug loads in resident rooms.

One glaring problem is the power recorded from the Lokelani C lounge meter. The Lokelani C meter had been reporting much higher power usage than all other lounges, double the average lounge at peak. As part of the audit, all the circuit breakers were turned off, but the meter still registered approximately 1800 W. On 1/23/2012 an electrician was brought in to troubleshoot the problem. The lounge panels have main feeds that come up from the basement, and each of these lines splits in two to power two lounge panels. The CTs on the Lokelani C panel had been incorrectly installed on the incoming power lines *before* they split off to the panel, instead of after. Thus the meter was functioning properly, it was just metering both the Lokelani C panel load and the load from Lokelani D. This explains the data I observed from Lokelani C: usage roughly double other lounge panels. For these reasons, the energy data from Lokelani C collected before and during the challenge must be considered invalid, and has been excluded from all analyses.

The networking equipment (router, switch, and occasionally power over Ethernet injectors) located in the telecom/IDF room of each lounge was sometimes different across towers and lounges. For example, the equipment in Lehua D's telecom room was recorded as 40 W, while Ilima E used 180 W.

The lounge panels are more complicated, because they control other loads in addition to the resident room plugs and overhead lights. Table 3.2 shows that the lounge power can go as low as 65 W, or as high as 694 W.

Unfortunately, it was not possible in this audit to track down all the loads from the lounge panels

Table 3.2: Lounge power use per panel, after unplugging, in increasing order

Lounge	Panel	Power after unplugging (W)
Mokihana D	telco	0
Lokelani D	telco	3
Lehua B	telco	4
Lokelani C	telco	4
Lehua D	telco	4.5
Lehua A	telco	4.7
Lehua E	telco	4.8
Ilima B	telco	4.8
Lehua C	telco	5.4
Lokelani E	telco	5.7
Lokelani A	telco	6
Ilima A	telco	6.8
Mokihana A	telco	6.8
Ilima D	telco	7
Lokelani B	telco	7
Mokihana B	telco	7
Mokihana C	telco	7
Ilima C	telco	7.5
Mokihana E	telco	7.7
Ilima E	telco	8
Lehua B	lounge	65
Lehua E	lounge	78
Mokihana A	lounge	106
Lokelani D	lounge	129
Lehua D	lounge	130
Ilima B	lounge	133
Ilima A	lounge	183
Lokelani A	lounge	195
Mokihana D	lounge	225
Ilima C	lounge	227
Ilima E	lounge	229
Ilima D	lounge	230
Lehua C	lounge	243
Mokihana C	lounge	252
Mokihana B	lounge	253
Lokelani B	lounge	287
Mokihana E	lounge	335
Lehua A	lounge	682
Lokelani E	lounge	694
Lokelani C	*lounge*	*1834*

for a few reasons. Most lounges had one or more residents present, and based on readings from the telco panels, residents did not always unplug all of their devices. They also were free to make use of the bathrooms during the audit, which contain overhead lights and power outlets. The inserts on the lounge panels that list what each breaker controls were mostly out of date or missing, making it difficult to tell whether the load on a breaker was from a resident room or something else. With the residents present and the time constraints of this audit, it was not possible to track down unexplained power from most breakers on the lounge panels.

The lounges from Lehua B to Ilima B in Table 3.2 show loads primarily from the networking equipment and the Shark meter, with a few scattered smaller loads (20–30 W). The rest of the lounges have increasing numbers of loads beyond the networking equipment, some quite sizable (up to 200 W). It seems quite likely that some of these loads were residents that didn't unplug their devices, plugged them back in before the audit was complete, or devices that were missed during a sweep of the room. However, on the basis of this audit, I cannot rule out that there might be loads totaling as much as 640 W in two lounges. Also, since the audit was performed at a single time, if there are non-resident loads that are time based, they could have been missed by the audit.

This audit cannot rule out some limited amount of hidden electrical load on a few lounges, but it appears that there are no large, pervasive hidden electrical loads in the Hale Aloha resident floors. While differences in power usage were observed from networking equipment, these differences would impact the absolute energy use of a lounge, but not their change in use over time. Thus these differences could potentially change the outcome of the competition between lounges, but would not affect changes in electricity use for a particular lounge over time.

3.4.5.2 Meter Accuracy

For the audits of Lokelani and Mokihana, I used a Conserve Insight plug load meter from Belkin [6] to directly measure the power usage from each piece of network equipment in the telecom room. I then added these values together and compared the result with power recorded by the Shark meter using the circuit breaker audit method. The two values were always within 10%, which is well within the expected accuracy of the Shark meter with such a small load. This provides some assurance that our meter installations are providing accurate data.

3.5 Energy Data Collection

The energy data recorded by the meters has to be retrieved in order to be useful. We needed a system that could collect data from a variety of types of meters, could collect data from a significant number of meters (40), and could collect data at fifteen second intervals. Based on a review of available software systems for collecting and storing energy data, I found that there was no system that met our requirements. Therefore, I developed an Java-based open source system called WattDepot to collect, display, and analyze the Kukui Cup energy data [8]. WattDepot provides an ecosystem for energy data, from the collection of data from meters, to storing it in a repository, to displaying it in a variety of formats [121]. Figure 3.1 shows a diagram of the WattDepot architecture.

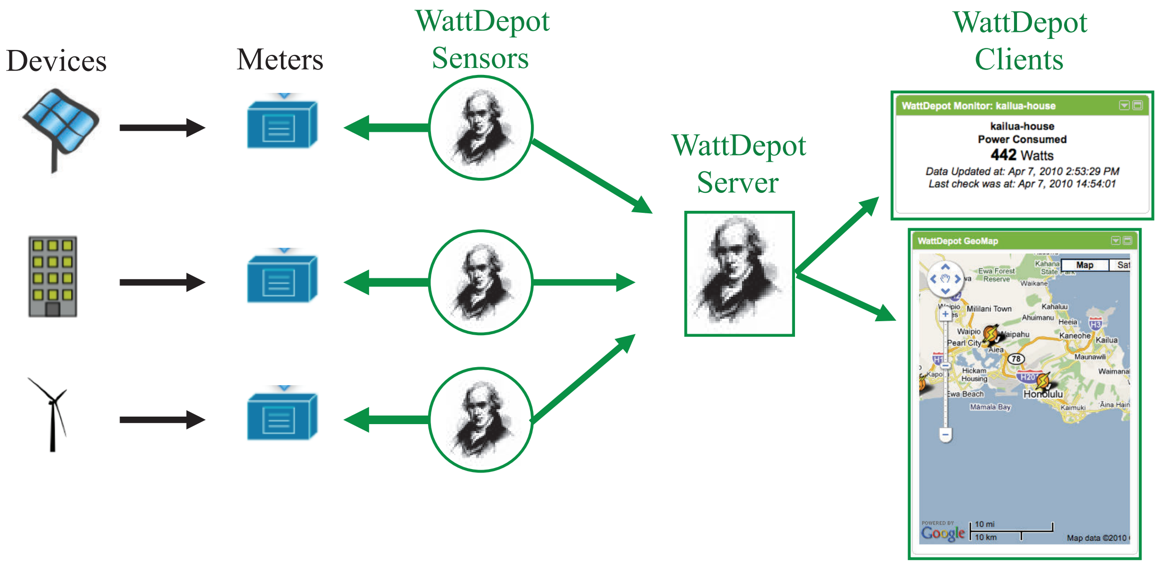


Figure 3.1: The architecture of the WattDepot system

WattDepot is broken into three kinds of services:

1. WattDepot *sensors*, a software process customized for a particular brand of energy meter, which requests data from a meter according to the meter's protocol, and then sends it to a WattDepot repository for storage;

2. WattDepot *servers*, which implement a REST [107] API for accepting energy data sent from sensors and providing this sensor data (or analyses based upon the data) to WattDepot clients; and

3. WattDepot *clients*, which request data from WattDepot servers and either display the data or analyses directly to users or provide the data to higher level energy services.

Data retrieved by sensors is associated with a *source* when stored in the server. Each physical meter is typically a source, but sources can also be virtual combinations of other sub-sources. For example, as discussed in Section 3.4.3, the electricity used by each lounge is provided by two different panels with separate meters. To view the total electricity use of the lounge, I created a virtual source with the two meters feeding that lounge as sub-sources.

Once the energy data has been stored in a WattDepot server, clients can query the server for the amount of energy used by a source between two arbitrary points in time. Since the sensor data is only retrieved periodically, in most cases the endpoints for an energy query will not precisely match the sensor data. To solve this problem, the WattDepot server will linearly interpolate between the two nearest sensor data values before returning data to a client.

To retrieve data from the Shark meters, I wrote a sensor that retrieves two values from the meter: the instantaneous power consumed and an energy counter that records how many watt-hours have flown through the meter since it was constructed. The meters were polled every 15 seconds before and during the challenge, and the resulting sensor data was stored in a WattDepot server. Both the sensors and server were installed on a Apple Xserve system housed in our research lab. The client use of the energy data is discussed in Section 3.7.3.

3.6 Challenge Design

The Kukui Cup challenge was designed to meet multiple needs. In order to be effective, the challenge needed to be interesting and engaging for the participants, or they would not be interested in participating. As a research project, the challenge also had to support the needs of our experimental design and data collection. In some cases, these two needs were in conflict, and I note those decisions in this section and in Chapter 4.

The Kukui Cup consists of two different competitions: an energy conservation competition, and a point competition. This section explains the design of those two competitions, and other important game components.

3.6.1 Rounds

The 2011 Kukui Cup was structured into three week-long rounds:

- Round 1: Monday October 17 to Sunday October 23;
- Round 2: Monday October 24 to Sunday October 30; and
- Overall Round: Monday October 31 to Sunday November 6.

Each round began at the start of the beginning day (12:00 AM) and ended at midnight on the end date. Each round had separate prizes. Rule changes typically took place at the start of a new round, such as the referral bonus (see Section 3.6.3.2). In Round 2, the points earned and energy used in Round 1 were set aside so that each player and lounge started at zero. The goal of this point/energy reset was to encourage residents who did not participate initially to start participating in a later round without undue disadvantage. In fact, since some activities could be performed in either Round 1 or Round 2, a player starting in Round 2 had an advantage in winning Round 2, as they could accrue all those points to their Round 2 total. In the Overall Round, the score and energy totals from Round 1 and Round 2 are combined, as well as any points earned in the Overall Round.

3.6.2 Energy Competition

The 2011 Kukui Cup energy competition had a straightforward goal: the lounge that uses the least electrical energy in the round wins. As discussed in Section 3.4.3, monitoring energy at anything other than the lounge level was infeasible, making the lounge the fundamental unit of the energy competition.

Most other building energy competitions (such as the Oberlin competition discussed in Section 2.4) do not use absolute energy use as the metric for success. Most competitions record energy data before the competition, and then average that data in some way to produce a baseline of energy usage for the unit of competition (e.g., floor, building). The metric of success is then defined as the team that reduced their energy use during the competition by the largest percentage compared to their baseline usage. As most competitions involve buildings of different sizes, construction dates, and occupancy levels, comparing to baseline usage is the only way to provide normalization between the teams.

Using percent energy reduction compared to a baseline as the success metric for a competition means that it is critical to determine the baselines accurately. As discussed in Section 3.6.4.1, determining an accurate baseline is challenging and potentially error prone. Also, using a baseline opens the possibility of a team artificially inflating their energy usage during the baseline collection period to make it easier for that team to win the competition. In another potential scenario, one can imagine two teams before the competition starts: team A is very conscientious about energy use and has already taken many energy saving measures, while team B uses energy very wastefully and has taken no energy saving measures. Team A would find it difficult to achieve much reduction from their baseline energy use during the competition, while team B can take the all the easiest energy-saving measures and achieve substantial reductions compared to their high baseline.

Absolute energy makes sense as a success metric for our energy competition because all four of the Hale Aloha towers have very similar construction, and they are all close to full occupancy since the demand for on-campus housing outstrips supply. On the other hand, baselines were used for the Daily Energy Goal Game, described in Section 3.6.4, to ensure that the goals were achievable based on the lounge's past energy use.

Participants were able to track their lounge's performance in the energy competition through the scoreboard provided on the challenge website, as shown in Figure 3.2.

We provided information to lounges on how to reduce their energy consumption through the activities and events available through the point competition.

3.6.3 Point Competition

In the point competition, individuals earned points by taking actions related to energy literacy or sustainability mediated through the challenge website. The points earned by individuals were also aggregated by lounge, to produce a score for each lounge.

Round 1 Energy Scoreboard

Rank	Lounge	kWh used
1	Lehua-E	759
2	Ilima-A	759
3	Mokihana-A	780
4	Mokihana-B	792
5	Lehua-A	835
6	Lehua-D	863
7	Lehua-C	875
8	Mokihana-C	919
9	Ilima-D	921
10	Ilima-E	922
11	Lokelani-E	927
12	Lokelani-D	966
13	Ilima-B	1014
14	Ilima-C	1052
15	Lokelani-A	1054
16	Lokelani-B	1056
17	Lehua-B	1117
18	Mokihana-D	1154
19	Mokihana-E	1219
20	Lokelani-C	1618

Figure 3.2: Round 1 energy scoreboard

One of the goals of the challenge was to improve the energy literacy of the participants. As discussed in Section 2.8, I defined energy literacy as consisting of knowledge, skills, attitudes, and behaviors. While the knowledge component can be conveyed through information displayed on the challenge website, the behaviors require the participants to engage in activities outside the website. Further, research in environmental psychology described in Section 2.5 indicates that the incorporation of techniques like public commitments can increase the likelihood of sustainable behavior change.

To increase the energy literacy of the participants and to motivate their participation, the website provides a variety of actions that participants can take. These actions are divided into three categories:

- *Activities:* one-time, verifiable actions
- *Commitments:* ongoing, non-verifiable behaviors
- *Events:* events scheduled at a particular place and time

The complete list of actions defined for the competition can be found in Appendix C, and a summary of the actions can be seen in Table 3.3.

Table 3.3: Summary of the actions available during the challenge

Action type	Number available
Activities	62
Commitments	21
Events	24

Actions can be either locked or unlocked. An unlocked action can be completed by a participant, while a locked action is completely inaccessible to participants until it is unlocked. Actions may be initially unlocked, while some actions may require other pre-requisite actions to be completed first. Actions may also be locked until a certain date. In the 2011 Kukui Cup, the available actions were divided roughly into thirds, and only the first third was available in Round 1, with the the second third available in Round 2, and then all actions were unlocked in the Overall Round.

When a participant successfully completes an action, they earn points. The points are intended to reflect the difficulty of the action. Table 3.4 shows a summary of the different point levels and what type of action they correspond to.

Table 3.4: List of point categories for actions

Point value	Type of action	Time commitment
5	Tweet something or complete a commitment	1–2 min
10	Watch tutorial video, slightly more involved activities	5 min
20	Attend an event	1–2 hours
30	Priority events or activities	10–60 min
5–50	Creative activities (e.g., writing a letter to editor)	multiple hours

3.6.3.1 Social Bonus

As discussed in Section 3.6.2, participants must work together to win the energy competition. Provide an incentive for participants to work together, some actions in the point competition were assigned a *social bonus*. The social bonus was worth 5 or 10 points, and was applied only to actions where two or more participants could reasonably complete the action together such as attending an event or making a commitment. To obtain the social bonus, a participant submits the email address of another participant with whom they completed the action. If the participant corresponding to the email address provided has completed the action, then the social bonus requester receives the bonus points. The social bonus does not require reciprocation: participant A can list participant B for the social bonus, and receives points even if participant B lists another participant or no one for the social bonus. The social bonus is a deliberately simplistic indication of social interaction, because only an email address exchange is required. There is no verification that an action where the social bonus has been used was completed collaboratively. However, obtaining another's email address provides participants with an excuse to initiate contact regarding the challenge, and we felt it was sufficient justification for any point inflation that might result.

3.6.3.2 Referral Bonus

In an effort to increase participation in the challenge, in Round 2, we instituted a *referral bonus* (the idea for the referral bonus was suggested by Jenna Amberg-Johnson). When a participant logs into the challenge website for the first time, as part of the first login process, they are asked to enter the UH email address of another participant if that other participant referred them to the challenge. Once the new participant earns 30 points in the challenge, then both the new participant and the existing participant are awarded 10 bonus points. New participants that successfully completed the first login process earned 25 points, so to earn the bonus, new participants had to complete at least one activity. There was no limit placed on the number of times a participant could be used as the referrer.

3.6.3.3 Activities

Activities are the most common type of action available to participants. Activities are one-time actions that can be verified through the challenge website. Example activities include:

- Watch a short YouTube video about Power & Energy,
- Replace an incandescent bulb with a compact fluorescent (CFL),
- Perform an energy audit of the participant's room, and
- Write a letter to the editor on a Kukui Cup topic.

Once the activity has been performed, the participant must verify the completion in order to receive points. Each activity uses one of these four methods of verification:

- A short answer to a question randomly selected from a list,
- An uploaded image (often a digital photo),
- An open-ended response in text, and
- An open-ended response in text paired with an uploaded image.

In each case, the participant enters their verification information, which is sent to a challenge administrator for review. The administrator either approves the submission, at which point the participant receives their points, or rejects the submission with an informative message that explains why the submission was rejected. When a submission is rejected, the participant can try again, taking into account the administrator's reply. The review process happens asynchronously, so participants do not immediately know if their submission has been accepted. However, any submission does count as completing the action, so other actions that depend on the action submitted are unlocked.

As an example of the verification process, the video activities where the user watched a short video about an energy or sustainability topic used the short answer verification type. Each video had several verification questions, and to make it more difficult for participants to cheat by sharing answers, the question posed to each participant was selected randomly.

Other activities are difficult to verify with text only (such as changing out a incandescent bulb with a CFL). For these activities, participants can take a picture that provides some proof that they have completed the activity (such as holding both the incandescent bulb and the CFL).

The open-ended response verification type was used for activities where output of the activity was text, such as the letter to the editor activity. The open-ended response could also be used for activities where the result was a URL to a resource, such as a participant-created video.

3.6.3.4 Commitments

Commitments are intentions to behave in a certain way in the future. The commitments in the Kukui Cup are intended to either improve participants energy literacy or reduce energy consumption, but for practical reasons cannot be verified through the website as activities are (see Section 3.6.3.3). Example commitments are:

- Turning off the lights when leaving a room,
- Turning off/shutting down all appliances before going to sleep, and
- Using sunlight instead of electric lighting.

While each of these commitments should reduce energy use, verifying compliance would require a massive network of embedded sensors throughout the towers, with a consequent massive invasion of participant privacy. The inability to verify that commitments are being met could lead participants to cheat and make commitments that they had no intention of meeting, just to earn points. We addressed this issue in two ways. First, commitments made by participants are public to all members of the same lounge. By making them public, we hope to encourage peers to point out commitments that have been made but are being violated. As discussed in Section 2.5.1, public commitments have been shown to be more effective than private commitments, providing further reason to make commitments public. Second, each commitment is only worth 5 points (with a possible 5 point social bonus), each participant can only make five commitments at a time, and each commitment lasts for five days. Since the challenge lasts 21 days, this cap limits the number of points that a participant can earn from commitments at 200 points, which is low enough that a cheating participant (who commits with no intention of acting on the commitment) would not sabotage the point competition.

When a participant has made a commitment, they can return to the challenge website in five days to collect their points. The participant verifies their completion of the commitment by clicking on a button to affirm that they did live up to the commitment. While this self-verification still allows a participant to receive points without actually performing the commitment, it requires the participant to make a conscious decision to do so. Participants can repeat commitments after they expire, if they wish.

3.6.3.5 Events

We held 24 events and excursions as part of the challenge. Events were generally workshops, games, or parties held on the UH Mānoa campus, while excursions took place off-campus. Some examples of events are:

- Kickoff party (held on evening of first day of challenge),
- Energy scavenger hunt (looking for devices using specific amounts of power), and
- Wind farm tour.

Participants could view the list of upcoming events on the challenge website, and could sign up to indicate their desire to attend. Signing up for an event earned participants 2 points instantly. To verify attendance, at each event a challenge administrator handed out small printed slips of paper that contain an *attendance code*. Each attendance code is unique to the event, and contains a random string of characters generated by the website in advance, such as `windfarm-it397`. After the event is complete, participants that attended can enter the attendance code they received into the challenge website. The website then verifies that the code is valid, has not already been used, and corresponds to the event in question. Unlike activity verification, if the code is valid, the participant is awarded points immediately upon submission. To encourage participants to only sign up for events they actually wanted to attend, participants that signed up for an event but failed to enter an attendance code (either because they did not attend the event or they forgot to enter the code) were penalized 4 points: reversing the 2 point signup bonus and deducting a 2 point penalty.

3.6.4 Daily Energy Goal Game

As described in Section 2.5.2, setting goals for energy conservation has been shown to aid in conservation efforts. To help lounges reduce their energy use, we created the Daily Energy Goal Game, where each lounge attempts to use less energy each day than the goal set. The goal was determined by computing a baseline of energy use for each lounge and subtracting a fixed percentage from each baseline. At the end of each day, if a lounge had met its energy goal, each resident in the lounge who is participating received 20 points.

The Daily Energy Goal Game had two additional benefits for the challenge design. First, it provided a short-term energy goal that participants could work towards, shortening the feedback cycle. If a lounge failed to meet the goal one day, the participants could redouble their efforts and try again the next day. Second, it provided a further linking of the energy competition to the point competition.

To aid participants in meeting their daily goal, the challenge website provided a visualization of progress towards the goal, shown in Figure 3.3.

Figure 3.3: Example of the Daily Energy Goal Game visualization

We computed the baseline of each lounge's energy use on an hourly basis. The visualization shows the number of kilowatt-hours used by the lounge so far in the day, and compares it to the energy use goal. The traffic light indicates the energy use: red, when the energy use is above the goal; yellow, when energy use is just below the goal; and green, when energy use is significantly below the goal. Both yellow and green thresholds are configurable.

It was important that the visualization compare the energy use for the day so far, to an equivalent goal for the day so far. Since cumulative energy use is monotonically increasing, if the energy use were compared to the goal for the entire day, it would generally lead to a traffic light that is green for part of the day and then stays red for the rest of the day, which would not be an actionable visualization for participants. Further, we computed the baselines at an hourly granularity, because energy use varies throughout the day. Not doing so, i.e., computing a single daily baseline value and averaging it throughout the day, would cause the visualization to show participants under the goal during the low usage period of the day, but then over the goal during the evening high use period.

3.6.4.1 Baseline and Goal Computation

The energy goal for the Daily Energy Goal game requires a baseline of energy use for each lounge. The baseline should reflect "normal" use, and be closely comparable to the energy use during the challenge period. Figure 3.4 shows the power used by one lounge over the course of a weekday before the challenge, while Figure 3.5 shows the power used by the same lounge over an entire week. The energy use for the lounge differs from an average home or apartment in a few ways: the peak power usage is shifted to near midnight for weekdays, the lowest usage occurs between 8 AM and 10 AM which is typically a high usage period in homes. Usage also varies based on the day of the week: Friday and Saturday evenings have lower and earlier peaks compared to other nights. To capture these hourly and daily variations, we computed baselines each of the days of the week (seven daily baselines), and for each hour of each day of the week (i.e., 168 hourly baselines).

Figure 3.4: Example power usage by Ilima B for one day, pre-challenge

The challenge ran for three weeks starting October 17, 2011. As shown in Table 3.1, full days of meter data for all lounges were only available for Lehua, Ilima, and Mokihana starting on September 10. For lounges in these three towers, I computed the initial baseline as the average energy use from September 10 to October 15 (five full weeks plus one day). The delay in getting meters installed and working properly in Lokelani complicated the baseline computations for that tower. Lokelani A and E got their first full day of data on October 7, so the baseline was computed from October 7 to October 15 (one full week and two days). The baseline for the days of the week with two days of data are were averaged, the rest reflect the actual usage.

The late installation of the meters in Lokelani B, C, and D meant that I had less than one week of data for those lounges before the challenge began. I felt that it was important from a challenge perspective for all lounges to be able to participate fully in the challenge, rather than exclude Lokelani B, C, and D from participating in the the Daily Energy Goal Game or the entire

Figure 3.5: Example power usage by Ilima B for one week, pre-challenge. Dates on x-axis indicate the start of that day (i.e., midnight).

challenge. Lokelani C and D had data from Wednesday October 12 to Saturday October 15, so I used the actual usage as the baseline for those days of the week. For the remaining two weekdays (Monday and Tuesday), I computed the baseline by averaging the data from the three weekdays. Usage on Sunday is different from both weekday and Saturday usage, requiring some additional calculation to provide a reasonable estimate. I computed the ratio of energy use between Sunday and Saturday for each lounges in Lehua, Ilima, Mokihana, and Lokelani A and E. I found the average increase in daily energy use from Saturday to Sunday from the baseline period is 5%, so the Sunday value for Lokelani C and D was the actual usage from Saturday October 15 multiplied by 1.05.

Lokelani B presented the biggest challenge in estimating an energy baseline, since I had only one full day of data from Saturday October 15. I assumed (for lack of other alternative) that the ratio of energy use between lounges on a single day is representative of the ratio of their energy use for each day of the week. For the weekday values, I computed the ratio of energy use on October 15 between Lokelani A and B, and between Lokelani B and E, since lounges A and E were in the same tower and had more than a full week of data. I set the baseline for each weekday as the average of the A to B ratio multiplied by the A baseline for that day, and the B to E ratio multiplied by the E baseline for that day.

Because of the limited energy data for Lokelani, the baselines for Lokelani were speculative extrapolations. However, as discussed earlier in Section 2.2, I was using the baselines here as part of a game mechanic to spur conservation, rather than as a way of evaluating the challenge.

3.6.5 Energy Goal and Baseline Changes

The energy goal for the Daily Energy Goal Game was initially set to a 5% reduction in energy use compared to the lounge's baseline energy use. On the first day of the challenge, 5 of the 20 lounges had already met the 5% daily energy reduction goal. Since the challenge had only been running for 24 hours, with the Kickoff Party event taking place at 6:30 PM, we felt it was unlikely that the challenge could have caused the change. Therefore, it seemed likely that those lounges made their goal due to random variations in energy use rather than behavioral change. For this reason, we set the daily energy goal to 10% for the remainder of Round 1 of the challenge.

Due to the problems we encountered in setting initial baselines for energy use in the lounges, in the interests of fairness, we decided that the baselines should be recomputed for Round 2. We recomputed the baselines for each lounge based on each lounge's energy use during Round 1, ensuring that the baselines were computed with a whole week of data for each lounge. For lounges that had reduced their energy use in Round 1, the new baseline had the side effect of making it harder to meet the goal, since the new baseline would be lower than the initial one. To compensate for the added difficulty, we changed the daily energy goal percentage back to 5%. We used the new baseline and goal percentage unmodified in the final round of the challenge.

3.6.6 Prizes

Prizes were awarded at the end of each round as incentives for participation. There were four categories of awards:

- The lounge that used the least energy (1 winner per round),
- The lounge with the highest score (1 winner per round),
- The individual with the highest score in each lounge (20 winners per round), and
- The individual with the highest score across all lounges (1 winner per round).

In Round 1 and Round 2, only the score earned or energy consumed for that round was used to determine the winner. In the third round, called the Overall Round, however, the overall score or energy was used. There were no prizes awarded just for scores from the third round. Table 3.5 summarizes the prizes awarded during the challenge. As one would expect, the prizes for the Overall Round (the third and final round) were substantially higher value than the prizes for Rounds 1 and 2.

3.6.7 Raffle Game

One problem with the prizes provided in the challenge as incentives is that they only go to the top performers in each competition. For those participants who are aware that they will not win the

Table 3.5: Prizes awarded during challenge

Round	Type of prize	Prize
1	lounge energy	mochi ice cream party
1	lounge score	cupcake party
1	individual per lounge	$5 ice cream gift certificate
1	individual overall	$25 UH bookstore gift certificate
2	lounge energy	malasada party
2	lounge score	locally-made popsicle party
2	individual per lounge	$5 gelato gift card
2	individual overall	$25 UH food service gift card
overall	lounge energy	pizza party
overall	lounge score	pizza party
overall	individual per lounge	$10 UH bookstore gift card
overall	individual overall	iPad 2

point competitions, the prizes provide little incentive, or possibly a disincentive: why play if there is no way to win a prize? Another problem with the prizes is that to be effective, they had to appeal to all participants, limiting the options for prizes.

We developed the Raffle Game to provide a prize-based incentive to play that was not limited to the top players, through inspiration from Balaji Prabhakar's work incentivizing road congestion reduction [83]. In the Raffle Game, there are a variety of raffle prizes available in each round of the challenge. For each 25 points a participant earns, they receive a virtual raffle ticket. Participants can allocate their raffle tickets among the prizes available, and they can change their allocations at any time. Shortly before the end of the round, the raffle is closed and the ticket allocations frozen. A winning ticket is "drawn" from those allocated to each raffle prize, and the owner of that ticket wins the prize. Tickets that are not allocated before the end of a round roll over to the next round, until the end of the challenge. Figure 3.6 shows an example view of the Raffle Game for a user with many tickets, including the odds of winning.

The Raffle Game ensured that every participant who has earned at least 25 points in a round can have some slim chance of winning a prize. Participants can increase their odds of winning a prize by earning more points, providing a clear incentive for further participation. Because participants can choose which raffle prizes to allocate their tickets to, the prizes can appeal to diverse interests, unlike the competition prizes.

3.7 Challenge Website

The Kukui Cup challenge required extensive online support for both the virtual and real-world activities. We developed a custom web application called Makahiki to be the online focus for the

Figure 3.6: Example display of the Raffle Game during the Overall Round

challenge. I was one of the principle designers of the functionality of the website, while application was implemented by George Lee, Yongwen Xu, with assistance from Greg Burgess, Nathan Dorman, and Nathaniel Ashe. The application is written in Python, using the Django web application framework [35].

3.7.1 Website Development

The website was developed in an iterative fashion. An initial version was developed in Fall 2010 with limited input from anyone outside the development team. After showing this alpha version of the website to some external individuals, we received feedback that the website was too confusing and not sufficiently engaging.

Our next step was to develop a series of user scenarios, and visualize them using mockup web pages developed with Balsamiq Mockups tool [2]. The mockups were evaluated by a series of walkthroughs conducted with three UHM ICS faculty members, two community members, and two undergraduate students. Each evaluation was conducted using a think aloud protocol, as the participants viewed each mockup screen on a projector, while the experimenter walked through each user scenario. We recorded the discussion between the participant and experimenter, as well as the computer display. After the evaluations, we revised the mockups based on the feedback we had received.

In Spring 2011, Makahiki was implemented using the revised mockups as the template. In April 2011, we conducted a series of in-lab user evaluations of the website using five first-year students who were living in the Hale Aloha towers. We told the participants that the website they were evaluating was part of an energy challenge we were going to hold in the Fall 2011. We provided no additional details, because one important goal of the challenge website was to be self-explanatory. In the first part of the evaluation session, each participant was asked to pretend they were participating in the challenge, using a think aloud protocol. Participants interactions with the website were recorded as a screencast, along with audio from their interactions with the experimenter. In the second part of the evaluation, the experimenter went over parts of the website with the participant, while asking them questions about their experiences. After reviewing the comments from all five participants, we generated a list of improvements to be made to Makahiki.

In July 2011, once the problems identified with Makahiki from the April evaluation had been resolved, we conducted another round of in-lab user evaluations with five more participants. This evaluation was conducted in similar fashion, with participants pretending to be participants in the challenge and using the website while their actions and discussion was recorded. These evaluations resulted in another set of improvements in Makahiki.

While the in-lab evaluations were helpful, each one involved less than one hour of play, and the website designers were at hand to answer any questions in person. Since we conducted the in-lab evaluations individually, they didn't provide any insight into the competitive aspects of the Kukui Cup. To address this gap in our evaluation, we organized a beta test of the Kukui Cup in August 2011. We recruited four teams of five players, from friends, family, colleagues from industry, and local environmental organizations. The beta test consisted of two three day rounds to allow us to test the awarding prizes and the Raffle Game. The beta test uncovered several implementation defects that were corrected, as well as suggestions for additional actions. Further details on the development of Makahiki can be found in George Lee's thesis [72].

3.7.2 Website Functionality

We designed the challenge website to be as easy as possible for residents to start participating. This section describes the features of the website.

3.7.2.1 First Login Process

During the challenge, when users went to the website [18], they saw a landing page like the one shown in Figure 3.7. The landing page guides the residents eligible to play (those living in Hale Aloha) into the challenge site, while providing some background information on the challenge for everyone else.

To provide each participant with personalized information, the challenge website required participants to log on with their University of Hawaiʻi username and password. Using their existing credentials ensured that participants did not have to remember another username and password, which could have been a barrier to participation. The integration was made possible using UH's

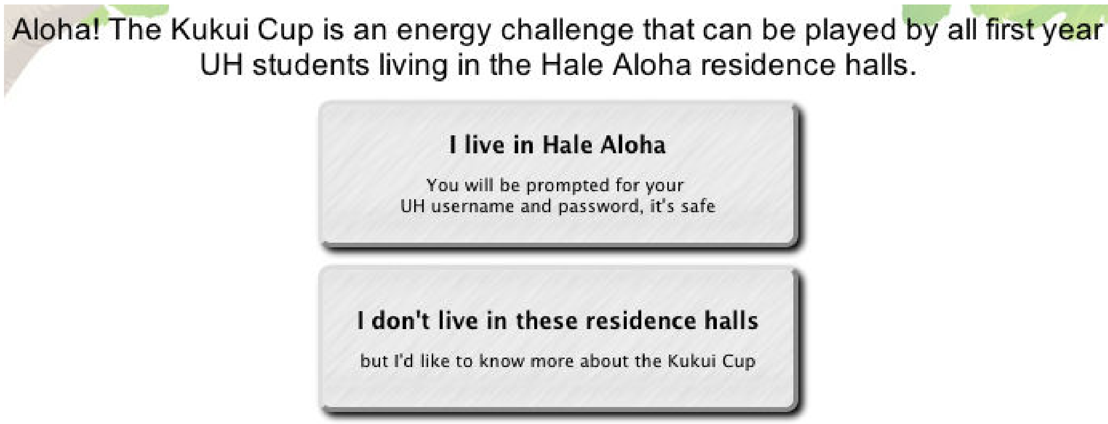


Figure 3.7: A portion of the challenge website landing page

Central Authentication System. Using a roster provided by UH Student Housing, we were able to prepare accounts for all residents, including which lounge they were living in.

The initial experience of bringing a new player into a game is referred to as *onboarding* [125]. This process is critical, because all players will experience it, and if the onboarding experience is poor, then potential participants may never sign up or play the game. In our user evaluations, we found that the onboarding process needed to explain the basic mechanics of the game, but remain short enough that new players would complete the process.

After logging in, new participants were sent through a first-login process. There were seven steps in the process:

1. Introduction and chance to verify tower and lounge residence;
2. Terms and conditions, including informed consent;
3. Referral bonus email address entry (see Section 3.6.3.2);
4. Profile setup, choosing display name, profile picture;
5. Introductory video, a 2:09 long embedded YouTube video;
6. Question based on introductory video; and
7. Completion of first-login process.

3.7.2.2 General Page Structure

After the first-login process is complete, and on each subsequent log-on, participants were taken to the home page as shown in Figure 3.8. The header of the page is shared across all pages on the website. On the left side of the header is the Info Bar, which shows how many points the participant has earned, their standing in the competition, and energy use by their lounge. The Info Bar rotates through the different displays every few seconds. On the right side of the header is the Navigation Bar that contains icons representing the six pages in the website: clicking on the icon takes the user to that page.

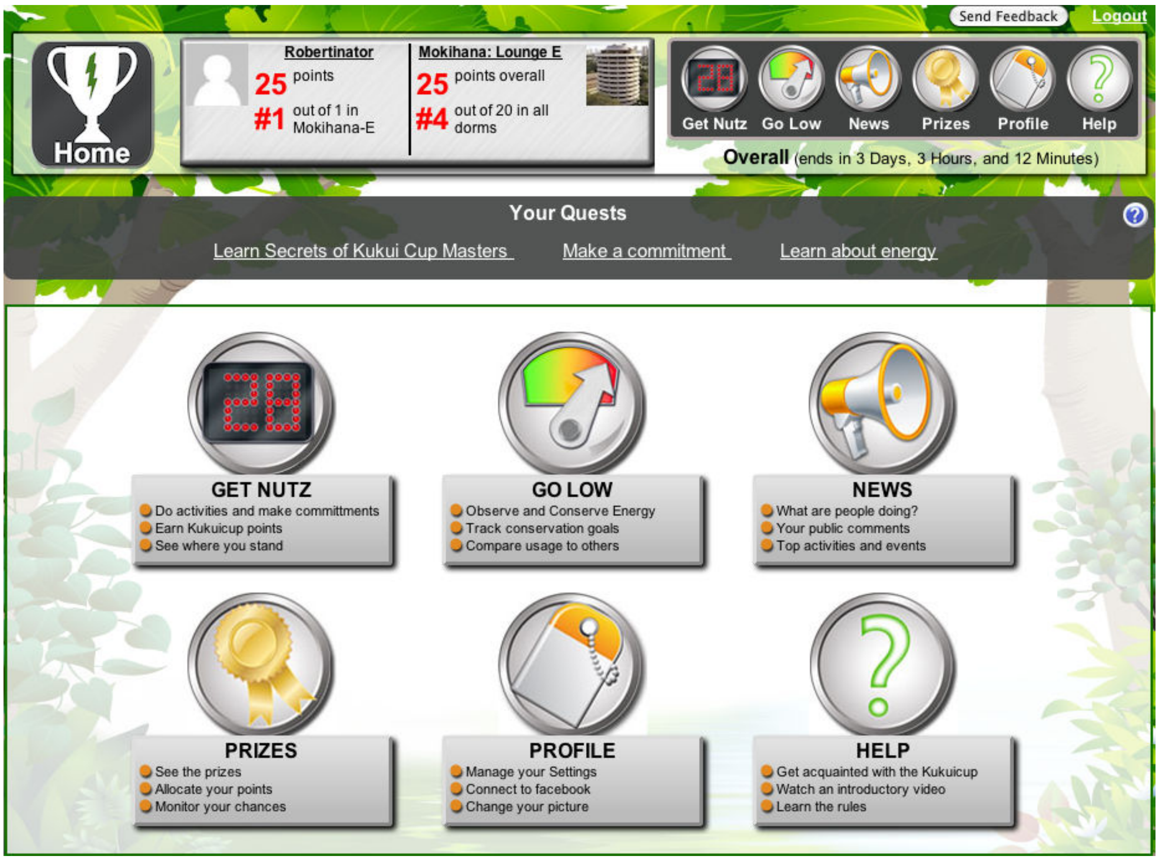


Figure 3.8: The challenge website home page

Below the header is the Quest Bar, which shows the quests available to the participant. We created quests to guide participants through the website and the actions they could take. Each quest has a name, a description, a level, unlock conditions, and completion conditions. The up to three unlocked quests were shown to participant in the quest bar, ordered by the level of the quest from lowest to highest. If the participant clicked on a quest title, the quest bar expands to show the quest description. After seeing the quest description, participants can choose to accept the quest or close the quest description. Once accepted, the quest is active until the participant meets the completion conditions. Some example quests from the 2011 Kukui Cup were:

- "Learn Secrets of Kukui Cup Masters", which required participants to watch a video explaining some tips on how best to play the Kukui Cup.

- “Sign up for an event”, which guided participants through the process of signing up to attend their first event.

- “Get the Fully Committed Badge”, which encourages participants to sign up for five commitments, thereby earning the badge.

The six pages of the site are:

- Get Nutz: take actions for points, view scoreboards;

- Go Low: real-time energy data, Daily Energy Goal game, energy; scoreboard

- News: shared lounge “wall” (like Facebook) with recent actions taken and discussion;

- Prizes: list of prizes and Raffle Game;

- Profile: make changes to display name, view list of past actions taken;

- Help: rules of challenge, frequently asked questions; and

- Canopy: a special area of the site where advanced users can view additional energy visualizations

I now examine each of the pages in turn.

3.7.2.3 Get Nutz Page

The Get Nutz page is the primary place where participants could engage in the point competition. The title of the page refers to the kukui nut that the Kukui Cup is named after. Figure 3.9 shows the a view of the Get Nutz page from the Overall Round of the challenge.

The main focus of Get Nutz is the Smart Grid Game, which takes up most of the right side of the page. The Smart Grid Game organizes the actions described in Section 3.6.3 that participants can take to earn points. Each column organizes actions around a particular topic, such as “Make Watts” for actions related to energy generation. Each type of action had a different color. Actions that are unlocked display only the point value associated with the action, while locked actions are displayed with a lock icon. Once an action has been completed, the cell displays the name of the action and a small checkmark in the upper-left corner.

On the left side of Get Nutz are the Upcoming Events widget and the Scoreboard widget. Upcoming Events showed events that will take place over the next seven days. Each entry is a link to the event page, which displays details of the event and allows participants to sign up for the event. The Upcoming Events widget also allowed participants to type in event attendance codes directly, without navigating to the event details page.

Figure 3.9: The Get Nutz point competition page

The Scoreboard widget rotates through four separate scoreboards showing the top ten entries in different categories for the current round: lounge scores, individual scores across all lounges, individual scores within participant's lounge, and participation rates of lounges (see Section 5.8.1).

3.7.2.4 Go Low Page

The Go Low page is the focal point for the energy competition. The page is titled Go Low to remind participants that in the energy competition, the lowest energy use wins (unlike the point competition, where the goal is to obtain as many points as possible). Figure 3.10 shows a view of the Go Low page from the Overall Round of the challenge.

The right side of the page shows the Daily Energy Goal game, described in Section 3.6.4. The visualization of the Daily Energy Goal game was implemented in JavaScript, so updates happen dynamically in the browser. To help participants meet their goal, below the Daily Energy Goal game is a section listing actions in the Smart Grid Game related to energy conservation (the list is empty in Figure 3.10 because the participant has completed all the relevant actions). The bottom portion of the right hand section contains the shared lounge discussion area, called the lounge *wall* after the similar feature in Facebook. Participants can type short messages on the lounge wall that are displayed to all members of the lounge in reverse-chronological order. The wall is intended to provide a communication tool for the participants to strategize about energy conservation.

The left side of the page contains the Current Power widget and the Energy Scoreboard widget. The Current Power widget shows the power consumption of the participant's lounge, updated once every 15 seconds. The gauge is calibrated so that the needle pointing directly up corresponds to the average baseline power usage for the current hour of the day. When the needle moves to the right side of the gauge, it represents higher than average power usage for the current time of day, while the left side represents lower than average power usage. The gauge was implemented in JavaScript using the Google Visualization API.

The Energy Scoreboard widget ranks all twenty lounges in order of increasing energy use for the current round, and all previous rounds. It also shows a ranking of lounges by the number of energy goals completed by the lounge.

3.7.2.5 News Page

The News page of the challenge website showed participants what was happening in the challenge and in their lounge. Figure 3.11 shows an example of the News page.

The left column shows two widgets: Lounge members and News Feed. The Lounge members widget shows a subset of the participants in the lounge along with their selected profile picture, with a link to a page showing all the members. The News Feed provides a simple discussion board for lounge members similar to the 'wall' concept on Facebook. Participants could type in messages that would be displayed to all other members of the lounge, in reverse chronological order. The

Figure 3.10: The Go Low energy challenge page

Figure 3.11: The News page of the challenge website

system created automated posts when participants performed an action like making a commitment or earning points.

The right column shows three widgets: Upcoming Events, Most Popular, and My Public Commitments. The Upcoming Events widget shows any events taking place today or in the next 7 days. After an event, participants can enter their attendance code directly into the text field to receive points without having to navigate to the specific event page.

The Most Popular widget cycles through a list of events, activities, and commitments ranked in order of how many participants have performed those actions. This widget is intended highlight the popular actions and encourage participants to take part in them. The My Public Commitments widget simply lists the commitments that the participant, which is intended as a reminder to live up to the commitments.

3.7.2.6 Prizes Page

The Prizes page showed participants more information about the incentives available in the challenge. Figure 3.12 shows a portion of the Prizes page from the Overall Round of the challenge.

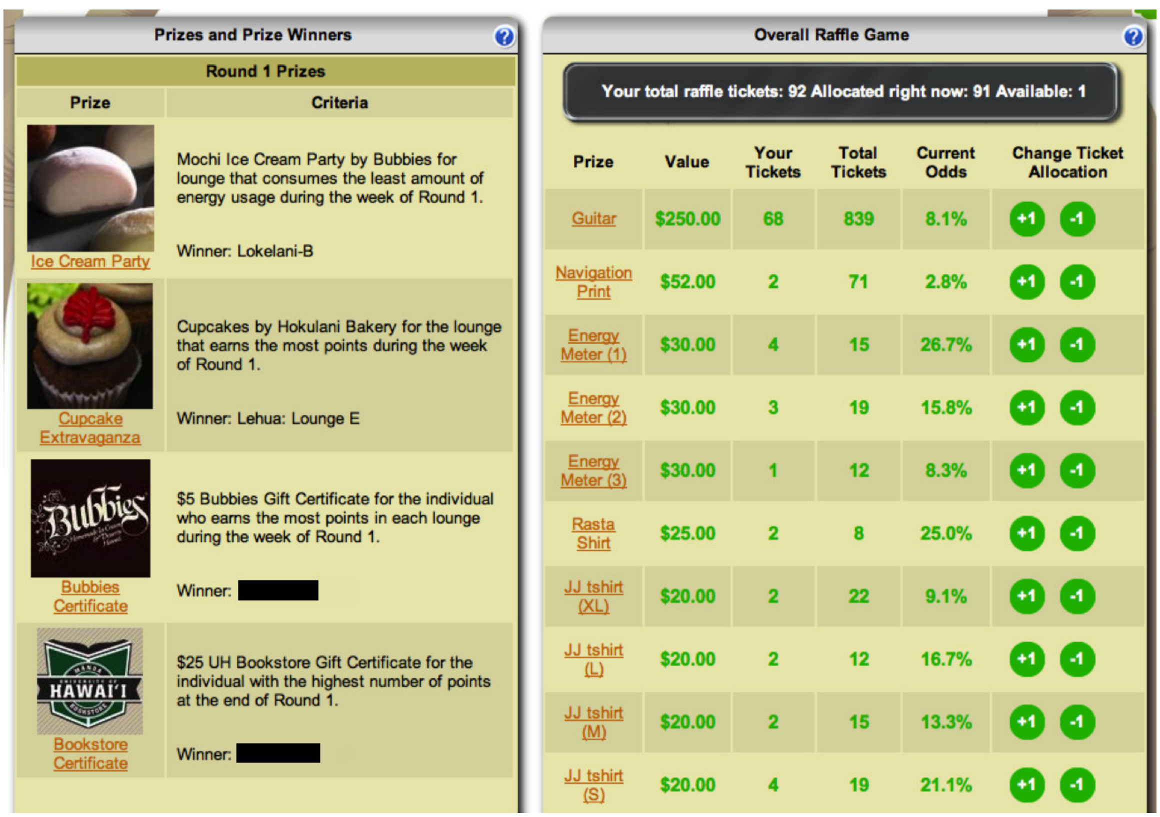


Figure 3.12: An excerpt from the Prizes page of the challenge website

The left side of the Prizes page shows the prizes awarded to the top participants in each category, as described in Section 3.6.6. For each prize, the widget showed the lounge or individual in first place for that competition (the currently projected winner). The right side of the prizes page showed the Raffle Game described in Section 3.6.7.

3.7.2.7 Profile Page

The Profile page allowed participants to edit their personal information and view data about their progress in the game. Figure 3.13 shows what the Profile page looks like.

Figure 3.13: The Profile page of the challenge website

The left side of the page contains the My Info widget. In My Info, participants could change their display name (used to identify the participant on the website, such as on scoreboards or the lounge News Feed), profile picture, and contact information used when event reminders were requested.

The right side of the page shows challenge information for the participant: My Badges, My Public Commitments, and My Achievements. Participants could earn badges for reaching certain goals, such as making five commitments, and the badges earned were displayed in the My Badges widget. My Public Commitments shows the participants commitments (also shown on the News page). My Achievements showed a complete record of all actions taken by the participant in the challenge and all points earned.

3.7.2.8 Help Page

The Help page is shown in Figure 3.14. On the left side of the page showed the introductory video and links to the rules of the challenge. On the right side, one widget showed links to frequently asked questions, and the Ask an Admin widget. Ask an Admin allowed participants to send questions to the challenge administrators, which was delivered by email. The Ask an Admin functionality was also available on every page of the website using the Send Feedback button at the top right corner of the page.

Figure 3.14: The Help page of the challenge website

3.7.2.9 The Canopy

The Canopy was an area of the website designed to provide an additional level of experience for the top participants in the challenge. The background of the challenge website featured a forest theme, so the Canopy was named to convey that it existed above the rest of the website. Many games feature different levels of difficulty, something that was not addressed in the Smart Grid Game. The Canopy was conceived as a way to keep the top participants engaged even if they had earned most of the points available in the Smart Grid Game.

The Canopy was intended to be introduced to top players at the beginning of Round 2 of the challenge. The top 50 participants would be sent an email inviting them to a new part of the website. In keeping with the Canopy motif, Canopy members would access the Canopy page by finding a hidden link at top of each web page. The link was hidden until the Canopy member's mouse moved over the link, at which point it was displayed permanently. The "Head up to the Canopy" link can be seen at the top of Figure 3.14.

Figure 3.15 shows the Canopy page itself. The Canopy provided a series of missions, which were displayed just under the header in a similar fashion to the quests in the forest portion of the website. Some Canopy missions were to be accomplished individually, while other missions required two or three participants to work together. Participants could indicate that they were "up" for a group mission to find other interested participants.

The Canopy missions contained links to Canopy activities. Canopy activities were like forest activities (see Section 3.6.3.3), but instead of earning points upon completion, Canopy activities earn *Canopy Karma*, which was a separate point system for the Canopy. Canopy Karma was used instead of the standard points to ensure that the Canopy itself did not unbalance the point competition by providing a way for the top players to earn more points that were not available to the rest of the participants.

The energy data and visualizations shown on the Go Low page were deliberately simple to avoid confusing participants, based on the results of usability testing. In addition, the detailed energy data shown on Go Low comes only from the participant's lounge. Since the Canopy was intended for the top participants of the challenge, who were believed to be more receptive to detailed energy data and data for other lounges, energy visualizations feature prominently in the Canopy. Several of the Canopy activities involved looking at the advanced visualizations and answering questions based on their understanding of the data.

Since the members of Canopy cut across different lounges, a special Canopy Feed discussion board was provided to allow collaboration. The Canopy Feed worked in the same way the lounge News Feed described in Section 3.7.2.5. The Canopy also featured a Canopy Karma scoreboard showing the top participants in the Canopy, and a $25 UH Bookstore gift card was offered as a prize to the participant with the most Canopy Karma at the end of the challenge.

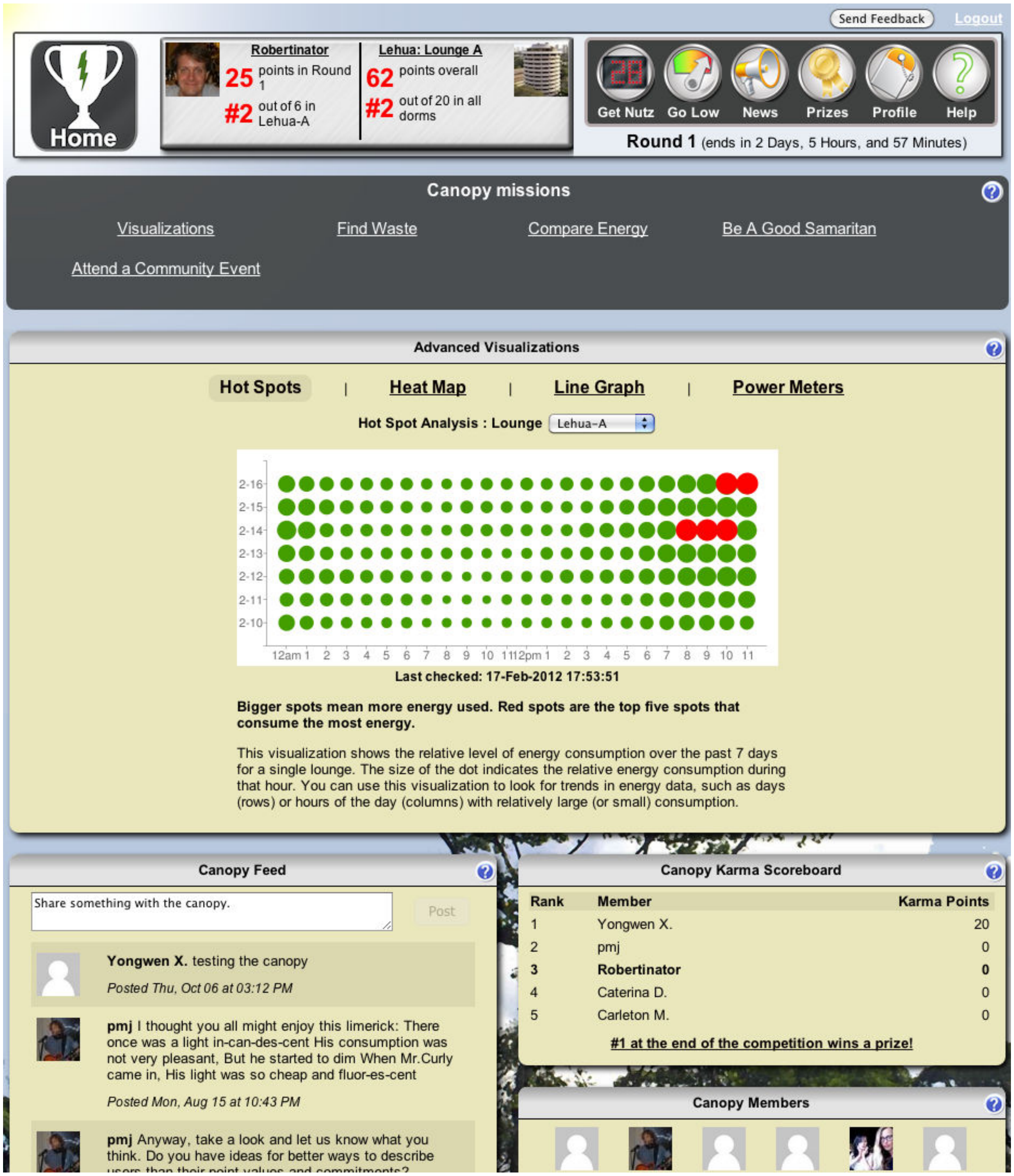


Figure 3.15: The Canopy page of the challenge website

3.7.3 Energy Data Integration

The energy data for the challenge was stored in a WattDepot server. Before and during the challenge, the energy meters were queried at approximately 15 second intervals. After the challenge was over, there was no need for real-time data, so I changed the query interval to 5 minutes.

The challenge website has several areas that require access to energy and power data: the Daily Energy Goal Game, the Current Power gauge, and the Energy Scoreboards. Since each of these components run in the browser and dynamically update, the load on the WattDepot server could be proportional to the number of participants in the challenge. To reduce the potential load on on the WattDepot server, Professor Philip Johnson wrote a system called WattDepot-GData [61], which periodically queries a WattDepot server and stores the results in a Google Docs spreadsheet. The spreadsheets created by WattDepot-GData are structured to meet the needs of the Makahiki visualizations, such as the total energy use since the beginning of the current round of the challenge. Using Google Docs to store the data in the cloud also insulates the WattDepot server from heavy client loads.

CHAPTER 4
EVALUATION

This chapter describes the way I evaluated the 2011 UH Kukui Cup challenge and associated software system described in Chapter 3. First, I cover the overall experimental design, followed by details on the three primary experiments I conducted: challenge participation, energy literacy, and energy use. The research questions the evaluation is intended to address are:

1. *To what extent did residents participate in the challenge?* I ask this question because without significant participation in the challenge, there would be insufficient data to answer the rest of the questions.

2. *How did energy literacy change after the challenge?* We designed the challenge to increase the energy literacy of participants, so this question assesses one aspect of the challenge's effectiveness.

3. *How did energy use change during the challenge?* A standard measure for energy competitions, the expected result is that energy is conserved during the competition.

4. *How did energy use change after the challenge?* Understanding changes in energy use after the challenge is over gives insight into whether changes during the challenge were sustainable. Existing research focuses primarily on the challenge itself, not examining the reasons why energy usage might rebound after the challenge is over.

5. *What is the relationship between energy literacy and energy usage?* I hypothesize that more energy literate participants will conserve more energy; therefore, I examined the relationship both during the challenge and afterwards.

6. *How effective were the* actions *available via the website?* Are the actions that players complete during the challenge effective at improving energy literacy?

7. *How appropriate were the point values assigned to actions?* The points assigned to actions are intended to motivate participants to perform the actions, but the values were assigned without any participant data.

8. *How important was lounge-level near-realtime feedback?* There are good reasons to believe that lounge-level near-realtime feedback will lead to increased energy conservation, but they also greatly increase the challenge budget and logistical complexity. Is the trade-off worth it?

4.1 Experimental Design

I have pursued a largely quantitative approach to the evaluation of my research questions [22]. From this perspective, the participants in the study are all the residents in the Hale Aloha towers, and the entire Kukui Cup challenge can be viewed as the intervention. To produce a *true experiment*, I would need to create control and treatment groups and assign participants to the groups randomly. Unfortunately, the logistics and design of the game experience led to complications for the experimental design. In designing the game, we felt that it would be unfair to residents to create a control group that was not allowed to play, especially because players could earn prizes. We also worried that if we created a control group that could not play, this decision could create a negative backlash against the challenge, with players in the control group encouraging those in the treatment group to not play. Creating a control group would have also created logistical issues around preventing access to the game, because we held public events such as workshops and award parties that were open to all Hale Aloha residents. Finally, we felt that our partners in Student Housing would not be supportive of a Kukui Cup challenge in which some residents could not participate only for the purposes of research design.

Since random assignment to control and treatment groups was not feasible in the 2011 UH Kukui Cup, I use a quasi-experimental design with non-randomized group assignment. While all Hale Aloha residents were able to participate in the challenge, I had no expectation that all of them would participate. Since participation in the challenge is the treatment, in effect residents self-selected whether they were in the treatment or control group by whether or not they participated in the challenge.

Unlike some interventions, the 2011 UH Kukui Cup was a dynamic experience that included direct interactions with participants by myself and other researchers both online in responding to emailed questions and in person at events held during the challenge. My research's combination of researcher involvement, attempting to "improve" the participants of the study, while simultaneously generating knowledge is similar to the *Action Research* approach [65]. Action Research commonly involves an organizational client that is trying to solve a problem. However, in the case of the Kukui Cup, the impetus for the change came from our identification of the problem rather than the participants. The challenge itself also changed during the study, such as the addition of referral bonus (Section 3.6.3.2).

The following sections describe the individual experiments I conducted in an effort to answer my research questions.

4.2 Challenge Participation Experiment

Research question #1 is "to what extent did residents participate in the challenge?" First, I must define what it means to participate in the challenge.

4.2.1 Participation Definition

Participation in the Kukui Cup challenge was a critical measure for the evaluation of the impact of the system. All residents were indirectly participating in the energy competition because their electricity use was being monitored in aggregate, regardless of their awareness of the competition itself. However, I use the term participation here to indicate a conscious participation in the Kukui Cup, which can be measured in a variety of ways.

I use the score of each user as the metric for participation in the Kukui Cup. The challenge website was its focal point. The website provided the only way to earn points, and the primary way to see scoreboards and information about events. When logging into the website for the first time, users are funneled through a first-login process where they must view and accept the consent form and choose a nickname. All users who complete the first-login process earn a minimum of 5 points, so any users that used the challenge website had a non-zero score. The first-login process also displays a short introductory video and prompts the user to answer a simple question about the video to earn an additional 20 points. So most first-time users will have earned 25 points by the time they arrive at the home page of the challenge website. Therefore, I classify any user with 25 points or more as a participant in the challenge, which is conservative threshold because it only requires a single visit and no activity beyond those mandated by the first-login process.

It is possible for resident of Hale Aloha to have participated in aspects of the Kukui Cup without earning points. For example, residents could have attended events by accompanying friends or come upon them serendipitously, without submitting the paper attendance code that would allow them to earn points for attendance. Residents also could have participated by discussing sustainability topics with active participants or been lobbied to reduce energy use to improve their lounge's standings in the energy competition. Neither of these activities would have generated any evidence in the form of points in the challenge. Despite these caveats, I believe a 25 point threshold is a good, minimal measure of participation.

4.2.2 Challenge Participation Experimental Design

The assessment of challenge participation does not include a control group, because the dependent variable is whether residents participated or not. In Creswell's terminology, this experiment is a one-shot case study [22, pg. 168]. Using the notation from Campbell and Stanley [14], the challenge participation experiment can be diagramed as shown in Figure 4.1, where X represents exposure to the treatment and O represents a measurement.

Residents X ——— O

Figure 4.1: Diagram of participation experiment

The data on participants are collected continuously, but the measurement made is the total of all data collected through the challenge period. Use of the website generated two different sets of data: an SQL database, and a log file. The SQL database (generated by MySQL) represents the entire state of the game: the configuration and the record of all player actions. The log file contains a single line of text for each user action (i.e., mouse clicks) on the website, including the user who initiated the action and the time of the action.

Using the website data, I can determine how many users met the 25 point threshold described earlier. Once logged in, the primary interactive feature of the website is the challenge action system. The number of actions completed per participant is another player participation. The data were extracted from the database using SQL queries, and then further analysis was performed in Microsoft Excel 2011 for OS X.

4.3 Energy Literacy Experiment

Research question #2 is "how did energy literacy change after the challenge?" I hypothesized that the experience of participating in the Kukui Cup challenge would increase participants' energy literacy. To address this question, I used a quasi-experimental design with non-equivalent (non-randomized) control group assignment [19]. Using the notation from Campbell and Stanley, the challenge participation experiment can be diagramed as shown in Figure 4.2, where X represents exposure to the treatment and O represents a measurement, and the dashed line represents groups not assigned by random selection.

```
Challenge participants        O ——— X ——— O
                              - - - - - - - - - - - - - -
Non-challenge participants    O —————————- O
```

Figure 4.2: Diagram of quasi-experimental design of energy literacy experiment

Note that participants self-select whether they belong to the treatment or control group by choosing whether or not to participate in the challenge.

4.3.1 Questionnaire Development

In answering research question #2, I used the definition of energy literacy introduced earlier in Section 2.8, consisting of attitudes, behaviors, and knowledge regarding energy. To assess energy literacy in participants, I developed an energy literacy questionnaire. The complete version of the questionnaire can be found in Appendix D.

The first section of the questionnaire I developed was the energy knowledge scale. While others have designed measures of energy knowledge, such as the one developed by DeWaters and Powers [31], I found the existing instruments inappropriate for use in the Kukui Cup for three reasons.

First, energy knowledge instruments designed for use in contiguous United States include information that is not accurate for Hawaiʻi. For example, the DeWaters and Powers instrument has a question that asks what activity uses the most energy in the average American home, the answer being heating and cooling rooms. However, for homes in Hawaiʻi, the largest consumer of energy is usually heating water (though not in homes that have a solar hot water heater). Hawaiʻi's energy situation has many differences from the other 49 States, and in the Kukui Cup we wished to emphasize Hawaiʻi's unique problems and solutions. Second, the DeWaters and Powers energy knowledge instrument was designed for high school students, and so some questions assessed energy knowledge of the type that might be learned in a class, but are not of practical use. Finally, the DeWaters and Powers energy knowledge instrument was quite long, consisting of 38 multiple choice questions.

Finding other energy knowledge instruments inappropriate for my needs, I developed my own energy knowledge instrument. It includes both generally applicable questions such as converting between power and energy, and Hawaiʻi-specific questions such as the sources of Hawaiʻi's energy. I piloted the energy knowledge instrument with fellow members of the CSDL research group, and with students in ICS 414 (Software Engineering II) and some graduate students taking ICS 699 (Directed Reading/Research) at the University of Hawaiʻi at Mānoa in May 2010. Based on the results of the pilot and feedback from Professor Johnson and members of CSDL, I revised the instrument to remove some less relevant questions.

For the energy attitudes section of the questionnaire, I used the DeWaters and Powers affective subscale with permission from the authors. The affective subscale asks participants to rate how they feel about statements on a five-point Likert-type scale from strongly agree to strongly disagree. I made two changes from the DeWaters and Powers affective scale. The wording of Statement 11 ("America should develop more ways of using renewable energy, even if it means that energy will cost more.") was changed from "using" to "generating", clarifying that there is no problem using renewable energy. The other change was the addition of Statement 18 ("Many of my everyday decisions are affected by my thoughts on energy use."), which was part of the behavior subscale for DeWaters and Powers but matched the attitude questions here better than the behavior items.

For the behavior section of the questionnaire, I started with the DeWaters and Powers behavior subscale, which listed behaviors with a five-point Likert-type scale ranging from almost always/always to hardly ever/never. However, the content of the subscale was inappropriate for Kukui Cup use because it included behaviors inappropriate for Hawaiʻi (such as turning down the heat at night), as well as certain behaviors less relevant to college students living in a residence hall. Instead of using the DeWaters and Powers behavior subscale, I used the format, but picked behaviors that were appropriate to the Hale Aloha residents. I developed the commitments available in the Kukui Cup point competition (Section 3.6.3.4) with the same requirements in mind. Therefore, I based the behavior items in the questionnaire around the list of commitments available in the challenge (see Section C.2 for a complete list).

In addition to energy literacy, I wanted to assess how much participants identified with their lounge team, and assess their connectedness to nature, since the CNS scale had been claimed to be a good predictor of energy conservation. I used the Arrow-Carini Group Identification Scale 2.0 [55] and the Connectedness to Nature Scale (CNS) [80] unmodified as additional sections in the questionnaire.

The questionnaire did not include any demographic questions such as asking participants their gender, intended major, or whether they were new to Hawaiʻi or had lived in Hawaiʻi before. These type of demographic questions were left out in an attempt to make the questionnaire simpler and shorter, but in retrospect they would have provided additional useful data.

4.3.2 Questionnaire Administration

My original plan administering the questionnaire was to present it to all players as part of the first login process. However, as discussed in Section 3.7.2.1, the critical player onboarding process is very sensitive, and adding a mandatory 20 minute energy questionnaire was completely infeasible. Also, administering the questionnaire as part of the first login process would not provide any data on the control group of non-challenge participants.

I settled on administering the questionnaire online using the SurveyGizmo web service [116]. Like many other online survey websites, SurveyGizmo allows researchers to design a questionnaire, invite participants to fill out the questionnaire, and export the results in a variety of ways. The email addresses of potential questionnaire participants were randomly selected from a roster provided by UH Mānoa Student Housing using the `rl` software package [26], which randomly selects lines from an input text file. The roster included the RAs who were living in the Hale Aloha towers, who were not first-year students, so questionnaire participants could potentially include RAs. Only those individuals that participated in the pre-challenge questionnaire were emailed to participate in the post-challenge questionnaire.

The order of the questions in the attitude and behavior sections was randomized for each participant using functionality provided by SurveyGizmo. For the energy knowledge section, within each page of questions, the order of the questions was randomized, as was the order of the multiple choice answers. The group identification and CNS sections were not randomized, since they have multiple items that test the same concept, which could be awkward if placed together.

Questionnaire participants were compensated for their participation by a payment of $10 in cash for each of the pre- and post-challenge questionnaires.

4.3.3 Questionnaire Data Analysis

I analyzed the data from the questionnaire responses using SurveyGizmo, SPSS 20, and Excel 2011 for OS X. Initially, for some exploratory data analysis, I exported data from SurveyGizmo in Excel format, and performed some initial analyses in Excel. Later, I exported data from SurveyGizmo directly in SPSS format, and pre-processed it using SPSS's command language, to perform tasks such as converting reverse-scored items into the overall scoring direction.

Once the data were prepared, I used SPSS to perform mixed-model design ANOVA with the pre- and post-challenge questionnaire repeated measure as the within-participants variable, and challenge participation as the between-participants variable.

4.3.4 Threats to Internal Validity

In this section, I address possible threats to the validity of conclusions drawn through analysis. By internal validity, I mean the "the approximate validity with which we infer that a relationship between two variables is causal or that the absence of a relationship implies the absence of cause" [19, p. 37]. In the case of the energy literacy experiment, internal validity refers to whether there are alternative explanations for changes in pre- and post-challenge energy literacy scores between challenge participants and non-challenge participants.

Because questionnaire participants self-select whether to receive the treatment (by playing or not playing the game), one alternative explanation for differences in energy literacy changes between the treatment and control groups is that those groups differed in their interest or aptitude in learning about energy. Cook and Campbell term this a *selection-maturation* threat [19, p. 53]. It could also be the case that individuals who participate in the challenge are also more likely to take classes related to energy, sustainability, or the environment, and thereby, any increase in energy literacy is due to class work and not the Kukui Cup.

Participation in the questionnaire was voluntary, and attrition in questionnaire responses from pre- to post-challenge is to be expected. However, the reasons for attrition could be a threat to validity, if those participants that consider their energy literacy to be poor after the pre-challenge questionnaire decide to not participate in the post-challenge questionnaire. Conversely, questionnaire participants with a particular aptitude or interest in energy might be more likely to complete both questionnaires. Cook and Campbell refer to this as a *mortality* threat.

Since selection between treatment and control groups was performed by participating in the challenge, members of the two groups were potentially in close proximity to each other: they could even be roommates! The members of the two experimental groups had the potential to interact and treatment group members could convey information they learned as part of the Kukui Cup to control group members, because they were potentially in close proximity. This *diffusion of treatments* effect would act to reduce the observed difference between the two groups.

4.4 Energy Use Experiment

Research questions #3 and #4 are "how did energy use change during the challenge?" and "how did energy use change after the challenge?" respectively. Based on results from other residence hall energy competitions, I hypothesized that energy use during the challenge period would decrease as compared to a baseline of energy use computed from energy use prior to the challenge. While most energy competition research does not examine long-term impacts on energy use, I hypothesized that energy use after the challenge would be higher than during the challenge, but lower than the baseline.

As described in Section 3.5, I was able to obtain energy data only at the granularity of pairs of floors. I recorded both instantaneous power and cumulative energy consumed on a lounge by lounge basis for each residence hall at roughly 15 second intervals. Analyses can only be performed at an aggregated level, because the energy data corresponds to aggregations of participants.

4.4.1 Energy Baselines for Analysis

Section 3.6.4.1 describes the methods and baselines used for the Daily Energy Goal Game. As discussed in Section 2.2, baselines can also be used as a means of assessing the success of an energy competition. The energy baselines used for assessment of lounges' energy use are substantially simpler. The Campus Conservation Nationals competition recommended that participating schools compute the baseline using the two weeks immediately before a three week competition [76]. To smooth out any anomalous energy use, I used an average of three weeks of data before the challenge. Because of the late and problematic installation of Lokelani's meters, I was not able to produce a useful baseline for Lokelani.

4.4.2 Energy Data Analysis

For the analysis of energy data, I used the WattDepot system to calculate the energy used for a lounge for a period of time. I developed a command-line utility written in Java that creates table of weekly energy use for each lounge for all the weeks from the start of the fall 2011 semester (August 22) until the end of finals in the spring 2012 semester (May 11). I used weekly data because weekend energy use differs significantly from weekday usage.

I imported the table of weekly energy use for each lounge into Excel 2011 for OS X. In Excel I noted special weeks (such as Thanksgiving and winter break) and computed average energy used, and comparisons to baselines.

4.5 Energy Literacy and Energy Use

Research question #5 is "what is the relationship between energy literacy and energy usage?" I hypothesize that more energy literate participants will conserve more energy. This hypothesized relationship is one of the goals of energy literacy: to make students understand the reasons for being concerned about energy use, and the techniques they can use to reduce their energy usage. This question can be broken down into three sub-questions:

1. Do lounges with higher average pre-challenge energy literacy scores have lower average weekly energy use during the pre-challenge period?

2. Do lounges with higher average pre-challenge energy literacy scores have a greater reduction in average weekly energy use during the challenge?

3. Do lounges with higher average post-challenge energy literacy scores have a lower sustained energy usage in the post-challenge period?

The first sub-question investigates whether participants who were already more energy literate were already using less energy before the challenge started. This hypothesis neglects the possibility of participants improving their energy literacy through means outside the challenge during the pre-challenge period (e.g., classes, involvement in campus organizations), but this seems a reasonable assumption.

The second sub-question examines whether those participants who started the challenge with higher energy literacy scores used less energy during the challenge, independently of any change of literacy during the challenge.

The third sub-question looks at the critical question of the sustainability of behavior changes in the wake of the challenge. Sustainability is the ultimate goal of any attempt at behavior change.

The data required to answer these questions will already be gathered as part of the energy literacy and energy use experiments described earlier.

4.6 Action Effectiveness Evaluation

Research question #6 is "how effective were the actions available via the website?" The design of the website (described in Section 3.6.3) and the actions it makes available to participants are specifically intended to increase the energy literacy of those that participate in them.

The data required to answer this question was gathered as part of the challenge participation experiment and the energy literacy experiment. The website data provides the number of points earned and actions completed for each challenge participant, and the energy literacy data provides a measure of both total energy literacy and change in energy literacy for participants that completed both pre and post-challenge questionnaires.

4.7 Point Value Appropriateness Evaluation

Research question #7 is "how appropriate were the point values assigned to actions?" Beyond just making actions available to participants, the challenge assigns point values to each action. We assigned point values by hand based on several factors:

- The expected difficulty of the action,
- The expected time required for the action,
- A guess as to how useful the action is to increasing energy literacy and/or reducing energy consumption, and
- The degree to which verification is possible (e.g., commitments, which are self-verified, are worth less than activities and events).

I measured the appropriateness of the point value of actions through website data showing the rate of action completion compared to action rejection (by challenge administrators). This set of data was supplemented by informal feedback from challenge participants on the relative merits of the different actions available.

4.8 Importance of Lounge-Level Real-Time Feedback Evaluation

Research question #8 is "how important was lounge-level near-realtime feedback?" Many energy competitions only use building-level energy feedback, and update at a relatively low frequency, such as once per day. The 2011 UH Kukui Cup used near-realtime energy feedback on a per-lounge level. Providing feedback at the lounge level enables challenge between lounges, allows individual participants to see their behavior changes reflected in electricity usage (which would be swamped by the level of activity if measured at the building level). Near-realtime feedback allows participants to perform their own 'experiments' and see how their behavior changes electricity usage.

Unfortunately, the logistics of lounge-level near-realtime electricity metering provide some of the most significant challenges to the research: the cost of purchasing the meters, the time and effort required to have them installed by electricians, and the lead time required to have the meters in place before the challenge can begin.

Thus it is reasonable to ask whether deploying lounge-level near-realtime electricity metering is worth the effort. All lounges received the near-realtime feedback, so I must use indirect indications of the utility of the metering. One source of data is the popularity of actions (based on website logs) that make use of the lounge-level near-realtime metering.

In order to obtain data on challenge participants' experiences with the Kukui Cup, we devised an in-game feedback questionnaire. Appendix E lists the contents of the questionnaire. Since it was only feasible to provide one questionnaire to participants, each member of the Kukui Cup research team wrote their own questions, which were placed in separate sections of the questionnaire.

The questionnaire was made available to challenge participants through the Smart Grid Game as part of the Overall Round of the challenge. Participants earned 40 points for participating in the questionnaire. Like the energy literacy questionnaire, the feedback questionnaire was administered using SurveyGizmo. Obviously, the in-game questionnaire only reached challenge participants, and only those that were still playing the game in the third week of the challenge.

I believe the importance of lounge-level near-realtime monitoring would be demonstrated if:

- Residents participate in the challenge in significant numbers;
- Of those participants that completed at least one action, 25% completed an action that required either lounge-level monitoring or near-realtime monitoring; and
- Respondents to the feedback questionnaire agree on average that having lounge-level near-realtime monitoring was helpful in the challenge.

Ultimately, the decision to use lounge-level near-realtime metering in future energy challenges will be a based on a cost/benefit analysis, and the answer for one institution or situation might not be appropriate for all.

4.9 Threats to External Validity

Like most research, my work is intended to be applicable outside the specific context of the 2011 UH Kukui Cup. External validity refers to the generalization of results to other populations and settings. This section covers some of the potential threats to the external validity of my results.

I have emphasized Hawai‘i's rather unique energy situation as a core part of the 2011 UH Kukui Cup experience. It is possible that this unique situation leads to more (or less) interest in the challenge among players than would be found at other institutions outside of Hawai‘i.

The energy measurement in the 2011 UH Kukui Cup required aggregation of energy data across a large group (54 people in a lounge) who may not identify as a group. Energy competitions in other circumstances including smaller team sizes and/or more close knit group identities might lead to different levels of participation in the challenge.

A university residence hall is a fairly unique setting in which the residents are presumably amenable to learning, since they are in this setting to learn. This potentially stands in contrast to another setting such as an office building, where occupants (like dorm residents) might not be aware of or pay for their energy use, but might not be as eager to play a game to learn about energy.

4.10 Summary

To address the eight research questions I posed at the start of this chapter, I have conducted three experiments on: challenge participation, energy literacy, and energy use. The challenge participation experiment used data generated from the website to determine how many residents actually participated in the challenge, using 25 points as the threshold for participation.

The energy literacy experiment used a quasi-experimental design with non-equivalent control group assignment. A randomly selected group of residents were sent a energy literacy questionnaire both before the challenge and after the challenge. Those residents that chose to participate in the challenge self-selected to the treatment group, while those that did not end up participating in the challenge remained as the control group.

The energy use experiment used continuously collected energy data from each lounge to compare energy use during and after the challenge to a three week average baseline of energy use before the challenge.

The remaining research questions were addressed primarily using data collected as part of the three experiments, with the addition of an in-game questionnaire that was provided to challenge participants as part of the actions available in the final round of the challenge.

CHAPTER 5
RESULTS

This chapter covers the results from the 2011 Kukui Cup challenge, and how those results address my research questions:

1. To what extent did residents participate in the challenge?
2. How did energy literacy change after the challenge?
3. How did energy use change during the challenge?
4. How did energy use change after the challenge?
5. What is the relationship between energy literacy and energy usage?
6. How effective were the actions available via the website?
7. How appropriate were the point values assigned to actions?
8. How important was lounge-level near-realtime feedback?

I begin by examining participation in the challenge, which is supported primarily through log data from the website itself (RQ#1). Second, I turn to an examination of energy literacy using the results from the pre- and post-challenge energy literacy questionnaire (RQ#2 and #5). Next, I cover the energy use before, during, and after the challenge (RQ#3 and #4), including a discussion on baselines. The following sections address the remaining research questions (RQ #6, #7, and #8), and some additional results unanticipated by the research questions.

5.1 Challenge Participation

Research Question 1 is “to what extent did residents participate in the challenge?”. I address this question using data collected from the challenge website logs. First, I examine individual participation as measured by points earned via the challenge website. Next, I review the number of actions completed by players through the website. Finally, I cover the participation of players on a lounge by lounge basis.

5.1.1 Individual Participation

According to a roster provided by Student Housing (which we used to populate user accounts for the challenge website), there were 1072 residents in the Hale Aloha towers during the challenge, including the 40 Resident Advisors. This number is approximate, because there were some errors in the roster, and residents sometimes move in or out of the residence halls. However, these changes are small and usually move-outs are balanced by move-ins.

According to the challenge website logs, 18 users logged into the website, but did not complete the first-login process.

Of the 1072 potential participants, 401 scored 25 points or more in the challenge (the threshold established in Section 4.2.1), for a participation rate of 37%.

As mentioned in Section 3.6.3.2, in Round 2 we instituted a referral bonus. 38.3% (159) of users logging into the challenge website for the first time entered in a referring email address. Of those referred users, 93% (148) went on to earn at least 30 points and earn the bonus. Given that the bonus was introduced in Round 2, this figure represents a significant use of the bonus.

Figure 5.1 shows the frequency distribution of the participants making the referral. All the referrals were made by only 20 participants, and the top two referrers accounted for 66% of all referrals made.

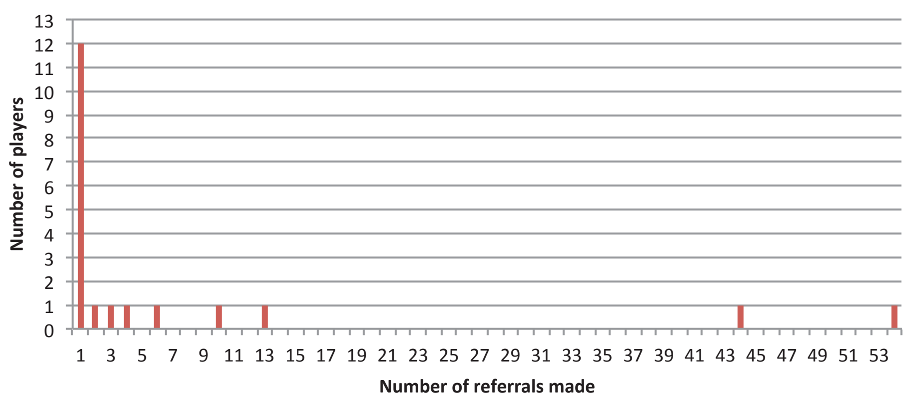


Figure 5.1: Histogram of number of referrals versus the number players who made that number of referrals.

One reason for the concentration of referrals by two participants was due to the challenge endgame. The overall point totals for the top two participants were very close as the Overall Round drew to a close. Having earned the vast majority of the points available through the Smart Grid Game, they seized on the referral bonus as an open-ended way to earn additional points. The two players attempted to sign up as many new participants as they could. On the final day, the overall winner reported that they used the participation scoreboard to determine which lounge had the lowest overall participation, and went door-to-door asking residents to log onto the challenge website and complete one activity to help the referrer win the challenge! This novel strategy was unanticipated by us, and shows that these two players were engaged in critical learning, as defined by Gee, to think at a meta level about how to earn points in the game [49, p. 25].

On the final day of the challenge, there were 68 first-time users (67 matching the 25 point participation threshold discussed in Section 4.2.1), and all of entered a referring email address, showing the impact of this referral bonus endgame.

While these final-day participants may have learned more about energy through their participation in online activities, by participating for less than a day they probably did not contribute significantly to energy conservation efforts in their lounge. Without this final day surge, the participation rate would be 31%. Figure 5.2 shows how the number of new and total participants varied over the challenge period.

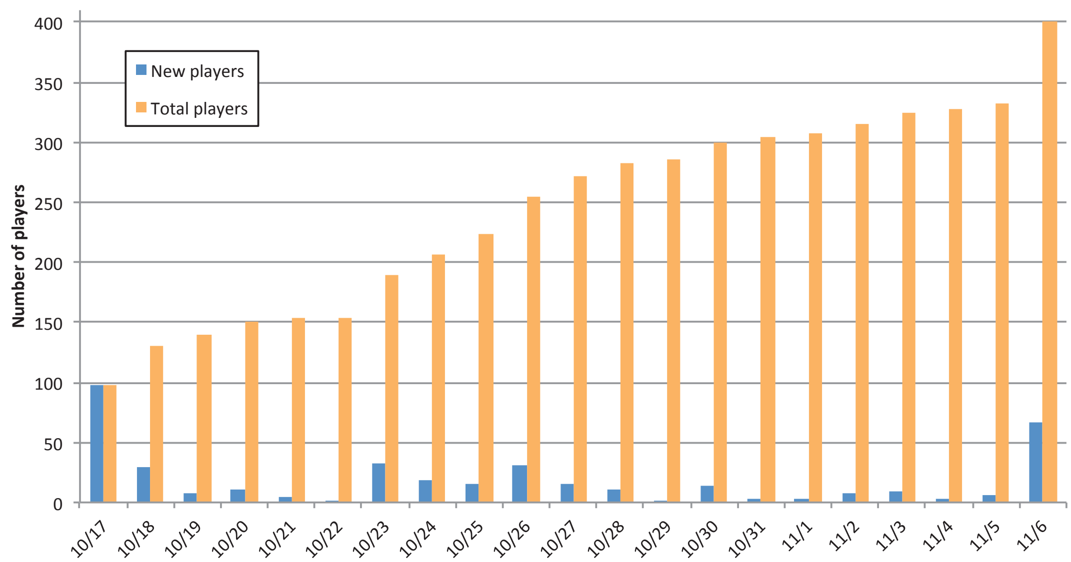


Figure 5.2: Number of new and total participants per day of challenge

5.1.2 Player Action Submissions

Players earn points by completing actions through the challenge website. During the challenge, players completed a total of 4,641 actions. Figure 5.3 shows a histogram of the number of actions completed versus the number of users that completed that number. While there are clearly many players that only completed one or two actions (some of them from the referral bonus surge), there is a long tail of players that completed many actions in the game.

5.1.3 Lounge Participation

Using the same 25 point participation threshold, I can compute the aggregate participation rate for each lounge. Table 5.1 shows the participation rate and total score for each lounge at the end of each of the three rounds of the challenge. The lounges that won the point challenge for each round are shown in bold. This table shows the significant disparities in participation between lounges, with

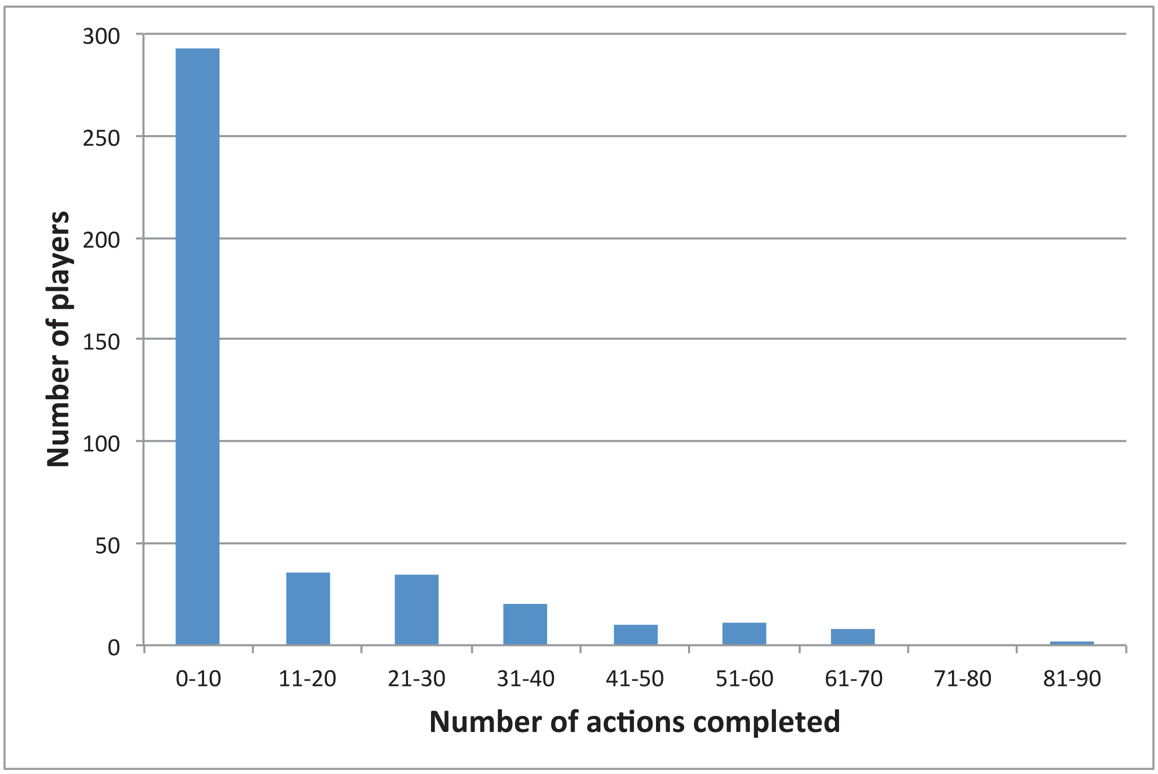


Figure 5.3: Histogram of number of players that completed a certain number of actions.

three lounges participating at 15% or less, and the with the best lounge participating at 74%.

Table 5.1: Score and participation per lounge at the end of each round, bold entries indicate round winners. Note that the Round 2 score started from zero (reset), not from the Round 1 total, but participation is cumulative.

	Round 1		Round 2		Overall Round	
Lounge	Participation	Score	Participation	Score	Participation	Score
Ilima-A	37%	5152	69%	**3893**	74%	**12840**
Ilima-B	19%	755	26%	725	35%	2248
Ilima-C	11%	754	13%	395	15%	1472
Ilima-D	13%	264	22%	762	26%	1469
Ilima-E	11%	406	11%	275	13%	1251
Lehua-A	7%	373	15%	526	15%	1493
Lehua-B	19%	1831	24%	1377	44%	5214
Lehua-C	13%	1140	24%	1596	31%	3868
Lehua-D	33%	4898	37%	1957	44%	8963
Lehua-E	43%	**5288**	44%	1549	52%	7702
Lokelani-A	17%	389	56%	2630	67%	5087
Lokelani-B	13%	455	20%	168	30%	1219
Lokelani-C	24%	1344	31%	598	35%	2391
Lokelani-D	11%	335	15%	637	26%	1585
Lokelani-E	15%	1989	19%	849	22%	3858
Mokihana-A	15%	745	37%	1820	54%	4436
Mokihana-B	13%	994	19%	837	31%	3427
Mokihana-C	6%	328	17%	498	37%	1501
Mokihana-D	7%	574	19%	1270	37%	4351
Mokihana-E	24%	2104	39%	3318	54%	8837

As discussed in Section 5.1.1, the final day surge of participants inflates the participation rate of lounges. Table 5.2 shows the final participation rates with and without the final day surge, while Figure 5.4 shows a plot ordered by participation rate. The participation rate without the final surge is more appropriate when the participation is being compared to other data, such as energy use, which would not have been significantly impacted by participants who joined on the final day of the challenge.

5.1.4 Discussion

Based on the data presented here, 37% of residents participated in the challenge by earning 25 points or more. Most energy competitions are unable to provide any data on participation rates, because they don't have any easy way to measure participation. While most energy competitions have a website, the website is not necessarily essential for participation, unlike the Kukui Cup; therefore,

Table 5.2: Overall Lounge participation with and without final day surge

Lounge	Overall participation	Minus final day
Ilima-A	74%	69%
Ilima-B	35%	26%
Ilima-C	15%	13%
Ilima-D	26%	22%
Ilima-E	13%	11%
Lehua-A	15%	15%
Lehua-B	44%	31%
Lehua-C	31%	26%
Lehua-D	44%	39%
Lehua-E	52%	50%
Lokelani-A	67%	63%
Lokelani-B	30%	22%
Lokelani-C	35%	33%
Lokelani-D	26%	19%
Lokelani-E	22%	19%
Mokihana-A	54%	54%
Mokihana-B	31%	24%
Mokihana-C	37%	24%
Mokihana-D	37%	20%
Mokihana-E	54%	39%

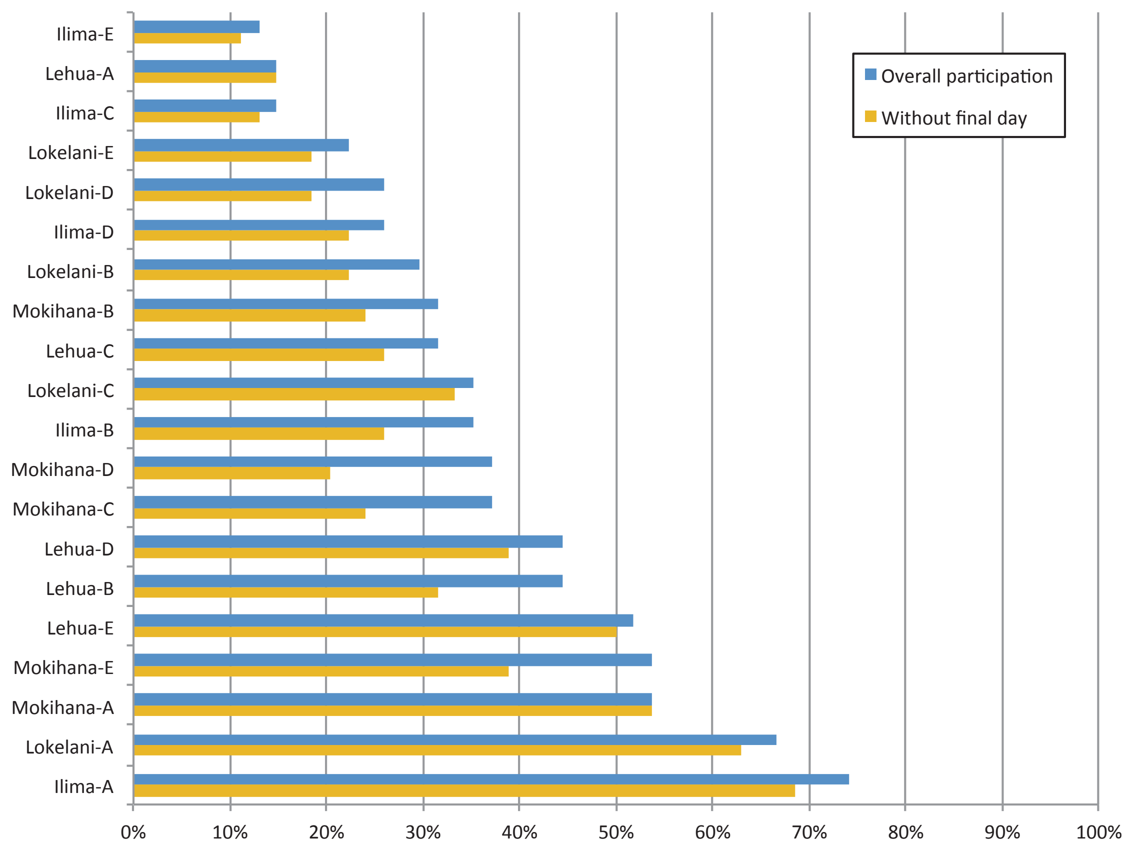


Figure 5.4: Plot of overall Lounge participation with and without final day surge

measurement of website use is not a good measure of participation for other competitions.

The Oberlin dorm energy competition did have a central website for energy feedback. For their 2005 competition, they report 4,082 "hits", and determined that 46% of dormitory residents viewed the website based on IP address logs [101]. However the Oberlin system did not ask users to log in or interact with the site in any way, so that reflects a less in-depth interaction compared to participation in the Kukui Cup website. The participation rate in the 2011 Kukui Cup appears comparable to the Oberlin results, and the evidence of participation is much clearer in the Kukui Cup due to the unifying website.

Participation over the challenge at the lounge level varied significantly between lounges, ranging from 69% to 11% (without final day surge). This range reflects lounges with high participation and high scores, such as Lehua E in Round 1), as well as lounges with a smaller number of participants each earning higher scores, such as Lokelani E in Round 1. Based on interactions with players at award events, it was clear that some lounges had highly active players who were able to rally other residents in their lounge to participate, while other highly active players were unable or unwilling to get other loungemates to participate.

In answer to research question #1, based on the results shown here, many residents chose to participate in the Kukui Cup. Obviously, participation was essential to the success of the Kukui Cup.

5.2 Energy Literacy Questionnaire

As discussed in Section 4.3, I administered an online energy literacy questionnaire to a set of residents in Hale Aloha twice: once before the challenge, and once after the challenge. This section covers the results from those questionnaires. The full text of the questions can be found in Appendix D.

5.2.1 Questionnaire Responses

Since each questionnaire participant was to be compensated, and I did not know beforehand how many potential participants would actually participate, I sent the questionnaire invitation in two waves. The first wave of 74 email invitations was sent on October 5, 2011, and a second wave of 107 invitations was sent on October 10. 68 questionnaires were completed, which is a response rate of 38%. There were 5 partial responses, but in each case the participants abandoned the survey before submitting any data other than the informed consent page, I have not included those participants in the following analyses.

After the challenge was complete, I sent the same questionnaire to all the individuals that had participated in the pre-challenge questionnaire. There were 51 complete responses, and 2 responses that stopped after filling out the consent form. Since the questionnaire was administered before the challenge began, I could not tell in advance how many questionnaire participants would go on to participate in the challenge. As discussed in Section 4.2.1, I call respondents challenge participants if they earned 25 points in the challenge. Table 5.3 shows the number of questionnaire responses from participants and non-participants, and those that completed both questionnaires. 48 questionnaire participants completed both the pre-challenge and post-challenge questionnaires, evenly split between challenge participants and non-participants. None of the 48 participants that completed both questionnaires were RAs, so all participants were first-year students. One participant moved out of Hale Aloha before the challenge started, and another moved out during the challenge. Neither of the two logged into the challenge website.

Table 5.3: Number of completed pre- and post-challenge questionnaires.

Group	Pre-challenge	Post-challenge	Completed both
Non-challenge participants	36	27	24
Challenge participants	32	24	24
Total	68	51	48

The relatively small number of participants that completed both pre- and post-challenge questionnaires were spread over the 20 lounges. Table 5.4 shows the distribution across the lounges. Note that the one participant that moved out before the challenge started was not listed in the roster we received from Student Housing, so their lounge is unknown.

5.2.2 Energy Knowledge

The energy knowledge section of the questionnaire consisted of 19 factual questions about energy, with a specific emphasis on Hawai‘i energy issues. Table 5.5 shows the average number of questions answered correctly for participants and non-participants in the pre- and post-challenge questionnaires. Non-participants showed no change in the number of questions answered correctly after the challenge, while participants improved by 18.8%. Figure 5.5 is a plot of the results. Using ANOVA, there was a significant interaction between participation and differences between pre- and post-challenge scores, $F(1, 46) = 3.84$, $p = 0.056$, MSE $= 3.52$. Challenge participants scores improved, and non-challenge-participants energy knowledge scores were unchanged. Therefore, this result supports the hypothesis that participating in the Kukui Cup increases the energy literacy of participants.

Figure 5.6 shows the percentage of questionnaire participants that correctly answered each of the 19 questions in the energy literacy section, from most correct to least correct. The full text of each question can be found in Section D.3. The questions answered correctly most frequently were on climate change, which indicates that the climate change message has reached most students attending college. Three of the quantitative questions were answered incorrectly most frequently by

Table 5.4: Distribution of questionnaire participants across lounges.

Lounge	Number of questionnaire participants
Ilima-A	1
Ilima-B	6
Ilima-C	2
Ilima-D	1
Ilima-E	1
Lehua-A	2
Lehua-B	3
Lehua-C	2
Lehua-D	2
Lehua-E	1
Lokelani-A	1
Lokelani-B	0
Lokelani-C	3
Lokelani-D	1
Lokelani-E	4
Mokihana-A	4
Mokihana-B	3
Mokihana-C	3
Mokihana-D	3
Mokihana-E	4
Unknown	1

Table 5.5: Average number of energy knowledge questions correct for participants and non-participants before and after the challenge

	Pre-challenge		Post-challenge		
Group	Mean	Std. Deviation	Mean	Std. Deviation	% Change
Non-challenge participants	7.46	2.377	7.37	2.570	-1.2%
Challenge participants	7.54	1.837	8.96	3.290	18.8%

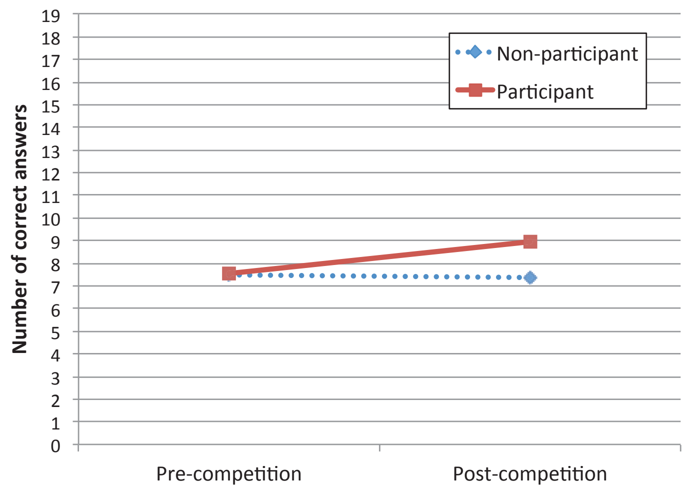


Figure 5.5: Plot of average number of energy knowledge questions correct for participants and non-participants before and after the challenge

participants, indicating an area that the Kukui Cup does not seem to be helping significantly.

5.2.3 Energy Attitudes

The energy attitudes section of the questionnaire was taken from the affective subscale of the energy literacy questionnaire developed by DeWaters and Powers [31]. There are 18 statements in the attitudes section using a five-point Likert scale from 1 for "strongly agree" to 5 for "strongly disagree", where strongly agree was the most preferred response for positive energy attitudes. Table 5.6 shows the average rating value across all 18 statements for participants and non-participants in the pre- and post-challenge questionnaires. Figure 5.7 is a plot of the results. Lower scores indicate improved energy attitudes.

Table 5.6: Average energy attitude scores for participants and non-participants before and after the challenge. Lower scores indicate improved energy attitudes.

	Pre-challenge		Post-challenge		
Group	Mean	Std. Deviation	Mean	Std. Deviation	% Improved
Non-challenge participants	2.23	0.438	2.11	0.561	5.5%
Challenge participants	2.11	0.428	2.13	0.719	-0.8%

Non-participants showed a small improvement in their attitude score in the post-challenge questionnaire, while participants' scores decreased slightly, but these results were not statistically significant. These results indicate that the 2011 Kukui Cup did not change the attitude of participants towards energy conservation and renewable energy. It may be that the three week challenge length

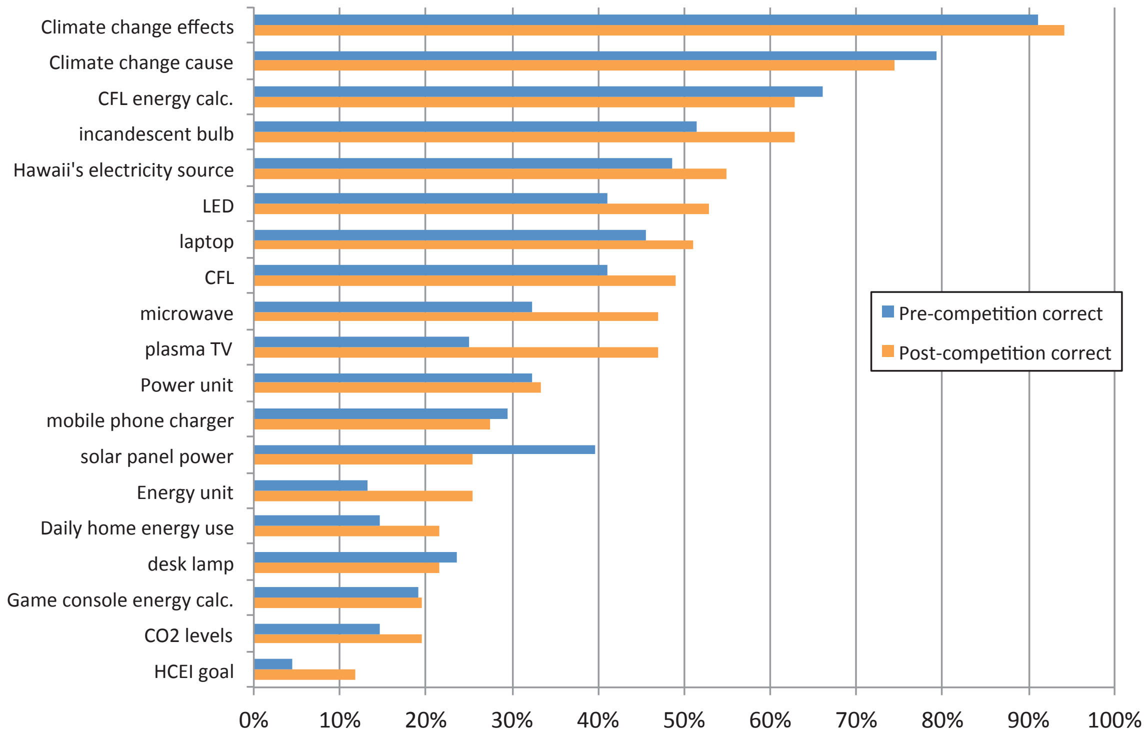


Figure 5.6: Percentage of correct answers for each energy knowledge question

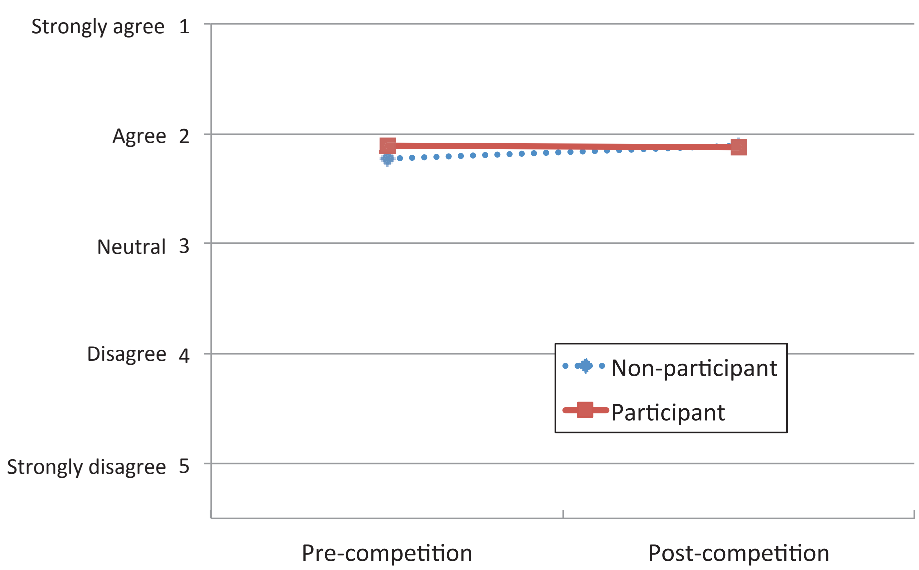


Figure 5.7: Plot of average energy attitude scores for participants and non-participants before and after the challenge

was not long enough to change attitudes, or perhaps the challenge's focus on direct energy conservation actions took away from potential changes in attitude.

Because the attitude section of the questionnaire is a slightly modified version of the DeWaters and Powers attitude subscale, it is worth comparing their results with high school students to the results from my questionnaire participants. DeWaters and Powers normalized their values to percentages (where 100% would be the most preferred answer to all questions), so for comparison purposes I have done the same normalization.

Table 5.7: Comparison of attitude scores between Kukui Cup and DeWaters and Powers results.

Group	Pre-challenge	Post-challenge	New York State
Non-challenge participants	69.3%	72.4%	
Challenge participants	72.2%	71.8%	
Middle School			73.0%
High School			73.9%

Table 5.7 shows the comparison. The New York State students very similar attitude scores compared to the Hale Aloha questionnaire participants. Since the Hale Aloha questionnaire participants were all in their first semester of college, their attitudes could be expected to be similar to that of high school students.

5.2.4 Reported Energy Behaviors

The energy behavior section of the questionnaire consisted of 17 statements about energy use behaviors inspired by the energy literacy instrument developed by DeWaters and Powers [31]. Each statement was rated on a scale from 1 for "always or almost always" to 5 for "never or hardly ever", where always or almost always was the most preferred response for positive energy behaviors. Table 5.8 shows the average rating value across all 17 statements for participants and non-participants in the pre and post-challenge questionnaires. Non-participants showed a small improvement in their behavior score in the post-challenge questionnaire, with participants showing a slightly larger improvement. Figure 5.8 is a plot of the results. Lower scores indicate improved energy behaviors.

Table 5.8: Average self-reported energy behavior scores for participants and non-participants before and after the challenge

	Pre-challenge		Post-challenge		
Group	Mean	Std. Deviation	Mean	Std. Deviation	% Improved
Non-challenge participants	2.56	0.510	2.52	0.596	1.7%
Challenge participants	2.52	0.443	2.35	0.339	6.6%

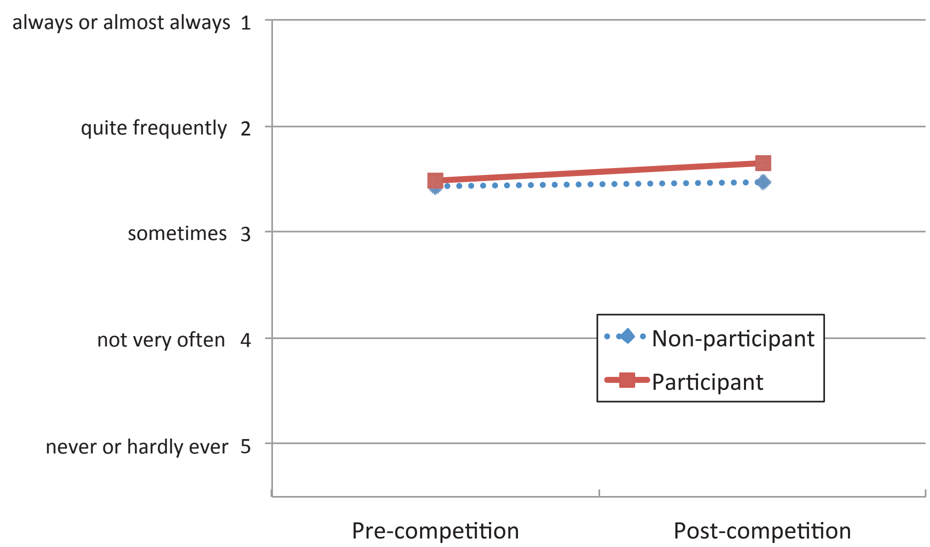


Figure 5.8: Plot of average self-reported energy behavior scores for participants and non-participants before and after the challenge

Using ANOVA, I found there was a significant difference between pre and post-challenge scores, $F(1, 46) = 4.09$, $p = 0.049$, MSE $= 2.94$, but interaction between participation and pre and post-challenge scores was not significant. Since the self-reports of behavior changes took place for both participants and non-participants, these changes provide the interesting possibility of *passive participants* who made changes in their behavior due to the challenge, but did not participate in the challenge (based on my definition participation: earning 25 points). It is not hard to imagine that non-participants might find themselves changing their behaviors due to requests from roommates who are participating, or new social norms developing as a result of participants' behavior, because most of the targeted behaviors are public and some involve shared resources (such as the overhead lighting in residents' rooms). Future iterations of the Kukui Cup could encourage these changes in behavior even among non-participants through additional activities that target non-participants ("get your non-participating roommate to take the stairs") or additional marketing materials designed around establishing new social norms as described in Section 2.5.3.

5.2.5 Group Identification

I used the Arrow-Carini Group Identification Scale 2.0 [55] for the group identification section of the questionnaire. It consists of 12 statements in three subscales: affective, behavioral, and cognitive. Questionnaire participants were asked to respond to each one on a seven-point Likert scale from 1 for "strongly disagree" to 7 for "strongly agree", where strongly agree was the response that reflected the most group identification. The group specified in the statements was the lounge that participants belong to, since lounges represent the teams in the Kukui Cup. Table 5.9 shows the average scale value for participants and non-participants in the pre and post-challenge questionnaires, while Figure 5.9 shows a plot of the results.

Table 5.9: Average group identification scores for participants and non-participants before and after the challenge

	Pre-challenge		Post-challenge		
Group	Mean	Std. Deviation	Mean	Std. Deviation	% Change
Non-challenge participants	4.10	0.869	4.14	0.872	1.0%
Challenge participants	4.13	0.823	3.79	0.963	-8.0%

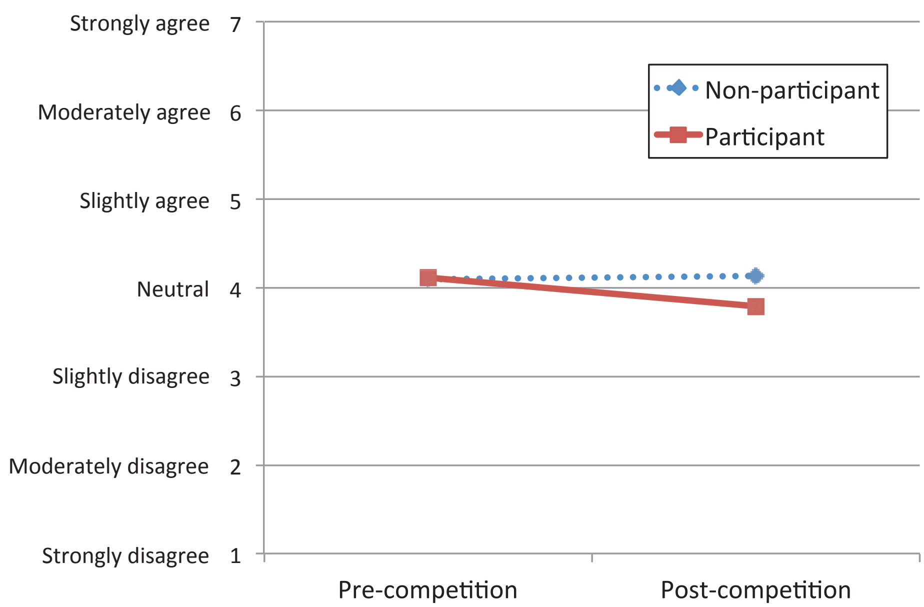


Figure 5.9: Plot of average group identification scores for participants and non-participants before and after the challenge

Both participants and non-participants were neutral towards their lounge. Participants showed a decline of 8% in their group identification with the lounge, while non-participants were mostly unchanged. These results were not statistically significant, but they provide interesting possibilities to be investigated further. While I had hypothesized that the Kukui Cup experience would increase participants' identification with the lounge, it may be that participants started to identify with other Kukui Cup participants rather than fellow loungemates. Another possible scenario could be that dedicated participants who are trying to reduce their lounge's energy use might find themselves alienated from their loungemates who are not making an effort to conserve energy.

In developing the scale, Henry et al. compared participants who completed the scale once for a group they belonged to that they considered highly important to them, and again for a group they did not consider important. Henry et al. found the average score for important groups was 5.93, while for the unimportant groups it was 3.89, which is close to the averages I found for lounge identification. Therefore, it appears that participants do not consider the lounge they belong to as an important group.

It is worth noting that two participants indicated in the questionnaire feedback that they did not know what a lounge was (see Section 5.2.7), and all the group identification statements referred to the participants' lounge. It is possible that other participants also did not understand the lounge grouping, which could also explain the neutral ranking and lack of significant change after the challenge.

5.2.6 Connectedness to Nature

For the connectedness to nature section of the questionnaire, I used the CNS scale developed by Mayer and Frantz [80]. It consists of 14 statements regarding the relationship between humans and nature. Questionnaire participants were asked to respond to each statement on a five-point Likert scale from 1 for "strongly disagree" to 5 for "strongly agree", where strongly agree was the response that reflected the most connectedness to nature. Table 5.10 shows the average scale value for participants and non-participants in the pre- and post-challenge questionnaires, while Figure 5.10 shows a plot of the results.

Table 5.10: Average connectedness to nature scores for participants and non-participants before and after the challenge

	Pre-challenge		Post-challenge		
Group	Mean	Std. Deviation	Mean	Std. Deviation	% Change
Non-challenge participants	3.39	0.822	3.55	0.794	4.4%
Challenge participants	3.47	0.547	3.51	0.602	1.1%

Using ANOVA, I found there was a significant difference between pre- and post-challenge scores, $F(1, 46) = 3.85$, $p = 0.056$, MSE $= 2.61$, but interaction between participation and pre- and post-challenge scores was not significant. However, the CNS scale was included in the questionnaire because it was claimed to be a predictor of energy conservation behavior (see Section 2.10), not because the Kukui Cup was necessarily expected to have an impact on connectedness to nature.

5.2.7 Questionnaire Feedback

At the end of both questionnaires, participants were given the opportunity to provide feedback about the questionnaire in an optional free response question. There were 12 feedback responses to the pre-challenge questionnaire, and 5 to the post-challenge questionnaire (excluding non-responses such as "N/A" and "No comment :)"). Table 5.11 shows a summary of the responses. Note that

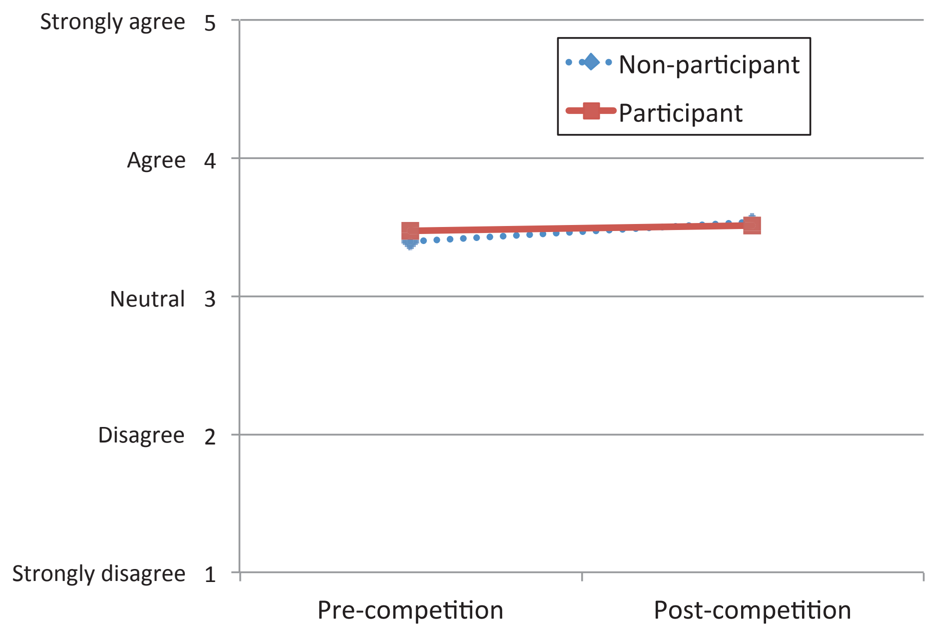


Figure 5.10: Plot of average connectedness-to-nature scores for participants and non-participants before and after the challenge

some participants' feedback spanned multiple categories, so the number of responses in the table is greater than the number of participants that gave feedback.

While only a small number of participants provided feedback, the results show a range of responses to the questionnaire. Two participants indicated that they were unsure what a lounge was, demonstrating that understanding of the lounge as an entity was not universal among participants (one participant indicated this on both pre- and post-challenge questionnaires, so two participants account for the three responses listed in the table). Two participants indicated that the questionnaire made them more aware of ways they could conserve energy. If they actually followed through with behavior changes, the effectiveness of future Kukui Cup iterations could be improved by administering the pre-challenge questionnaire to a greater percentage of residents. This effect would also mean that the questionnaire itself could have resulted in attitude or behavior changes.

5.2.8 Discussion

Research question #2 is "how did energy literacy change after the challenge?" Based on the questionnaire results, it appears that the energy knowledge of challenge participants increased modestly compared to those that did not participate in the challenge. Energy attitudes did not change significantly for participants or non-participants, which is unexpected since many actions and events in the challenge were intended to raise awareness and change attitudes. Energy behaviors improved slightly for both participants and non-participants, but there was no interaction between participa-

Table 5.11: Summary of free-response questionnaire feedback

Type of response	Pre-challenge	Post-challenge	Example response
Accolade	1	2	“Great Survey!”
General confusion	3		“I am confused... But I did it!”
Lounge confusion	2	1 (same subject)	“The questions about the ‘lounge’ were very confusing. I assumed it was about the other members of where I am living but I’m not completely sure.”
Long questionnaire	1		“its long”
Importance of energy		2	“Saving energy is very important”
Questionnaire concerns	2	1	“. . . I do not understand why half of the questions from the lounge section were reworded versions of the first half.”
Energy introspection	2		“this survey made me think. i feel more aware now that i could do more to save energy.”
Other	2		“I am one with nature. I am one with the lounge.”

tion and non-participation. Overall, there is evidence of improvement in energy literacy, at least in the knowledge component, as a result of participation in the challenge.

From the group identification section, it seems that questionnaire participants do not identify strongly with their lounge. Because the lounge consists of two floors, it is likely that people would identify even less with the lounge than they would for their floormates.

Research question #5 is “what is the relationship between energy literacy and energy usage?” In retrospect, this question reflected significant naiveté on the major challenges of assessing energy literacy, and how energy literacy might affect energy use. The first problem is obtaining a sufficient number of questionnaire responses across the different lounges in order to have a large enough sample size to make comparisons with lounge energy use. The energy meter data provides an accurate aggregation of energy use for each lounge, but the sparse number of questionnaire responses across the lounges (0–6 per lounge, see Table 5.4) does not provide a sufficient sample to draw accurate conclusions about the energy literacy of a lounge. Better correspondence between energy literacy data and energy use data could be possible by a much larger budget for the questionnaire participation incentives, or by studying the relationship in an environment where individual energy use could be measured, rather than the large aggregation of 54 individuals in the 2011 UH Kukui Cup.

However, even with energy measurement at the household or individual level, there is a leap between energy literacy (which can be measured by questionnaire), actual energy use behaviors (which are very hard to measure), and overall energy use (which is easy to measure). The data I gathered are insufficient to answer research question #5, but one contribution of this research is a greater understanding of the inherent difficulty in answering the question.

5.3 Energy Use

This section analyzes the energy usage data collected before, during, and after the challenge and relates it to the appropriate research questions.

5.3.1 Before Challenge

Figure 5.11, Figure 5.12, and Figure 5.13 show the energy use for Ilima, Lehua, and Mokihana towers during the weeks from the start of the fall 2011 semester until the start of the challenge. Due to the timing of the meter installations, (as shown earlier in Table 3.1), Lehua had more weeks of data than Ilima and Mokihana. There is no chart for Lokelani since the lounges in Lokelani had at most 1 week of data before the challenge start.

As the figures show, there can be significant and sustained variation in energy use between lounges, and there can also be significant changes in energy use for a single lounge over time. For example, Ilima C’s weekly energy use is consistently over 200 kWh higher than Ilima A or D. Trends over time are sometimes matched between lounges, such as Lehua B and C, but also can

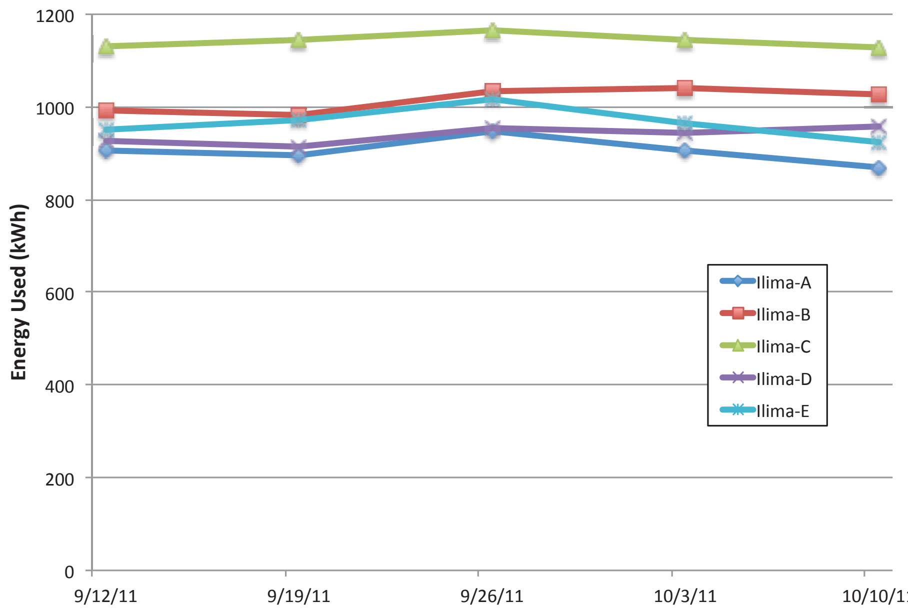


Figure 5.11: Weekly energy use in kWh for each lounge in Ilima for the pre-challenge period. Dates reflect the start of each week of data.

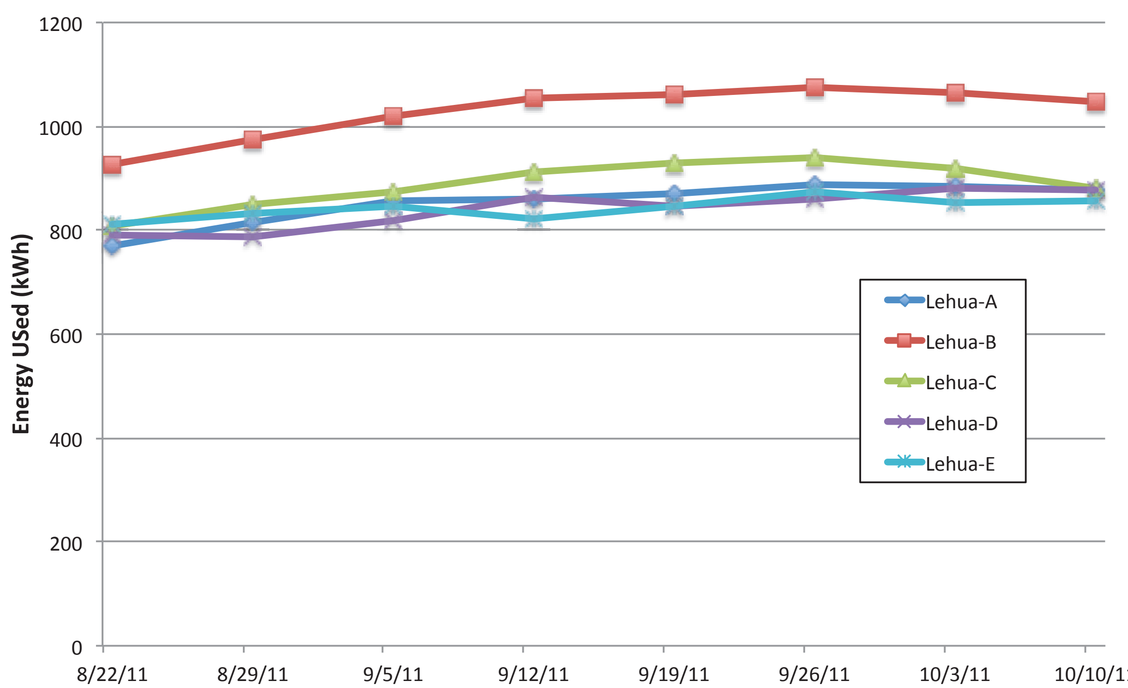


Figure 5.12: Weekly energy use in kWh for each lounge in Lehua for the pre-challenge period. Dates reflect the start of each week of data.

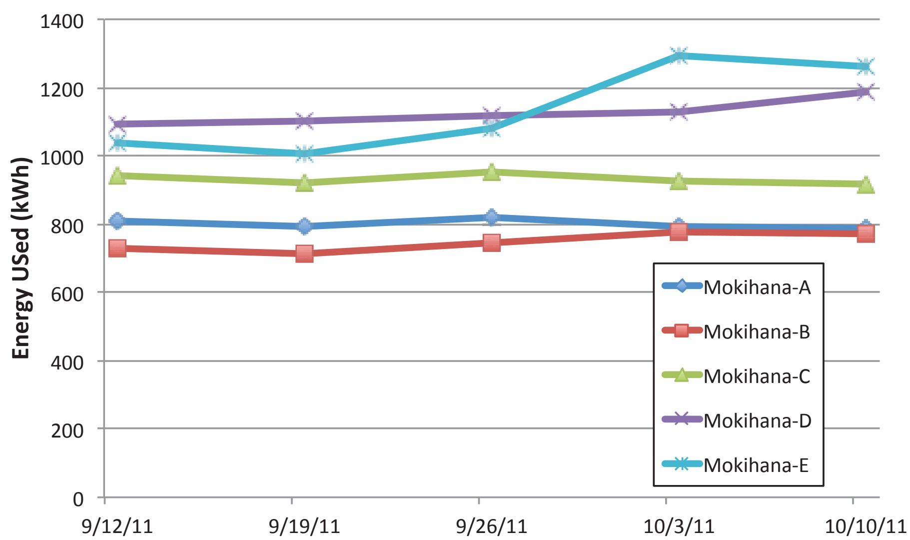


Figure 5.13: Weekly energy use in kWh for each lounge in Mokihana for the pre-challenge period. Dates reflect the start of each week of data.

be highly divergent such as Mokihana C and E. These differences in energy use over time between lounges show the difficulty in picking a representative baseline from historical data. For example, Mokihana E shows a steep rise in energy use over the two weeks just before the challenge compared to the previous three weeks. The choice of whether to average the three weeks before the challenge or the two weeks before the challenge would have a significant change in Mokihana E's baseline.

For the purposes of evaluation, I used a three-week average of energy use before the challenge for the baselines (see Section 4.4.1).

5.3.2 During Challenge

During the challenge, some lounges reduced their energy use, while others increased. Figure 5.14 shows the average energy use in kilowatt-hours for each of the 15 lounges during the challenge compared with their baselines.

Using the baseline, the amount of energy that the 15 lounges would be expected to use is 43,351 kWh for the three week challenge period. The actual energy usage for the 15 lounges during the challenge period was 42,504 kWh, for an overall conservation percentage of 1.95%.

Table 5.13 shows the percentage of energy conservation on a per-lounge basis. The best lounge (Ilima A) reduced energy use during the challenge by 16.1% compared to their baseline, but three lounges increased their energy use compared to the baseline during the challenge.

Lounges' energy conservation did not seem to be related to the participation rate. Figure 5.15 shows a chart comparing the percentage energy conservation to the participation rate for each lounge. While the highest conserving lounge (Ilima A, 16.1%) had the highest participation rate,

Table 5.12: Energy baselines for each lounge used for data analysis.

Lounge	Baseline (kWh)
Ilima-A	908
Ilima-B	1034
Ilima-C	1146
Ilima-D	952
Ilima-E	968
Lehua-A	884
Lehua-B	1063
Lehua-C	913
Lehua-D	872
Lehua-E	861
Mokihana-A	800
Mokihana-B	764
Mokihana-C	933
Mokihana-D	1143
Mokihana-E	1212

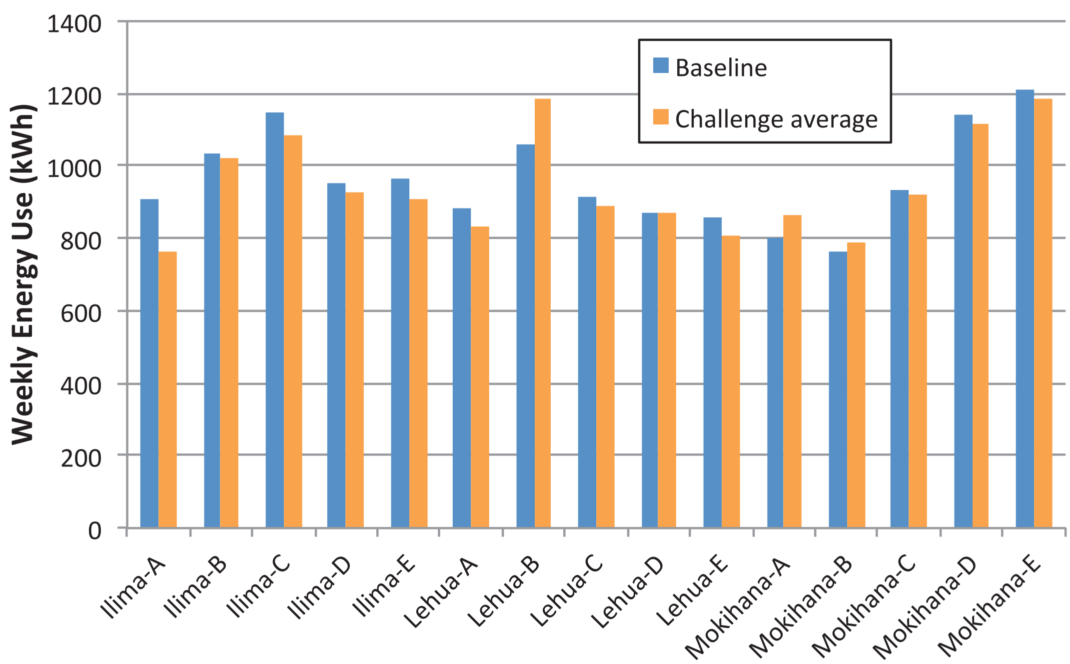


Figure 5.14: Weekly baseline energy use compared to average weekly energy use during the challenge for each lounge.

Table 5.13: Percentage energy conservation compared to baseline for lounges (positive percentages are conservation, negative are increased use).

Lounge	Conservation
Ilima-A	16.1%
Ilima-E	6.4%
Lehua-E	6.1%
Lehua-A	5.5%
Ilima-C	5.3%
Mokihana-D	2.5%
Lehua-C	2.4%
Ilima-D	2.3%
Mokihana-E	2.1%
Mokihana-C	1.5%
Ilima-B	1.3%
Lehua-D	0.5%
Mokihana-B	-3.4%
Mokihana-A	-8.4%
Lehua-B	-11.7%

the second highest participating lounge (Mokihana A) had the second worst energy conservation rate (-8.4%). The lack of correlation between participation and conservation can be further seen in the scatterplot in Figure 5.16.

Total lounge score also does not appear to be correlated with conservation. Figure 5.17 shows a scatterplot of lounge conservation and score.

While there is no obvious trend between lounge score or participation and conservation, it is worth noting that the lounge with the highest score had the highest participation, and the highest conservation. Based on informal discussions with members of this team at events and award parties, it was clear that this winning lounge was highly motivated to win and was taking active measures to reduce energy use.

5.3.3 After Challenge

Energy monitoring continued throughout the post-challenge period until the end of the spring 2012 semester. Figure 5.18 shows the weekly energy use averaged across all lounges during the post-challenge period. As can clearly be seen, there are large drops in energy use during five periods: Thanksgiving week, fall finals, winter break, spring break, and spring finals. These drops are expected, as many students use these periods as opportunities to travel or return to their homes. Figure 5.18 clearly shows the impact that changes in occupancy have on energy use in Hale Aloha. While these five periods are predictable because they are scheduled on the university calendar, in

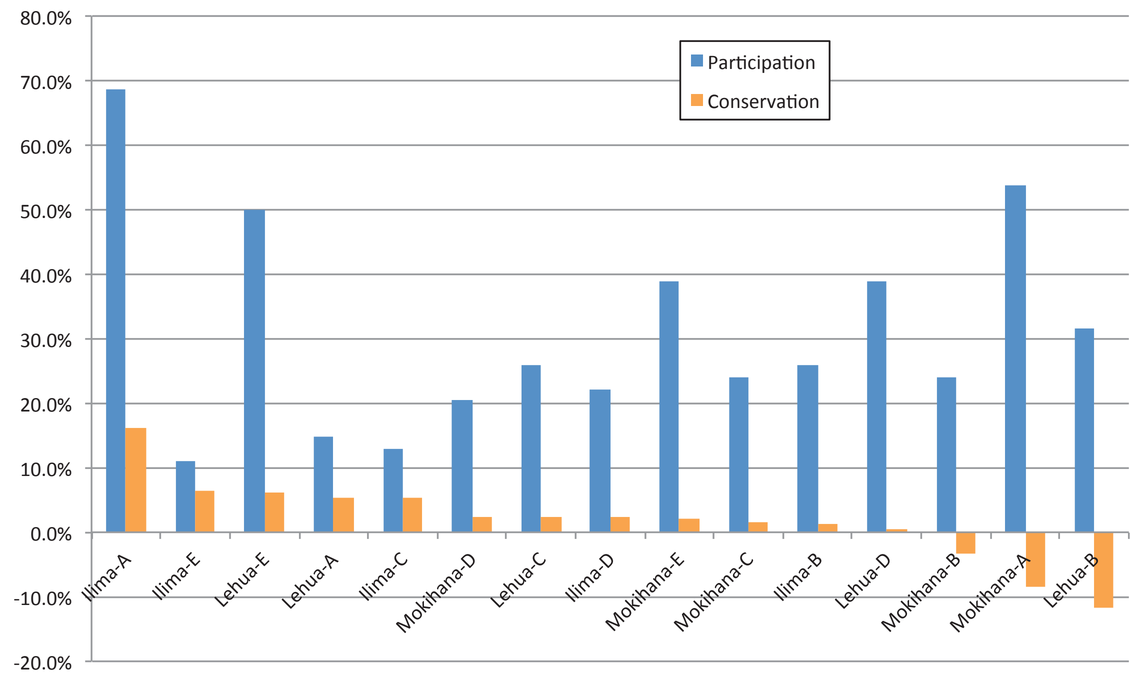


Figure 5.15: Percentage energy conservation compared to baseline and participation rate for lounges (positive percentages are conservation, negative are increased use). Lounges are sorted from most to least conservation.

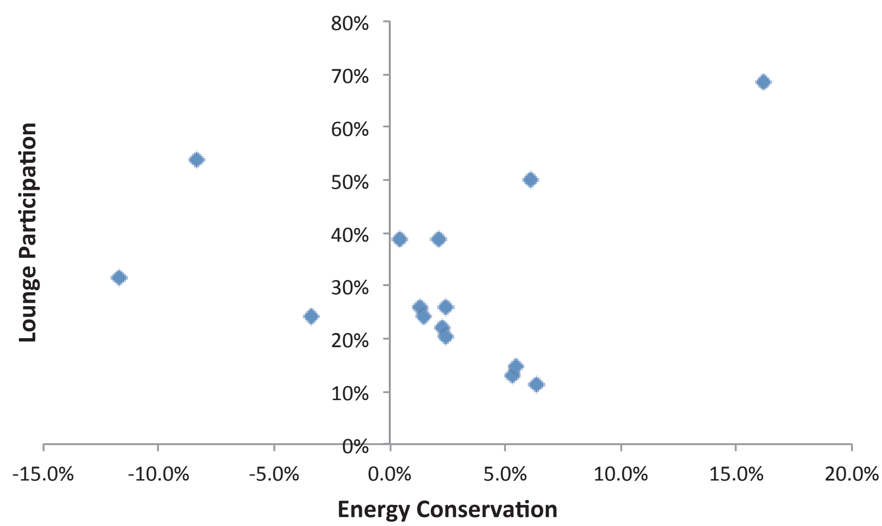


Figure 5.16: Scatterplot of percentage energy conservation compared to baseline and participation rate for lounges (positive percentages are conservation, negative are increased use).

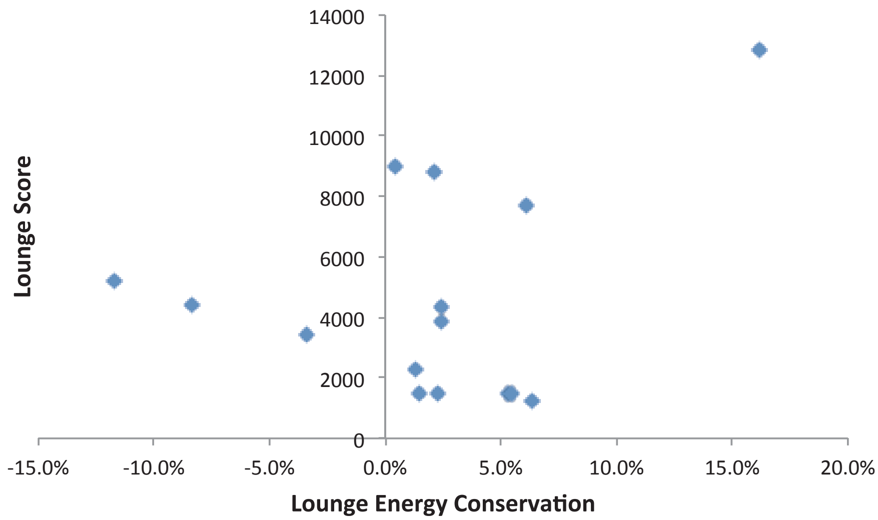


Figure 5.17: Scatterplot of percentage energy conservation compared to baseline and total score for lounges (positive percentages are conservation, negative are increased use).

general, changes to occupancy are difficult to measure directly. Official rosters from Student Housing only reflect an approximation of occupancy, because residents can move unofficially between rooms without approval or notification to Housing. For example, during the post-challenge energy audit (described in Section 5.7), four beds were found in one room that was intended for two residents. Occupancy changes are difficult to track, yet can have a major impact on energy use.

Because these five periods of known lower occupancy reduce energy use, I have removed them from the analyses of energy use in the rest of this section. Figure 5.19, Figure 5.20, and Figure 5.21 show the energy use in kilowatt-hours for Ilima, Lehua, and Mokihana respectively for the post-challenge period, with the low-occupancy periods removed. As was seen in the pre-challenge period, there is considerable variation in energy use between lounges, but there are no clear patterns of post-challenge energy use.

Figure 5.22, Figure 5.23, and Figure 5.24 show the energy use for Ilima, Lehua, and Mokihana in the post-challenge period as a percentage change from the baseline. As mentioned earlier, energy use in the post-challenge period was wildly variable, but there are several notable points. Ilima A, the lounge that reduced their energy use the most during the challenge, did not maintain that reduction throughout the post-challenge period (see Figure 5.22). During the remainder of the fall 2011 semester, Ilima A's energy use was below its baseline, but it was higher than during the challenge itself. However, in the spring 2012 semester, Ilima A's energy use increases above the baseline value for most of the semester.

The five lounges of Lehua show an interesting pattern of parallel changes in energy use compared to their baseline during the spring 2012 semester until spring break (Figure 5.23). Neither of

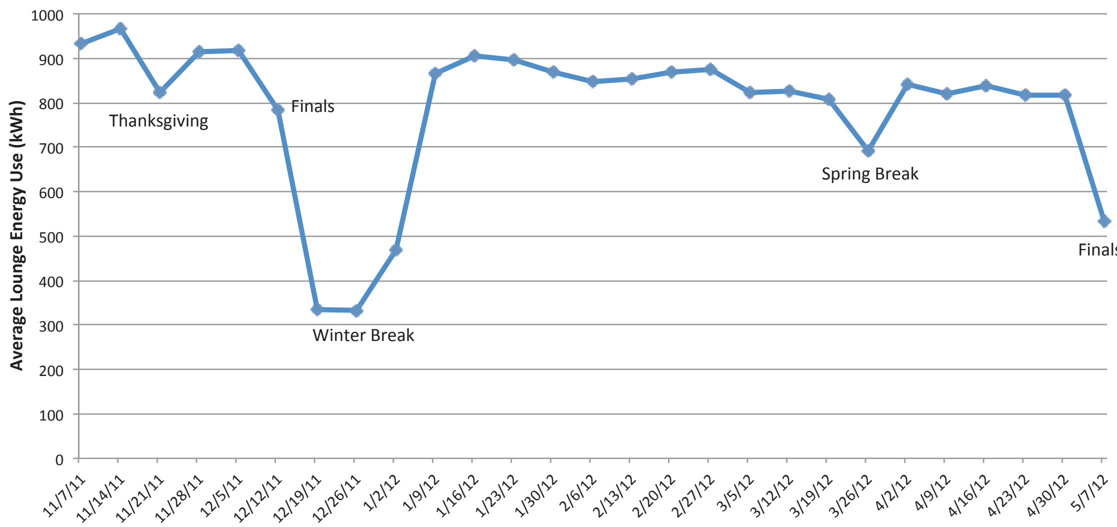


Figure 5.18: Weekly energy use averaged across all lounges during post-challenge period.

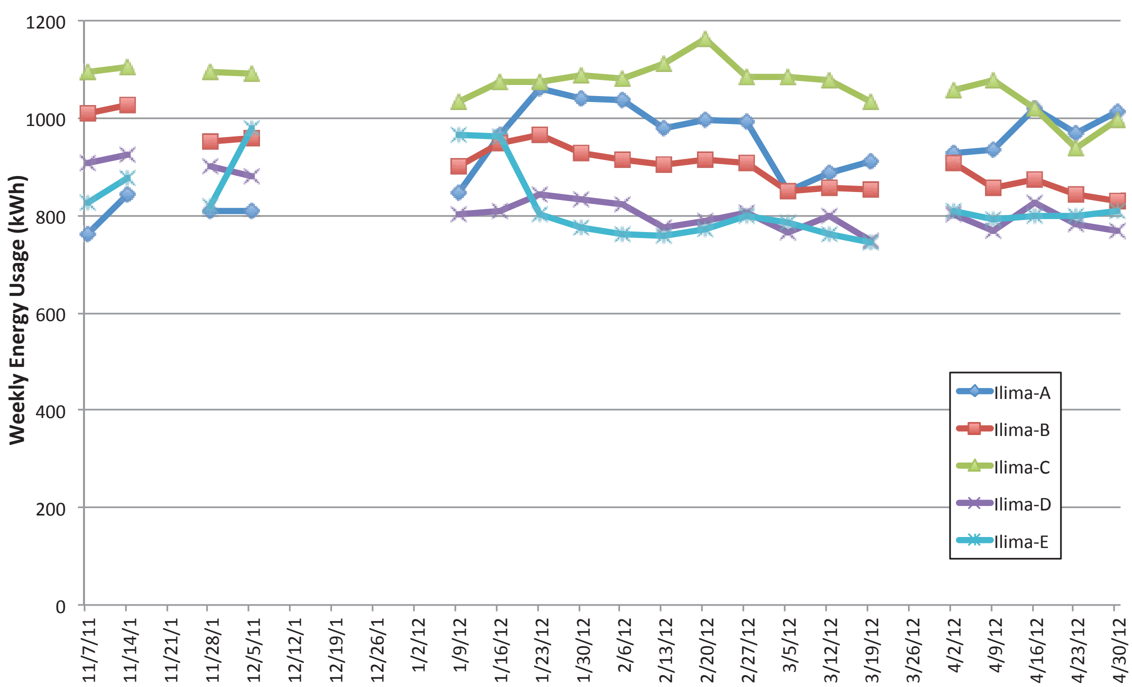


Figure 5.19: Weekly energy use in kWh for each lounge in Ilima for the post-challenge period, with weeks of low occupancy removed. Dates reflect the start of each week of data.

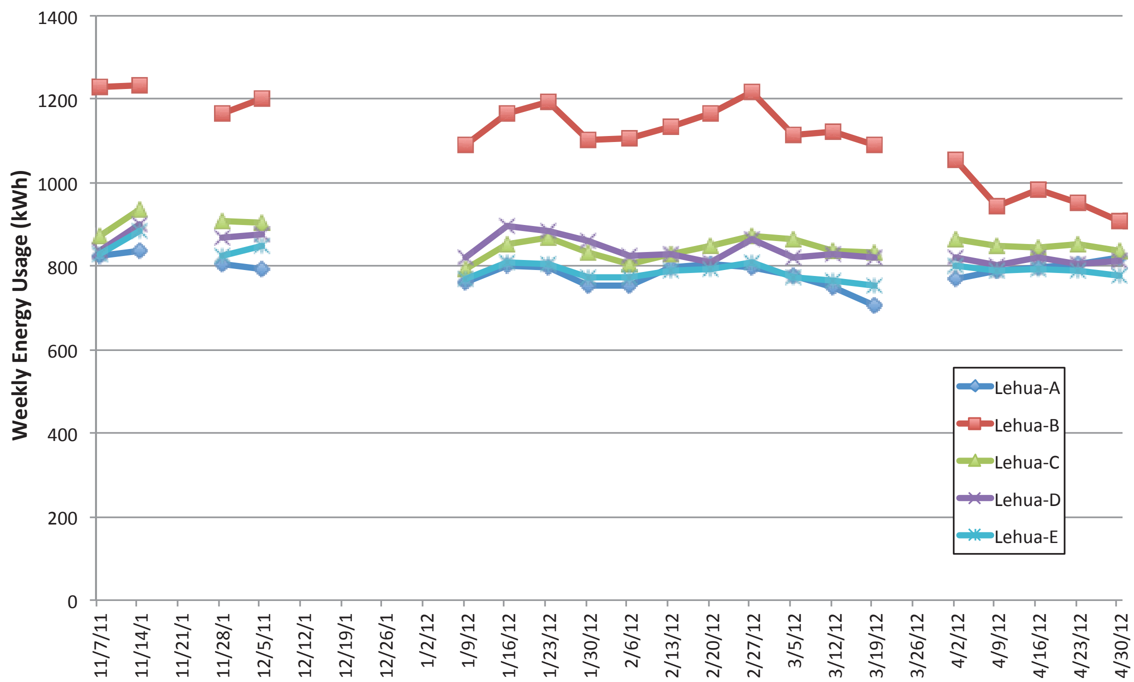


Figure 5.20: Weekly energy use in kWh for each lounge in Lehua for the post-challenge period, with weeks of low occupancy removed. Dates reflect the start of each week of data.

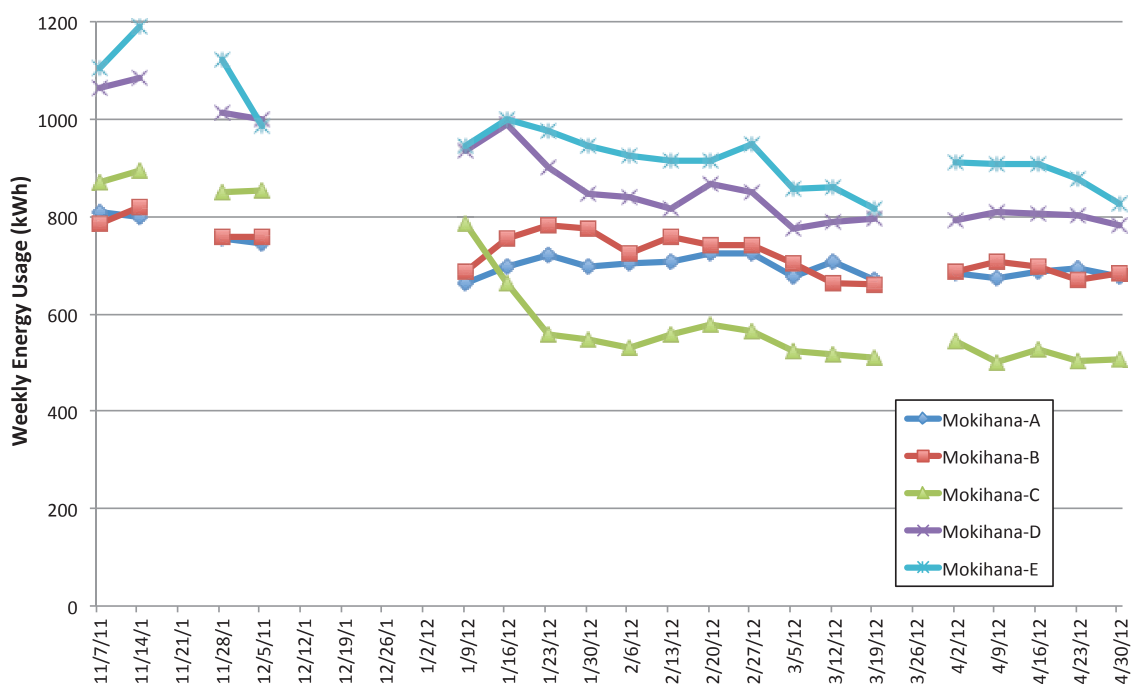


Figure 5.21: Weekly energy use in kWh for each lounge in Mokihana for the post-challenge period, with weeks of low occupancy removed. Dates reflect the start of each week of data.

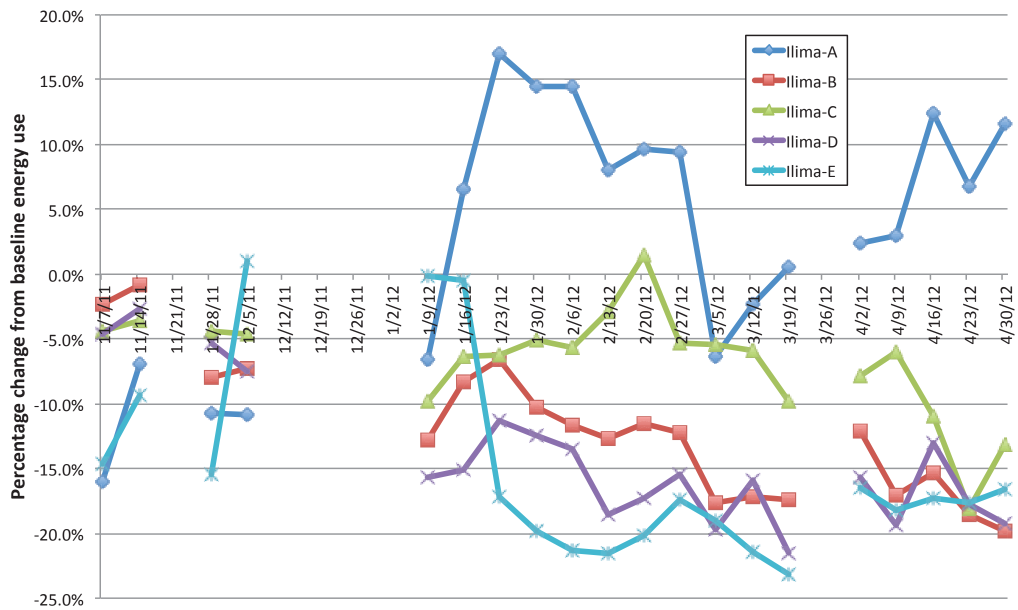


Figure 5.22: Percentage difference for weekly post-challenge energy use compared to baseline for each lounge in Ilima, with weeks of low occupancy removed (positive percentages are increased use, negative are reduced use). Dates reflect the start of each week of data.

the other two towers show this same pattern across all lounges.

One dramatic change is the reduction in energy use by Mokihana C during the spring 2012 semester (Figure 5.24). Mokihana C's energy use quickly dropped by 40% compared to its baseline in the week of 1/23/12, and stays around this level for the remainder of the semester. I noticed this change in February 2012, and asked the RD for Mokihana whether there had been any changes in occupancy or appliances (such as the removal of in-room air conditioners) that could account for the change. The RD and RAs indicated that there were no such changes that they were aware of, so it is unclear what caused this change in energy use.

5.3.4 Discussion

Research question #3 is "how did energy use change during the challenge?" Based on the data presented in this section, some lounges reduced their energy use during the challenge, while others increased their usage. For a lounge to reduce its energy usage, its residents need to make concerted changes to their behavior. If the Kukui Cup is the facilitator of the behavior changes, then residents will participate in the Kukui Cup game experience by earning points. However, Figure 5.15 and Figure 5.16 show that participation alone is not sufficient to ensure energy conservation. While the lounge that conserved the most during the challenge also had the highest participation, participation did not lead to conservation in other cases.

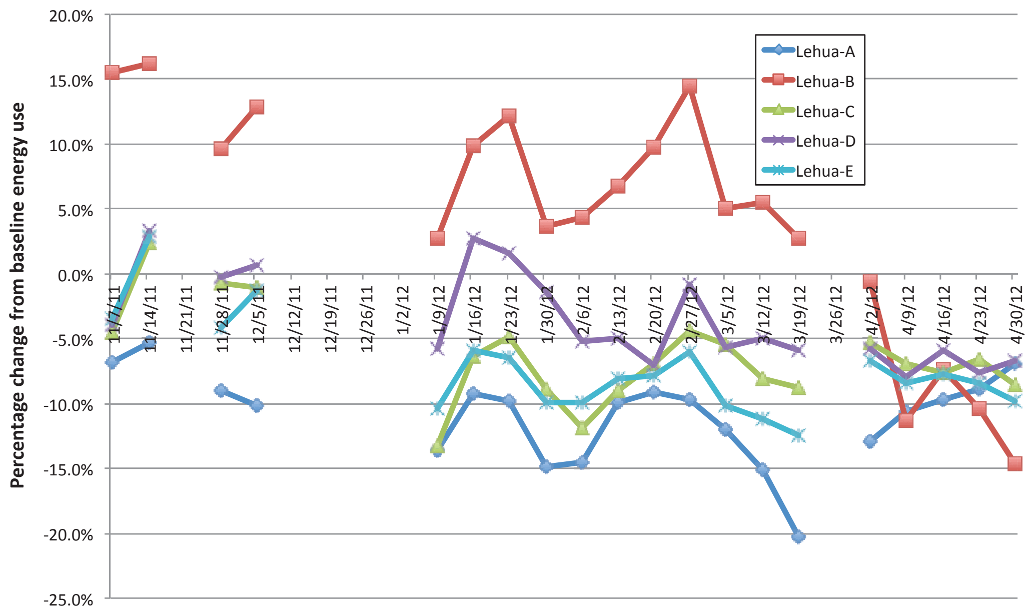


Figure 5.23: Percentage difference for weekly post-challenge energy use compared to baseline for each lounge in Lehua, with weeks of low occupancy removed (positive percentages are increased use, negative are reduced use). Dates reflect the start of each week of data.

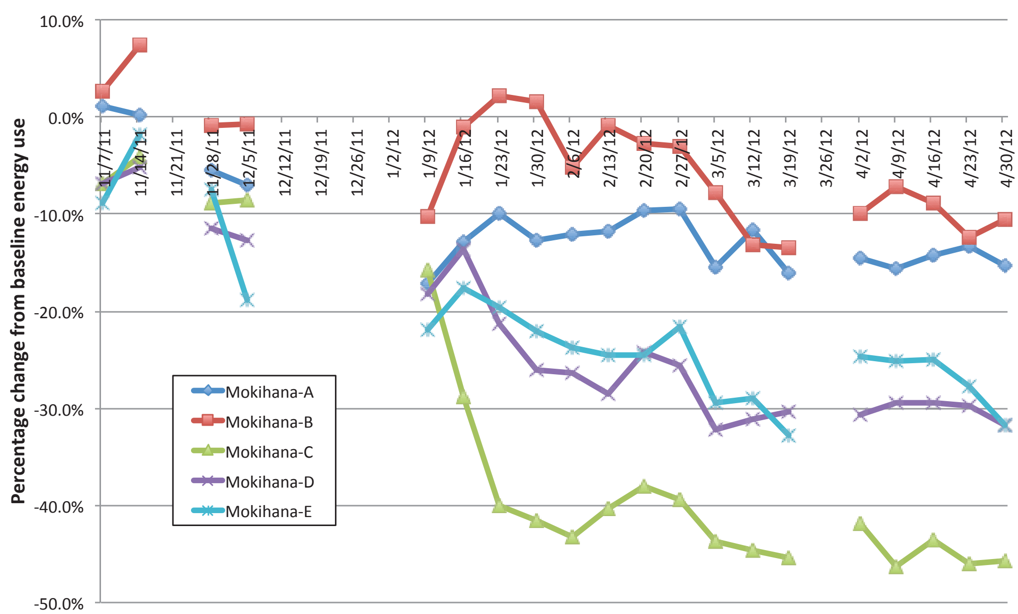


Figure 5.24: Percentage difference for weekly post-challenge energy use compared to baseline for each lounge in Mokihana, with weeks of low occupancy removed (positive percentages are increased use, negative are reduced use). Dates reflect the start of each week of data.

One possible reason for the lack of greater energy conservation relates to our use of lounges as the team unit for the 2011 UH Kukui Cup. Lounges consist of a fairly large group of 54 residents, and since they are split across two floors, some lounge members may only rarely see residents that live on the other floor of the lounge. While the shared lounge space and lounge-level elevator create some potential for interaction between the two floors, the choice of the lounge as team was forced by electrical infrastructure in Hale Aloha. The results of the group identification scale further show that residents do not strongly identify with their lounge, and in some cases may not even be aware of the lounge concept. These factors work against the type of esprit de corps needed for a team to pull together and make changes in behavior as a group.

Research question #4 is "how did energy use change after the challenge?". Post-challenge energy use varied substantially over time and across lounges, even after accounting for predictable occupancy changes. There is no evidence of any sustained change in behavior, as reflected in energy use. The lounge that conserved the most energy during the challenge failed to maintain that conservation through the rest of the academic year. Further, given the variation in energy use over time, it seems unlikely that one could tease out the impact of the Kukui Cup from all the other factors that could influence energy use such as temporary changes in occupancy, weather patterns, and semester schedules.

Finally, these results bring to light the multifaceted problems with using energy baselines as a means of evaluating the effect of energy competitions or other energy interventions. The two primary ways of computing baselines are: averaging energy data for the challenge period from previous years, and averaging data from weeks before the start of the challenge.

Averaging data from previous years exposes the baseline to any changes in building infrastructure that may have taken place. As energy prices rise and building operation budgets tighten, building managers are increasingly investing in infrastructure improvements that reduce energy use such as more efficient lighting, heating and cooling, or increased insulation. Weather changes between years could also dramatically affect baseline calculations, making them poor predictors of energy use.

Using energy data collected shortly before the challenge sidesteps some of the problems from previous year data, such as changes in weather and building infrastructure, but creates new problems. Creating a baseline using only two or three weeks of data magnifies the impact of any anomalous activity that changes energy use. When energy use has a clear trend upward or downward during the period being averaged, the baseline will smooth out that trend. For example, in Figure 5.13, Mokihana E's energy increases substantially during the two weeks before the challenge. If this increase reflects a permanent change to the lounge's energy use (such new residents moving in), then a baseline computed from three weeks of data will lower the baseline, making it an inaccurate predictor of future use and making it harder for Mokihana C to win any competition using that baseline. If the increase is a temporary change (abnormally warm weather or out-of-town guests visiting), then a three-week baseline will be higher than it should be to predict future use and make it easier for Mokihana C to perform well in a competition. In short, there are many possible causes of changes in energy use during the baseline period, and without deep insight into those changes, the choice of a particular baseline computation method will be arbitrary and likely inaccurate. Using baselines to assess long-term changes in behavior are even more problematic, as the further away in time from the baseline period one gets, the less likely the baseline is to be an accurate predictor of energy use.

These problems with baselines are not limited to the Kukui Cup. The Berkeley Greek Green Cup was an energy competition between Greek Houses at Berkeley in 2011 [32]. The results of the competition are shown in Figure 5.25. The top team reduced their energy use by an 63.47%, an impressively high number. However, the bottom team *increased* their energy use by 66.84%! While it is possible that the competition led some teams to dramatically decrease their energy use, and other teams to dramatically increase their energy use, it seems much more likely that this result was due to a problem with baseline selection, or some factor other than the competition.

Competition Rank	Council	Chapter	Electricity use % change	Natural gas use % change	Sum % change
1	IFC	Phi Gamma Delta (Fiji)	-39.66	-23.81	-63.47
2	IFC	Kappa Alpha (KA)	-38.38	-23.14	-61.52
3	IFC	Tau Kappa Epsilon (TKE)	-36.04	-19.55	-55.59
4	PHC	Chi Omega	-19.94	-28.79	-48.73
5	IFC	Delta Upsilon (DU)	-3.73	-31.02	-34.75
6	IFC	Alpha Epsilon Pi (AEPi)	-30.30	-4.24	-34.53
7	IFC	Theta Delta Chi (TDX)	-14.67	-18.57	-33.24
8	IFC	Sigma Alpha Mu (Sammy's)	-13.37	-18.56	-31.94
9	PHC	Kappa Alpha Theta	-13.70	-17.96	-31.66
10	PHC	Kappa Kappa Gamma	-9.02	-17.81	-26.83
11	PHC	Delta Delta Delta	-9.52	-6.76	-16.28
12	IFC	Alpha Tau Omega (ATO)	-8.99	3.21	-5.78
13	PHC	Alpha Phi	0.22	-1.36	-1.13
14	MCGC	Alpha Delta Chi	21.29	-7.24	14.05
15	PHC	Alpha Chi Omega	24.75	2.78	27.53
16	PHC	Delta Gamma	3.19	26.42	29.60
17	PHC	Alpha Delta Pi	-14.17	52.81	38.64
18	PHC	Gamma Phi Beta	-4.20	71.04	66.84

Figure 5.25: Outcome data for the 2011 UC Berkeley Green Cup

The arbitrariness of baselines can be further demonstrated through problems Oberlin College encountered during the 2010 Campus Conservation Nationals [122]. During the first two weeks of the competition, Oberlin had a 5% increase in electricity use, which led to a ranking of 32nd place, which is surprising since Oberlin was a leader in campus energy competitions [101]. The poor ranking led to frustration among some student participants, one of whom is quoted as saying "We've turned off every fucking light in this building, dude, and it's not making a goddamn difference." Oberlin challenge organizers felt that the baseline was not accurate: "During the competition, it became clear that this common baseline period . . . was, in some cases, resulting in percentage changes for individual buildings and sometimes for whole campuses that were more attributable to changes in weather and other factors than to the choices that students were making in their dorms". After discussing with the national competition organizers, the baseline was changed (presumably increased) "for schools with resource increases greater than 15 percent". While there is little doubt that the Oberlin challenge organizers felt there were good reasons for changing the baseline, these reasons only came to light because Oberlin was faring poorly in the competition. Since there is little justification for picking a particular baseline, it is easy for competition organizers to pick them in such a way that competitions are found to be successful in spurring energy conservation through behavior change.

Since baselines form the basis for evaluating energy competitions, these fundamental problems with computing baselines call into question the published results from all competitions. Further, the problems with baselines are not discussed in the literature. The articulation of these issues with baselines is one of the major contributions of this research.

5.4 Action Effectiveness

Research question #6 is "how effective were the actions available via the website?" One measure of the effectiveness of the actions is to examine their relationship with energy literacy. Since only 24 participants completed both pre- and post-challenge energy literacy questionnaires, the effectiveness of the actions on energy literacy levels will be limited to that data. My hypothesis is that participation in the challenge (as evidenced by score and actions completed) would correlate with improvement in energy knowledge.

Table 5.14 shows the change in the number of energy knowledge questions answered correctly from the pre-challenge questionnaire to the post-challenge questionnaire, along side the participants' scores and the number of actions they completed. For comparison, Table 5.15 shows the changes for non-participants.

Figure 5.26 is a scatterplot of the change in energy knowledge questions answered correctly against the participant's score. While the plot shows two data points in the upper right hand quadrant representing high scores and large improvements, the overall trend is unclear. There is substantial variation in the knowledge change among low-scoring participants, perhaps indicating that light participation in the Kukui Cup does not have much impact on energy knowledge.

Since we assigned scores to actions based on guesses of how effective they might be (see Section 5.5 for more discussion), using total score as the indicator of participation might not fully reflect participation. Figure 5.27 is a similar scatterplot, showing change in energy knowledge questions answered correctly, but plotted against the number of actions a participant completed. The results are quite similar to the score scatterplot; therefore, score seems to be a reasonable assessment of a participant's degree of participation.

Plots based on *change* in energy knowledge do not account for players that might already know

Table 5.14: Change in number of energy knowledge questions answered correctly between pre- and post-challenge questionnaires for challenge participants, compared to score and number of actions completed.

Participant #	Knowledge Δ	Pre	Post	Points	Actions completed
1	7	8	15	1154	61
2	7	6	13	405	28
3	5	6	11	260	27
4	5	6	11	45	1
5	5	9	14	1279	69
6	3	5	8	248	23
7	3	8	11	357	22
8	3	2	5	45	2
9	3	5	8	297	17
10	2	6	8	25	1
11	2	10	12	105	9
12	2	7	9	45	2
13	2	6	8	65	2
14	1	12	13	385	28
15	0	6	6	355	28
16	0	7	7	110	5
17	-1	13	12	295	28
18	-1	10	9	642	43
19	-1	9	8	512	38
20	-2	11	9	85	2
21	-2	5	3	45	3
22	-3	6	3	25	1
23	-3	8	5	35	2
24	-3	10	7	105	1

Table 5.15: Change in number of energy knowledge questions answered correctly between pre- and post-challenge questionnaires for non-challenge participants.

Participant #	Knowledge Δ	Pre	Post
25	3	5	8
26	2	7	9
27	2	6	8
28	2	9	11
29	2	9	11
30	2	7	9
31	1	3	4
32	1	6	7
33	1	7	8
34	1	8	9
35	1	8	9
36	1	4	5
37	0	6	6
38	0	6	6
39	0	5	5
40	-1	9	8
41	-1	5	4
42	-1	8	7
43	-1	8	7
44	-2	9	7
45	-2	9	7
46	-3	10	7
47	-4	12	8
48	-6	13	7

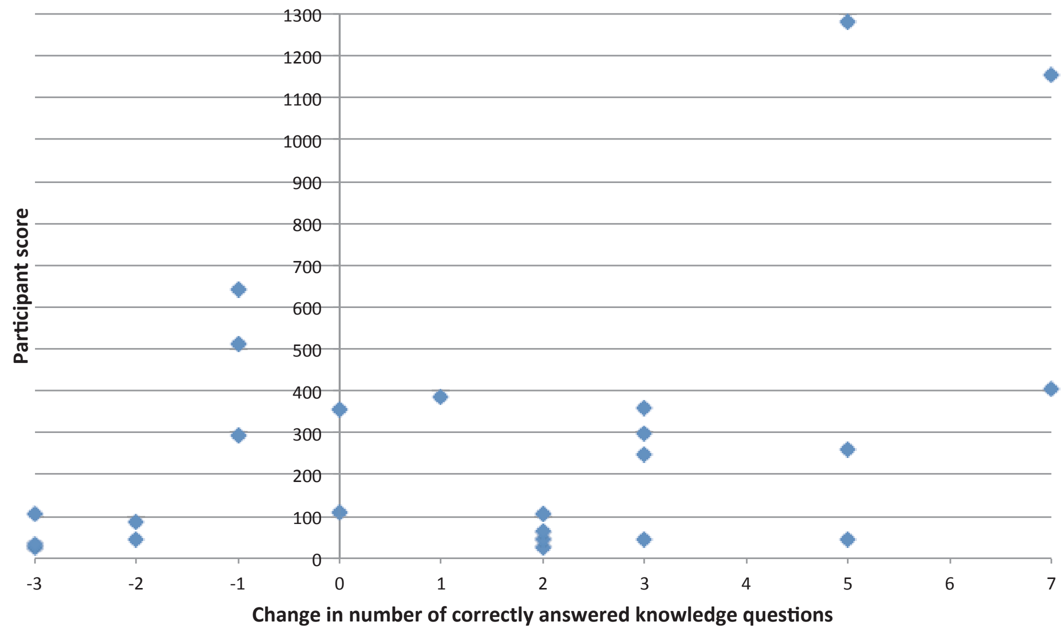


Figure 5.26: Scatterplot of change in number of energy knowledge questions answered correctly between pre and post-challenge questionnaires for challenge participants, compared to score.

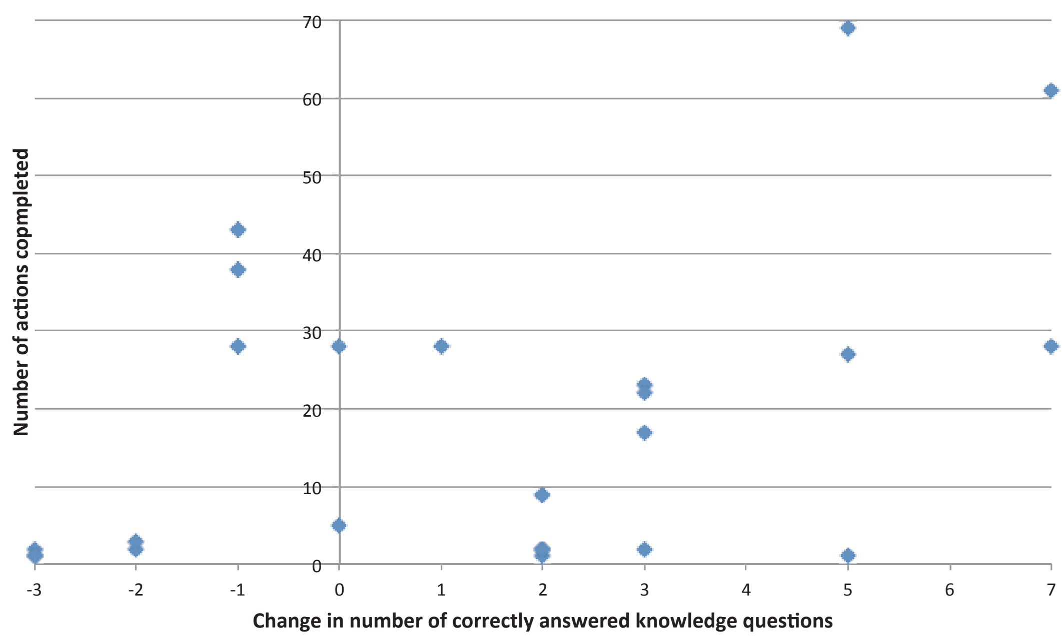


Figure 5.27: Scatterplot of change in number of energy knowledge questions answered correctly between pre and post-challenge questionnaires for challenge participants, compared to number of actions completed by participant.

about energy, since they might see little or no change in their energy literacy despite playing the game. Figure 5.28 is a scatterplot showing participants post-challenge energy knowledge score plotted against their score. While constrained by the sample size, there are no data points that contradict the hypothesis that participating in the challenge increases energy literacy. All the data points lie to the right of a diagonal line drawn from lower left to upper right, showing that as players earned more points, they were more likely to score better on the energy knowledge questions. Note that a low Kukui Cup score need not correlate with a low post-challenge energy knowledge score, since players might stop playing the game for a variety of reasons and still demonstrate high energy knowledge due to prior knowledge or aptitude.

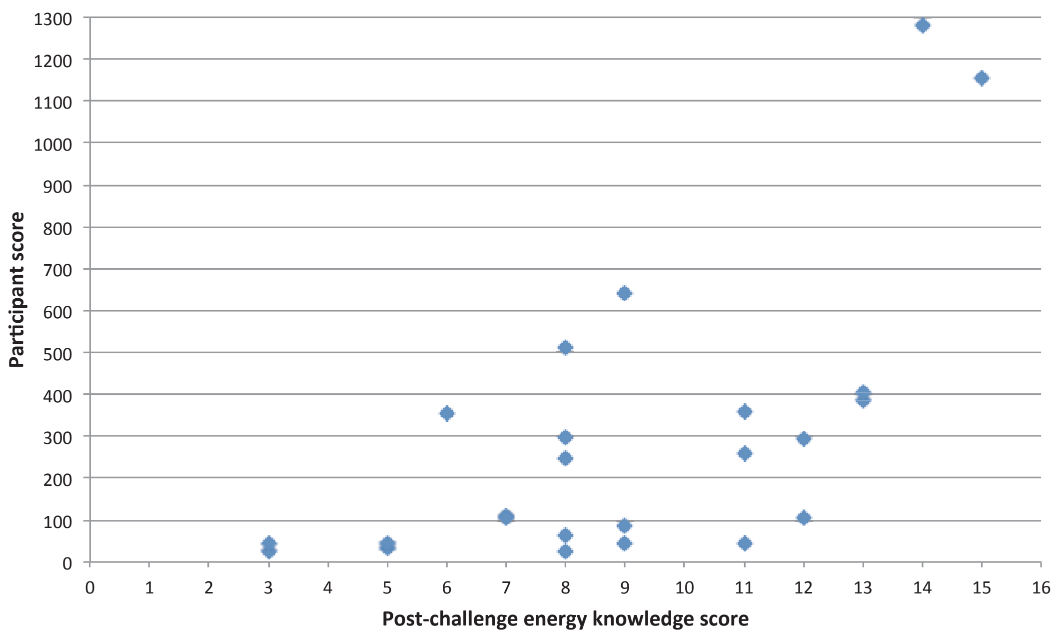


Figure 5.28: Scatterplot of post-challenge energy knowledge questions answered correctly for challenge participants, compared to score.

Based on the limited data available, it is unclear how effective the individual actions available in the challenge were to increasing energy knowledge. However, I did not find any evidence that contradicts the conclusion that the more points earned and actions completed, the higher the participant's post challenge energy literacy score.

5.5 Action Point Value Appropriateness

Research question #7 is "how appropriate were the point values assigned to actions?" As described in Section 4.7, we assigned points to actions primarily based on the expected difficulty of the action, and a guess as to how effective they might be at increasing energy literacy. Table 5.16 shows the general rubric we used for assigning point values to actions.

Table 5.16: List of point categories for actions (repeated from Table 3.4)

Point value	Type of action	Time commitment
5	Tweet something or complete a commitment	1–2 min
10	Watch tutorial video, slightly more involved activities	5 min
20	Attend an event	1–2 hours
30	Priority events or activities	10–60 min
5–50	Creative activities (e.g. writing a letter to editor)	multiple hours

One issue with this point rubric is that the range is quite narrow, and point values do not scale with the expected amount of time required to complete the action. For example, sending a tweet with Twitter might take one minute for 5 points, but creating a video about the Kukui Cup could take hours and has a maximum potential of 50 points (for an excellent video). This disparity was also a concern for events, which required attendance at a particular time and place, often for an hour or more, but were often worth only 20 points. Making points scale more linearly with the expected time commitment would better balance the rubric. Off-campus excursions were poorly attended during the challenge. The attendance level could have partly been due to their low point values compared to player's investment in time to attend them.

One measure of the appropriateness of questions is the number of rejected submissions from players compared to the number of completions. Table 5.17 shows the activities that had a rejection rate above 20% based on the total number of activity submissions that were accepted compared to those that were rejected.

Table 5.17: A list of activities with rejection rate above 20%

Activity	Points	Completions	Rejections	Reject rate
Make a video on a Kukui Cup topic	5–50	4	3	75%
Refer a friend to the Kukui Cup	5	12	6	50%
Write a song about a Kukui Cup topic	5–50	2	1	50%
Learn more about opala	15	31	14	45%
Watch video about Power & Energy	10	198	80	40%
Share Kukui Cup link on Google+	5	45	15	33%
Label power hogs in your room	15	22	7	32%
Learn more about transportation	15	69	19	28%
Learn more about the Hawaii Clean Energy Init.	15	33	8	24%
Play the photo chain game	10	22	5	23%
Watch video on Energy Intuition	10	147	29	20%

The first and third activities in the table are from the creative category, and already have the a high point value as the top end of the variable range. As discussed earlier in this section, higher point values for activities that require a greater time investment would be worthwhile. The second activity was intended to encourage players to refer new players to the game using the referral bonus. The referral bonus was confusing to some players who sometimes thought they had referred new players when they had not done so. However, confusion with the referral bonus is best handled by thoroughly examining the referral bonus mechanism directly and not by increasing the value of this ancillary activity.

Some of the activities in the in table refer to watching a video, and we created most of these videos. Those videos that had high rejection rates probably reflect confusing videos that could be improved by creating better videos, or switching to another means of communicating the information. For example, many players had problems understanding the difference between power and energy. While this can be a tricky concept, it also might be better understood through an interactive game or display where players can explore the two concepts by turning on and off electricity to different virtual appliances.

The Google+ link sharing activity was intended only as a way to increase awareness of the Kukui Cup, but at the time of the challenge, Google+ was a new service and not as easy to share content compared to Facebook and Twitter. This activity could easily be removed with no negative impact on the challenge. Labelling appliances with their energy use ("Label power hogs in your room") required more effort than comparable 15 point activities, so its point value should be increased.

Overall, it appears that the point rubric we used was appropriate, with the exception of not providing enough points for events, which had a higher time investment than most other actions.

5.6 Importance of Lounge-Level Feedback

Research question #8 is "how important was lounge-level near-realtime feedback?" Lounge-level feedback was integrated into the challenge in several ways including: the energy competition, the Daily Energy Goal Game, and two different types of lounge-level energy prizes per round.

There was only one activity (excluding Canopy activities) that required players to use the lounge-level energy data: "Examine your lounge's energy use". To complete this activity, players had to view the Go Low page that contained the energy data and report back on "is your lounge above or below the energy goal, by how much, and name one activity that might help your lounge conserve energy." 95 players completed this activity, which is 23.6% of the participants in the challenge. This percentage is quite close to the 25% threshold I established in Section 4.8.

In the final round of the challenge, we provided players with an online survey that they could complete for 40 points. Appendix E provides a list of the questions in the survey. 43 players completed the survey. One of the questions in the survey was "The Kukui Cup website shows energy data updated every 15 seconds. Did you find this helpful in conserving energy?". Table 5.18 shows the results.

The in-game survey suffers from some limitations: it did not come from a random sample

Table 5.18: Survey answers to the question "The Kukui Cup website shows energy data updated every 15 seconds. Did you find this helpful in conserving energy?"

Answer	Count	Percentage
not really, updating the data daily would be enough	2	4.7%
not really, updating the data hourly would be enough	7	16.3%
not really, I only care about the final result of the competition	2	4.7%
yes, it is helpful to see the energy usage changing in real time	32	74.4%

of players, players were incentivized to participate using points, and players may have felt that giving positive responses would curry favor with the administrators and thereby help them in the challenge. Given these limitations, survey respondents did report that the real-time lounge-level energy feedback was helpful by a wide margin.

Based on the results presented here, the case for lounge-level feedback is not clear cut. Providing feedback at a finer grain than an entire building enables a variety of possibilities in a challenge such as floor versus floor competitions and energy goals. However, in at least in the case of Hale Aloha, players do not strongly identify with their floor (as discussed in Section 5.2.5), making the utility of floor competitions unclear. It is possible that with smaller team units, or teams built around groups that players identify more strongly, the problems we experienced in Hale Aloha might not occur.

The case for providing real-time data, which requires effort and expense beyond the lounge-level metering, is less clear. The only game component in the challenge that required real-time feedback was the Current Power widget (see Section 3.7.2.4). The inclusion of this widget on the Go Low webpage provides an element that updates every 15 seconds, which adds to the visual interest of the page. While the Current Power widget was originally conceived as a way for players to experiment with how much energy their devices use, we have no evidence that players actually did experiment in this way. Since the energy data is aggregated across 54 residents, only fairly large loads (such as microwaves) are likely to be visible amongst the noise of other loads being turned on and off. However, 74% of the players responding to the in-game survey indicated that they found the rapidly-updated energy data helpful, which is a positive factor in considering whether to provide real-time data in energy competitions.

5.7 Post-Challenge Energy Audit

As described in Section 3.4.4, installation of the electricity meters for the challenge was completed during the Fall 2011 semester. A joint team from UH Mānoa Student Housing and the Kukui Cup project conducted an energy audit of the four Hale Aloha towers during the winter break after the Fall 2011 semester [7]. Residents are not required to leave during the winter break, but many residents do leave, providing an opportunity to unplug all devices in resident rooms and examine the power usage recorded by the lounge meters. The power usage results are discussed in Section 3.4.5.1. However, Housing had these additional goals for the audit:

1. Making a count of the types of appliances residents have in their rooms.
2. Unplugging unused & unneeded appliances for residents who were away for winter break to conserve energy.
3. Noting any violations of rules, such as attaching things to fire sprinkler heads, or having an unapproved air conditioner.

It is likely that some residents that left during the winter break took some portable appliances with them, such as laptops, and might have moved out "contraband" appliances. Therefore, the appliance count will probably be an underestimate of what was actually present during the Fall 2011 semester.

5.7.1 Auditing Procedure

The four Hale Aloha towers were audited between December 19 to December 22, auditing lounge by lounge using the following procedure:

- One team examined each room on the first floor of the lounge. They recorded the appliances present in the room on a worksheet.
- For unoccupied rooms, all appliances were unplugged.
- For occupied rooms, the resident was asked to unplug all devices until the audit is complete.
- Once everything has been unplugged, we examined the power readings on the two meters that monitor each lounge. Using the electrical panel that each meter is attached to, we turned off each circuit breaker and recorded any change in power use from the meter display.

5.7.2 Appliance Count

The energy audit also produced a list of the number of appliances in each room. Table 5.19 shows the total number of appliances per tower, while Table 5.20 shows the average number of appliances per room for each tower.

From these counts, we see that most rooms have a printer, and that microwaves and TVs are quite popular. The count of laptops is likely a major underestimate since many residents were away for the break, and likely took their laptop with them. We did record a laptop when there was some evidence that a laptop was usually present (such as a laptop stand, mouse pad, or power adapter). Desktop computers seem to be quite rare, presumably displaced by laptop usage.

Table 5.19: Total appliance count per tower

Tower	Microwaves	Desktop Computers	Laptops	Fans	Lamps	TVs	Printers
Lehua	120	5	25	224	96	69	150
Ilima	103	2	44	273	93	79	131
Lokelani	86	2	48	273	121	67	139
Mokihana	89	18	43	252	88	68	129

Table 5.20: Average number of appliances per room for each tower

Tower	Microwaves	Desktop Computers	Laptops	Fans	Lamps	TVs	Printers
Lehua	0.86	0.04	0.18	1.60	0.69	0.49	1.07
Ilima	0.74	0.01	0.31	1.95	0.66	0.56	0.94
Lokelani	0.61	0.01	0.34	1.95	0.86	0.48	0.99
Mokihana	0.64	0.13	0.31	1.80	0.63	0.49	0.92

A surprising finding was the prevalence of rooms with more than one mini refrigerator. Table 5.21 shows the distribution of refrigerators across the four towers.

Table 5.21: Refrigerator distribution by tower

Tower	# fridges	avg. fridges/room	0 fridges	1 fridge	2 fridges	3 fridges
Mokihana	149	1.06	19	93	28	0
Lehua	176	1.26	7	90	43	0
Ilima	176	1.26	7	91	41	1
Lokelani	177	1.26	12	79	49	0

We see that most rooms have a refrigerator, and many have two. Based on this, it seems possible that a significant portion of the base load in Hale Aloha comes from refrigerators. Further examination of the refrigerator issue would be worthwhile such as assessing how much energy they consume, and finding ways to reduce the number of refrigerators in Hale Aloha.

5.8 The Role of RAs

One question that we discussed in preparation for the challenge was whether RAs should be allowed to actively participate in the challenge (i.e., log into the website, earn points, and win prizes). We were concerned that if RAs could win prizes, it could demotivate the residents, who might believe that the RAs had an unfair advantage due to their position. We also felt that since the RAs were already being compensated for their work as an RA, further compensation in the form of prizes was unnecessary.

Based on this line of thought, we told RAs that they could participate in the challenge, including earning points, but they would not be eligible to win prizes through either the point challenge or the raffle game. RAs were to be entered into a separate RA-only drawing with unspecified but lower value prizes.

Unfortunately, we found that after Round 1, RA participation was low at 40% (16 of 40), and in our interaction with RAs they lamented the fact that they were unable to win prizes. We decided to change course and starting on October 26 (day 3 of Round 2), we made them eligible to win prizes and participate in the raffle game. RA participation after the change took effect was 62% (23 of 37, due to some RAs attrition). In an anonymous followup survey with the RAs after the challenge was over [60], prizes were listed as a common motivation for those that participated (8 of 19 responses), and confusion over the inability to win prizes was mentioned as a reason for not participating (2 of 14 responses). The survey results provide a strong indication that allowing RAs to fully participate was the correct decision and should be implemented from the beginning in future challenges.

5.8.1 Active Participation Bonus

In an effort to further motivate RAs to encourage their residents to participate in the challenge, we instituted an additional incentive for RAs on October 26 (at the same time as the rules were changed to allow RAs to win prizes). We computed a new metric we called *active participation*, which is the percentage of residents in each lounge that have earned more than 50 points in the challenge. RAs were given a gift card to the UH Mānoa bookstore based on their lounge's active participation at the end of the challenge: $25 for 25%, $50 for 50%, and $100 for 100%. To allow RAs (and others) to track their progress, a new scoreboard was added to the rotation that showed the percentage of participation for each lounge, updated in real time.

At the end of the challenge, the RAs of three lounges received the $50 bonus (for active participation of 74%, 53%, and 51%), and the RAs of four lounges received the $25 bonus (44%, 43%, 37%, and 35%).

Based on conversations with some RAs, the active participation bonus was a motivator to get their residents playing the game. However, it would likely have been more effective if it was instituted at the beginning of the challenge.

5.9 Summary and Conclusions

37% of Hale Aloha's residents participated in the challenge, which is comparable to results from other competitions. 6% of that total only played on the last day due to a final day surge driven by the two top players using the referral bonus to increase their scores. Overall, many residents chose to participate in the Kukui Cup (RQ#1), which was essential for a successful Kukui Cup challenge. Lounge-level participation in the challenge varied wildly, ranging from 74% to 13%. Lounges with low participation rates can not be expected to conserve much energy.

Based on the results from my energy literacy questionnaire, participants in the challenge appeared to have modestly increased their energy knowledge compared to non-challenge participants ($p = 0.056$). Energy attitudes and self-reported energy behaviors did not appear to differ between participants and non-participants, and attitude scores for questionnaire participants were close to those of New York State middle and high school students reported by DeWaters and Powers. Energy literacy appears to have modestly increased as a result of the Kukui Cup (RQ#2).

Lounge energy was quite variable before the challenge started, both between lounges and within lounges over time. During the challenge, some lounges did reduce their energy use compared to a baseline computed as an average of energy use the three weeks before the challenge (RQ#3). The best performing lounge reduced their energy use by 16%. While the most conserving lounge was also the lounge with the highest participation (69% without the final day surge), there did not appear to be any correlation between participation and energy conservation. The results of the group identification section of the energy literacy questionnaire showed that participants did not strongly identify with their lounge, which complicates any effort to encourage conservation of energy as a group.

Energy use after the challenge was also quite variable. Lower occupancy during certain periods such as Thanksgiving and winter break led to dramatically lower energy use during those periods. Excluding those lower occupancy periods, there is no evidence of sustained energy behavior change (RQ#4). In fact, the lounge that conserved the most during the challenge compared to their baseline went on to substantially exceed that baseline during the spring 2012 semester.

These energy results call into question the common practice of evaluating energy competitions through percentage change from a computed baseline. First, finding representative pre-competition energy data is difficult, especially when the energy use is changing over time. This difficulty can lead competition organizers to make an arbitrary choice of which baseline to use, which impacts any evaluation of effectiveness compared to the baseline. However, baselines can also be used as part of game mechanics, such as for setting energy goals. When using a baseline to motivate conservation rather than to evaluate whether conservation has taken place, these problems with baselines are less important.

I was unable to determine what relationship (if any) exists between energy literacy and energy usage (RQ#5), due to, in part, insufficient energy literacy data for each lounge. The deeper realization is that energy literacy affects energy use by way of energy behavior, which is very hard to measure directly. Investigating this question further will likely require methods of actually measuring behavior, and ways to measure energy use at finer granularity than is possible in most multi-occupant buildings.

Due to the small number of participants that completed both pre- and post-challenge energy literacy questionnaires and participated in the challenge, I was unable to determine the effectiveness of actions provided in the challenge (RQ#6). However, the data do not contradict the hypothesis that increased participation in the challenge leads to higher energy knowledge after the challenge.

The initial point values we assigned to actions were based on guesses as to their effectiveness and difficulty for players. Based on experiences with the 2011 Kukui Cup, the overall range of points assigned to actions was too narrow, which led to events and creative activities that can require a greater time investment not being rewarded proportionally with more points (RQ#7). Most actions with high rejection rates appeared to be related to the content itself, and higher point values would probably not reduce the number of rejected responses.

The 2011 UH Kukui Cup provided players with real-time lounge-level energy feedback. Almost a quarter of players completed an activity that required the use of lounge-level feedback, and 74% of players who completed an in-game survey indicated that they found real-time feedback helpful in conserving energy (RQ#8). While providing real-time lounge-level feedback can entail considerable additional expense and effort, there is some indication that it can be helpful to players.

An energy audit of Hale Aloha conducted after the challenge found that refrigerators were common in most rooms, and many had two. These appliances use electricity around the clock, so further research into refrigerator use could provide a way to reduce energy use in residence halls.

Finally, Resident Advisors played an important role in the 2011 Kukui Cup. Initially, RAs were allowed to participate in the challenge, but not able to win prizes. RAs found this demoralizing, and potentially blunted one of the means of promoting the challenge to residents. During Round 2, RAs were allowed to fully participate and were further incentivized by a special bonus payment depending on how many of their residents participated in the challenge. Motivating RAs to participate in the Kukui Cup and encourage their residents to participate remains an important area of focus for future challenges.

CHAPTER 6
CONCLUSIONS

This dissertation investigated the design, implementation, and evaluation of the 2011 UH Kukui Cup challenge. This chapter summarizes the results of the research, the contributions of the research, and possible future directions.

6.1 Research Summary

In an effort to foster energy conservation and increase energy literacy in students living in campus residence halls, we designed the Kukui Cup challenge. Based on a review of the literature, the Kukui Cup challenge combines a variety of elements into an overall game experience, including: real-time energy feedback, energy conservation goals, activities, commitments, real-world events, competition between teams, and prizes.

We designed a software system called Makahiki to provide the online portion of the Kukui Cup challenge that players experience through the challenge website. We installed 40 smart meters to monitor the electricity use of each pair of floors in the four Hale Aloha tower residence halls, with the data stored in the WattDepot system.

In October 2011, we ran the 2011 UH Kukui Cup challenge for the over 1000 residents of the Hale Aloha towers over three weeks. To evaluate the Kukui Cup challenge, I conducted three experiments on: challenge participation, energy literacy, and energy use.

Many residents (37%) participated in the challenge, as measured by points earned and actions completed through the challenge website. Participation rates for individual lounges varied from 74% to 13%. I measured the energy literacy of a random sample of Hale Aloha residents using an online energy literacy questionnaire administered both before and after the challenge took place. I separated the respondents into two non-equivalent groups: those who participated in the challenge, and those who did not. I found that the energy knowledge of challenge participants increased compared to that of non-challenge participants. Energy attitudes did not appear to differ between challenge participants and non-participants. Self-reported energy behaviors increased after the challenge for both challenge participants and non-participants, leading to the possibility of passive participation by the non-challenge participants as information or peer pressure diffused from the challenge participants to the non-participants. Respondents in both groups were neutral towards their lounge based on group identification scores.

I found that energy use varied substantially between lounges and within lounges over time. Variations in energy use over time complicated the selection of a baseline of energy use to use for comparison to energy use during and after the challenge. Some lounges did reduce their energy use during the challenge, the best team reducing by 16% compared to their baseline. However, lounge energy conservation did not appear to correlate to participation in the challenge. Energy use after the challenge period also varied dramatically, but there was no evidence of sustained energy conservation. The problems inherent in assessing energy conservation using a static baseline call into question this common practice.

6.2 Contributions

My research has generated several contributions, including: a demonstration of increased energy literacy as a result of the challenge, the discovery of fundamental problems with the use of static baselines for assessing the effectiveness of energy competitions, the creation two open source software systems, and the creation of an energy literacy assessment instrument.

6.2.1 Design of the Kukui Cup Serious Game

I was the principle designer of the overall Kukui Cup serious game experience. The game experience covers the entire player experience: from logging into the game for the first time, the rubric for assigning points to actions, and the selection of real-world events. I drew upon literature from game design, serious game design, and environmental psychology in designing the game to be both engaging and effective. The two sides of the challenge, energy literacy and energy use, were intended to be mutually reinforcing, creating a virtuous cycle between learning about energy literacy, changing energy use behaviors, and seeing those changes reflected in lower lounge energy use. The Kukui Cup is the first competition to combine both energy use and energy literacy activities into one game experience. We have published one conference paper on the design of the Kukui Cup [9].

6.2.2 Improvement in Energy Literacy Due to the Kukui Cup

One of the major hypotheses of my research was that participating in the Kukui Cup challenge could increase energy literacy. Testing this hypothesis required extensive effort over a period of two years including: the development of the Kukui Cup challenge structure, the development and implementation of the Makahiki web application, the creation of the energy literacy content, the development of the energy literacy instrument, the execution of the 2011 UH Kukui Cup challenge, and the administration of pre- and post-challenge energy literacy questionnaires. No energy competition discussed in the literature has been subjected to this level of rigorous assessment of impact on energy literacy. Further, it seems rare for the effectiveness of any serious game to be assessed with this degree of rigor.

The results of my energy literacy experiment, described in Section 5.2, show that participants in the Kukui Cup did appear to improve their energy knowledge as a result of participation. This demonstration is significant, because the challenge was a purely optional activity for the participants, and shows quantitatively that serious games can be effective in meeting their "serious" goals. Self-reported energy behaviors increased during the challenge for both participants and non-participants, raising the possibility of passive participants whose behavior could be changed simply by living in the same environment as the participants. This diffusion effect could provide a way to increase the impact of serious games beyond those who actively participate in them.

6.2.3 Energy Reduction From Baseline Is Misleading

The other major hypothesis in my research was that increased energy literacy would lead to increased energy conservation. Gathering the data to test this hypothesis required all the effort described in the previous section, plus the installation of smart meters and collection of energy data. I was unable to test this hypothesis due to insufficient data, but in the process of analyzing the energy data, I discovered a serious problem with the use of baselines to assess the effectiveness of energy competitions.

As I described in Section 2.2, the use of baselines to assess the effectiveness of energy competitions is almost universal, because it provides a convenient number (kilowatt-hours saved) that can easily be converted into money saved or carbon emissions avoided. However, as I discussed in Section 5.3.4, determining an accurate baseline that can be used as an accurate predictor of future energy use is difficult or impossible. Baselines are usually computed by averages of team energy use recorded shortly before the competition, but without detailed information about what participants are actually doing, this single scalar value is likely to be inaccurate. Because simple averaged baselines are poor predictors of future energy use, any assessment of the effectiveness of a competition, such as "energy saved", is unlikely to be accurate.

This serious problem with baselines is undiscussed in the literature around energy competitions. When a problematic baseline is discovered, it is dismissed as a temporary anomaly rather than a specific instance of the systemic problems with baselines. This finding calls into question the published results from energy competitions assessed by comparison to a baseline, and calls for new methods for assessing competitions that are less error prone. In Section 6.3.1, I present our first attempt at a new assessment mechanism: daily energy goals completed, based on a dynamic baseline. We have published one conference paper on the problems with static baselines [62].

6.2.4 WattDepot

The WattDepot system described in Section 3.5 represents a significant contribution to the field of energy research. I developed WattDepot over a period of two years, and it currently consists of over 25,000 lines of source code. I created WattDepot because the Kukui Cup project needed a way to collect, store, analyze, and display energy data, and existing systems were not able to meet our requirements. WattDepot fills a need between small systems intended to handle data from a single smart meter, and utility-scale systems intended to handle data from many thousands of meters. Existing systems were often developed by meter manufacturers, tying the software to the meter hardware, which is undesirable for end-users who want the flexibility to mix and match meters from different vendors. While the functionality of WattDepot could have been built into Makahiki, I felt it was important to build a reusable and extensible system that could be useful as more than just infrastructure for the Kukui Cup.

I have released WattDepot as an open source system hosted on Google Code [121] to make it as accessible as possible to other researchers working with energy data. Since WattDepot's first public release in October 2009, WattDepot has been downloaded over 900 times. WattDepot has been used by ICS students in software engineering classes, but has also been used by external researchers around the world, such as the Optical Zeitgeist Lab at the Institut National de la Recherche Scientifique (INRS) in Quebec [77]. In addition to the WattDepot system itself, we have published two peer-reviewed conference papers about WattDepot [8, 63].

6.2.5 Makahiki

The Makahiki system described in Section 3.7 represents a contribution to the field of serious games and energy competitions. Makahiki was developed over a period of two years by multiple developers. My role in the Makahiki project was primarily articulating the requirements needed to support the Kukui Cup, and as the primary internal tester. Along with George Lee, I worked on the user evaluation of the Makahiki user interface through walkthroughs using mockups, in-lab user evaluations, and external beta tests. Makahiki represents a unique type of serious game that combines both data on energy consumption and game content related to energy literacy, breaking new ground in this area.

Makahiki is an open source system hosted on GitHub [71], and consists of over 63,000 lines of code. The design and evaluation of Makahiki is the subject of George Lee's masters thesis [72], and two conference papers for which I am coauthor [63, 10]. The version of Makahiki used in the 2011 UH Kukui Cup (Makahiki 1) is no longer under active development, having been replaced by development of a new version (Makahiki 2) primarily by Yongwen Xu as part of his Ph.D. dissertation, described later in Section 6.3.2.

6.2.6 Hawai‘i-Focused Energy Literacy Content

We created over 100 actions for the Smart Grid Game to educate participants about energy and engage them in the game experience. Appendix C provides a full listing of the activities, commitments, and events available to participants of the 2011 UH Kukui Cup, and the descriptions of each action. I developed the majority of the actions, including five short videos hosted on YouTube on topics such as solar energy, and how to perform an energy audit.

The energy literacy content was an essential part of the Kukui Cup challenge. Players completed actions in order to earn points in the game. Much of the content had to be created from scratch or adapted for use in Hawai‘i because existing content (such as YouTube videos) often incorporate assumptions about energy use that are not accurate for Hawai‘i. To ensure that others can use or adapt the content, the Kukui Cup informational website [68] includes a summary of the energy literacy content we developed, and the Makahiki code repository includes the content as database fixtures.

6.2.7 Hawai‘i-Focused Energy Literacy Instrument

I created a questionnaire to assess the energy literacy of the residents of the Hale Aloha residence halls. Section 4.3.1 explains my development process, and Appendix D provides the actual content of the questionnaire. I started developing the instrument in early 2010, and collected some pilot data in May 2010. My questionnaire is based on the instrument for middle and high school students by DeWaters and Powers [31], but I found that changes were needed for use in my research. The DeWaters and Powers instrument was designed for use on the US mainland, which means it has implicit assumptions that are not appropriate for use in Hawai‘i, such as the primary source of electricity or the largest consumer of electricity in the home. Therefore, to be useful for assessing the impact of the Kukui Cup on energy literacy, I needed to develop my own instrument.

The instrument I developed is freely available for use by other researchers, and provides a useful method for assessing energy literacy of Hawai‘i residents. Other locales may find that they also need an instrument tailored to their area, such as one tailored to the Pacific Northwest of America, where hydropower is a substantial source of electricity. Instruments assessing the frequency of self-reported energy behaviors need to be tailored to the specifics of the population that is being targeted in order to be effective. The energy behaviors possible for a grade school student living in an apartment differ from those of a retired person living in a single-family home. Behaviors available at home differ from those at work, or at school. My questionnaire and its development process can serve as a model for researchers working in other locations with unique energy circumstances who wish to assess the energy literacy of their residents.

6.2.8 Smart Meter Infrastructure at Hale Aloha

As part of the preparation for the 2011 UH Kukui Cup, I oversaw the installation of 40 Shark 200S smart meters throughout the four Hale Aloha towers. Section 3.4 details the process I went through to install the meters. The entire process of getting the meters installed, including the selection of the meter vendor, developing a WattDepot sensor to collect the energy data, and overseeing the installation process took over 18 months. Despite the enthusiastic cooperation of all parties involved in the installation, the last meters were providing accurate data only a few days before the challenge, as explained in Section 3.4.4. An installation error in one meter was only verified and corrected after the challenge was over.

Now that the meters have been permanently installed in Hale Aloha, we have created an environment where the Kukui Cup challenge can be repeated, allowing future researchers the opportunity to explore the effects of energy challenges. Two Ph.D. students are currently basing their research around Kukui Cup challenges conducted in the Hale Aloha towers, and we hope to institutionalize the Kukui Cup so that it can become a regular part of the resident experience in Hale Aloha.

6.3 Future Directions

The 2011 UH Kukui Cup represents only the first step in examining the fertile ground of this research area. This section discusses a variety of areas for future research.

6.3.1 2012 UH Kukui Cup

While outside the scope for my dissertation, we have developed and are currently conducting the 2012 UH Kukui Cup based on our experiences with the 2011 UH Kukui Cup. Some notable improvements in the 2012 UH Kukui Cup are:

- Longer duration. The 2012 UH Kukui Cup started on September 4, 2012 and will run until April 14, 2013 (with a break during December and all of the 2012 winter break). The longer challenge is intended to give participants more time to change their behaviors (something mentioned in the literature around energy feedback), give latecomers the opportunity to join the challenge, and provide a greater opportunity for more creative, time consuming activities.

- More user generated content. The 2012 Kukui Cup has only slightly more content in terms of activities and events available to participants, compared to the 2011 UH Kukui Cup. Because the 2012 challenge lasts much longer, we have created a series of Do-It-Yourself ("DIY") activities that provide participants the opportunity to come up with new commitments and events. Participants are responsible for actually organizing the DIY events they propose, and the events are placed into the Smart Grid Game for other players to attend. This addresses Gee's *insider principle*, which suggests that learners should go beyond being consumers of content to be producers of content in the learning environment [49, p. 212].

- Recruiting players for deeper involvement with organizing the Kukui Cup. To help facilitate the addition of player-created content, we have invited highly-involved players to join a group we call the Aina Agents ('aina being the Hawaiian word for land). The Aina Agents meet to discuss projects to activities they would like to perform in the context of the Kukui Cup.

- Greater RA involvement. We conducted a survey of the RAs after the 2011 Kukui Cup challenge was over, and found that many RAs indicated they did not have time to participate or promote the Kukui Cup. [60]. Some RAs indicated that if the Kukui Cup were incorporated into their official duties, they would be better able to support the Kukui Cup. Therefore, in

2012 we worked with the Residence Directors to make involvement with the Kukui Cup an explicit part of the RA's job duties.

- A different measure of energy conservation for the energy competition. The 2011 UH Kukui Cup used absolute energy use per lounge as the metric for energy competition between lounges, based on the belief that differences in electricity use between lounges were driven by resident behavior. Due to the many problems we have identified with using baselines for assessing energy conservation, and the much longer time span of the 2012 UH Kukui Cup, we have switched to a new metric for energy competition: the number of daily energy goals met per team. Using energy goals instead of absolute energy use removes the need for teams to have similar energy infrastructure, and also encourages longer-term sustainable changes rather than abrupt short-term changes.

- Dynamic baselines. The daily energy goal for each team is determined by subtracting a percentage from the team's baseline usage. Due to the problems with static baselines, we now use *dynamic baselines* to track teams' energy use over time. The daily baseline is determined by averaging the energy use for that day of the week from the previous two weeks. So the baseline for a Monday is determined by averaging the energy use for the two previous Mondays. This dynamic baseline tracks resident usage, so as residents conserve, their baseline will decrease over time. Once their usage plateaus, they will no longer be able to meet their goal, but then the dynamic baseline will increase over time.

- Smart Grid Game with multiple levels. To make the game less intimidating for new players, we implemented a Smart Grid Game with different levels, as shown in Figure 6.1. Using multiple levels allows the content to be broken up so the entire grid of options is not displayed at once. Levels can be unlocked by completion of actions, or the passage of time. Switching to series of smaller levels also made it easier to display the Smart Grid Game on mobile devices without scrolling around a large grid.

As part of the 2012 UH Kukui Cup, Michelle Katchuck is investigating the motivations of residents regarding energy conservation as the subject of her Ph.D. dissertation.

6.3.2 Makahiki 2 and Other 2012 Kukui Cups

After using Makahiki to support the 2011 UH Kukui Cup, we redesigned and reimplemented the Makahiki system to be more flexible and modular. Some of Makahiki 2's new features are:

- The ability to customize all aspects of Makahiki to support Kukui Cup challenges tailored to the needs of an organization;

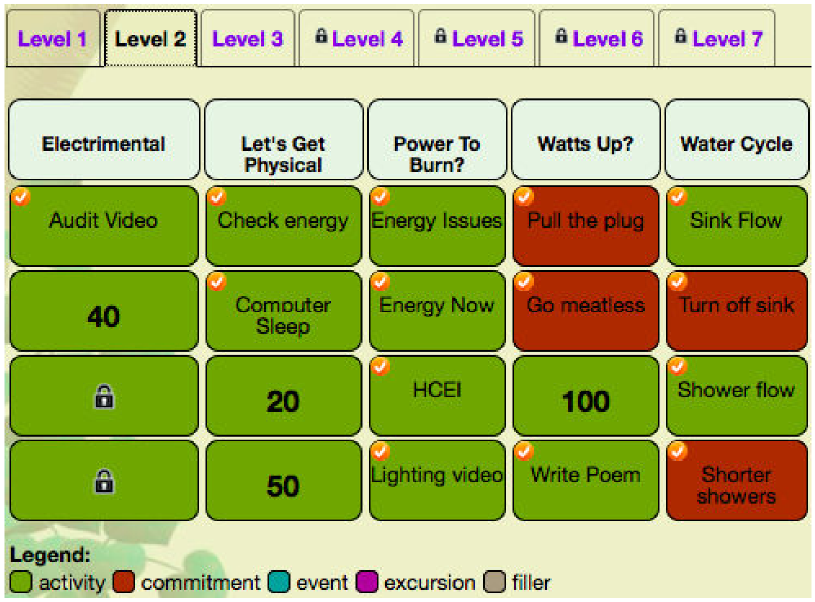


Figure 6.1: The level-based Smart Grid Game from Makahiki 2

- The ability to support water use in addition to energy use, and enter the data manually in addition to the existing automated collection using WattDepot;
- Support for deploying Makahiki to a scalable cloud hosting provider (Heroku) to reduce cost and complexity for system administrators; and
- A new architecture intended to be easier for developers to modify and extend.

Two organizations ran their own Kukui Cup challenges in fall 2012 using Makahiki 2's new functionality: Hawai'i Pacific University (a private university in Honolulu), and the East-West Center (an education and research organization affiliated with the University of Hawai'i). These were the first deployments of the Kukui Cup outside of UHM, and provided new insight into the Kukui Cup, such as how to run a challenge without prizes, as the East-West Center did.

6.3.3 Deliberately Attempt to Diffuse Treatment

One of the threats to validity I described in Section 4.3.4 is the diffusion of treatment, where members of the control group (non-challenge participants) are indirectly experience the treatment (the Kukui Cup) through their interaction with the treatment group (challenge participants). As alluded to in Section 5.2.4, some diffusion of treatment may have taken place in the 2011 UH Kukui Cup. From the point of view of assessment, diffusion of treatment makes it more difficult to determine whether the treatment is having the desired effect, or any effect at all. However, the goal of the Kukui Cup is to educate and foster changes in energy behavior as effectively as possible, so any diffusion from challenge participants to non-participants is actually a positive outcome since it broadens the reach of the challenge. Future Kukui Cup challenges could deliberately attempt to get players to engage non-players through commitments such as “convince my roommate to take the bus rather than drive for one week.” These types of player outreach may lead to further impact on non-players, and may lead to more non-players deciding to play as a result of the outreach.

6.3.4 Energy Literacy Questionnaire Improvements

The energy literacy questionnaire I developed represents an initial attempt to create an instrument tailored to both Hawai‘i and students living in a residence hall. It could be improved in several ways:

- Further analysis of the questionnaire, examining: item difficulty, reliability (Cronbach’s Alpha), and distractor analysis;
- Determining whether energy literacy results are stable across repeated measurements;
- Collaborating with other experts in the Hawai‘i energy community to assess whether there are additional areas of energy knowledge the instrument should cover; and
- As the Kukui Cup expands beyond student residence halls, adapting the questionnaire to assess literacy in other populations.

6.3.5 Additional Game Content

Although the Kukui Cup now includes over 100 actions in its library of content, there are several additional areas that could be expanded. The Kukui Cup currently lacks a video explaining the important relationship between water and energy: many forms of energy generation require water, and use of water requires energy to pump, heat, cool, and treat. We also lack videos delving into Hawai‘i’s options for future energy use, and a Native Hawaiian perspective on energy issues.

One issue with the Kukui Cup is that the educational content is largely of interest only until its content has been assimilated. We do not anticipate that players would want to revisit most actions unless they were able to earn additional points. This limited engagement is in contrast to games that players enjoy playing over and over, such as the rich game environments Gee describes as being so important for learning in games [49]. Some serious games such as the protein folding game Foldit do manage to attract repeat players and meet their serious goals [64].

Beyond additional videos, the Kukui Cup could benefit from additional actions that are more interactive in the way people traditionally think of games. Developing a complete game requires much more effort than our current actions, but could potentially provide a much higher level of engagement among players. One option would be to partner with developers of educational energy games such as Energy City, a city simulation game where players pick must figure out how to supply the energy needs of a growing city while minimizing environmental impact [48]. Figure 6.2 shows a screenshot from Energy City.

Figure 6.2: The educational Energy City simulation game

6.3.6 Expansion Beyond Higher Education

All of the Kukui Cup challenges held to date have been held in institutions of higher education (the participants in the East-West Center Kukui Cup were mostly students). While the student residence hall environment has been a useful setting for our initial research, the Kukui Cup could have greater impact if we expand to other settings.

One area we are actively exploring is deploying the Kukui Cup in the K-12 school environment. Schools have certain similarities to the student residence halls, in that the participants would be students, but many differences. In a K-12 environment, the Kukui Cup could be woven into existing curricula, rather than being an extra-curricular activity. The Kukui Cup action content would have to be redeveloped to be appropriate for the grade level being targeted, which is a substantial undertaking. Potentially energy data could be measured on a per building or per classroom basis, depending on the availability of smart metering infrastructure at the schools.

If the Kukui Cup is deployed at hundreds of schools in Hawai‘i, we will need to make the solution easier to use for the challenge designers and managers, who will likely be teachers. Most of our effort in improving the user experience to date has been focused on the player, but with a large number of novice Kukui Cup challenge designers, we will need to switch our focus to improving the user experience both for the design of the challenge and for administering a challenge.

Beyond schools, the Kukui Cup could eventually be deployed to the general public. Several issues would need to be resolved before it could be deployed on such a wide scale:

- The energy literacy content would have to be made sufficiently generic that it could apply to the wide range of potential participants.
- Makahiki would have to provide a way for participants to sign up for an account, something that is currently configured in advance by administrators.
- Energy data from homes would need to be imported into the system in some way. One promising option is the Green Button standard being promoted by the US Department of Energy, utilities, and companies interested in engaging customers with their electricity use [39].
- The current manual approval of actions by administrators would need to be automated in some way, since manual approvals would not scale to many thousands of players.

6.3.7 Impact of the US Natural Gas Revolution

Natural gas is a fossil fuel that can be burned to generate electricity or run vehicles. Natural gas produces 30% fewer greenhouse gas emissions than oil, and 43% fewer emissions than coal [92]. Over the past decade, improvements in drilling and extraction have made extraction of natural gas from shale rock economically viable, with 1,000 trillion cubic feet of natural gas recoverable in North America [59]. This leads to the question of whether this new, cheaper source of energy might obviate the need for renewable energy or energy conservation.

The US natural gas revolution does not appear to undermine the need for a transition to renewable energy sources, and increased energy conservation and efficiency. Natural gas is better thought of as a “bridge” resource that can be used to replace coal and oil use until the shift to renewable sources is complete. Even this use of natural gas as a bridge is being called into question, because methane leaks from natural gas fields may overshadow the reduced CO_2 emissions [118].

Since Hawai‘i has no natural gas reserves, switching Hawai‘i’s primary energy source from oil to natural gas would only replace one type of imported, non-renewable source with another: replacing oil tankers with liquefied natural gas (LNG) tankers.

6.3.8 Refrigerator Usage

Based on the prevalence of mini-refrigerator use (see Section 5.7.2), future iterations of the Kukui Cup should include programs designed specifically to address this issue. For example, when first moving into their rooms, residents could be strongly encouraged to share a refrigerator with their roommate. The impact of shared refrigerators on energy use would have to take into account the likelihood of purchasing larger refrigerators to accommodate shared usage. However, most mini-refrigerators have little insulation due to their smaller size, so a larger refrigerator will not necessarily use much more energy.

APPENDIX A
PUBLICATION LIST

These are the publications that have come out of the Kukui Cup project that I have authored or co-authored:

A.1 Conference Papers

- **Robert S. Brewer**, Yongwen Xu, George E. Lee, Michelle Katchuck, Carleton A. Moore, and Philip M. Johnson. Energy feedback for smart grid consumers: Lessons learned from the Kukui Cup. In *Proceedings of the Third International Conference on Smart Grids, Green Communications and IT Energy-aware Technologies (ENERGY 2013)*, Lisbon, Portugal, March 2013. To Appear.

- Philip M. Johnson, Yongwen Xu, **Robert S. Brewer**, Carleton A. Moore, George E. Lee, and Andrea Connell. Makahiki+WattDepot: An open source software stack for next generation energy research and education. In *Proceedings of the 2013 Conference on Information and Communication Technologies for Sustainability (ICT4S)*, February 2013.

- Philip M. Johnson, Yongwen Xu, **Robert S. Brewer**, George E. Lee, Michelle Katchuck, and Carleton A. Moore. Beyond kWh: Myths and fixes for energy competition game design. In *Proceedings of Meaningful Play 2012*, October 2012.

- **Robert S. Brewer**, George E. Lee, and Philip M. Johnson. The Kukui Cup: a dorm energy competition focused on sustainable behavior change and energy literacy. In *Proceedings of the 44th Hawaii International Conference on System Sciences*, January 2011.

- **Robert S. Brewer** and Philip M. Johnson. WattDepot: An open source software ecosystem for enterprise-scale energy data collection, storage, analysis, and visualization. In *Proceedings of the First International Conference on Smart Grid Communications*, Gaithersburg, MD, October 2010.

A.2 Workshop Papers

- **Robert S. Brewer**. The Kukui Cup: Shaping everyday energy use via a dorm energy competition. In *Proceedings of the CHI 2011 Workshop on Everyday Practice and Sustainable HCI*, Vancouver, Canada, May 2011.

- **Robert S. Brewer**, George E. Lee, Yongwen Xu, Caterina Desiato, Michelle Katchuck, and Philip M. Johnson. Lights Off. Game On. The Kukui Cup: A dorm energy competition. In *Proceedings of the CHI 2011 Workshop on Gamification*, Vancouver, Canada, May 2011.

APPENDIX B
PHYSICAL CONCEPTS: POWER AND ENERGY

When discussing energy, and in particular electricity, it is important to understand what power and energy are, and how they interrelate.

B.1 Energy

Energy is defined as the amount of work that can be done by a force. Most of us have an intuitive notion of energy: e.g., is makes things move, it heats things up. There are many units used to measure energy: joules (a very small amount of energy), calories, BTUs (British Thermal Units). When talking about electricity, the most common unit is the watt hour, abbreviated as ”Wh”, which is equal to 3600 joules. A watt hour is the amount of energy required to to provide 1 watt of power for one hour. Note that from a certain perspective it is somewhat peculiar to measure energy in units that include power (watt), since power is defined in terms of energy in the first place. This definition underlines how central the concept of power is in most of our dealings with electricity.

B.2 Power

Power is defined as the rate of change for energy. As with any rate, it is expressed as a quantity of energy over a unit of time. The most common unit for power is the watt, abbreviated as ”W”. One watt is defined as one joule (a measure of energy) per second. You might be familiar with a 60 watt incandescent light bulb, which expresses how much power it uses when turned on.

B.3 Analogy To Cars

Power and energy are closely related, but frequently confused. As an analogy, think about a car. We can talk about the speed of a car (in miles per hour, or kilometers per hour) and we can also talk about a distance driven in a car (miles or kilometers). The speedometer in the car measures the speed (distance over time), while the odometer measures the distance traveled. Speed is a rate, like power, while distance is like energy.

When we talk about speeds, we usually talk about instantaneous measurements of speed. A speed limit is the maximum instantaneous speed at which you are allowed to drive, i.e. the car’s speedometer should never register a speed greater than the limit. However, when we talk about distance driven, it only makes sense to talk about a distance driven between two locations, or the distance driven over a particular time interval. There is no such thing as an instantaneous distance driven, because in at a precise instant in time, the car is not moving.

B.4 Power vs. Energy

Since power is the rate of change of energy, if you know how power changes over time, you can determine how much energy was consumed or produced (the area under the power curve). Similarly, if you know how much energy was used over an interval of time, you can compute the average power over that period of time (but not the instantaneous power).

In our interactions with appliances, we usually talk about their power consumption and not their energy consumption. For example, we have 60 watt light bulbs, but we wouldn't generally talk about a 60 watt hour lightbulb (unless it consumed 60 watts for an hour and then burned out!). This is because power consumption is an intrinsic characteristic of things that use electricity, while the amount of energy used by an electrical device is determined by how long you keep it plugged in or turned on. On the other hand, energy is very important to the utility that provides your electricity, since you are billed by how much energy you have used (typically in kilowatt hours).

The two key points to remember are: power is a rate, and we always talk about energy over an interval of time.

APPENDIX C
PARTICIPANT ACTIONS

This appendix lists the actions available to 2011 UH Kukui Cup participants. Overall, the actions were intended to increase the energy literacy of the participants performing it, help them modify their behavior to reduce their electricity usage, or both. However, not every action met these goals. For example, some actions were included that were related to sustainability in general, and linked to energy only indirectly. Other actions were included primarily for the entertainment of participants, in keeping with the design of the challenge as an interesting and fun game to play.

The following sections list all the actions, and indicate how they would be performed, and validated by administrators. The actions are grouped into three categories: activities, commitments, and events.

C.1 Activities

See Section 3.6.3.3 for a description of what activities were in the Kukui Cup and how they were processed. Table C.1 lists all the activities that were available in the 2011 UH Kukui Cup.

Table C.1: A list of the activities available during the challenge

Activity name	Points	Confirmation type
Watch introduction video	20	Q&A
Watch video "Secrets of the Kukui Cup Masters"	10	Q&A
Like Kukui Cup on Facebook	5	open-ended
Tweet about Kukui Cup	5	open-ended
Share Kukui Cup link on Google+	5	open-ended
Door Art Challenge	5–15	image
Play the photo chain game	10	open-ended
Watch video about Power & Energy	10	Q&A
Watch video on Energy Intuition	10	Q&A
Learn more about Power & Energy	15	Q&A
Learn more about Energy Intuition	15	Q&A
Examine your lounge's energy use	10	open-ended
Watch video on how to audit your energy use	15	Q&A
Find out how much power your stuff uses	30	open-ended
Label power hogs in your room	15	image
Watch video about Lighting	10	Q&A

Continued on next page

Table C.1 – *Continued from previous page*

Activity name	Points	Confirmation type
Learn more about lighting	15	Q&A
Replace incandescent bulb with compact fluorescent (CFL)	10	image
Estimate your room's total daily energy consumption	35	open-ended
Watch Energy Generation: What's the fuss?	10	Q&A
Watch Energy Generation: Where are we now?	10	Q&A
Watch Energy Generation: Hawaii Clean Energy Initiative	10	Q&A
Learn more about the fuss regarding Energy Generation	15	Q&A
Learn more about how Hawaii generates energy now	15	Q&A
Learn more about the Hawaii Clean Energy Initiative	15	Q&A
Take a survey about the Kukui Cup	40	open-ended
Watch video about solar energy	10	Q&A
Learn more about solar energy	15	Q&A
Watch video about transportation energy use	10	Q&A
Learn more about transportation	15	Q&A
Configure your computer to sleep after inactivity	20	image
Watch Trash is Treasure video	10	Q&A
Learn more about opala	15	Q&A
Energy Geo Trek across campus	5–45	open-ended
Measure shower water flow	15	open-ended
Measure sink water flow	15	open-ended
Watch a video about climate change	10	Q&A
Learn more about climate change	15	Q&A
Refer a friend to the Kukui Cup	5	open-ended
Go on a No Impact date	10	open-ended & image
Watch a video about OTEC	10	Q&A
Write a poem on a Kukui Cup topic	5–50	open-ended
Write a letter to the editor on a Kukui Cup topic	5–50	open-ended
Make a video on a Kukui Cup topic	5–50	open-ended
Write a song about a Kukui Cup topic	5–50	open-ended
Interview someone about a Kukui Cup topic	5–50	open-ended
Make a photo blog a Kukui Cup topic	5–50	open-ended
Create Energy Window Art	5–50	open-ended & image
Create art around a Kukui Cup topic	5–50	open-ended
Design a Kukui Cup 2012 T-shirt	5–50	image

Continued on next page

Table C.1 – *Continued from previous page*

Activity name	Points	Confirmation type
Do something else creative on a Kukui Cup topic	5–50	open-ended

C.1.1 Intro video

Description: If you missed it during your the first login process, watch this video explaining the competition and this website

Expected benefits: Basic understanding of the challenge

C.1.2 Cup Secrets

Description: Watch this video that provides some hints on how to get the most out of the Kukui Cup

Expected benefits: Deeper understanding of challenge, including commitments

C.1.3 Like Cup

Description: Show support for the Kukui Cup by Liking the Kukui Cup page on Facebook (it will open in a new window). Follow the link, click on the “Like” button, and then back on this page click the *I Did This!* button. You will be prompted for your name on Facebook so we can verify your Like.

For you eager beavers that have already liked the Kukui Cup before the competition started, you can get points too. Just click *I Did This!* and tell us your Facebook name.

Expected benefits: Awareness of Kukui Cup events through future news posts, promotion of Kukui Cup to friends

C.1.4 Tweet link

Description: If you use Twitter, tweet a link to the Kukui Cup website by pressing this button (will open in a new window) so other folks will learn about the competition:

Once you have tweeted, come back to this page and click the “I Did This!” button. You will be prompted for your Twitter username so we can confirm your tweet.

Expected benefits: Awareness of Kukui Cup events through future tweets, promotion of Kukui Cup to friends

C.1.5 Share link

Description: If you have an account on Google's new social network Google+, share the Kukui Cup website `http://kukuicup.manoa.hawaii.edu/` there to get the word out about the competition. Go to Google+ (will open in a new window) and click on the small paperclip icon to share a link.

Enter the text "http://kukuicup.manoa.hawaii.edu/" next to the paperclip icon and press the *Add* button. Above that, type something about the Kukui Cup. Make sure this post is set to be shared with the *Public*, you may have to click the "+Add more people" link to see the Public circle. If you do not share the link publicly, we will not be able to verify it. Then press the *Share* button.

Once you have updated your status, go to your Google+ profile and copy the URL which will look something like "https://plus.google.com/" followed by a long number. Then come back to this page and click the "I Did This!" button. Paste in that profile URL so we can see your snazzy public post.

Expected benefits: Awareness of Kukui Cup events through future news posts, promotion of Kukui Cup to friends

C.1.6 Door Art

Description: Show your support for the Kukui Cup by decorating your door in an "energy conscious" fashion. You can do any of the following: include Kukui Cup logos or screen shots, invent new tag lines, show pictures related to energy, or anything else that communicates energy consciousness. When completed, take a photo of your door and click the *I Did This* button to submit the picture. Based on the awesomeness of your design, you will get between 5–15 points!

If you want to show off your mad skillz, in addition to uploading your photo to us, you can publicly post your door art picture to the Kukui Cup 2011 Door Art Flickr group (will open in a new window). If you don't already have a Flickr account, you can sign up for one for free.

Expected benefits: Promotion of Kukui Cup to loungemates, have fun. [Note, this action was inspired by Nathan's description of door art [89, pgs. 23–27]

C.1.7 Photo Chain

Description: Show off the Kukui Cup and your creativity at the same time by playing the Kukui Cup Photo Chain Game. The rules are simple. You are going to add a photo of yourself to the end of the chain of photos in the Flickr Kukui Cup 2011 Photo Chain Game group. Each photo contains:

1. yourself in some kind of "pose"
2. taken at some location on the UH Manoa Campus
3. you holding or wearing some Kukui Cup item (t-shirt, water bottle, eco-tote, or tumbler)

To make the sequence of photos a chain, your photo must "match" the preceding photo posted to the group with respect to either the pose, the location, or the Kukui Cup item.

The caption to each photo should list the pose, the location, and the item.

Here's how you do it:

1. Go to the Flickr Kukui Cup 2011 Photo Chain Game group. See what photo is at the end of the list.

2. Take a photo of yourself in a way that extends the chain (match either the pose, location, or item)

3. Upload your photo to your own Flickr account (creating it if necessary).

4. Go back to the Flickr Kukui Cup 2011 Photo Chain Game group, and "join" the group.

5. Click "Add Photos" and select your photo.

6. Provide a title, such as "Photo Chain Game 12" (or whatever the next number is in the chain).

7. Provide a caption that indicates: pose, location, item, and which of the three matches.

8. Save.

9. Click *I Did This!* button and tell us your Flickr name so we can confirm your upload to the group and award your points.

Expected benefits: Promotion of Kukui Cup, have fun

C.1.8 Power & Energy

Description: Watch this video explaining the difference between power and energy

Expected benefits: Learn about concepts of power and energy and their interrelationship

C.1.9 Energy Intuition

Description: Watch this video about improving your energy intuition.

Expected benefits: Learn the energy consumption of different appliances

C.1.10 Power & Energy 2

Description: While you've watched the Power & Energy video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- What is a kilowatt?
- What is electricity?

Expected benefits: Learn about concepts of power and energy and their interrelationship

C.1.11 Energy Intuition 2

Description: While you've watched the Energy Intuition video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Chart of Hawaii's oil consumption over the past five years¿
- Watts, Volts, Amps, and Butter Heaters

Expected benefits: Learn the energy consumption of different appliances

C.1.12 Check energy

Description: One important aspect of the Kukui Cup is the Daily Energy Goal Game, which can be found on the Go Low page. Every lounge is assigned a daily energy goal that represents a 5% reduction in electricity use from what the lounge was using before the competition. The Energy Goal Game shows how much energy your lounge has used so far today, and how that compares to the energy goal. The game also shows some activities that might be helpful in getting your lounge to reduce its energy use.

For this activity, you will check out the Go Low page. Read the page over, and come back to here and report three things: is your lounge above or below the energy goal, by how much, and name one activity that might help your lounge conserve energy.

Expected benefits: Awareness of lounge energy use and energy goal, reflection on how to conserve energy

C.1.13 Audit Video

Description: Watch this video that explains how to figure out how much energy your stuff uses.

Expected benefits: Understanding of how to conduct an energy audit of appliances using a plug load meter

C.1.14 Audit Room

Description: Check out a Belkin Conserve Insight meter from your tower's front desk (CDC), and then check 5 plug-in devices in your room to see how much power they use when turned on & when turned off. Write down both the on and off values for each device as you check them because you will need that to get your points!

Expected benefits: Experience conducting an energy audit of appliances using a plug load meter, knowledge of the power consumption of appliances in player's room

C.1.15 Power Hogs

Description: This is a followup activity to the energy audit activity. If you haven't performed that activity, do it first and keep your notes around for this activity.

Based on the audit results, make a label for each device in your room that shows the number of watts consumed when on and off, and put it close to the power switch for those devices that have them.

Once you have made the labels, take a photo of the labels of as many devices as you can fit in one picture to be used for verification.

Expected benefits: Knowledge of the power consumption of appliances in player's room, understanding of the power of prompts in reducing energy use

C.1.16 Lighting video

Description: Watch this video about the ways we use energy to generate light.

Expected benefits: Knowledge of how energy is used for lighting, and how different lighting technologies compare

C.1.17 Lighting video 2

Description: While you've watched the Lighting video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Incandescent lighting and chocolate bunnies

Expected benefits: Knowledge of how energy is used for lighting, and how different lighting technologies compare

C.1.18 CFL swap

Description: Find an incandescent bulb and replace it with a CFL (compact fluorescent). If you've already replaced all the incandescent bulbs in your room with CFLs or LEDs, you might have to go hunt for one elsewhere. You should throw away the incandescent bulb, because even though it isn't burned out it is a massive energy hog and you don't want someone using it later.

For verification, please take a single photo showing both the incandescent bulb you replaced and the CFL you installed.

Expected benefits: Knowledge of how energy is used for lighting, and how different lighting technologies compare

C.1.19 Room Energy

Description: Ever wonder how much energy your room consumes in a day? Here's a simple procedure to figure it out.

1. Check out a Belkin Conserve Insight meter from your tower's front desk (CDC)

2. Find out how much energy your appliances use on average. For refrigerators, monitor their energy consumption for 30 minutes, then multiply by 48 to get an estimate of its total consumption for 24 hours. For microwaves, monitor its energy consumption during a 1 minute period, then multiply by the number of minutes per day that you and your roommate typically use it. Do the same for your other appliances: computer, Xbox, fans, etc.

3. To receive credit for this activity, submit a list of the appliances in your room, your estimate of the energy each of them consume per day, and the total amount of energy your entire room uses per day (in watt-hours or kilowatt-hours). Remember to include an estimate for the overhead light if you use it. Are you surprised by this data?

Expected benefits: Understanding of how to calculate daily energy use, reflection on personal energy use

C.1.20 Energy Issues

Description: Watch this video that talks about how we generate our energy in Hawai‘i, and what the fuss is about.

Expected benefits: Understanding of Hawai‘i’s energy situation

C.1.21 Energy Now

Description: Watch this video that talks about how we generate our energy in Hawaii right now, and how that differs from the mainland US.

Expected benefits: Understanding of how Hawai‘i generates energy now

C.1.22 HCEI

Description: Watch this video that talks about the Hawaii Clean Energy Initiative, a plan for increasing clean energy use in Hawaii.

Expected benefits: Understanding of what the HCEI goals mean

C.1.23 Energy Issues 2

Description: While you’ve watched the Energy Issues video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Hawaii: The State of Clean Energy

Expected benefits: Understanding of Hawai‘i’s energy situation

C.1.24 Energy Now 2

Description: While you’ve watched the Energy Issues video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

- State by State Energy Prices, by the US Energy Information Office
- US Energy Facts, by the US Energy Information Office

Expected benefits: Understanding of how Hawai‘i generates energy now

C.1.25 HCEI 2

Description: While you've watched the Hawaii Clean Energy Initiative video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- HCEI Update: Year 2 (PDF)
- Island Energy Projects to move toward HCEI goals

Expected benefits: Understanding of what the HCEI goals mean

C.1.26 Take Survey

Description: We're in Round 3 of the Kukui Cup now, and we'd like to get some feedback from you about the competition. Click the following link to the survey, which will open in a new window. Once you are done, return here and just tell us you completed the survey, and we'll award your points.

Expected benefits: Data on participants experiences with the Kukui Cup

C.1.27 Solar Energy

Description: Watch this video that explains how we can get energy directly from the sun.

Expected benefits: Understanding of solar energy

C.1.28 Solar Energy 2

Description: While you've watched the Solar Energy video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Energy 101: Solar Power
- Introduction to PV

- How PV cells produce electricity

Expected benefits: Understanding of solar energy

C.1.29 Transport Video

Description: Watch this video that explains how your choice of transportation impacts your energy use.

Expected benefits: Understanding of how much energy different transportation options use, and alternatives available to participants

C.1.30 Transport Video 2

Description: While you've watched the Transportation video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Carbon Footprint Calculator
- Keep Pedalling (bicycle hip hop)
- How PV cells produce electricity
- Cycle Manoa
- Trains, Planes, and Automobiles: Which is the greenest way to travel long distances in the US?

Expected benefits: Understanding of how much energy different transportation options use, and alternatives available to participants

C.1.31 Computer Sleep

Description: Configure your computer and any external monitor to sleep after 20 minutes of inactivity (or less). You can find instructions on enabling sleep functionality at the EnergySTAR website.

Once you have changed your settings, please take a screenshot showing the new settings for use in verification.

Expected benefits: Reduced energy use from computers not actually being used

C.1.32 Trash video

Description: Check out this video called Trash is Treasure and maybe change your thinking about trash

Expected benefits: Understanding of where trash goes after being thrown away and ways to reduce the waste stream

C.1.33 Trash Video 2

Description: While you've watched the Trash is Treasure video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- How the City Manages Our Waste
- Make A Juicer Out Of A Plastic Bottle

Expected benefits: Understanding of where trash goes after being thrown away and ways to reduce the waste stream

C.1.34 Geo Trek

Description: Want to go on a "geo trek"? Have a smart phone that can display Google Maps (or a friend who has one and wants to play with you)? Have an hour to walk around campus and learn about UH energy and sustainability projects? Then you're all set!

Here's the deal: you'll use your smartphone (and your own smarts) to follow a trail of clues around campus and discover eight different locations related to energy or sustainability. Each location is tagged with a special Kukui Cup sign so you'll know when you've found it. Once there, take a picture of yourself with the sign in the background for verification, and upload to Flickr. You will earn 5 Kukui Cup points for each location you find. The sign also contains a URL that you can retrieve to obtain directions to the next location.

Ready? Here's the first clue (you'll want to open it on your smartphone):

When you are done, come back here, click *I Did This!* and provide us with a link to your Flickr account so we can verify your trek.

Expected benefits: Understanding of different energy-related locations on campus, have fun

C.1.35 Shower flow

Description: Figure out how much water is used by the showers in your floor's bathroom. To do this, you will need a large container with a known volume (like a water bottle or bucket) that you can fill in the shower, and a clock of some type (like your watch or cell phone). Make sure to not get your clock wet if it isn't waterproof!

Hold the container up to the shower head, turn on the shower faucet to the level you use normally when showering, and note the time on the clock (or use a stopwatch). Watch the container fill, and note the time when it is completely full of water.

Now you know the volume of water that the shower put out, and the amount of time it was running. From these two values, you can compute the flow rate of your shower by dividing the volume by the number of seconds it took to fill. For example, if you filled a 1 gallon bucket and it took 30 seconds, then the flow rate is 2 gallons per minute.

As you will see, water comes out of shower heads pretty fast, which is why it is important to turn off the water when you aren't actively using it, like while soaping up.

Expected benefits: Experience measuring water flow, understanding of how to calculate flow rate, reflection on personal water use

C.1.36 Sink Flow

Description: Figure out how much water is used by the sinks in your floor's bathroom. To do this, you will need a large container with a known volume (like a water bottle or bucket) that you can fit in the sink, and a clock of some type (like your watch or cell phone). Make sure to keep your clock dry if it isn't waterproof!

Hold the container up to the faucet in the sink, turn on the water to the level you use normally when using the sink, and note the time on the clock (or use a stopwatch). Watch the container fill, and note the time when it is completely full of water.

Now you know the volume of water that the sink put out, and the amount of time it was running. From these two values, you can compute the flow rate of your sink by dividing the volume by the number of seconds it took to fill. For example, if you filled a 1 gallon bucket and it took 30 seconds, then the flow rate is 2 gallons per minute.

As you will see, water comes out of faucets pretty fast, which is why it is important to turn off the water when you aren't actively using it, like while brushing your teeth.

Expected benefits: Experience measuring water flow, understanding of how to calculate flow rate, reflection on personal water use

C.1.37 Climate change

Description: Watch this video talking about climate change and how it will affect Hawai‘i.

Expected benefits: Better understanding of climate change and its expected impacts in Hawai‘i

C.1.38 Climate Change 2

Description: While you've watched the Climate Change video once, this activity gives you a chance to learn more about the topic. You can rewatch the video below and explore the resource links provided. When you are done, you can get your points by answering a more difficult question. The question may require information from the video, the resource links or both.

Resource links (will open in new windows/tabs):

- Hawaii's Climate Crisis Sea Level Rise is a seven minute video that includes interviews with Chip Fletcher discussing the impact of climate change, specifically rising sea levels, on Hawaii
- How it all ends is Greg Craven's followup to his ”The Most Terrifying Video You'll Ever See”, which got 7M views on YouTube.
- Scientific American article discusses why Americans are so ill-informed about climate change

Expected benefits: Better understanding of climate change and its expected impacts in Hawai‘i

C.1.39 Refer friend

Description: Starting in Round 2, the Kukui Cup provides a new feature: referral bonuses. Each time you get a new user to sign up for the Kukui Cup, you can earn 10 points. All you need to do is have the new user enter your email address on the new ”Referral Bonus” page during their initial login. Both you and they will earn 10 extra points as soon as the new user earns 30 points with regular game play. There is *NO LIMIT* to the number of times you can earn a referral bonus, so start signing up your friends now!

To help you get started, you can earn five extra points for one of your referrals by completing this activity. Just type in the email address of the new user you brought to the Kukui Cup in the box below. You will get your five points after the new user gets to 30 points.

Note that while this activity is just a one-shot deal, the referral bonus feature that it introduces you to can be done repeatedly. You do not have to wait for your first referral to complete before getting new referrals. Nor do you have to even do this activity at all in order to get referral bonuses. So, go out there, get as many new players to sign up and enter your email as possible, and you will get 10 points each time they achieve 30 points. (You can even coach them through their first 30 points to make sure they get a proper introduction to the game).

Expected benefits: Increased participation in Kukui Cup through referrals, have fun

C.1.40 Impactless Date

Description: While traditional ideas of a date include significant consumption, here's your chance to do something radical: have a good time with a friend while using the minimum amount of electrical energy possible! Use this as an opportunity to be creative: how many different things can you do with a friend while using the least possible energy? Consider your transportation: can you walk, ride a bike, or take public transportation? Consider your food: what can you eat together that is delicious but was grown, delivered, and prepared with minimal energy? Consider your entertainment: what can you do together that is interesting, novel, and fun that does not consume resources?

Expected benefits: Reflection on how to have fun with minimal energy use, have fun

C.1.41 OTEC video

Description: Watch this video that explains how energy can be cleanly extracted from cold ocean depths here in Hawai'i.

Expected benefits: Understanding of OTEC energy generation and potential in Hawai'i

C.1.42 Write Poem

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will write a *poem* (or limerick or haiku) on the subject of one of the categories from the Smart Grid such as energy, lighting, transportation, etc. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your poem, the more points you will receive.

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.1.43 Letter to Editor

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will write a *letter to the editor* of a local publication on the subject of one of the categories from the Smart Grid such as energy, lighting, transportation, etc. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your letter, the more points you will receive.

Some local publications you might write to:

- Honolulu Weekly
- Star-Advertiser
- MidWeek

Expected benefits: Creative expression and reflection on a Kukui Cup topic, experience with community advocacy and involvement

C.1.44 Make Video

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will make a *video* on the subject of one of the categories from the Smart Grid such as energy, lighting, transportation and post it on YouTube. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your video, the more points you will receive.

Making a interesting video can be hard work. You'll find it much easier if you write out a little "screenplay" beforehand and think about what you want to communicate. YouTube has a Handbook with lots of great tips on making videos. Points will be awarded based on your video's originality, quality, and impact. For example, you talking into your webcam will get fewer points than visualizing your points with images or outdoor video. Make sure you mention the Kukui Cup either in your video or in the description field. When your video is ready, you can submit the URL for verification and scoring.

When submitting a video created by a group of players, please let us know how many people are planning to submit the video for points so we can divide the credit.

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.1.45 Write Song

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will write a *song* on the subject of one of the categories from the Smart Grid such as energy, lighting, or transportation. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your song, the more points you will receive.

For example, writing new energy-oriented lyrics to an existing song is pretty easy, and so not worth that many points. Writing an original song with lyrics and music is harder. Recording an original song is even harder, and so worth the most points.

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.1.46 Interview

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will *interview* an expert on one of the subjects used as categories in the Smart Grid such as energy, lighting, or transportation. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your interview, the more points you will receive.

Some possible interview subjects:

- UH Manoa administrators (Facilities Management, Manoa Sustainability Corps)
- UH Manoa faculty (SOEST, HNEI, REIS)
- Local environmental organizations (Blue Planet Foundation, Kanu Hawaii, Surfrider Foundation)
- Local politicians (City Council, State Legislature, Congressional delegation)
- Local industry (First Wind, solar installation companies)
- Local government (DBEDT energy office, PUC)

You will have to find someone to interview, figure out what questions you want to ask them in advance, and then go interview them. You will probably want to record your interview so that you can refer to it later, but make sure you ask your subject if recording them is OK!

Your resulting interview can be written (like you might see in a magazine), and audio recording, or even a video. Note that making a quality audio and video interview is quite challenging, so make sure you know what you are getting into.

Expected benefits: Creative expression and reflection on a Kukui Cup topic, experience conducting an interview

C.1.47 Photo Blog

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will create a *photo blog* around one of the subjects used as categories in the Smart Grid such as energy, lighting, or transportation. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your photo blog, the more points you will receive.

A photo blog is a series of photographs on a particular subject, possibly with some explanatory text on each photo. You will need to find a place to host your photo blog, some options are: Tumblr, Flickr, or Wordpress. Remember to pick a theme for your photos related to the Kukui Cup. Here are some starter ideas:

- Pictures of things using electricity across campus
- Pictures of energy generators (harder to find)
- Pictures of trash across campus (litter, recycling, dumpsters)
- Pictures of the different types of lighting used across campus
- Or something else Kukui Cup-related

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.1.48 Window Art

Description: Every night, the Hale Aloha residence halls create a mosaic of lit windows as students quietly study in their rooms. At least, that's what we hope you're doing in there.

It occurs to us that this mosaic of lit windows provides an opportunity for you to both be creative and inform fellow students coming back from the library about the Kukui Cup and/or energy conservation.

So, for this activity, create art on your room window that is visible from outside at night. The art should have some relationship to the theme of the Kukui Cup: use your imagination. To receive credit for this activity, take a picture of it (preferably at night) and include some text describing what your art is about. The more amazing, creative, and energy-related your window art, the more points you can earn. Since you still want to save energy, we recommend that you light up your art between 9-9:15 PM, you don't need to keep it lit all night long.

Another way to get more points for this activity is to enlist your neighbors beside you, above you, or below you to create a coordinated group window art effort. Take a photo of all of the windows, then tell us in the description which one is yours.

The more awesome your art, the closer to 50 points you'll earn.

Expected benefits: Creative expression and reflection on a Kukui Cup topic, have fun

C.1.49 Make Art

Description: This activity is an opportunity to creatively explore one of the topics of the Kukui Cup in more depth. For this activity, you will create a *work of art* around one of the subjects used as categories in the Smart Grid such as energy, lighting, or transportation. Note that this activity will require significantly more effort than normal activities, but it is also worth more points. This activity is worth a variable number of points, so the more effort and the higher quality of your art, the more points you will receive.

The art you create for this activity should be different from the other options in this category. Here are some ideas:

- painting
- sculpture
- collage
- sketch

You will have to capture your art in some way (scan, photograph, etc) so you can present it to us for verification and scoring.

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.1.50 Design Tshirt

Description: We already have awesome 2011 Kukui Cup T-shirts, but what about 2012? For this activity, you will create a design for the 2012 Kukui Cup T-shirt. Things to keep in mind:

- Include our logo & the words "Kukui Cup"
- Include 2012 somewhere
- Include our URL: kukuicup.manoa.hawaii.edu
- Make it stylin' and awesome

You will submit an image file with your T-shirt design for us to look at.

Expected benefits: Creative expression and reflection on a Kukui Cup topic, thinking about next year's challenge

C.1.51 Wildcard

Description: If you have a really creative idea for exploring one of the Kukui Cup topics that isn't covered by the other advanced activities, this is the place. We strongly recommend you contact the Kukui Cup admins using the *Send Feedback* button at the top right corner of this web page and pitch your idea to us before you start on it. This will let us give you feedback on whether or not we think it is appropriate for this activity, and how many points it might be worth.

Expected benefits: Creative expression and reflection on a Kukui Cup topic

C.2 Commitments

See Section 3.6.3.4 for a description of what commitments were in the Kukui Cup and how they were processed. Note that commitments were participant-verified without outside intervention, so that field is not used for this category. Table C.2 shows a summary of the commitments. The unlocking pattern for commitments in the Smart Grid Game was quite simple: all commitments were unlocked after participants completed either the "Secrets of the Kukui Cup" or "Power and Energy" video activities.

C.2.1 Turn off vampires

Description: A vampire load is a device that uses power when plugged in, even when it is turned off and not doing anything. Commit to turning off any vampire loads (cell phone charger, iPod charger, game consoles, TVs) using a power strip when you are not using them, thereby saving energy. If you need a power strip, you can buy them at the UH Bookstore, or many other stores (grocery stores, drug stores, etc).

Expected benefits: Reduced electricity usage due to vampire loads, awareness of vampire loads.

C.2.2 Off b4 bed

Description: Commit to turning off all appliances in your room (computer, TVs, DVD/Blu-ray players, game consoles) every night before you go to sleep. Appliances use a significant amount of electricity, so turning them off when you definitely won't be using them (like when you are asleep) will save energy.

Expected benefits: Less electricity wasted on appliances that aren't being used.

Table C.2: A list of the commitments available during the challenge

Commitment	Category	Points
I will turn off vampire loads using a power strip	Basic Energy	5
I will turn off all appliances every night before going to sleep	Basic Energy	5
I will limit my TV use to 1 hour a day	Basic Energy	5
I will turn off the lights when leaving any room	Lights Out!	5
I will use task lighting instead of overhead lights	Lights Out!	5
I will use sunlight instead of electric lighting	Lights Out!	5
I will turn off printer when not printing	Lights Out!	5
I will do something ‘unplugged’ every day	Lights Out!	5
I will turn off my music when leaving my room	Lights Out!	5
I will use stairs instead of elevator	Moving on	5
I won’t drive alone	Moving on	5
I will take public transportation	Moving on	5
I will walk to destinations less than one mile away	Moving on	5
I will recycle all beverage containers	Opala	5
I will bring reusable bags when shopping	Opala	5
I will turn off water when brushing my teeth or shaving	Wet and Wild	5
I will turn off water when sudsing and scrubbing in shower	Wet and Wild	5
I will wash only full loads of laundry	Wet and Wild	5
I will wash my laundry in cold water	Wet and Wild	5
I will reduce my shower time by 1 minute	Wet and Wild	5
I will not eat meat	Mixed Bag	5

C.2.3 Limit TV

Description: Commit to using your TV (watching shows, movies, playing games) for less than 1 hour per day. Widescreen TVs use a lot of electricity, so putting a limit on how much you use them will reduce your electricity use.

Expected benefits: Less electricity used by television.

C.2.4 Turn off lights

Description: Leaving lights on wastes energy for no purpose. Commit to turning off the lights when leaving any room.

Expected benefits: Reduced electricity usage due to less unneeded lighting, noticeable behavior reminder to others.

C.2.5 Task lighting

Description: Commit to using task lighting (like a desk lamp) instead of overhead room lights when possible. Often overhead lights provide more light than you need, or might not provide the light where you need it. Using a desk lamp will reduce your electricity use while giving you the light you need, where you need it.

Expected benefits: Reduced electricity usage due to less excess lighting.

C.2.6 Use sunlight

Description: Commit to using sunlight from windows or outdoors instead of turning on electric lighting. This can mean opening shades instead of turning on the lights, and/or planning your day so that tasks that require light (like reading books) are done during the day.

Expected benefits: Reduced electricity usage due to less use of electric lights.

C.2.7 Printer off

Description: Commit to turning off your printer when you aren't actively printing something out. This will reduce electricity use, since printers draw some power if they are turned on even when they aren't printing.

Expected benefits: Reduced electricity usage due to less standby electricity for printer.

C.2.8 Pull the plug

Description: Commit to turning off your computer/TV/game console and doing something that doesn't require electricity instead every day. There are many things you can do both on and off campus that don't require electricity, go find them!

Expected benefits: Reduced electricity usage, potentially increased exercise.

C.2.9 Turn off music

Description: Commit to turning off your music (from computer, stereo, etc) when you leave your room. You save electricity when you turn off your music when you aren't there to enjoy it.

Expected benefits: Reduced electricity usage.

C.2.10 Use stairs

Description: Commit to using the stairs instead of elevators during your day, whenever that is feasible. Elevators use electricity, so by using the stairs you will save some energy. Also, using the stairs is good exercise!

Expected benefits: Reduced electricity usage due to less elevator traffic, increased exercise for participant.

C.2.11 Car pool

Description: Commit to not driving in a car by yourself. Try riding the bus, riding a bike, walking, driving a moped, or using a vehicle with 3+ occupants instead. Transportation fuel is a major use of energy and it generates a lot of greenhouse gases, so traveling more efficiently saves energy and the planet.

Expected benefits: Reduced carbon emissions due to less single occupant car travel, reduction in traffic and parking.

C.2.12 Take bus

Description: Commit to taking public transportation whenever you go off campus during the commitment period. Every UH Manoa student gets a U-Pass sticker for their ID that allows unlimited free rides on the bus each semester! If for some reason you don't have your U-Pass, go to the ID counter in Campus Center.

TheBus has a great website that will help you plan trips, and even tell you when the next bus will arrive based on GPS location!

Expected benefits: Reduced carbon emissions due to less single occupant car travel, reduction in traffic and parking.

C.2.13 Walk to destinations less than one mile away

Description: Commit to walking to any destination less than one mile away. Walking saves energy, costs nothing, and is good exercise.

Expected benefits: Reduced gasoline usage due to car usage, increased exercise for participant.

C.2.14 Recycle cans

Description: Commit to recycling all (recyclable) beverage containers at one of the recycling bins on campus or around town. Making things from recycled materials generally costs less and uses less energy than making them from raw materials.

Expected benefits: Reduced carbon emissions due to recovery and eventual reuse of recyclable material, reduction in waste stream.

C.2.15 Reusable bags

Description: Commit to bringing and using reusable bags when shopping instead of the paper or plastic ones offered by stores. Making disposable bags requires energy, and often the bags end up in our landfills or worse yet they blow away into the ocean. Using a reusable bag saves energy and keeps trash out of our landfills.

Expected benefits: Reduced waste, reduced carbon footprint.

C.2.16 Turn off sink

Description: Commit to turning off water at sinks when you aren't actually using the water, such as when brushing your teeth, shaving, applying makeup, etc. Clean water is a valuable resource that shouldn't be wasted. Also pumping water from the ground into a building, heating it, and then treating the used water takes energy, so reducing the amount of water used saves energy.

Expected benefits: Reduced electricity usage due less pumping of water, reduced water use.

C.2.17 Turn off shower

Description: Commit to turning off water when showering except when actively rinsing off soap or shampoo. Clean water is a valuable resource that shouldn't be wasted. Also pumping water from the ground into a building, heating it, and then treating the used water takes energy, so reducing the amount of water used saves energy.

Expected benefits: Reduced electricity usage due less pumping and heating of water, reduced water use.

C.2.18 Full loads of laundry

Description: Commit to always washing full loads of laundry. Washing less than a full load is less efficient, leading to more electricity and water being used per piece of laundry washed.

Expected benefits: Less electricity and hot water used per item of laundry washed.

C.2.19 Wash laundry in cold water

Description: Commit to washing your laundry in cold water instead of warm or hot water. There are now detergents designed to be used in cold water, and it takes lots of energy to heat water up. By using cold water, you will be saving energy.

Expected benefits: Reduced electricity usage by reduction in water heating and pumping.

C.2.20 Shorter showers

Description: Commit to measuring the length of your shower with a watch or phone, and reducing the time by 1 minute. Clean water is a valuable resource that shouldn't be wasted. Also pumping water from the ground into a building, heating it, and then treating the used water takes energy, so reducing the amount of water used saves energy.

Expected benefits: Reduced electricity usage by reduction in water heating and pumping.

C.2.21 Go meatless

Description: Commit to not eating any meat (beef, pork, chicken, fish, shellfish, etc) during the commitment period. Producing meat (beef in particular) uses a great deal of energy, and produces a great deal of greenhouse gasses. A vegetarian diet uses less energy and emits less greenhouse gasses. There are many of vegetarian food options both on campus and around Honolulu, try them out!

Expected benefits: Reduced carbon footprint, potentially improved health.

C.3 Events

See Section 3.6.3.5 for a description of how events were handled in the Kukui Cup and how they were processed. Table C.3 shows a summary of the events. The unlocking pattern for events was completely time based: events were unlocked seven days before they occurred, and remained unlocked for seven days after the event took place (to allow time for entry of attendance codes).

Table C.3: A list of the events available during the challenge. Entries marked with an asterisk are off-campus excursions.

Event name	Date/Time	Points
Kickoff Party	2011-10-17 18:30	20
Play outside the cafe (1)	2011-10-18 18:30	10
Energy scavenger hunt	2011-10-18 22:00	20
Recycled fashion design	2011-10-19 22:00	20
Play outside the cafe (2)	2011-10-20 18:30	10
Flashmob design	2011-10-20 22:00	20
Kahuku Wind Farm*	2011-10-22 10:00	30
Sustainable and Organic Farming	2011-10-22 16:00	20
Pedalpalooza	2011-10-23 15:00	20
UH Manoa Food Day	2011-10-24 13:00	20
Round 1 Awards Party	2011-10-24 18:30	20
Play outside the cafe (3)	2011-10-25 18:30	10
Your Sustainable Future	2011-10-25 22:00	20
Energy Efficient Eating	2011-10-26 22:00	20
Play outside the cafe (4)	2011-10-27 18:30	10
Movie Night	2011-10-27 22:00	20
Off-The-Grid Living*	2011-10-29 10:30	40
Kokua Market Excursion*	2011-10-30 12:00	25
Round 2 Awards Party	2011-11-01 18:30	20
Manoa Sustainability Corps	2011-11-02 15:30	20
High Energy Art and Music	2011-11-02 22:00	20
Energy Efficient Chillaxation	2011-11-03 22:00	20
First Green Friday	2011-11-04 10:00	15
North Shore Beach Cleanup*	2011-11-05 09:00	45

C.3.1 Kickoff Party

Description: It has begun: The Quest for the Kukui Cup 2011! If you've been wondering about the Kukui Cup banners, all will be revealed at the Kickoff Party, hosted by MC Kai and MC Cookie and featuring sick beatz by the infamous DJ Mr Nick. Get there early to score your **free** limited edition Kukui Cup 2011 t-shirt and a **secret high tech gadget** to help you in your quest for energy saving supremacy.

Expected benefits: Introducing residents to the Kukui Cup, providing t-shirts to promote the challenge, and smart strips to reduce energy usage.

C.3.2 Play outside the cafe

Description: On your way to dinner? Stop by the Kukui Cup table outside the Hale Aloha cafeteria to play an energy game. If you succeed, you can win a **free** prize. Even if you don't, you can get an Attendance Code and earn some points. The prizes vary from night to night, so stop by every time and try to collect them all. The table goes away when all the prizes have been given out, so get there early to maximize your chances! This is the first of four Play Outside The Cafe events.

Expected benefits: Increase energy literacy through game, promote challenge through distributed swag, and physical reminder about the challenge in a heavily trafficked place.

C.3.3 Energy scavenger hunt

Description: Yes, we've all scavenged for leaves and cute rocks and flowers in grade school. But this isn't Miss Mizumoto's second grade science class: you're going after the big game now – Kilowatts!

We'll start by teaching you how to measure power. Then, you'll divide up into teams, and get exactly 30 minutes to go back to your tower and measure the power used by appliances. Prizes will be awarded to both the team that finds the appliance that uses the least amount of power as well as well as the team that finds the appliance that uses the most amount of power.

Note: at least one member of each team needs a camera (cell phone camera OK) in order to take a picture of the appliance reading. Free food at the end of the night? We've got you covered.

Expected benefits: Increased energy intuition, familiarity with plug-load meters

C.3.4 Recycled fashion design

Description: As Heidi Klum reminds us, "In fashion, one day you're in, and the next day you're out." Go fashion forward by attending the Recycled Fashion Design Workshop, hosted by Project Runway Season 8 Finalist Andy South.

Assisted by UH Manoa fashion design students, you'll form small groups and use recycled materials to create a new look, while Andy provides advice and encouragement. Then a model will walk the runway to show off your creation. No matter what colors you choose, your look will be green! If you just want to watch, that's fine too.

After party snacks included, so sign up soon!

Expected benefits: understanding sustainability benefits from reused clothing, awareness of Goodwill for purchasing used clothing

C.3.5 Flashmob design

Description: Do you ever experience an intense, uncontrollable urge to break into song and dance in large, public places? If you've got that fever, we've got the cure: a heaping helping of the Kukui Cup Flashmob.

At this workshop, you'll start designing a clandestine energy-related song and dance skit to be busted out near the end of the Kukui Cup while consuming free munchies. Who knows, it could be the YouTube hit of November, 2011.

Expected benefits: group work, promotion of the challenge

C.3.6 Kahuku Wind Farm

Description: Want to see sky farmers harvesting the winds? Come with us to Kahuku to see firsthand how energy is plucked from the sky and generated for our use by First Wind's turbines.

The wind farm staff requests that everyone wear long pants and closed toe shoes. We hope to stop in Kahuku for lunch, so bring some money.

You need to register for this free event to reserve your seat on the bus by clicking the **I want to sign up** button below.

Meet in the Hale Aloha courtyard, from there we'll get on the bus. Don't be late!

Expected benefits: Better understanding of wind power

C.3.7 Sustainable and Organic Farming

Description: Your mother always told you to eat your vegetables, but did you ever consider where they came from while you forced down that last bite of rutabaga? The Sustainable Organic Farm Training (SOFT) club is a student-run organization devoted to getting at the "roots" of fresh produce, literally and figuratively.

At this workshop you'll get a chance to help out at the farm, taste fresh produce, and discover out what it really means to eat natural, local, organic, sustainable produce! Yum!!

Expected benefits: Understanding of farming and its relationship to energy, introduction to the SOFT campus group

C.3.8 Pedalpalooza

Description: Is the Queen song "I want to ride my bicycle" whirring furiously through your brain while you stare down at your broken two wheeler? Have no fear, Freddy Mercury fans! Cycle Manoa is here to save your day with the Pedalpalooza workshop. If your wheels are broken, they'll teach you how to fix them for free. If your wheels are rocking, join them for a quick one hour ride around Manoa. And you can even cool down afterwards with a free bicycle-powered smoothie.

Meet at Hale Aloha Courtyard at 3pm with your wheels for a guided 1 hour ride, ending up at the Cycle Manoa HQ. If you don't have a bike but would like to attend, meet in the courtyard at 3:40 and we'll walk up to the Cycle Manoa together. At 4 PM you'll hear from the Cycle Manoa team about bicycle advocacy and bicycle repair.

Expected benefits: Understanding of benefits of bicycle transportation compared to fossil-fuel driven vehicles, introduction to Cycle Manoa group

C.3.9 UH Manoa Food Day

Description: Do you care about your food? Want to find out more about how to eat tasty, healthy food? Come to the UH Manoa Food Day event, which will include presentations on nutrition and food followed by Dr. Ted Radovitch a CTAHR specialist in Sustainable and Organic Farming Systems, and Dean Okimoto from Nalo Farms.

Following the presentations will be a food demonstration by Philip Shon, UH Sodexo Executive Chef who works in collaboration with Donna Ojiri, RD, General Manager of Sodexo. Taste local fresh produce, sample grass-fed Big Island beef, and local fruit beverages. By celebrating food day, helps emphasize the importance of making healthy food choices, and promote changes in food and farm policies that benefit health, the environment and well-being of us all in Hawaii.

Since this is an external event, you should sign up here but also RSVP on the UHM Food Day website (will open in a new window). When you get to the event, look for a Kukui Cup staff member (white t-shirt), and they will give you your attendance code that will get you the points for this event.

Expected benefits: Understanding of food's relationship to sustainability

C.3.10 Round 1 Awards Party

Description: If you have an indiscernible memory of attending an awesome awards party before, you may be experiencing some pre-deja-vu of what is soon to come: the Kukui Cup's first Round 1 Awards Party - a melange of interactive energy awareness games, an ultra-cool student DJ who goes by the oh-so-natural name of Pearl, the last of the custom limited edition Kukui Cup t-shirts, and the ever-popular smart strips.

As you are reading this, you may experience pre-withdrawals from the general awesomeness of this Party, oh, and did I mention that Awards will be being handed out as well? Yes, it may be implied in the name of this event, but along with the natural high you will inevitably feel from all the free goodies while simultaneously doing something good for the earth and jamming out to clam shell beats, you may just find yourself going home with a cool prize.

Deja-vu or dream come true? You decide.

Expected benefits: Promotion of the challenge, distribution of incentives

C.3.11 Your Sustainable Future

Description: A famous British poet once wrote: "You say you want a revolution? Well, you know, we'd all love to see the plan."

If you're interested in helping create an energy and sustainability revolution in your classes, university and community, come plan with representatives from Blue Planet Foundation, Sustainable UH, Surfrider Foundation, Kokua Hawaii Foundation, College of Engineering, School of Architecture, Shidler College of Business, Environmental Studies, and more.

Planning the overthrow of our oil-based economy will work up an appetite, so we'll also provide snacks.

Expected benefits: Introduction to sustainability organizations, awareness of classes on sustainability topics

C.3.12 Energy Efficient Eating

Description: Has cafeteria food got you down in the dumps? Are you no longer amused by mystery meat? Want to get new ideas for late night munchies?

Join experts from Kokua Market in a discussion of where our food comes from in Hawaii, and inexpensive, residence hall friendly groceries. You'll sample a variety of free gourmet popcorn toppings and learn how to make your own for just pennies a serving.

We'll even stuff your goodie bag with a custom recipe book to cure those Hale Aloha hunger pangs.

Expected benefits: Understanding of food's role in sustainability, awareness of where to purchase locally-produced foods, ways to prepare food with less energy

C.3.13 Movie Night

Description: Watch two of the artsiest and the most hilarious shorts from the Bike Shorts Film Festival Hawaii and continue the night with the journey of a revolutionary architect in a maze of obstacles towards sustainable communities of "Earth Ships", completely energy autonomous off-the-grid houses built with recycled materials.

An adventure full of beautiful images and extraordinary personages. Accompanied by free popcorn and free delicious lemonade!

Expected benefits: Awareness of options for sustainable living

C.3.14 Off-The-Grid Living

Description: The Reppun family has been living on their farm and growing taro, coffee, honey and other food in beautiful Waihole valley for over 20 years. Though they have the Internet, they don't any power lines. See how they live off the grid in comfort and style through hydro-electric and solar power. You'll take a bus over to the Windward side, hike into the valley to their farm, and see an amazing blend of old school and next generation Hawaii. Make sure you eat breakfast beforehand; we won't be back until after lunch.

Make sure to wear clothes and shoes that you don't mind getting wet or muddy on the farm!

Reserve your seat on the bus by clicking the **I want to sign up** button below.

Meet in the Hale Aloha courtyard, from there we'll get on the bus. Don't be late!

Expected benefits: Understanding of real-world renewable energy options and farming as a part of sustainable living

C.3.15 Kokua Market Excursion

Description: Does purchasing groceries from corporate supermarkets leave a negative taste in your mouth? Satiate your craving to support local farmers and businesses by taking a tour of the Kokua Market, the only natural foods cooperative in Hawaii.

Sample foods whilst browsing a bountiful bulk selection, innovative deli items, and a plethora of produce, and learn why Coops are so crucial to the food chain of Hawaii. At Kokua Market, the customer reigns supreme, not profit.

Meet at Hale Aloha Courtyard and we'll walk over – it's just five minutes away!

Expected benefits: Awareness of where to purchase locally-produced foods

C.3.16 Round 2 Awards Party

Description: If you went to the Kickoff and Round 1 parties (which were, obviously, awesome), you might be thinking you can skip the Round 2 party. But that would be a huge FAIL because the Round 2 party is going to totally kick it.

There will be live music by Breath of Fire, speakers from local organizations like Blue Planet Foundation and Sustainable UH, awards to Round 2 winners, and some special surprises. The Round 2 award party is being organized by the Aloha Movement Project so you know it's gonna rock.

The party starts at 5:30pm, awards are at 6:30pm, and Breath of Fire is playing two sets at 6 and 7pm.

Expected benefits: Promotion of the challenge, distribution of incentives

C.3.17 Manoa Sustainability Corps

Description: Want to find out how UH's sustainability efforts tie together? Come to the monthly meeting of the UH Manoa Sustainability Corps. The Sustainability Corps is a forum for all of us to share information, ideas, data, and suggestions regarding sustainability on campus. It is also a forum to propose projects and programs that will make UH Manoa a green leader in Hawai'i and abroad.

This external event is being held in Krauss Hall, Room 012, known as the Yukiyoshi Room. When you get to the event, look for a Kukui Cup staff member (white t-shirt), and they will give you your attendance code that will get you the points for this event.

Expected benefits: Introduction to Manoa Sustainability Corps, awareness of opportunities to get involved in sustainability on campus

C.3.18 High Energy Art and Music

Description:

> Electric blood flows through the veins of the city
> drip, drip, drip, every drip a drop of oil
> do I flip the switch or does the switch flip me?

Oh. hey there. We just get carried away when we think of slam poetry. And saving electricity. If you feel the same way, join us with Kealoha, Hawaii's premier slam poet. Afterwards, you'll have a chance to lay down verse of your own with the open mic session and munch on free snacks.

Expected benefits: Understanding of how art can promote sustainability

C.3.19 Energy Efficient Chillaxation

Description: Stress is the cancer of emotions, and undue amounts can lead to the demise of your study habits!

At the Energy Efficient Chillaxation Workshop, discover green methods to reduce stress, such as pranayama (deep breathing techniques), massage, and yoga. We'll provide you with free herbal tea and snacks, teach you some techniques, and help you blow off steam.

But don't stress out too much about being on time!

Expected benefits: Awareness of ways to relax that don't require electricity

C.3.20 First Green Friday

Description: First Green Friday is a showcase is to bring together faculty, students, and staff to showcase UHM's sustainability education, research, and demonstration projects. This new event is launching for the first time this Friday! Check out groups like the Environmental Center, the Ecology Club, Surfrider and the UHM Sustainability Corps. The Kukui Cup will have a table there as well!

This event is taking place in the Sustainability Courtyard, which is between Kuykendall Hall and the Hawaii Institute for Geophysics. Check out the booths at the event, and find the Kukui Cup table to get your attendance code.

Expected benefits: Awareness of opportunities to get involved in sustainability on campus

C.3.21 North Shore Beach Cleanup

Description: According to Wikipedia, "utopia" is an ideal community or society possessing a perfect socio-politico-legal system. Hawaii, perhaps the closest thing we have to environmental perfection on earth, is regularly polluted by all the garbage washing up on our precious beaches.

Do your part to bring Oahu one step closer to utopia by attending this beach cleanup sponsored by Surfrider Foundation. Yes, you'll have to wake up early, but it's totally worth it: a free ride to the North Shore, a couple of hours making Haleiwa Beach even more beautiful than it already is, then a free lunch and prizes provided by Spy Optics!

Make sure you bring a hat, sunscreen, swim suit, and water (in a reusable water bottle, of course!)

Reserve your spot on the bus by clicking the **I want to sign up** button below. Spaces are limited.

Meet in the Hale Aloha courtyard, from there we'll get on the bus. Don't be late, this one leaves early. Note that this excursion is worth the most points of all! Good attendance by your lounge could just put you over the top!

Expected benefits: Awareness of waste stream and how it impacts Hawaii's beaches

APPENDIX D
ENERGY LITERACY QUESTIONNAIRE

This appendix details the contents of the questionnaire that was administered to assess participants' energy literacy, group identification, and connectedness to nature. Each section briefly relates the source and goal of that segment of the questionnaire, and then lists the actual items presented to participants.

When participants filled out the questionnaire via the SurveyGizmo [116] website, the questions were broken into pages. Each page provided participants the ability to move forward to the next page in the questionnaire, but not back to previous pages. In the energy knowledge section of the questionnaire, this inability to backtrack allowed later questions to include of information that might provide the answer to previous questions (such as what unit electrical power is measured in). The pages of the survey were:

1. Informed consent via email address,
2. Energy attitudes and behavior,
3. Energy knowledge 1 (questions 1–5),
4. Energy knowledge 2 (questions 6–9),
5. Energy knowledge 3 (questions 10–13),
6. Group identification and connectedness to nature,
7. Open feedback on questionnaire, and
8. Thank you page.

Most items on the questionnaire were *required*, meaning that participants could not move to the next page of the questionnaire without submitting an answer. However, each required item included the choice “Choose not to answer” for those participants that did not want to answer the item. The one exception is the entry of the email address on the informed consent page, which was required with no option to skip. Due to way the knowledge ranking questions (questions 5a–5c and 7a–7e) were presented in SurveyGizmo, these questions did not have a “Choose not to answer” option, so they were not marked required.

D.1 Energy Attitudes

The energy attitudes section of the questionnaire was based on the affective subscale of the energy literacy questionnaire developed by DeWaters and Powers [31]. There are 18 statements in the attitudes section, and participants were asked to respond to each one using the following five-point Likert-style scale:

1. Strongly agree
2. Agree
3. Neutral
4. Disagree
5. Strongly disagree
6. Choose not to answer

Those statements marked with (**R**) were reverse scored so that their scores would match the direction of the rest of the statements. I made two changes from the DeWaters and Powers affective scale. The wording of statement 11 was changed from "using" to "generating", clarifying that there is no problem using renewable energy. The other change was the addition of statement 18, which was part of the behavior scale for DeWaters and Powers but matched the attitude questions here better than the behavior items.

The statements were prefaced with the following instructions: "Please indicate how you feel about each statement below. There are no right or wrong answers."

The statements in the attitude section were:

1. Energy education should be an important part of every school's curriculum.
2. I would do more to save energy if I knew how.
3. Saving energy is important.
4. The way I personally use energy does not really make a difference to the energy problems that face our nation. (**R**)
5. I don't need to worry about turning the lights or computers off in the residence halls, because the school pays for the electricity. (**R**)
6. Americans should conserve more energy.
7. We don't have to worry about conserving energy, because new technologies will be developed to solve the energy problems for future generations. (**R**)
8. All electrical appliances should have a label that shows the resources used in making them, their energy requirements, and operating costs.

9. The government should have stronger restrictions about the gas mileage of new cars.
10. We should make more of our electricity from renewable resources.
11. America should develop more ways of generating renewable energy, even if it means that energy will cost more.
12. Efforts to develop renewable energy technologies are more important than efforts to find and develop new sources of fossil fuels.
13. Laws protecting the natural environment should be made less strict in order to allow more energy to be produced. (**R**)
14. More wind farms should be built to generate electricity, even if the wind farms are located in scenic valleys, farmlands, and wildlife areas.
15. More oil fields should be developed as they are discovered, even if they are located in areas protected by environmental laws. (**R**)
16. I believe that I can contribute to solving the energy problems by making appropriate energy-related choices and actions.
17. I believe that I can contribute to solving energy problems by working with others.
18. Many of my everyday decisions are affected by my thoughts on energy use.

D.2 Energy Behaviors

The energy behaviors section of the questionnaire was inspired by the behavioral subscale of the energy literacy questionnaire developed by DeWaters and Powers [31]. There are 17 statements in the behaviors section, and participants were asked to respond to each one using the following five-point Likert-style scale from DeWaters/Powers:

1. Always or almost always
2. Quite frequently
3. Sometimes
4. Not very often
5. Never or hardly ever
6. Not applicable

7. Choose not to answer

The choice of "not applicable" was added to allow participants to respond to statements that might not apply to them, such as driving a car if they do not own a car. Those statements marked with (**R**) were reverse scored so that their scores would match the direction of the rest of the statements.

The statements in DeWaters and Powers behavior subscale were tailored for middle school and high school students in New York State, which unfortunately made many of the statements inappropriate for college students in Hawaiʻi. For example, two questions from the DeWaters/Powers behavior subscale are: "My family turns the heat down at night to save energy." and "I walk or bike to go short distances, instead of asking for a ride in the car.". Instead of the DeWaters/Powers statements, I used statements derived from the commitments that participants could make as part of the challenge (see Section 3.6.3.4). The commitments were already tailored to college students in Hawaiʻi living in student housing.

The statements were prefaced with the following instructions: "For the following statements, please select the choice that best describes your behavior. Please be honest, there are no right or wrong answers."

The statements in the behavior section were:

1. I turn off all appliances (TV, computer, game console, etc) every night before going to sleep.
2. I leave my computer and/or monitor on, even when they are not being used. (**R**)
3. I turn off vampire loads (like cell phone chargers) using a power strip.
4. I leave the lights on when I leave a room. (**R**)
5. I use task lighting (like desk lamps) rather than overhead lighting.
6. I use sunlight rather than electric lighting whenever possible.
7. I take the stairs rather than the elevator whenever feasible.
8. I drive alone (no passengers). (**R**)
9. I walk, bike, or roll to go short distances, instead of driving.
10. I use public transportation.
11. I recycle my cans and bottles.
12. I bring reusable bags when shopping.
13. I eat meat. (**R**)
14. I turn off water when brushing my teeth, shaving, etc.

15. I turn off water in the shower when soaping and scrubbing.

16. I wash only full loads of laundry.

17. I wash my laundry in warm or hot water. (**R**)

D.3 Energy Knowledge

These factual questions assess energy knowledge. As discussed at the beginning of this appendix, the knowledge questions were separated into three pages. When presented to participants, the order of questions within the page was randomized, as was the order of the multiple choice answers. I have assigned keywords to each question to indicate which participants they attempt to assess.

Each page was prefaced with the following instructions:

"Please answer the following questions to the best of your ability, without consulting any books or the Internet. We are interested in what you know right now."

D.3.1 Knowledge Page 1

1. Electrical power is commonly measured in units of:

a) volts (V)

b) watt-hours (Wh)

c) joule (J)

d) watts (W)

e) British Thermal Units (BTU)

f) Choose not to answer

Correct answer: watt
Keywords: power, units

2. What is the primary cause of current climate changes?

a) Carbon dioxide released from burning fossil fuels

b) There is no cause, climate change isn't real

c) Natural solar cycles

d) Radioactive waste from nuclear power plants

e) Melting glaciers in Greenland

f) Choose not to answer

Correct answer: Carbon dioxide released from burning fossil fuels
Keywords: climate change

3. Electrical energy is commonly measured in units of

a) erg

b) ampere (A)

c) British Thermal Units (BTU)

d) watt-hours (Wh)

e) watts (W)

f) Choose not to answer

Correct answer: watt-hour
Keywords: energy, units

4. What is the breakdown of the clean energy mandated by 2030 by the Hawaii Clean Energy Initiative?

a) 20% from renewable sources, 80% from energy conservation

b) 30% from energy conservation, 40% from renewable sources

c) 50% from renewable sources, 10% from conservation

d) 30% from solar, 30% from wind, 10% from waves

e) 30% from renewable sources, 20% from conservation, 10% from natural gas

f) Choose not to answer

Correct answer: 30% from energy conservation, 40% from renewable sources
Keywords: HCEI

5a–5c. Order these types of light sources from lowest to highest power usage, assuming they provide the same amount of light:

a) incandescent bulb

b) compact fluorescent lightbulb (CFL)

c) light-emitting diode (LED)

Correct answer: c, b, a
Keywords: lighting, energy intuition

D.3.2 Knowledge Page 2

6. Approximately how much carbon dioxide (CO2) is in the atmosphere now, and what level is considered the safe upper limit to avoid the worst effects of climate change?

a) 450 ppm CO2 in atmosphere now, 500 ppm CO2 safe upper limit

b) 331 ppm CO2 in atmosphere now, 350 ppm CO2 safe upper limit

c) 393 ppm CO2 in atmosphere now, 350 ppm CO2 safe upper limit

d) 600 ppm CO2 in atmosphere now, 450 ppm CO2 safe upper limit

e) 100 ppm CO2 in atmosphere now, 50 ppm CO2 safe upper limit

f) Choose not to answer

Correct answer: 393 ppm, 350 ppm
Keywords: climate change

7a–7e. Order these appliances from lowest to highest power usage:

a) desk lamp with compact fluorescent lightbulb (CFL)

b) mobile phone charger (while charging)

c) plasma TV

d) microwave

e) laptop

Correct answer: b, a, e, c, d
Keywords: energy intuition

8. On average, how much electrical energy does a home in Hawaii use per day?

a) 400 W

b) 20 kWh

c) 87 kWh

d) 328 kWh

e) 4 kWh

f) Choose not to answer

Correct answer: b
Keywords: energy intuition, Hawai‘i

9. What is the approximate maximum power generated from a single standard rooftop solar panel?

a) 25 W

b) 800 W

c) 50 W

d) 10 kW

e) 200 W

f) Choose not to answer

Correct answer: 200 W
Keywords: power, energy intuition, generation, PV

D.3.3 Knowledge Page 3

10. What are the expected long-term effects of current climate changes?

a) A significant rise in the sea level

b) Global temperatures increasing by a few degrees on average

c) Increasing sea water acidity

d) Changes in seasonal rainfall patterns (droughts, floods)

e) All of the above

f) Choose not to answer

Correct answer: All of the above
Keywords: climate change

11. What is currently the source of approximately 80% of Hawaii's electricity?

a) oil

b) wind

c) natural gas

d) coal

e) solar

f) Choose not to answer

Correct answer: oil
Keywords: generation, utility, Hawaiʻi

12. A compact fluorescent lightbulb (CFL) uses 13 W. If it is run for 2 hours, how much energy does it use?

a) 13 Wh

b) 7.5 Wh

c) 26 Wh

d) 130 Wh

e) 52 Wh

f) Choose not to answer

Correct answer: 26 Wh
Keywords: power, energy, calculation

13. If your game console uses 200 W when turned on, how much energy would it waste if you left it on all weekend while you were away?

a) 15000 Wh

b) 100 Wh

c) 960 kWh

d) 9.6 kWh

Correct answer: 9.6 kWh
Keywords: power, energy, calculation

D.4 Group Identification

I used the Arrow-Carini Group Identification Scale 2.0 [55] for the group identification section of the questionnaire. It consists of 12 statements in three subscales: affective, behavioral, and cognitive. Participants were asked to respond to each one using the following seven-point Likert-style scale:

1. Strongly disagree
2. Moderately disagree
3. Slightly disagree
4. Neutral
5. Slightly agree
6. Moderately agree
7. Strongly agree
8. Choose not to answer

Those statements marked with (**R**) were reverse scored so that their scores would match the direction of the rest of the statements. The statements were prefaced with the following instructions: "Please answer each of these questions in terms of the way you generally feel about your lounge. There are no right or wrong answers. Using the following scale, simply state as honestly and candidly as you can what you are presently experiencing."

The statements in the group identification section were:

1. I would prefer to be in a different lounge. (**R**)
2. In this lounge, members don't have to rely on one another. (**R**)
3. I think of this lounge as part of who I am.
4. Members of this lounge like one another.
5. All members need to contribute to achieve the lounge's goals.

6. I see myself as quite different from other members of the lounge. (**R**)
7. I enjoy interacting with the members of this lounge.
8. This lounge accomplishes things that no single member could achieve.
9. I don't think of this lounge as part of who I am. (**R**)
10. I don't like many of the other people in this lounge. (**R**)
11. In this lounge, members do not need to cooperate to complete group tasks. (**R**)
12. I see myself as quite similar to other members of the lounge.

D.5 Connectedness To Nature

This section of the questionnaire used the Connectedness to Nature Scale (CNS) developed by Mayer and Frantz [80]. It consists of 14 statements. Participants were asked to respond to each one using the following five-point Likert-style scale:

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. Choose not to answer

Those statements marked with (**R**) were reverse scored so that their scores would match the direction of the rest of the statements. The statements were prefaced with the following instructions: "Please answer each of these questions in terms of the way you generally feel. There are no right or wrong answers. Using the following scale, simply state as honestly and candidly as you can what you are presently experiencing."

The statements in the group identification section were:

1. I often feel a sense of oneness with the natural world around me.
2. I think of the natural world as a community to which I belong.
3. I recognize and appreciate the intelligence of other living organisms.

4. I often feel disconnected from nature. (**R**)
5. When I think of my life, I imagine myself to be part of a larger cyclical process of living.
6. I often feel a kinship with animals and plants.
7. I feel as though I belong to the Earth as equally as it belongs to me.
8. I have a deep understanding of how my actions affect the natural world.
9. I often feel part of the web of life.
10. I feel that all inhabitants of Earth, human, and nonhuman, share a common ’life force’.
11. Like a tree can be part of a forest, I feel embedded within the broader natural world.
12. When I think of my place on Earth, I consider myself to be a top member of a hierarchy that exists in nature. (**R**)
13. I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.
14. My personal welfare is independent of the welfare of the natural world. (**R**)

APPENDIX E
IN-GAME QUESTIONNAIRE

This appendix details the contents of the questionnaire made available to participants via the in-game questionnaire during the Overall Round of the challenge.

When participants filled out the questionnaire via the SurveyGizmo [116] website, the questions were broken into pages. Each page provided participants the ability to move forward to the next page in the questionnaire, but not back to previous pages. The topic of the pages of the survey were:

1. Informed consent via email address
2. Promotion and Events
3. Prizes
4. Adoption
5. Website
6. Gamification
7. General feedback on Kukui Cup
8. Open feedback on questionnaire
9. Thank you page

Questions that allowed multiple answer selections (i.e., checkboxes) are shown as "□". Questions that allowed only a single selection from a list of options (i.e., radio buttons) are shown as "○". Questions that provided a text field for open answers do not have any special notation.

The questions were prefaced with the following instructions: "The goal of this survey is to learn about your experiences during the Kukui Cup. Please answer honestly, we want to know how you really feel."

E.1 Promotion and Events

Figuring out the best way to promote the challenge and events to residents was one of our major concerns. The goal of this section was to elicit feedback on how to improve our promotion efforts.

1. Did the banners in the tower lobbies stimulate your curiosity about the Kukui Cup?

○ Yes

- ○ No
- ○ Don't remember seeing banners

2. Did the banner in the Hale Aloha cafeteria during week 1 help you remember about events?

- ○ Yes
- ○ No
- ○ Don't remember seeing a banner

3. For the workshops and excursions that you attended, how did you like them? You can leave blank any events that haven't taken place by the time you fill out this survey.

[Each event was ranked on the following Likert-type scale:]

1. Liked a lot
2. Liked
3. OK
4. Boring
5. Very Boring
6. Didn't attend

Event list:

- Kickoff party
- Play Outside the Cafe (any)
- Energy scavenger hunt
- Recycled fashion design
- Flashmob planning
- Kahuku wind farm
- Student Organic Farm Training (SOFT)
- Pedalpalooza

- Round 1 awards party
- Your sustainable future workshop
- Energy efficient eating
- Movie night
- Reppun farm (off-the-grid living)
- Kokua Market excursion
- Round 2 awards party
- High energy art and music
- Energy efficient chillaxation
- Beach cleanup excursion

4. What can we do to improve attendance at workshops and excursions?

5. Did you sign up for any events via the website, but then end up not attending?

○ Yes

○ No

[If No] Why did you end up not attending?

E.2 Prizes

As an incentive to participate in the Kukui Cup, players could win a variety of prizes. In designing the challenge, we did our best to select prizes that would be appealing to participants. In this section we solicited feedback on what prizes participants wanted to see.

6. What prize (if any) did you find most motivating in the Kukui Cup?

7. If you had a budget of $5/person for a prize to be given to everybody in a lounge, what would you want?

8. If you had a budget of $10/person for a prize to be given to everybody in a lounge, what would you want?

E.3 Adoption

Understanding how residents find out about the Kukui Cup, and what motivated them to play could be helpful in designing future challenges. The questions in this section were written by Michelle Katchuck to gather pilot data for a potential dissertation proposal topic.

9. How did you first hear about the Kukui Cup? (choose all that apply)

- ☐ I saw a Kukui Cup banner
- ☐ I read about it in an email I received
- ☐ I attended one of the courtyard events
- ☐ A friend referred me
- ☐ My RA
- ☐ Other
- ☐ Yes
- ☐ No

10. Prior to playing the Kukui Cup, were you interested in energy conservation?

11. Has the Kukui Cup increased your interest in energy conservation and sustainability?

12. Which of the following motivated you the MOST to keep playing the Kukui Cup?

- ○ to win prizes
- ○ to be on the top of the scoreboard
- ○ to play with my friends
- ○ to learn more about energy and how to save energy
- ○ attending events and excursions
- ○ other: ______________________

13. What motivated you to participate in the online portion of the Kukui Cup?

14. What motivated you to participate in the "real" world activities of the Kukui Cup?

15. What has been the most fun and/or interesting activity of the Kukui Cup?

16. How would you like to hear about Kukui Cup events? (i.e. text message, email, RAs, posters, Facebook, Twitter, the website, etc)

E.4 Website

The 2011 UH Kukui Cup was the first time the challenge website had been used with a large number of participants. The questions in this section focus on the players' experiences with the website. George Lee wrote the questions in this section to collect data for his masters thesis [72].

17. What did you like about the website?

18. What did you find confusing about the website?

19. If you could add or change something in the website, what would that be?

20. Rate how much you agree with each statement below
[Each statement was ranked on the following Likert-type scale:]

1. Strongly disagree
2. Disagree
3. Neutral
4. Agree
5. Strongly agree
6. Not Applicable

Statements:

- It was easy to find what I was looking for in the website.
- The website was responsive. I did not wait too long after I clicked on something.
- The website provided adequate help in teaching me how to play the game.

- I understood the rules of the game and how to play.

21. Have you accessed the Kukui Cup website from a smartphone?

○ Yes

○ No

[If Yes] How satisfied were you with the mobile website?

○ Very Satisfied

○ Satisfied

○ Neutral

○ Dissatisfied

○ Very Dissatisfied

○ Not Applicable

E.5 Gamification

This section primarily covers questions about the game aspects of the challenge. Many of the questions in this section were written by Yongwen Xu to gather pilot data for a potential dissertation proposal topic.

22. Have you made any commitments through the website during the game?

○ Yes

○ No

[If Yes] Did you change your behavior during the competition based on the commitment(s) you made?

○ Yes

○ No

○ Not sure

23. Which of the followings Kukui Cup achievements would you want to share on Facebook? (choose all that apply)

- ☐ made a commitment
- ☐ participated in an activity
- ☐ attended an event or excursion
- ☐ earned a badge
- ☐ current leader in the scoreboard
- ☐ other

24. How much time do you usually spend on the following activities?
[Options for each activity:]

1. 3 or more hours a day
2. about 1 hour a day
3. about 1 hour a week
4. 1 hour a month or less
5. never

List of activities:

- Playing games on a laptop computer
- Playing games on a game console (Xbox, PS3, Wii)
- Playing games on a handheld game device (DS3, PSP)
- Playing games on a mobile phone
- Checking Facebook
- Checking Twitter

25. How would you describe the Kukui Cup? (check all that apply)

- ☐ Fun

- ☐ Educational
- ☐ So-so
- ☐ Boring
- ☐ Not useful
- ☐ Difficult
- ☐ Addictive
- ☐ Other

26. The Kukui Cup website shows energy data updated every 15 seconds. Did you find this helpful in conserving energy?

- ○ not really, updating the data daily would be enough
- ○ not really, updating the data hourly would be enough
- ○ not really, I only care about the final result of the competition
- ○ yes, it is helpful to see the energy usage changing in real time

27. Which of the following do you wish there were more of in the game? (choose all that apply)

- ☐ events
- ☐ excursions
- ☐ commitments
- ☐ videos
- ☐ social activities
- ☐ physical activities
- ☐ online activities

28. On average, how many minutes a day did you spend on the Kukui Cup website?

29. On average, how many hours a week did you spend at Kukui Cup events?

E.6 General Feedback

This section covers feedback on the challenge overall.

30. What can we do to improve participation in the Kukui Cup website?

31. What was the best thing you liked about the Kukui Cup so far?

32. What was the thing you liked the least about the Kukui Cup so far?

33. If you were able to play the Kukui Cup next year, would you?

- ○ Yes
- ○ I enjoyed it, but I wouldn't play again
- ○ I didn't enjoy it, and I wouldn't play again
- ○ No, because: ____________________________

34. How likely would you be to recommend playing the Kukui Cup to a first year student in Fall 2012?

- ○ Very Likely
- ○ Likely
- ○ Neutral
- ○ Unlikely
- ○ Very Unlikely
- ○ Not Applicable

35. Is there anything else you would like to tell us about your experience playing the Kukui Cup that this survey didn't ask?

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