The Kukui Cup:
Design of a next generation dorm energy competition

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1 Executive Summary

Kukui nut oil was used by ancient Hawaiians to light their homes. In honor of this original form of energy in the islands, we propose to design and implement a Dorm Energy Competition for the University of Hawaii called the "Kukui Cup". It will be held for the first time during the month of October, 2010. The three goals of this project are: (1) Improve the energy literacy of participating students; (2) Conduct innovative research in information technology for energy-related behavioral change; and (3) Save money for the university by reducing energy costs. As part of this project, we will implement a new web application to provide information regarding UH Dorm Energy in general and the Kukui Cup competition in particular. This software will also support research on energy behavior by the Collaborative Software Development Laboratory in the Department of Information and Computer Sciences. We propose to hold the October, 2010 dorm energy competition in two freshman dorms, and then expand the program to include more dorms in future years.

We propose the installation of commercial energy meters on each floor of the two dorms that will provide sub-minute energy consumption data regarding each floor. We have developed a set of meter requirements for this project including: the total number of meters, max current, required energy data, data sampling interval, network communication, software interface, internal storage, and submetering. Our research indicates that there are at least four models of meters that should satisfy our requirements: Accu-Energy Acuvim IIR, Electro Industries Shark 200S, Yokogawa PR 300, and Quad-Logic RSM5c. We will develop software that will query each meter via TCP/IP at sub-minute intervals for current energy data and send that information to a WattDepot energy data repository service for collection and analysis. The Dorm Energy web application will then query the WattDepot service for energy data and analyses as required.

The Kukui Cup dorm energy competition implements a variety of novel features intended to support sustained, positive, behavioral change in energy behaviors. These features include: personalized, private pages; near-real time display of energy consumption data; and a "Kukui Nuts" competition that implements a point system for actions intended to improve energy literacy. The competition provides incentives for three kinds of actions: activities, goals, and commitments. The design of the competition is based upon prior research in behavioral change and will support data collection and analysis to provide new insights into effective incentives for energy conservation and information technology support.

The project involves a variety of stakeholders, including: the Collaborative Software Development Laboratory, UH dorm residents, UH dorm resident advisers, UH Housing Office, UH Facilities, Sustainable UH, and local energy organizations. The needs of each of these stakeholders must be identified and satisfied for this project to move forward.

The estimated budget for the first year of this project is \$53,000, based upon: purchase of 24 meters (\$36,000); installation of the meters (\$12,000); funding for parties and prizes (\$3,000); and billboard hardware (\$2,000). The estimated direct return on this investment for the first year of this project is \$45,000, or close to break-even. Because the purchase and installation of meters is a one-time cost, we expect the direct return of this project to begin saving the University at least \$40,000 per year beginning in year 2011. The indirect return on this investment is potentially even greater, as the project will provide infrastructure that facilitates extramural research grants, as well as the creation of a community of energy literate students who will conserve energy elsewhere on campus and after they leave the dorms.

2 Goals

We are designing the UH Dorm Energy Competition (Kukui Cup) to achieve three goals:

1. Improve the *energy literacy* of the participating students;
2. Conduct *innovative research* in information technology for energy-related behavioral change;
3. *Save money* for the university by reducing energy costs.

2.1 Improve energy literacy

Energy literacy [3, 4] has three components: knowledge, attitudes, and behaviors. Energy knowledge refers to factual information and skills, such as the ability to estimate the energy savings in watt-hours from switching lights from incandescent to compact fluorescent. Energy attitudes refers to one's opinions and beliefs related to energy, such as that conserving energy is good for the environment. Energy behaviors combine knowledge and attitudes to produce concrete action, such as replacing the incandescent bulbs in one's home with compact fluorescent.

While one might assume from the above definition that energy literate behaviors follow naturally from knowledge and attitudes, there is substantial research to the contrary. For example, Geller [6] performed an experiment in which 40 consumers attended a three hour workshop on energy conservation. A pre and post workshop questionnaire determined that all participants gained greater awareness of energy issues, more appreciation for what could be done in their homes to reduce energy use and save money, and a willingness to implement the changes that were advocated in the workshop. However, a one month followup indicated very little actual change in behavior. One person lowered the temperature on the hot water heater. Two additional people had installed insulating blankets around their hot water heaters, but they had already done this before the workshop. Finally, eight people installed low-flow shower heads—after all 40 participants had been given the low-flow shower heads at the workshop.

As this and similar research illustrates, simply providing people with information about energy, even if it affects their attitudes, is generally not enough to create sustained, positive behavioral change with respect to their energy usage. Fortunately, there is also a growing body of research on techniques that do support behavioral change [1, 2, 5, 15, 11, 10, 13, 16], which can be summarized as follows. First, provide *personalized information* that reflects the consumer's unique circumstances. For example, a dorm resident will not respond well to energy tips involving improved insulation. Second, provide both *general and specific commitments*, especially when they can be tied to a broader issue. For example, pledging to use a clothesline rather than a dryer because it reduces green house gas emissions. Third, provide *achievable goals* that can be objectively measured. An example might be to reduce energy consumption by 10% over the previous month. Fourth, elicit *social reinforcement* which can be manifested in both overt and subtle ways. For example, in dorm settings, as more and more residents publicly participate, it implicitly becomes "the thing to do". Fifth, provide *constant and contextual feedback* which helps verify progress toward goals and can reinvigorate commitments, as long as the feedback is provided in the right way at the right time. Sixth, *financial incentives* can be a powerful motivator for energy conservation. For example, a prize such as iPods to the members of the dorm floor who conserved the most energy.

Thus, the first design goal of this project is to increase factual knowledge about energy by participants, foster more sophisticated attitudes based upon this knowledge, and, most finally, facilitate actual behavioral change. If we are successful in improving the energy literacy of participants, their changes in behavior will be sustained beyond the competition, and even beyond their time in the dormitories.

2.2 Conduct innovative IT energy research

As noted in the previous section, there is evidence in support of a variety of techniques for promoting sustained, positive behavioral change, but current dorm energy competitions either do not employ these techniques, or they do not utilize information technology effectively to deploy the techniques or support assessment of their effectiveness.

The most common form of information technology support for dorm energy competitions is a simple relatively static web site, as illustrated in Figure 1. These websites provide access to resources about energy, and feedback regarding energy usage for the entire building every few days. The most sophisticated technology to date is the Campus Resource Monitoring System at Oberlin College, which has the potential to provide near-real time energy consumption data[1].

We are designing a collection of software services that will provide UH dorm residents participating in the competition with unparalleled information technology support for improving their energy literacy. Our software will support a unique combination of features including: (a) near-real time energy consumption data, (b) floor-level as well as building-level energy data; (c) personalized, login-protected pages for each student; (d) energy literacy activities with a "Kukui Nut" award system for participation; and (e) integration with other information technologies used by students, including text messaging, Facebook, email, and Twitter.

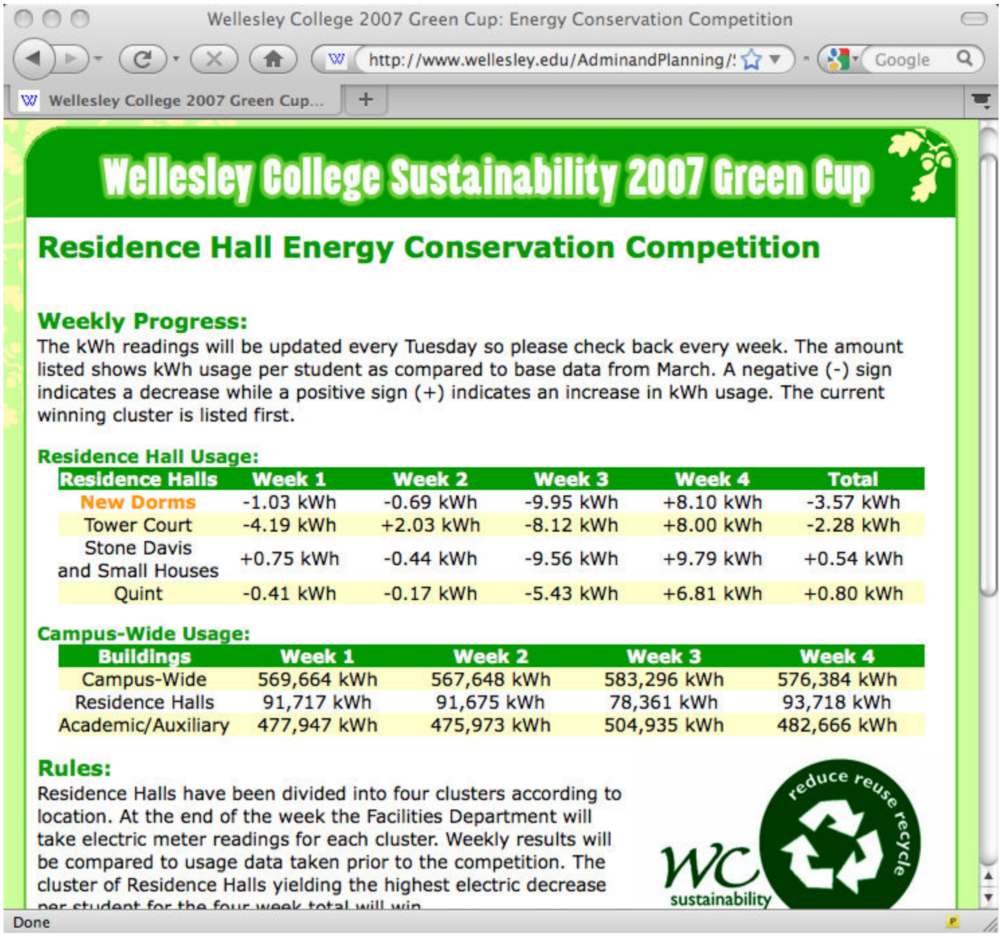
Our software services are not designed merely to be cool or trendy; they are designed to enable substantial, important research into energy behavior. While prior research has generated evidence regarding a variety of techniques for fostering behavioral change, there is relatively little understanding of the relative importance or impact of these methods. Our software will enable us to present students with a variety of avenues for participation and incentives and then track many of the ways in which they participated. It will enable us to observe and record participant energy usage (on a floor-by-floor basis) before, during, and after the competition. In addition, we will request student volunteers for an energy literacy assessment both before and after the competition. The result of these three streams of data will provide a uniquely rich source of insight into the popularity of various activities, their impact on energy literacy, and the final impact on actual energy usage.

More details on the software are provided in Sections 3.1 and 3.4, but in summary, the goal of our software is to provide innovative support for improving energy literacy in students combined with infrastructure to enable ground-breaking empirical research in sustainability and energy.

2.3 Save money

The final goal is to save money. Previous dorm energy challenges at Brandeis University, Carleton College, Harvard University, MIT, Mount Holyoke College, Ohio University, and Williams College have reported energy savings, generally in the range of 7% to 16%. If we can achieve these results,

[1]With respect to energy consumption data, we define "near-real time" as sub-minute update intervals. For example, obtaining meter data every 10 seconds is "near real time", while obtaining meter data every 15 minutes is not.



Wellesley College 2007 Green Cup: Energy Conservation Competition

http://www.wellesley.edu/AdminandPlanning/

Wellesley College 2007 Green Cup...

Wellesley College Sustainability 2007 Green Cup

Residence Hall Energy Conservation Competition

Weekly Progress:

The kWh readings will be updated every Tuesday so please check back every week. The amount listed shows kWh usage per student as compared to base data from March. A negative (-) sign indicates a decrease while a positive sign (+) indicates an increase in kWh usage. The current winning cluster is listed first.

Residence Hall Usage:

Residence Halls	Week 1	Week 2	Week 3	Week 4	Total
New Dorms	-1.03 kWh	-0.69 kWh	-9.95 kWh	+8.10 kWh	-3.57 kWh
Tower Court	-4.19 kWh	+2.03 kWh	-8.12 kWh	+8.00 kWh	-2.28 kWh
Stone Davis and Small Houses	+0.75 kWh	-0.44 kWh	-9.56 kWh	+9.79 kWh	+0.54 kWh
Quint	-0.41 kWh	-0.17 kWh	-5.43 kWh	+6.81 kWh	+0.80 kWh

Campus-Wide Usage:

Buildings	Week 1	Week 2	Week 3	Week 4
Campus-Wide	569,664 kWh	567,648 kWh	583,296 kWh	576,384 kWh
Residence Halls	91,717 kWh	91,675 kWh	78,361 kWh	93,718 kWh
Academic/Auxiliary	477,947 kWh	475,973 kWh	504,935 kWh	482,666 kWh

Rules:

Residence Halls have been divided into four clusters according to location. At the end of the week the Facilities Department will take electric meter readings for each cluster. Weekly results will be compared to usage data taken prior to the competition. The cluster of Residence Halls yielding the highest electric decrease

Figure 1: *The Wellesley College Dorm Energy Competition Web site.*

and if the savings can be sustained for the remainder of the school year, then energy costs for the dorms alone could be reduced by tens of thousands of dollars[2].

However, those are just the "first-order" savings to the university. If the competition achieves the goal of improving the energy literacy of students, then their energy literate behavior will be manifested everywhere on campus, not just in their dorm floors. A more energy literate student will choose energy saving behaviors in campus cafeterias, classrooms, and labs, producing additional, "second-order" savings to the university. Furthermore, the "return on investment" in improved energy literacy will occur over their entire time at the university, not just during the one month competition, and not just during their one year in the dorm. We also hope that these energy literate students will influence their friends in positive ways, reaping additional dividends.

There is even the possibility of "third-order" savings. We are designing this project to begin with dormitory energy competitions, then extend into residential community energy challenges [8]. In addition, we are releasing all software developed under this project as open source in order to facilitate more wide-spread adoption. Thus, this project could lead to eventual energy cost savings in our community and elsewhere.

[2]Section 3.7 provides a more detailed analysis of the estimated costs and savings associated with this project

3 Approach

Our pursuit of the three goals of energy literacy, innovative research, and saving money results in the following proposed approach to a UH Dorm Energy competition.

To summarize, we propose to hold the first annual UH Dorm Competition during Fall semester of 2010. The first competition will involve just two of the freshman dormitories. We will conduct focus groups in these dorms this spring to better understand how to achieve buy-in through feedback from current residents and Resident Advisers. During the summer, floor-level energy metering will be installed in the selected dorms. During early fall, a specialized web application will become available. The competition will be held during the month of October, 2010. We will continue to monitor energy usage for the remainder of the year and conduct follow-up studies to assess the impact and permanence of any energy reductions observed during the competition period.

We plan to build upon the results from the first year to hold improved versions in following years, hopefully expanding the number of involved dorms as well.

3.1 User Interface

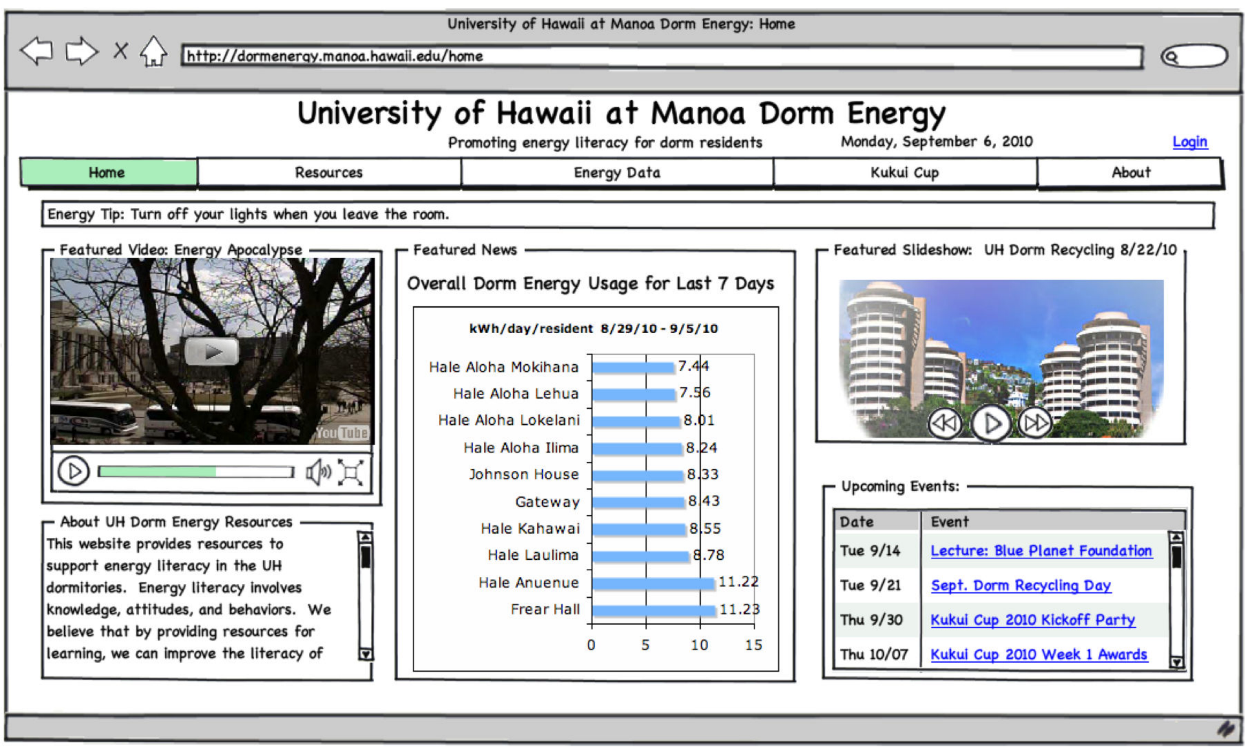


Figure 2: *Home page mockup.*

We plan to embed the Dorm Energy Competition within a more general web application called "University of Hawaii Dorm Energy". This site will, in addition to competition data, provide general information and resources about dorm energy usage on a year-around basis. Figure 2 illustrates a mockup of the public home page for this site.

The public home page provides general information about energy usage, and tabs to other pages including: a Resource page with links to further information about energy usage and conservation; an Energy Data page that displays charts generated from meter data; a Kukui Cup page that will present current standings and activities related to the competition during October, and more general information about it at other times of the year; and an About page that provides contact information.

A distinguishing feature of our approach is a personalized private page that each resident of the dorm can access by logging in to the site using their UH account information. Figure 3 illustrates what such a private page might provide for a hypothetical dorm resident named Maile Kalama. In addition to profile information, the page displays Maile's activities, commitments, and goals, the current and cumulative energy usage of her floor, and her individual and floor-level standings for the previous and current rounds of competition.

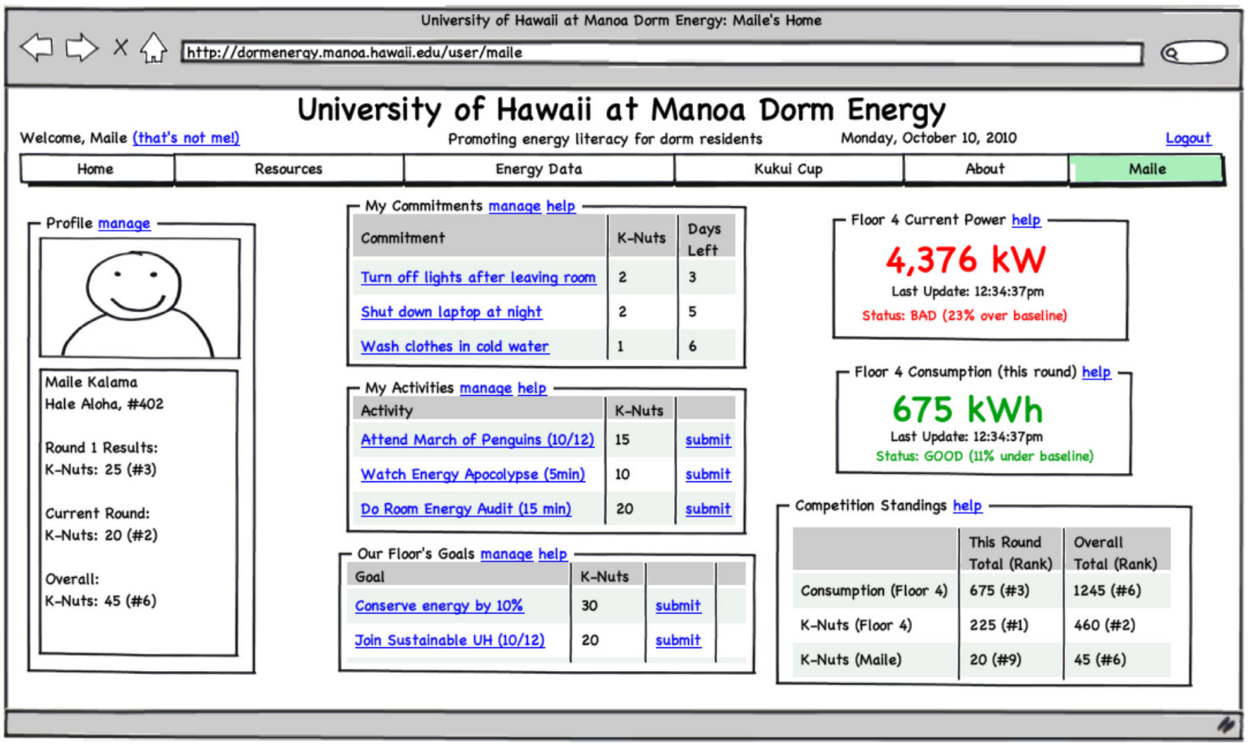


Figure 3: *Personalized page with individual and floor status.*

A final example of our proposed user interface is an "electronic billboard", which is a large font web page that is intended to be displayed on an HDTV monitor mounted near the entryway to each dorm. Each dorm will have their own custom billboard page that displays information relevant to their dorm and the standings of their residents within it. The billboard cycles through a set of screens, pausing on each for approximately 5 seconds. The goal of the billboard is to remind students upon entering and leaving the dorm of the competition and give them an easy way to see the current standings without having to check their own computer or mobile device. Figure 4 illustrates one example screen from the billboard display for Hale Ilima dorm.

For more details on the site and its functionality, see Section 3.4.

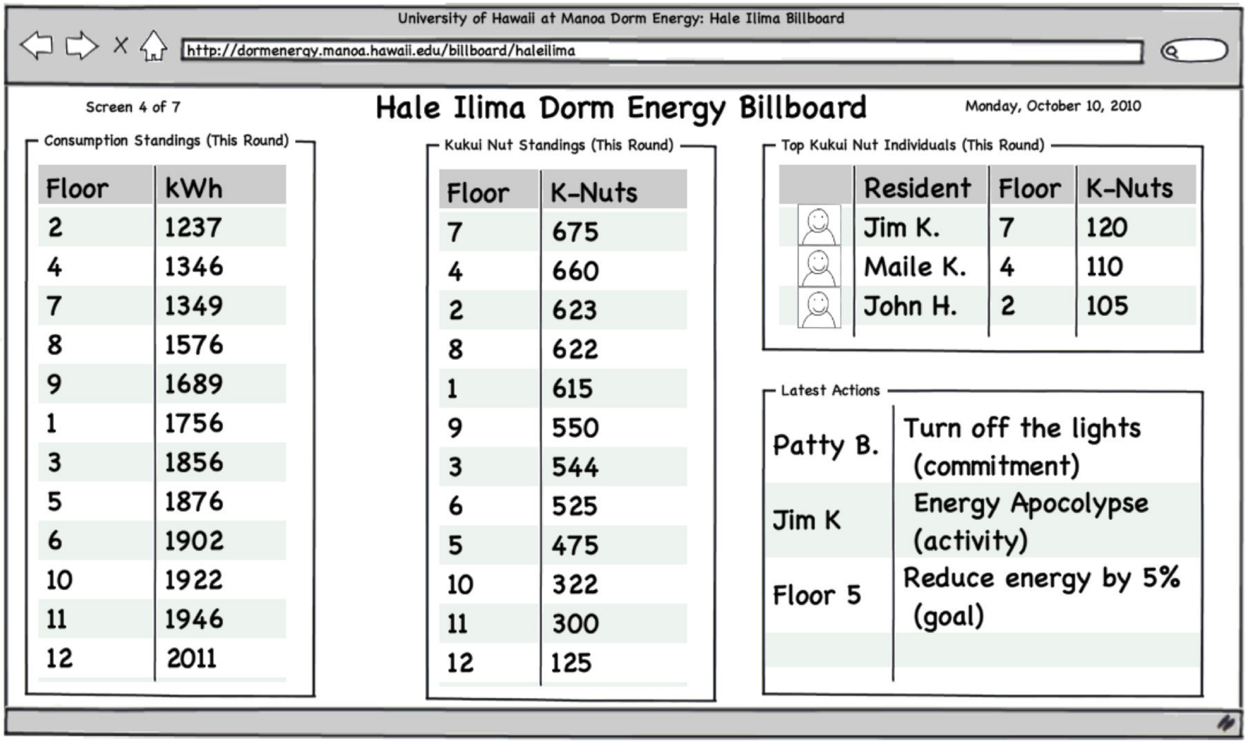


Figure 4: *Example billboard screen for Hale Ilima dorm.*

3.2 Architecture

The primary hardware and software components are summarized in Figure 5.

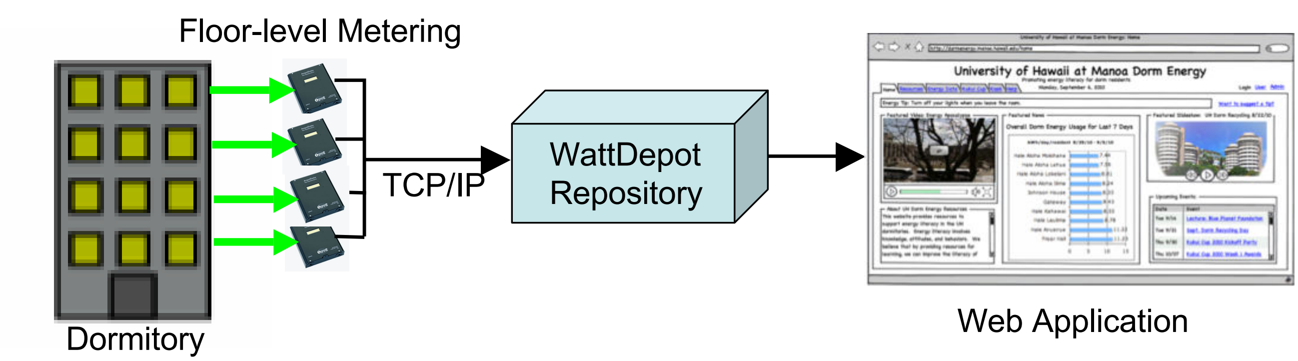


Figure 5: *Basic architecture of the dorm energy data collection system.*

An energy meter will be installed on each floor of each dorm involved in the competition. Section 3.3 presents the results of our research so far on appropriate commercial meters for this installation. Each meter will have an Ethernet connection, and energy data from each meter will be sent at sub-minute intervals to our software service, WattDepot [17]. We directly connect each meter to the UH network via Ethernet, rather than use a building-wide ModBus with a single Ethernet gateway, in order to avoid bus contention that might occur due to the sub-minute polling requirements for our system.

The energy data collected from each floor of each dorm at sub-minute intervals is stored in WattDepot, which can perform various analyses including aggregation and interpolation to transform it into a convenient form for display within the web application.

We recognize that several aspects of our proposed architecture are unusual: installing meters on every floor (versus one for the entire building); directly connecting each meter to Ethernet (versus using ModBus or a mesh network); and sub-minute polling (versus 15 minute or greater polling). These decisions are based upon our research into effective incentives for sustained, positive behavioral change, which includes personalized, constant, and contextual feedback.

As a simple example, let's say that the residents of a dorm floor want to figure out their "baseline" energy usage: how much electricity is used on their floor after they turn off everything under their control. If the only meter available is at the building-level, the residents could not succeed, since energy fluctuations in the remainder of the building would drown out their action. Similarly, if energy data from the meters is collected only once every 15 minutes, the experiment becomes difficult to perform, since they would have to keep everything off for an extended period of time.

Other behavioral incentives affected by this architecture include personalized information and social norms. By providing floor-level meters, we can support competition between floors as well as between dorms. This finer granularity of competition makes the actions of any individual vastly more significant, since they are one of 24 members, as opposed to one of 200 or more.

3.3 Meters

This proposal requires the installation of energy meters on each floor of the dorms participating in the competition. We conducted a review of commercial building meters to determine which ones might be suitable. To support this process, we developed the list of requirements summarized in Figure 6 below:

Requirement	**Description**
Total meters	24 (estimate based on 2 dorms with 12 floors each)
Building power (BP)	3 phase
Max current (MC)	500 amps (estimated)
Required data (RD)	kW (instantaneous power); kWh (cumulative energy usage)
Data sampling interval (DSI)	Every 10 seconds (desired); sub-minute (required)
Network comm. (NC)	TCP/IP via Ethernet (desired); WiFi (possibly acceptable)
Software Interface (SI)	Two options: (1) The meter can be polled using the standard ModBus/TCP protocol; or (2) the vendor provides a specialized API that we can use to query the device at the data sampling interval.
Internal storage (IS)	Optional, but desirable in case Internet connection goes down. Historical data not needed at sub-minute intervals.
Submetering (SM)	Optional, but desirable in case we want to track a shared resource (laundry room) separately

Figure 6: *Meter requirements*

Based upon these requirements, we contacted a variety of vendors to see which of their models could satisfy these requirements. Figure 7 summarizes our current findings.

Company/Meter	BP	MC	RD	DSI	NC	SI	(IS)	(SM)	Cost
Accu-Energy/Acuvim IIR	X	X	X	X	X	X	X	X	$1361
Electro Ind./Shark 200S	X	X	X	X	X	X	X	X	$1156
Yokogawa/PR300	X	X	X	X	X	X		X	$1560
Quad-Logic/RSM5c	X	X	X	X	X	X	X	X	$ n/a
PowerLogic/PM800	X	X	X	X	X		X	X	$3889
Dent/PowerScout	X	X	X	X	X			X	$535
Microdaq/Elite Pro	X	X	X	X	X		X		$995
D-Mon/Class 2000	X	X	X				X	X	$940

Figure 7: *Meter Results. Parenthesized columns are optional capabilities. Cost is based upon informal quotes. Meters above the double line appear to qualify for this project.*

We have prepared a separate technical report [9] that provides details on our meter research and how we came to these conclusions.

3.4 Web application features

Section 3.1 provides a sense for the look-and-feel of the web application through a small selection of screen shots. This section summarizes the functionality of the system.

3.4.1 General UH dorm energy information (year round)

The system will provide a set of public pages that provide residents and community members with general information about dorm energy usage, including: (a) charts with current and historical energy usage data; (b) pointers to on-line references relevant to dorm energy issues; and (c) who to contact for more information. For the two dorms in which energy meters will be installed, we will collect energy usage data automatically. For other dorms, we hope that building-level energy meters are available that we can read manually on a weekly basis and input into WattDepot, so that aggregate energy usage data for all UH dorms can be made available from this website.

3.4.2 Kukui Cup competition (October only)

During October of each year, the system will provide specialized features to support the Kukui Cup competition. These features include: (a) login-protected, personal pages for residents in participating dorms; (b) login-protected, admin pages for monitoring the competition and/or updating pages; (c) current standings for an "Energy Conservation" competition, in which individual floors compete against each other to reduce their energy usage; and (d) current standings for a "K-Nuts" competition, in which individual floors compete against each other to obtain the highest number of Kukui Nuts through engaging in energy literacy-related activities. The next sections look at these components of the Kukui Cup competition in a bit more detail.

3.4.3 Login-protected pages

In September, the system will be configured with a list of UH accounts corresponding to the residents of the dorms participating in the Kukui Cup. When a dorm resident logs in to the Dorm Energy web site (using the UH Web Login service), they are taken to a personalized page that provides meter data for their floor, their floor's current standings in both the Energy Conservation and K-Nuts competitions, and activities they can carry out to improve their standings.

The system is also configured with a set of UH accounts whose owners are provided with administrator privileges on the site. This enables them to edit public pages and award K-Nuts to students who have successfully completed activities.

3.4.4 Energy Conservation Sub-competition

One of two competitions held during October, the Energy Conservation competition uses data from the floor meters to determine what amount of energy conservation (if any) has been achieved by occupants of each floor of each dorm. We calculate conservation as the total number of kilowatt-hours consumed by each floor for a given time period, minus each floor's "baseline" energy consumption level (determined during the summer prior to occupancy of the floor).

To foster early and ongoing interest and participation, the energy conservation competition will be structured into three week-long sub-competitions called "Rounds", with prizes for the top conservation and Kukui Nuts for each round. At the conclusion of the fourth week, the competition is over and instead of weekly awards, a set of "Grand Prize" awards will be given for floors and dorms achieving the most conservation over the entire period.

3.4.5 K-Nut Sub-competition

While the energy conservation competition rewards participants on the basis of reduced energy usage on their floor, it does not, by itself, support the goals of energy literacy (improved knowledge, attitudes, and behavior). To complement the energy conservation competition, we propose a parallel competition based upon a point system called "Kukui Nuts" (K-Nuts). To earn K-Nuts, students can engage in three types of tasks: activities, commitments, and goals.

Activities. To earn Kukui Nut points, the system will provide students with a selection of "activities", including things like: attending an energy-related movie sponsored by the competition, joining a campus energy conservation group like SustainableUH, watching an energy-related YouTube video, reading a short energy-related article, and so forth. Each activity, when carried out, earns the student a certain number of Kukui Nut points, depending upon the effort required for the task. Most activities will be worth from 10 to 20 Kukui Nut points.

To keep the competition fair, the system will implement a simple verification system for each activity. For example, if a student wants Kukui Nuts for having watched one of the YouTube videos listed as an activity, the system will ask them to answer a very simple question about the video—just enough to verify that they actually watched it. Submitted answers are then reviewed by site administrators and Kukui Nuts are awarded as long as the answers are reasonable.

The goal of activities are to provide opportunities to increase the knowledge component of their energy literacy.

Commitments. Research has shown that public commitments are a powerful incentive for changing behavior, and there has been interesting design work on energy-related commitments [12, 14]. Our system will implement a way for students to make public commitments and earn Kukui Nut points for doing so.

Unlike an activity, which is a one-time, verifiable event, a commitment is a pledge to make a more general, long-term change in behavior (such as "turning off the lights when I leave the room").

Since commitments are impractical to verify, the system will implement constraints intended to simultaneously incentivize the making (and keeping) of commitments. First, commitments are worth less than activities—1 to 2 K-Nuts per commitment, rather than 10-20. Second, a student can have a maximum of 5 active commitments at a time, preventing them from simply committing to every possible commitment. Third, a student's commitments are made public, appearing to their floor members, on the public billboard system at the dorm entrances, and in the public pages of the web site. Fourth, commitments expire after one week. This enables students to collect more Kukui Nut points by taking on new commitments (or re-committing to the same ones) at multiple times during the competition month. Also, it serves as a reminder to re-think their commitments several times during the competition.

Goals. Another powerful incentive for behavioral change is specific, achievable, measurable goal-setting. For example, deciding to "lose 2 pounds of weight this week by exercising 30 minutes daily and not eating dessert" is a generally more effective than deciding to "stop being overweight", since the former is specific, concrete, and measurable.

The system will support this approach to incentivizing behavioral change through defined goals, such as: our floor will reduce its energy consumption this week by 10%, or all members of our floor will attend the public showing of the "March of the Penguins" movie.

Similar to activities, goals are verified by site administrators. Upon achieving a goal, all participants in the goal are awarded Kukui Nut points.

3.5 Project Timeline

Figure 8 presents the major activities and milestones for the next twelve months of this project.

3.6 Stakeholders

For this project to succeed, we must engage with and satisfy the needs of a variety of stakeholders, including the following:

Collaborative Software Development Laboratory (CSDL). This research group will develop the web application and associated technology associated with the project. This stakeholder needs the project to provide innovative research opportunities.

UH Dorm Residents. UH dorm residents are the most important users of the application and the participants in the competition. The project needs to be interesting, engaging, and educational.

UH Dorm RAs. UH dorm resident advisers will provide an important role in publicizing and promoting the project. We must engage them early and often and make sure that the project has their support.

UH Housing. We must align this project with the goals and constraints of the Housing office.

Date	Activities
March, 2010	Refine proposal, decide on dormitories that will participate in competition, obtain approval from UH Housing and UH Facilities to proceed with competition development.
April, 2010	Conduct focus group meetings with current dormitory residents and RAs to obtain feedback on site and competition design.
May, 2010	In collaboration with UH Facilities, decide upon meter model to install and order.
July, 2010	Install meters in dormitories. Verify that WattDepot collection and analysis facilities work correctly.
Aug., 2010	Bring Dorm Energy website on-line. Configure website with information about all residents; test logins. Conduct meetings with RAs and Housing staff to lay groundwork for October competition. Determine baseline energy consumption for each floor.
Sep., 2010	Finish planning competition events. Carry out pre-contest publicity activities. Install LCD display in entrance way to dormitory that will provide real-time competition and energy usage information.
Thu, Sep. 30	Competition Kick-off Party takes place.. Pre-competition energy literacy assessment begins.
Mon, Oct. 3	Round 1 begins.
Mon, Oct. 10	Round 1 ends and prize winners announced, Round 2 begins.
Mon, Oct. 17	Round 2 ends and prize winners announced, Round 3 begins.
Mon, Oct. 24	Round 3 ends and prize winners announced. Final week of competition begins.
Mon, Oct. 31	Competition ends.
Thu, Nov. 3	Competition Finale party takes place. Grand Prize winners announced.
Nov., 2010	Immediate post-contest feedback and analysis.
Feb., 2011	Delayed post-contest feedback and analysis (to determine longer-term retention of energy literacy.)

Figure 8: *Project timeline*

UH Facilities. The project includes installation of technology (floor-level metering), and we must ensure that UH facilities approves and supports this approach and helps us select the meters to install.

Sustainable UH. This organization is the premier environmental organization on campus, with experience organizing students and putting on events. Shanah Trevenna from Sustainable UH has agreed to ask her organization to sponsor this project and take the lead in organizing events related to it (such as the Kick-Off and concluding parties). They can also assist with locating locating businesses to donate prizes.

Local Energy Organizations. We have contacted other local organizations, such as Blue Planet Foundation and Kanu Hawaii, and they are enthusiastic supporters of this project. We hope to engage them further as this project moves forward.

3.7 Budget

Figure 9 presents the anticipated cost items for this project:

Item	Cost	
Meters (hardware)	\$36,000	(estimate based upon 24 meters at \$1,500 each)
Meters (installation)	\$12,000	(estimate based upon 1 hour installation per meter at \$50 per hour)
Kickoff, Finale parties	\$2,000	(estimate based upon \$1000 food for each party).
Prizes	\$1,000	(estimate based on 20 prizes with an average \$50 value)
Billboard computers	\$2,000	(estimate based on two 40" HDTV monitors plus two netbooks)
Software & Hosting	\$0	(provided by CSDL)
Total	*\$53,000*	

Figure 9: *Project budget.*

Funding. For the first line item, Meters (hardware), we will pursue funding from the following sources: University of Hawaii Housing, University of Hawaii Office of Sustainability, and REIS (Renewable Energy and Island Sustainability) project.

For the second line item, Meters (installation), we will request in-kind donation of labor and personnel from University of Hawaii Facilities Management.

For the parties and prizes line items, we plan to solicit in-kind donation from local businesses.

We propose that an electronic billboard consisting of a 40" HDTV driven by a low-end netbook computer be installed in the entryway to each dorm. After the competition is over, these can be repurposed to provide general dorm information.

CSDL will provide the software, hosting, and loan the computers for the billboard displays. Note that licensing for similar software and hosting by Lucid Design Group costs approximately \$15,000 per year.

Return on investment. Given that one of the goals of this project is to save money for the university, it is important to consider the return on this investment. The ROI has two important components: direct return in electrical savings, and indirect return as research infrastructure.

The direct return in electrical savings per year can be estimated as follows: multiply the total cost of electricity for the dorms[3] by an estimate of the sustained percentage reduction per year. For example, if electricity for the two freshman dorms costs \$900,000 per year, and the competition reduces consumption by an overall sustained rate of 5%, then the first year cost savings is \$45,000, nearly enough to cover the entire investment. Given that the recurring costs are just a few thousand dollars, and that the cost per kWh will almost certainly rise in future, UH could save \$40,000/year or more from this project starting in 2011. If the project is expanded to cover more dorms, then the savings should scale in a proportional manner.

The indirect return on investment results from the fact that this project creates state-of-the-art infrastructure for research on understanding and changing energy usage. The capability to run dorm energy competitions with floor-level, near-real time energy monitoring creates a competitive advantage for University of Hawaii faculty across many disciplines to pursue federal funding, such as National Science Foundation grants. Such grants typically result in multi-year funding amounts from several hundred thousand dollars to \$1M or more.

[3] I have requested this number but have not yet received it. Internet research indicates that a typical dorm resident consumes approximately 6,000 kWh/year. Given two freshman dorms with 250 residents each, and a cost per kWh of \$0.30, the estimated total annual electrical cost for the dorms is \$900,000.

3.8 Aligning incentives and design components

To conclude Section 3, it might be useful to review how the elements of this project relate to the research objectives. Figure 10 summarizes the components of our design and how they together satisfy each of the six behavioral incentives listed previously:

Design Component	**Behavioral Incentive**
Near-real time energy data	constant feedback
Floor-level data	contextual feedback
Personalized (login-protected) home pages	personalized information
Kukui Nut competition	social reinforcement
Kukui Nut commitments	general and specific commitments
Kukui Nut goals	achievable goals
Kukui Nut activities	energy literacy
Energy conservation competition	social reinforcement
Competition prizes	financial incentives

Figure 10: *Design components and how they satisfy various incentives for behavioral change*

4 Final thoughts: Why care about behavior?

There is a school of thought that views human behavior as too difficult to change and ultimately unreliable, and that the only realistic approach to energy conservation is through "top-down" incorporation of new technology that eliminates the need for human decision-making/behavior. For example, to reduce energy in the dorm, the best approach is to have the Housing Office and Facilities Management improve the efficiency of air conditioning, replace the light bulbs, increase the amount of insulation, and so forth.

We certainly agree that the introduction of new technology is desirable and should be done whenever possible. Indeed, a study by Granade [7] shows that U.S. energy consumption could be reduced by almost 25% if cost-effective energy saving technology already available was implemented.

However, we disagree that behavior is too difficult or leads to only marginal results. An old, inefficient air conditioner uses far less energy than a state-of-the-art unit if an energy literate student decides to turn it off when leaving the room (or not turn it on at all). The energy associated with landfill management is reduced when an energy literate student chooses a non-Styrofoam container, or to bring their own bag to the farmers market.

Finally, we disagree that "top-down" approaches are the only viable way to effect conservation-related change, and suggest that the rapidly growing organic foods industry provides a compelling example. There was no top-down mandate for organic foods in this country. Rather, a growing number of "food-literate" consumers began buying these foods despite their generally higher price. The result is annual industry growth of over 20% for the past several years. We believe that energy literacy can catalyze a similar appetite for energy conservation.

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