The 1kWh Challenge: An Experiential Learning Program Designed to Promote Energy Efficient Behavior

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ABSTRACT

The "1 kWh Challenge" program, co-sponsored by Toshiba America Information Systems, Inc. and housed in the California Plug Load Research Center, is designed to promote consumer awareness of the power consumption of plug load devices and appliances. The "gamified" active learning process consists of four engaging tasks designed for participants to accomplish: Hot-Air-Pong, Gaming Central, Power Kitchen and Movie Night—all using everyday electronics, and together taking approximately one hour and one kilowatt-hour. Participants are grouped in teams to compete for the most efficient completion of all tasks. Through the challenge participants receive experiential learning of basic energy concepts, such as the wattage of each device, kWh consumption breakdown and estimated carbon dioxide emissions per task. Before and after the challenge, participants take on-site surveys to evaluate the incremental change in knowledge, skills and attitudes toward key concepts. To date, approximately 120 participants have finished this challenge, including college students at UC Irvine, and students attending junior high schools in Orange County school districts. Over 90% of the participants have shown significant growth in mastery of plug load energy consumption and efficiency concepts. Long term voluntary follow-up study of behavior change has been conducted through email and social media engagement. The efficacy of the program for long lasting behavior change and impact on California plug load energy usage are currently understudy, with interesting implications.

Introduction

Culture, education and technology aside, there seem to be a common set of Energy Efficient behaviors that are known to the general public. Tips such as "Turn the Lights Out When You Leave", or "leave your AC at 75 degrees when you are home and off when you are away", are fairly straight forward, but only practiced by a relative few. As more sophisticated consumer electronics and appliances are introduced to the households, the required knowledge set for efficient behaviors is growing exponentially with the number of devices. Energy efficiency program designers are facing a much tougher market when dealing with plug load devices that are predicted to consume more than 30% of household electricity by 2020 [[1]2].

As centralized air conditioning systems and lighting technology are fully explored for their energy savings potentials, behavior changes have been elevated to be the next biggest opportunity for efficiency programs. Technology advancement in personal and mobile communications, combined with behavioral psychology findings, becomes very promising tools to achieve these "changes". Many products and services emerged with a goal to modify user

[1] CPUC action plan data

behaviors. However, when it comes to plug load devices, there are simply too many devices existing to be managed. Effective user behavior modification for every single device can be easily lost in the big picture. Consumers are left confused facing numerous power states of each device for them to operate. On the other hand, many current utility programs and services use a "top-down" approach by providing high-level aggregated information to the users, some leveraging competition among users. However, for the plug load category, there is an apparent gap between the high level information and device level awareness for users to change behaviors.

The 1KWh Challenge is designed to address such a gap by engaging end-users in a gamified learning environment. Device level awareness for energy consumption and economic impact are introduced through activities involving daily plug load devices. The overarching goal of "doing more with less" is designed into all four blocks of activities. The environment and appliances implemented are monitored and controlled by state-of-the-art energy management systems. Knowledge and behavior questions are surveyed before and after the engagement for each participant. The research group set out to test if knowledge and awareness on plug load efficiency are established through active engagement, especially for K-12 and college students. Behavior change questions are asked immediately following the challenge, as well as in long-term follow up programs.

The 1KWh Challenge is hosted within the California Plug Load Research Center (CalPlug). CalPlug is the leading enabler for energy efficiency solutions in the use and design of appliances and consumer electronic devices. CalPlug is supported by the California Energy Commission to promote a cleaner, more efficient State of California. The center focuses on emerging technologies and user behavior studies for plug load devices. CalPlug addresses challenges in plug load efficiency for both residential and commercial buildings by collaborating closely with utilities, manufacturers, advocacy groups, research institutions, and energy policy makers.

Figure 1. Overview of 1kWh challenge tasks: 1) hot-air-pong, 2) gaming central, 3) power kitchen and 4) movie night.

Design

The design process of the 1kWh Challenge was an iterative process with several "design, build and test" cycles since the beginning of 2012. The primary objective of the design is to create a one-hour training course that is both entertaining and educational for plug load device energy consumption. The target audience was originally set for college students as CalPlug is located within the University of California, Irvine. Besides availability, this decision was also because Millennial Generation commands the most number of consumer electronics and appliances. As the program reached out to several K-12 groups, we also discovered that with a slight modification of the tasks, the challenge is equally effective in engagement and efficacy of that group. The desired learner outcome, in either age group, would be a multidimensional understanding of kWh as the primary energy measurement unity for electricity usage, and long term memories for the cost of energy associated with plug load devices used during the challenge.

One of the most emphasized metrics for the design process was the level of positive engagement, or simply the "fun factor". This is based on understanding the target audience's characteristics and learning style. Over twenty different tasks were evaluated with this key metric, alongside with appliances required, energy consumption, team involvement and time required. Four engaging tasks were finally chosen for average participants to use approximately one hour of time and 1 kWh of energy to finish. The tasks were also improved and updated over the course of two years, based on feedback from participants. For example, the original set of tasks included a Green Screen task, requiring the team to create a music video in front of a green screen. The level of knowledge on utilizing computer software for video editing was determined to be too high for K-12 students. The task was replaced by "Power Kitchen" in the later version. To describe the 1 KWh Challenge activities in the framework based on Dr. Howard Gardner's theory of multiple intelligences (Gardner 1993),

Table 1 summarizes the characteristics of the learner activities in different learning methods (Anderson 2005).

Table 1. Activities for multiple intelligences

Learning Method	Learner Activity
Visual	• Instant display of power consumption • Periodic update on energy consumption • Final report on time and energy breakdown analysis • Hand-eye coordination tasks
Auditory	• Initial introduction by facilitator • Group interaction during tasks • Final summary by facilitator
Kinesthetic	• Physical activities associated with tasks • Facility tour before or after program • Quotations with emotional appeal to environmental stewardship • Energy efficiency facts and tips
Logical/mathematical	• Measurement display • Quizzes for energy estimation • Charts & tables in final report
Interpersonal	• Group interaction during tasks • Interview during and after the challenge
Introspective	• Follow up quiz through email
Musical	• Theme background music during activities

During the actual challenge, each group of four participants sets out to go through the four tasks collaboratively, which are located in four corners of a 400 sq. ft. room (**Figure 1**). The first task is Hot-Air-Pong where participants drive a set number of ping pong balls into six paper cups from 6 feet away. The ping pong balls were elevated sequentially using the hot air from a hair dryer as the primary energy consumer in this task. Every member of the group takes turns to serve the next ball until a hit is made. Once finished, participants are polled to estimate the average wattage usage of the hair dryer. (Most of the answers were around 50 W compared to the actual 1200 W). The Game Central task was to complete two out of the three available levels in a Kinect game with gold medals. Kinect is chosen due to the kinesthetic nature of the games and that X-Box has become the most popular gaming console in the United States. The Movie Night task was to watch a 15 min clip of a 3D movie while making pop corns in a popcorn stand. This task is relatively less active. However, it represents the energy consumed while average family spending over four hours per day in front of a home entertainment center. The fourth and final task was to make muffins in the "Power Kitchen", where blenders and small baking ovens are used. This is the rewarding task where participants can enjoy their effort at the end of the task. K-12 students enjoyed this task in particular.

Sponsored by initial funding from Toshiba's social responsibility outreach program, a moderate budget is used to create the 1 kWh challenge room. Over ten undergraduate students participated in the design, test and build process of the challenge, spending their part-time effort during the academic year and the entire summer, which equates to approximately 180 hours of work per student. Over 1000 invitations were extended through channels such as email invitation, Facebook page advertisement, UCI campus bulletin boards, and personal word of mouth distribution. Various student organizations from UCI participated, including Green Campus, CAMP, New University groups, and FABbrication summer camp program through UCI School of Engineering. Over 50 visitor groups from industry affiliates experienced the 1KWh Challenge, such as Intel, Google, Broadcom, California Energy Commission, Los Angeles Department of Water and Power, and Taiwan's National Applied Research.

Evaluation

The challenge combines quantitative and qualitative metrics in evaluating each team's performance and learning effectiveness. Before the challenge, all participants were asked to fill a pre-test survey to establish the baseline of their understanding of core concepts of electric energy consumption. For example, one question of the survey asked what the approximate cost rate is for electricity by the local utility company. Then at the end of challenge a post-test survey was administered to determine whether the association of the concept of a kilowatt-hour is established with typical household electronics usage.

Table 2 summarizes the major quantitative and qualitative evaluation methods used in supporting the challenge.

Table 2. Evaluation channels

	Real-time data collection (Power, Energy, Time)	Pre-survey (On-site)	Post-survey (On-site)	Facebook Page	Post-event Updates and Awards

Activity	x		x		
Participants satisfaction			x	x	
Change in skills/attitudes		x	x	x	x
Behavior change effectiveness				x	x
Inform future design	x		x	x	

A total of 124 students finished the challenge to date. Half of the participants are in junior high and the rest in college. 98% of the participants indicated they learned at least one new concept from the challenge, and 90% said they really enjoyed it. In the preliminary results, only 20% of students were aware of the actual definition and usage of the term 1 kWh. Immediately following the challenge, 96% of the students were able to interpret the actual meaning of the unit and relate it to at least one appliance in terms of time of use. The participants were also asked questions during the challenge, such as what they thought the energy difference was between a LED television, used in task two, and 3D LED television used in task three. These short questions engaged participants' minds while they performed the tasks.

From our pre and post surveys, as well as the Facebook page posts, a significant improvement in understanding the amount of work 1 kWh can do in terms of electrical energy consumption was achieved. After the challenge, over 85% of the students can adequately quantify energy use associated with individual appliances. The group that finished the challenge with the least amount of energy was announced the winner and received a Kindle device, which is one of the most efficient electronics ever built.

Results

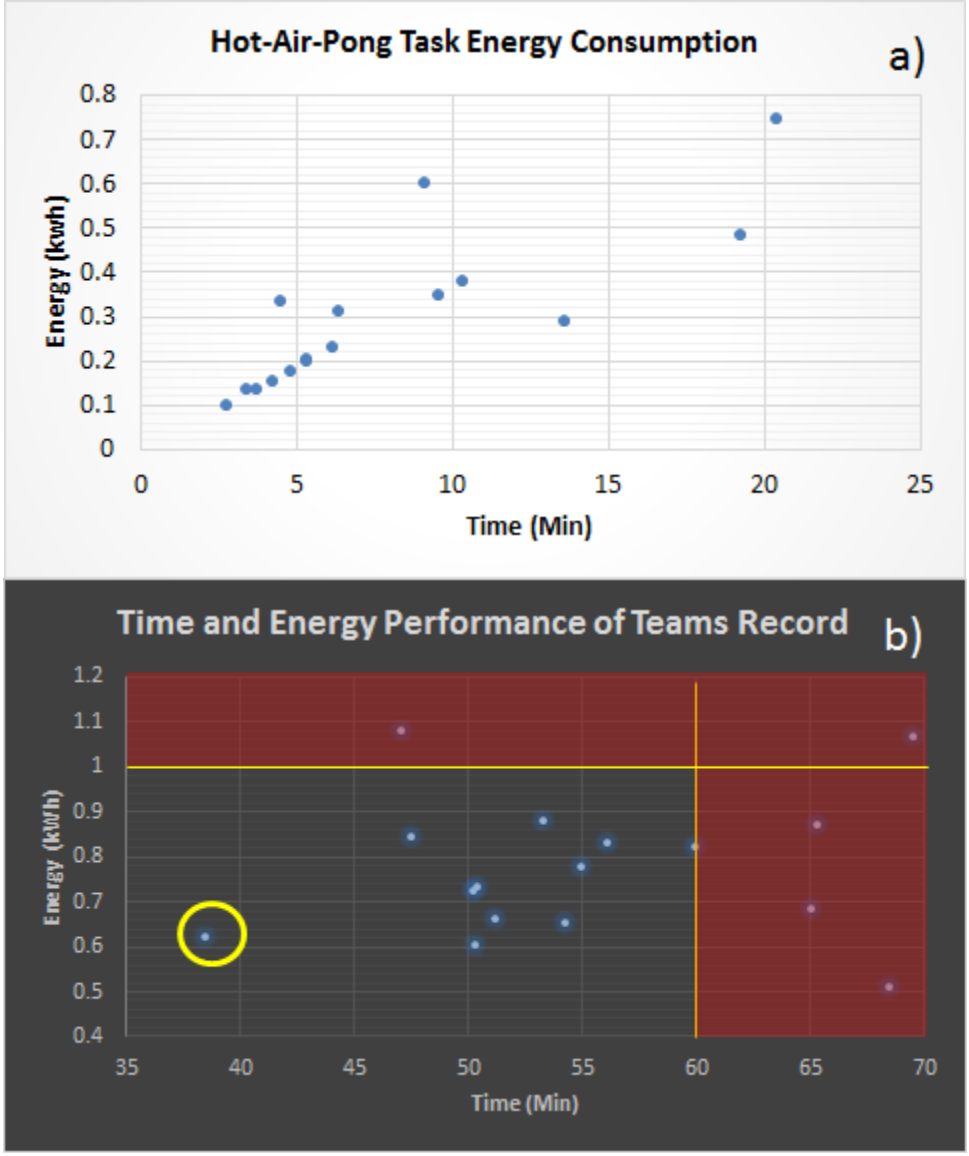

Figure 2. a) Task energy consumption and time used for Hot-Air-Pong; b) Overall challenge energy consumption and time used.

In **Figure 2** a), the Hot-Air-Pong task is illustrated for the energy consumption and time used for each group participated. Energy is generally proportional to the time used, with the outliers due to preferred hair dryer settings variation (low, high, heater etc.) The summation of all four tasks for each group is plotted in **Figure 2** b), where the qualifying zone is defined by two limits of 1 KWh and 60 minutes. The circled team was the winner for the first round, with a clear margin relative to other teams. Except for a few groups, generally the first activity consumed the most amount of energy. It was a difficult task and many participants explained the difficulty in hitting the ping pong ball with their hands. On average people use their hair dryers at home for approximately the same amount of time as the average time of 19 minutes spent completing task 1.

The cost of the electricity used for the appliances is also estimated right after each group's participation. Their group performance and how they compare to other teams are presented to them while they are taking their post-test survey. This is meant to provide immediate feedback to the participants on the economic impact of the activities. **Figure 3** shows the average cost from each task and the overall cost of the challenge in electricity. If one were to continuously use the energy that was used for the challenge for 6 hours every day for a month, it would amount to near $63, which surprised many participants. This level of aggregated information becomes relevant and useful only after the participants developed disaggregated awareness of the appliances utilized.

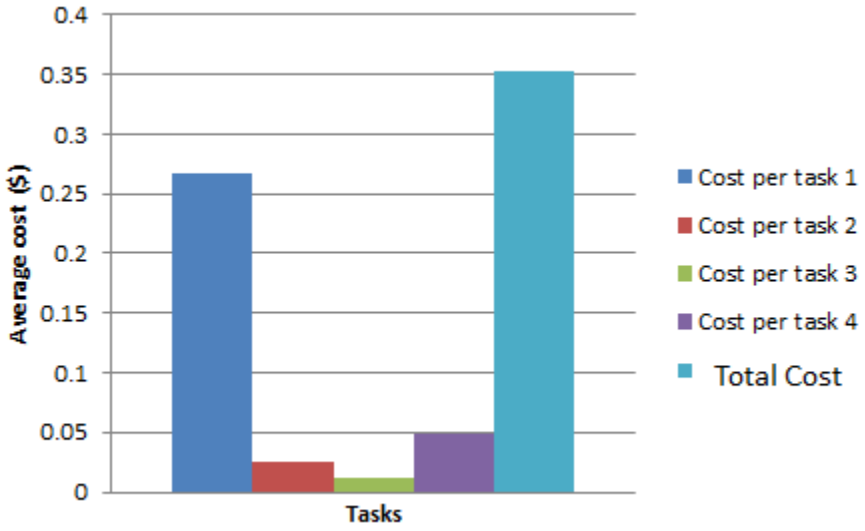

Figure 3. Average electricity cost estimated using Southern California Edison 2014 rate.

Conclusions and Future Work

The 1KWh Challenge developed at the California Plug Load Research Center is a fun, engaging and effective platform for plug load energy efficiency education. A wide range of support and participation from academia and industry were developed since 2012. Participants' short-term and long-term learning efficacy has been monitored and feedback through various channels including real-time measurement, immediate data report, questionnaires, email updates and social networks. Long term voluntary follow-up study of behavior change has been conducted through email and social media engagement. The efficacy of the program for long lasting behavior change and impact on California plug load energy usage are currently being evaluated through follow-up surveys with previous participants. Further analysis of the participants' data is underway for adaptation to individual learning styles, optimization of incentive methods and interview questions.

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