Effectiveness of a Task-based Residential Energy Efficiency Program in Oahu

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***Abstract*—Energy wasted in buildings is a major fraction of total energy wasted in today's cities. Most people are not aware of inefficiencies and energy wasted in their homes. Making people aware about energy wasted in their homes and inefficiencies in their energy consumption behaviors could contribute to large energy savings at the city scale. Many energy-saving programs, run by the governments, non-profits, or utilities, are designed to help people improve their energy efficiency at homes by providing feedback. The critical factor in the effectiveness of energy saving programs is user engagement. Best energy saving tips will not save noticeable energy if users do not use those tips. In this project, we design several intentionally simple energy-saving activities with a goal to help citizens understand how they use energy and find ways to save energy. To evaluate the effectiveness of proposed energy-saving guidelines, 740 volunteers at Oahu, Hawaii are provided smart meters and are asked to follow proposed activities in their daily life. Results from the program indicate that our program helps users reduce their bill by 2.83%, which is comparable with similar programs but the simplicity of our proposed energy saving activities boosted up participation rate to 35%.**

***Index Terms*—Energy Saving, Smart Meter, User Engagement**

I. Introduction

Energy is a major concern for governments and also people all around the world. Homes and buildings consume around 40% of the energy used in the United States. Energy wastage in each household is between 20% to 40% of the bill [1]. There are many hardware and software tools to make people aware of flaws in their energy consumption behavior and also encourage them to reduce their electricity wastage. Studies show feedback tools help users to reduce 3% to 15% of their total energy consumption [2].

The effectiveness of energy saving programs is highly dependent on participants' engagement. In simpler terms, the most efficient hardware-based or software-based energy saving tools will not be effective enough if people do not use them regularly.

We design an energy saving program targeting high user participation as the primary objective. We combine hardware tools along with simple activities and guidelines to motivate participants to interact with the program and reduce their energy consumption. To measure the performance of designed program, volunteers at the island of Oahu at Hawaii are asked to participate in a 12 weeks program to save energy while their energy consumption is being monitored. The project provides participants with: the ability to access their energy data through a mobile app (Presence); smart plug devices for their homes; and a twelve-week: 'Energy Engagement Program' consisting of weekly challenges to save energy and earn points/rewards. The designed program establishes a mobile-based platform with a fun and highly engaging behavioral modification approach delivering energy savings higher than that of historical energy efficiency programs. The focus of this work is studying the impact of simplicity of designed activities on participants' engagement rate and also measuring the amount of energy saved directly from participating in our program.

Of the 740 households enrolled in the program, 140 households: opted in for historical data sharing; did not have solar panels; had energy use profiles resembling residential use; had spent sufficient time after the end of the program to measure the change in energy use, and hence were selected as participants for analysis. In collaboration with Hawaii Energy, we identified 140 control users that had similar energy use profile to the 140 participants. Energy savings were calculated by adjusting for the baseline provided by the control group, which also achieved a reduction in energy use likely due to favorable temperatures during the program period. The participants were divided into different groups with different treatment starting dates. Aggregating the results of the six groups, we found that top 25% of the participants saved 14.21% and top 35% of the participants saved 9.1%, after adjusting for the control group baseline changes in energy use during the measurement periods. Among all the results, of note is the significant impact of engagement in the energy savings achieved: 2.83% savings, after adjusting for control group baseline, for highly engaged homes across all the participant groups. These results suggest the potential of highly engaging energy efficiency programs to achieve higher savings compared to the standard of 1-2%. At the end of the program, participants asked to fill out a survey about each activity. The interesting point to mention is we did not receive any complaints about the complexity of the program, and most of the participants liked the simplicity of designed activities. Considering achieved simplicity, 2.83% is a remarkable accomplishment for our energy-saving program.

Here is the list of our contributions in this work:

- Design simple but effective energy saving activities aim-

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ing to increase user participation rate
- Design and develop user-friendly mobile application which enables users to provide their feedback regard each activity
- Run program with 740 households as participants which is a large number of participants size
- Provide effective guideline to design high participation energy-saving programs

II. Related Work

Energy saving has been a global concern for many years. Governments supported enormous amount of programs and studies [3]–[5] to find effective ways to modify people's energy consumption behavior and reduce energy wastage in households. There are many energy monitoring tools which provide real time and also delayed feedback to users (Eco-feedback) to help them reduce their energy waste. The performance of Eco-feedback devices in energy reduction and behavior modification has been studied before [6], [7]. Providing feedback to the user showed around 3% to 15% saving for the duration of energy saving programs [2]. There are many research works about system design and information representation in Eco-feedback devices which suggest a diverse range of guidelines and rules to increase user engagement [8]–[10]. All these guidelines can be categorized in four strategies: marketing and communication, Tips & Assistance, Goal setting, and reward & recognition [6]. Incentive-based programs are another type of energy management efforts conducted by utility companies to convince their customers to reduce their wastage. In these programs clients receive monthly or yearly rewards based on their reduction in their usage. In most of these programs, the users also receive real-time energy monitoring devices which help them to instantly monitor their total energy consumption. Incentive based programs in average help families to save 8% of their bill which seems not to be convincing enough for users to continue their engagement with the program. Besides, some feedback tools use daily or weekly consumption values to forecast monthly or yearly costs which are not reliable because these predictions do not consider changes in home appliances in different times of the year. Also, householders seemed to be confused about the mapping between their activities and impact of those activities on their energy consumption; since they are only able to see the total energy consumption [11].

At [12], the effectiveness of non-price incentives to motivate conservation behavior has been investigated. The results prove that environment and health-based messages can save in average 8% of households' energy consumption. In summary, based on previous studies, learning will have much more persistent results compared to saliency in energy saving program [13]

Despite the considerable investment on Eco-feedback and incentive-based energy-saving programs; recent studies show that participation rate in any type of consumption management program is very low ($< 10\%$) [14]. The convenience is a critical factor to determine participation rate of energy-saving programs [11]. Lack of convenience and user satisfaction could cause low participation rates like 1-3% [15].

In order to address convenience and simplicity in energy-saving programs, recently game based energy-saving programs have been suggested. Despite the simplicity and attractiveness of game based energy-saving programs, engaging participants and also persistent savings still are serious problems in these kinds of programs. Studies show that, although around 10% saving can be achieved in narrowly targeted programs, in general, gamified energy-saving programs provide 3âĂŞ6% saving among a sizable number of participants [16].

To sum up, based on previous studies, providing complicated feedbacks via energy monitoring tools will not make substantial or persistent reductions in user's energy consumption. The current Eco-feedback tools can not save significant energy by themselves, and their effectiveness highly depends on user's engagement. This fact seems to be obvious, but it has been overlooked by policy makers [17]. To the best of our knowledge, our energy-saving package is unique in terms of simplicity, providing feedback and guiding participants to utilize their kit over time.

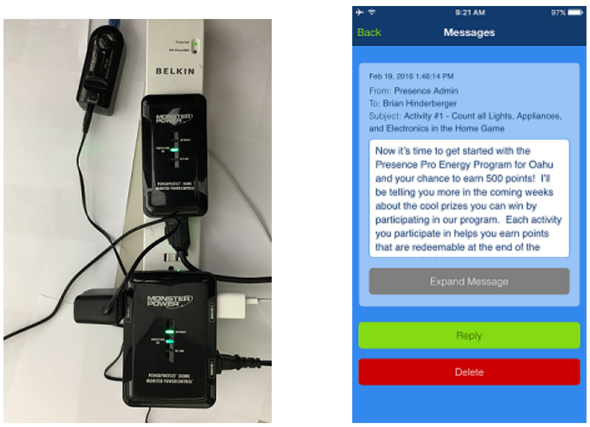
III. Program Design

The goal for our designed Energy Engagement program is to make participants aware of their energy use, motivate them to change their energy consumption behavior and finally persuade them to reduce their energy consumption. The island of Oahu is selected as the site for program implementation. 740 participants are accepted into the Program; 55% through Hawaii Energy's promotional efforts, 35% through local television, radio, and print promotions, and the remaining 10% from customer referrals. The participants receive two Monster smart plug devices (Fig 1a) and are paired with our designed Presence Pro iOS/Android application (Fig 1b). Our application turns smartphones into smart homes by enabling homeowners to control and monitor their electrical appliances. Via Presence Pro application, users can monitor their energy consumption (reported by Monster smart plugs) and receive weekly activities and surveys. They also can post their feedback and comments regarding each activity through their cellphones. Fig 1b shows an example message received by Presence Pro app.

The participants are presented with twelve weekly activities as part of the Energy Engagement Program, through the Presence mobile-based platform, designed to encourage behavioral modification, through fun, highly engaging games and challenges in their homes ('Activities'). Simplicity considered as the key criteria during activity design phase. Table I contains the list of designed activities. Activity number 1 and 2, try to make the user aware about power consuming tools inside his/her property. Activity 3 makes sure that users start playing with the provided smart meter. Activity number of 4 is first behavior modification activity, in which users are asked to set their Thermostat, Refrigerator and water heater to a constant value and do not change it for a while. Activity 5, saves power by turning off energy consuming appliances while they

TABLE I: Designed Weekly Energy Saving Activities

Week 1	Count all Lights, Appliances, and Electronics in the Home
Week 2	Find the Plugged in Appliance that Consumes the most
Week 3	Find the Plugged in Appliance that has the most Vampire Power
Week 4	Thermostat, Refrigerator, and Water Heater Set It and Forget It
Week 5	Create a Rule for your Monster Smart Plug and SAVE
Week 6	Plant a Seed and Spread Roots in the Community
Week 7	Energy Efficient Appliance and Electronics Wish List
Week 8	Get To Know Your Energy Meter
Week 9	Study Your Electric Usage Profile
Week 10	Detecting Air Leaks
Week 11	Turn Lights Out for one Evening and Spend your Time with your Family
Week 12	Final Survey



(a) Monster Smart Plug (b) PresencePro App

Fig. 1: Home Energy Management System

TABLE II: Age Distribution across Participants

	Number of Occupants			
Age Range (Year)	1(%)	2(%)	3(%)	4+(%)
0-6	14.77	8.77	3.85	2.3
7-13	11.69	7.69	1.69	0.62
14-20	11.23	5.23	0.77	0.31
21-100	9.54	49.85	18.15	16.47

are not in use. For activity 6, users are asked to talk with their friends and relatives about the program and share their experiences with them. After monitoring the energy profile for each appliance for a while, users are asked to create a list of appliances which they think need to be upgraded or replaced. This activity is designed to make sure users go back to use their meter, in the case, they forgot or lost their interest to use it. Activity number 9 is designed to inform users about their energy bill. In week 10, users become familiar with air leakages as one of the primary sources of energy waste in residential areas. Outdoor activities are encouraged in week 11, as a way to modify users energy consumption behavior. Finally, in last of week of the program, users fill out a survey about their overall experience participating in our program.

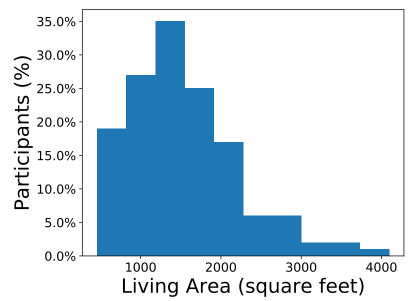


Fig. 2: Participating Home's Living Area Distribution

A. User Demographics

Participant's demographics play an important role in the effectiveness of the energy-saving program. We select our participants from volunteers at Oahu, Hawaii. Participants are asked to provide self-estimate of their living area. Fig 2 shows the histogram of reported living areas by participants. Users can be divided into 4 age groups. Table II includes the contribution of each group in our participant's population. Each cell in table II shows percentage of households with specific number of occupants in each age range.

IV. Measurement & Verification Methodology

In this section, we describe the planning and implementation of energy savings achieved due to the Energy Engagement Program.

A. Data Collection

A mechanism is set up during project planning to collect all the data that would allow us to calculate credible energy savings achieved due to the Program. In order to mitigate the impact of time on the validity of our results, the participants are divided into six different groups. Each group starts the program on different dates (Fig 3).

1) Energy Use Data of the Participants: Historical data is necessary to establish the baseline for each home. The participants are not required to share their historical data. As a result, we have data for only a subset of the homes that enrolled into the Program and shared their history. Further, an arrangement is made with Hawaii Energy for this data sharing to continue for several months after completion of the Program to calculate the savings post-Program.

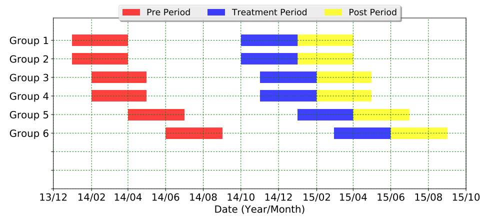


Fig. 3: Program Dates Across Different Groups

TABLE III: Dataset Characteristics

Number of Participants	140
Number of Bills For Participants	5305
Number of Control Users	140
Number of Bills for Control Users	5841
Number of Activities	12
Number of Participants Groups	6
Earliest Bill Date	1/1/2013
Latest Bill Date	10/1/2015

2) Engagement Data of the Participants: Engagement of participants is quantified via two different approaches. First, the scores that the participants obtained after reporting the completion of the particular activity. Second, through collected data regarding participants' usage of the Presence application (such as API calls from our mobile application).

B. Preparing Data for Analysis

1) Filtering the Data: One of the challenges to prepare data for further analysis is the existence of homes that have solar panels or other ways of generating power. In this paper, for both the participants and the control group, we discard homes that have local generation capability because the energy savings reflected in their utility bills could be due to behavioral changes or due to the changes in power generated by their solar panels. In this design, there is no reliable way to separate the contributions of these two factors. Although 740 participants were accepted into the Program, this paper only considers 140 homes. 199 homes opted in to share their utility bills with us and were confirmed as homes with no local power generation capability by Hawaii Energy. Out of these 199 homes, only 140 homes provided bills for the program period and had per-month energy usage of less than 2500 kWh; the threshold used to determine the target homes and filter commercial sector from residential one. Table III gives an overview of the collected data which is used in this paper.

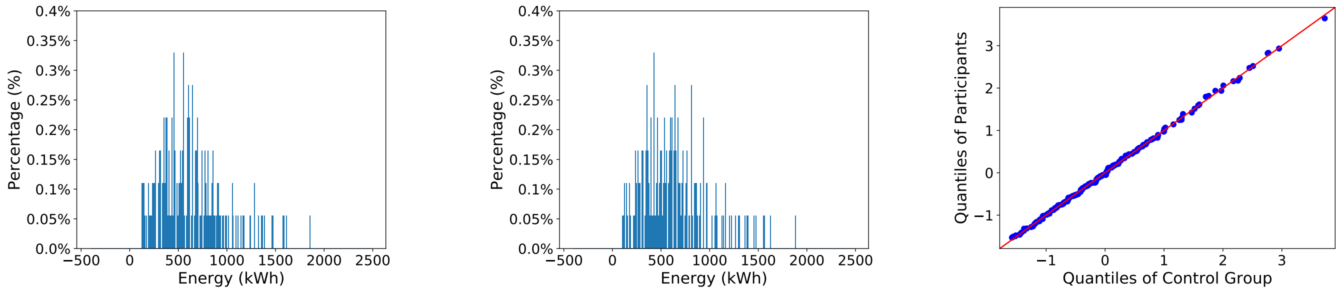
2) Setting up the Control Group: People's behavior is not the only factor that impacts the energy consumption. There are other factors like weather or utility base rate changes which have an impact on the user's energy consumption. In this paper, we want to calculate direct energy saved because of participation in our program. We select nonparticipant homes which are located in close distance (same zipcodes) to our participants and have similar monthly power consumption patterns with our program volunteers; we call them control group. In this case, the difference in the power consumption between the control group and participants is because of participation into program since all other before mentioned factors have the same impact on both control and participants groups. The energy use distribution of the control group candidates provided by Hawaii Energy is similar but not exactly the same as the participants, because the candidates were identified by geographical proximity rather than energy use. From this candidate set, we identified a set of homes that had energy use closely similar to the participants and called them 'Control Group'. To select the control group, we divided the participants to 50 bins based on their average monthly consumption, then, made sure in control group we have the same amount of members in each consumption bin.

Fig 4a and 4b show the distribution of average monthly energy use reported on the utility bills for both participants of the Engagement Program and the control group before the program's start date. Of note for both the participants and the control group, there were large monthly bills, up to 2500 kWh per month, in a small number of cases. We assume these are commercial users and are excluded from this study. Fig 4c shows the Q-Q plot of both the participant's and control group's average energy bills indicating the control group selected for comparison resembles the participants in energy use.

Table IV summarizes the overall energy used by the participants and the control group. The data indicates the resemblance between the participants and control users in their statistical summaries. The monthly average of energy use by the participants and the individuals in the control group is similar to the Hawaii-wide average of 615 kWh/month per meter. Hawaii Energy website [18] states that an average residential meter in Hawaii uses 615 kWh per month.

C. Energy Savings Calculation Methodology

For each participant group, there was a pre-Program period, a treatment period, and a post-Program period. The treatment period refers to the three months of the Energy Engagement Program, during which the fore-mentioned twelve activities were issued. The post-Program period refers to the four months following the end of the Program. The pre-Program period refers to the four months which are identical with post-Program period but one year before. Using data from one year ago from the same months for pre-Program energy profiles allows us to eliminate (to the extent possible) the impact of changes in weather on the changes in utility bills of both the participants and control group. The goal of this project is to calculate the change in energy used by the participants due to their participation in the Program against the pre-Program baseline and across the control group. We compute the average energy used by a group of individuals (e.g., participants or control) for the pre-Program period. We then compute the average energy used by the same group of individuals for the post-Program period. We then compute the difference between these two averages to report average savings (if the difference between the Post and Pre-averages is negative). This is the utility view of energy savings because this method



(a) Monthly Energy Use-Participants

(b) Monthly Energy Use-Control Group

(c) QQ plot-Participants Vs. Control

Fig. 4: Control Group Accuracy Verification

TABLE IV: Summary of Energy Use for Participants and Control Group

	Pre Treatment Period (4 Months)		One Year Average	
	Participants(kWh)	Control Group(kWh)	Participants(kWh)	Control Group(kWh)
Minimum	115.5	111.0	130.0	102.4
Maximum	1783.0	1765.7	1718.8	1750.2
Mean	616.2	614.0	621.0	637.7
Standard Deviation	334.5	317.7	334.1	348.9
Skew	1.03	1.03	0.97	0.96

aggregates the energy used by all the individuals in the group concerned into a single bucket for averaging. This method can be summarized as 'difference of average' since we calculate the average of energy used by the entire group between the Pre and Post periods and compute the difference between those average values.

V. Evaluation

In this section, we summarize the main achievements of our program in the terms of energy saving and user participation. The savings are put in context by comparing them with the energy use trends of the control group, wherever applicable. In all the following sections whenever we are adjusting participants saving considering control group savings, we are using formula 1 :

$$AS = PS - CS \tag{1}$$

In formula 1, 'AS' stands for Adjusted Participant's Saving, 'PS' means Participant's Saving and finally 'CS' refers to Control Group's Saving.

A. Energy Saving Across All Individuals

The control group showed the decrease of 15.84% in their monthly energy use over the same time period a year before the program's start date. After sorting all the participants by how much energy they saved, we found that the top 25% of the participants saved 14.21% and the top 35% of the participants saved 9.1% of their monthly energy use. These results have been justified using the control group baseline changes in energy use during the measurement periods (Original savings were 30.05% and 24.94%). The results show that energy savings were not achieved uniformly in all the households;

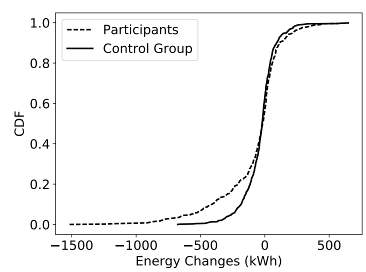


Fig. 5: CDF of Changes in Monthly Energy Consumption

In some participant households, the energy consumption went up after program dates compared to the same period one year before. Fig 5 shows the cumulative distribution function (CDF) of monthly energy use changes among both the participants and the members of the control group. The CDF shows larger savings for a significant portion of the participating homes compared to the control group households.

B. Energy Saving and Bill Size

Our hypothesis is people who pay more for their electricity bill will save more energy compared to people who do not pay large bills. If our hypothesis is true, energy saving programs can focus on homes with larger bill sizes. We divided participants and the control group into two categories. If average monthly energy consumption before starting the program was more than 600 kWh/month; we categorized that home as a 'High Use' home, otherwise, we labeled the home as a 'Low Use' one. Table V presents the savings achieved by high and low use homes, both for participants and control group. We found out that the Energy Engagement Program was effective at causing 'High Use' homes to save more energy than 'Low Use' homes: the 'High Use' homes in the Program saved 1.01% energy after taking into account the baseline provided

TABLE V: Change in Monthly Energy Use achieved by High vs. Low Use Individuals

	Low Use Home	High Use Home
Participants	-3.07%	-17.07%
Number of Participants	77	63
Control Groups	-14.90%	-16.05%
Size of Control Group	73	67

by the control group (Adjusted saving). On the other side, 'Low Use' homes did not save energy, and their consumption went up compared to 'High Use' homes of the control group.

Another important fact here is that homes with smaller bill sizes had a noticeable increase (11.83 %) in their consumption compared to control group members with similar consumption patterns. The first point here is our program did not help them to save energy and our justification for that is the designed activities were too simple and the 'Low Use' participants were aware of most of these rules before starting to participate in our program. The second more important point here is that 11.83 % is actually energy waste in these kinds of homes which can be totally saved by more advanced programs; because this amount is the difference between control group consumption and participants which means they could have the same amount of consumption but they are wasting it somehow.

C. *Effectiveness of Designed Activities*

Two major factors impact the participants' final saving: The effectiveness of designed activities and User's participation. In other words, we need to find out that are the activities effective enough? and if people put enough effort to follow them, will they benefit from them? or in the case of high engagement still the savings are not remarkable and we need to redesign our activities.

The participants received scores when they completed the activities. In order to quantify effectiveness of designed activities, in this section, we divided the participants into two groups - the *Slightly Engaged* and the *Highly Engaged*. The Slightly Engaged group consisted of participants who earned 1500 points or less by the end of the Energy Engagement program, corresponding to completing an average of three or fewer activities. Participants who earned over 1500 points were designated Highly Engaged; due to their active engagement and high completion rate of the games and challenges presented to them. Table VI presents the energy savings achieved by the Slightly and Highly Engaged groups. Based on the results in table VI, High engagement translates to higher savings. Effective savings can be calculated by subtracting 15.84% saving corresponding to the change shown by the control group. We found that the highly engaged participants saved 1.2% after taking into account the baseline provided by the overall control group (Adjusted Saving). 1.2 % saving compared to the industry standard(1 to 2 percent) is reasonable considering the simplicity of designed activities.

We also collected energy consumption per day for each household during the program dates. We analyzed the reduction in energy consumption during the program. To monitor changes over time, we used linear regression to track power consumption changes over month and calculated slope of this line to find the rate of changes. Table VIII shows our findings across different participant's groups. The slope is negative for all groups suggesting the energy consumption goes down during the program dates which is a clear indicator of our designed activity's effectiveness.

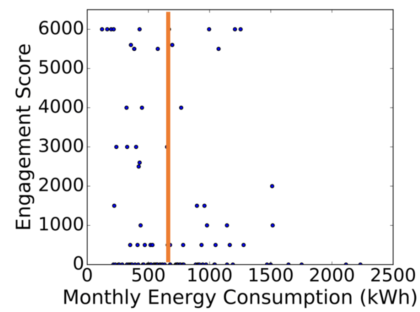


Fig. 6: Engagement vs. Monthly Bill Size

D. *Energy Use and Participation Rate*

Our designed program is effectiveness considering amount of savings achieved by high use and highly engaged homes. In addition, we showed that participation in our program reduced all the participant's electricity consumption during program dates. Next interesting result we have is combining these two factors (Energy Profile and Engagement Rate) and quantify the correlation between them. Graph 6 shows scatterplot of participants usage profile and their engagement score. As it can be seen in fig 6, participants with bill sizes smaller than 650 kWh per month have higher engagement scores compared to homes with higher usages.

We also calculated Pearson correlation value for bill size and engagement score variables to measure the correlation between these two factors. Our calculated correlation is -0.17 with the p-value of 0.07% which indicates a negative relationship between bill size and engagement value. Based on fig 6 and calculated correlation factor, we can conclude that people with smaller bill sizes paid more attention to our guidelines compared to people with larger bill sizes.

This negative correlation is interesting fact when it is combined with above-mentioned sections. It proves that although people with larger bill sizes put less amount of effort and attention to our program, they saved more energy compared to people with smaller bill sizes who paid more attention to the program.

In next step, the impact of bill size and engagement rate on final savings is measured. We divide the participants into four groups: (high use, low engagement), (high use, high engagement), (low use, low engagement), and (low use, high engagement). We label each participant with one of the above mentioned groups and calculate the savings achieved by each group. We use the same thresholds for high/low use and high/low engagement as used in the previous sections to assign

TABLE VI: Participant's Energy Saving

All Participants	#	Pre Period (stdev) kWh	Post Period (stdev) kWh	Consumption Change
Slightly Engaged	81	749.45(406.85)	655.36(304.99)	-12.55%
Highly Engaged	25	569.25(373.60)	472.31(302.32)	-17.04%

TABLE VII: Monthly Energy Use Change Achieved by different groups of Low, High Energy Users and Slightly, Highly Engaged Participants

	Highly Engaged (Num Participants)	Slightly Engaged (Num Participants)
High Use Consumers	-18.67% (9)	-17.53% (42)
Low Use Consumers	-14.37% (16)	-0.32% (39)

TABLE VIII: Energy Consumption Changes During Program

#	Mean	Max	Min	std	Variance
1	-0.001	0.32445	-0.237	0.0433	0.002
2	-0.00002	0.506	-0.449	0.0437	0.001
3	-0.002	0.100	-0.093	0.025	0.0006
4	-0.004	0.515	-0.657	0.119	0.0142
5	-0.004	0.0470	-0.267	0.032	0.001
6	-0.014	0.030	-0.111	0.040	0.001

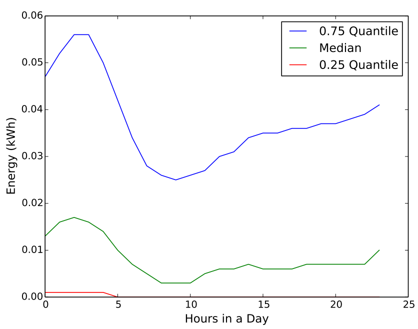
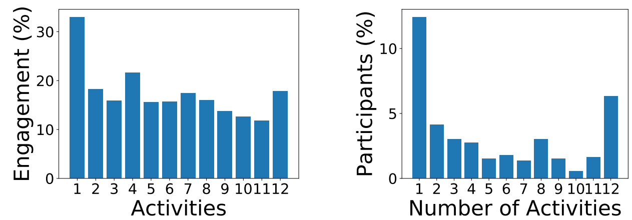


Fig. 7: Hourly Energy Consumption

group labels to the participants. Table VII shows the changes in monthly energy use achieved by each group. We found out that the high use and highly engaged participants saved 2.83% energy after taking into consideration the baseline energy use provided by the control group (Adjusted Saving). Consistent with our expectation, people were paying for large bill sizes and were actively involved in our program, achieved apparent benefit from their participation.

E. Trends at Different Timescales

We collected energy consumed by deployed smart plugs with the frequency of 1 sample per hour and illustrated this data as fig 7. Fig 7 is consistent with general expectation about peak hours of energy consumption which is 7 pm until midnight. Interesting point inferable from fig 7 is that to increase the amount of saving, activities should focus on evening hours. Another fact noticeable from fig 7 is that during early morning hours which the most of people are sleeping, energy consumption is not zero. Activity 5 designed to address this problem. In this activity, we asked people to set up a rule



(a) Participation per Activity (b) Participation per User

Fig. 8: Participation Analysis

for their smart plugs and based on the feedbacks we received most of them set up a rule to turn off their TV after midnight.

F. Per Activity Analysis

In this section, we analyze each individual activity in more detail. Fig 8 illustrates participation rate for each activity during the program. We estimated participation rate based on the feedbacks provided by program participants. The first interesting fact illustrated in fig 8 is that average participation rate for each activity is 35%. The maximum participation we achieved was around 52% for activity 1 and the minimum is 30% for activity 3.

In fig 8b, we plotted the number of activities in which each user participated. Over-time participation rate can decrease as the excitement wears off. This phenomenon is observed in our program but as it can be seen in fig 8b amount of reduction in participation in the second half of the program is not significant compared to participation in the first half. In other words, the number of people who participated in more than 6 activities is almost the same as the number of people with less than 6 activities.

As shown in fig 8a most interesting activity is activity number 1 which is counting the number of lights and appliances. The first reason for the popularity of this activity is its order. At the very start of the program, participants are excited and try to follow program guidelines. Another reason is the simplicity of this activity. Activities number 2 and 3, despite their orders which are in early stages of the program, did not receive enough attention. Our justification for this result is the complexity of these activities compared to the rest of guidelines. The common answers for most energy consuming energy consumer appliances are refrigerator and water heater.

Activity number 4 is the second most popular activity. The interesting result here is most of the participants did not really notice a significant difference in their comfort. Based on the results of activity 3 and 4, people think refrigerator and water heater are most energy consuming devices in homes and they are curious about these devices. They wanted to know about these devices and they believe this activity would have a noticeable impact on their electrify bill. In few words, to increase participation rate, people need to be convinced about the effectiveness of the activity.

During activity 5, participants mentioned several instances of forgetting to turn off appliances during the night before using smart plugs. After week 6, all the people who send their feedbacks for this activity felt great about this experience and want to continue sharing their lessons learned with others. In activity 7, people created a wishlist of future home appliances and interesting part is 90% of people who posted their feedback, were considering to buy energy star appliances and also replace old energy consuming devices. This activity is third most popular activity. In week 8, participants were asked to provide some information about their installed smart plug. In week 9, participants reviewed their energy consumption profile provided by their utility company. The idea was making people more familiar with different numbers exists on a normal utility bill. Activity 10 was trying to make people aware of air leakage in their home. Windows had the highest population in the received responses. All the participating users liked activity 11 and spent a great time with their family and friends. Most of them are going to continue this as a hobby once per week. For activity 12, participants filled out a survey which is used to extract all above mentioned interesting information.

VI. Discussion

All the analysis in our paper is based on monthly energy usage bills. Although, we have user's feedback per activity which helped us to find how interesting each activity was to our participants, we were not able to measure effectiveness of each individual activity for saving energy (activities were on weekly basis).Our arrangement with Hawaii energy ended 4 months after program end date and we were not able to evaluate persistence of achieved saving over long time.

VII. Conclusions

People need to learn how to reduce their energy wastage. This awareness can be created via energy saving programs. The critical factor which determines the effectiveness of such energy saving program is participant's engagement. In this paper, we analyzed engagement of people into our designed program and measured their energy savings. Our results show that if people really participate in awareness programs, despite the simplicity of programs, these types of programs are really beneficial and effective. Our analysis of the Energy Engagement Program revealed three major findings:

1) The Program benefited the participants who have high use homes (i.e. homes that use more energy than an average home on Oahu). Their monthly energy use decreased by 1.01%. Thus, the program benefits the individuals who need the most help: the homes that are paying large electric bills. 2) The Program benefited highly-engaged participants (i.e. those residents who engaged most in the Activities). Their monthly energy use decreased by 1.2%. These savings have a potential to create a positive feedback cycle - the participants that are highly engaged see savings in their electric bill and maybe even more motivated to seek additional savings. 3) The most important finding, however, is that the Program benefits were largest for the participants who were both high energy users, and highly-engaged program participants. Their monthly energy use decreased by 2.83%.

These results emphasize the importance of: 1) selective inclusion of high-energy users in energy efficiency programs; 2) the impact of engaging users in fun and interactive activities to achieve behavioral modification related to their energy consumption, versus simply showing users their consumption data. The results of this analysis show a direct correlation between 'engagement' and savings, as well as the need to target programs primarily to those residents' with high energy use.

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