ENERGY CONSERVATION THROUGH SOCIAL COMPETITIONS IN BLOCKS OF FLATS

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Abstract: Buildings are responsible for a large fraction of the world's total electrical consumption. Energy awareness of residents, by means of timely electrical consumption feedback through smart metering, aims to reduce the waste of energy. Further savings can be achieved by leveraging social norms and entertainment to drive sustainable behavior. In this paper, we investigate two important pillars in the energy saving initiatives, which are the recreational aspect and the social influence of the neighborhood. We performed a small case study in two blocks of flats, creating a social competition among the flats, to award those with the best energy management. Our evaluation results indicate that energy-related social games have the potential to contribute significantly in reducing the electricity footprint of home residents, engaging them in more sustainable lifestyles.

1 INTRODUCTION

Increasing energy demands, depletion of natural resources and rising costs proliferate the concerns about rational energy management. Buildings consume a large proportion of the world's total electrical energy (Europa Press Release, 2008). More than 30% of all greenhouse gas emissions can be attributed to houses and buildings. Predictions denote that by the year 2030, the global energy demand will more than double, rising up the energy-related green gas emissions by 55% (International Energy Agency, 2007).

According to technological and psychological studies (Darby, 2006), (Seligman et al., 1981), timely electrical consumption feedback through smart metering, is believed to reduce electrical consumption by a fraction of 5-15%. Smart meters are sensor devices that record consumption of electrical energy in frequent intervals. Enabling residents to monitor their electricity footprint in real-time using visualization tools, allows more intelligent energy management.

In general, people are willing and capable to adapt their behavior to energy-saving lifestyles if given the necessary feedback, support, and incentives. Even though energy awareness through real-time feedback has contributed in more rational utilization of electricity, we believe there still exists some margin for further energy conservation.

While detailed usage of energy makes people more aware about electricity, the influence of the community by means of comparisons with other people's consumptions, has the potential to drive residents towards a more persistent behavioral change (Cialdini, 2001).

In general, social context can be very influencial for people (Allcott, 2011). Social norms can motivate people to question their behavior, if they discover it is not "normal". Residents generally learn from their neighbors and receive encouragement and support. Receiving daily feedback and taking energy-saving actions in a social context can increase people's effectiveness (Ehrhardt-Martinez et al., 2010).

In this paper, we investigate whether a social competition towards efficient energy utilization between neighboring flats, can help residents increase their energy awareness and reduce their electricity footprint. Thus, we explore two relatively new parameters, recently introduced in the energy conservation domain: *entertainment* through a social game and the *social influence of the neighborhood*. We aim to study the effect of the community in affecting people to save energy, but also recreation as a means to make residents more interested about their electrical consumption. We believe that commitment by means of a competition can help people ensure that their actions are consistent with the common benefit.

In the rest of the paper, we describe the social competition we developed, discussing our findings

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from a small case study involving two blocks of flats, one in an urban area and another at a suburb.

2 RELATED WORK

Energy conservation is a global issue and numerous techniques have been proposed for saving energy in houses and buildings. Some of these techniques include energy awareness through real-time feedback (Darby, 2006), (Seligman et al., 1981), utilization of sensors and actuators for energy-efficient home automation (Barbato et al., 2009) and deployment of camera networks to obtain occupancy and usage patterns of residents, in order to intelligently control the lighting and HVAC system (Erickson et al., 2009).

Furthermore, various studies examined the behavior, preferences and habits of residents, to assist them then towards saving energy. Some of these studies include understanding the conflict in the landlord/tenant relationship (Dillahunt et al., 2010) and perceiving how householders manage their consumption of natural gas, electricity and water (Chetty et al., 2008).

The social influence of the community was recognized as an important factor in energy saving initiatives. People who are forced to cooperate to achieve a common goal tend to form a trust between them, influenced by their actions (Cialdini, 2001).

As an example, OPOWER company exploits social norms to influence people conserve energy, by sending energy report letters to residential utility customers, comparing their electricity use to that of their neighbors (Allcott, 2011). According to the company, this practice has reduced consumption by 2.0%.

StepGreen.org leverages online social networking sites to promote energy-saving behaviors of users (Mankoff et al., 2010). SocialElectricity is a Facebook application that allows people to compare the electricity footprint of their street with that of their friends, or their own consumption with that at their neighborhood/village/town (Kamilaris et al., 2011a).

The first social competition for energy conservation took place at Louisiana State University, through the UNPLUG project[1]. This was a competition among campus communities to see who could reduce energy consumption the most. Students were educated and encouraged to conserve energy. Nine campus communities, housing altogether 4,800 residents participated in the competition, yielding an average 3.7% reduction in energy consumption over a one-month period. The reduction translated to a savings of $2,470.

[1]http://unplug.lsu.edu/

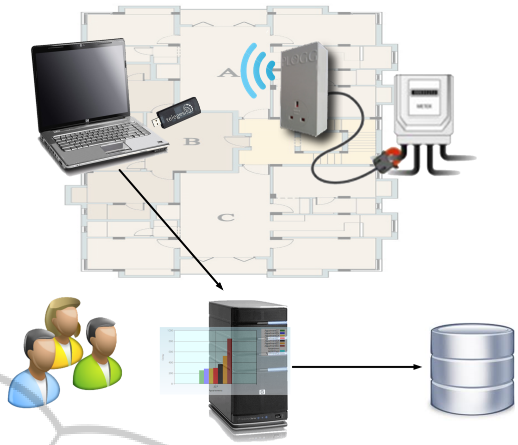

Figure 1: System Infrastructure.

Our work, partly motivated by the UNPLUG project, targets a social competition in residential blocks of flats, to investigate also the neighborhood's social influence to the overall energy saving practice. In contrast to the UNPLUG project, we provided the residents with continuous electricity-related (indirect) feedback, giving them incentives to win the competition, saving energy and money.

3 A SOCIAL COMPETITION FOR ENERGY CONSERVATION

To motivate people become more aware about energy and reduce their electrical consumption, we created a social competition between neighboring flats in large residential blocks. In the next subsections, we explain our methodology for realizing this competition.

3.1 Technical Details

For acquiring the electrical consumption of each flat in real-time, we employed Plogg[2] smart meters equipped with external current transformers for loads up to 100 Ampere. Ploggs are high-accuracy, ZigBee-based wireless metering devices, which measure whole-home or device-specific energy consumption. We attached one Plogg to the mains meter of every flat, which communicated wirelessly the electricity data in JSON format to a laptop computer that received them by means of a Telegesis USB stick.

We installed on the computer the Web-based smart home application framework described in (Kamilaris et al., 2011b), (Kamilaris et al., 2011c). The framework was responsible to parse the electricity-related

[2]http://www.plogginternational.com/

data, extract the important information and forward them to a Web server and a Microsoft SQL Server database. The Web server was developed in C# and ASP.NET, tightly coupled to the online database. The system infrastructure is illustrated in Figure 1.

3.2 Feedback and Services to Residents

Through the Web server, residents could authenticate themselves and get informed in real-time about their overall ranking in the competition, according to their electricity footprint. They could also view their historical electrical consumption at the previous days of the competition, as well the overall electricity consumed by the block. All information about electricity is translated to money costs, based on the current tariffs of the electric utility.

Our aim was to motivate tenants to reduce their own energy consumption, but also to acquire energy awareness for the whole block, contributing to the overall reduction of energy. We believe that people generally respect the sense of social engagement and coherence and this helps them keep commitment over time (Passy and Giugni, 2001). In our case, the block's community becomes engaged to the goal of reducing the total electricity consumed.

We did not want to inform people in real-time about their own consumption, so as to focus our study most on the social competition as a way to save energy.

Our Web site included a forum, where people could communicate and exchange tips about energy saving practices and techniques. After some requests from residents, we also developed a Facebook application, showing real-time information about the competition and a Facebook group, in which residents were encouraged to discuss about the study.

For those residents who were not familiar with the Web, we updated every day the ranking of the competition, together with brief reports about the energy performance of the building, in a notice box located at the main lobby. We anticipate that when activities become pervasive, integrated into daily life, strong participation in social actions is more likely (Kuznetsov and Paulos, 2010).

3.3 Rules and Conditions

We decided to elect the winning flat, as the flat that reduced most effectively its electrical consumption. To mitigate the possibility that residents could consume much energy in the first few days just to reduce it then and win the competition, we asked them to provide us with electricity bills from previous months. By analyzing the bills, we obtained a complete report of each flat's energy performance.

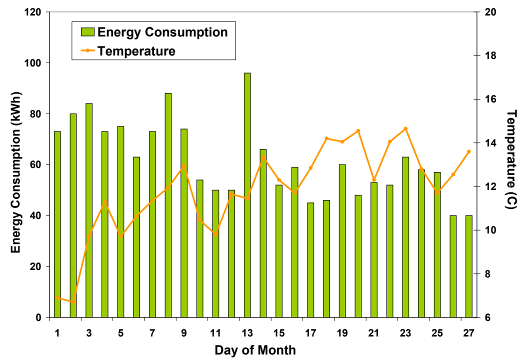

Figure 2: Everyday Electrical Consumption of the whole Suburban Block.

Our award to the winning flat was a real-time energy monitor from Current Cost[3]. These smart meters are convenient in installation and use.

The duration of the competition was one month for each block. In the middle of the competition, in case there were any flats with high electrical consumption, we decided to inform their tenants about their energy use and discuss possible ways to reduce it. In this way, they could become more energy-aware.

Finally, to achieve more complete evaluation, we prepared questionnaires, which we distributed to the residents after the competition.

4 CASE STUDY IN BLOCKS OF FLATS

Our case study included two blocks of flats. The first is at a suburb, having 10 flats and the second in an urban area, having 20 flats. In the following subsections, we present the findings of our case study in these blocks.

4.1 A Block of Flats at a Suburban Area

The first block had 10 flats and was located at a suburban area, 10 Km from the city. Six flats accepted to participate in the competition, counting in total 10 residents. Two flats refused to collaborate, an old woman in another flat could not understand our study, while in one flat the landlord was absent abroad. The ages of the participants are listed in the first row of Table 1. The total energy performance of the block, as a summation of the electrical consumption of all the participating flats, is depicted in Figure 2.

[3] http://www.currentcost.com/

Table 1: Age Distribution of Residents.

No.	Block	Flats	Residents	18-25	26-35	36-45	46-55	56+
1	Suburban	6	10	2	6	2	-	-
2	Urban	20	29	10	12	4	3	-

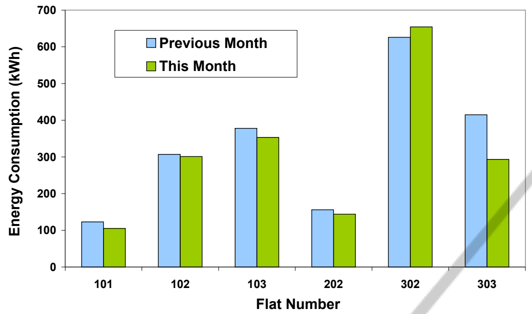

Figure 3: Electrical Consumption Comparison with the Previous Month for each Flat at the Suburban Block.

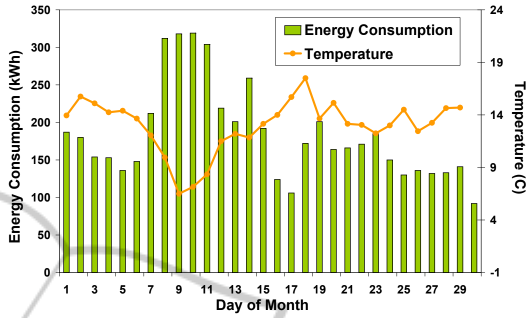

Figure 4: Everyday Electrical Consumption of the whole Urban Block.

Observing the figure, we can see the strong correlation of daily temperature to the energy consumption of the building. This is clear evidence that a considerable percentage of consumed electricity is utilized for heating.

Because of the high dependencies to temperature, we can not extract safe conclusions about the energy savings due to the competition. However, we can just mention, comparing the first two weeks of the study with the last two, that the energy consumption in the last two weeks is reduced by 260 kWh or 26%. Furthermore, in days with similar temperature (e.g. days 10 and 25), the energy consumption towards the end of the month is reduced by 22%.

The study at this block was conducted in February, 2010 with average monthly temperature 11.60° Celsius and humidity around 63%. Our findings show that there not exist different consumption patterns in weekends than in weekdays. Comparing with the electricity bills of the flats in January, 2010, as shown in Figure 3, most of the flats have reduced effectively their electricity footprint. Flats located on higher floors needed more heating and consumed more electricity. For better comparisons, we normalized the energy-related results of February.

Considering that the average monthly temperature in January was very similar to February, around 11.56° Celsius with humidity 67%, we strongly believe that the social competition has influenced the participating flats to reduce their consumption. Only one flat had increased its consumption. The average reduction of energy is 11.90%. For our comparisons, it would be better if we could had found the electricity bill of the same month last year, however, this was not possible.

In the middle of the competition, we discussed with the tenant of flat 302 and asked him why he was consuming so much electricity. He explained to us that he was not willing to sacrifice his comfort to save energy and money, as he did not encounter financial problems. He was not really motivated to contribute in protecting the environment.

The winners of the competition were a couple around 30 years old, living in flat 303, who reduced their electrical consumption by 41%! They both found this competition as a first-class opportunity to save money.

4.2 A Block of Flats at an Urban Area

The second block had 20 flats and was located in an urban area, near the middle of a city. Surprisingly, all flats, counting 29 residents, accepted to participate in our study. We estimate that this happened because most of the residents were young, educated people, enthusiastic with the idea of a social competition on their block. The ages of the residents are listed in the second row of Table 1. The total energy performance of the block is presented in Figure 4.

Also in this case, energy consumption is strongly correlated to temperature conditions. Comparing the first two weeks of the study with the last two, the energy consumption in the last two weeks is reduced by 1091 kWh or 33%. Since in the second week of the competition there was a significant drop in temperature for 5 days, our conclusions can not be accurate. We can notice that in days with similar temperature (e.g. days 7 and 26), the energy consumption towards the end of the month is considerably reduced, of the order of 13%.

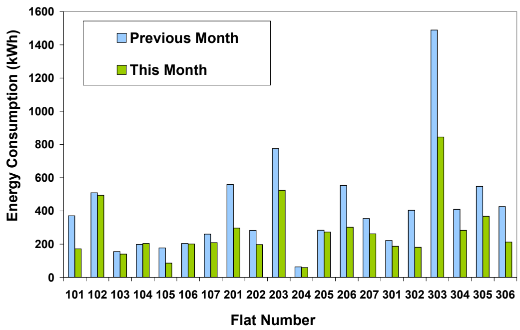

Figure 5: Electrical Consumption Comparison with the Previous Month for each Flat at the Urban Block.

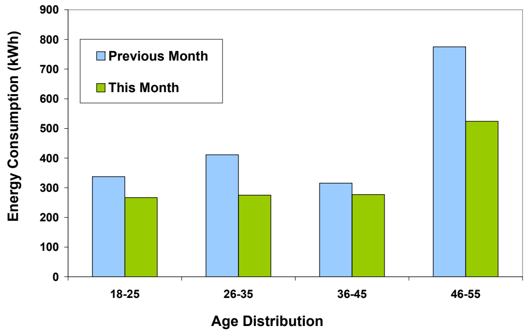

Figure 6: Electrical Consumption Vs Age Distribution of Residents.

This study was conducted in March, 2010 with average monthly temperature 13.00° Celsius and humidity around 59%. In Figure 5, we compared the electrical consumption of each flat with the consumption at the previous month (February, 2010), as indicated at their electricity bills.

From the figure, we can see that all flats have reduced their consumption significantly. Impressively, the average energy reduction reaches 27.74%. An important factor for this reduction is the average increase of temperature in this month by 2° Celsius. Once more, residents leaving on the third floor needed more heating and consumed more energy.

During the competition, we gave notice to residents of flats 102, 203, 303 and 305 about their increased consumption. The tenant of 102 was a student who had computer equipment working 24/7, and he could not do much about it. Using more energy-efficient infrastructure was out of his budget. We discovered that three tenants lived at flat 203, while most of the other flats had only one tenant. Finally, the tenants of 303 and 305 wanted their flats warm the whole day and they earned a good salary to afford that. Nevertheless, all reduced their consumption, as we can conclude from Figure 5.

A 31-years-old woman, staying at flat 303, was the winner of this competition. She managed to reduce her electricity footprint by 43%, and she was really proud of this, because she believed she helped protecting the environment.

5 DISCUSSION

Our findings suggest that social competitions can influence residents to reduce remarkably their consumption. We discuss in the following subsections our general observations and experiences from the case study.

5.1 Suburban Vs Urban Block of Flats

Comparing the block at the urban location with that at the suburb, average energy savings in the urban case were 2.4 times more. People at the suburban block consumed in average 11% more energy compared to the urban block. However, temperature strongly affected this fact. Residents at the urban block were more excited about the competition and took it more seriously. Since a large proportion of them were highly educated students, it was easier for them to understand and accept the motivation and terms of the competition, inspiring also the other residents to pay more attention to it.

5.2 Demographic Analysis

In Figure 6, we can study the residents' distribution of ages, in relation to their energy consumption. The results are normalized according to the number of flats and residents involved. Examining the figure, older people (ages 46-55) consume more electricity[4]. This probably happens because they spend most of their time at home. However, this age group, together with the age group 26-35, are mostly influenced by the competition, reducing their consumption by 32%. It is more convenient for people that spend much time at home, to observe and analyze their consumption, taking countermeasures. For example, students may be sometimes busy with their studies, not having in these periods much free time in order to dispose a high priority for reducing their consumption.

Comparing the sex of the residents, as shown in Figure 7, females tend to consume more electricity. This is logical, as they usually spend more time at home, having energy-demanding habits[5] (e.g. wash-

[4]We discuss this finding with some reservation because of the small sample of older people involved in the study.

[5]To avoid misunderstandings, we note that males also have energy-demanding habits, even those listed in the ex-

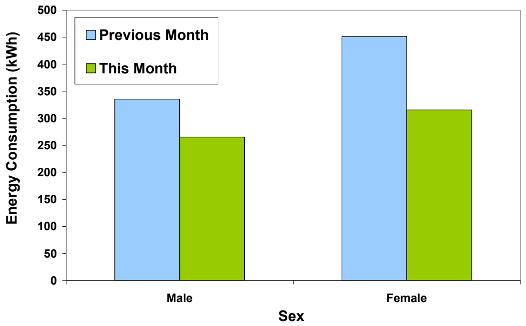

Figure 7: Electrical Consumption Vs Sex of Residents.

Figure 8: Electrical Consumption Vs Number of Residents Per Flat.

ing and drying their hair, preparing food). Nonetheless, women have contributed more in saving energy, reaching 30% reductions, while men around 20%. In general, females were more interested in the competition and in our efforts than males. They found the perspective of protecting the environment appealing.

We then compared the electrical consumptions, according to the number of residents at each flat. We display this comparison in Figure 8. Obviously, more tenants at each flat implies more consumption. While this difference is more significant when comparing flats having one or two residents, reaching 44%, it becomes very small between flats of two and three residents, around 4%. Concerning energy-savings, flats with one tenant achieved most savings, nearing 30%. We believe it is easier for someone living alone to develop his own energy-efficient practices. These observations indicate that future energy-saving campaigns should target one-bedroom flats, as the margin of potential savings is much bigger.

Our final comparison, presented in Figure 9, was about the income of the residents, in relation to their consumption. People with no income are students who are financially-dependent on their families. As expected, tenants with high income consumed more energy. We assume that they are not willing to sacrifice their comfort just for saving money. On the contrary, residents with low income consume less than half the energy of their high-income neighbors. This group of people had the least savings in the competition, perhaps because they had already tried to save energy in the past, in order to reduce their costs. Even though residents with high income consumed increased electricity, maintaining high comfort levels, their percentage of energy savings reached 30%. Most of them were motivated because of environmental reasons and not because of saving money. This observation suggests that future practices should try to influence people from the upper classes, by giving them incentives about protecting the environment.

amples, probably to a lesser degree.

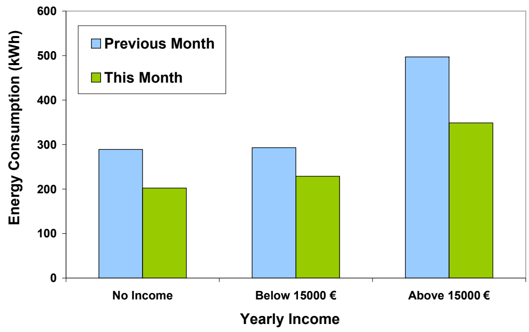

Figure 9: Electrical Consumption Vs Income of Residents.

5.3 General Statistics

Generally, 72% of the tenants stated that they were actively involved with our social competition and that this competition helped them acquire a more sustainable lifestyle. 94% believed that this competition will influence them to save energy in the future. 69% of them consider that the method of comparing consumption with neighbors is a promising way for saving energy.

48% of people used our Web site for being updated about the competition. All residents also checked the information placed everyday in their notice boxes. Younger people preferred to use the Web in order to get informed, however, older people found much more practical the notice box. Perhaps, this inconvenience of older people using technology needs to be considered when researchers design energy feedback systems in the future.

Unfortunately, our online forum was not utilized by the residents for exchanging energy-saving tips. Our Facebook application was used by six residents or 15% of people, who preferred to be informed about the competition while amusing through the popular social networking site. Although these six people initially used our Facebook group for discussing about the competition, they soon stopped doing that. Some tenants found it somehow weird to discuss online with the person next door.

Asking the residents whether they wanted to be informed in real-time about their electricity footprint, 89% were positive. From them, 88% were willing to buy a product that would show them their energy consumption in real-time. They would invest at most 70 Euro for such a product. Some of them were surprised when we explained to them that this is possible at these costs. Some people did not even know that such products exist.

5.4 Suggestions from Residents

We also asked the tenants for suggestions concerning more effective feedback about energy consumption. The most popular suggestion concerned feedback through SMS, sent by the utility once per day. Daily feedback through email was another interesting suggestion. Some people requested that the electric utilities should provide more detailed electricity bills. Still, 61% believed that our approach is more effective than what they suggested.

Finally, all residents agree that the government must give smart incentives to people to save energy. According to them, these incentives could be similar competitions with awards from the utilities, scalar pricing schemes that reward green flats and houses while punishing energy-wasting buildings, more pervasive and real-time energy feedback techniques and grants from the utilities or the government for renewable energy systems and green lighting.

6 CONCLUSIONS

In this paper, we examined the effectiveness of a local competition for energy conservation using real-time information about consumption of electricity. A social competition for blocks of flats was created, encouraging tenants to actively take part in the competition by following energy-saving practices. We wanted to demonstrate whether the combination of social influence and amusement can motivate people to save energy. A small case study was performed in two blocks, one in an urban location and the other at the suburb, counting in total 26 flats and 39 residents.

Our findings are very positive, however, they just constitute the product of a small case study and can not be considered safe to extract conclusions about the general population. Furthermore, the selected months of the study have prevented a solid analysis of the results, due to the fluctuations of temperature. Future studies need to select months in which temperature is not a dominant factor in the energy consumption of residents.

An important issue when attempting to perform such studies is to respect the privacy of people. It must be solely their option whether they are willing to participate and it must be defined from the very beginning in which extend their personal data will be exposed. Written declarations of participation are needed, to avoid legal problems.

A main drawback of our approach is related to the necessity of having costly real-time energy monitoring devices installed in the flats, which is not a common practice nowadays. Nevertheless, the smart grid[6] of electricity suggests the massive deployment of smart meters in residences, for real-time acquisition of household electrical consumption. It is planned that every home in Britain will be equipped with a smart meter by the end of 2020[7]. Hence, our approach complies with the future smart grid, as the smart power outlets we currently employ could be replaced by residential smart meters. Accordingly, such social competitions for saving energy could be enabled by the electric utilities in the near future.

Future work needs to include a larger case study, involving also blocks of buildings in more rural areas. Such studies need to be performed to validate our initial findings and consider more confidently the effect of social norms on energy conservation. A longer period of observation may also be interesting, to foster the learning effect of the participants.

Long-term influence on residents' behavior is an important dimension not yet explored. For example, considering energy awareness through real-time feedback, the saving effects are persistent mostly when the feedback systems are present (Van Houwelingen and Van Raaij, 1989). Thus, we need to consider also the influence of the social competition at the blocks in the coming months.

In this study, we tried to differentiate our social-based efforts for saving energy from real-time feedback techniques. In such a way, we evaluated our approach without direct influence from other factors. Future work could combine continuous energy feedback with a social competition, to examine whether further savings could be achieved.

Also, it would be interesting to consider if any other incentives, other than the "ranking and awards" approach we followed, may be most efficient in such social competitions.

Our study conforms to the broader vision of smart

[6]http://smartgrid.ieee.org/ieee-smart-grid

[7]http://news.bbc.co.uk/2/hi/business/8042716.stm

neighborhoods[8], defined as groups of buildings (e.g. blocks of flats) mimicking living systems, collaborating inside the smart cities of the future. Similar to living systems in nature, buildings will act collectively in relation to the ecosystem (e.g. neighborhood) they reside in. This will help to address safety, health-related or sustainability issues in the smart city, such as energy conservation and reduction of carbon emissions.

We encourage researchers, organizations and utilities to follow our methodology and perform similar studies, giving awards and incentives to residents. Social influence has the potential to boost the energy-saving initiatives towards a greener world.

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[8]http://paper.li/CityInnovation/1324428156