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SPECIAL ISSUE PAPER

Energy informatics for behavioral change

Increasing the participation rate in an IT-based energy conservation campaign using social norms and incentives

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Abstract Behavior change has been identified as an important determinant to curb energy consumption. In this context, information and communication technology (ICT) and especially feedback instruments can provide a significant contribution by motivating behavior change on a large scale. Yet, related smart meter pilot projects often fail to produce the hoped-for energy saving effects—mostly as they fall short in motivating an initial adaption and recurrent usage of the technology. In order to overcome this problem, we describe and empirically test a scalable and cost efficient solution that uses elements from behavioral sciences to motivate people to initially adapt and continuously use the technology provided. The approach draws on social normative feedback and externally emitted incentives. In the energy informatics domain, there is a big gap in the understanding of the effects of these elements, which is crucial to improve the overall effectiveness of programs. Therefore, we empirically investigate how these mechanisms motivate initial participation in an ICT based program to reduce in-home energy consumption. We conducted our study in a real world setting with a sample of 17,500 customers of a Swiss utility. Our findings show that participation heavily depends on the motivational mechanisms used. Therewith, targeted messages could enhance program participation rates by up to 45 % and dramatically increase the overall impact with no additional costs.

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1 Introduction

Despite the increasing global hunger for energy [1], the current system of energy supply is not build on principles of sustainability. As a direct result, resource depletion and greenhouse gas emissions are a major concern of our society and pose a significant economic threat. In recent years, policy makers in Europe have agreed on several different principles to enhance the transition of the energy systems towards a more sustainable, efficient, and carbon-less supply of energy. The common goal is to mitigate climate change and reduce the dependencies on fossil fuels. Amongst the more prominent examples are the Swiss *Energiestrategie 2050* and the 20–20–20 targets of the European Union (EU). Both legal frameworks name three superordinate key measures to reach the common targets: (1) A reduction of final energy consumption by an increase of energy efficiency, (2) an increase of the share of renewable energy sources, and (3) a reduction of carbon-dioxide emissions caused by energy consumption [2–4]. For 2020 the European Union, and Switzerland set up quantifiable goals: The EU aims for a decrease of 20 % in carbon-dioxide emissions (compared to 1990 levels), a share of renewables in the energy production of 20 %, and a 20 % improvement in energy efficiency. The current draft of the Swiss Energy Act aims for a reduction of annual energy consumption per capita of 16 % in 2020 compared to 2000 levels, and a reduction of total electricity consumption by 3 %.

Following legislative regulations, and latest political discussions, utility companies will play an important role in realizing these ambitious goals. With obligatory directives, such as the system of so called white certificates, utility com-

panies are obliged to realize a share of the yearly savings in end use energy (e.g., 2 % as stated in the draft for the Swiss energy act), and even may be fined if they fail to meet their targets (e.g., with 5 Rp. per kWh of target in Switzerland). These obligations, and associated penalties create a new economic need to decrease end use energy consumption for utility companies and to seek for cost efficient ways to do so.

Generally, for all economic stakeholders that are obliged to realize the savings in end use-energy, the overall goal is to minimize costs. When striving to control (reduce and shift) end use energy consumption, economic benefits for utilities exist in the reduction of final energy consumption to meet regulatory requirements and in the load shifting of demand load peaks [5]. Hence, relative costs of programs to control end use energy consumption decrease as a function of the number of consumers participating and power to control the amount, and point in time of energy consumed. On one hand this implies a large scale adoption of energy efficient technologies, and on the other hand it also requires behavioral changes of individual consumers and a general increase in awareness of the impact of their actions. Thus, a change needs to be initiated on different system levels and for consumers with a high potential ability to adapt more efficient technology, and ecological behaviors.

Information and communication technology (ICT) can play a key role to meet regulatory energy efficiency targets and realize load shifting potentials. ICT provides the opportunity to create scalable solutions that hold the potential to interact with environmental issues on different levels. On a very concrete level, applications like smart meter, teleworking or smart home can directly reduce environmental impacts, whereas on broader levels ICT holds the potential to shift consumer patterns, or even transform industry and society [6]. In recent years the ICT industry has actively driven a sustainable economic development. Energy Informatics (EI) have emerged as a result of this development as a new discipline that analyses, designs and implements systems to increase the efficiency of energy demand and supply systems [7]. In the context of the energy transition EI create the opportunity to establish a bidirectional communication that connects the supply and demand side. Therewith, consumption cannot only be measured but also controlled, enabling suppliers, e.g., utility companies, to manage demand needs with small temporal latencies. Smart metering for electricity appears to be the most important ICT component on an applications level that enables information-exchange and serves as a vector to motivate energy savings and shift consumer demand.

However, utilities and network operators first of all face the difficulties of a nationwide smart meter roll-out that are mainly the costs to set up the infrastructure. Considering the overall economic impact of a nationwide smart meter roll-out, studies generally emphasize the benefits [5]. The Swiss impact assessment for a smart meter roll-out estimates that for a nationwide roll-out economic benefits outweigh the costs by a factor of approximately two. Thereby, benefits lie in the load shifting, and consumption reduction potential of end users. Importantly, these potentials are foremost evident for the domestic sector and smallest for the industry sector. With residential energy consumption accounting for about 30 % of total energy use in western countries [1,8] potentially small individual savings can scale to a significant contribution.

On the level of single households energy consumption tends to vary greatly. This is particularly due to differences regarding behaviors and decisions made by individuals. For meeting the 20 and 16 % efficiency target, respectively, for private household's two kinds of measures are available: (1) efficiency measures like the purchase of energy efficient appliances and (2) curtailment measures like shortening shower time or lowering thermostat settings. The first kind of measures have a higher energy savings potential but the latter kind of measures also contributes to the national energy savings without waiting for new technologies to appear, or making major economic sacrifices [9]. Behavioral interventions alone can cause a reduction of carbon emissions from domestic energy consumption by 20 % within 10 years [10]. Therefore, interventions targeting consumers' energy relevant decisions and behaviors are promising tools to effectively reduce end use energy consumption [11] and control peak load demands. Overall, interventions stimulating energy savings, and the total effectiveness of a smart meter roll-out heavily depends on (1) the amount of households participating and adapting the feedback-technology and (2) the continuous interaction with the system that affects the energy saved by these households.

Human behavior as domestic energy demand or the willingness to engage in programs to reduce it do not show to follow the rational of simple economic models but is rather controlled by (socio-) psychological factors. Thus, feedback interventions to reduce and shift end consumer demand often lack effectiveness [12], or produce results that overestimate effects because of a selection bias of participants [13]. Somewhat successful, campaigns to reduce residential energy consumption combine different, tailored instruments to control demand: consumption feedback, general information, and means to decrease consumption, and motivational elements like incentives or social norms [14]. Especially social norms have proven to be a powerful tool to improve the effectiveness of descriptive consumption information [15]. Incentives (e.g., money) can motivate the recurring engagement with applications that provide such information [16] which is necessary, because most people have to be extrinsically motivated to do so. However, there is a surprising lack of studies investigating the main and interactional effects of these elements on the willingness to initially engage in these programs

which is crucial for the overall effectiveness of these interventions.

Therefore, we investigated the effects of promising motivational elements used in programs to control domestic energy consumption, namely social normative feedback and incentives, on the actual initial participation in these programs in a large scale field experiment. Importantly, the program is not hypothetical but a real online based smart meter data-driven like service. Thus, initial participation is measured as real decisions made by real customers of a utility, providing results with high external validity.

The following section provides a broad overview of related work and the derivation of the hypothesis tested. Section 3 describes the methodological approach followed by a presentation and discussion of the empirical results obtained.

2 Literature

This section provides an overview of related work for feedback driven studies to initiate behavior change for private households followed by a presentation of psychological concepts to enhance the effectiveness of these interventions.

2.1 Energy informatics as a driver for the energy transition: smart meter to reduce domestic energy consumption

Studies that estimate the general effectiveness of smart meter based interventions to motivate energy savings and load shifting provide mixed results. The Swiss impact assessment for a smart meter roll-out estimates the potential for smart meter enabled electricity conservation of on average 2.7 % and up to 5 % for more responsive users [5]. Load shifting potentials are estimated to be relatively large with about 10 % of total end consumer load. A comparable analysis for Germany resulted in savings ranging from 0.5 to 2.5 %. Savings thereby showed to be linearly depending on the absolute amount of energy consumed [17]. Both analyses emphasize the importance of the user–technology-interaction to achieve desired effects.

Field studies of smart meter roll-outs support the size of the estimated effects. However, only few studies investigate the voluntary initial adoption of smart meter technology users. Field studies often report a high adaption rate of around 20 % (e.g., [18]) but have a strong pre-selection bias or take multiple costly measures to recruit participants and most studies emphasize the research aspects of the project in the recruitment process. Thus, more research is needed to get a more realistic estimate of an adoption rate. Once the technology is initially adopted system usage usually shows a rapid decline. This decline in usage frequency seems to be associated with lower energy savings. An Austrian review of smart meter studies reports that online portals fail to get people back on the website after the first initial use but that bonus systems and reminders can effectively motivate continuous system usage [19]. A more detailed analysis of motivators is needed as well. Overall, the results of the field experiments suggest that smart meter technology in combination with elements to facilitate the interaction foster energy conservation. However, to stimulate meaningful overall savings, a large number of consumers have to initially adapt the technology provided.

2.2 Energy informatics as an enabler for the application of behavioral concepts to engage private households

In recent years field experiments to test the effectiveness of ICT based interventions to motivate sustainable behaviors have shown to not only to stimulate scalable energy savings, but also provide the opportunity to further our understanding of the behavioral mechanisms driving these effects [15,20]. Considering the heterogeneous results of various ICT based interventions to motivate private households to save energy, ranging from 0 to 20 % savings [9,21], this understanding is crucial. The results of the smart meter field experiments mentioned, and other lab based studies show that after an initial adaption of the technology, effects strongly depend on the feedback provided and on the behavioral mechanisms to motivate an ongoing interaction with the system. Obviously, this only accounts for people which use the system at least once. So basically, the question for social scientists to answer is how behavioral tools can motivate an initial adaption and ongoing interaction with the system.

From a socio-psychological standpoint, as formulated in the theory of planed behavior, behavior is trigged by intentions. Intentions are formed by attitudes, perceived behavioral control and norms regarding the respective behavior [22]. Thereby, motivational elements can change the factors determining the intention to act. Attitudes are basically formed by individual beliefs about the outcome of a given situation. Incentives change the associated outcome of a behavior, and thereby change attitudes towards that behavior. The norm regarding a behavior is shaped by the individuals beliefs about what others think about a certain behavior which is basically build by social normative information, such as feedback. However, factors influencing either attitudes or norms cannot be considered independently, because effects might not simply add up, but interact.

Practical oriented research shows that social norms, e.g., communicated via social normative feedback, and the change of attitudes towards a behavior, e.g., by using incentives, are both powerful tools to control behavior but can, if not applied right, backfire and produce unwanted effects, like for example crowd out intrinsic motivation [15,16,23]. In a field experiment [15] showed that social normative feedback can significantly motivate electricity savings when pre-

sented in an online campaign but does not affect the voluntary repeated exposure to the system. Cross domain studies have shown that incentives can effectively promote the establishment of good habits, like exercising [24] or support drug abstinence programs, like smoking cessation [25]. Thus, combined, social normative feedback and incentives might not only motivate short-term energy savings but a lasting reduction of consumption. EI enable the transfer of these powerful motivational elements into scalable solutions that maximize the positive socio-economic effects of interventions to control energy consumption of end consumers [20].

2.3 Social normative feedback for behavioral change

One of the most powerful options to promote sustainable behaviors using in the domain of EI is the application of social norms [7]. Social norms represent the beliefs about the behavior of others. They can be further classified into descriptive norms, and injunctive norms [26]. Descriptive norms are beliefs of what most people are doing, whereas injunctive norms are beliefs concerning what most people approve or disapprove of. Social norms have been proven to effectively influence ecological behavior, such as littering [11], towel reuse [27], and energy consumption [14,15]. In the energy domain, social norms can be applied to enhance the effectiveness of consumption feedback information, as provided by smart meter applications or paper based reports. However, when launching an ICT based program to reduce energy consumption, such as an online portal for smart meter, social normative information can be utilized to motivate initial interest for the topic as such, and foster long-term participation. Following the feedback, the need for action may be stronger for people with a higher consumption, respectively for those who get a bad feedback. Therefore, we state the following hypothesis:

- H1: People with a higher consumption than their neighbors are more likely to participate in a program to reduce energy consumption after receiving this information as social normative feedback than people with a lower consumption.

Regarding long-term participation incentives are a powerful motivator. The question to ask is not if incentives work, but how they work, and if they interact with other motivating elements, such as social normative feedback.

2.4 Energy informatics to initiate a lasting consumer engagement: the role of incentives

In the context of interventions to promote residential energy conservation the effects of incentive mechanisms to promote energy conservation campaigns show to be rather inconsistent and temporary [14]. The ineffectiveness of evident financial incentives to produce cost minimizing behavior is commonly known as the energy efficiency gap [12]. A reason for this might be that most interventions incentivize actual energy savings rather than actions and decisions which directly or indirectly contribute to the superior, somewhat abstract goal of saving energy. In other contexts, incentives have been implemented in schemes that have shown to be more effective. Rewarding target behaviors has shown to be an effective method to motivate people to exercise more frequently [24] and support compliance in psychotherapeutical interventions or weight loss trials [28,29]. In general, incentives seem to be an effective instrument to establish good habits [16]. However, the success of interventions, using incentive schemes to reinforce target behaviors, heavily depends on the consideration of various psychological factors. In an action based view, incentives change the way people perceive a task [30], how much effort they spend on a task [31], and how they engage in a task when incentives are removed [23]. The effects strongly depend on the type of incentive in place (e.g., monetary, non-monetary), and the interaction of incentive type and size [31]. The participation in a program to reduce in-home energy consumption can be regarded as prosocial behavior. Prosocial behavior is to a large degree guided by perceived norms regarding this behavior. Once rewards are introduced this decision guiding frame can shift from a normative frame to a frame determined by the incentive, e.g. a monetary frame [31]. Thereby, the decision maker does weight the social normative information less and behavior is controlled by the rewards promised. Different incentives induce different frames that determine how we interpret the situation. Monetary incentives induce a monetary frame that diminishes the influence of other norms, like those elicited by social normative information. In a money based incentive system, actual effort, such as the registration for a program, strongly depends on reward size—behavior is to a large degree controlled by the normative belief about incentive size. Non-monetary rewards (like praise or virtual badges) depict a more social frame in which effort is shaped by altruism and normative beliefs are shaped according to this dimension. Our central proposition is that the influence of social normative information depends on the type of frame induced by the incentives offered. Thus, we have following hypothesis for the motivation to participate in programs to reduce in-home energy consumption after receiving social normative feedback:

- H2: When a monetary incentive system is introduced, social normative consumption feedback has no influence on participation in a program to reduce in-home energy consumption.
- H3: When a social incentive system is introduced, the influence of social normative consumption feedback on

program participation is stronger than when no incentive system is introduced.

3 Methods

To test our hypotheses we used a postal energy efficiency report sent out by a Swiss utility to 17,500 randomly selected customers. The report gave customers an individual feedback concerning the electricity consumed by the receiving household within the past year and was sent as a free service offered by the utility. To test the effects of social normative feedback, incentive information, and incentive type on participation we compared the individual electricity consumption of the household to the respective street median and classified it as either good or bad depending on actual consumption and manipulated the incentive information, respectively.

The letter contained a personal introduction to the subject that announced a cost-free online energy efficiency portal, recipients could use to monitor electricity and water consumption and get help to actively lower their energy consumption. The introductory section also contained the incentive information to induce a monetary incentive frame, and a social incentive frame, and no frame, respectively. The section below contained a graphical display of the electricity consumed in the last year of the respective household compared to the street mean and top 10 % of the street (descriptive norm). Below the descriptive normative information the consumption was evaluated as either good (when consumed less than mean; "Not bad"), or bad (when consumed more than mean; "Do you have saving potential?") depending on the deviation to the street mean (injunctive normative feedback) with the detailed information of how many percent more or less the household consumed compared to the street mean. Furthermore, the letter displayed the URL of the online portal and an individual code that was needed to register online. The back of the letter contained a FAQ-like section that explained some functionalities of the portal.

(a) *Participants* We sent out the mailing to 17,500 customers of the utility company. After an initial filtering that excluded extreme consumers (because the utility did not want to provide an extreme social comparison (+2 SD compared to street mean) we randomly selected participants from the customer base of the utility (>250,000) customers. 12,500 people received a mailing with no incentive information, 2,500 people received a mailing that announced an non-monetary incentive, and 2,500 people received a mailing that announced a monetary incentive. For each of these groups about half of the recipients received a positive, and the other half a negative consumption feedback. On the portal, people were assigned to the incentive group that was announced on the mailing. Fewer people received a mailing in which incentives were announced, because the group size for the monetary incentives on the online portal was limited due to the budget. Recpients who got the mailings in which no incentives were announced were randomly assigned to one of the incentive groups on the online portal. 619 people were excluded from further analysis of social normative feedback on portal signup, because their consumption did not differ to that of their neighbors (difference $<\pm 2\,\%$).

(b) *Manipulation of incentive information* Two different messages concerning incentive information were added to the introductory section of the letter and a third version of the letter contained no incentive information. Incentives were promised for the progress on the online portal that was defined as the active reduction of ones energy consumption—the overall goal of the program. The monetary incentive was announced as a bonus on the invoice, the non-monetary incentive was announced as online energy efficiency badges. For the monetary incentive no information concerning incentive size was given.

(c) *Quasi Experimental Design* The design does not exclude the display of the normative consumption feedback for any of the experimental groups and only displays actual consumption information. Therefore we did not experimentally vary the normative consumption information. The incentive information was randomly assigned to the participants. We either showed no incentive information, announced the monetary incentive, or the non-monetary incentive. Therefore, we empirically tested our hypothesis in a quasi-experimental 2×3 between subject design.

(d) *Data collection and analysis* The letter served as a free service to inform recipients about their electricity consumption. However, we tested how the different features of the mailing motivated people to join the online efficiency portal. Thus, the signup rates for the different quasi experimental groups serve as the dependent variable. We could identify which letter version people received based on the unique code they entered to register on the portal. We performed Chi square-test to test our hypotheses.

4 Results

To test the effects of social normative feedback and incentive information on participation in the online campaign we analyzed the signup rates on the online portal. Overall, 4.02 % of the recipients registered on the online portal. Consistent with our first hypothesis, a Chi square test revealed that the negative social normative feedback yielded a significantly higher signup rate (4.82 %) than the positive feedback (3.02 %) when no incentive information was given ($\chi^2(1, N = 12{,}056) = 25.992$, $p = 0.001$, $\Phi = 0.05$) with an odds-ratio of 1.62.

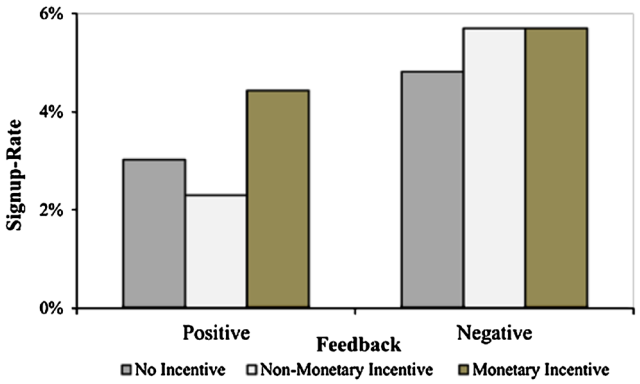

Fig. 1 Signup rates for the experimental groups as percent of recipients. Households that consumed less electricity than their neighbors in 2013 received positive social normative feedback, households that consumed more received negative feedback

To check for a main effect of incentive information on signup rate we compared the signup rates for the monetary incentive group (4.96 %), and the non-monetary incentive group (3.92 %), respectively, with the signup rate when no incentive was announced (3.88 %). Only the announcement of a monetary incentive yielded a significantly higher signup rate ($\chi^2(1, 2{,}500) = 6.239$, $p = 0.05$, $\Phi = 0.049$) with an odds ratio of 1.29.

To check for the hypothesized interaction of social normative feedback (pos. vs. neg.) and incentive information (monetary vs. non-monetary) we compared the signup rates for the different incentive and feedback groups, respectively. When a monetary incentive for the usage of the online portal was announced the signup rate did, as hypothesized, not significantly differ for positive (4.43 %) or negative feedback (5.70 %) ($\chi^2(1, 2{,}404) = 2$, $p = 0.0162$, $\Phi = 0.003$; see Fig. 1 for overview of results). However, when a non-monetary incentive was introduced, the social normative feedbacks yield a significant difference on signup rate with 2.30 % signups for positive, and 5.70 % signups for negative consumption feedback ($\chi^2(1, 2{,}421) = 18.56$, $p = 0.001$, $\Phi = 0.009$) with an odds ratio of 2.57 that is higher compared to an odds ratio of 1.62 when no incentive is introduced, suggesting that the effect of social normative feedback is enhanced as hypothesized.

5 Discussion

Our results enable practitioners to significantly increase the effectiveness of campaigns to recruit participants for ICT based interventions to reduce in-home energy consumption. Based on our results a targeted marketing approach could increase the signup rate by up to 45 % with no additional costs (e.g., no use of financial incentives). Furthermore, our empirical data show that different externally emitted incentives (monetary, non-monetary) can change the influence of other elements to motivate participation, like social normative feedback, differently. Thus, the results further our understanding regarding the interaction of motivational elements energy efficiency programs can use to motivate participation. With a set budget for marketing this can dramatically increase the total impact of such programs.

To test the effect of incentives to participate in ICT based programs to lower in-home energy consumption on actual signup for these programs, and the interaction of the incentive information with social normative feedback we conducted a real-behavior experiment. People received a letter by their local utility that was announced as a new service to promote energy efficiency, and displayed a social normative comparison by comparing the households electricity consumption to that of the street mean, and top 10 % of the street. Additionally, the utility offered an online portal to reduce the individual energy consumption. Thereby, we varied the rewards promised for doing so, that were either monetary (bonus on invoice), or non-monetary (virtual badges), or no reward was promised, and induced a monetary incentive frame, and a social incentive frame, respectively.

When no incentive frame was induced, people who received a negative social normative comparison were more likely to register on the online portal. Signup rates differed by a factor of 1.60. This not only demonstrates the power of social norms as a motivator, but also gives an important hint to practitioners: People who received the negative feedback actually consumed more than their neighbors and are more likely to hold the potential to actually save energy. Thus, the cost efficiency and total impact can be drastically enhanced by exclusively addressing people who consume more than the respective normative reference group and telling them so.

When a monetary incentive frame was induced the signup rate increased across groups. However, there was no longer a significant difference between social normative feedback groups—it did not matter much whether people received a positive or negative normative consumption feedback. When a social incentive frame was induced, the influence of the social normative feedback was not only significantly evident, but seemed to be enhanced by the social incentive frame with an odds ratio of 2.57 between feedback groups. This indicates, that externally emitted rewards can either weaken or enhance the influence of social normative feedback on the motivation to sign up for the program, depending on whether a monetary, or social incentive frame is induced. This has to be considered in the design of incentive schemes to motivate the usage of ICT based systems to lower domestic energy consumption, like those based on smart meters. Obviously, cost-efficiency plays a role, because feedback information, as non-monetary incentives come for free but can be as powerful motivators as if you pay for participation.

There is no doubt that monetary incentives are a very powerful tool to control behavior, but the effectiveness strongly depends on the amount paid. In the design and marketing of a program this has to be estimated when defining the budget. Nonetheless, using monetary incentives to motivate participation may undermine other motivational elements used in the campaign.

6 Outlook

Following this evaluation of initial recruitment, we will further analyze the effects of the incentives in place on actual usage behavior of the online portal participants signed up for and evaluate effects on energy savings. Furthermore, in the present study the normative feedback is dependent on actual consumption and it would be of interest if the mere classification into good or bad would yield effects and thus, be independent of actual consumption.

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