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Framework for the assessment of household electricity saving by integrating behavioural aspects

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Abstract

In order to achieve energy savings at the final consumer, electricity savings in households should be on the agenda for sustainable energy systems. Smart metering projects are increasingly used to achieve electricity savings; nevertheless feedback from smart meters themselves is not sufficient to reduce energy consumption in the longer term, thus the behavioural aspects of the users should be taking into account. Currently the research is focused on various policies and programs to target households, but due to authors' knowledge, there are no studies done in the attempt to model the household behaviour and electricity savings in a holistic and dynamic way. Therefore the main aim of this research is to outline the framework for the construction of this model. With the help of this model the future savings of policy or programs could be assessed.

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Keywords: smart metering; goal frame theory; system dynamics; energy efficiency; behavioural studies

1. Introduction

To increase energy efficiency at the final consumers is one of the priorities for energy sustainability. Households in these terms are one of the major energy end consumers. Therefore electricity saving in households should be on the agenda for sustainable energy systems.

Electricity saving in households could be achieved in two major ways: by investing in energy efficient appliances and by changing the usage of these appliances. Nevertheless, efficiency gains are not tangible straight away in the

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situation when electricity bills are only available monthly. Thus smart metering provides the opportunity for each household to receive online feedback on the electricity consumption and analyse data archive in various time frames.

Various researchers have shown that the introduction of smart metering gives the reduction of electricity consumption. For example, Laicane et al. [1] show electricity consumption savings at 13 % by 2020 in households using smart electricity meters. Based on the obtained data from a smart metering project, Laicane et al. [2] constructed the model for electricity use modelling in households, and concluded that the behavioural aspects of the electricity use should be studied in order to increase the model's performance. Also the study by Schultz et al. [3] concluded that feedback itself is not sufficient to reduce energy consumption in the longer term, thus the behavioural aspects on the users should be taken into account. Joachain and Klopfert [4] came to the same conclusion, that feedback on energy consumption should be coupled with tools for consumer motivation. The study by Krishnamurti et al. [5] also showed that social acceptance of smart meters is high, but the expectations of the smart meters where immediate energy savings, thus the carefully planned policy should be used to help households to achieve the desired saving.

The research by Anda and Temmen [6] proposed to use community awareness and behaviour change programs to reach the aim outlined for smart metering introduction. D'Oca et al. [7] showed that, by providing the correctly targeted information, energy saving in households with smart metering reached as high as 57 %, with an average of 18 % instead of the previously expected 15 %.

We can observe that the smart metering projects are increasingly integrating the social aspects of consumer behaviour, since feedback on its own has only a short term effect. Currently the research is focused on various policies and programs to target households, but according to the authors' knowledge, there are no studies done in the attempt to model household behaviour and electricity savings in a holistic and dynamic way. Therefore the main aim of this research is to outline the framework for the construction of this model.

In this study the Goal Frame theory by Lindenberg & Steg [8] is used to model the behaviour of households. The role of goals was studied by Steg et al. to encourage pro-environmental behaviour [9] and to study the sustainable energy behaviour [10]. The Goal Frame theory can be applied widely – to study the general values of humans or to study specific values in specific situations, for example, when selecting food, showering time or automobile preferences [11].

As far as the authors' have been able to determine, this is the first attempt to include the Goal Frame theory within a system dynamics model. This study is the continuation of the research by authors [12], where we showed higher electricity savings for households using smart metering – on average 20 % higher electricity savings than in the control group (without smart metering); and these findings where above the range of previously conducted studies on smart metering pilot projects. We present this research in order to explain these electricity savings by bringing to light outlining causes – including the households' behaviour. With this model not only the retrospective situations could be analysed, by also the future savings of policy or programs.

2. Materials and methods

The methodology combines an empirical study with system dynamics modelling and is developed by the co-authors of this [13]. The methodology is modified to model the changes in households' behaviour and electricity use patterns under the various policy tools.

For the design of study group, a quasi-experimental design was used, with 500 households in a target group (with smart meters) and 500 – in a control group (without smart meters). Both groups were equally split based on electricity consumption: below 200, 300, 450, 650, 1000 and above 1000 kWh per month, given in more detail [12].

To study the households' behaviour, the Goal frame theory by Lindenberg & Steg [8] is used. This theory explains the motivation behind the households' choice, based on three guiding principles or goal frames: gain, normative and hedonic. In the case of gain goal, the households would save the electricity because it saves money. In the case of normative goal, the savings could be explained by social pressure or environmental awareness. And finally, the hedonic goal would be activated in the case that saving energy brings joy, for example, the commodities with higher energy efficiency are more user-friendly. To assess focal and background goal frames, the survey was used with the corresponding values to each goal frame. Later the obtained results are analysed and used in the modelling.