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Research article

Reducing domestic heating demand: Managing the impact of behavior-changing feedback devices via marketing

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ABSTRACT

Feedback devices can be used to inform households about their energy-consumption behavior. This may persuade them to practice energy conservation. The use of feedback devices can also—via word of mouth—spread among households and thereby support the spread of the incentivized behavior, e.g. energy-efficient heating behavior. This study investigates how to manage the impact of these environmental innovations via marketing. Marketing activities can support the diffusion of devices. This study aims to identify the most effective strategies of marketing feedback devices. We did this by adapting an agent-based model to simulate the roll-out of a novel feedback technology and heating behavior within households in a virtual city. The most promising marketing strategies were simulated and their impacts were analyzed. We found it particularly effective to lend out feedback devices to consumers, followed by leveraging the social influence of well-connected individuals, and giving away the first few feedback devices for free. Making households aware of the possibility of purchasing feedback devices was found to be least effective. However, making households aware proved to be most cost-efficient. This study shows that actively managing the roll-out of feedback devices can increase their impacts on energy-conservation both effectively and cost-efficiently.

1. Introduction

To quickly reduce CO_2 emissions, one way that seems promising is to change heating behavior. In the EU, residential buildings account for ca. 30% of final energy consumption; about 60% of this is taken up by space heating (Itard and Meijer, 2008). The potential for the reduction of this share via behavioral changes is 20–30% (Wood and Newborough, 2003), e.g. by practicing energy-efficient ventilation behavior (Galvin, 2013) and setting lower thermostat temperatures (Guerra Santin et al., 2009).

Providing feedback to energy consumers about their energy consumption behavior can help them tap into this savings potential. Feedback about behavior was found to decrease energy consumption up to 20%, with an average around 10% (Karlin et al., 2015, 2014; Wood and Newborough, 2003). Numerous approaches exist to give feedback to energy consumers, e.g. email, online platforms, or installed feedback devices (Karlin et al., 2014; Laschke et al., 2011; Darby, 2006). One example of a feedback device is a so-called 'CO_2 meter', which shows the indoor air quality—measured by CO_2 level—in the form of a traffic light. This was shown to be effective in convincing households to practice the energy-efficient 'shock ventilation' (*'Stoßlüften'*) of rooms (see Section 2).

This study focuses on feedback devices installed in the home, due to their potential to create greater effects in the long term. One challenge to feedback interventions is *behavioral relapse* (Verplanken and Wood, 2006), i.e. energy consumption levels returning to the levels before intervention occurred. However, feedback from devices appears to be less prone to behavioral relapse or decreasing attention for feedback—particularly when installed quasi-permanently and made directly accessible to users (Burchell et al., 2014).

To reduce heating energy demand significantly, market introduction of feedback devices should be managed effectively—and ineffective management should be avoided early on. Especially in the earliest phase of product diffusion, good marketing can significantly support the adoption of that product (Delre et al., 2007). There are various established marketing strategies, such as advertising devices to the general public or giving the first devices away

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as free promotional gifts. It is critical to identify the best options among such strategies given the requirement of maximum behavior change. We argue the respective merits of each strategy should be well estimated ex-ante—before any real-world implementation. This is crucial to avoid actions that have low or counterproductive effects and would delay achievement of desired results.

Simulation modeling is useful for identifying effects of actions on product diffusion before their implementation (van Dam et al., 2012; Schwarz and Ernst, 2009; Rixen and Weigand, 2014). Simulation, being quicker than real-time, can thus help avoid ineffective action in the real world. Simulation modeling is capable of estimating the potential future effects of marketing strategies towards sustainable household products and the resulting impacts (Schwarz and Ernst, 2009; Delre et al., 2010). Yet, such undertaking has to acknowledge the uncertainties of forecasting social systems and the energy sector (van Dam et al., 2012). Therefore, goal of this study is not predicting the exact impact of marketing strategies of great detail. Instead, high-level marketing strategies are merely to be compared in a relative way, regarding their general effectiveness and cost-efficiency.

This study therefore aims to use simulation modeling to compare and propose marketing strategies for feedback devices ex-ante. This assessment will adopt and refine a simulation model on the diffusion and effect of a CO_2 meter (Jensen et al., 2016). From this, we aim to identify the management strategies for rolling out feedback devices that show the best impact over a range of future scenarios. To facilitate practical results, we also suggest stakeholders that would be well suited to putting these devices into action. Altogether, this study addresses the following research question: *Which innovation management is most effective at creating additional energy-efficient heating behavior via the marketing of behavior-changing feedback devices?*

The rest of this paper is organized as follows. First, we present previous findings on the device used in this case study. Second, we present the state of literature on modeling marketing strategies, the specific simulation model adopted for this case study, and the strategies we assess with this model. Third, we answer the research question by simulating and analyzing these strategies.

2. The CO_2 meter case study

In this section, we present the CO_2 meter as a case study of a device and previous findings on its effects. This device gives feedback to its users about indoor air quality and gives them an incentive to ventilate energy-efficiently. The device shows its feedback in the intuitive colors of a traffic light: good air quality is shown by green, intermediate by yellow, and unhealthy air by red.

Field tests have shown that the use of a CO_2 meter has the potential to change the ventilation behavior of householders, which consequently supports a reduction in heating demand. For ventilation, most households in Germany have windows that have two sets of hinges that allow the option of opening windows completely (i.e. practicing so-called 'Stoßlüften' or 'shock ventilation') using one set of hinges, or only partially, by tilting them open on the second set of hinges (Galvin, 2013). The CO_2 meter increases the attractiveness of shock ventilation, because this behavior increases the ventilation rate and thus the speed at which improved air quality is shown by the feedback. Increased ventilation rate and avoidance of overly long ventilation times, in turn, reduce heating energy demand (Galvin, 2013). The savings from adopting shock ventilation have been shown to amount to an average of approximately 8% (Lovric, 2015; Jensen et al., 2016).

Previous research assessed not only the effect of the CO_2 meter for its direct users, but for an entire city—comprised of adopters and non-adopters of feedback devices. Impact from the CO_2 meter relied on three processes: (1) its diffusion among households, thus increasing the number of users, (2) the feedback effect for its users, and (3) consequent spread of this induced behavior change, e.g. to households that do not use the device.

3. Methods

This study aims at designing marketing strategies for feedback devices, and then identify which would be most effective. We adopted the four-step method by Roozenburg and Eekels (1995) for this task: (1) analysis of the problem and gathering of existing options to solve it; (2) synthesis of the analyzed options to tentative solutions; (3) simulation of these solutions to forecast *"the behavior and properties of the designed product by reasoning and/or testing models"* (Roozenburg and Eekels, 1995, p. 91); and (4) empirical evaluation of the most promising solutions.

In this study, we focus on the first three of these steps—analysis, synthesis and simulation. Feedback devices for behavior change in heating are still in the early phases of market entry. This study will prepare and support the future real-world evaluation and implementation of marketing strategies of these devices.

3.1. Analysis: marketing options

We analyzed various possible marketing strategies for feedback devices by drawing on the wide base of literature on managing the diffusion of innovations with marketing.

3.1.1. Classifying marketing options in the literature

The challenge of getting more households to adopt a product is a problem tackled by the field of marketing. We thus reviewed multiple promising marketing strategies. These strategies were classified in a widely used array of marketing options: E. Jerome McCarthy's 'marketing mix' (1996). In addition to the product itself and its characteristics—we assume a situation where an already designed device needs to be marketed—the marketing mix classifies actions into three additional categories: (1) The price of the product, on which the willingness of adoption may depend; (2) Promotion activities that communicate the product to potential adopters; and (3) the place, i.e. the distribution channels via which a product is marketed. Motivated by our intention to simulate selected marketing strategies with agent-based modeling, we focused our literature search on this field. Thus, the Scopus database Elsevier (2015) was queried with the search term *'simulation AND agent-based AND diffusion AND innovation* AND (promotion* OR policy).'* The selection criterion for strategies was their reported success. In addition, we included sources in the review article by Kiesling et al. (2012) on this question.

3.1.1.1. Price. The most frequently modeled marketing strategy in the reviewed studies were discounts on products. Successful incentives were found in the form of discounts (or subsidies) (Ferro et al., 2010; Cantono and Silverberg, 2009; Zhang et al., 2015) and purchase bonuses (Rixen and Weigand, 2014); the changing of economic interactions in a system has also been found to be indirectly successful (de Holanda et al., 2008). The overall economic effect of giving away a limited number of products for free may also be greater than if discounts or rebates are offered. This approach has shown particularly promising when compared to discounts (Zhang et al., 2015).

3.1.1.2. Promotion. Regarding product promotion, advertising and social marketing have repeatedly been found to be successful at supporting product diffusion: