Doctoral Thesis

Smart metering for behavioral change: the effects of goal setting and feedback interventions on domestic energy consumption

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SMART METERING FOR BEHAVIORAL CHANGE: 
THE EFFECTS OF GOAL SETTING AND FEEDBACK 
INTERVENTIONS ON DOMESTIC ENERGY 
CONSUMPTION

A dissertation submitted to 
ETH ZURICH

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presented by 

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2012
Acknowledgments

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believing in me. In addition, I would like to thank my close friends and Daniel for being with me every step along the way.

Zurich, October 2012

Claire-Michelle Loock
Abstract

Global energy consumption is steadily rising due to population growth, increasing incomes, and the industrialization of developing countries. To secure future generations’ energy supply, governments around the world have committed to increasing energy efficiency. The emerging Smart Metering infrastructure has the potential to greatly increase energy efficiency in the residential sector. To maximize their effectiveness, accompanying feedback systems need to account for the fact that individuals do not act fully rationally based on cost/benefit arguments. This thesis presents a novel approach to increase the effectiveness of the costly Smart Metering infrastructure at no additional cost, helping energy consumers make good decisions by combining traditional behavioral interventions with tailored behavioral nudges. To demonstrate the approach, two core functionalities of feedback systems, goal setting and feedback, are combined with social influence and defaults. An innovative web portal was developed to evaluate the interventions’ success in large-scale field experiments with 10,700 customers of an Austrian utility company. The energy savings potential amounts to 8.02% and would lead to savings of 2.84 billion kilowatt hours, 1.60 billion tons less CO₂ emissions, and monetary benefits of 730 million Euro for Germany. Hence, Smart Metering can play an important role in conserving the energy supply of the future if used in combination with smart feedback systems.
Kurzfassung

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<tr>
<td>EC</td>
<td>European Commission</td>
</tr>
<tr>
<td>ANOVA</td>
<td>Analysis of Variance</td>
</tr>
<tr>
<td>b</td>
<td>b coefficient</td>
</tr>
<tr>
<td>BfE</td>
<td>Bundesamt für Energie (Swiss Federal Office of Energy)</td>
</tr>
<tr>
<td>Bp</td>
<td>Beyond petrol (company)</td>
</tr>
<tr>
<td>CI</td>
<td>Confidence Interval</td>
</tr>
<tr>
<td>CO₂</td>
<td>Carbon dioxide</td>
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<tr>
<td>CRM</td>
<td>Customer Relationship Management</td>
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<tr>
<td>D</td>
<td>Default</td>
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<tr>
<td>e.g.</td>
<td>Example given</td>
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<td>EDM</td>
<td>Energy Data Management</td>
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<tr>
<td>EEA</td>
<td>European Environment Agency</td>
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<tr>
<td>EERS</td>
<td>U.S. Energy Efficiency Resource Standards</td>
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<tr>
<td>EIA</td>
<td>U.S. Energy Information Administration</td>
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<tr>
<td>EMGB</td>
<td>Extended Model of Goal-Directed Behavior”</td>
</tr>
<tr>
<td>EU</td>
<td>European Union</td>
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<tr>
<td>EUR</td>
<td>Euro (currency)</td>
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<tr>
<td>EVO</td>
<td>Efficiency Valuation Organization</td>
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<tr>
<td>F</td>
<td>F-statistic</td>
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<tr>
<td>FT</td>
<td>Focus theory of normative conduct</td>
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<td>G</td>
<td>Goal</td>
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<tr>
<td>GUI</td>
<td>Graphic User Interface</td>
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<td>H</td>
<td>Hypothesis</td>
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<tr>
<td>HAN</td>
<td>Home Area Network</td>
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<tr>
<td>ICT</td>
<td>Information and Communication Technology</td>
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<td>ID</td>
<td>Identification</td>
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<td>IS</td>
<td>Information Systems</td>
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kWh
M
MED
Mod
N
NAM
OECD
p
r
SD
SE
t
TIB
TPB
TRA
U.S.
USD
VBN
WAN
Θ

Kilowatt hour
Median
Model on effortful decision-making and enactment
Mode
Sample size
Norm activation model
Organization for Economic Co-operation and Development
p-value
Pearson’s correlation coefficient
Standard deviation
Standard error
t-statistic
Theory of interpersonal behavior
Theory of planned behavior
Theory of reasoned action
United States
U.S. Dollar (currency)
Value belief norm theory
Wide Area Network
Theta (indirect effect in nonlinear mediation models)
1 Introduction

This chapter outlines the motivation for this research. It further highlights the objectives of this thesis and briefly describes the methodological approach and the research setting. Subsequently, the contributions of the research to theory and practice are addressed. The chapter closes with the thesis outline.

1.1 Motivation

Energy supply is a key challenge for society. Due to growing world population, increasing incomes, and the industrialization of developing countries, world primary energy consumption is expected to increase annually by 1.6% [15]. To satisfy the steadily increasing ‘global hunger for energy’ [225], governments and industries are pursuing various strategies such as subsidizing energy from renewable resources and increasing and improving the efficient production and distribution of energy. However, against the background of limited resources, rising costs for energy production, and increasing pollution, it is becoming clear that a more sustainable approach is needed to assure future generation’s energy resources. In this context, governments the world over are emphasizing the potential of reducing energy consumption by increasing energy efficiency. According to the European Commission (EC), energy efficiency is Europe’s biggest energy resource and it is one of the most cost-effective means to secure supply and reduce the emission
of hazardous substances [89]. In line with the first argument, a recent U.S. report found that American households and businesses could decrease energy consumption by 23% and thereby earn $1.2 trillion if they made use of their end-use efficiency potentials by insulating their houses or by replacing old appliances with energy-efficient ones, for example [10,126]. Steven Chu, the U.S. secretary of Energy, therefore concluded that “energy efficiency isn’t just a low hanging fruit; it’s just fruit lying around” [63]. The approach of increasing energy efficiency to secure future energy supply hence seems very promising.

Acknowledging the significance of energy efficiency for future energy supply, the European Union has committed itself to reducing annual primary energy consumption by 20% compared to projections [89]. To achieve this saving target, public sector, industry, residential consumers, and utility companies in Europe are obliged to save energy. The EU wants the public sector to lead by example and to buy energy-efficient buildings, products, and services. Further, the public sector is supposed to gradually reduce the energy consumed by their own properties by renovating 3% of their total floor area each year [90]. Large industrial companies will have to conduct energy audits to evaluate saving potentials while small and medium-sized companies will receive incentives for doing so [90]. The EU has introduced several policies designed to affect consumption behavior and purchase decisions of residential consumers. For example, one European policy mandates the phasing out of
incandescent bulbs. Other European policies specify higher energy performance standards for residential buildings, incentives for buying alternative fuel-vehicles, incentives for using electricity from renewable resources, grants for supporting residential energy conservation projects, and rebates for investing in water-efficient equipment and solar panels (for an overview see [225]).

Success in meeting energy saving targets hinges crucially on utility companies. Since their revenue depends on the amount of energy they sell, normally their interest in increasing energy demand contradicts energy-saving goals. Consequently, in Europe as well as in the U.S. policies have been introduced to change the incentives for utilities companies to ultimately support energy efficiency. According to European energy efficiency policies, European utilities are now required to support their residential energy customers in saving on average 1.5% of their energy consumption compared to the previous year. This requirement is based on the importance of the residential sector as a target group for energy efficiency interventions: Households account for 20% - 30% of total energy use [92,93]. The utility companies have to achieve savings either by implementing energy efficiency measures or by funding programs that support energy conservation [90]. Switzerland shares Europe’s assessment of energy efficiency as a central means to secure future energy supply but has not yet implemented any policies that require utilities to meet specific
saving targets.\(^1\) In contrast to Switzerland but in line with European policies, national policies in the U.S. require utilities to fulfill energy efficiency resource standards (EERS) which specify a percentage reduction in energy use to be achieved through energy efficiency measures. Twenty-four states in the U.S. have passed an EERS with Vermont and Massachusetts having the most stringent saving requirements (2.5% annually).\(^2\) Going even further than European policies, in some states such as California and Oregon, utility profits and sales are decoupled so that utilities are compensated for lost volumes of sales.\(^3\) Other states such as Massachusetts are about to introduce decoupling policies, too.\(^4\)

Against this regulatory background, it is evident that utility companies both in Europe and in the U.S. will try to introduce energy efficiency programs that are both effective in terms of energy savings and efficient in terms of costs per kilowatt hour (kWh) saved. While some interventions such as energy retrofitting, energy audits, or the purchase of EnergyStar appliances are relatively expensive, so-called behavioral interventions that aim at changing people’s attitudes and behaviors are very cost-efficient. For example, energy

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\(^2\) [http://www.aceee.org/topics/eers](http://www.aceee.org/topics/eers) [accessed on 23.07.2012]

\(^3\) [http://www.aceee.org/sector/state-policy](http://www.aceee.org/sector/state-policy) [accessed on 23.07.2012]

consumers who received energy reports on how their energy consumption compared to their neighborhood’s average consumption achieved savings of 2% on average at a cost of 2.5 cents per kWh saved [10].

Utility companies also offer energy efficiency programs for other reasons than fulfilling their regulatory requirements. Since 1999 European energy markets have been continuously liberalized based on the European Directive 96/92/EC, allowing energy customers in EC member states to freely choose their supplier [88]. Although the majority of customers are not using their freedom of choice and churn rates are still low (e.g., 7% in Germany, [244]), utilities have realized that the competition in the residential sector is increasing and are expecting more customers to switch their supplier in the future. Even in countries like Switzerland, where the energy market is not fully liberalized yet, utilities regard the liberalization of the market and customer relationship management as key challenges [266]. To differentiate themselves from other competitors and create a positive brand image, utilities are introducing innovative services such as energy efficiency programs meant to retain existing customers and attract new ones. The utility companies anticipate that existing customers will not switch them because they feel attached and that other customers will switch to them because of the additional benefits that they anticipate from changing their supplier. Finally, by providing energy efficiency programs, utilities aim at gaining local support for building new power plants. Utilities are often dependent on local support due
to their ownership structure (e.g., city as stakeholder) or for political reasons. In Switzerland, for example, the Swiss population ultimately decides whether new power plants are built or not according to Swiss direct democracy. Since customers have a huge direct (retail) and indirect (public decisions) influence on their revenues, utilities are highly interested in satisfying their customers’ needs.

While traditional energy efficiency programs offered by utility companies - (e.g., replacement of old and inefficient appliances) relied on the power of technology to achieve energy efficiency - modern and innovative programs like the energy reports mentioned above are characterized by a stronger focus on human behavior. This paradigm shift is based on the finding that technology-based efficiency improvements can be easily amplified or dampened by human behavior [10,195]. To support the design of effective interventions, a plethora of studies have investigated factors that influence pro-environmental behavior [156]. According to behavioral models that have been built based on this research, pro-environmental behavior is influenced by a complex interplay between factors that are intrapersonal (e.g., attitudes, values), interpersonal (e.g., norms, social comparison), and external (e.g., rewards, punishment) [118]. In the context of energy consumption, habits and situational conditions (e.g., budget, time, knowledge) also have an essential influence on behavior. Numerous behavioral interventions have been developed to address one or more influence factors in a favorable way [5]. To have full effects, behavioral interventions
must be tailored to the basic characteristics and situational conditions of the energy consumer. For example, when energy consumers are compared to their neighbors, they are typically motivated to reduce their consumption if their consumption levels are higher [259]. If energy consumers learn that they consume more modestly than their neighbors, however, they tend to increase their consumption. Hence, behavioral interventions can backfire and produce boomerang effects if the intervention is not tailored to the characteristics of the energy consumer. Goldstein and colleagues have shown that it is also important to fit an intervention to the situational context of the energy consumer [121]. The authors tested the effect of several persuasive messages on the reuse of towels by hotel guests. They found that a message stating how many hotel guests in a specific room have reused their towels is more effective in motivating reuse by a guest in that same room than a message saying how many hotel guests in general reuse their towels. The two studies show that it is advisable to tailor the interventions to personal and situational characteristics when creating behavioral interventions to increase energy efficiency among energy consumers. However, in traditional energy efficiency programs, it is often not feasible to address a large group of energy customers and to provide personalized feedback at the same time since this approach is not scalable.

To overcome this problem, Information Technology (IT) constitutes a promising tool for supporting large-scale and tailored energy efficiency interventions. While traditionally both
academia and practitioners have been concerned with reducing the detrimental influence of IT with regard to energy consumption and CO₂ emissions [219], they have just recently also started to regard IT as potential solution to the problem. First, IT can be used as a technology to gather and display detailed information on energy-related behavior. Such information is a prerequisite for behavior change. For example, the smartphone’s accelerometer can be used to measure forward acceleration and thereby determining fuel economy or carbon footprints [110]. The increasing availability of cheap sensors and the availability of wireless technology have contributed to the integration of the physical world (e.g., household appliances) and the cyber world. The resulting “cyber-physical-system” [83] is of great interest in the energy context, because it allows collecting and integrating detailed information on energy consumption and providing consumption feedback via various user interfaces. Hence, energy consumers can monitor and control their consumption which allows them to improve energy efficiency in their households. Second, IT helps to cost-effectively reach a large group of consumers with tailored interventions and thus bridges the classical trade-off between reach [98] and richness [74]. For example, electronic feedback can automatically adjust to multiple standards (e.g., personal and social), reference points (e.g., financial costs per hour, the previous day, or the upcoming month), and units (e.g., $ or kWh) [216] for different user groups based on user characteristics such as a priori consumption levels or household characteristics.
One example of a cyber-physical-system is the emerging Smart Metering infrastructure. Smart electricity meters (Smart Meters) are gradually replacing the electromechanical induction watt-hour meters. They enable the automatic reading, processing, and transmission of metering data to a network. Smart Meters allow energy consumers to continuously monitor their consumption and provide utilities with the opportunity to control energy supply remotely [22]. They will soon become available to millions of households in Europe and the U.S. In Europe, for example, 80% of all households will be equipped with Smart Meters by 2020 [256]. Impact assessments have shown that the benefits of the Smart metering infrastructure highly depend on the savings potentials of the households [16,112]. Given that savings potentials of the households differ between countries, the advocated roll-out strategy may not be the ideal solution for every EU member state. For example, the impact assessment by the Swiss Federal Office of Energy (BfE) concluded that, for Switzerland, a selective roll-out is less effective than the current status quo that comprises traditional electricity meters and energy efficiency campaigns [16]. The full roll-out by contrast may achieve benefits of 2.5 Billion Swiss Francs at upfront investments of one billion Swiss Francs [16]. In addition to impact assessments that test economic models for various scenarios, utility companies throughout Europe carry out Smart Metering pilots to empirically quantify the effectiveness of the Smart Metering infrastructure and the accompanying feedback systems on energy consumption behavior [126]. In a Smart Metering pilot with 2,000 households in Germany and Austria,
for example, savings of about 3.7% were achieved [249]. Although these savings may seem moderate, they amount to 1.3 billion Euro (3500kWh/a * 0.037 savings * 0.25 cents/kWh * 40.3 Mio households) assuming that the pilot study’s findings can be extrapolated to all German households. Given that the Smart Metering infrastructure requires a significant investment of for example, 3.8 to 5.7 billion Euro in Germany [112], the utility companies are interested in increasing savings and thus the benefits of the Smart metering infrastructure in order to obtain positive net benefits.

The feedback systems that are so far used in Smart Metering infrastructures do not tap the full potential of Smart metering yet. They usually display energy consumption and associated saving potentials. The implicit belief is that an individual who is confronted with an opportunity to save money by reducing energy consumption will act accordingly because the potential benefits exceed the costs. However, “…consumers don’t seem to act like fully informed and rational decision makers when they make energy choices” [63]. Behavior is not only driven by cost and benefit considerations but also by factors such as prevalent social norms and habits. In addition, the way information on energy consumption is presented highly mediates the effects on behavior. For example, Pichert and Katsikopoulos showed that more participants choose a green power tariff if green electricity instead of electricity from non-renewable resources is the default option [240]. This indicates that there might be no such thing as a neutral design [291].
Small and apparently insignificant details like the provision of default options can have major impacts on people’s behavior [10] which contradicts the classic economic perspective that posits that people act on their preferences. But preferences often depend on a given choice set and are constructed on the spot when needed [44]. This said, it is obvious that choice architecture, that is the way decisions are influenced by the manner in which the choices are presented, and its effects cannot be avoided. Therefore, little nudges should be offered that are most likely to help make good decisions and least likely to inflict harm [291]. According to the authors a nudge is “…any aspect of the choice architecture that alters people’s behavior in a predictable way without forbidding any option or significantly changing their economic incentives…” [291]. These nudges cost very little compared with other interventions such as price changes [10] and thus may be used within the Smart Metering infrastructure to achieve large and cost-efficient savings. This requires the identification and design of effective behavioral nudges for the purpose of energy conservation. In addition, these nudges need to be tailored to the characteristics and the context of the energy consumers in order to avoid undesirable effects such as an increased consumption.

To conclude, it seems promising to apply behavioral interventions to increase energy efficiency, since the behavior of energy consumers can significantly amplify or dampen the effects of technology-based efficiency improvements. The emergence of the Smart Metering infrastructure allows for
addressing many energy consumers with tailored interventions, which may help to increase energy efficiency. However, this goal can only be achieved if accompanying feedback systems account for the bounded rationality of the energy consumer and help them to make good choices by means of a carefully-designed choice architecture.

1.2 Objective

Smart Metering has the potential to provide large-scale, but at the same time highly tailored interventions to residential energy consumers. Behavioral interventions that use Smart Metering have thus far been restricted in their effectiveness because they are based on the assumption that energy consumers act fully rational. Furthermore, existing interventions are not tailored and hence do not consider differences in motivation. To overcome these shortcomings and improve feedback systems accompanying the Smart Metering infrastructure, this thesis aims to identify effective behavioral nudges and tailor them to relevant characteristics of the energy consumers. The thesis focuses on goal setting and feedback interventions for a number of reasons. First, utility companies are required to provide energy customers with feedback on their electricity consumption and to empower them to reduce consumption and costs [75,88]. Second, goal setting and feedback represent basic functionalities that residential customers expect from energy management systems (e.g., [303]). Third, goals and feedback play central roles in the individual’s decision-making processes [20]. Fourth,
goal setting and feedback strategies are both effective strategies in motivating energy conservation [48,201,277,309]. To exemplarily demonstrate how their effectiveness can be increased at essentially no extra cost, the two strategies will be combined with the nudges “social influence” and “defaults” [291]. The nudges are successful in affecting energy consumption [240,259,260] and are suitable for behavioral interventions that make use of information systems [120,193]. To prevent undesirable effects, the two nudges will be tailored to relevant energy consumer characteristics, such as the baseline consumption levels [259]. The approach of improving traditional behavioral interventions by combining them with tailored nudges is meant to serve as a blueprint for future research endeavors.

Specifically, the thesis comprises four studies (for an overview see Figure 1) that combine goal setting and feedback with two different tailored nudges each. The first study combines goal setting with defaults (“the option that you get if you do not make other decisions” [56]) and investigates whether default-goals are capable of nudging energy consumers toward higher savings targets and larger energy savings. Furthermore, low, medium, and high default goal levels are tested to see which level works best and thus should be used for feedback systems. The second study combines goal setting with identity signaling and examines whether energy consumers can be motivated to set higher saving targets if they are provided with the possibility to signal their identity as a green consumer to others. In addition,
the study examines how identity signaling approaches need to be tailored to the degree to which consumers regard energy conservation as a domain to express themselves. The third study combines feedback with social norms and tests the effects of different types of social normative feedback on energy consumption. Descriptive normative feedback tells consumers how they compare to their neighbors, and injunctive normative feedback indicates if significant others approve their consumption behavior. Furthermore, the interplay of injunctive and descriptive normative feedback is examined in order to better understand the underlying mechanisms. Finally, the study investigates how social normative feedback needs to be tailored to a priori consumption levels to avoid undesirable effects on energy consumption. The fourth study also combines feedback with social norms and investigates the effects of different reference groups in descriptive normative feedback on energy conservation. The reference groups differ with regard to their geographical proximity to the energy consumer. Energy consumers are compared to the average performance of their neighbors, their region, or their country. In addition, the study examines if reference groups need to be tailored to the consumer’s location.
The results of this thesis will assist the design of cost-efficient and effective goal setting and feedback interventions and aim at increasing the benefits of the Smart Metering infrastructure by increasing energy savings at no extra costs. Unlike previous approaches, these interventions account for the bounded rationality of human beings and address motivations other than maximizing utility. In addition, the design of the goal setting and feedback interventions accounts for differences in
motivation because they are tailored to important characteristics of the energy consumers. Due to empirically proven and tailored interventions, the Smart Metering infrastructure will become “smarter” and is likely to achieve higher energy savings than before.

1.3 Approach

To achieve the goals of this thesis, the studies outlined above are conducted in a real-world setting. Conducting field studies makes it more likely that the feedback systems that will be designed based on findings obtained here will actually be effective in meeting the intended goal, that is, motivating energy consumers to save energy. In contrast to laboratory studies, field studies are supposed to provide insights with higher external validity, since they allow for testing effects in a naturalistic environment [50]. The experiments are therefore conducted in cooperation with a utility company that is based in Austria and has about 120’000 residential energy customers. At the time of study design and implementation, a Smart Metering infrastructure was not available to conduct the experiments. Consequently, an innovative feedback system was built that works with today’s technology and that would look exactly the same if it were already using Smart Metering data. Building this system made it possible to derive empirically proven design guidelines for Smart Metering feedback systems even before Smart Meters were actually introduced to the energy customers.
Specifically, a web portal called Velix was developed to serve as a basis for an energy efficiency campaign that allowed the energy customers of the Austrian utility company to turn their traditional electricity meters into “smart” electricity meters. Velix applied a gamification approach that combines storytelling, different levels, feedback, and rewards to engage customers in energy conservation. The partnering utility company considered the system an essential part of their energy efficiency endeavors and made the portal available to all its private customers. A detailed description of the system is provided in section 3.2.3. Unlike previous energy efficiency campaigns, the web portal was built as a collective effort of experts from different departments of the utility company (marketing, communication, energy efficiency, metering), academia (computer scientists, psychologists, engineers), and the in-house advertising agency of the utility company. The campaign ran from April 1, 2010 to December 31, 2011 and was very successful in attracting a large number of customers (10,700) and to motivate intense interaction with the web portal (e.g., 319,169 entered meter readings, 4,988 participants in survey). The campaign pursued several goals. Among the objectives were to raise awareness among consumers, to engage consumers in energy conservation, and to prepare them for the introduction of Smart Metering. Another objective was to position the company as a sustainable player among important stakeholders and gain local support for building a new hydroelectric power plant. As part of the campaign, customers were incentivized with bonus points for registering and
transferring the readings of their (traditional) electricity meter to the web portal. Based on the manually entered meter readings, the customers were provided with feedback on their electricity consumption. The web portal allowed us to conduct field experiments with high internal validity, since customers were randomly assigned to the experimental conditions or control group upon registration. This means that each customer was provided with a different view, which permitted the evaluation of the view’s effectiveness with regard to energy savings. The design guidelines derived from the experiments with Velix will be highly generalizable for future feedback systems to be used within the Smart Metering infrastructure.

1.4 Contributions

This thesis aims to contribute to both theory and practice. The theoretical foundations of the studies relate to theories from social psychology as well as marketing. More specifically, social norm theory, identity signaling theory, and the concept of defaults are used to improve the two behavioral interventions of goal setting and feedback. Apart from applying these theories to the context of energy consumption, this thesis also aims at advancing general knowledge on social norms, identity signaling, and defaults. With regard to social norms, it is unclear, how descriptive and injunctive norms operate together, as literature and prior research suggest contradictory mechanisms. This thesis contributes to this area by empirically testing the interplay of the two types of norms. Furthermore,
prior research on the relevance of contextual factors for norm adherence is sparse. This thesis addresses this gap by testing the effectiveness of various reference groups in descriptive normative feedback that differ with regard to closeness in geographical proximity. The thesis further contributes to identity signaling theory by addressing the relationship between signaling behavior and the costs that come along with showing a certain behavior. This relationship has not been empirically tested before. Lastly, the use of defaults is extended from one-time behavior to continuous behavior as defaults have been primarily used in the context of purchase decisions until now, not for reoccurring energy-related behaviors. In addition, potential detrimental effects of default goals on energy consumption are investigated. With the ultimate goal of automated tailored behavioral interventions within the Smart Metering infrastructure in mind, the foundations for an algorithm that tailors energy efficiency interventions to the specific characteristics of energy consumers are provided by identifying factors that moderate the effectiveness of the behavioral nudges under consideration. All studies will be conducted in large-scale field experiments, which allow for conclusions with high internal and external validity since biases due to selection effects and measurement errors are less likely to occur than in previous studies in the area of behavioral energy research.

In addition to contributing to the advancement of theories in social psychology and marketing, the results of this thesis aim at
increasing the energy savings for residential energy consumers that can be achieved by the Smart Metering infrastructure. The goal setting and feedback interventions investigated in this thesis have the potential of doubling the effect of Smart Metering. Considering the 3.7% savings that were obtained with “traditional” feedback systems in the pilot study in Germany and Austria [256], even one percent of additional savings would amount to additional savings of 1.4 billion kilowatt hours, 798.3 billion tons of CO₂, and 363.1 million Euro.⁵ Given that the costs for the Smart Metering infrastructure essentially remain the same, this would be a very desirable outcome – not only for utility companies who are in charge of financing the infrastructure but also for residential energy consumers and the society in general.

More specifically, this thesis provides benefits for system developers, governmental institutions, and utility companies. First, system developers learn how to build effective feedback systems for the Smart Metering infrastructure. More specifically, they are provided with a decision support framework that facilitates an automated tailoring of goal setting and feedback interventions to relevant consumer characteristics. The design principles are empirically proven and consider the energy consumer from a less rational and more socially-oriented perspective. Second, managers at governmental institutions such

⁵ Calculations are based on the following statistics: 40.3 million households in Germany, annual average consumption of 3,500 kWh, electricity costs of 25.74 cents per kWh, and CO₂ emissions of 0.556 kg per kWh (also see section 8.3.1, Table 11).
as the “Swiss Federal Office of Energy” (BfE) and at utility companies who are in charge of planning energy efficiency campaigns, receive guidelines on how to develop tailored behavioral interventions on a large-scale. These guidelines are more general in nature than the design guidelines for system developers, and they concern the process of creating an effective energy efficiency campaign. Utility companies will profit from carefully designed behavioral interventions for several reasons. First, they meet their regulatory obligations and achieve significant energy savings. Since they can use the emerging Smart Metering infrastructure to deliver the behavioral interventions, the savings can be achieved quite cost-efficiently. In addition, utility companies extend their product portfolio by introducing innovative energy efficiency services to their residential customers which supports them in differentiating themselves from other competitors and hence attracts new or retains existing customers. In addition, as in this thesis, utility companies can also position themselves as a sustainable company, which in turn allows them to gain local support for important investment projects.

1.5 Outline

The structure of this thesis allows the reader to approach the thesis in a very flexible way. One possibility is to read it like a book because the thesis comprises a general introduction, a general theoretical background, and a general discussion in addition to the four empirical studies outlined above. More
specifically, while Ch. 1 introduces the overall problem that will be addressed in this thesis, Ch. 2 provides a general background on residential electricity consumption, human decision-making, and behavioral interventions that are used to motivate energy consumers to conserve electricity in their homes. Ch. 3 introduces a framework for the design of behavioral interventions that is thereafter adapted to develop the interventions tested within this thesis. The chapter further describes this thesis’ evaluation approach. Chapters 4 to 7 include the empirical evaluations of the four behavioral interventions. Ch. 4 presents a study on the effectiveness of default goals on the choice of savings targets and reductions in electricity consumption. Ch. 5 presents a study on the effectiveness of an identity signaling approach in nudging energy consumers towards higher savings goals. Ch. 6 presents a study on the effectiveness and the interplay of descriptive and injunctive normative feedback on electricity consumption. Ch. 7 offers a study on the effects of reference group proximity on electricity consumption. The thesis closes with a general discussion of the main findings and outlines implications for theory, Smart Metering, households, and society as well as for the design of feedback systems and energy efficiency campaigns (Ch. 8).

Alternatively, instead of reading the thesis like a book, the reader can also focus on a specific behavioral intervention (e.g., goal setting and defaults). Each empirical study represents a scientific article that has been published (Ch. 5), accepted (Ch.
7), and conditionally accepted (Ch. 4). Ch. 6 is a working paper (for references see Table 1). Each empirical chapter provides an introduction to the specific problem that is being addressed by the study, the theoretical background particular to the behavioral intervention that is tested, the methodological approach, the results, and a closing section that discusses the study’s implications for theory and the design of feedback systems and energy efficiency campaigns. The structure of the thesis is depicted in Table 1.

*Table 1: Overview on thesis structure*

<table>
<thead>
<tr>
<th>Thesis structure</th>
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<tbody>
<tr>
<td>Introduction</td>
<td>Theoretical background</td>
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<tr>
<td>Methodology</td>
<td></td>
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<tr>
<td><strong>Intervention 1:</strong></td>
<td>Specific introduction</td>
</tr>
<tr>
<td><em>Goal setting and defaults</em>&lt;sup&gt;6&lt;/sup&gt;</td>
<td>Specific theoretical background</td>
</tr>
<tr>
<td></td>
<td>Empirical study</td>
</tr>
<tr>
<td></td>
<td>Results</td>
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<tr>
<td></td>
<td>Discussion</td>
</tr>
<tr>
<td><strong>Intervention 2:</strong></td>
<td>Specific introduction</td>
</tr>
<tr>
<td><em>Goal setting and identity signaling</em>&lt;sup&gt;7&lt;/sup&gt;</td>
<td>Specific theoretical background</td>
</tr>
<tr>
<td></td>
<td>Empirical study</td>
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<td></td>
<td>Results</td>
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<tr>
<td></td>
<td>Discussion</td>
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</tbody>
</table>

<sup>6</sup> Loock, C.; Staake, T., Thiesse, F. Green IS design for action formation: An empirical investigation of goal setting and the role of defaults. *MIS Quarterly* (conditionally accepted for publication), 1-31. [194]

Intervention 3: Feedback and injunctive and descriptive norms

Specific introduction
Specific theoretical background
Empirical study
Results
Discussion

Intervention 4: Feedback and reference groups

Specific introduction
Specific theoretical background
Empirical study
Results
Discussion

Discussion and conclusions

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8 Loock, C., Landwehr, J., Staake, T., Graml, T., Herrmann, A., Fleisch, E. Well-intentioned is not well done: An empirical investigation of an IS-based energy efficiency intervention using normative consumption feedback. 2012, 1-40. [192]

2 Theoretical background

This chapter provides theoretical background on residential electricity consumption and gives an overview of behavioral models that helps to understand and as a consequence change residents’ energy consumption behavior. Thereafter, it introduces goal setting and feedback interventions as behavioral intervention strategies that represent the two most important functionalities of energy feedback systems due to the central role of goals and feedback in individual decision-making processes. Lastly, this chapter highlights the research gaps that are addressed subsequently in the thesis.

2.1 Residential electricity consumption

This section highlights the importance of addressing residential electricity consumption to secure future energy supply. It also proposes behaviors that are relevant and feasible to change.

2.1.1 Electricity uses in the household

To assure energy supply for future generations, reducing electricity consumption represents a promising avenue. Today, electricity consumption constitutes one-fifth of the world total final energy consumption. It will become even more important in the next twenty years since it is projected to grow more rapidly than total energy [15,152]. The residential sector is responsible for a large share of electricity end use. Households
account for 37% in the U.S. and 29% in the EU.\textsuperscript{10} Residential electricity consumption has risen continuously since 1949 mainly because of the increasing electricity use for household appliances.\textsuperscript{11} From 1990 to 2005 the use of electricity by household appliances grew by 57%.\textsuperscript{12} In 2005 electricity consumption by appliances constituted the largest share of total household electricity use.\textsuperscript{13} Since major appliances such as refrigerators, washing machines, and dryers have become more energy-efficient due to minimum energy performance standards over the years, the increase in electricity consumption can be attributed to the increasing ownership of small appliances such as personal computers or audio equipment.\textsuperscript{3}

In order to reduce electricity consumption, it is important to understand that individuals largely determine residential consumption by their behavior, although they do not demand electricity per se. Instead, electricity demand is a “derived demand” meaning that electricity is combined with other goods in order to produce services individuals wish for [225]. A review of electricity uses in the U.S. residential sector shows that space cooling constitutes the largest share of total electricity consumption (22.4%), followed by lighting (14.2%), and water heating (8.9%).\textsuperscript{14} Other electricity uses include refrigeration,

\textsuperscript{14} http://www.eia.gov/tools/faqs/faq.cfm?id=96&t=3 [accessed on 23.07.2012]
watching television, space heating, drying clothes, using computers, cooking, washing dishes, using the freezer, and washing clothes (see Table 2). Cutting residential electricity consumption therefore requires targeting not just one but a whole set of behaviors that need electricity.

Table 2. Overview on electricity uses in the U.S. residential sector\textsuperscript{15}

<table>
<thead>
<tr>
<th>End use</th>
<th>Billion kWh</th>
<th>Share of total</th>
</tr>
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<tbody>
<tr>
<td>Space cooling</td>
<td>326</td>
<td>22.4%</td>
</tr>
<tr>
<td>Lighting</td>
<td>207</td>
<td>14.2%</td>
</tr>
<tr>
<td>Water heating</td>
<td>129</td>
<td>8.9%</td>
</tr>
<tr>
<td>Refrigeration</td>
<td>107</td>
<td>7.3%</td>
</tr>
<tr>
<td>Color televisions and set-top boxes</td>
<td>100</td>
<td>6.8%</td>
</tr>
<tr>
<td>Space heating</td>
<td>84</td>
<td>5.8%</td>
</tr>
<tr>
<td>Clothes dryers</td>
<td>54</td>
<td>3.7%</td>
</tr>
<tr>
<td>Personal computer and related equipment</td>
<td>53</td>
<td>3.6%</td>
</tr>
<tr>
<td>Furnace fans and boiler circulation pumps</td>
<td>41</td>
<td>2.8%</td>
</tr>
<tr>
<td>Cooking</td>
<td>31</td>
<td>2.2%</td>
</tr>
<tr>
<td>Dishwashers</td>
<td>27</td>
<td>1.8%</td>
</tr>
<tr>
<td>Freezers</td>
<td>23</td>
<td>1.6%</td>
</tr>
<tr>
<td>Washing machines</td>
<td>10</td>
<td>0.7%</td>
</tr>
<tr>
<td>Other uses</td>
<td>264</td>
<td>18.1%</td>
</tr>
<tr>
<td><strong>Total consumption</strong></td>
<td><strong>1363</strong></td>
<td></td>
</tr>
</tbody>
</table>

Behaviors that determine residential electricity consumption can be divided into two categories: The adoption of household equipment (e.g. insulation, household appliances) and the use of that equipment [287]. The two types of behavior differ with

\textsuperscript{15} http://www.eia.gov/tools/faqs/faq.cfm?id=96&t=3 [accessed on 23.07.2012]
regard to frequency and financial costs. Residents make investment decisions much less frequently than they use existing appliances. In addition, financial costs are more important for decisions involving the adoption of household equipment than for the use of existing appliances [287]. In accordance with the two types of electricity-related behaviors, activities to conserve electricity involve so-called efficiency and curtailment behaviors [5,113,287]. Efficiency behaviors are one-shot behaviors and require the purchase of energy-efficient equipment or the installation of efficiency-improving modifications to existing equipment. Curtailment behaviors involve continuous efforts to reduce electricity use by using equipment less frequently or intensively [5,113]. From an economic and technical perspective, efficiency-improving actions have a higher savings potential than curtailment behaviors [113]. However, the way residents operate their appliances can significantly amplify or dampen the effects of technology-based efficiency improvements [10,195].

2.1.2 Reasons for the efficiency gap

According to the classic economic perspective, individuals should act rationally and thus are more likely to show efficiency behaviors than curtailment behaviors because they involve a higher potential for energy conservation [10]. For example, buying a highly fuel-efficient car saves more energy than car sharing, reducing highway speeds, consolidating errand trips, and changing driving habits all together [113]. In addition, efficiency behaviors also require less effort in terms of
frequency. However, they often do not engage in efficiency behaviors. Households and businesses in the U.S. could reduce their consumption by 23% and thereby save 1.2 trillion USD if they took straightforward measures (e.g., insulation) at an upfront cost of 520 billion USD [10,126]. The differences between the current levels of energy efficiency and those that should be observed if consumers had made the “appropriate” rational decisions are often referred to as the “energy efficiency gap” [158].

The reasons for this efficiency gap are manifold and include economic, structural, and psychological barriers. First, efficiency behaviors involve higher financial costs than curtailment actions [113]. From a rational perspective, the high upfront costs pay off in the long-term, but people often refuse to take actions which have strong long-term benefits if they are unpleasant in the short run [10]. The preference for investments that pay off very soon can be attributed to the high implicit discount rates that energy consumers use [140,209] Another significant barrier to efficiency behaviors is incentive splits between tenants and landlords [126,158]. For example, landlords do not benefit from insulating their houses because it is the tenant who pays the energy bill. While these factors certainly represent important reasons for the energy efficiency gap, other reasons are rooted in the nature of human information processing.

The fact that people do not act rationally when making decisions concerning energy and thus do not maximize benefits [253] is
often explained by the concept of bounded rationality [278]. According to this perspective, individuals cannot act like fully informed and rational decision makers when making energy choices because their decision making is limited by available information, cognitive capacities, and time [63,278]. Therefore, individuals are seeking satisficing solutions instead of optimal decisions. For this purpose, individuals use mental short cuts or so-called heuristics. Heuristics work as rule of thumb and help individuals to reduce the effort involved in decision making [295]. For example, individuals rely on a simple heuristic when estimating the energy consumption of appliances: They believe that the larger the appliance the more energy it uses [21]. Furthermore, people often overestimate the amounts of energy used and the savings potential from appliances that are visible and must be activated each time they are used [169,253]. The use of heuristics such as size, visibility, and frequency of action therefore leads people to overestimate the effectiveness of curtailment behaviors in reducing their energy bill.

2.1.3 Smart Metering for large-scale energy conservation

The recent emergence of Smart Meters provides interesting opportunities for reducing residential electricity consumption [283]. The Smart Metering infrastructure allows for addressing a large group of energy consumers with behavioral interventions due to its pervasiveness. According to a European directive, Smart Meters should be installed when an existing meter is replaced, when a new building is connected to the electric grid, or when an existing building undergoes major renovations, as
long as the equipment is technically feasible and economically reasonable. By 2020 at the latest, 80% of all households in Europe will be equipped with Smart Meters [88,249]. Given that savings potentials of the households differ between countries due to different household characteristics according to impact assessment [16,112], the advocated roll-out strategy may not be the ideal solution for every EU member state. For example, in Switzerland only a full roll-out would be more effective and cost-efficient than the current status quo that comprises traditional electricity meters and energy efficiency campaigns [16]. The full roll-out is expected to achieve benefits of 2,5 Billion Swiss Francs at upfront investments of one billion Swiss Francs [16]. A recent report shows that early adopters like Italy have already reached a penetration rate of close to 100% which amounts to 30 Mio households with Smart Meters [126]. In Norway, Sweden, Finland, and Denmark more than 50% of all households already have Smart Meters. Some countries haven’t rolled out Smart Meters yet but are actively testing them in pilot projects and have set up timelines for roll-out. The status quo shows that millions of households are already equipped with Smart Meters or are about to receive them. This provides a unique infrastructure for large-scale energy efficiency interventions but it also requires a careful design of these interventions in order to make the costly infrastructure more cost-efficient.

The Smart Metering infrastructure includes IS to provide energy consumers with feedback on their electricity consumption. The
European directive requires utility companies to provide customers with information on actual electricity consumption and costs to enable them to make better-informed decisions with regard to electricity use [75,256]. The Smart Metering infrastructure encompasses three basic components: Metering devices and associated devices, communication and data processing infrastructure, and in-home energy use display (see Figure 2, [22]). The Smart Meters measure the electricity consumption and transfer the data either directly or indirectly to the consumer. In the first case, the data is transferred via a Home Area Network (HAN) and is displayed on an in-home display. In the latter case, the consumption data measured by the Smart Meter is transferred via Wide Area Network (WAN) to the electronic data management (EDM) system at the network operator, metering operator, or supplier. Feedback on electricity consumption is then presented via in-home display, web portal, invoice, or mobile phone [22]. Depending on the architecture of the Smart Metering infrastructure and the mode of presentation, the energy consumer is provided with feedback on electricity consumption at different time intervals, ranging from real-time direct feedback (e.g., in-home display, direct data transfer) to hourly, monthly, or even less frequent indirect feedback (e.g., bill, indirect data transfer).
The Smart Metering infrastructure can be used for behavioral interventions that target either efficiency behaviors, curtailment behaviors, or both. To support efficiency behaviors, it is essential to provide device-specific feedback. Several attempts have been made to break down the aggregate electricity consumption to the specific use of appliances since this would allow residents to identify energy guzzlers in the household and replace them with new energy-efficient appliances, if necessary (for an overview see [103]). Until now, the breakdown of consumption does not work automatically, instead requiring additional user effort involving self-reports of appliance usage or manual input [167,296,303,307], or it involves additional technological equipment like voltage sensors [85,302]. Curtailment behaviors by contrast can be supported by the Smart Metering infrastructure without much effort. Feedback on
overall electricity consumption compared to either previous consumption or other households helps individuals to understand if their electricity consumption is relatively high or low and thus creates awareness of the problem of cutting electricity consumption [103]. Consequently, energy users know that they have to use their appliances less frequently or less intensely in order to conserve electricity. The different feedback channels (e.g., in-home display, web portal) can further be used to provide customers with advice on how to reduce their electricity consumption.

2.1.4 Summary

To secure future energy supply, cutting residential electricity consumption represents an important strategy due to its high share and its expected increase in the future. Since residents do not demand electricity per se, it is necessary to focus on a whole set of behaviors in the household that are associated with electricity consumption. Individuals need to be motivated to operate their appliances in a more efficient and electricity-saving manner. Addressing these curtailment behaviors is feasible since people naturally prefer curtailment behaviors over efficiency behaviors and since the emergence of Smart Metering enables behavioral interventions for millions of households in Europe and the U.S.
2.2 Factors that influence residential electricity consumption

This chapter reviews the most prominent behavior models to show which factors determine electricity consumption. Understanding human decision-making processing is crucial to build effective behavioral interventions. The variety of influence factors make clear, that interventions that only address rational cost/benefit arguments consider just one factor among many others. The chapter outlines the meaning of normative concerns, contextual factors, goals, and feedback for electricity consumption in addition to self-interest. The chapter starts with a brief overview, describes models that focus on specific relationships, and then continues with more comprehensive models.

2.2.1 Overview of behavioral models that explain environmental behavior

To reduce residential electricity consumption, it is important to understand the underlying motives that drive human behavior [281]. Models of pro-environmental behavior or of behavior change represent frameworks that help to identify factors that should be addressed by behavioral interventions. The models originate mainly from two perspectives: (i) the economic paradigm and (ii) the behaviorist paradigm [207,251]. The former takes the perspective of rational choice theory, which postulates that individuals make decisions by estimating the individual costs and benefits of different behavioral option and
choosing that option that maximizes their expected net benefits [156]. Rational choice theory assumes that individuals are mainly driven by self-interest. Furthermore, it assumes that individuals make reasoned choices based on the entirety of information available to them. This model is often used by policy makers who consequently try to change people’s behavior by providing them with sufficient information to make adequate behavioral choices [156]. However, scientific evidence shows that individuals are ultimately bounded in their rationality because of the cognitive burden of information processing, which limits their ability to make optimal decisions [278]. Instead, individuals look for satisficing decisions (= decisions that are good enough) and use mental "short-cuts" (e.g., rules, habits, emotions) which may reduce or even bypass cognitive deliberation entirely, undermining the assumptions that underlie the models of rational choice [138]. Models of rational choice further claim that individual decisions are based on individual deliberation and thereby neglect the fact that human behavior is always embedded in a social context and as such is influenced by social and interpersonal factors [156]. Furthermore, rational choice models cannot explain why individuals sometimes exhibit a certain behavior even if it is not benefitting them. Behavior seems not only driven by self-interest but also by moral and altruistic concerns. The shortcomings of the economic paradigm led to the emergence of the behaviorist paradigm. This paradigm assumes that an individual’s behavior is determined by the complex interplay between intrapersonal factors (e.g., attitudes, values), interpersonal factors (e.g.,
norms, social comparison), and external factors (e.g., rewards, punishments) [118]. Depending on the importance that researchers attribute to the different groups of influence factors, they use different models to explain pro-environmental behavior. Researchers who view intrapersonal factors as most important rely on models like the “theory of reasoned action” (TRA) [13,105] or its successor, the “theory of planned behavior” (TPB) [8,13]. These models are based on rational choice models and extend the basic assumptions by incorporating intrapersonal factors such as subjective norms or perceived behavioral control. In contrast, researchers who view behavior primarily as pro-socially motivated often use “Norm-Activation-Model” (NAM) [24,132,265] or “Value-Belief-Norm-Model” (VBN) [164,286] as theoretical framework. These models elaborate on the antecedents of moral or pro-social behavior. The ‘Focus Theory of normative conduct’ (FT) [66] has a stronger focus on interpersonal factors that determine environmental behavior. According to the FT, behavior is affected not only by intrapersonal factors such as personal norms, but what other people do and think about a certain behavior (i.e., social norms) has a strong influence on whether individuals exhibit a certain behavior or not.

Since the predictive power of behavioral models increases if the models account for both intrapersonal and interpersonal factors, some models have been developed to integrate the different theoretical views. According to integrative models like Triandis’s ‘Model of Interpersonal Behavior’ (TIB) or the
‘Motivation-Opportunity-Ability Model’ (MOA), behavior is best viewed as a mixture of self-interest and concern for other people [24,294,315]. The models further consider external factors like habits, the household’s budget, or the choice context since the ability to save energy is highly dependent on these factors. When these non-motivational factors strongly inhibit or ease pro-environmental actions, psychological motivations are relatively unimportant [134]. The most comprehensive model to date to explain pro-environmental behavior is Bagozzi’s “Model on effortful decision-making and enactment” (MED) [19]. In addition to the previously mentioned factors, the model considers the bidirectional relationship between behavior and antecedents and elicits the role of feedback for future decision making processes and the formation of habits. The model further attributes a key role to behavioral goals since the desire to achieve a certain goal triggers a chain of decision making processes and ultimately leads to the enactment of the goal-directed behavior. The key characteristics of the behavioral models are depicted in Table 3.

Table 3. Overview on behavioral models that explain pro-environmental behavior

<table>
<thead>
<tr>
<th>Behavioral model</th>
<th>Intra-personal factors</th>
<th>Inter-personal factors</th>
<th>External factors</th>
<th>Goals</th>
<th>Feedback</th>
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<tbody>
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<tr>
<td>TPB</td>
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<tr>
<td>VBN</td>
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2.2.2 Self-interest as driver for environmental behavior

In their TRA (Figure 3), Fishbein and Ajzen regard the intention to perform a specific behavior as the strongest predictor for the actual performance of that behavior [105]. “Intentions are assumed to capture the motivational factors that influence a behavior; they are indications of how hard people are willing to try, of how much of an effort they are planning to exert, in order to perform the behavior” [8]. Behavioral intentions always relate to a specific behavior and can only influence behavior if it is under volitional control. The strength and direction of the intention depends on the attitude towards the behavior which is formed by the beliefs about and the evaluations of the outcome. The attitude is hence the result of a rational evaluation of costs and benefits. A second major influence on intention has a person’s subjective norm, that is the perception that most people who are important to the individual think he or she should or should not perform the behavior in question [105]. The subjective norm can be understood as the perceived social pressure to perform or not perform a certain behavior. The primary motive why people tend to conform to social norms is the fear of social exclusion [23]. If attitude and subjective norm contradict each other - that is, point to different actions - the

<table>
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<td>FT</td>
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<tr>
<td>TIB</td>
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<tr>
<td>MOA</td>
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<tr>
<td>MED</td>
<td>Yes</td>
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individual will compare the two aspects and choose that action that is related to the more important factor.

The ‘theory of planned behavior’ (TPB) [8] builds on the TRA and extends it by incorporating perceived behavioral control (PBC) as an additional predictor of both intention and behavior. PBC is defined as “the person`s belief as to how easy or difficult performance of the behavior is likely to be” [197] and is similar to Bandura’s concept of self-efficacy [25]. It influences behavior both directly and indirectly by affecting behavioral intentions. The higher the perceived behavior control, the stronger is the intention to perform a certain behavior and the more likely are individuals to achieve a good performance.
Both TRA and TPB stress the importance of cost/benefit arguments and assume that the individual will make a rational choice based on all available information. The individual is seen as a utility-maximizing actor [8,24] who would choose that course of action that is associated with the most positive behavioral consequences in terms of monetary benefits and social approval. The two models assume that non-motivational factors such as the availability of requisite abilities and resources are given and focus on behavior that is under volitional control [8]. Thus, automatic processes such as habits are not considered. In addition, the two models state that behavior is mediated by attitudes or intention, but they do not consider the reverse relation. Still, individuals sometimes infer their attitudes from the observation of their behavior [34] which shows that behavior change does not necessarily require a preceding attitude change.

The TPB has proven to be successful in explaining environmental behavior that is characterized by high behavioral costs or strong situational constraints [281]. It has been applied to explain travel mode choice [24], household recycling [163], waste composting [199], purchase of energy-saving light bulbs, use of unbleached paper, water use, meat consumption [137], and general pro-environmental behavior [165]. Meta-analyses of the TRA and TPB show that the models are better in predicting behavioral intentions than actual behavior. For example, the meta-analysis by Armitage and Connor revealed that the TPB explains about 39% of variance in intention and 27% in
behavior [13]. Another meta-analysis showed that the two models explain between 40% and 50% of the variance in intention and between 19% and 38% of the variance in behavior [289]. The inclusion of the PBC component by the TPB has proven to increase the predictive validity of the model [197].

2.2.3 Moral and normative concerns as driver for environmental behavior

Given that individuals sometimes perform behaviors that are not beneficent for them from an economic point of view, some researchers have focused on the role of moral and normative concerns underlying behavior from different theoretical perspectives. The NAM (Figure 4, [265]) tries to explain under which conditions people feel morally obliged to act pro-environmentally. The model regards personal norms, that is the feeling of moral obligation to perform or refrain from specific actions [264], to be the only direct determinant of pro-social behavior. Whether the personal norm is activated depends on whether one is aware of the consequences of one’s behavior and accepts the responsibility for one’s own behavior.
Stern and colleagues investigated under which conditions people accept the consequences of their behavior and suggest in their VBN that the acceptance is influenced by the “…view that human actions have substantial adverse effects on a fragile biosphere” which he calls an ecological world view [286]. The strength of the ecological world view in turn depends on the value orientations of a certain person that can be either egoistic, altruistic or traditional. Individuals with altruistic values are more likely to engage in pro-environmental behavior than individuals with egoistic values [281].

While both NAM and VBN theory shed light on and stress the importance of intrapersonal factors such as moral concerns and value orientations, they do not account for interpersonal or external factors. The theories have been successfully applied to explain political behavior (e.g., [135]), environmental
citizenship [284], and policy acceptability [282], but they have far less explanatory power in situations characterized by high behavioral costs or strong constraints on behavior [24,281]. Similar to TRA and TPB, the VBN and NAM theory focus on deliberate behavior and do not consider automatic, non-conscious behavior. In addition, they also do not consider the reverse effect of behavior on value orientations and normative concerns.

Another theoretical perspective on normative concerns underlying pro-environmental behavior is offered by the FT [66]. The theory addresses the influence of social norms on behavior. Unlike the TRA or TPB, the definition of social norms is not restricted to the perceived social pressure to show a certain behavior. Instead, Cialdini and colleagues redefine the concept of social norms since a norm has more than one meaning [271]. A norm can either refer to what is commonly done (descriptive norm) or to what is commonly approved – that is, what is socially sanctioned (injunctive norm) [66]. The two types of norms represent different sources of motivation. Descriptive norms are used to gain an accurate understanding of a current social situation and to choose an adequate action [66,67]. They represent a decision shortcut or heuristic since they do not require much cognitive effort [211]. Injunctive norms by contrast indicate what ought to be done and thus motivate action by promising social rewards or punishment (social sanctions) [66]. People hence adapt their own behavior to injunctive norms in order to be liked and accepted by other
people [14]. A second refinement of the FT was the definition of “norm focus” as a requirement for normative influence. According to Cialdini and colleagues, social norms are unlikely to exert influence on behavior unless they are salient for an individual at the time of behavior [66].

The explanatory and predictive value of social norms has been questioned ever since meta-analyses on the TPB found the normative component to have a weak predictive power. However, this could be explained by a combination of poor measurement and the need for expansion of the component [13]. By refining the concept of “norm” Cialdini and colleagues solved the long-standing controversy and showed that behavioral interventions applying social norms are very effective in motivating pro-environmental behavior such as not littering [66], recycling [262], re-using towels [121] and conserving energy [259]. A meta-analysis has shown that descriptive and injunctive norms have strong effects on both attitudes and behavior with descriptive norms having larger effects on behavior and injunctive norms having larger effects on attitudes. Both types of norms are especially effective in the context of socially responsible behaviors [212].

2.2.4 The role of non-motivational factors in energy consumption behavior

The behavioral models presented above do well in predicting behavioral intentions; however, they perform worse in explaining actual behavior [13]. The gap between the motivation to perform a behavior and the actual behavior is termed
“intention-behavior gap” or “attitude-behavior gap” [171,280]. Whether someone turns intention into behavior depends not only on intrapersonal factors such as attitudes and values but also on external factors (e.g., budget, physical abilities) or habits [171]. When these factors strongly inhibit or ease pro-environmental behavior, psychological motivations are relatively unimportant [281,287]. One study, for example, showed that more individuals engage in recycling if it is convenient for them; however, the increased convenience reduces the explanatory power of psychological factors [134]. Thus, unless contextual factors are considered, behavioral models fail to explain behaviors that are constrained in some aspect [114,281,315].

Models like the MOA [315] or the TIB (see Figure 5, [294]) account for the influence of contextual factors on behavior in addition to intrapersonal and interpersonal factors. Since Triandis’ theory has gained more scientific attention and has been applied more often than the MOA model to explain and predict behavior, this section focuses on the TIB. Similar to the TPB, Triandis’ s TIB includes expectancy-value and normative beliefs constructs and tries to explain the intention to perform a specific behavior and the actual performance of that behavior [24]. The TIB adds to the TPB by suggesting habit as another important predictor of behavior since behavior is often habitual and guided by non-conscious cognitive processes rather than preceded by elaborate reasoning [281]. Habit is defined as “situation-behavior sequences that are or have become automatic, so that they occur without self-instruction. The
individual is usually not ‘conscious’ of these sequences” [294]. The TIB proposes that the level of consciousness decreases as the level of habit in performing the behavior increases [24]. A second difference between TIB and TPB is the consideration of affect as influencing the intention to perform a specific behavior. In addition, the definition of the normative belief construct is much broader than in the TPB and includes personal norms, role beliefs about the appropriateness of the behavior for one’s perceived social role, interpersonal agreements, and self-definitions [24]. Unlike TPB, the TIB further addresses the intention-behavior gap and suggests that the execution of the intention can either be facilitated or hampered by situational conditions. While Triandis’ TIB does not specify these external forces on the intention-behavior gap, the MOA Model gives some examples: According to that model, these facilitating conditions can refer to ability, knowledge, opportunity, and overall situational conditions [315].
The TIB is a comprehensive model and can be regarded as a synthesis of other popular behavioral models that focus more on one specific aspect. It includes intrapersonal, interpersonal, and external factors that are highly relevant for the energy context. By doing so, it accounts for the fact that individuals do not act as utility-maximizing ration decision makers but look for satisficing options by using mental short-cuts such past behavior. The model further accounts for non-conscious actions and is applicable not only to low-cost behaviors but also to behaviors that are constrained by situational conditions.
However, similar to the other models presented above, the TIB does not account for the influence of behavior on attitudes.

Several studies have compared the predictive validity of the TIB to other established models such as the TRA or TPB. For example, one study compared the TRA and the TIB in the context of predicting exercise intention and behavior [297]. The authors found that the addition of habits and affect as well as social and personal belief components helped to explain intention and behavior. Another study compared the TRA, TPB, and TIB in the context of predicting undergraduate condom use [52]. In this study, one construct of the TIB, personal norm, significantly increased the predictive power offered by TRA or TPB in explaining intention. Bamberg and Schmidt (2003) found that Triandis’ model can better explain the students’ car use than the TRA and the NAM. In explaining behavior, Triandis’ habit construct significantly raises the explained behavioral variance (from 45% to 51%) [24].

2.2.5 The role of goals and feedback in energy consumption behavior

One of the most elaborate attempts in recent years to capture a wide range of influences on behavior in a single composite theory of human behavior is the “Model on effortful decision-making and enactment” [19,20,156]. Like the TIB, the model includes intrapersonal factors, interpersonal factors and external factors. However, it adds to the previous behavioral models by highlighting that goals and feedback play a central role in the decision making process (see Figure 6, [20,156]). The desire to
achieve a certain goal is key to the whole process since it triggers a chain of decision making processes and ultimately leads to the enactment of the goal-directed behavior. Specifically, Bagozzi distinguishes between decision making and goal striving and propose that a decision has two components [20]. The first component is goal intention, the decision maker’s self-commitment to achieve a chosen goal, which represents the result of deliberative processes wherein alternative outcomes are evaluated based on their desirability and feasibility [20]. This component is comparable to the intention construct in the TRA, TPB, or the TIB. After forming the goal intention, the decision maker proceeds to the implementation intention stage, where he or she makes an implementation plan that finalizes details regarding when, where, how, and how long to perform the goal-directed action. The two types of intention are preceded by “desires”. Whereas goals refer to specific end-states that the decision maker seeks to attain, desires pertain to the intensity or level with which the goal is sought [17]. The strength of the goal desire depends on multiple factors such as goal feasibility, anticipated emotions (“emotions experienced in anticipation of imagined future goal success/failure”), and anticipatory emotions (“presently felt emotional responses to the prospect of a desired/undesired future event”). Behavioral desire precedes implementation intention and is mainly influenced by factors that have been proposed by the TPB [8] such as attitudes, subjective norms, and PBC among others. In addition to the concept of intention, Bagozzi’s model introduces the concept of “trying” which
represents a “singular subjective state summarizing the extent to which a person believes that he or she has tried or will try to act, including the effort put forth in this regard” [18]. Trying mediates the influence of intentions to act on actual goal-directed actions [20].

As soon as a certain goal-directed behavior is enacted, the goal attainment or failure provides feedback on the effectiveness of a certain strategy in achieving the goal. Feedback influences future decision-making processes because it affects both antecedents of goal desire (goal feasibility, anticipated emotions, anticipatory emotions) as well as behavioral desire (outcome expectancies, attitudes, subjective norms, PBC, moral values, etc.). By informing individuals about the success or failure of a certain strategy for achieving a goal, feedback plays an important role in habit formation. When feedback is positive, it is likely that the individual will choose the same strategy for goal achievement in the future. The more often a certain action is performed, the less deliberate processing is required. Once a habit is acquired, habitual behavior is initiated and performed more or less automatically as a response to learned cues with little conscious self-regulation [17].
The model by Bagozzi has several advantages and disadvantages [20]. It provides a very detailed conceptualization of the decision-making process and offers a more sophisticated understanding of consumer behavior than simple expectancy-value theories [156]. In addition, it is one of the very few models that considers the role of goals for the decision making process and explicitly models the role of performance feedback on antecedents and subsequent behavior. However, it is so comprehensive and complex that it lacks parsimony [8].
Consequently, empirical evidence for the whole model is sparse [156].

The only attempt to test the model has been made by Bagozzi and colleagues, who conducted a study with 169 students to assess the validity of a (preceding) model [19]. The authors found that their proposed model explained 70 percent of the variance in goal realization, whereas only 10 percent of the variance can be explained by variables in the TPB. Furthermore, a number of studies have focused on specific relationships between different variables and have found empirical support [156]. For example, a meta-analysis on 10 meta-analyses involving 82,107 subjects shows that goal intentions accounted for 28% of variance in behavior [272]. Another study focused on implementation intentions and found that they facilitate goal intentions [122]. Similarly, the validity of other concepts that are central to Bagozzi’s model (e.g., goal desire, implementation desire, anticipated emotions) have been assessed [122] or can be assumed since some of the components and relationships are drawn from other behavioral models (e.g., TPB) that have been extensively assessed elsewhere [13].

2.2.6 Summary

This section reviewed the most prominent behavioral models and showed that electricity consumption or behavior in general is determined by the complex interplay between intrapersonal, interpersonal, and external factors [118] and not just by cost/benefit arguments that are primarily considered in traditional feedback system design. Goals and feedback play a
key role in the whole decision-making process. The models help to understand behavior but cannot be used as a blueprint for behavioral interventions [76], as it is not feasible to address all influencing factors at the same time. Consequently, it is necessary to focus on those factors that seem most relevant for motivating energy conservation.

2.3 Behavioral interventions for changing residential electricity consumption

This section provides an overview of behavioral interventions that have been applied to change environmental behavior. Thereafter, goal setting and feedback are explained in further detail because they represent two basic functionalities of feedback systems that are required by law [88] and by energy consumers [303] and that address two central factors in individual decision-making processes. The section highlights both the effectiveness and shortcomings of the two strategies and outlines the research gaps that are addressed later in this thesis.

2.3.1 Overview of behavioral interventions used to motivate energy conservation

In the last three decades various strategies for behavior change have been developed, each focusing on a different set of behavioral determinants [5,281]. To classify the variety of interventions, several frameworks have been proposed. Geller, for example, states that interventions address and try to modify
the “ABCs” of behavior, that is antecedents, behavior, and consequences [115]. Later, this framework was modified by other researchers [5,87]. The taxonomy now encompasses only two categories: Antecedent and consequent strategies.

Antecedent strategies aim at changing factors that precede environmentally significant behavior. For instance, households could be provided with information on the necessity of reducing their electricity consumption to increase problem awareness or with advice on how to save electricity in order to increase their knowledge and ability to successfully cut electricity consumption. Further strategies include commitment, prompts, role models, and goal setting. In contrast to antecedent strategies, consequence strategies try to influence factors after the target behavior has occurred, by means of providing a consequence which depends on the outcome of the behavior [5,281]. For example, feedback on energy savings may encourage households to reduce energy use, because they perceive that the feasibility of achieving energy savings has increased and hence believe that positive outcomes of their efforts are more likely to occur. Further examples for consequence strategies include rewards for achieving a certain behavioral goal and penalties for not attaining it.

2.3.2 Goal setting as an antecedent strategy

One of the most successful antecedent strategies is goal setting since goals have a central meaning for the whole decision-making process [17,20]. A goal is "the object or aim of an action, for example, to attain a specific standard of proficiency,
usually within a specified time limit" [188]. Goal-directed behavior can either be under volitional control or automatic, since the origins of automatic or habitual behavior reside in prior deliberative processing or learning [17]. In habituated actions such as driving a car, goals are activated by external stimuli or cues and cognitive and behavioral processes operate to initiate and guide action automatically.

Since goals ultimately guide behavior, the activation and setting of a goal represents the beginning of a course of mental and physical actions [189]. Once a goal is set, it acts as a reference point for a future desirable state or standard. Consequently, the goal setting process is "first and foremost a discrepancy-creating process" [27]. The effect of goal setting on behavior is argued to stem from different mechanisms. First, a goal directs a person’s attention and effort toward the activities relevant to the goal and away from irrelevant activities [188]. After the goal is set, a person engages in so-called action planning which includes planning on when, where, and how to achieve the goal. Consequently, goal setting holds the potential to bridge the intention-behavior gap [280]. Second, goals have an energizing function and affect one’s persistence [177]. If people are free to choose the amount of time that they would like to invest in achieving a goal, then ambitious goals will prolong the amount of time required to do so. Third, goals also indirectly affect action by leading people to desire, discover, and/or use knowledge and strategies related to the task at hand [312].
The effects of goal setting on behavior have been summarized and formalized by the goal setting theory, which represents one of the most prominent theories in psychology. Since Locke and Latham formulated the theory in 1990, the theory has generated more than 1,000 studies [181]. Empirical evidence for the theory has been found across various study settings, time spans, and cultures [181]. The theory explores the kind of goals effective in motivating behavior change and also specifies the conditions under which goals exert a positive influence on behavior. According to goal setting theory, there is a positive linear relationship between goal difficulty and behavior, meaning that the more difficult the goal the higher the performance [188]. However, a goal should still be realistic and not too high because goals need to be attainable and plausible [72]. In addition, specific goals are more effective than vague “do your best” goals. Hence, people with specific hard goals perform better than those with vague or specific easy goals. However, similarly to the behavioral models presented earlier, goal setting theory states that goals only have positive effects on behavior if certain conditions are fulfilled. For example, individuals need to have the knowledge and ability to perform a certain behavior. Individuals also need to be committed to achieve a certain goal which is more likely if they perceive the goal as being relevant and believe that the goal is attainable [182,188]. For reasons of ability and goal commitment, goals that are self-set are often more effective than assigned goals. If individuals set their own goal, they consider their abilities and set a goal that seems realistic to them. Assigned goals, in contrast, may have zero or
negative effects on performance if they are too high. They affect the individual’s belief that he or she can attain the goal since goals communicate normative information to the individual by suggesting the level of performance that he or she can expect to attain [214].

Since goal setting is one of the most successful strategies for behavior change, researchers have also used goal setting strategies to change energy consumption behavior. Given that feedback represents a requirement for goals to be effective, goal setting is often combined with feedback. For example, one study that used an Internet-based tool to motivate households (N = 189) to reduce their energy use, tested whether the combination of tailored information, goal setting (5%) and tailored feedback is more effective than information and feedback alone [6]. As expected, households that received the combination of interventions saved 5.1%, while households in the control group even increased consumption by 0.7%. Households exposed to the interventions not only adopted a higher number of energy-saving behaviors, but also had significantly higher levels of energy conservation knowledge levels than the control group. Similarly, McCalley and Midden found that participants who had been given a goal as well as feedback saved more energy per (virtual) washing trial than participants who had only received feedback (without a goal) [201]. Other studies tested the effect of different levels of goal difficulty or different types of goals (self-set vs. assigned). For example, in one study two groups of 40 households were either given electrical
consumption feedback or not, three times a week [31]. The two groups were also divided into those with an easy savings goal (2%) or a difficult savings goal (20%). The results showed that the households that received difficult saving goals plus feedback used significantly less (13%) electricity.

Since theory and empirical evidence suggest that high and specific goals lead to higher performance, it is a challenge to motivate people to choose ambitious goals. Assigning high goals does not seem to be an appropriate approach because these goals might induce lower commitment levels and impair the self-efficacy of individuals. However, individuals naturally prefer easy goals over difficult goals. Scott and colleagues asked participants to choose energy conservation goals from a list and gave immediate feedback on the effectiveness of the conservation goals in terms of money saved or impact on carbon footprint [267]. The goals varied in difficulty and specificity. The researchers found that the most popular goal choices were very ineffective in terms of savings (kWh and money) [268]. The preference of easy goals over difficult challenging goals is problematic since easy goals are not only less effective in terms of energy conservation but also less motivating according to goal setting theory. Hence, people need support to choose the right goals in terms of effectiveness and strength of motivation.

2.3.3 Feedback as a consequence strategy

Providing feedback is one of the mostly widely applied psychological interventions [170]. Feedback on goal success or failure closes the loop between behavior and behavioral
antecedents [17]. By relating past experience with future decision-making processes, feedback significantly guides human behavior and enables behavior change. The power of feedback on behavior stems from its learning and motivational functions [170]. Feedback provides information about the consequences of one’s actions and hence reduces uncertainty. Apart from that, it supports the formation of habits and routines. When feedback about a certain action is positive, that is the goal of a certain behavior has been achieved, the particular strategy that was chosen to achieve the goal is reinforced and is thus more likely to be chosen in the future, when the individual wants to achieve the same goal again. As a result of habit formation, individuals behave in an energy-conserving way without being energy-conscious all the time [149]. In addition, since feedback affects behavioral antecedents such as attitudes and values [17], it supports the internalization of behavior. Through the confrontation with one’s own behavior pro-environmental attitudes are formed. According to Bem’s ‘Self-Perception Theory’ individuals infer information about their attitudes by observing their own behavior [34]. These new, energy-conscious attitudes consequently enter into future decision-making and increase the likelihood for pro-environmental behavior [149]. In addition to these informational functions, feedback also affects motivation. It informs individuals about their progress toward their behavioral goals (e.g., energy conservation) and highlights discrepancies between the current status quo and the goal. Discrepancies in turn motivate individuals to adjust their effort or revise their goals [154,170],
because people are motivated to remove or reduce the discrepancy between their goals and their performances [61]. Furthermore, feedback can be seen as having a reward function because individuals will be satisfied if the feedback indicates to them that they achieved their goal.

Feedback interventions vary in terms of frequency (e.g., continuous vs. monthly), duration (e.g., a month vs. a year), content (e.g., kWh vs. costs), breakdown (e.g., aggregated vs. disaggregated), medium and way of presentation (e.g., in-home display vs. website), and combinations with other instruments (e.g., goal setting or commitment). Early studies on feedback on energy consumption focused primarily on the effect of providing information about energy consumption. For example, Seligman and Darley provided 29 physically identical households with feedback on their consumption four times a week over one month [269]. Feedback was expressed as a percentage of actual consumption over predicted consumption. Results showed that households receiving feedback on their consumption used 10.5% less electricity than the control group. Other studies investigated the effectiveness of different feedback characteristics such as frequency, content or mode of presentation. Van Houwelingen and van Raij tested the differential effect of daily versus monthly feedback on gas consumption [149]. Households that had received continuous feedback saved more gas (12.3%) than those that had received monthly feedback (7.7%), those that had been taught to read their gas meter (5.1%) and those that had only received
information (4.3%) [5]. Brandon and Lewis provided 120 households with various forms of feedback. They compared the households’ consumption to previous consumption and to that of similar households and they provided energy saving tips in leaflets or on a computer. Feedback either related to financial or environmental costs [53]. Results indicated that the installation of computers helped reduce consumption most significantly. Since technological advances have made feedback much easier to provide than in the 1970s, several recent studies have used various kinds of information technology to gather and display information on energy consumption. Parker investigated the effects of a feedback system that was installed in 20 households. In the second year, the participating households had on average reduced their consumption by 7% [231]. Similarly, Faruqui and colleagues provided households with feedback on electricity consumption via in-home displays with an average 7% savings as a result [99]. Since advances in technology (e.g., Smart Metering) facilitates large-scale interventions, some studies test the effects of large-scale technology-based feedback interventions. For example, Schleich and colleagues investigated the effects of feedback provided under a Smart Metering program with 2,000 households in Austria and Germany and found that feedback results in savings around 3.7% [256].

A recent meta-review summarized the effects of 57 feedback initiatives throughout the U.S., Europe, Canada, and other countries [95]. Overall, average household electricity savings ranged from 4 to 12%. As in the studies cited above, feedback is
more effective when it is presented very frequently. Real-time feedback achieved an average savings of 9.2% whereas daily or monthly feedback only achieved savings of 6.8%. Specific feedback on appliance level as compared to aggregated feedback even increased the savings potentials of real-time feedback (12.0%). Simple information provision proved to be least effective (3.8%). Feedback interventions were even more effective when combined with other strategies such as social norms (2-10%), goal setting (5-17%), competition (10-32%) or commitment (5-8%). Savings seemed to be persistent in 70% of all studies under consideration for both consistent and discontinued feedback.

However, in some cases, feedback had either no effect or worse, even caused increases in consumption. For example, in the study of Sexton and colleagues, consumers received feedback on current use and projected costs, while a light signal alerted them to the switch between peak and off-peak hours [270]. The results showed that savings in peak periods were cancelled out by increased off-peak consumption: Customers increased consumption in off-peak hours because feedback signaled customers that electricity was unexpectedly low-priced at that time. Kluger and DeNisi, who also find variable results of feedback on energy consumption in their meta-analysis, conclude that feedback is a “double edged sword” [170]. While on average feedback exerts a positive influence on behavior, it can also impair performance. However, some studies show that
negative effects can be prevented if feedback is designed carefully and based on theoretical considerations [259].

2.3.4 Research gaps

If designed carefully, goal setting and feedback interventions are among the most effective interventions for changing energy consumption behavior. However, the interventions are not always designed in a way that allows them to have full effects. Research gaps concern the choice of 1) the target behavior, 2) the intervention, and 3) the evaluation methodology. First, goal setting and feedback interventions do not always focus on relevant behaviors. Researchers tend to focus on energy uses that are highly visible (such as public transport) but that do not have large direct effects [285,287]. To increase the impact of a behavioral intervention on the environment, it should be targeted toward behaviors with high impact such as the purchase of energy efficient appliances or the usage of appliances that consume a high amount of energy (e.g., air conditioning system). Second, the interventions are sometimes designed in an inadequate way, resulting in zero effects [203], negative effects for certain energy consumers [208], or unsustainable effects [202]. The two main reasons why goal setting and feedback interventions sometimes produce mixed effects is a neglect of choice architecture and a lack of tailoring. Goal setting interventions could be more effective if researchers considered the effects of choice architecture on behavior and thought carefully about how to frame different goal options to get individuals to choose high saving targets. If choice architecture
is neglected, individuals will choose low and inefficient goals, which results in lower levels of motivation and hence smaller energy savings. Feedback interventions could achieve higher effects if the interventions were tailored to the energy consumers’ characteristics [259,270]. For example, the effects of social normative feedback depends on whether the type of this feedback is matched with the a priori consumption levels [259]. Hence, researchers and practitioners who aim to motivate energy savings should focus on tailored interventions that account for human irrationality. Third, some methodological issues have hampered the identification of effective behavioral interventions. Many studies used small sample sizes, which in combination with large within-group variances in energy use have reduced the statistical power of experimental designs [5]. In addition, the behavioral interventions have often been probed with volunteer participants, which in general may cause a selection bias since those participants tend to have higher motivation levels, higher incomes, and have above-average education levels. This makes it difficult to draw conclusions about the general effectiveness of the behavioral interventions under investigation [5]. Furthermore, the evaluation of behavioral interventions often relies on self-reported data instead of objective measures of environmental behavior [119]. Given that many studies have shown large discrepancies between self-reported measures and behavioral observations [116,203], it is advisable to conduct large-scale field experiments, which assure unbiased samples and the acquisition
of data on actual behavior. The research gaps are summarized in Figure 7.

<table>
<thead>
<tr>
<th>Target behavior</th>
<th>Research gap: Focus on behaviors with high impact instead of highly visible but low-impact behaviors</th>
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</thead>
<tbody>
<tr>
<td>Intervention</td>
<td>Research gap: Focus on tailored interventions that account for human irrationality</td>
</tr>
<tr>
<td>Evaluation</td>
<td>Research gap: Conducting of large scale field experiments to increase internal and external validity</td>
</tr>
</tbody>
</table>

*Figure 7. Research gaps of behavioral energy research with regard to target behavior, intervention, and evaluation*

### 2.3.5 Summary

Behavioral interventions address factors that either precede or follow the behavior that is to be changed. Goal setting is one of the most successful antecedent strategies and is often combined with performance feedback, which represents one of the most successful consequence strategies. However, both intervention strategies sometimes do not fully unfold their effects if a) they do not address high-impact behavior, b) they are not designed carefully, and c) they are tested with small and biased samples.
3 Methodology

This chapter first introduces the heuristic framework by Steg and Vlek (2009), which serves as a basis for the design of the goal setting and feedback interventions to be subsequently tested in this thesis. Thereafter, the four behavioral interventions are described in further detail. Finally, the chapter introduces the thesis’ evaluation approach.

3.1 Research framework

3.1.1 Designing behavioral interventions

After reviewing numerous intervention studies in the area of pro-environmental behavior, Steg and Vlek concluded that although behavioral interventions have a huge potential for improving environmental quality, they are sometimes not designed in a way that allows them to fully unfold their potential. To support researchers and practitioners in building behavioral interventions that are effective in changing people’s environmental behavior, they developed a heuristic framework that comprehends four steps that need to be addressed when designing an intervention [281]. According to Steg and Vlek, the effect of a behavioral intervention is enhanced when the researcher or practitioner a) carefully selects the behaviors to be changed, b) examines which factors cause those behaviors, c) applies adequate interventions to change relevant behaviors and their antecedents, and d) systematically evaluates the effects of
these interventions on the behaviors themselves, the antecedents, environmental quality, and human quality of life (see Figure 8). The framework is described in further detail below.

Figure 8: Framework for the design of behavioral interventions

<p>| | |</p>
<table>
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<tr>
<td>1</td>
<td>Target behavior</td>
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<tr>
<td>2</td>
<td>Influence factors</td>
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<tr>
<td>3</td>
<td>Intervention</td>
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<tr>
<td>4</td>
<td>Evaluation</td>
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</table>

When designing a behavioral intervention, one should target a behavior or set of behaviors that has a significant influence on environmental quality. In addition, it is necessary to consider the feasibility of the required behavior change and the acceptability of the behavior change’s consequences. It should further be considered which groups or individuals should be targeted or whether interventions need to be tailored to achieve high effects. After the target behavior has been selected, the factors that determine the relevant behavior should be examined because the effectiveness of behavioral interventions generally increases
when they are aimed at important antecedents of the target behavior and at removing barriers for behavior change. Therefore, it is important to understand which factors promote or inhibit behavioral change. Thereafter, one has to choose an adequate intervention. For that purpose, various strategies have been developed to address different sets of behavioral determinants [281]. Finally, once a particular behavioral intervention has been chosen, as stressed by Steg and Vlek [281], the effects of the applied intervention(s) on the target behavior, the antecedents, environmental quality and human quality of life must be systematically evaluated. For this purpose, the authors recommend using an experimental approach that measures the dependent variables before and after the intervention and that includes a control group to determine the treatment effects.

The behavioral interventions in the experimental parts of this thesis aim at reducing residential electricity consumption. Cutting electricity consumption is relevant since it contributes to a significant share of total world energy consumption. In addition, the high acceptability of curtailment behaviors by energy consumers and the emerging Smart Metering infrastructure enhance the feasibility of changing residential electricity consumption. Among the most important factors that drive energy-related decisions and behaviors are behavioral goals and feedback on goal attainment because these two factors have central roles in the decision making process [20]. In addition, goal setting and feedback represent core functionalities
of energy feedback systems and are required by the European Directive 97/66/EC [88] and expected by energy consumers [303]. Therefore, this thesis applies goal setting and feedback interventions to achieve electricity savings. To avoid undesirable effects and make goal setting and feedback interventions more effective, choice architecture and tailoring are considered in the interventions’ design. The interventions are combined with behavioral nudges that address further relevant influence factors on electricity consumption. Specifically, defaults and social influence are applied to make goal setting and feedback interventions more effective. Thereby, the relevance of intrapersonal and external factors for energy consumption is acknowledged. The empirical studies in this thesis are meant to be examples for how traditional behavioral interventions can be modified to account for human irrationality and different motivations and to increase as a consequence the effects of Smart Metering on residential energy consumption. This approach could serve as a blueprint for future research endeavors in the area of energy efficiency.

The first intervention combines goal setting with defaults. The hypothesis that default goals are capable of nudging energy consumers toward higher saving targets and higher energy savings compared to self-set goals is tested. Different default goal levels are tested to see which level is effective and to determine what happens if default goals are lower or higher than naturally preferred self-set goals. The second intervention combines goal setting with an identity signaling approach. It is
investigated whether energy consumers can be motivated to set higher saving targets if they are provided the opportunity to signal their identity as a green consumer to others. Further, it is tested whether the intervention needs to be tailored to the relevance that an energy consumer attributes to energy conservation. The third intervention combines feedback with two different types of social norms: descriptive and injunctive social norms. It is tested how the two types of social normative feedback affect below-average and above-average energy consumers and how the types of feedback interact. The fourth intervention combines feedback with different reference groups. It will be investigated which reference group works best for motivating electricity conservation. It is also tested whether the reference group needs to be tailored to the location of the energy consumer. The behavioral interventions are summarized in the framework below (Figure 9).
In the following, the ideas of choice architecture (section 3.1.2) and tailoring (section 3.1.3) are explained since they represent the two strategies that are applied to improve the effectiveness of goal setting and feedback interventions. Then, the four behavioral interventions and the research gaps that they address with regard to underlying theory are explained in further detail (section 3.1.4). In section 3.2, the evaluation approach will be presented. It considers the state of the art on evaluation approaches and aims at overcoming the shortcomings of previous intervention studies (see 2.3.4).

### 3.1.2 Choice architecture and Nudging

When designing behavioral interventions such as goal setting or feedback, one has to be aware that contextual factors have a

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**Figure 9. Overview on the goal setting and feedback interventions investigated in this thesis**

<table>
<thead>
<tr>
<th>Target behavior</th>
<th>Intervention</th>
<th>Nudge</th>
<th>Target group</th>
<th>Tailoring</th>
<th>Choice architecture</th>
</tr>
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<tbody>
<tr>
<td>Electricity consumption</td>
<td>Goal setting</td>
<td>Defaults</td>
<td>n.a.</td>
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<td></td>
<td>Identity signaling</td>
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<td>Above average</td>
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<tr>
<td>Feedback</td>
<td>Type of norm</td>
<td>?</td>
<td>Rural area</td>
<td>?</td>
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<tr>
<td></td>
<td>Reference group</td>
<td>?</td>
<td>Urban area</td>
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significant influence on behavior. Contextual factors refer to the context in which decisions are made and not only concern abilities or opportunities but also the way in which information about savings goals or energy consumption is presented. The way different behavioral options are framed highly determines preferences and decisions [44]. Message framing and other small and seemingly minor design elements can have a massive impact on decision outcomes [35]. For example, just by changing the default option from “no action” to “automatic enrollment,” the percentage of employees saving for retirement increased from 49% to 86% [198].

The effects outlined above show that individuals do not act fully rationally, because framing effects should not occur from the perspective of rational choice. Individuals seem to be bounded in their rationality [278]. They are not able to act like fully informed and rational decision makers when making choices because their decision making is limited by available information, cognitive capacities, and time [63,278]. Consequently, individuals try to make satisficing instead of optimal decisions and rely on a limited number of heuristic principles that reduce the complexity of decision tasks [295]. In general, these heuristics are quite useful since they reduce the effort involved in decision making, but sometimes they lead to severe and systematic errors [295].

Since apparently small details affect the outcome of a decision, it is obvious that choice architecture and its effects cannot be avoided. Consequently, there is no such thing as a neutral design
However, this also implies that choice architecture can be used in a constructive way; supporting individuals to make decisions that correspond to their interests. Therefore, little nudges should be offered that are most likely to help make good decisions and least likely to inflict harm [291]. A nudge is defined as “any aspect of the choice architecture that alters people’s behavior in a predictable way without forbidding any option or significantly changing their economic incentives…” [291]. The power of nudges comes from focusing the attention of individuals in a particular direction. The principle of affecting behavior with nudges while respecting freedom of choice is called “Libertarian Paternalism.” Among the most prominent nudges according to Sunstein and Thaler are social influence and defaults.

3.1.3 Tailoring
Tailoring is often used in health psychology to improve the effects of health interventions and achieve behavior change [6]. The extent to which health messages are tailored can range from so-called “generic communication,” which is not at all individualized to “tailored communication,” which is quite individualized [174]. Tailoring is defined as “any combination of strategies and information intended to reach one specific person, based on characteristics that are unique to that person, related to the outcome of interest, and derived from an individual assessment” [173]. Examples of criteria that can be used for tailoring include current behavior (e.g., energy consumption levels), motivations (e.g., saving money versus
helping the environment), and stages of behavior change (e.g., problem awareness versus intention to conserve energy). Extensive meta-reviews of health interventions have shown that tailored campaigns outperform non-tailored similar campaigns [223]. In using IS tailoring is not only efficacious but also very cost-effective [6,223]. The reason tailoring is more effective than generic messages in persuading individuals to change behavior is provided by the elaboration likelihood model [223,239]. This model distinguishes between two types of information processing. When individuals engage in central route processing, they carefully examine the arguments within a message. However, if they engage in peripheral processing, they rely more strongly on heuristics which may be convincing in the short term but tend to be unrelated to the central arguments within a message. To produce sustainable behavior change, interventions should stimulate central route processing. Whether individuals engage in central processing strongly depends on how much individuals are involved with a message. If messages are tailored to an individual’s characteristics and situation, they will be perceived as more relevant, are more likely to be centrally processed, and are more likely to persuade the individual.

3.1.4 Combining goal setting and feedback interventions with tailored behavioral nudges

This section presents the four behavioral interventions investigated in this thesis. It outlines how the two nudges “social influence” and “defaults” are used to make goal setting and
feedback more effective and nudge energy consumers toward higher savings goals and energy savings. Furthermore, the research gaps with regard to underlying theories addressed by each of the four studies are outlined.

Goal setting and defaults

For goals to be effective, they need to be both specific and ambitious. Unfortunately, individuals prefer easy goals over difficult goals. To nudge people toward higher saving goals and consequently higher electricity savings, one could assign difficult goals to energy consumers. However, assigning goals implies the risk of reducing commitment and self-efficacy – both important requirements for goal setting success. This thesis presents a novel approach: using default-goals to nudge consumers toward higher savings targets and higher electricity savings. Defaults represent “the option that you get if you do not make other decisions” [56]. In the first study, users are confronted with a default savings goal (e.g., 15%), and they can either choose to maintain the default or they can adjust it. Other studies have used different goal setting approaches that vary in how much the individual is involved in the decision-making process. Goals were either self-set or assigned [201] or set in cooperation with others or under the guidance of third parties [274]. Default-goals, in contrast, represent a combination of an assigned goal and a self-set goal. Hence, they should nudge the users toward higher savings targets while assuring commitment and self-efficacy at the same time, since they respect the freedom of choice.
Previously, defaults were primarily used to affect one-shot behaviors or a sequence of one-shot behaviors. For example, they have been applied to affect consumer choices when configuring and buying a new car [47,229,230,242], donating organs [33,206], ordering pizza [184], selecting electricity tariffs [240], and choosing retirement plans [198]. In the study presented in this thesis (see Ch. 4) the knowledge on defaults is extended by applying the concept of defaults to the energy conservation domain. Setting a saving goal requires the consumer to continuously engage in energy conservation efforts. Therefore, this study will allow a test of whether defaults are also effective in affecting continuous behavior.

Since defaults have not been applied to energy conservation before, the mechanism that underlies the effect of defaults on energy-related behaviors is as yet unknown. It is not clear whether commonly used explanations for the effect of defaults on behavior are valid in this context. Several mechanisms for the effectiveness of defaults have been discussed. First, defaults are understood as a request to make a choice (“endorsement”; [206]). Consumers acknowledge that the manufacturer knows what is best for them and perceive the default option as a recommendation [120]. Second, defaults are often chosen due to laziness. Diverging from the default implies cognitive and emotional effort [204]. Consumers use emotions to judge a product or make a product choice. If they have to make multiple decisions in a row (e.g., configuring a car), the emotions get depleted after a while (“depletion effect”). As a consequence,
consumers often maintain the default option. Third, defaults are used as a reference point for the evaluation of any other option. The alternative options are therefore either rated as being better (gain) or worse (loss) than the reference option, whereas losses loom larger than gains [56]. The default creates a certain feeling of endowment with the product serving as default [229]. Once individuals feel endowed (regardless if they own the product or just anticipates the ownership), individuals are only willing to give up the product for a higher amount of money than they would actually pay if they were not endowed. In the context of energy conservation, laziness does not seem to be a valid mechanism because energy conservation requires active decisions and behavior. Furthermore, the endowment explanation is not likely to work for an abstract concept such as a savings goal, since it is not tangible and only exists in the mind of the consumer. In contrast, it is possible that default-goals affect behavior by working as a recommendation. That is, individuals could perceive the default goal as a recommendation or normative statement, suggesting to them what kind of goal is likely to be achieved [214]. If they are perceived as performance norms or recommendations, it is likely that the default will work in both directions, that is, nudging consumers either toward higher or lower savings goals and thus higher or lower energy savings. For example, when consumers were allowed to add ingredients to a basic cheese pizza (low default) instead of subtracting them from a fully-load pizza (high default), they ended up with fewer ingredients in total [184]. Unfortunately, the authors did not include a neutral condition since this setting
did not allow for one (there is always a default). Consequently, it is not clear to what extent defaults detrimentally affect the consumer’s interests. To investigate the detrimental effects of defaults, the study presented in Ch. 4 includes a condition whereby users are allowed to choose their own goal with no default-goal set. Consequently, this study allows one to determine the most effective default goal level in terms of savings goal choice and electricity conservation.

Goal setting and identity signaling

Another strategy for nudging energy consumers to higher saving goals is the use of social influence. In contrast to using defaults, using social influence is less invasive since the individual is not provided with a goal if he or she is not actively making a goal choice. The study presented in Ch. 5 makes use of the fact that people make decisions in a social context. The basic idea of this study is to nudge people toward higher savings goals by providing them with the opportunity to signal their green identity to others. The identity signaling opportunity can be regarded as a benefit in return for reducing energy consumption, which is negative from a hedonistic point of view since it is associated with a loss of comfort [215].

In marketing research, it is well known that consumers are not solely functionally oriented [133]. Instead, product purchase is related to the desire to convey a certain image to others and to communicate one’s identity [38]. Consequently, people are more likely to buy products that evoke positive self-images
rather than negative self-images [279]. Recently, a study showed that identity signaling is capable of motivating efficiency behaviors, that is the purchase of energy-efficient products [131]. The results showed that people chose green products over more luxurious non-green products (negative from a hedonistic point of view) when status motives were primed. This identity signaling effect was only found when shopping behavior was public as opposed to private and when green products cost more than non-green products [131]. The study presented in Ch. 5 extends the knowledge on identity signaling by applying it to curtailment behaviors, which by definition require continuous efforts to achieve energy savings as opposed to efficiency behaviors. Specifically, an identity signaling approach is used to motivate individuals to set higher savings targets with regard to showering time reduction. Since taking a shower is not a public behavior and does not involve high financial investments, it is not clear based on prior research whether identity signaling also works for that particular purpose. The subjects are presented with an image of a person that promotes energy conservation and the person is either depicted as a trendy or a non-mainstream greenie. It has been found that the decision to engage in a negative behavior depends not only on perceived risk but also on the identity such behavior signals to others [40]. Apart from investigating the effect of a certain identity that is associated with energy conservation on goal choice, the study also tests whether individuals react differently to the different identities depending on how relevant they perceive energy conservation to be. It is likely that individuals who regard
energy efficiency as a part of their identity will be more motivated when energy conservation is associated with a non-mainstream identity. This is because these individuals should be motivated to send clear identity signals to others, which is not possible if too many people show a certain behavior (as indicated by the mainstream greenie). Previous research has shown that people mainly diverge from others when the product domain is hedonistic rather than utilitarian. Hence, this study examines whether identity signaling can be used for a commodity (i.e., electricity). Furthermore, identity signaling theory suggests that individuals should choose high savings goals to signal a green identity to others because signals that require high effort are less likely to be poached [41]. This assumption (called “effort costs”) has not yet been empirically tested; but it is feasible to test this assumption in the context of continuous behavior (as opposed to binary purchase behavior). As opposed to identity signaling theory, the “low-cost hypothesis” assumes that the less effortful a certain behavior is, the more likely individuals are to show that behavior. The study on goal setting and identity signaling in Ch. 5 addresses these contradictory assumptions and systematically assesses the relationship between identity signaling and level of effort.

Feedback and injunctive and descriptive norms

Meta-analyses have shown that feedback on energy consumption in general is quite effective for motivating energy conservation [170]. However, in one-third of the studies under investigation, feedback had either no effects or negative effects
on energy consumption, that is, people increased their consumption in response to receiving feedback. Since social norms have proven to be effective in changing energy-related behavior [259,262] and are said to provide the most solid basis for energy conservation [283], they will be applied in this thesis to increase the effectiveness of feedback interventions. In accordance with Cialdini’s distinction between descriptive and injunctive social norms [66], social normative feedback on energy consumption either displays the consumption of relevant others in comparison to the individual’s consumption that is the target of the behavioral intervention (descriptive normative feedback) or provides the individual with information to what extent relevant others approve or disapprove of his or her energy consumption (injunctive normative feedback). Comparative feedback has been quite effective for inducing energy savings [103,259]; however, as with other kinds of feedback, energy consumers sometimes increase consumption. For example, Schultz et al. [259] showed in a study with 290 households in California that whereas above-average energy consumers always reduce their consumption as a response to any type of feedback, below-average consumers increase their consumption when learning that they perform better than their neighbors (descriptive normative feedback). Hence, if people should be nudged into socially desirable behavior, they should not be told that they are better than the social norm [103]. However, the study by Schultz et al. found that this detrimental effect can be buffered when the injunctive norm is presented in addition to the descriptive norm. The first goal of the study on injunctive and
descriptive normative feedback (Ch. 6) is to replicate this finding and test whether this approach is also applicable to IS-based interventions. The study of Schultz and colleagues used handwritten smileys to indicate the injunctive norm. This may have overestimated their effectiveness since people might conform just because they think that others “have their eyes fixed on them” [103].

Apart from replicating the effect of descriptive and injunctive normative feedback on energy consumption, the study in Ch. 6 also aims at shedding light on the interaction of the two types of norms. This is very important, since different conclusions can be drawn for the design of social normative feedback interventions depending on how the buffering mechanism actually manifests itself. However, Schultz et al. did not include a condition in which participants were provided with injunctive feedback, only one which would have been necessary to explain the interplay of descriptive and injunctive normative feedback. To date, the current literature does not offer a clear picture of the exact interplay of these two frequently used types of social norms. In particular, the literature offers three contradicting underlying mechanisms that may explain why injunctive feedback is able to buffer the detrimental effect of isolated descriptive feedback on people with low a priori energy consumption. First, injunctive feedback can reduce energy consumption, thereby countering the detrimental effect of descriptive feedback (additive effect, [66,166]). Second, injunctive feedback dominates the perception of consumers and therefore overshadows the effect of
descriptive feedback (ordinal interaction, [101,250]). Third, the two types of feedback have detrimental effects if presented alone and only stimulate savings if presented in combination (disordinal interaction, [211]).

Feedback and reference groups

To build an effective social normative feedback intervention that uses descriptive normative feedback, the a priori consumption level is just one factor that needs to be considered. In addition, for descriptive norms to be effective, a) the norm needs to be salient and b) the reference group needs to be relevant to the targeted individual. According to the “Theory of Normative Conduct”, a norm must be focal for an individual at the time of behavior to influence an individual’s behavior [66,166]. Similarly, the ‘Theory of Social Impact’ [180] states that the social impact of a group increases when the strength or salience of the normative source is high. Unless norms are salient and in the focus of an individual’s attention, they cannot enter the decision process to change potentially detrimental behaviors [103]. Studies on the salience of social norms have used priming techniques or spreading activation approaches to direct the intention of an individual to a specific norm [66,166]. In the context of this thesis (Ch. 7) social norms are made salient to the energy consumers by providing them with feedback on how they compare to the consumption of a particular reference group. Feedback is a common means to make a norm salient [103].
The second factor that determines norm adherence and thus the effectiveness of social norm interventions is the choice of the reference group. Social norm interventions are based on the assumption that individuals will take the behavior and opinions of their peers into account when making decisions. However, individuals will only orient themselves to the reference group if the group is relevant to the individual. One important driver of the perceived relevance of a group is its apparent similarity. “Social comparison theory” stipulates that people compare themselves to similar others to gain information for self-evaluation [102]. Similar comparison targets are claimed to be especially useful in this context as they allow one to draw conclusions on the reasons for possible differences in performance. If the individual engages in a comparison with a person who differs from him in numerous attributes, he wouldn’t know if a lower performance was caused by a lower ability or by differences in other attributes such as age, weight, and gender [200]. However, Festinger did not specify the basis of similarity between the self and the comparison-other [200]. In most studies, similarity is defined with regard to personal characteristics or ability [121]. However, similarity can also be interpreted in terms of contextual characteristics. Goldstein and colleagues [121] found that local norms are sometimes more effective in motivating people to show a certain behavior than global norms because the former may lead to behavioral choices that are tailored to the individual’s specific situation. Since research on contextual factors determining perceived similarity and hence the acceptance of a reference group is sparse, the
study presented in Ch. 7 extends research by testing the effects of similarity in terms of geographical proximity. That is, energy consumers are either compared to the average performance of their neighbors, their region or their country. In addition, the study presented in Ch. 7 also tests whether the location of an energy consumers moderates the effectiveness of the different reference groups. Since the context in which decisions were made in Goldstein et al.’s study was held constant (a hotel room), the authors were not able to test for the moderating effect of the individual’s context.

3.1.5 Summary

The goal setting and feedback interventions in this thesis consider the effects of choice architecture and are tailored to some important characteristics of the energy consumers, in contrast to previous interventions that sometimes produced mixed results. Goal setting will be combined with defaults and an identity signaling approach and feedback will be combined with different types of social norms and different reference groups.

3.2 Evaluation approach

This section reviews commonly applied and recommended evaluation approaches and outlines the potential of IT and IS in supporting rigorous evaluations. Lastly, this section describes an innovative web portal that is used by a large group of real energy customers and that allows for rigorously testing the goal setting and feedback interventions investigated in this thesis.
3.2.1 Overview of evaluation approaches

Behavioral interventions need to be systematically evaluated to judge their success, enable conclusions about why they were successful or unsuccessful, and infer how they could be adapted to increase their effectiveness [281]. The evaluation can focus on different outcomes depending on the intended goal of the intervention. Behavioral interventions in the energy context can be evaluated with regard to (changes in) energy consumption, (changes in) behavioral antecedents, (changes in) environmental quality, and (changes in) individual quality [281]. No matter what the goal of the intervention and hence the evaluation is, the accurate measurement of ecological behavior is a precondition [165].

To measure the effects of energy efficiency interventions on behavior, researchers use either self-reported measures or behavioral observations. Self-reported measures can be gathered by questionnaires or interviews. For example, Thøgersen used a questionnaire with 17 behavior items to assess the effects of descriptive and injunctive norms on a wide range of environmentally responsible behaviors including purchasing behaviors, travel mode choice, conservation of energy and water, and waste handling [293]. Behavioral observations rely on objective rather than subjective measures of pro-environmental behavior. For example, White et al. [306] tested the effectiveness of different message frames (loss/gain) and mindsets (low construal level/high construal level) on recycling behavior and measured the height of recycled materials in the
bin and the number of different categories of material to obtain objective and precise measures of recycling behavior.

Although a large majority of consumer energy studies have used self-reports of conservation actions or self-reports of energy consumption for reasons of feasibility, these self-reports have some reliability problems. Many studies have shown large discrepancies between self-reported measures and behavioral observations [116,203]. For example, one study with 100 randomly selected Mexican families showed that the correlation between self-reported and objective measures of recycling was quite low [70]. Already in 1981, Geller suggested including behavioral checks on self-report measures using actual energy consumption as indicated by meters and utility bills [116]. The collection of consumption data (e.g. from energy suppliers) is regarded as a cornerstone of future energy-research efforts [203]. However, a review of methodological approaches published in popular journals used to assess the effects of behavioral interventions on environmental behavior reveals that studies using interviews and questionnaires are overrepresented compared with experimental studies and field studies that use objective measures of environmental behavior [119].

Despite the underrepresentation of experimental approaches, there is a public agreement that the effects of behavioral energy efficiency interventions should be tested with experiments [10,94]. According to Frondel, experiments are the most desirable empirical strategy for the evaluation of environmental interventions [111], because the simple difference in mean
outcomes across treatment and control groups would result in an unbiased estimate of the effects of that intervention. The requirement for unbiased results is a random assignment of the households to the experimental conditions. If the experiment uses a randomized group assignment, the researcher can pay little or no attention to other observable characteristics that might affect the results. Unless a randomized experimental approach is used, the evaluation of energy efficiency interventions is a complex task since energy consumption is influenced by many factors such as household characteristics, appliances, weather, season, and number of people [94]. Another factor that often biases the estimation of an intervention’s success is the fact that households that volunteer to participate in a study are already environmentally conscious and tend to be more responsive to high prices of electricity (“self-selection bias”, [111]). In a recent paper published in Science, it was stated that randomization is essential because people who are more motivated and engaged often have different treatment effects [10] with both under- and overestimation being likely consequences. In addition to randomization, the inclusion of a group that does not receive any treatment (control group) is necessary, especially if the goal is to estimate absolute energy savings as opposed to relative savings among different conditions. Without an experimental control group, either a difference estimator, which compares energy consumption in the treated population before and after the treatment, or a difference-indifferences estimator with nearby households as a control group can be applied. However,
these econometric approaches seem to provide biased results. Allcott compared the two econometric estimators with an experimental estimation of the average treatment effect and found that the difference-in-difference estimator was almost double the mean of the experimental average treatment effect [11]. Despite the benefits of an experimental evaluation approach, they have often not been applied because they are costly and time-consuming in contrast to other evaluation approaches [281].

3.2.2 Information Technology and Information Systems as evaluation tools for behavioral interventions

IT and IS hold the potential of supporting a rigorous evaluation of the effectiveness of behavioral interventions on energy conservation. As outlined above, researchers who aim at evaluating behavioral interventions should try to obtain objective behavioral data and should further use an experimental approach [10,203]. IT and IS facilitate both the collection of behavioral data and the conducting of experiments.

First, IT such as Smart Metering can be used to gather information about energy consumption so that the evaluation can be based on objective behavioral data. This may reduce the possibility of biased results. Traditional evaluation approaches (i.e. evaluation approaches that did not use IT to collect consumption data) that aimed at gathering objective data had to rely on consumption information available from utility companies or had to send research assistants to the energy consumers’ households to read the electricity meters. For
example, the software company OPower uses the data that the utility companies makes available to them in order to provide the utilities’ customers with social comparative feedback on their energy consumption [11]. Another study tested the effects of different energy conservation messages on energy consumption and used meter readings that were obtained by research assistants [65]. Although both approaches allow the acquisition of objective behavioral data, they also include some disadvantages. Evaluation approaches that use utility data are dependent on how often utility companies send their employees to the customers to read the electricity meters. The time that passes between the meter readings ranges from one month to one year, depending on a country’s policies on how often energy customers need to be provided with bills. Consequently, data from utility companies are often characterized by a low level of granularity. The low number of measurement points may impede the detection of behavior changes because the effects of behavioral interventions often wash out after a few weeks or months [95]. In addition, it is impossible to infer what happens between the different bills since the recognition of behavioral patterns requires detailed consumption data. In one study, customers who received feedback on their consumption decreased it at first but then increased it after four months [143]. If the researchers had not measured consumption on a monthly base but, for example, every four months, they would have concluded that the provision of feedback has detrimental effects on energy conservation efforts that do not correspond to reality. Compared to utility data, the data gathered by research assistants
who read the energy consumers’ electricity meters may exhibit a higher level of granularity. However, it is very costly and time-consuming to obtain data in this way [281].

IT helps to overcome the outlined shortcomings of traditional approaches and facilitates the cost-efficient collection of detailed consumption data. Consequently, IT-based interventions allow for conducting behavioral interventions with a large sample of customers because costs for data collection remain relatively constant regardless of whether a study is conducted with a small or large sample. Addressing a large sample of energy consumers improves the reliability of statistic estimators of the intervention’s success and hence reduces the likelihood of biased results [50]. In addition to making large-scale interventions cost-effective, IT also allows for conducting long-term studies at no extra cost. If a technology such as Smart Metering is used for evaluation, it does not matter whether a study is conducted over a short or long time period since data collection is based on a system that is already implemented. Conducting long-term studies is important, because they allow one to determine whether a certain intervention has only short-lived or long-lasting effects [5,281]. In addition to allowing large-scale and long-term interventions, IT also allows for gathering consumption data at any desired frequency level since the costs for data collection are independent of measurement frequency.

While IT enables the cost-effective collection of objective behavioral data, IS support the conducting of experiments. First,
IS such as websites, in-home displays, and mobile phone displays represent a medium that provides energy consumers with information about their consumption [103]. Consequently, IS deliver the actual behavioral intervention to the energy consumers and as such work as a promoter for energy efficiency [216]. With IS it is easy to make diverse behavioral interventions available to different customer groups. Providing groups of energy consumers with different representation formats allows for comparing the effectiveness of the experimental conditions under consideration. Consumers can be automatically assigned to the experimental conditions based on characteristics of the energy consumer or of a specific context. For example, IS could provide customers with different types of feedback depending on the measured a priori consumption level. In a study about the differential effects of descriptive and injunctive normative feedback for above and below-average energy consumers, researchers had to calculate the baseline consumption of each household manually and then assign above and below-average consumers equally to the different experimental groups [259]. If the researchers had used IS, the baseline consumption could have been calculated automatically and below-average and above-average consumers would have been automatically provided with the two types of feedback. In addition to assigning individuals based on specific characteristics, IS also allow for randomly assigning energy consumers to different experimental conditions. As outlined earlier, randomized experiments are regarded as the most rigorous evaluation approach since they allow for obtaining
unbiased estimates of the effectiveness of different behavioral interventions [10,94]. As opposed to matching energy consumers based on pre-defined characteristics, the randomized assignment accounts for both observable and unobservable characteristics or unconsidered factors that might bias the evaluation of the effectiveness of the different experimental conditions. For example, even if each experimental group consists of equal shares of low and high income households (i.e., they have been matched based on their income), the groups could still differ with regard to their attitudes toward the environment. Hence, differences between the experimental groups could result from dissimilarities in pro-environmental attitudes rather than from the behavioral interventions even though different income levels have been controlled for. As a consequence, randomization is essential in evaluating the effectiveness of behavioral interventions [10].

Apart from allocating the energy consumers to the experimental conditions, IS also allow for investigating the effects of even small differences in behavioral interventions. For example, one online study tested the effects of different frames and defaults on participation rates in health surveys [162]. To change the valence of the frame, the researchers just added the word “not” to the participation statement; and to vary the default from “participation” to “no participation” or “no default” they just modified the checkboxes in front of each statement. This shows that changes in the choice architecture can be easily conducted with IS. Apart from being capable of confronting individuals
with different defaults, IS further enable social influence interventions. Prior research has shown that individuals respond socially to computers [107,246] and that certain website features may establish a feeling or social presence [276].

In addition to supporting sophisticated randomized experiments, IS also allow for investigating the effectiveness of behavioral interventions under realistic conditions. As outlined earlier, IS will accompany the Smart Metering infrastructure to provide the energy consumers with information on their energy consumption [22,256]. Hence, IS allow for testing behavioral interventions with real customers in a naturalistic environment. So-called field experiments are believed to be superior to laboratory studies in terms of external validity since the interventions are tested in a setting that corresponds to the application setting [50].

3.2.3 Introduction of Velix, an experimental and IS-based evaluation tool

Given the emergence of Smart Metering and the potential of IS for rigorous evaluation, the behavioral interventions tested in this thesis will be delivered to the energy consumers with IS. Since most European countries have not yet rolled out Smart Meters or are still testing them in pilot projects [126], an alternative and innovative approach was developed to rigorously test the goal setting and feedback interventions even before Smart Meters are actually introduced to energy consumers. Specifically, a web portal was developed since the Internet reaches a relatively large number of households, while at the
same time providing customized interventions to individual users [6]. A web portal represents a cost-effective evaluation tool since the costs for developing and hosting it remain essentially constant regardless of the measurement frequency, the number of customers addressed, or the time period covered.

The web portal Velix (Figure 10) served as a basis for a large-scale energy efficiency campaign for real energy customers. The partnering utility company considered the system an essential part of their energy efficiency endeavors and made the portal available to all its private customers (around 120,000). The campaign ran from April 1, 2010 to December 31, 2011 and was very successful in terms of public response and customer involvement. A total of 10,700 customers joined Velix and entered 319,169 meter readings. Customers used the web portal very often and intensely. The web portal was visited over one million times and customers spent an average of 4.59 minutes per visit on the site (Table 4). The campaign aimed at raising awareness among consumers, engaging consumers in energy conservation, and preparing them for the introduction of Smart Metering. Unlike previous energy efficiency campaigns of that utility company, Velix was built as an collective effort of experts from different department of the utility company (marketing, communication, energy efficiency, metering), academia (computer scientists, psychologists, engineers), and a local advertising agency. The underlying assumption of the campaign was, that energy conservation is not about Smart Meters but about smart people. That means, that for the first
time the focus shifted from technological efficiency gains to behavioral efficiency gains acknowledging that technology alone does not lead to energy savings. Instead, people need to use energy in an efficient and smart way [42,84] to achieve energy savings. The purpose of the web portal then is to help the customers turn their traditional electricity meters into “smart” electricity meters by allowing them to learn more about their consumption in a simple and playful way.

![Image of Velix landing page]

**Figure 10. The landing page of Velix**

**Table 4. Overview of key performance indicators of the campaign Velix**

<table>
<thead>
<tr>
<th>Activity</th>
<th>Descriptive statistics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Registration</td>
<td>10,700 users</td>
</tr>
<tr>
<td>Entering of meter readings</td>
<td>319,169</td>
</tr>
</tbody>
</table>
Against the background that traditional energy efficiency campaigns suffer from a low participation rate and only involve customers who are already involved in energy efficiency, an innovative gamification approach was used to make people use the web portal. Gamification is defined as the use of game design elements in a non-game context and is used to improve user experience and user engagement [79,80]. Reeves and Read propose ten basic game elements that can also be found outside of games and that are not readily identified as gameful if used in isolation. These elements include: self-representation with avatars, three-dimensional environments, narrative context, feedback, reputations, ranks, and levels, marketplaces and economies, competition under rules, teams, communication systems, and time pressure [247]. In contrast to serious games, gamified applications are restricted to the use of a small set of design elements from games and do not fulfill all characteristics of a game [79]. Velix uses a narrative context (people turn electricity meters into smart meters, see above), feedback (social normative and historical feedback on electricity consumption), different levels, and communication systems. To give customers the opportunity to explore and to prevent information overflow, features of Velix are not all available at once. With every login,
new features or information is made available to the customers. When users first log on the web portal, they can perform the meter hunt (assisted search of their electricity meter), then enter the meter reading and household profile and set reminders. In addition, they can invite friends to spread the word, perform savings tips and little tasks to learn more about energy guzzlers, or discuss about energy related topics in the forum. The web portal also includes various reward mechanisms to motivate participation and engagement such as bonus points or a monthly lottery. When logging-in for the second time, they can enter a second meter reading and finally receive feedback on their average weekly electricity consumption in comparison to the average performance of their neighbors. They can further set savings targets. With every subsequent meter reading entry, they can track their progress with regard to energy savings. The experience chain in Velix is depicted in Figure 11.

![Experience chain in Velix](image)

*Figure 11. Experience chain in Velix*
Rewards are often used to engage individuals to show a particular behavior (e.g., usage of web portal), since the motivation for showing or not showing a certain behavior also depends on rational cost/benefit analysis [8]. Studies in the realm of operant conditioning have found that rewards are very powerful and control behavior [77]. However, the provision of rewards has also been criticized, since meta-studies have found mixed evidence for their effectiveness [77]. An extensive meta-analysis by Cameron and colleagues finally concluded that in general rewards do not undermine intrinsic motivation. If rewards are given for low-interest tasks (like the use of energy management tools), they enhance intrinsic motivation [59]. Rewards can be contingent or non-contingent, that is, they either refer to the target task or not. Furthermore, they can enforce the engagement in the task (task-contingent) or the performance (performance-contingent). A further distinction can be made between task-contingent rewards that depend on completing the target task (completion-contingent rewards) and those that are dependent upon engaging in the activity but do not necessitate completing it (engagement-contingent rewards) [77]. The rewards that are implemented in Velix are task-non-contingent, task-contingent and completion-contingent rewards. That is, the rewards motivate participation as well as the fulfillment of tasks (e.g., meter hunt), but they do not refer to performance (e.g., energy savings). Specifically, the utility company gives its customers bonus points for reading their electricity meter on a weekly basis, answering surveys, performing tasks, and inviting friends among others (task-contingent and completion-
contingent). The points can be redeemed in the utility company’s online shop for various energy efficient products or services. In addition, there is a monthly lottery for people who enter their meter reading at least once a month to attract large customer groups (task-non-contingent). In addition, people receive a welcome gift of a value of 5-10 Euros after having entered at least three meter readings (task-contingent and completion-contingent). The welcome gift is provided to support habit formation. It is assumed that after using the web portal for three weeks, people have become used to participating and to reading their electricity meter. Research has shown that habit formation takes between 18 and 254 days, depending on the complexity of the task [178]. Despite the great variety in habit formation duration, the welcome gift was provided after three weeks since the usage of a website is not regarded as a difficult and complex task.

To promote the web portal and motivate people to register, the utility company informed their customers via their customer magazine and collaborated with a local media corporation that placed ads in various newspapers. In addition, the web portal was promoted via a local trade fair, radio ads, and billboards in the region of Vorarlberg, where the utility company is based. For the first time, the Austrian utility company chose an emotional communication strategy as opposed to emphasizing rational cost/benefit arguments. To facilitate the communication with the energy consumers, a cartoon-like electricity meter called Velix served as a mascot (see Figure 10). A mascot is
considered to be a very influential visual clue [168,218]. It catches the customer’s attention and helps to communicate the key attributes of the product or organization [73,168]. Importantly, they help to establish an emotional relationship between the customers and the product or organization. If the customers have strong feelings for a mascot, they will probably create favorable perceptions of the products or organizations associated with that mascot [1]. The mascot Velix was used to promote the web portal, to establish an emotional relationship to the web portal, and to guide the customer through the web portal. Velix has childish features such as large eyes, short limbs, and a chubby body since these features are perceived as cute. Individuals respond in a positive way to cute mascots [32]. In addition, Velix’s body looks like a real electricity meter because figurative mascots are preferred over abstract mascots [32].

Functionalities of Velix

At its core, Velix allows its users to collect and analyze data about their electricity consumption. Since no widespread smart metering infrastructure was available when the portal was launched in 2010, Velix currently depends on manual data collection by its users. This allows for deriving empirically proven design guidelines for Smart Metering feedback systems even before Smart Meters are actually introduced to the energy customers. The users can enter the meter readings at any time (Figure 12). The website stores consumption data separately for day and night consumption at the household level, if information
on both day and night consumption is available. To make people search their meters and read them correctly, a task called “meter hunt” was implemented and users were rewarded with bonus points for completing the task. To motivate the users to periodically enter their data at least once a week, the system can be configured to send automatic reminders via e-mail or SMS (see Figure 13), and people also get bonus points for doing so (10 points). Prompts, that is cues that remind individuals to do something, are effective in motivating behavioral change and keeping engagement levels high [110]. They reduce the barriers to showing a certain behavior because they lower the cognitive effort. That is, people do not have to remember to carry out a specific action. The frequency, with which the prompts are sent is critical to the prompts’ success because individuals will be annoyed if the prompts are sent too often [110]. Therefore, Velix-users can decide on their own, when and how they would like to be reminded.

![Figure 12. Data entry form for meter readings in Velix](image)

*Figure 12. Data entry form for meter readings in Velix*
Users can retrieve the historical data in the form of a table (see Figure 14) that depicts all of the meter readings entered in the past 12 months. The table further includes previous consumption levels and the associated energy efficiency levels (see below). In addition, the user gets a graphical depiction of his or her consumption history over time (see Figure 15), which allows for comparing his or her actual consumption with prior consumption levels and to track the progress [103]. As outlined above, feedback plays an important role in guiding behavior. It enables behavior change by informing the individual about the effectiveness of behavioral strategies and by motivating the reduction of the discrepancy between the current status quo and the behavioral goal [154,170].
In addition to feedback on historical consumption, the users are provided with feedback on consumption efficiency in two ways.
(see Figure 16). First, the weekly electricity consumption of each household is compared with the corresponding average in the user’s neighborhood. The data on the neighborhood’s consumption comes from the utility company (alongside with data on street, zip code, area). This type of comparative feedback can be termed as descriptive normative feedback, since people learn which consumption levels are typical or “normal” for their neighbors and how they compare to them [66,259]. The calculation of the average value is based on households with similar characteristics. Second, the web portal calculates the efficiency level of each household based on the household’s consumption and the household characteristics. Each user creates a household profile upon registering with the website. This profile includes the type of building, the total size of the house or apartment, the number of people living in the household, the number of appliances, and the type of heating. Then, based on the collected raw data, the web portal calculates the weekly averages and the efficiency levels, which range from “A” (high efficiency) to “G” (low efficiency). This type of feedback can be regarded as injunctive normative feedback, because the efficiency level represents an indicator for social approval or disapproval [66,259].
In addition to multiple types of consumption feedback, Velix offers its users a variety of information and services to help them reduce their electricity consumption. For instance, the users may consult the web portal to learn more about the efficiency improvements that they can make by employing the newest generation of household appliances. Additionally, the users may receive simple behavioral advice (e.g., unplug electrical items before leaving for vacation). These savings tips are tailored to the characteristics of the energy consumers; tenants are not advised to insulate their houses, for example. An example of the more sophisticated services offered by Velix is the “Appliance Oracle” (see Figure 17). The Oracle provides the
users with estimates of their weekly electricity demand based on a list of the appliances in their households and their daily average operating time. The consumption data depend on the average values, which can be modified by the user if he or she knows the exact values. Finally, Velix offers a quiz on energy-related knowledge (e.g., “How much electricity does a traditional light bulb convert into light?”). All aforementioned services aim at increasing the knowledge and ability of energy consumers since these factors may facilitate or impede the enactment of energy conservation behaviors and influence individual motivations [315]. When these factors strongly inhibit or facilitate pro-environmental actions, psychological motivations are relatively unimportant [281,287]. The tasks and the quiz aim to convey knowledge in an entertaining way since fun has a positive effect on the learning process. Fun reinforces intrinsic motivation [46]. In addition, quizzes have been found to motivate people to log on regularly to a website [125].
System architecture of Velix

The overall architecture of Velix is depicted in Figure 18. The whole system is hosted on a server called debian, while the Nginx server handles the static content (e.g., background colors), and the Apache Server hosts the non-static content (e.g., consumption feedback). The data used and obtained by the web portal are stored in a Mysql database and an extra backup server. A staging server is used as a temporary stage to test new or revised web pages before they are made available to the
customers. This is especially important when new experiments are implemented in order to make sure that the graphical user interface (GUI) differs between the experimental groups only in the intended way. The components of the system can be divided into three classes: One set of components supports the general functionalities of the web portal (as described earlier), a second set serves the handling of the system for the utility company and a third set supports the conducting of experiments. The components of each category are briefly described in the following.

Velix contains modules that support the general functionalities of the web portal. It comprises modules for the email and sms reminder functionalities, for the log-in process, the survey (which is used to receive additional data on consumer characteristics and attitudes), and for forum (which provides customers with the opportunity to discuss various energy-related topics). An sms gateway and a mail server are used to send email and sms reminders to the customers; and cronjobs is applied to send these reminders at a particular time that is chosen by the customers. The system further includes task layers that determine the GUI for any given time, since the web portal is organized in levels.

To support the campaign handling for the utility company, the web portal includes a module for “Customer Relationship Management” (CRM), which provides the utility company with

an overview of all customers and allows for filtering by specific criteria. For example, customers can be filtered by bonus points to identify power users. The report analytics module provides the utility company with basic descriptive statistics on the user base (e.g., number of registered users and meter readings) to derive some key performance indicators for the campaign’s success. The CRM and report analytics modules are based on information that is represented in the energy customer model and the behavioral model. The energy customer model contains information about the characteristics of the energy customer and his or her household, while the data about the customer’s website usage and electricity consumption are embodied in the so-called behavioral model.

To conduct experiments and test different behavioral interventions, Velix uses a few widgets and an experiment layer. Widgets provide the basis for personalized behavioral interventions since they allow one to modify the GUI based on specified rules (e.g., random assignment). In addition, the experiment layer represents the GUI for each customer based on the assigned experimental group. Velix assigns every new user to an experimental group or control group randomly after he or she has registered, since randomized experiments allow for unbiased estimates of an intervention’s effectiveness [10]. A user is only in one experimental group at a time and is assigned to the regular GUI as soon as the experiment is finished. The customers can opt-out at any time if they do not want to take part in the experiment.
3.2.4 Summary

Randomized controlled field experiments represent the state of the art of evaluation approaches and are now become cheaper
and more feasible since IT and IS facilitate data collection and the conducting of randomized experiments. To test the behavioral interventions in this thesis, a web portal was developed for the customers of an Austrian utility company that uses self-entered electricity meter data and provides energy consumers with different interventions depending on the assigned experimental group.
4  Green IS design for action formation: An empirical investigation of goal setting and the role of defaults\textsuperscript{17}

4.1 Introduction

The increasing scarcity of natural resources, the accelerating pollution of the environment, and the looming threat of global climate change have attracted the interest of IS scholars worldwide in several questions surrounding the concept of environmental sustainability [51,160,300]. A steadily growing research stream has emerged in recent years under the umbrella of "Green IS", which explores information systems’ potential contributions in support of sustainable practices across the entire firm [300]. The thematic scope of the Green IS movement encompasses diverse topics, such as the improved eco-efficiency of business processes through automation, the development of sustainable strategies with the aid of decision support systems, and the overall optimization of environmental information flows [292].

\textsuperscript{17} See Loock, C.; Staake, T., Thiesse, F. Green IS design for action formation: An empirical investigation of goal setting and the role of defaults. \textit{MIS Quarterly} (conditionally accepted for publication), 1-31. [194]
Whereas the majority of Green IS studies are conducted at the organizational level of analysis [159], the present work focuses on the cognitions of individuals by investigating the role of IS in stimulating energy-efficient behavior in private households. The practical motivation for this research emerges from the significant and still increasing contribution of domestic energy consumption to global energy demand. In Western countries, households account for 20 – 30% of the total energy use [92,93]. However, energy consumption shows high variance on the level of single households due to the many isolated decisions made by individuals (e.g., investing in better insulation or more efficient heating and cooling systems, purchasing more energy-efficient appliances). Therefore, changing consumption behavior may be an effective catalyst for increasing energy efficiency on a large-scale [84].

To investigate how Green IS needs to be implemented in order to change residential energy consumption, this research follow the design science research paradigm, which is increasingly accepted as a viable IS research approach [104,145,153]. Accordingly, an objective of this work is to create a technological artifact that is innovative and purposeful in terms of its ability to address a specific problem [145]. Thus, this research respond to Melville’s call for research on the effectiveness of IS design choices in influencing environmentally sustainable human behavior [210]. The second objective is to utilize the system as a test of the theoretical propositions underlying its design. For this purpose, a
"hypothetico-deductive, theory-testing mode of design science" [29] is employed, which is characterized by a design that is informed by kernel theories, which, in turn, can be refined by design research [60,145,175,224,299]. This research approach can serve as a powerful tool to fundamentally extend the understanding of sustainable behavior within the IS context and in more general settings.

The study is positioned within the larger context of intervention strategies based on findings from socio-psychological behavior research. It concentrates on a specific type of Green IS functionality based on goal setting theory, which posits that concrete and realistic goals result in higher performance than vague and non-ambitious objectives [213]. In addition, this study tests the effect of defaults, a well-known concept from the marketing literature, or "the option you get when you do not specify otherwise" [56]. As proposed in the following, IS functionality that supports user-set goals and the systematic use of defaults may encourage consumers to adopt long-term eco-friendly behavior. To rigorously evaluate the hypotheses, electricity consumption data from 1,791 utility customers was collected in a field experiment and analyzed to what extent goals and defaults lead to higher energy savings. The results allow drawing conclusions for both, Green IS design (i.e., which system design works) and the socio-psychological foundations of this research (i.e., how and why the system design works).

Following the six-step methodology of IS design research proposed by Peffers and colleagues, the remainder of the chapter
is organized as follows [232]. After having identified the problem that motivates this research, this chapter reviews prior Green IS design research in the next section and delineate the research gap addressed by the present study. Thereafter, the research model and a set of testable hypotheses are developed, which lay the foundation for the design and implementation of a real-world IS as well as for its empirical evaluation. A detailed description of the system from a user’s perspective is given thereafter. The chapter continues with a description of the practical demonstration phase, in which data from a large sample of users was collected. For evaluation purposes, this chapter subsequently provides an in-depth analysis of the collected data and the results of the hypothesis testing. The chapter closes with a discussion of the main findings, theoretical and practical implications, limitations, and suggestions for further research.

4.2 Previous research on changing energy consumption behavior via Green IS

Research on energy consumption behavior has become an extraordinarily fruitful research stream in the social sciences in the past 30 years with two main paradigms dominating the field: (i) the economic paradigm and (ii) the behaviorist paradigm [207,251]. The former takes the perspective of rational choice theory, which posits that consumers seek to maximize their own expected utility [97,148]. According to this view, the behavior of energy consumers is determined by costs, benefits, and
individual preferences, with rational consumers being those who make reasoned choices based on the entirety of information available to them. The belief in the effectiveness of information provided the starting point for many of the early pilot projects conducted by utilities, which were based on the assumption that individuals would conserve energy if they were given sufficient information on different energy sourcing options, prices, and environmental impacts, among others [195]. However, scientific evidence shows that individuals are ultimately bounded in their rationality because of the cognitive burden of information processing, which limits their ability to take deliberative actions [278]. A wealth of results from experimental and field research has shown that a variety of mental "short-cuts" (e.g., rules, habits, emotions) may reduce or even bypass cognitive deliberation entirely, undermining the assumptions that underlie the models of rational choice [138].

In contrast, the behaviorist paradigm assumes that an individual’s behavior is determined by the complex interplay between intrapersonal factors (e.g., attitudes, values), interpersonal factors (e.g., norms, social comparison), and external ones (e.g., rewards, punishments) [118]. The different schools of psychological research have contributed a plethora of behavior models that may be relevant to the debate on environment-related behavior change [156,298]. None of the current models seems sufficient by itself to account for the complexity of behavior, but some are more widely used. Among the most prominent examples is the Theory of Planned Behavior
(TPB) proposed by Ajzen, which posits that the intention to undertake a behavior precedes actual behavior [8]. Behavioral intentions, again, are determined by attitudes toward the behavior, perceptions of social norms, and perceptions of behavioral control. In the years following its original publication, researchers have proposed several additions to the model, such as self-identity processes, anticipated emotions, or habit [235]. A second theory worth mentioning is Schwartz’s Norm-Activation Model (NAM), which explains pro-social behavior by the activation of personal norms (i.e., strong feelings of moral obligations) [265]. Both theories have been successfully applied in studies of environmentally aware behavior, sometimes in combination with NAM variables extending the original TPB [4].

TPB, NAM, and similar models take the role of "meta-theories" [128] in that they provide a conceptual framework for understanding human behavior across disciplines and to guide the design of effective intervention strategies [287]. Following the latter avenue, several studies investigated the effects of behavioral interventions on energy consumption [5]. Scholars have aimed at both changing the context in which consumption decisions are made by, for example, offering rewards that render pro-environmental choices more attractive [227,281] or by targeting an individual’s perceptions, preferences, and abilities in order to induce eco-friendly behavior [12,243,283]. Unfortunately though, traditional intervention strategies suffer from a lack of scalability, as in the case of personal energy
audits. Here, the strength of information systems as enabler of fully automatic processes of consumption data collection and analysis comes into play.

4.2.1 IS enabled intervention strategies

Early behavioral interventions that aimed at motivating energy conservation have primarily focused on the basic effects of providing information on individual energy consumption. For example, Seligman and Darley provided their subjects with feedback on their electricity use [269]. After one month, the subjects had reduced their consumption by 10.5%. Other, more sophisticated studies investigated the effects of specific aspects of feedback such as frequency [85,149], aggregation level [85,296], and content [64,124,259] on energy consumption. Prior research indicates that feedback is more effective if it is provided immediately after the target behavior occurs [117]. In addition, consumption feedback that is broken down to specific appliances is more effective than aggregated feedback [201]. With regard to feedback content, social feedback (e.g. peer comparisons) is more effective than individual feedback [277], but only if it is tailored to a specific situation, state of knowledge, or feeling [144].

Though the potential of IT for implementing the before-mentioned modes of providing feedback on energy consumption in a cost-efficient and scalable way is evident, only a small number of studies on feedback interventions make use of information systems [226]. Examples can often be found in the HCI literature, where IS are used to test preferences for different
information presentation formats. For instance, Shiraishi and colleagues presented a user study with six families over four weeks, who were confronted with an in-home display called “EcoIsland” that visualizes the users’ current eco-friendly behavior to persuade them to change their lifestyle patterns and thereby reduce their CO₂ emissions [275]. Other examples include "UbiGreen", a mobile tool used to track and support green transportation habits [110]; "Energy Life", a system utilizing wireless sensors, mobile networks, and ambient interfaces [49]; a public display that shows electricity usage to educate consumers and curtail their power usage (Holmes 2007) and a web portal used to socially visualize energy-saving behavior [130].

Green IS design proposals made in these prior studies often refer to the social psychology literature – however, they usually neither formulate testable hypotheses nor attempt to evaluate them with the help of large data sets collected in naturalistic environments. The respective systems are rather evaluated in small scale user studies that typically last only a few days or weeks. In contrast, manifold behavioral interventions exist that have shown their ability to trigger behavioral change or influence user choice in isolated lab studies [5]. However, when it comes to applying such intervention strategies to large-scale campaigns that are now becoming possible with IS-enabled energy conservation campaigns, it remains unclear which behavioral cues work best, how they can be combined, and how they should be parameterized (e.g., concerning default goal
level, proximity of reference group, etc.). Traditional lab studies are hardly capable of answering such questions in a coherent setting as this would require extensive test groups. Only few exceptions of related work can be found in the literature that utilize IT in one or the other form as a means of implementing rigorous experimental designs (see Table 5). However, even in these studies, IS are limited to their role as transport media for executing traditional intervention strategies. No details are given on the technological details of the corresponding systems and the actual implementation of the employed invention types, and no empirically proven IS design guidelines are derived for reuse in future projects. Against the background of this lack of synergies between theory and IS design, a window of opportunity has opened particularly for IS researchers with respect to Green IS applications that combine technological expertise and socio-psychological theory.

Table 5. Overview of related studies testing IS-based feedback interventions

<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Intervention</th>
<th>System</th>
<th>Resource</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>McClelland &amp; Cook (1980)</td>
<td>Feedback</td>
<td>In-home display</td>
<td>Electricity</td>
<td>Feedback group saves 12%</td>
</tr>
<tr>
<td>Hutton et al. (1986)</td>
<td>Feedback, information</td>
<td>In-home display</td>
<td>Gas, electricity</td>
<td>4-5% savings in two out of three cities</td>
</tr>
<tr>
<td>Van Houweling-en &amp; van Raij (1989)</td>
<td>Feedback (frequency), goal setting</td>
<td>In-home display</td>
<td>Gas</td>
<td>Continuous feedback + goal setting leads to the highest savings (12.3%)</td>
</tr>
<tr>
<td>Author(s) and Year</td>
<td>Feedback Type/Content</td>
<td>Platform</td>
<td>Sector</td>
<td>Summary</td>
</tr>
<tr>
<td>--------------------</td>
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</tr>
<tr>
<td>Dobson &amp; Griffin (1992)</td>
<td>Continuous and appliance specific feedback leads to savings of 12.9%</td>
<td>Software</td>
<td>Electricity</td>
<td>Feedback (breakdown, frequency)</td>
</tr>
<tr>
<td>Abrahamse et al. (2007)</td>
<td>Feedback + goal setting + tailored information leads to 5.1% savings</td>
<td>Web portal</td>
<td>Energy</td>
<td>Feedback, goal setting, information</td>
</tr>
<tr>
<td>Loock et al. (2011)</td>
<td>Injunctive feedback always reduces consumption, descriptive feedback leads to increased consumption for below-average consumers</td>
<td>Web portal</td>
<td>Electricity</td>
<td>Feedback (content)</td>
</tr>
<tr>
<td>Graham et al. (2011)</td>
<td>Combination of monetary and environmental feedback works best for reducing car use</td>
<td>Web portal</td>
<td>Fuel</td>
<td>Feedback (content)</td>
</tr>
<tr>
<td>Peschiera &amp; Taylor (2012)</td>
<td>Social feedback is more effective when using peer norms instead of impersonal</td>
<td>Web portal</td>
<td>Energy</td>
<td>Feedback (content), competition</td>
</tr>
</tbody>
</table>
4.2.2 Research objective and theoretical context

As outlined above, Green IS design as a distinct research field examining the intersections among IS, energy efficiency, and the individuals’ behaviors is nevertheless still in its infancy. The objective of the present study is to address this research gap by a theoretically sound IS design and its empirical evaluation based on a large sample of real-world data, which could serve as a blueprint for future research endeavors in this emerging area. Among the many theories explaining human behavior, the “Extended Model of Goal-Directed Behavior” (EMGB) by Perugini and Conner [236] was chosen as the theoretical locus of this research. EMGB poses a redefinition of TPB, which incorporates constructs from various new theoretical areas: (i) motivation, (ii) habit, and (iii) affect. The key construct introduced by the EMGB is desire, which represents appraisals and reasons to act that motivate behavioral intentions. In addition to attitudes and subjective norms, positive and negative anticipated emotions are hypothesized to influence the desire to perform a given action. The EMGB also posits that past

<table>
<thead>
<tr>
<th>Chen et al. (2012)</th>
<th>Feedback (content)</th>
<th>Web portal</th>
<th>Energy</th>
<th>Social feedback is more effective than individual feedback</th>
</tr>
</thead>
</table>

energy consumption norms
behavior as a proxy for habit has an impact on both desires and intentions. Furthermore, the model distinguishes the desire to perform a given behavior from the desire to achieve a goal (i.e., the outcome of behavior), which is assumed to play a central role in any form of goal-directed behavior [234].

The model offers various starting points for interventions on the human decision-making process. Among these, the present study sets the focus on the causal chain between goals and behavior. The objective is to investigate the effectiveness of an IS in the form of a web-based energy feedback platform, which supports users in their attempt to save energy by influencing their desire for a particular goal. For this purpose, the system implements an intervention strategy and measures the users’ behavior in terms of energy consumption. Using the collected data, the system provides feedback on goal attainment, which again influences behavior. It should be noted that from a theoretical point of view, the concept of feedback mechanisms goes beyond the logic of TPB in that behavior is not only influenced by its antecedents, but also vice versa. The rationale behind the use of feedback is often traced back to Bem’s Self-Perception Theory [34], which posits that individuals infer their attitudes by observing their own behavior. Feedback has been commonly used in behavioral intervention design, especially in the health context [9,13]. The extension of the EMGB by a feedback loop eventually results in the framework depicted in Figure 19, which provides the broader theoretical context to this research. On this foundation, the following sections discuss the
concepts of goal-setting and defaults, which are then translated into a saleable intervention strategy and a set of hypotheses to reveal the principles underlying its mode of action.

Figure 19. Theoretical context and research focus of this study

4.2.3 Research model and hypotheses development
Previous scholars have inductively formulated goal-setting theory over a 25-year period by conducting over 400 laboratory and field studies [188,189]. The theory posits that difficult yet realistic goals lead to higher levels of goal achievement than easy goals. The applicability of goal setting theory has been the subject of prior IS-related studies, for example, in the context of decision support systems [150,248] or software project
management [3,245]. A second theoretical foundation of this study is the concept of so-called "defaults", which is borrowed from the marketing literature. In practice, defaults are used to "nudge [...] customers toward better choices" [120] and can have a massive impact on consumer behavior. The research model is developed based on these two concepts (Figure 20) and proposes a causal relation from default goals and goal choice to energy consumption. In the following, the hypotheses are developed, starting with the basic effects of goal choice and default goal level (H1-H4) and proceeding to more complex effects, such as mediation (H5) and moderation (H6).

![Figure 20. Structural research model and hypotheses of the study on goal setting and defaults](image)

In a first step, the study considers the impact of goals on energy consumption. Goals encourage behavior changes by acting as a reference point for a future desirable state. Locke and Latham define a goal as "the object or aim of an action, for example, to attain a specific standard of proficiency, usually within a
specified time limit" [188]. Once a goal is set, it remains in the periphery of a person’s consciousness as a reference point and guides his or her subsequent mental and physical actions [189]. Researchers have argued that goal-setting can affect performance by means of several different mechanisms. First, a goal directs a person’s attention and effort toward the activities relevant to the goal and away from irrelevant activities [188]. Second, a goal affects one’s persistence [177]. If individuals are free to choose the amount of time that they would like to invest in achieving a goal, then ambitious goals will prolong the amount of time required to do so. Third, goals also indirectly affect action by leading individuals to desire, discover, and/or use knowledge and strategies related to the task at hand [312]. For these reasons, it is argued that users who have a goal setting functionality and make use of it are more likely to conserve energy than users who do not have such functionality at their disposal.

**H1. Compared to users in the "no goal" condition, users who are offered a goal setting functionality and who set an energy saving goal will conserve more energy.**

If an individual must make a decision (here: choose a goal), then reference points in the given situation (e.g., the recommended savings goal) often become the most important factor in determining the decision outcome [47,161,295]. Prior studies in the marketing literature have successfully applied defaults to provide consumers with a reference point that helped them evaluate other options. For example, in a laboratory study
conducted by Pichert and Katsikopoulou [240], more participants chose a green utility tariff when green electricity was the default than when electricity from non-renewable or undeclared sources was the preselected option. Individuals typically evaluate the alternative options that are close to their reference point before focusing on the options that are more distant from their reference point [62,291]. As a result, the default works as an "anchor", which tends to influence an individual’s decision in favor of adherence to the standard [220]. Accordingly, it is argued that default goals will work as an anchor for goal choice, so that higher levels of default goals are expected to lead to a choice of more ambitious goals. However, providing default goals as anchors may also lead to bad choices if individual attitudes do not impact decisions enough to affect the prevailing default policy [120]. In these cases, negative effects may occur if the default is not chosen carefully. Therefore, it is expected that the use of default goals in a Green IS may negatively influence goal choice if they are lower than the preferred goal that an individual would have chosen if he or she had set a goal without any reference point.

**H2a.** Compared to users in low default goal conditions, users in high default goal conditions will choose more ambitious goals.

**H2b.** Compared to users in the "goal & no default" condition, users in the "goal & default" condition will choose less ambitious goals if defaults are set too low.
Goal setting theory posits that difficult and specific goals lead to higher levels of goal achievement than easy and vague goals (e.g., "do your best") [188,189,213]. Under high-level goals, individuals perceive a large discrepancy between their actual performances and their desired standards and attempt to reduce or eliminate this discrepancy by improving their performances [170,188]. However, a goal should still be realistic because goals need to be attainable and plausible [72]. If the goals are set too high, then the individual’s belief that he or she can attain the goal (i.e., his or her self-efficacy) may be affected because the goals communicate normative information to the individual by suggesting the level of performance that he or she can expect to attain [69,214]. Considering these aspects, it is expected that users who are provided with default goals and set a goal show significant savings – compared to users who do not have a goal-setting functionality – only for the case of medium-level default goals.

**H3.** *Compared to users in the "no goal" condition, only users in the "medium-level default goal" condition will attain significant savings.*

Similarly, if the goals are too low, then they will only produce small discrepancies and, thus, trigger low levels of motivation. Unlike high-level goals, these low-level goals will further decrease one’s persistence such that one will invest less time in solving a task [177]. Hence, it is hypothesized that if default goals are set too low (i.e., lower than the preferred goal that an individual would have chosen if he or she had set a goal without
any reference point), they do not lead to any significant savings and it might be more advisable not to use defaults at all.

**H4.** *In contrast to users in the "goal & no default" condition, users in the "low default goal" condition will not achieve significant energy savings.*

Given the aforementioned relationships, it can be assumed default goals indirectly affect energy consumption by affecting goal choice. Defaults represent a reference point, which affects goal choice in that the higher the default goal, the higher the goal choice becomes. The set goal will then create a discrepancy between a person’s actual and desired performance. The higher this discrepancy is, the higher the energy savings that the user can achieve. However, this relation only holds up to a certain point because unrealistic saving goals decrease self-efficacy and, as a consequence, render goal attainment less likely. In sum, it is expected that goal choice acts as mediator between default goals and energy consumption.

**H5.** *The effect of default goals on energy savings is mediated by goal choice.*

Feedback has proven to be an effective means to motivate energy conservation, especially when combined with goal setting [5,201]. Feedback on goal attainment helps individuals evaluate their progress in relation to their goals [221]. A discrepancy between goal and performance can trigger two possible reactions: Users will either modify their efforts or revise their goals [154,170] because individuals are motivated to
remove or reduce the discrepancy between their goals and their performances [61]. If the goal-performance discrepancy is negative, individuals are likely to adjust their goals downward, but if the discrepancy is positive, individuals tend to further increase their goals by setting goals that are higher than their past performances [154]. Prior research has shown that the size of the adjustments correlates with the extent of the discrepancy [86,308]. In terms of the previously hypothesized default-goal relationship, it is argued that feedback on goal attainment will moderate the effect of default goals on goal choice. That is, users in the high default level condition will adjust their goals to a larger extent than users in the low default goal condition because the former are more likely to encounter goal-performance discrepancies.

**H6. Feedback on goal attainment moderates the effect of default goals on goal choice.**

### 4.3 Artifact design: The Velix system

Velix is a web portal that motivates its users to reduce their electricity consumption, which was developed in cooperation with an Austrian utility company. The portal provides its users with feedback on their electricity consumption and combines energy record keeping with game-like tasks that center around environmental sustainability. The utility considers the system an integral part of their energy efficiency endeavors and made the portal available to all its private customers.
In addition to achieving immediate energy savings, the portal was developed to experimentally investigate socio-psychological concepts (e.g., goal setting, social norms, cost projections) that may help to promote eco-friendly behavior among its users when implemented in some form of Green IS (e.g., feedback systems that built upon smart metering). To render related studies possible, the system allows for randomly assigning users to different treatment groups (i.e. experimental conditions) and for recording electricity consumption data for each user. It is thus possible to compare the effects of different interventions on energy demand. For the study at hand, the portal was used to test hypotheses regarding the structural relations between defaults and goals, the impact of defaults and goals on energy consumption, and the moderating role of feedback on goal choice.

In order to gather a large user base, the utility company informed their customers via their customer magazine and teamed up with a local media corporation that placed ads in various newspapers and a news website. Moreover, the company gave its customers incentives for using the system in the form of bonus points that can be traded for products in an online shop. Between April 1, 2010 and December 31, 2011, a total of 10,700 users registered with Velix.

The sequence of user interactions on the portal is structured as depicted in Figure 21. After registration, users can participate in the "meter hunt", a game-like instruction on how to find the electricity meter and interpret its reading. Participants who
already know where to find their meter can directly enter the reading in the portal. Next, users are asked to voluntarily set a reminder to foster repeated system usage, either in the form of an e-mail or a text message sent to their mobile phone at intervals and times as selected by the users. Since it is not possible to determine household consumption with only one meter reading, several subsequent functionalities of the portal, such as the neighborhood comparison, the efficiency check, goal setting, and feedback on goal attainment are not enabled at the time of the first login but only briefly explained as an outlook to the next visit. However, during the first visit, users can already invite other potential participants, receive savings advice, and read or write comments in a moderated forum. Following a subsequent meter entry at least one week after the first data input and after the completion of the household profile, users receive feedback on their consumption performance. To provide tailored information for each consumer, the household profile includes data on the number of inhabitants, the size of the apartment or house, the type of space and water heating system, the number of household appliances, and the address/location of the residence.
4.4 Empirical evaluation

To date, it is an open question as to how to design Green IS platforms that successfully promote residential energy conservation. To shed light on the specific roles played by goal setting and defaults in this issue, the experiment was designed and implemented as follows.

4.4.1 Experimental design and data collection

The study design distinguishes among three different categories of consumers: no-goal & no-default subjects (G-D-), goal & no-default subjects (G+D-), and goal & default subjects (G+D+). The first two groups represent the two control groups. The group G-D- is used to evaluate the absolute effects of goal setting and G+D- to determine whether default goals differ from self-set goals with regard to their impacts on goal choice and energy conservation. The treatment group G+D+ is further
divided into three subgroups to compare the effects of low-, medium-, and high-level default goals on energy-saving goal choice and energy savings (0% default goal: G+D+0, 15% default goal: G+D+15, 30% default goal: G+D+30). All users who have registered with Velix since the release of the website in April 2010 are randomly assigned to the five different groups in a between-subjects design. For all of the groups, only the participants were considered in the analyses that were still active (i.e., the participants who entered electricity meter readings in the observed period of time). Additionally, for the goal & no-default group G+D- and the goal & default group G+D+, only participants who set two or more conservation goals were considered. In sum, 1,962 users fulfilled these conditions.

This study used data of electricity meters which continuously measure behavior. The meter readings are transferred to the website by the users on a regular basis. To make data transfer as simple as possible, multiple strategies are applied. First, detailed graphical and textual instructions about the location of the electricity meter and how to read it are incorporated. The utility company has used this information for many years to support its customers, who read their electricity meters for billing purposes. Second, algorithms were implemented that assessed the validity of the transferred electricity meter readings. For example, if a customer enters a negative value or a reading that is lower than the previous reading, then he or she will receive an error notification, and the value will not be saved. It can also be presumed that the collected data are highly reliable because
Velix offered no bonus points for low energy consumption and it is thus profitless to fake meaningful counter readings over a period of several weeks to receive unhelpful feedback. Additionally, the validity of the transferred meter readings was checked for a subset of 115 customers. The correlation between the level of energy consumption in 2009, which was provided by the utility company, and the level of energy consumption in 2010, which was a projection based on the meter data that has been transferred by the customers to the portal, was substantial ($r = .80$, $p < .01$). This correlation indicates that in general, it can be assumed that there were no problems with media discontinuity. However, for the specific time period under consideration, some examples of extreme consumption data volatility could be observed in the dataset that may not be explained by household characteristics or behavior change alone but rather by other reasons, such as construction work and absenteeism. Consider the real example of a customer in the G+D+30 group who consumed 99.80 kilowatt hours before and 127.22% more after the intervention. Here, it is likely that the family of the customer spent more time at home due to Christmas resulting in a large increase in consumption even though the customer might have tried to reduce consumption. To sort out such outliers, Grubbs’ test from the ‘outliers’ package for R was applied to the data in two subsequent steps [133]. First, outliers with regard to the users’ baseline consumption were removed. The baseline consumption level is each consumer’s average weekly consumption before he or she sets a goal. Second, the outliers in terms of energy savings relative to
the baseline were detected. In both cases, a tail-wise approach was used that removes outliers, which differ significantly from the mean, at both tails of the data distribution. As a result, 8.7% of the participants were excluded from further analysis. In total, a final sample of 1,791 customers of the Austrian utility company was used for this study, which took place in a high use period between November 2010 and March 2011. Table 6 provides descriptive statistics of the subsamples, their energy consumption profiles, and the hypotheses tests that were conducted on these subjects. The different groups did not differ with regard to their baseline consumption levels (F(4,1786) = .029, p = .998).

Table 6. Subsamples in the study on goal setting and defaults

<table>
<thead>
<tr>
<th>Subsamples</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Hypotheses</th>
</tr>
</thead>
<tbody>
<tr>
<td>G⁻D⁻</td>
<td>927</td>
<td>108.19</td>
<td>55.97</td>
<td>H1,3</td>
</tr>
<tr>
<td>G⁺D⁻</td>
<td>199</td>
<td>109.00</td>
<td>50.04</td>
<td>H1,2a/b,4</td>
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<tr>
<td>G⁺D⁺</td>
<td>213</td>
<td>109.25</td>
<td>57.76</td>
<td>H1-6</td>
</tr>
<tr>
<td>G⁺D⁺₀</td>
<td>213</td>
<td>109.25</td>
<td>57.76</td>
<td>H1-6</td>
</tr>
<tr>
<td>G⁺D⁺₁⁵</td>
<td>242</td>
<td>108.26</td>
<td>48.18</td>
<td>H1-6</td>
</tr>
<tr>
<td>G⁺D⁺₃₀</td>
<td>210</td>
<td>109.08</td>
<td>54.70</td>
<td>H1-6</td>
</tr>
</tbody>
</table>

*Table 6. Subsamples in the study on goal setting and defaults*

N = Sample size, M = Mean baseline consumption (in kilowatt hours), SD = Standard deviation (in kilowatt hours)
4.4.2 Intervention

The goal setting functionality was introduced at the end of November 2010 and the participants’ energy consumption was tracked over 4.5 months. Each customer’s average consumption level in kilowatt hours was depicted in a bar graph. For the G⁺D⁺ group, the default goals (0%, 15%, or 30%) were presented next to the bar graph. The participants could modify their conservation goals with the help of two buttons for increasing and decreasing the value. The participants had to push a button to set the goal (see Figure 22). As a result, the bar graph indicates the target consumption level. In the G⁺D⁻ group, no reference point was provided, that is, the customer had to enter his or her conservation goal into an empty text box (see Figure 23). Regardless of the condition, the customers could choose a conservation goal between 0% and 100%. By contrast, the G⁻D⁻ group did not have a goal setting functionality.

After setting a goal, the participants were asked to wait for at least one week before entering their electricity meter readings again. By entering this reading, each participant received feedback on their goal attainment and learned if he or she had met the goal, exceeded the goal, or missed the goal. After receiving feedback, the participants could again set conservation goals by following the same procedure used in the first goal-setting process (i.e., a participant who had previously set a 15% default goal received the same default goal again).
4.5 Results

In a first step, a one-factor between-subjects ANOVA was conducted to compare the effect of goal setting on energy savings in the goal-setting (\(G^+D^-\), \(G^+D^+\)) and the no-goal conditions (\(G^-D^-\)). On average, the participants in group \(G^-D^-\) increased their consumption by 4.09%. They likely did so because the study took place at the beginning of winter when electricity demand typically rises. Therefore, the savings in
electricity consumption were normalized to 4.09%. Thus, savings in electricity consumption represent a reduction in the overuse of energy. For simplicity’s sake, whenever energy savings are discussed, this chapter refers to a reduction in the overuse of energy. It was found that goal setting has a significant effect on energy savings ($F(1, 1789) = 7.23, p < .01$). Customers who had a goal-setting functionality at their disposal and who set a goal saved, on average, 2.3% (SD = 21.97) more than those in the no-goal condition. The results suggest that users with a goal-setting functionality save more energy than users who do not have that functionality at their disposal. Thus, hypothesis 1 is supported.

Another one-factor between-subjects ANOVA was conducted to compare the effect of default goal level on goal choice in the low-default goal ($G^+D^+_0$), medium-default goal ($G^+D^+_15$) and high-default goal groups ($G^+D^+_30$) with the goal & no-default group ($G^+D^-$). The default goal level had a significant effect on goal choice ($F(3, 860) = 44.47, p < .01$). Customers in the low-default condition $G^+D^+_0$ chose, on average, a goal of 4.30% (SD = 5.81); customers in the medium-default condition $G^+D^+_15$ chose an average goal of 12.31% (SD = 6.85); customers in the high-default condition $G^+D^+_30$ chose an average goal of 19.13% (SD = 11.08). A post hoc test using Tukey HSD showed that the three default goal levels differed significantly with regard to goal choice. The results suggest that defaults affect goal choice in that higher default goal levels lead to higher goal choice. Therefore, hypothesis 2a is supported. However, only the mean
score for the participants in the low-default-goal condition was significantly different from the scores of those in the goal & no-default condition (M = 15.74, SD = 24.71). The medium-default goal condition and the high-default goal condition did not significantly differ from the goal & no-default condition (see Figure 24, error bars indicate 95% confidence intervals). The results suggest that if the default goals are set too low, then they lead to a goal choice lower than that induced by the self-set goal condition. Therefore, hypothesis 2b can be confirmed.

![Figure 24. The effect of default goal level on energy-saving goal choice compared with self-set goals in the goal & no-default condition.](image)

To examine the effect of default goal level on energy savings, the low-default-goal (G⁺D⁺₀), medium-default-goal (G⁺D⁺₁₅), and high-default-goal groups (G⁺D⁺₃₀) were compared with the
goal & no-default (G⁺D⁻) group and with the no-goal & no-default group (G⁻D⁻). The results of the one-factor between-subjects ANOVA showed that default goal level has a significant effect on energy savings \((F(4, 1786) = 4.07, p < .01)\). The customers in the low-default condition \(G^+D^-0\), the medium-default condition \(G^+D^-15\), the high-default condition \(G^+D^-30\), and the goal & no-default condition \(G^+D^-\) saved, on average, 0.76% (SD = 23.36), 4.02% (SD = 19.53), 0.001% (SD = 24.83), and 4.18% (SD = 19.78) more than the customers in the no-goal & no-default condition \(G^-D^-\), respectively. Post hoc comparisons using Tukey HSD revealed that the customers in the medium-default condition and the goal & no-default condition saved significantly more energy than the customers in the no-goal & no-default condition, whereas the customers in the low-default goal condition and the high-default goal condition did not (see Figure 25, error bars indicate 95% confidence intervals). The results suggest that only medium-level default goals lead to significant savings. In addition, it seems that when the default goals are set lower or higher than the users’ preferences in the form of self-set goals, they are not superior to the "no goal & no default" condition in contrast to the self-set goals. It is hence better to use self-set goals than default goals that are too low or too high, because the latter conditions do not lead to significant savings compared to the no goal & no default condition. Thus, the results support hypotheses 3 and 4.
After investigating basic effects, the assumption that the effect of default goals on energy savings was mediated by goal choice was tested. For this purpose, a nonlinear mediation model was applied, as depicted in Figure 26. Based on the findings that supported hypothesis 2, the effect of default goals (X) on goal setting (M) was modeled as a positive linear relationship (path a). In accordance with goal-setting theory, the effect of goal setting (M) on energy savings (Y) was modeled as curvilinear (path b), with the medium-level goals leading to a stronger effect than the low and extremely ambitious goals. Following the findings from hypothesis 4, it was assumed that the direct effect of X on Y is curvilinear as well (path c’). Because the
independent variable X has equal intervals and even a true zero, X is regarded to be an interval-scaled variable.

Figure 26. Mediation model in the study on goal setting and defaults

\(X = \text{default goal level}; M = \text{goal choice}; Y = \text{energy savings}; a, b1, b2, c'1, c'2 = \text{path coefficients}; i1, i2 = \text{constant terms}; e = \text{error terms}\)

A bootstrapping approach was used to test the mediation model. As an alternative approach to Baron and Kenny’s mediation tests [28], bootstrapping allows one to account for nonlinear causal relationships [141]. Moreover, the nonparametric test does not require the normality of the sampling distribution [142] and has been shown to perform better in terms of statistical power and Type I errors in small- to moderate-sized samples [109]. In this study, Hayes and Preacher’s SPSS macro
"MEDCURVE" was used to analyze 5,000 bootstrap resamples [141]. As shown in Table 7, the default goal level had a significant and positive direct effect (path a) on the goal choice (a = 0.4962, p < .01). The direction of the effect is consistent with hypothesis 2. With respect to the effect of goal setting on energy savings (b paths), the coefficient of the linear term is positive and significant (b₁ = 0.6926, p < .01), whereas the coefficient of the quadratic term is negative and not significant (b₂ = -0.0069, p = .15). These findings lead to the following regression equation:

\[ Y(x) = 2.7689 + 0.0813 X - 0.0118 X^2 + 0.6926 M - 0.0069 M^2. \]

Table 7. Direct effects and total effect of default goal level on energy savings

<table>
<thead>
<tr>
<th>Path</th>
<th>Coeff</th>
<th>SE</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Mediated Model</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a</td>
<td>0.4962</td>
<td>0.0265</td>
<td>.0000</td>
</tr>
<tr>
<td>b₁</td>
<td>0.6926</td>
<td>0.2186</td>
<td>.0016</td>
</tr>
<tr>
<td>b₂</td>
<td>-0.0069</td>
<td>0.0048</td>
<td>.1498</td>
</tr>
<tr>
<td>c’₁</td>
<td>0.0813</td>
<td>0.2716</td>
<td>.7648</td>
</tr>
<tr>
<td>c’₂</td>
<td>-0.0118</td>
<td>0.0082</td>
<td>.1524</td>
</tr>
<tr>
<td>i₁</td>
<td>4.4728</td>
<td>0.5068</td>
<td>.0000</td>
</tr>
<tr>
<td>i₂</td>
<td>-1.7039</td>
<td>1.6931</td>
<td>.3146</td>
</tr>
<tr>
<td><strong>Unmediated model</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c₁</td>
<td>0.2371</td>
<td>0.2529</td>
<td>.0775</td>
</tr>
<tr>
<td>c₂</td>
<td>-0.2638</td>
<td>0.0081</td>
<td>.0495</td>
</tr>
<tr>
<td>i₂u</td>
<td>0.8873</td>
<td>1.5478</td>
<td>.5667</td>
</tr>
</tbody>
</table>
In a mediation model with nonlinear relationships, the instantaneous indirect effect $\Theta$ of $X$ on $Y$ is the product of the first partial derivative of function $M$ with respect to $X$ and the first derivative of function of $Y$ with respect to $M$. With $M(X) = i_1 + aX$ and $Y(M) = i_2 + b_1M + b_2M^2$, $\Theta$ becomes:

$$\Theta(X) = ab_1 + 2ab_2i_1 + 2a^2b_2X = 0.3130 - 0.0034 X.$$ 

The term indicates that the indirect effect of default goal level on energy savings through goal choice decreases linearly as the goal default level increases. $\Theta$ is derived for $X = 0$, $X = 15$, and $X = 30$ because these values correspond to the default goal levels in this study and represent the low, medium, and high levels. Table 8 shows the bias-corrected bootstrap confidence interval of the instantaneous indirect effect for 5,000 bootstrap samples. These values were positive at a 95% confidence level. The results show that goal choice is a significant mediator of the relationship between goal default level and energy savings. Therefore, hypothesis 5 is supported.

<table>
<thead>
<tr>
<th>Default goal</th>
<th>$\Theta$</th>
<th>95% CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>0.3132</td>
<td>0.0630, 0.5830</td>
</tr>
<tr>
<td>15%</td>
<td>0.2624</td>
<td>0.1129, 0.4383</td>
</tr>
<tr>
<td>30%</td>
<td>0.2117</td>
<td>0.0852, 0.3650</td>
</tr>
</tbody>
</table>

To test the assumption that feedback on goal attainment moderates the effect of default goals on energy-saving goal
choice, a two-way repeated measures ANOVA was used with a Greenhouse Geisser correction, a default goal level (low $G^+D^+_{0}$, medium $G^+D^+_{15}$, high $G^+D^+_{30}$) as the between-subjects factor, and feedback on goal attainment as the within-subjects factor (before first feedback, after first feedback). The default goal level had a significant main effect on the goal choice ($F(2, 661) = 169.25, p < .01$). It was also found that feedback has a significant main effect on goal choice ($F(1, 661) = 179.27, p < .01$). As assumed, the interaction between the default goal and the feedback was also significant ($F(2, 661) = 32.98, p < .01$). Post hoc comparisons with Tukey HSD revealed that the customers in the low default goal condition ($M_1 = 4.25, SD_1 = 5.78; M_2 = 3.15, SD_2 = 4.92$), in the medium default goal condition ($M_1 = 12.31, SD_1 = 6.85; M_2 = 7.86, SD_2 = 5.88$), and in the high default goal condition ($M_1 = 19.13, SD_1 = 11.08; M_2 = 11.23, SD_2 = 10.18$) lowered their conservation goals after receiving the first feedback on their goal attainment (see Figure 21). However, only the customers in the medium and high default conditions significantly adjusted their savings goals downward (Figure 27). The results indicate that feedback on goal attainment moderates the effect of default goals on goal choice. Therefore, hypothesis 6 is supported.
Figure 27. The effect of the default goal level on the energy-savings goal choice before and after receiving the first feedback on the goal attainment.

4.6 Discussion and conclusions

The objective of the present study was to investigate the effectiveness of goal-setting functionality and defaults implemented in the user interface of a web-based energy feedback platform. The study provided an example of theory-driven design research at the intersection of IT and behavior models from social psychology. Research in this emerging area with the aim of influencing energy conservation behaviors is practically relevant for a number of reasons. Many commercial organizations feel pressure from legal regulations to adopt environmentally sustainable strategies for their products and services [219]. For example, in the European Union, fixed
energy consumption targets have compelled the member states to reduce their greenhouse gas emissions, increase their renewable energy use, and reduce their energy consumption [89]. These political targets translate into obligations to achieve energy efficiency for firms [255] and utility companies in particular, whose profits usually increase with the quantity sold. Some states in the U.S. (e.g., California and Oregon) recently introduced policies that require utilities to provide cause for and credibly document their reductions in energy consumption [176].

In this context, IS serve as an enabler for large-scale and cost-effective customer engagement. A far-reaching development that will further increase the potential of IS is currently underway in the utility sector where smart meters are gradually replacing the electromechanical induction watt-hour meters. Smart meters measure consumption data and feed them to a network at intervals from seconds to months. By 2020, due to regulatory requirements, 80% of all households in Europe will be equipped with smart meters [249]. Although widespread diffusion is still some years away, it is important to understand today how smart meter-based interventions may motivate end-consumers to change their behavior. For this purpose, a Green IS implementation was designed to encourage its users to reduce their electricity consumption. The results allow drawing conclusions on how consumption data should be organized and displayed not only with today’s technology but also on the basis of future smart metering infrastructures. Specifically, this study
has implications for behavioral theory and IS design and could serve as a blueprint for other research endeavors, which will be discussed in the following.

4.6.1 Theoretical implications

Based on socio-psychological theory, a number of hypotheses were formulated and tested regarding the structural relations between defaults and goals, the impact of defaults and goals on energy reduction, and the moderating role of feedback in a field experiment with 1,791 participants. With regard to the kernel theories underlying this study, the results have implications for the existing literature on goal setting and defaults. First, the results confirm that goal-setting functionality in a web-based energy feedback platform may stimulate a large number of users to significantly conserve energy. With regard to the concept of defaults, this study showed that defaults may have both positive and negative effects on behavior, not only in the context of individual consumer decisions [161] but also performance goals that require continual effort. The data indicates that only medium-level default goals lead to significant savings, whereas detrimental effects on behavior may occur if defaults are set too low or too high in comparison with a self-set goal. In addition, the fact that defaults influence continual behavior suggests that the effect of defaults cannot be merely explained by lazy individuals making a passive choice. Defaults have a normative character that informs user of the savings that they are likely to achieve. Thus, default goals can induce active consumer behaviors because individuals have to engage in behavioral
changes to obtain energy savings. Beyond the basic effect of default goals on actual energy savings, this study also uncovered the underlying causal relationship. By showing that default goals indirectly affect energy consumption by influencing goal choice, the existing knowledge on the default concept is extended. Finally, the results show that feedback on goal attainment moderates the effect of default goals on goal choice. Feedback allows one to critically check the appropriateness of the former goal choice and, as a consequence, allows individuals to reduce the discrepancy between their goals and their behaviors by lowering their new goals.

4.6.2 Practical implications

The results presented in this study show that the savings achievable by goal-setting functionalities are ultimately worth the effort. Notwithstanding the complexity of effectively designing and configuring a feedback system for electricity customers, the savings observed over a large customer group constitute a substantial contribution to sustainable development with respect to cost and emissions. For example, for 10 million households 1% additional savings equals 1.2 billion kWh which translates into about 120 million USD and 800 thousand metric tons of CO₂. The potential impact of this research may grow even further in the next years with the diffusion of millions of smart meters, which provide an even better quality of data than the self-read metering data used in the present study. Future energy feedback systems may be implemented in different forms regarding the performance indicators that goals refer to, the
number and levels of default goals, the granularity of the measured data (e.g., household vs. appliance), and the timeliness, the periodicity, and the level of detail of feedback messages. The results may support practitioners who are developing such systems by providing a number of well-founded and empirically tested design principles.

A first principle that can be drawn from this study is that goal setting can effectively nudge users towards energy conservation beyond one-time decisions. Consequently, practitioners implementing a Green IS should include some type of functionality that allows users to define their own goals instead of just providing information about their actual consumption or general energy-saving tips. Second, it was shown that defaults influence goal choice and goal attainment. However, the impact of defaults on savings seems to be only on par with self-set goals in the best case and indistinguishable from the no-goal condition in the worst case. Therefore, system designers are advised to consider defaults with either great care (i.e., if the most effective default goals are already known) or not at all because defaults may counteract the desired effects. If the exact impact of defaults on goal choice is unknown, experiments should be conducted to test and adjust the employed default goals. Third, this research showed that feedback influences goal adjustment. Feedback on saving performance poses the core functionality that users expect from any energy feedback system and can hence not be omitted. However, feedback on unattained goals can easily demotivate or discourage users, and the
presentation formats of feedback should be designed in way that limits this effect as best as possible. In addition, tailored default goals should be given based on the users’ historical data and household characteristics to avoid frustration after users receive initial feedback on their performance.

4.6.3 Opportunities for future research
Beyond the immediate insights into the effectiveness of goals, defaults, and feedback, this study opens a window to considerably more research opportunities surrounding the application of modern IS to the questions of energy consumption behavior. First and foremost, the research approach itself – that is, the combination of hypotheses rooted in the behavioral sciences and design-oriented IS research – can serve as a powerful tool to fundamentally extend the understanding of both, user behavior within the IS context and consumer choice in more general settings. This especially holds true for IS that grant direct access to fine-grained behavioral data, for example, as smart metering does for electricity, gas, or water consumption. Such systems render possible to measure the effects of behavioral interventions over time for large number of users, in real-world-settings, and with only very little interference between measurement activity and measured object. Second, opportunities for future researcher arise from a large number of interventions that deserve a better understanding as they might help to increase the overall effect of feedback systems on energy efficiency. Examples of interventions worth investigating are social normative feedback, competitions,
framing, social incentives, and rewards, which could be investigated analogous to the approach that was applied to goal setting and defaults in this study. Third, future research could apply longitudinal experimental designs in addition to cross-sectional designs to better understand the short-term and long-term effects of interventions as well as the interplay between multiple behavioral interventions that are sequentially introduced (e.g., like goal setting and feedback in this study). Only with a detailed knowledge on the short-term and long-term effects as well as the interaction of interventions, system designers will be able to unleash the full potential of smart metering infrastructures and thus yield a good cost-performance ratio. The behavioral interventions mentioned above hold the potential to influence many habits and decisions in both corporate and private life. The application of the knowledge that is to be acquired is hence not limited to electricity consumption but is applicable to other domains, too. In a private context, the acquired knowledge can be used to promote a healthy lifestyle (e.g., like Nike Plus and the corresponding online services) and in an organizational context, such knowledge can be applied to promote a sustainable car fleet usage (e.g., accounting systems often capture mileage and field consumption) or printer utilization. Not least, additional research issues arise from the consideration of other theoretical frameworks, such as the Theory of Interpersonal Behavior [263], Persuasion Theory [228], or Self-Discrepancy Theory [146], which could all be applied to change individual behavior in different domains. In sum, it can be said the IS researchers’ strong roots in socio-
psychological theory put them in a favorable position to structure problems related to Green IS, to identify feasible solutions, and to guide the subsequent design process of future Green IS.

4.6.4 Limitations

Although great care was taken to conduct a study with high internal and external validity, its limitations should be taken into account when interpreting the results. In this study, feedback on goal attainment was a within-subjects factor, which means that every participant except individuals in the no-goal & no-default condition received feedback on their goal attainment as they chose a goal for the second time. This experimental design implies that feedback was not independent of the mediator goal choice. As a result, it was not possible to conduct a mediation analysis for the full observation period. Instead, the analysis had to be restricted to the first time period before the participants received their feedback on their goal attainment. Therefore, researchers who want to test a moderated mediation should only provide feedback on energy conservation, not goal attainment. Moreover, the default goal levels were set at 0%, 15%, and 30%, respectively. Future studies should test different default goal levels to replicate the findings and increase the validity of this study’s results.
5 I am green: The role of effort and image on green identity signaling

5.1 Introduction

It is widely accepted that energy consumption needs to be diminished for a sustainable future. Recent research has shown that behavioral interventions are very effective to reduce energy consumption while being at the same time relatively inexpensive [10]. Energy conservation is commonly associated with a loss of comfort and is therefore negative from a hedonistic point of view [215]. However, pro-environmental attitudes are more likely to be translated into behavior if loss of comfort is compensated by benefits. Benefits may originate from positive associations with pro-environmental behavior like altruistic attitudes or a high status [131,252]. In their work, Griskevicius and colleagues show that people choose a costly green product instead of the cheaper ordinary alternative if status motives are primed [131]. Product choice is therefore used to communicate or signal identity [38]. This study investigates whether people can be nudged toward higher goals with regard to showering time reduction if they perceive a possibility to signal their green identity. Participants will be presented with a fictional saving campaign of a utility company by showing a postcard that

displays either a trendy or a non-mainstream greenie and the amount of effort that is associated with a certain reference saving goal. To make showering appropriate for identity signaling, participants were able to signal their identity by choosing a goal on a postcard.

This chapter starts with an overview on identity signaling and thereafter presents the hypotheses that are tested within this study. Thereafter, the experimentation setting is described and the results are reported. The chapter closes with a discussion of the result’s implications for both theory and practice.

5.2 Previous research on identity signaling

5.2.1 Identity signaling

Already in 1959, Levy has denoted that the consumer is not solely functionally oriented [185]. Rather, the purchase, display, and use of goods communicate symbolic meaning to the individual or others [133]. For reasons of self-esteem and self-consistency needs, people are more likely to buy products that evoke positive self-images rather than negative self-images [279]. Recently, studies have revealed that there are certain product domains people use more to signal their identity (e.g., music) than others (e.g., dish-soap) [38]. The authors suggest that people engage in identity signaling in product domains which are seen as appropriate for self-expression and personality inferences both by the signaler and by the perceiver to assure that their identity signal will be identified and correctly understood. Thus, the meaning is created in a social
communication process [41]. Since identity signaling is a strong motivator for human behavior, the concept has already been used to inducing behavior change. Berger and Heath used identity signaling to improve consumer health with regard to alcohol and fast food consumption [40]. According to them, “the decision to engage in detrimental health behaviors depends not only on perceived risk but also the identity such behavior signals to others.“ The possibility to convey the image of belonging to the cool crowd might outweigh the risks of smoking in the eyes of some smokers. Berger and Heath related unhealthy behavior to dissociative reference groups and found that undergraduates made healthier food choices and reported lower alcohol consumption when it was associated with a dissociative group [40].

As research has shown that high goals are related to high performance (for a review see [5]), the goal of this study is to get people to set high saving goals. In the next section, findings concerning the main influencing factors on identity signaling are presented and hypotheses are defined.

5.2.2 The influence of reference groups and domain relevance

Whether people diverge from others depends mainly on the characteristics of the social group which is associated with a certain taste or behavior. Berger and Heath showed that people diverge from disliked others, low-status others and dissimilar others [38]. The authors suggest that people diverge to make sure that others understand who they are and try to avoid sending undesired identity signals to others. White and Dahl
showed that males were significantly less likely to select and had more negative evaluations of the ladies’ cut than the house cut steak indicating that dissociative effects can be stronger than associative effects [305]. Berger and colleagues showed that people diverge when too many people are holding a certain taste [41]. Students who learned that their preferences were shared by the majority of students were more likely to abandon their former preferences [41]. For symbolic concerns, people also tend to avoid products which have become too soon too popular, as these products might turn out as fads later on [39].

The meaning of a signal is created in a social communication process. Therefore, people only engage in identity signaling in domains that are commonly perceived as providing relevant information for making identity inferences [38]. The intention to conserve energy highly depends on the attitude a person has towards saving energy. The identity that is associated with saving energy can either be perceived as beneficial (if saving energy goes along with the image of being trendy and cool) or as costly (if saving energy is associated with someone who is outdated and non-mainstream), and should thus influence the height of the self-set goal. If saving energy is presented as a trendy and well-adopted topic by the mainstream, people aiming at signaling their green attitudes might recognize that high saving goals are not suitable to send clear identity signals because perceiver could have the impression that the “greenie” just shows pro-environmental behavior because everybody does it. To increase the diagnosticity of their signals as a means to be
correctly recognized as “greenie”, identity signaler will not go with the crowd and set high goals if saving energy is presented as a trend. Instead, they will stand out from the crowd and set higher goals if saving energy is presented as being non-mainstream. Therefore, it is predicted that people who rate energy saving as highly relevant will diverge and set high goals if the greenie is presented as non-mainstream. Contrary to them, people who do not aim at signaling their identity will more focus on external cues (e.g., regarding attractiveness or lifestyle) and will set higher goals when saving energy is associated with a trendy person. Research on sympathy has revealed that individuals like people who are similar to us [58], regardless if this similarity concerns character, opinions, origin or lifestyle. It is assumed that effects of sympathy and attractiveness are likely to occur for people who do not aim at identity signaling meaning that these people will set higher goals if a likable person stands for sustainability.

**H1.** There will be a crossover-interaction between image of greenie and domain relevance on energy saving goal setting. People who aim at signaling their identity will set higher goals when being confronted with a non-mainstream greenie and people who do not aim at identity signaling will set higher goals when being confronted with a trendy greenie.

5.2.3 The influence of effort

Identity signaling only works if signals are clear and specific. As soon as dissimilar or disliked people start to adopt a certain
taste, the taste no longer communicates the desired identity. For reasons of preventing imitation, people should acquire skills or products that are related to high effort or high costs. The rationale behind this is that low-cost signals are more likely to be copied whereas high-cost signals should be more likely to persist over time because they make adoption relatively difficult [41]. For example, a person who aims at expressing himself as a music expert tries to find a signal which is hard to acquire and maybe also to identify for possible poachers. For instance, this person would rather go to bars where newcomers perform instead of going to mass-events. “Effort costs” play a significant role in identity signaling [41]. The authors assume that signaling domains that require a high initial cost of effort are especially effective.

People who want to signal their green identity should set high goals because this is associated with high effort. Thus “Identity Signaling Theory” would predict a positive linear relationship between effort costs and goal height: The higher the effort for saving is, the higher should the self-set goals be for those rating the domain relevance of saving energy high. Contrary to this, other studies have shown that pro-environmental behavior is most likely to occur when the effort is low [82]. The so-called “Low-Cost-Hypothesis” assumes a negative linear relationship between effort costs and behavior. Effort has also an indirect effect on behavior as it moderates the relationship between attitudes and behavior. While the negative direct effect has been replicated several times, the indirect effect has been modified
within the last years. Schahn and Möllers have shown that the attitude-behavior-correlation shows an inverse u-shaped pattern instead of a linear relationship meaning that attitudes will be more likely translated into behavior when the effort is medium [254]. Based on these findings it is assumed that people will set the highest goals when effort is medium.

**H2.** *The relationship between effort and goal height will show an inverse u-shaped pattern meaning that people will set the highest saving goals when the effort is medium.*

### 5.3 Empirical evaluation

#### 5.3.1 Experimental design and data collection

One-hundred-seventy-three people ($M_{age} = 30.17; SD_{age} = 12.31; 49.7\%$ male) participated in the study. The sample was recruited by a market research company to ensure to get a representative sample regarding age. The study comprised a 2 (image of greenie: trendy vs. non-mainstream) x 3 (effort: low, medium, high) between-subjects design with subjects being randomly assigned to the different experimental conditions.

On the first page of the online survey, participants learned that they were taking part in a study on attitudes towards saving energy and energy-efficient behavior. They were asked to imagine that they had received a postcard of their local utility informing about their latest energy saving campaign. Within this campaign they are asked to set an energy saving goal with
respect to showering for the next three months. To make showering appropriate for identity signaling, participants are able to communicate their goal choice by means of a fictional postcard. The postcard shows either a trendy or non-mainstream greenie. A slogan communicates low, medium or high effort.

On the following page which is supposed to be the back of the postcard participants are asked to set their individual saving goal between a range of 0% to 50% with the help of a visual slider. Choice was restricted to 50% because commercial sources estimate potential savings by 50%.

The goal choice is the central dependent variable in this study. Participants were thereafter asked to rate the domain relevance of saving energy on a 7-point Likert scale (“how well do you think can you express yourself by showing pro-environmental behavior (e.g., saving energy)?”, “how well can others make inferences on your personality by showing pro-environmental behavior?”; α = .77).

5.3.2 Intervention
A designer developed two different pictures of a greenie: One showing an aspirational modern and trendy greenie and the other showing a dissociative outdated and non-mainstream greenie. Both images represent sketched figures as this allows manipulating characteristics of the person as well as the surroundings in a better way. The cool one sits in a Starbucks coffee shop and works at his Apple laptop wearing a T-Shirt with an environmental emblem. The non-mainstream on the

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19 http://www.derenergiesparcheck.de/lew/ [accessed on 23.07.2012]
contrary looks like a hippie wearing a colored pullover and sits in his scruffy kitchen while playing the guitar and drinking tea. Two extreme characters were chosen in order to get distinct effects.

To control for sympathy and similarity effects a pretest with 31 students was conducted. Both pictures were presented and students were asked to rate the perceived similarity (“I am very similar to this person.”), motivation for saving energy (“This person just saves energy because it is hip.”), and sympathy (“I think this person is very likeable.”) on a 7-point Likert scale. Participants indicated that they feel more similar to the trendy greenie ($M_{trendy} = 3.67$ vs. $M_{non-mainstream} = 2.04; t(26) = 3.812, p < .01$) and like him more than the non-mainstream one ($M_{trendy} = 4.00$ vs. $M_{non-mainstream} = 2.81; t(26) = 5.472, p < .01$). As predicted, the participants feel that it is more likely that the cool and modern greenie solely behaves in a pro-environmental manner in order to be hip than the non-mainstream one ($M_{trendy} = 4.48$ vs. $M_{non-mainstream} = 2.19; t(26) = 3.171, p < .01$).

Effort is represented via a slogan-like statement on the picture of each greenie. To communicate high / medium / low effort the slogan claims “Save 12% of your weekly energy consumption by reducing your shower time by 50% / 30% / 10%”. Showering was chosen as target behavior of the fictional saving campaign for three reasons: First, the amount of energy for boiling water is one of the main cost drivers within the home [155]. Second, everyone takes a shower at least once but more likely several times a week. Third, shower time is a continuous variable and
thus is suitable for manipulating the effort. By communicating the effort for reducing weekly consumption by 12%, the participants were provided with a reference point for judging the effort that is associated with a certain goal.

5.4 Results

The dependent variable of the study is participants’ goal choice (between 0% and 50%). To test the hypotheses, a two factor between-subjects ANOVA with “effort” (50% vs. 30% vs. 10% reduction of shower time) and “image of greenie” (trendy vs. non-mainstream) was conducted. In addition, a median-split with domain relevance was accomplished. The analyses were performed with a sample of N = 146. Participants who chose a goal of either 0% or 50% were excluded because people with extreme attitudes are not prone to experimental manipulation as strong attitudes are likely to be automatically activated [100].
People who rate domain relevance high and see a non-mainstream greenie choose higher saving goals than people who see a mainstream greenie ($M_{high/non-mainstream} = 18.50, SD = 1.19; M_{high/mainstream} = 16.08, SD = 1.35; Figure 28). Contrary to them, people who rate domain relevance low and see a non-mainstream greenie choose lower saving goals than those who saw a mainstream one ($M_{low/mainstream} = 20.33, SD = 1.56; M_{low/non-mainstream} = 16.60, SD = 1.58; Figure 29). The analysis reveals a significant interaction between image of greenie and domain relevance ($F_{1,146} = 6.12; p = .033^*$). Effort has a significant effect on goal setting ($F_{2,146} = 7.28; p = .001^{**}$). People who are told that effort to save 12% of their weekly electricity consumption is medium, choose the highest goals
\( M_{\text{medium}} = 21.01, \ SD = 1.30; \ M_{\text{low}} = 14.58, \ SD = 1.10; \ M_{\text{high}} = 18.04, \ SD = 1.31 \).

![Domain Relevance = low](image)

**Figure 29. Effect of image and effort when domain relevance is low**

### 5.5 Discussion and conclusions

This chapter presented a study that was designed to test whether an identity signaling approach can be used to nudge people toward higher energy conservation targets. Therefore, an online experiment was conducted with 173 participants. Participants were presented with a fictional saving campaign of a utility company that was claimed to be designed in order to support energy consumers to save water and energy in the shower. Specifically, participants were presented with a postcard that
displays either a trendy or a non-mainstream greenie and that states the amount of effort (low vs. medium vs. high) that is associated with a certain reference saving goal (12%). To make showering appropriate for identity signaling, participants were able to signal their identity by choosing a goal on the postcard. Based on prior research on identity signaling, it was assumed, that people who aim at signaling their identity by saving energy will set higher goals when energy conservation is presented as being not trendy and lower saving goals when energy conservation is presented as being mainstream. The reason for this assumption is that people who want to engage in identity signaling prefer sending clear identity signals even if this means that they are associated with a less likeable person. For people, who do not aim at identity signaling, the effect should be reversed. They should set higher goals when energy conservation is presented as being trendy due to sympathy effects. This study further tested the relation between effort and goal choice. Prior research on identity signaling and the “low cost hypothesis” [82] suggest that people should choose goals that require a medium level of effort since this allows them to signal their identity and to keep effort at an agreeable level. The results show support for both hypothesis. People who aim at signaling their identity chose higher goals when energy conservation is presented as non-mainstream as opposed to mainstream while for people that did not aim at identity signaling the reverse was true. In addition, people chose higher goals when effort was medium instead of low or high.
5.5.1 Theoretical implications

This study showed that identity signaling is indeed a strong motivator to nudge people toward higher saving goals. Sadalla and Krull have provided first evidence for the appropriateness of saving energy as an identity signal in 1995 by showing that behaviors associated with resource conservation lead to systematic attributions regarding the performer’s identity and that conservation behavior is appropriate for conveying a specific image of the self to a social audience [252]. The identity that is associated with energy conservation can be perceived as beneficial and thus compensate for the effort that is associated with energy conservation or can be perceived as costly, if it is associated with a non-desirable image. This study showed that it depends on the identity signaling desires that a person has which image of energy conservation is perceived as beneficial or costly. Both people that aim and aim not at identity signaling (high vs. low domain relevance) by engaging in energy conservation rate a trendy person as being more likeable and more similar to themselves. However, a sympathy effect is only found for people that rate domain relevance low, indicating that they perceive a trendy image as beneficial and a non-mainstream image as costly. For people with high domain relevance, it is the other way around: A trendy image is costly because it impedes the possibility to send clear identity signals. People perceiving the signal could infer that the signaler does so for signaling and not for authentic purposes. A non-mainstream image in contrast is perceived as beneficial for these reasons. The findings are in accordance with research that has shown that people abandon
their original tastes when the signal is poached by dissociative groups [39,41].

In addition, the finding that people set higher saving goals when the effort is medium represents a synthesis between the assumption made by Berger and Heath [41] and the “Low-Cost-Hypothesis” [82]. According to the “effort costs”-assumption, people should set higher goals the higher the effort for saving energy is to reduce the possibility that the signal will be poached by people who want to save energy for signaling purposes whereas according to the “Low-Cost-Hypothesis” people should set the highest goals when effort is low. Instead, the relationship between effort and goal height shows an inverse u-shaped pattern which is supported by findings concerning the modification of the “Low-Cost-Hypothesis” [254]. Thus, people set the highest goals when effort is medium because by doing so they can signal their identity at a moderate level of effort. Choosing the highest goals when effort is low does not allow signaling green attitudes to others. To conclude, identity signaling nudges people toward higher saving goals since research has shown that people usually choose low effort behaviors. When people are presented with an identity signaling opportunity they choose a behavioral goal that requires medium effort.

5.5.2 Practical implications

The results of this study may support practitioners from utility companies or public institutions who are designing energy conservation campaigns by providing well-founded and
empirically tested design principles. Energy conservation campaigns often display a certain character as a role model to promote the targeted behaviors (like saving water and energy in the shower, as in this campaign). Usually, these characters are chosen with regard to relevance (shares characteristics with the target group) and sympathy [5]. This study has shown that the reliance on the sympathy effect could backfire for people that want to express their identity by conserving energy. These people, although being motivated and thus likely to reach with an energy conservation campaign, refuse to putting a lot of effort in saving energy when they feel that they are not able to send clear signals to others. Since both types of people (signalers and non-signalers) are influenced by the image that is associated with energy conservation, practitioners in charge of designing an energy conservation campaign need to personalize the campaign to the different needs of the energy consumers. For example, a utility company already has data on which people participate in energy conservation campaigns. These people are likely to be identity signalers. Therefore, it is feasible to address identity signalers and non-signalers in different ways. The utility could create two different brochures, for example, and display a very likeable person for non-signalers and a non-mainstream person for identity signalers. If addressing energy consumers is not feasible (for example, public institutions often do not have detailed data on energy consumers) the energy conservation campaign should include features that allow identity signalers to send clear identity signals. For example, the campaign could include a reward system that rewards and
displays people that are putting a lot of effort in energy conservation. This would allow people who aim at identity signaling to show their green identity and their conservation efforts by sending clear signals than can only be used by people that are actually “green” and not pretending to have green attitudes.

5.5.3 Limitations and future research

Although this study showed successfully that identity signaling has a strong influence on goal setting, there are several limitations. First, the dependent variable was goal choice meaning that people could say “I want to reduce my showering time by 50%” without having any consequences afterwards. Future studies should conduct a longitudinal study to measure both showering time and energy consumption to test whether higher goals are actually related to higher energy savings. Second, this study only applied two different images or stereotypes of a greenie although there are more than just two kinds of people who would save energy for other reasons than being trendy or being ecological motivated (e.g., save money). Future studies should therefore test which image works best for which customer segment.

To conclude, this study clearly indicates that if energy saving campaigns include an opportunity for identity signaling and address identity signalers and non-signalers differently, people may be more motivated to save energy.
6 Well-intentioned is not well done: An empirical investigation of an IS-based energy efficiency intervention using normative consumption feedback²⁰

6.1 Introduction

Against the background of the steadily increasing global hunger for energy [225], carbon dioxide emissions and resource depletion have become major concerns in the society. Given that natural resources are a public good [293], the action of the society as a whole is necessary to preserve these resources for future generations. In this context, the intelligent use of IS may play an enabling role in motivating individuals to trigger self-serving energy conservation efforts [201]. While researchers, under the term “Green information technology (IT)”, have traditionally focused on limiting the effects of information and communication technology (ICT), which gave rise to environmental concerns [219], they recently have begun to explore the opportunities that ICT offers in support of sustainability under the more expansive term “Green IS” [301].

²⁰ See Loock, C., Landwehr, J., Staake, T., Graml, T., Herrmann, A., Fleisch, E. Well-intentioned is not well done: An empirical investigation of an IS-based energy efficiency intervention using normative consumption feedback. 2012, 1-40. [192]
According to this perspective, the intelligent use of IS may contribute to the establishment of sustainable practices not only at the organizational level [300] but also at the individual level [210].

Addressing the individual level in conservation campaigns is especially relevant, as households are responsible for 29% of total electricity use [43]. Therefore, to foster related energy savings, it is necessary to increase awareness among individuals as to how much electricity they consume [136]. In most cases, however, information concerning electricity usage is provided only on a monthly or yearly basis and is generally stated on the utility bill. As a result, energy consumers rarely know whether their demand is relatively high or low compared to others or whether it has decreased or increased over time, thereby making it difficult for consumers to evaluate their performance and relate their electricity demand to actual consumption practices [103].

To improve this situation, a far-reaching development toward promoting sustainable consumption practices by means of Green IS is currently underway in the utility sectors where smart electricity meters (smart meters) are gradually replacing the electromechanical induction watt-hour meters, which, going back to the discovery of their underlying principle by Galileo Ferraris in 1885, have served to measure electricity consumption for more than one hundred years. Smart meters, which resemble sensor nodes, measure consumption data and feed it to a network at high frequency (at intervals from seconds to months).
By 2020, due to regulatory duties, 80% of all households in Europe will be equipped with smart meters [249]. Smart meters will enable enhanced monitoring and will control tasks within the electrical grid, thereby contributing to powerful, information-based energy conservation campaigns and achieving savings of up to 4.6 to 4.9 billion kilowatt hours or more [112].

Being widely deployed in the US and in Europe, the availability of high-resolution consumption data at the household level gives rise to the question on how best to use the data to induce saving effects among consumers. Web portals and smart phones constitute tools that make consumption data available to a large number of households at low cost. Developing smart meter-based consumption feedback into an influential and cost-efficient tool, however, requires a good understanding of the effects of feedback information on individuals. Without this understanding, smart metering infrastructures will not meet the high expectations and will, conversely, produce zero or only minimal effects on behavior [139] or, even worse, may cause energy consumers to respond to consumption feedback with an increase in energy demand [193,259]. Although several years will pass before smart meters exit the pilot stage and become widely adopted, it is important to develop an understanding of how corresponding information systems such as websites need to be designed to effectively motivate energy conservation. Therefore an approach that is capable of both working with
today’s technology answering the design issues of tomorrow is needed.

In the context of resource usage, social norms have proven to trigger energy conservation efforts [121,259,261]. Although social norms are an agile area of research in psychology, the types of norms that are most effective in given situations is still not fully understood. In their seminal work, Schultz and colleagues [259] provide private households with social normative feedback that compared the electricity consumption of each household to the electricity consumption of other households in the neighborhood (descriptive normative feedback). Whereas above-average energy consumers reduced consumption when faced with descriptive feedback, below-average consumers increased consumption when they learned that they were already performing better than most of the others. However, when adding the injunctive norm (the approval or disapproval by relevant others), below-average consumers maintained their energy consumption at a desirably low level. This insight ultimately helps to prevent undesirable boomerang effects that have often occurred as a response to social norm interventions [233,304]. However, the authors did not investigate the effect of injunctive feedback alone, and therefore the current literature does not offer a clear picture of the exact interplay of these two frequently used types of social norms. In particular, the literature offers three contradicting underlying mechanisms that may explain why injunctive feedback is able to buffer the detrimental effect of isolated descriptive feedback on
people with low a priori energy consumption. First, injunctive feedback can reduce energy consumption, thereby countering the detrimental effect of descriptive feedback (additive effect [66,250]). Second, injunctive feedback dominates the perception of consumers and therefore overshadows the effect of descriptive feedback (ordinal interaction [101,250]). Third, the two types of feedback have detrimental effects if presented alone and only stimulate savings if presented in combination (disordinal interaction [211]). Depending on how the buffering mechanism actually manifests itself, different conclusions can be drawn for an optimal Green IS design. In the case of an additive effect, only injunctive feedback should be used. If an ordinal interaction occurs, either injunctive normative feedback or descriptive plus injunctive feedback can be used. Finally, in the case of a disordinal interaction, only the combination of descriptive and injunctive feedback should be implemented. The purposes of this research are to contribute to social norms research by advancing the understanding of the underlying mechanisms of social normative feedback and to provide empirically based design principles that enable Green IS to change individual energy consumption behavior effectively. Given that the wrong choice of a social norm can render a feedback system ineffective [259], this undertaking is also of considerable practical importance for the design of future feedback systems in general and smart metering frontends in particular.
This research follows a “hypothetico-deductive, theory-testing mode of design science” [29]. An IT artifact is designed to test which of the three different theoretical propositions with regard to the effect of social normative feedback on household electricity consumption finds empirical support. In addition, the artifact allows for a consumption reduction according to the approach of Hevner [145]. This study’s approach corresponds closely with Baskerville’s specification of “design as research methodology” [30]. The IT artifact under consideration can be categorized as application content [313] and can, therefore, be examined from a behavioral perspective in a social context with individuals and society as the beneficiaries.

To answer the research question rigorously, the IT artifact was introduced to the residential customers of a utility company in a field experiment. Data from 487 customers was collected and analyzed to determine how descriptive and injunctive normative feedback interactively impacted energy consumption. Based on these results, implications for practitioners who are designing IS for the smart metering infrastructure are provided to attain significant energy savings. Thus, this research follows the call by Briggs and colleagues [55] to go the last research mile by using “… academic knowledge (on social normative feedback) to solve real problems (energy conservation) for real people (actual energy customers) with a real stake in the outcome (designing effective Green IS)”.

The remainder of the chapter is organized as follows. First, prior energy efficiency intervention studies with and without the
support of IS are reviewed and an overview on social norm research is provided. Thereafter, the research question is developed based on social norms theory and current empirical evidence in this field of research. Then, a real-world IT artifact is presented that implements social normative feedback and that allows for conducting an empirical study by using a large sample of real energy consumers. Subsequently, the results of this study are presented. The chapter closes with a discussion of the main findings and their theoretical and practical implications.

6.2 Previous research on energy efficiency Interventions

Interest in behavioral energy efficiency interventions has increased continuously during the last several decades, due to the relative cost-effectiveness of the interventions and their potential to affect energy demands that are comparable to large changes in relative prices [11]. Behavioral interventions can address habits and promote curtailment behaviors, such as switching the lights off when leaving the room, which requires continuous effort, or they can encourage one-shot efficiency behaviors, such as the purchase of new energy-efficient household appliances [5]. A common framework to classify the many different types of behavioral interventions is to divide the strategies in antecedent and consequence strategies [5,309]. Antecedent strategies, such as information campaigns, aim to influence determinants of behavior prior to the environmentally
significant behavior. However, there is often no clear evidence that information campaigns result in reductions of energy use. Rather, these campaigns tend to result in an increase in pro-environmental attitudes or knowledge without necessarily affecting behavior [5]. Consistent with this notion, Luyben has shown that a general prompt by former US President Carter to lower thermostat settings has only motivated one-third of residents to actually do so [196]. However, if information campaigns are more tailored, substantial behavior change can be achieved [6]. For example, Gonzales and colleagues showed that the subjects who received tailored energy audits were more likely to act on auditors' recommendations [123].

Similar to antecedent strategies, consequence strategies are only successful in changing consumption behavior if they are highly tailored to and consider the characteristics of the energy consumer. Consequence strategies address the determinants of behavior after the environmentally significant behavior has occurred by presenting a positive or negative consequence to make pro-environmental behavior more attractive or an environmentally unsound behavior less attractive, respectively [5]. Examples include rewards or feedback [48,149,202,310].

A recent large-scale approach is presented by Allcott [11], who evaluates the effectiveness of home energy report letters sent to residential utility customers that compare their electricity use to that of their neighbors. The program, in place throughout the US, is run by a company called OPower. OPower is a software company that combines insights from behavioral science with
data of utility companies to generate tailored reports that account for household and consumption characteristics. Based on data from a natural field experiment of 600,000 households that are randomly assigned to treatment and control conditions, Allcott estimates average savings of approximately 2% [11]. However, while high-energy consumers decrease their consumption by 6.3%, low energy-consumers may decrease their consumption by a lesser extent or may even slightly increase their consumption (p. 10, Figure 7). This study shows that the effectiveness of feedback interventions depends on household consumption patterns. Additionally, social aspects, such as political views, play an important role [71,195]. People with liberal preferences tend to decrease their consumption when confronted with peer comparisons, whereas conservatives tend to increase consumption [71]. These findings hint at the necessity for tailored consumption feedback. In conclusion, interventions that refer to a specific situation, state of knowledge, or feeling appear to yield higher savings than less specific interventions [144].

The findings motivate the use of IS as the findings have the potential to offer tailored interventions at a low cost for a large number of individuals. For example, feedback can be personalized based on consumption patterns or savings advice can be provided based on household characteristics. With the aid of modern technologies in data processing, personalization, and immediate feedback [226], IS can bridge the classical trade-off between reach (i.e., “the ability to connect with a large number
of actors” [98]) and richness (i.e., “the ability of information to change understanding within a time interval” [74]). Consequently, IS-related energy efficiency interventions offer the potential to be superior to traditional interventions, such as those described earlier, if they are carefully designed.

6.2.1 Information systems as promoters of energy efficiency interventions

Research in the area of energy efficiency made an early discovery of the potential of IS, such as in-home displays, for conducting antecedent or consequence interventions [149,151,201,202]. Early IS-related studies have primarily focused on testing specific aspects of consumption feedback, such as the presentation format of the feedback [151], the frequency of the feedback [149], the source of the feedback [310], or the location of the feedback device [311]. These studies provided useful insights on general aspects of consumption feedback; however, they did not take into account different user characteristics, such as baseline consumption, attitudes, or preferences that sometimes determine whether an intervention will be successful [71,259]. A “mixed-message-strategy” to reach all individuals in a heterogeneous population is therefore necessary [71] and requires knowledge from psychology about the formation and modification of attitudes and preferences, as well as the systematic testing of feedback information presentation formats for energy consumers with different mindsets. As the smart electricity meters are being widely deployed because of enforced regulations [249], the
infrastructure for “mixed-message-strategies” is currently becoming available. Information on consumption, that is high in temporal resolution as well as household characteristics, can subsequently be used to develop influential and cost-efficient tailored energy efficiency interventions. The emergent large-scale studies on smart metering, however, have primarily focused on assessing the general effects of consumption feedback on energy savings and load-shifting potentials [99,256]. Because the design of the feedback systems within these pilot studies was not research-driven, the studies have a rather limited scope with respect to the development and testing of theory-based energy efficiency interventions.

6.2.2 Social norms as promoters of energy conservation efforts

In the context of resource usage, social norms have proven to trigger energy conservation efforts [5,45,273]. People often use social norms to gain an accurate understanding of a current social situation to respond adequately [67]. Furthermore, they adapt their own behavior to social norms so as to be liked and accepted by other people [14]. Social norms are one of the most powerful determinants of behavioral change, as they have a strong effect on both attitudes and behavior and are especially effective in the context of socially responsible behaviors [212], such as not littering [66], recycling [262], re-using towels [121] and conserving energy [259]. Social norms play an important role in one’s social life in that they restrain egoistic impulses in favor of collective outcomes [127,273] and therefore they play an important role in social dilemmas [293]. Focus theory of
normative conduct [66] refines the concept of social norms by differentiating between descriptive norms and injunctive norms. Descriptive norms refer to the typicality of a given behavior, while injunctive norms refer to the degree of social approval or disapproval for the behavior. For example, recycling may be highly approved by the peer group, but at the same time, only a few actually recycle, due to situational conditions (e.g., no containers for old glass available). While injunctive norms are relevant for building and maintaining social relationships, descriptive norms provide information that is relevant for choosing accurate behaviors [157]. A second refinement of focus theory on normative conduct concerns the circumstances under which social norms actually affect behavior. To influence an individual’s behavior, a norm must be focal for the individual at the time of the behavior [66,166]. For example, Kallgren and colleagues [166] found that people who were aroused and consequently more focused on normative statements concerning the anti-littering norm littered significantly less than those who were not similarly aroused.

In the context of pro-environmental behavior, a common means to activate social norms is the use of feedback. Studies examining the effect of normative feedback on energy consumption [5,277] have, however, reported mixed results; that is, at times, normative feedback has been found to be effective, while at other times, it has not. According to Schultz and colleagues [259], these inconsistent findings originate from the application of the wrong type of norm. Many studies provided
information about the amount of energy that consumers use as a descriptive norm. The descriptive norm, however, may “act[s] as a magnet for behavior for individuals both above and below the average” [259]. As a consequence, boomerang effects can occur when individuals who already demonstrate a desirable behavior adjust to the descriptive norm. To examine how normative messages can have differential effects depending on whether the message the recipient receives about personal behavior is above or below the norm, Schultz et al. [259] conducted a study of 290 households in California over a period of eight weeks. According to the baseline consumption of these households, the authors assigned the participants to either a high- or a low-energy consuming group. Within each group, one half of the households received feedback on their energy consumption (in kilowatt hours) for the previous week and on the energy consumption of an average household in their neighborhood. The second half of the households received the same information and additional injunctive feedback, which was represented by a handwritten smiley face to indicate the approval of their energy consumption. The feedback was provided on door hangers. For the above-average energy consumers, any type of feedback led to a decrease in consumption. In contrast, individuals who consumed less energy compared to their neighbors increased their consumption in response to the descriptive normative feedback on their performance. However, with the addition of the injunctive feedback, the energy consumption of below-average energy consumers remained at a desirably low level. Thus, injunctive
norms are able to offset the boomerang effect that descriptive normative feedback causes. These findings ended a long-standing controversy with regard to the general effectiveness of social norm interventions.

However, Schultz et al. [259] did not focus on the isolated effect of the injunctive normative feedback, even though this particular experimental condition would allow the uncovering of important insights into the mental processing of normative feedback. Knowledge on the interplay between injunctive and descriptive normative feedback would ultimately help to decide whether injunctive, descriptive or a combination of both should be used for information systems within the smart metering infrastructure to obtain durable energy savings.

Therefore, the objective of this study is to address this research gap by developing and empirically evaluating a theoretically sound IT artifact through a large sample of real-world data. In the following section, the theoretical rationale underlying the research question is discussed step by step. The rationale is based on focus theory of normative conduct and empirical evidence regarding injunctive and descriptive norms.

6.2.3 Development of the research question

In their seminal work, Schultz et al. [259] focused on the reconstructive power of the injunctive norm. Their main goal was to show that the detrimental effect of descriptive normative feedback for people who are already consuming energy at a
desirably low level can be buffered if the injunctive norm is added. Hence, their research design did not include an injunctive feedback only condition. However, the relative performance of the isolated injunctive feedback condition in comparison to the combined feedback would allow the determination of how descriptive and injunctive feedback operate together. The buffering effect can be explained by three potential mechanisms, which will be outlined herein. The results by Schultz et al. (2007) are used to illustrate the possible buffering mechanisms. The illustrations focus on the effects of the feedback conditions for below-average energy consumers, as above-average consumers reduce their consumption in all feedback conditions. The following three outcomes can be explained by theory; however, they are contradictory. It is, thus far, unknown which outcome will occur, and therefore empirical clarification is needed.

First, injunctive feedback could always reduce energy consumption and counter the detrimental effect of descriptive feedback (additive effect, see Figure 30). That is, if this feedback is presented in isolation, it should reduce energy consumption for below-average consumers (and for consumers with high baseline consumption levels). When presented in combination with descriptive feedback, injunctive feedback should counter the detrimental effect of descriptive feedback for low-level consumers, thereby resulting in a null-effect (buffering). The rationale for this potential buffering mechanism is based on the trans-situational influence of injunctive norms.
In two studies [66,166], it was found that injunctive normative appeals reduce littering regardless of the environmental conditions (e.g., clean vs. littered environment). If the existence of an additive effect was shown empirically, only injunctive normative feedback should be used for both consumers with high and low baseline consumption levels to maximize savings effects.

Second, injunctive feedback could have a buffering effect on its own and be dominant over descriptive feedback (ordinal interaction, see Figure 31). Injunctive normative feedback alone

*Figure 30. Changes in energy consumption (kWh) if the effect of the two types of feedback was additive*
would subsequently motivate below-average consumers to keep their consumption at a desirably low level. In combination with descriptive normative feedback, it would overshadow the effect of descriptive normative feedback. Supporting this assumption, Cialdini and colleagues [66] found that when a descriptive norm that points consumers in the direction of the detrimental behavior of others is in conflict with an injunctive norm that focuses attention on what others ought to do (e.g., “do not litter”), the injunctive norm tends to actually reduce the emergence of the detrimental behavior, but the injunctive norm does not completely eliminate the negative behavior. The dominance of injunctive norms over descriptive norms is also supported by Reno et al. [250] and Fehr and Fischbacher [101]. Reno and colleagues [250], for instance, find that injunctive normative appeals are more effective in reducing littering, even if the descriptive norm is adjusted to situational conditions. If the existence of an ordinal interaction was supported empirically, either injunctive normative feedback or descriptive plus injunctive normative feedback for above- and below-average energy consumers can be used to maximize energy savings because it has equal effects. However, the descriptive norm alone should not be used.
Third, each type of feedback could, by itself, have a detrimental effect, and only the combination of these two types of feedback would have a buffering effect (disordinal interaction, see Figure 32). That is, both descriptive and injunctive normative feedback should motivate an increase in consumption for below-average energy consumers if presented in isolation; however, if presented in combination, consumption levels should remain low. This buffering mechanism is based on Melnyk et al.’s [211] finding that both descriptive norms and injunctive norms can have negative effects on pro-environmental attitudes and intentions under certain conditions. Under conditions of cognitive load, descriptive norms have a positive effect on
attitudes toward environmentally friendly processed potatoes and a negative effect on intentions towards buying. Under conditions of cognitive deliberation injunctive norms have a negative effect on attitudes and intentions as positive thoughts in favor of the advocated behavior are suppressed. However, presenting the two types of norms in combination should balance the effects of the two types of social norms because, in either condition (high or low deliberation), one type of norm would influence attitudes and intentions in the desirable direction. Thus, only the combination of both norms should have a buffering effect. If a disordinal interaction was actually found, only the combination of the two types of norms should be used to achieve energy savings.

To conclude, three outcomes are likely to occur based on the theory, namely, an additive effect, an ordinal interaction or a disordinal interaction. Therefore, the research question that will be addressed in this study is the following:

*What is the underlying mechanism of the buffering effect of injunctive normative feedback, and what are the implications for the design of Green IS?*
6.3 Artifact design: The Velix system

In this study, an IT artifact is designed to obtain knowledge on how to display social normative feedback on energy consumption to advance the understanding on social normative feedback and to build effective IS-based feedback systems. This study’s approach, therefore, fits well with the “design as research methodology” mode of design science research specified in Baskerville’s framework [30] on the relationship between design and science in IS research. The methodological orientation, as such, can be classified as both “empirical” for scholars who are generally interested in the interaction of
injunctive and descriptive normative feedback and as “design science” for those who are primarily interested in implementing effective IS-based feedback systems [314]. The core of the IT artifact is the content of a web-application as data regarding residential electricity consumption are collected, organized and manipulated to support the energy conservation efforts of households. To probe the design in a natural setting, the study was conducted in collaboration with an Austrian utility company. A web portal was developed and served as a basis for an energy efficiency campaign that ran from April 1, 2010 to December 31, 2011 (for details see 3.2.3). In a nutshell, the customers were incentivized for registering and transferring the readings of their electricity meter as part of the campaign. The meter readings were verified based on official utility bills. Incentives to foster participation included a gift worth EUR 5 to EUR 10 for three meter readings, the opportunity to participate in a monthly lottery, and bonus points that could be traded for a number of energy-related products and services. All participants of the study had equal access to the incentive system. Between April 1, 2010 and December 31, 2011, a total of 10,700 users joined Velix and entered 319,169 meter readings. On average, visitors spent approximately 4.59 minutes per visit on the site. For the present study, 487 users were drawn from the total number of users and randomly assigned to one of the experimental conditions.

The website was structured as follows (see Figure 33). After registration, users could participate in the “meter hunt”, a
gamified explanation to find the electricity meter and interpret its reading. Participants who already knew where to find their meter could directly enter the reading in the portal. Next, users were asked to voluntarily set a reminder to foster repeated system usage, either in the form of an email or a text message sent to their mobile phone at intervals and times as selected by the users. With only one meter reading, it is not possible to determine household consumption. Consequently, several subsequent functionalities of the portal, such as the neighborhood comparison and the efficiency check, were not enabled during the first login but only briefly explained as an outlook for the next visit. However, during the first visit, users could invite new potential participants, receive savings advice, and read and write comments in a moderated forum. All users had equal access to savings advice and to the forum.

Figure 33. Chain of experience of the social normative feedback intervention
Following a subsequent meter entry at least one week after the first data input and after the completion of the household profile, users received feedback on their consumption. To provide tailored information for each consumer, the household profile included data on the type of space, the type of water heating system, the number of inhabitants, the address/location of the residence, the number of household appliances, the size of the apartment or house and the size of the water heating system.

The website served as an experimental platform to test various kinds of consumption feedback with respect to their effectiveness on energy conservation. In particular, feedback was either given or withheld according to the experiment group the users were automatically and randomly assigned to upon registration. Velix subsequently provided each participant with a different view. User ID and data input (e.g., username and password, meter readings with time stamps, and household characteristics) where stored in a data base.

6.4 Empirical evaluation

6.4.1 Experimental design and data collection

Four hundred eighty-seven residential energy customers of the Austrian utility company participated in this field study (71.5% male, \( \text{Mod}_{\text{age}} = 41 - 50 \) years). The study comprised three experimental groups that compared the effects of each of the two isolated feedback types with the combination of the two feedback types (descriptive feedback vs. injunctive feedback vs. combined feedback). The feedback types were randomly
assigned in a between-subjects design. In accordance with the procedure by Schultz and colleagues [259], the sample was quasi-experimentally divided into two subgroups based on their baseline energy consumption level (below vs. above the median). The data was analyzed separately for both groups. Participants with electric heating systems (N = 124) were excluded from further analysis, due to their over-proportional consumption patterns. Furthermore, households that did not provide information regarding the size of the household (N = 20) were excluded because this information was crucial for assigning a household to the high vs. low consumption group. In addition, the 5% most extreme entries (both 2.5% at the lower and the upper end of the distribution) were excluded from further analyses to guard the analyses against outlier-biases. If the baseline measurement was an outlier, the whole dataset from this household was discarded because a valid baseline is a prerequisite for the analytic approach. This procedure resulted in a final sample of 324 households that serve as a basis for the statistical analyses. Table 9 provides an overview of central sample characteristics.
Table 9. Subsamples in the study on feedback and social norms

<table>
<thead>
<tr>
<th>Subsamples</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below-average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>descriptive feedback</td>
<td>64</td>
<td>57.12</td>
<td>18.60</td>
</tr>
<tr>
<td>injunctive feedback</td>
<td>54</td>
<td>59.89</td>
<td>23.92</td>
</tr>
<tr>
<td>combined feedback</td>
<td>52</td>
<td>57.77</td>
<td>18.92</td>
</tr>
<tr>
<td>Above-average</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>descriptive feedback</td>
<td>53</td>
<td>115.52</td>
<td>26.89</td>
</tr>
<tr>
<td>injunctive feedback</td>
<td>50</td>
<td>118.26</td>
<td>32.05</td>
</tr>
<tr>
<td>combined feedback</td>
<td>51</td>
<td>118.04</td>
<td>42.68</td>
</tr>
</tbody>
</table>

N = Sample size, M = Mean baseline consumption (in kilowatt hours), SD = Standard deviation (in kilowatt hours)

The baseline level of consumption was calculated using the readings that were obtained during the first two weeks of the study. The intervention began immediately after the baseline consumption was measured, and the consumption was monitored weekly over the following four weeks. To ensure the correct entry of the electricity meter readings to the portal, multiple strategies were applied. First, the users were provided with detailed graphical and textual instructions on the location of the electricity meter and how to read it. The utility company has been using this information for many years to support customers who read the electricity meter for billing purposes. Second, algorithms that assess the validity of the entered meter readings of electrical usage were implemented. For example, if an individual enters a negative value or a reading that is lower than the previous reading, he or she will receive an error notification. Additionally, the validity of the entered meter readings for a subset of 115 customers was checked. The
correlation between the level of the yearly energy consumption for 2009 (which was read by the utility company) and the level of the yearly energy consumption for 2010 (which was a projection based on the meter data that had been entered by the customers in the portal) was substantial \((r = .80; \ p < .01)\). This correlation underscores the validity of this study’s approach to obtaining quality data.

6.4.2 Intervention

To provide participants with descriptive normative feedback on their consumption of electricity, historical data from recent years on all customers of the utility company was used. In the descriptive feedback condition, customers were presented with a bar chart that compared their weekly energy consumption (in kilowatt hours) to the average energy consumption of similar households (with respect to size and heating systems) in the neighborhood (see Figure 34a). The injunctive feedback assigned grades ranging from A to G, with A representing a high level of approval of the customer’s energy consumption and G representing a high level of disapproval (see Figure 34b). The injunctive feedback on the household’s energy efficiency level took into account certain basic household characteristics (e.g., the number of appliances and the type of heating). The two types of feedback were also combined to investigate their joined effects (see Figure 34c). During the study, users were only participants of one experiment, and they had not been previously assigned to another experiment.
All customers were additionally provided with advice on how to conserve energy. Customers could use a customer-care-hotline, a contact form, and/or a forum to contact the utility company with questions regarding the feedback on energy consumption.

Figure 34. View of feedback page in (a) a descriptive-feedback-only condition (left), (b) an injunctive-feedback-only condition (middle) and (c) a descriptive-plus-injunctive-feedback condition (right)

6.5 Results

For each household, five measurements (baseline plus four weeks of treatment) were collected, which results in a repeated measurement structure of the data. Repeated measurements violate the core assumption of traditional statistical techniques, such as regression analysis or analysis of variance, which require completely independent observations. In particular, repeated measurements, over time, are usually characterized by correlated error terms that follow an autoregressive pattern. That is, the shorter the temporal distance between two measurements of one observational unit, the higher the correlation between the
error terms of these two observations. If this complex error structure is not considered in the analysis, a biased statistical test will be the consequence. To model such data adequately, linear mixed models were proposed approximately 30 years ago, but due to the recent advances in computational power, these models have become available to a wider audience of researchers [106]. The analysis used the lme()-function that is available in the nlme package of the R statistical software [241] for all subsequent analyses. The three experimental conditions were dummy-coded with the baseline measurement acting as the respective reference category. As outlined above, two separate models for consumers were estimated. That is, high versus low (median-split) in their baseline energy consumption. The consumption $Y$ of household $i$ was modeled as follows:

$$Y_i = X_i \beta + Z_i u_i + \varepsilon_i,$$

$Y_i$ was a $5 \times 1$ vector of the energy consumptions, $X_i$ was the $5 \times 4$ design matrix of the independent variables (intercept, descriptive, injunctive, and combined feedback), $\beta$ was the $4 \times 1$ vector of the estimated fixed coefficients, $Z_i$ was the $5 \times 1$ design matrix of the random effect (intercept), $u_i$ was the $1 \times 1$ vector of the estimated random effects, and $\varepsilon_i$ was the $5 \times 1$ vector of the residuals that were assumed to have a multivariate normal distribution with a mean of zero and a $5 \times 5$ variance-covariance-matrix $R_i$, which had an AR(1) structure. The corresponding descriptive statistics are presented in Figure 35 (error bars indicate 95% confidence intervals).
For the households that had a high level of baseline consumption, the model estimated a baseline consumption of 115.49 (SE = 3.03) and indicated that descriptive feedback ($b = -5.34, p < .05$), injunctive feedback ($b = -5.06, p = .07$), and combined feedback ($b = -6.46, p < .05$) all reduced energy consumption during the experimental phase. Importantly, the coefficients of the three experimental cells did not differ from each other ($p > .10$), indicating that all three types of feedback were equally efficient in reducing energy consumption. For the households that had a low level of baseline consumption, the model estimated a baseline consumption of 58.16 (SE = 1.67) and indicated that descriptive feedback increased consumption ($b = 4.74, p < .05$), thereby indicating a boomerang effect. In contrast, for this group (households with a low level baseline consumption), the injunctive feedback ($b = .88, p > .10$) and the combined feedback ($b = .37, p > .10$) led to consumption levels
that were similar to the baseline levels during the experimental phase. Notably, the coefficients of the injunctive feedback and the combined feedback differed significantly from the coefficient of the descriptive feedback ($p < .05$); however, the coefficients did not differ from one another ($p > .10$), thus indicating that injunctive feedback alone is sufficient to offset the undesirable boomerang effect. Figure 31 depicts the changes in energy consumption in kilowatt hours for the different feedback conditions for the below- (left) and the above- (right) average energy consumers.

6.6 Discussion and conclusions

The objective of this study was to elucidate the underlying mechanism of the buffering effect of injunctive normative feedback on energy consumption. Three possible buffering mechanisms were outlined based on the focus theory of normative conduct by Cialdini et al. [66] and prior research. For this purpose, Velix was presented, an IT artifact designed to both advance theory on social norms and to encourage consumers to reduce their electricity consumption and thereby create benefits for the individual household, the utility company and society. Velix was used to conduct a field experiment with 487 participants over the course of six weeks. The study has implications for both theory and practice, which are discussed in the following paragraphs.
6.6.1 Theoretical implications

This is the first study that provides empirical evidence for the interplay of descriptive and injunctive normative feedback. The study by Schultz et al. [259] raised the question how injunctive and descriptive normative feedback operate together. Specifically, the authors found that descriptive normative feedback alone or in combination with injunctive feedback reduces the energy consumption of people with high a priori consumption levels. However, the isolated application of descriptive norms has been found to produce an undesirable rebound effect toward higher consumption for people with low a priori consumption levels—an effect that is neutralized when, in addition to descriptive norms, injunctive norms are activated. This effect can be explained by three potential mechanisms which follow from contradictory theoretical accounts and would each have very different practical implications for the application of normative feedback in IS systems. First, injunctive feedback on its own may reduce energy consumption, thereby countering the detrimental effect of descriptive feedback when presented in addition (additive effect [66,250]). Second, injunctive feedback on its own may not change the energy consumption level of below-average consumers but dominates the perception of consumers and therefore overshadows the detrimental effect of descriptive feedback (ordinal interaction [101,250]). Third, the two types of feedback have detrimental effects when presented alone and only stimulate savings if presented in combination (disordinal interaction [211]). By examining the effect of an isolated injunctive feedback
condition which had not been included in the study by Schultz et al. [259], it was possible to elucidate the underlying mechanism. It was found that both injunctive feedback and the combination of injunctive and descriptive feedback maintain energy consumption for consumers with high a priori consumption levels at a desirably low level. Hence, injunctive normative feedback alone is as effective as the combination of the two types of norms in motivating the above and below-average energy consumers to reduce or maintain their low level of energy consumption, respectively. The findings show evidence for the second buffering mechanism (ordinal interaction). Injunctive normative feedback has a buffering effect of its own and overshadows the effect of the descriptive feedback when presented in combination. This process highlights the relative dominance of injunctive feedback over descriptive feedback. This study therefore provided an answer to the open question regarding the interplay of the two types of norms that had been raised by Schultz et al. [259]

The type of the buffering mechanism ultimately determines which conclusions can be drawn for an optimal Green IS design. The existence of an ordinal interaction means that either injunctive normative feedback or descriptive plus injunctive normative feedback can be used for above- and below-average energy consumers to maximize energy savings because it has equal effects. However, the descriptive norm alone should not be used. Given that an incorrectly chosen social norm can render a feedback system ineffective [259], these design principles are
of considerable importance for the design of future feedback systems in general and smart metering frontends in particular.

One additional interesting insight of this study is that IS appears adequate to serve as a relevant other. Social normative feedback, if delivered via a website, can actually exert social pressure and induce behavior change. In the research area of computers as social actors [107,246], it has been found that the relationship between computers and humans is fundamentally social. Therefore, IS is capable of persuading and inducing change in human behavior.

6.6.2 Practical implications

The results of this study may support practitioners who are designing information systems for the upcoming smart metering infrastructure by providing well-founded and empirically tested design principles. System designers must consider that below- and above-average energy consumers respond differently to different types of feedback. Specifically, the consumer should use either injunctive normative feedback alone or in combination with descriptive normative feedback. However, energy consumers who are already performing well should not receive descriptive normative feedback alone, as it is likely to cause boomerang effects. Information systems that implement these guidelines will be able to provide a large audience with tailored information, thereby supporting energy conservation efforts and substantially increasing savings effects.
In addition to the importance of energy efficiency to individual households and society as a whole, this research is also relevant to managers of companies, in general. In addition to financial performance, companies are increasingly being held accountable for their environmental and social responsibilities [57,96]. More and more companies are “going green” because they are forced to adopt environmentally sustainable strategies for their products and services [219] due to legal regulations. For example, in the European Union, member states have committed to reduce greenhouse gas emissions, increase their renewable energy use, and reduce their energy consumption by 2020 and beyond [91]. To achieve these political targets, firms have to commit to environmentally sustainable strategies [255]. In this respect, utility companies play a particularly important role because their profits increase with the quantity sold. Other political efforts aim at decoupling profits from sales (see, e.g., California and Oregon). Consequently, utility companies are now incentivized to introduce effective energy efficiency programs that motivate their residential customers to save energy. The companies are, furthermore, required to document obtained savings [176]. In this context, IS-based feedback systems represent a technological enabler for large-scale customer engagements. As those feedback systems become available due to the upcoming smart metering infrastructure, the energy savings can be obtained in a very cost-efficient way and therefore can increase the benefit and competitiveness of utility companies in a liberalized market. If this study’s findings are considered in the design of the feedback systems, it can be
assumed that much greater savings effects and better cost-effectiveness can be achieved.

6.6.3 Limitations and future research

Although great care was spent to conduct a study with high internal and external validity, several of the limitations of this study are worth mentioning and may provide fruitful avenues for future research. First, the participants in the study registered and engaged voluntarily in the utility company’s energy efficiency program. It is, therefore likely that such participants are already interested in the topic and are already attempting to conserve energy. As a result, potential savings would either be over- or underestimated. An overestimation would occur if the participants are more motivated than the average person to engage in energy conservation, and an underestimation is likely if the participants have already improved their efficiency before the study such that there was no room for improvement. However, the aim of this study was to compare the different feedback conditions and not to evaluate absolute savings in kilowatt hours. Therefore, a systematic bias of the results is not expected. Second, the study was conducted over a period of six weeks, that is, during April and May of 2010. It is possible that the effects would be greater during the time when people use their space heating units and spend more time at home. Again, this possibility is not a problem for this research purpose, as a systematic bias is not expected. Third, because this study used real-life data, processing data is missing. For example, data with regard to the psychological variables that could have explained
the effect of the feedback conditions on energy conservation was not collected. Additional research is needed to understand the cognitive and emotional processing of the different types of social norms. This goal is already being pursued by psychologists [157], as it requires laboratory studies. Last, it is not clear what the customers actually did to save energy. Future research should include surveys or interviews to relate feedback conditions to specific behavioral actions.

This study clearly established the superiority of injunctive normative feedback and provides useful design principles for the development of Green IS systems that will significantly increase the benefit of the upcoming smart metering infrastructure.
7 The influence of reference group proximity and location on the effectiveness of social normative feedback on electricity consumption

7.1 Introduction

Energy supply is a key challenge of the society. Due to growing populations, increasing incomes and the industrialization of developing countries, the world primary energy consumption is expected to increase annually by 1.6% [15]. One of the most promising and cost-efficient means to counter this upward trend is to improve energy efficiency. The European Commission regards energy efficiency as “Europe’s biggest resource”. Similarly, the U.S. secretary of Energy, Steven Chu, states that “energy efficiency isn’t just a low hanging fruit; it’s just fruit lying around” [63]. A recent report found that households and businesses could reduce energy consumption by 23% and thus gain $1.2 trillion if they would make use of their end-use efficiency potentials by insulating their house or by replacing old appliances through energy-efficient appliances, for example

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In order to realize the efficiency potential, several policies have been introduced throughout the U.S. and Europe. The EU, for example, is committed to save 20% of annual primary energy consumption compared to projections [89]. This saving target translates into obligations for public sector, industry, utility companies, and residential energy consumers. In this context, green information systems (Green IS) could contribute as a powerful enabler to achieve the saving targets across stakeholders. In this study, an IT artifact is presented that allows for motivating households to reduce their energy consumption.

Related to corporate responsibility, technology is both a cause of the environmental burden (due to the resources that need to be invested) and a potential solution (due to efficiency gains) [300]. Under the concept of ‘Green IT,’ firms and researchers traditionally place a focus on information and communication technologies as a cause of environmental concerns [219]. Research in this area concentrates on hardware design and implementation issues, with the aim of improving energy efficiency of data centers, minimizing the ecological footprint of IT, and reducing the impact of electronic waste [37,78,159,217]. Recent developments in Green IS research acknowledges that IT is not only part of the problem, but could also be a potential solution to the problem of steadily increasing worldwide energy consumption. For example, the efficiency of business processes can be improved by automation and by developing more sustainable strategies by using decision support systems [292].
While the improvement of energy efficiency at the organizational level has been the objective of numerous studies in the realm of IS Research, the individual level has been largely overlooked. Only a few studies address the application of Green IS for motivating energy consumers to be more energy-efficient, although it has been widely acknowledged that IT can have a positive influence on individual behavior and attitudes [110,129,147]. Very recently, some IS researchers have employed the idea that individuals play an important role in realizing environmental sustainability [210]. Addressing the individual level (i.e. households) to achieve the saving targets is extremely important as households contribute to 20 to 30% of final energy use [93]. And due to growing populations and incomes, residential energy consumption is expected to increase even further [225]. Increasing the energy efficiency of appliances alone will not be sufficient to stop this undesirable trend. Energy consumers ultimately determine the energy efficiency of technology in the way they operate it [195]. Therefore, it is advisable to address human behavior.

To change the behavior of energy consumers, behavioral interventions have proven to be effective and cost-efficient at the same time [10]. Interventions can either change the context in which consumption decisions are made by, for example, offering rewards that render pro-environmental choices more attractive [227,281] or by targeting an individual’s perceptions, preferences, and abilities to induce eco-friendly behavior [12,243,281,283]. One of the most powerful strategies to change
behavior seems to be presenting information on what friends, neighbors, students, or other significant people and groups do in a given situation and which behavior they approve, that is, providing descriptive and injunctive norms, respectively. However, while being powerful if designed in the right way, social norm interventions can backfire if people are told that they perform better than others [103]. To avoid negative effects, interventions need to be tailored to the specific characteristics of the energy consumer and the situational conditions. For example, by considering the a priori consumption levels of the energy consumers and thus providing them with different types of social normative feedback, Schultz and colleagues were able to eliminate the boomerang effects of descriptive normative feedback with regard to consumers with low consumption levels [259]. Similarly, by considering the political views of energy consumers, energy efficiency campaigns increase more strongly problem awareness of climate change [258] or engage more people in participation [71]. Hence, social norm interventions should be tailored to the targeted individual to fully unfold their effects.

However, to offer such tailored interventions, one must gather and process information. These processes often do not scale well if they are being deployed over a large number of customers, as in the case of personal energy audits, for example. Traditional intervention strategies suffer from the classical trade-off between reach (i.e., “the ability to connect with a large number of actors” [98]) and richness (i.e., “the ability of information to
change understanding within a time interval” [74]). IS could provide a powerful solution to the problem as it enables large-scale interventions and personalization at the same time. A far-reaching development toward promoting tailored and large energy conservation practices by means of Green IS is currently underway in the utility sectors where smart electricity meters (smart meters) are gradually replacing the old electromechanical induction watt-hour meters. Smart meters resemble sensor nodes and measure consumption data and feed it to a network at high frequency (at intervals from seconds to months). By 2020, due to regulatory duties, 80% of all households in Europe will be equipped with smart meters [249]. Information systems such as web portals or in-home displays that provide energy consumers with timely feedback on their consumption will accompany the smart meter infrastructure to allow energy consumers to act upon it and to change their behavior. However, the potential benefits of smart meters on energy efficiency can only be achieved if the design of feedback systems is driven by empirically proven design guidelines. Otherwise, the introduction of smart meters will only achieve disappointing low savings or even zero effects.

The goal of this study was to develop an IT-based artifact and empirically test different types of social normative feedback with regard to the effects on electricity conservation. According to the framework of Zhang et al., the IT artifact under consideration can be categorized as application content [313]. The approach of this study corresponds closely with
Baskerville’s specification of “design as research methodology” [30]. Specifically, a web portal was developed that was available to all customers of an Austrian utility company. The experiment was conducted with 560 participants over six weeks and was designed to test the effect of descriptive normative feedback with three different reference groups that varied in the closeness in terms of geographical proximity. The consumer’s consumption was either compared to his neighborhood’s average consumption, his region’s average consumption or his country’s average consumption. Furthermore, the moderating effect of the energy consumer’s location on the intervention’s effects was tested to tailor the social norm intervention and ultimately achieve higher savings.

7.2 Previous research on social norm interventions

This section first presents theory on social norms and provides theoretical background on norm salience and the relevance of reference groups in social normative feedback since these two factors determine the success of social norm interventions and descriptive normative feedback in particular. Thereafter, prior research on IT artifacts that were built to influence energy consumption at the individual level is presented. In addition, an overview on IT artifacts which use social influence to address environmental behavior is provided. Based on the theoretical background and the outlined research gaps, the hypotheses that will be tested in this study are defined.
7.2.1 Social normative influence on energy consumption

When choosing an adequate action in a given situation people’s cognitive capabilities of taking all relevant information into account is limited. People are bounded in their rationality [278]. To deal with the complexity and ambiguity of situations they have developed mental short-cuts or heuristics, that help them to make not optimal, but satisficing decisions. One of those heuristics includes the authority of others. That is, individuals often orient themselves toward social norms to better understand and effectively respond to social situations [67,81]. This informational normative influence is often referred to as descriptive norm [66]. According to the ‘Focus Theory of Normative Conduct’ by Cialdini and colleagues [66] descriptive norms inform individuals about the typicality of a specific behavior in a certain situation (the norm of ‘is’) and injunctive norms, a second type of social norms, tell individuals if this behavior is approved or disapproved by significant others (the norm of ‘ought’). As social norms are known to be one of the most powerful determinants of behavior change, they have been applied to change a wide range of behaviors including littering [68], eating [205], alcohol consumption [186], towel reuse [121], and energy consumption [259,277]. Social norm interventions are based on the assumption that individuals tend to overestimate the prevalence or typicality of undesirable behaviors and that they use the perceived descriptive norm to make behavioral choices [259]. Thus, social norm interventions try to reduce the prevalence of undesirable behavior by correcting the misperception regarding the predominant
descriptive norm. To build an effective social norm intervention, it is important to choose a reference group that is relevant to the target group and to assure that the descriptive norm is made salient \cite{66,166,200}. Both factors determine norm adherence and are thus critical to an intervention’s success. The two aspects are discussed in the following.

To influence an individual in a specific situation, a norm needs to be salient. According to the ‘Theory of Normative Conduct’, a norm must be focal for an individual at the time of behavior to influence an individual’s behavior \cite{66,166}. Similarly, the ‘Theory of Social Impact’ \cite{180} states that the social impact of a group increases when the strength or salience of the normative source is high. Unless norms are salient and in the focus of an individual’s attention, they cannot enter the decision process to change potentially detrimental behaviors \cite{103}. Studies on the salience of social norms have used priming techniques or spreading activation approaches to direct the intention of an individual to a specific norm. For example, subjects in a study by Kallgren et al. \cite{166} had to read diary passages that contained normative statements which differed in their conceptual relatedness to the antilittering norm. The results showed that littering was only reduced when the salient norm was related to littering. Similarly, Cialdini and colleagues manipulated the salience of the antilittering norm by telling a confederate of the research team to either drop handbills in front of the subjects or to pick up a handbill that was lying on the ground \cite{66}. The latter condition was meant to increase the
salience of the antilittering norm. In accordance with expectations, subjects littered less when the anti-littering norm was activated by the confederate picking up the handbill. Related to energy consumption behavior, social norms are made salient to the energy consumers by providing them with comparative consumption feedback. This type of feedback compares an energy consumer’s consumption to that of other households in the neighborhood, for example [103]. Comparative feedback has proven to have a large influence on energy consumption, that persists even after some months [5,259,277].

The second factor that determines norm adherence and thus the effectiveness of social norm interventions is the choice of the reference group. Social norm interventions are based on the assumption that individuals will take the behavior of their peers into account when making decisions. However, individuals will only orient themselves to the behavior of the reference group when the group is relevant in some aspect to the individual. One important driver of the attributed relevance to a group is the perceived similarity. ‘Social comparison theory’ stipulates that people compare themselves to others to gain information for self-evaluation [102]. These self-evaluation can aim at evaluating one’s performance, ability or opinion [288]. Similar comparison targets are claimed to be especially useful as they allow drawing conclusions from differences in performance with regard to possible reasons. If the individual engages in a comparison with a person that differs in numerous attributes
from him, he wouldn’t know if a lower performance was caused by a lower ability or by differences in other attributes such as age, weight, gender [200]. However, Festinger did not specify the basis of similarity between the self and the comparison other [200]. In most studies, similarity is defined with regard to personal characteristics or ability [121]. Another theory that addresses the importance of similar others for social influence is ‘Social learning theory’ [26]. According to Bandura, individuals learn from the observation of role models. One premise for social learning is the identification with the role model which is enhanced when the role model is similar to the learning individual. Identification with the reference group or person is another factor that contributes to norm adherence [121]. The membership to a social group contributes to the individual’s social identity which forms an important part of an individual’s self-concept according to the ‘Social identity theory’ by Tajfel and Turner [290]. It is argued that people conform to the norms of a group that is perceived to be an important part of their social identity and thus self-concept [121]. Both similarity and identity can not only be interpreted in terms of personal attributes but also in terms of contextual characteristics. For example, Aarts and Dijksterhuis showed that people lowered their voice when they were confronted with pictures of a library where a situational norm of being silent is automatically activated [2]. Goldstein and colleagues found that local norms are sometimes more effective in motivating people to show a certain behavior than global norms because the former may lead to behavioral choices that are tailored to the individual’s specific
situation [121]. Larimer and colleagues found that fraternity members are more likely to reduce their alcohol consumption if they are provided with fraternity specific norms on drinking behavior [179].

To conclude, social normative feedback has been successfully applied to change behavior. For norm adherence, norm salience and relevance of the reference group constitute two important factors. In the context of energy consumption, norm salience can be achieved by providing social normative consumption feedback. Relevant reference groups have so far been defined in terms of similarity with regard to personal attributes. This study extends research on social norms by investigating the importance of a contextual attribute – closeness in geographical proximity – for reference group relevance.

7.2.2 Information Systems as enabler of large-scale social norm interventions

IS hold the potential to enable cost-efficient energy efficiency interventions with the aid of modern technologies in data processing, personalization, and immediate feedback [226]. They allow to address a large group of individuals with personalized interventions and thus help to overcome the trade-off between reach and richness [74,98] that many traditional energy efficiency interventions like energy audits suffer from. Despite its obvious potential, there are only a few examples for IT artifacts that aim at influencing individual consumption behavior. These artifacts are often developed based on social
psychological theory, but do not formulate testable hypotheses. In addition, evaluations are often restricted to small scale usability studies over a short period of time. For example, Mankoff and colleagues developed an applet that sits on top of social networks like Facebook or MySpace and that tries to motivate people to taking green actions [130]. The applet further tracks progress and suggests new actions. For each action the CO₂ and dollar impact are indicated. In a study with 32 users over 3 weeks, the authors found that the applet actually motivated users to take more green actions. Another IT artifact is Ubigreen [110], a tool that uses information from various sensors and self-reported behavior to track and support green transportation habits. Feedback is provided on the mobile phone with two different visualizations: One includes a polar bear sitting on an iceberg which grows in size when green transportation behavior increases, and the other one contains a tree that gets more green leaves and flowers when the user shows the desirable behavior. In a usability study with 14 participants over 18 days the authors tested the preferences of the users regarding the visualization but they did not assess the effect of the two different visualizations on behavior. An IT artifact that was tested more rigorously is a web based tool presented by Benders and colleagues [36]. After filling out a questionnaire on energy requirements in the household, the web tool provided users with personalized saving tips and feedback on estimated energy savings [36]. In an experiment with 190 users over five months, the savings of the experiment group were compared to the savings of a control group that did not
receive savings tips and feedback showing that the web tool achieved savings of 8.7%.

Recently, researchers have acknowledged that IS are not only capable of measuring energy consumption and providing historical feedback, but also enable interventions that use social influence to change people’s behavior. Based on the insight that individuals respond socially to computers [107,246] and that certain website features may establish a feeling or social presence [276] several IT artifacts have been developed to provide people with the opportunity to compare or compete with different social actors. For example, EcoIsland is an in-home display that aims at motivating families to reduce their daily CO₂ emissions by comparing each user with other family members or other families [275]. Petersen and colleagues developed a data monitoring system to provide dormitory residents with real-time feedback on their consumption and the performance of other competing dorms [237]. While these studies hint to the effectiveness of IS to support social norm interventions, other researchers have used IT artifacts to systematically assess the effectiveness of different kinds of social norm interventions. Petkov and colleagues stress the importance of choosing a relevant reference subject for social normative feedback and states that normative feedback is only effective if contextualized [238]. Based on these assumptions, the authors developed an application called EnergyWiz that compares a user’s energy consumption with the average performance of both efficient and inefficient neighbors and adds
a message of social approval based on their performance according to the approach of Schultz and colleagues [259]. The application further allows one-on-one comparisons with friends and a ranking with similar users. Unfortunately, the authors haven’t tested the effects of the different social comparisons on energy consumption yet. Foster and colleagues have developed a similar application, but tested it with regard to energy savings [108]. They developed a Facebook application called Wattsup that visualizes the consumption data from the Watson home energy monitor [108]. The application included comparisons to friends as well as a ranking. In a within-subjects experiment with 8 households over 18 days it was tested whether households would save more energy when provided with the social features. They found that households saved significantly more energy when the social features were enabled. Based on a taxonomy of dimensions of social comparisons Grevet and colleagues developed a system called stepgreen.org which includes comparisons with other individuals and with groups based on geographic location [130]. The authors argue that the groups are grouped by geographic location because the location emphasizes group identity and creates a close relationship [130]. The system was tested in a competition with 24 participants over one month but the authors were not able to find significant effects of the social features on environmental concern and actions taken to save energy.

The studies described above hint to the opportunity for IS research that traditionally combines technological expertise with
psychological theories [187]. They underline that the right choice of the comparison target and the consideration of the situational context (here geographic location) are important factors for norm adherence. The authors developed the IT artifacts and the different social comparison features based on theories from social psychology. However, the studies were rather exploratory in nature and did not formulate testable hypotheses. Instead of systematically manipulating a certain aspect of the social comparison (e.g., geographic location, number of comparison targets) they included comparison targets that varied in multiple aspects. In addition, the IT artifacts were tested only with small groups and over a short period of time.

This study aims to overcome these shortcomings and presents an IT-based artifact that is used by over 10,000 real energy customers and that aims at motivating energy conservation. Specifically, a web portal was developed that was available to all customers of an Austrian utility company. The experiment was conducted with 560 participants over six weeks. The participants were provided with descriptive normative feedback. The relevance and salience of the reference group was manipulated by altering the closeness in terms of geographical proximity. Specifically, the participants are either compared to the average performance of their neighbors, their region, or their country. Furthermore, the moderating effect of the location (rural vs. urban area) on the intervention’s effects is tested.
7.2.3 Hypothesis development

As outlined above, the effectiveness of social norm interventions depends on the salience of the social norm and the choice of the reference group. People are more likely to adhere to a social norm if the particular norm is in their focus of attention [66,166,180]. In addition, people tend to conform with the norms of reference groups that are relevant to them. This relevance may originate from perceived similarity with regard to personal attributes and abilities, or with regard to shared contexts. In this study, the closeness of the reference group in terms of geographical proximity is manipulated and compare the performance of the energy consumers either with the average performance of their neighbors, their region or their country. Based on theory and previous research it is expected that reference groups that are close in geographical proximity will lead to higher energy savings than more distant reference groups for two reasons: First, energy consumers have the possibility to interact with people that live close to them and to observe their behavior. Therefore, the norms of close reference groups are salient to the energy consumer. In contrast to close reference groups, the norms of more distant reference groups (e.g., country) are less salient to a consumer. Second, close reference groups are more relevant to the energy consumers than more distant groups because they share the same geographical context. Grevet and colleagues have shown that geographical location emphasizes group identity and creates close relationships [130]. In addition, local norms seem to be more important than global norms because they provide more
information about the adequate behavior in a particular situation [121]. Thus, the following hypothesis will be tested:

**H1:** Reference groups that are close in geographical proximity lead to higher energy savings than more distant reference groups.

It is further assumed that the influence of social normative feedback on energy consumption depends on the environment of an individual. If an individual lives in a rural area he or she should be more affected by social normative influence than someone who lives in an urban area. In rural areas people live in very small cities where people have strong social relationships (social ties) in contrast to urban areas [183]. It is more likely that an individual’s behavior is observed by others in a rural than in an urban area. Therefore, it should be important for individuals in rural areas to conform to normative standards in order to be liked and accepted [14]. Living in urban areas on the contrary is more anonymous and social ties amongst residents in urban areas are weaker than amongst residents in more rural areas [183]. Hence, it should be less relevant for individuals who live there to conform to the expectations and norms of others. In support of this notion, research has shown that people in large groups show less socially responsible or altruistic behavior than people in small groups [54]. The following hypothesis will be tested:

**H2:** The effect of close reference groups on energy savings is moderated by the location of the energy consumer. That is,
energy consumers in rural areas will be more influenced by social normative feedback than energy consumers in urban areas.

7.3 Artifact design: The Velix system

To test the hypotheses a web portal called Velix was developed in cooperation with an Austrian utility company that has about 120,000 residential energy customers. The web portal was designed to provide customers with feedback on their electricity consumption and help them to conserve energy by providing energy saving tips. Velix served as the basis for an energy efficiency campaign that aimed at raising awareness about electricity consumption and at preparing customers for the introduction of smart metering. The underlying rationale for building this system was to create a behavioral intervention that uses IS to cost-effectively address a large number of people and that is capable of providing users with different kinds of feedback to rigorously evaluate their effectiveness on electricity consumption. The utility company promoted the campaign via various channels, including the company’s customer magazine, ads in printed and online newspapers, and billboards. As part of the campaign, customers were incentivized for registering and transferring the readings of their electricity meter to the web portal. The meter readings were verified for a subset of the participants (N = 115) based on official utility bills ($r = .80, p < .01$). Incentives to foster participation included a gift worth EUR 5 to EUR 10 (USD 6 to USD 12) for three meter readings, the
opportunity to participate in a monthly charity, and bonus points
that could be traded for a number of energy-related products and
services. All participants of the study had equal access to the
incentive system. Between April 1st, 2010 and December 31st,
2011, a total of 10,700 users joined Velix and entered 319,169
meter readings. On average, visitors spent approximately 4.59
minutes per visit on the site. For the present study, 534 users
were drawn from the total number of users and randomly
assigned to one of the experimental conditions.

After registration, users could participate in the “meter hunt”, a
game-like explanation to find the electricity meter and interpret
its reading. If they already knew where their electricity meter is
located and were already familiar with the data format, they
could skip this game. To facilitate frequent meter readings the
users were provided with the possibility to set either an email or
sms reminder. Upon registration, users were randomly assigned
to different groups. In this study, the participants received
descriptive normative feedback with different reference groups
(neighbors vs. region vs. country). To promote the website users
could also invite their friends and earn bonus points for sending
out the invitations. To increase knowledge and ability, the web
portal included saving tips and little tasks. One task for example
was called “meter sleep” and required users to decrease their
consumption close to zero. This task should raise the awareness
of the users about their standby consumption and help them to
identify possible energy guzzlers. The experience chain is
depicted in Figure 36.
The data that was used by the web portal originate from both the utility company and the user. The utility company provided the consumption data that they used for billing purposes broken down on street level so that the data could be used to provide the users with comparative feedback on different aggregation levels (neighborhood or region). Data on Austria’s average consumption was taken from external resources. In addition, the energy saving tips were drawn from earlier energy efficiency campaigns and edited by the advertising agency. The user provided the web portal with data on household characteristics, address including streets, household number and city, personal characteristics, and meter readings. During the experiment, user ID and data input (e.g., username and password, meter readings with time stamps, and household characteristics, personal characteristics) were stored in a relational data base. Based on the group assignment upon registration, the users were presented with different types of feedback.
7.4 Empirical evaluation

7.4.1 Experimental design and data collection

Five hundred and sixty real energy customers of an Austrian utility company participated in this field study. Participants indicated that on average three individuals were living in the households (SD = 1.45) and that the houses were on average 126.8 sqm (SD = 57.59). The size of the cities where the participants lived ranged between 265 and 42,300 inhabitants (Med = 7096), data was obtained from the regional authorities of Vorarlberg). The study contained a one factorial between subjects design. The closeness of reference group in terms of geographical proximity was manipulated and participants were either compared with the average consumption of their neighbors, of people from their region (Vorarlberg), or with the average consumption of people from their country (Austria). The participants were randomly assigned to the experiment groups at the time of registration. After measuring the baseline consumption over two weeks consumption was tracked for the following four weeks (April – May 2010). Households that did not provide information regarding the size of the household and/or their city (N = 73) were excluded because this information was needed to provide adequate descriptive normative feedback. In addition, households with electric heating systems and electric water heating systems (N = 142) were discarded from further analysis because their consumption patterns were over-proportionally high. Furthermore, both 2.5% at the lower and the upper end of the distribution (5% in total)
were eliminated from further analyses to guard the analyses against outlier-biases (N=23). If the baseline measurement was an outlier, the whole dataset from this household was discarded because a valid baseline is a prerequisite for the applied analytic approach. This procedure resulted in a final sample of 322 households that serve as a basis for the statistical analyses. An ANOVA shows that there were no statistical differences between the baseline consumption levels of the three experiment groups ($F(2,319) = .65$, $p = .524$). Table 10 provides an overview on the descriptive statistics of the subsamples.

Table 10. Subsamples in the study on feedback and reference groups

<table>
<thead>
<tr>
<th>Subsamples</th>
<th>N</th>
<th>M</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference group: Neighbors</td>
<td>136</td>
<td>99.69</td>
<td>47.67</td>
</tr>
<tr>
<td>Reference group: Vorarlberg (region)</td>
<td>88</td>
<td>93.66</td>
<td>48.05</td>
</tr>
<tr>
<td>Reference group: Austria (country)</td>
<td>98</td>
<td>93.76</td>
<td>43.45</td>
</tr>
</tbody>
</table>

$N =$ Sample size, $M =$ Mean baseline consumption (in kilowatt hours), $SD =$ Standard deviation (in kilowatt hours)

7.4.2 Intervention

To calculate the electricity consumption for each user, the system uses the electricity meter readings that are entered by the users. As soon as the user enters the meter reading for the second time and at least one week after entering the first reading, the baseline consumption was calculated. The intervention started immediately after the baseline consumption was measured. Electricity consumption was tracked over six
weeks, between April and May 2010. The three experiment groups were provided with descriptive normative feedback which depicted a bar chart that compares the user’s consumption with either the average consumption in the neighborhood (street level), the region, or the country (see Figure 37). If the street comprehended less than four households, the users were assigned to the next higher aggregation level (region) for reasons of privacy. In addition to comparative feedback, users were also provided with feedback on the energy efficiency level of their households. Based on consumption data and household characteristics, customers were assigned to an energy efficiency level ranging from A (high efficiency) to G (low efficiency). This energy efficiency scale is well known in Europe and used to indicate the efficiency of household appliances. During the study, users were only participating in one experiment, and they had not been previously assigned to another experiment. All customers were also provided with advice on how to conserve electricity. Customers could use a customer-care-hotline, a contact form, and/or a forum to contact the utility company with questions regarding the feedback on energy consumption.
7.5 Results

For each household, up to five measurements (baseline plus four weeks of treatment) were collected, which results in a repeated measurement structure of the data. Repeated measurements over time are usually characterized by correlated error terms that follow an autoregressive pattern. That is, the shorter the temporal distance between two measurements of one observational unit, the higher the correlation between the error terms of these two observations. This data pattern violates the core assumption of traditional statistical techniques as they require completely independent observations. If this complex error structure is not considered in the analysis, a biased statistical test will be the consequence. Therefore a linear mixed-effect model was applied using the lme()-function that is available in the nlme package of the R statistical software [241]
for all subsequent analyses. The three experimental conditions were dummy-coded with the baseline measurement acting as the respective reference category. Two separate models were estimated; one for consumers who live in rural areas and one for those who live in urban areas (based on a median split on city size). The savings $Y$ of household $i$ was modeled as follows:

$$Y_i = X_i \beta + Z_i u_i + \varepsilon_i,$$

$Y_i$ was a $5 \times 1$ vector of the energy savings in kilowatt hours (kWh), $X_i$ was the $5 \times 4$ design matrix of the independent variables (intercept, neighborhood reference, region reference, country reference), $\beta$ was the $5 \times 1$ vector of the estimated fixed coefficients, $Z_i$ was the $5 \times 1$ design matrix of the random effect (intercept), $u_i$ was the $1 \times 1$ vector of the estimated random effects, and $\varepsilon_i$ was the $5 \times 1$ vector of the residuals that were assumed to have a multivariate normal distribution with a mean of zero and a $5 \times 5$ variance-covariance-matrix $R_i$, which had an AR(1) structure. For people in rural areas, the model estimated that comparisons with the neighborhood ($b = -7.78, p < .05$) and with the region ($b = -4.65, p < .06$) lead to significant and marginal significant savings, respectively, whereas comparisons with the country ($b = -2.36, p > .05$) did not reduce energy consumption during the intervention. For people in urban areas, the model estimated that neighborhood comparisons ($b = -6.55, p < .05$) and comparisons with the region ($b = -4.90, p < .05$) lead to significant reductions in electricity consumption. Again, this group did not reduce electricity consumption significantly when compared to the country ($b = -1.27, p > .05$). The
corresponding descriptive statistics are depicted in Figure 38 (the error bars indicate the 95% confidence intervals). The results show that comparisons with reference groups that are close in geographical proximity work better than more distant reference groups. This effect is not moderated by the location of the energy consumer.

![Figure 38. Average savings from baseline consumption (kWh) as a function of feedback and location](image)

7.6 Discussion and conclusions

In this chapter the development and implementation of an IT artifact was described that aimed at motivating households to conserve energy. Specifically, a web portal provided the customers of an Austrian utility company with feedback on their electricity consumption and suggestions on how to conserve energy. This platform was introduced in April 2010 and was used by over 10,000 customers. The web portal was used to conduct an experiment with a subset of 560 customers who were
randomly assigned to different experimental conditions. The experiment tested the effect of three kinds of social normative feedback that differed in the closeness of the reference group in terms of geographical proximity. The participants’ consumption was either compared to the average consumption of the neighborhood, the region, or the country. Furthermore, the moderating effect of the energy consumer’s location (urban vs. rural area) on the intervention’s effects was tested to be able to provide tailored social norm interventions. Based on prior research from social psychology and Green IS it was hypothesized that reference groups that are close in terms of geographical proximity are more effective in motivating energy conservation than reference groups that are less close. The hypothesis was confirmed. In addition, the moderating effect of location (operationalized by a median-split on city size) on the effect of reference group proximity and energy conservation was evaluated. However, the difference between the two groups was statistically not significant.

7.6.1 Theoretical implications

The findings allow for drawing a number of implications for theory. The study showed that social norm interventions are successful in motivating energy conservation. In contrast to prior studies in the field of Green IS, a large sample of real energy customers was used and testable hypotheses based on theory from social psychology were formulated. The effectiveness of reference groups that are close in geographical proximity can be attributed to their higher relevance and
salience to energy consumers. This underlines that, in order to be effective, social normative feedback should use reference groups that are relevant to the energy consumer in terms of contextual similarities [121] and that are able to make the prevalent social norm salient to actually affect behavior. If these two criteria for norm adherence are not met (e.g., comparisons with the country’s average performance) social normative feedback does not have any effects on energy consumption. Although research on social ties in urban vs. rural areas would suggest that energy consumers in rural areas respond stronger to social normative feedback than energy consumers in urban areas, this hypothesis could not be confirmed. There is however, a trend, that energy consumers that live in rural areas where social ties are usually stronger than in urban areas are more affected by social normative feedback.

7.6.2 Practical implications

With regard to Green IS it was proven that IS are successful in achieving energy savings at the individual level. Furthermore, the results showed IS enable social norm interventions. Based on this study designers of Green IS can be provided with empirically proven guidelines. System designers are recommended to use the neighborhood or region as a reference group if they want to apply social normative feedback. Based on this study’s findings, it does not seem necessary to tailor the descriptive normative feedback to the location of the energy consumer. Taken together, IS-based behavioral interventions – if designed carefully - contribute to accountable savings and
therefore help utility companies to fulfill future regulatory requirements at low cost. In sum, the results evidently indicate that the type of reference group determines how well the system achieves the intended goal (“reduce energy consumption”). Only by choosing the right reference group energy savings can either be achieved – or not. This clearly underlines how important it is to consider user behavior in the design of IT-based efficiency campaigns.

7.6.3 Limitations and further research

Even though every effort has been made to ensure the validity of this study’s findings, the present study comes with limitations that provide opportunities for future research. A first limitation concerns a possible selection bias. Although a large sample of customers was used in this study, it cannot be ruled out that the voluntary participation of the customers creates a bias. Due to this selection effect, results could be biased in that effects could be both over- or underestimated. On the other hand, the field study conducted under real-world conditions offers insights into the effects of real campaigns. A second limitation includes the operationalization of the consumer’s location. A median split on city size was calculated, however, the area of Vorarlberg in Austria consists of a lot of very small cities so that urban areas are strictly speaking still rather rural than urban. It is possible that effects would be different if larger cities would have been considered. A third limitation includes the experimental design. Based on the importance of both salience of the social norm and relevance of the reference group it was argued that neighbors
should be the most effective reference group in social comparative feedback. However, the design of this experiment did not allow for disentangling the effects of the two factors. Future studies should use an experimental design that manipulates both factors systematically. For example, the experiment could manipulate the relevance by providing comparisons with similar vs. non-similar households and the salience by manipulating the closeness to the own house in meters. Other possible avenues for future research include the investigation of criteria that are relevant for tailoring descriptive normative feedback apart from location or to test other factors that might influence the perceived relevance of a reference group such as expert level, financial budget or value orientation. It is concluded that IS can be used to enable social norm interventions and that they thereby contribute to solving environmental problems [300] if user behavior is considered in the design.
8 General discussion and conclusions

This chapter provides a summary of the studies that have been conducted and their results. It further discusses implications for theory and practice. To support the design of feedback systems, systems designers are provided with a framework of empirically proven design guidelines. Managers are provided with recommendations on how to develop effective large-scale energy efficiency campaigns. The chapter closes with limitations, avenues for future research, and a conclusion.

8.1 Summary

Improving energy efficiency is regarded as a promising strategy to counter the trend of steadily increasing world primary energy consumption [63,89]. However, “the biggest energy resource” [89] is thus far widely unused since residential energy consumers – although contributing significantly to the overall energy consumption – have not yet realized possible efficiency gains in their households [10,126]. The emerging Smart Metering infrastructure that allows for providing energy consumers with feedback on their energy consumption and for giving tailored advice on how to improve their energy efficiency. Given that the Smart Metering infrastructure requires investments of billions of euros by utility companies [16,112], the utility companies are searching for ways to increase the benefits of the infrastructure.
One approach suggested in this thesis is to no longer expect energy consumers to act fully rationally and according to cost-benefit arguments. An individual’s motivation to show a certain behavior is not only driven by cost-benefit considerations, but is also largely affected by social influence and external factors [118]. Furthermore, the way behavioral decisions are framed, that is choice architecture, has an important influence on individuals’ preferences for behavioral options. Until now these factors have not been considered in the design of feedback systems in the Smart Metering infrastructure or in the design of energy efficiency campaigns for residential customers. In addition, existing feedback systems often use a “one size fits all approach” instead of tailoring interventions to the energy consumers’ characteristics, which sometimes negatively influences their savings potentials [259]. To conclude, there is a need for tailored energy efficiency interventions that consider human irrationality and motivate large groups of energy consumers to realize energy efficiency gains in their households.

To meet this need, this thesis suggested using information systems (e.g., feedback systems within the Smart Metering infrastructure) to deliver behavioral interventions to residential energy consumers. Information systems facilitate choice architecture and help to cost-efficiently address a large customer group with tailored interventions. In contrast, traditional energy efficiency interventions (e.g., energy audits) typically either reach a large audience or are tailored, but cannot meet both aspects cost-efficiently at the same time. In this thesis, four IS-
based behavioral interventions were developed to motivate residential energy consumers to conserve energy based on the framework of Steg and Vlek for the systematic design of effective behavioral interventions [281]. Goal setting and feedback interventions were chosen since these interventions address factors that are most relevant to guiding and changing behavior. In addition, goal setting and feedback are core functionalities of energy feedback systems that are required by the European Directive 97/66/EC [88] and by energy consumers [303]. To show exemplarily how behavioral interventions can be modified in order to account for human irrationality, goal setting and feedback interventions were combined with two behavioral nudges (default and social influence). In addition, the studies investigated if the nudges need to be tailored to the characteristics of an energy consumer. The interventions were delivered via a web portal (except the second intervention) that was developed in cooperation with a utility company and served as the basis of an energy efficiency campaign. The web portal was introduced in April 2010 and was used by 10,700 customers until December 2011. It allowed randomized field experiments to be conducted, which permit the rigorous evaluation of the effectiveness of these interventions [10,111].

The first two studies showed that goal setting in general is an effective strategy for motivating electricity savings. The first nudge, defaults, positively affected goal choice and electricity savings, but only if the default goal was medium (15%). Individuals in the low and high default goal condition did not
achieve significant savings compared to a control group. The mediation results showed that defaults affect savings by nudging energy consumers toward higher savings targets. When feedback was provided and indicated that no group was able to achieve the savings target, the customers reacted with a downward adjustment of their goals. The second nudge, identity signaling, also affected the effectiveness of goal setting interventions. It was shown that energy consumers who do versus do not aim at signaling their green identity respond to the image that is associated with energy conservation. While energy consumers who do not aim at identity signaling choose higher goals when energy conservation is displayed as trendy, identity signalers set higher goals when energy conservation is associated with a non-mainstream greenie. In addition, energy consumers choose goals that require medium effort when they are able to signal their identity.

The third and the fourth interventions, which combined feedback with social norms showed that social normative feedback is effective in motivating electricity savings. However, descriptive and injunctive normative feedback have different effects on above-average energy consumers than on below-average energy consumers. Consumers with high a priori consumption levels reduced their consumption regardless of the type of social normative feedback. Consumers with low a priori consumption levels increased their consumption when they learned that they consumed less energy than their neighbors (descriptive normative feedback) but maintained their low
consumption level when they received injunctive feedback only or both types of feedback in combination. The fourth study showed that the effectiveness of social normative feedback also depends on the reference group that is used for social comparison. Reference groups that are closer in terms of geographical proximity motivate higher savings than more distant reference groups, regardless of the location of the consumer.

8.2 Theoretical implications

This section presents the implications of this thesis’ results for goal setting theory, feedback, social norms, identity signaling, defaults, and nudging.

8.2.1 Goal setting and defaults

The study on goal setting and defaults (Ch. 4) showed that goal setting is indeed an effective strategy to motivate electricity conservation since energy consumers in the goal setting conditions saved significantly more electricity than the control group. This finding confirms the central role that goals play in human decision making [17,20] and represents a replication of previous findings on goal setting effects [6,31,201]. Default goals represent an innovative goal setting strategy that can be regarded as a combination of assigned goals and self-set goals since energy consumers are able to adjust the default goals. They have thus far only been applied to one-shot behaviors or series of one-shot behaviors. The results proved that defaults are also applicable to continuous behavior since energy
conservation requires constant engagement. While previous research has attributed the effects of defaults on one-time behaviors such as purchase decisions to customers’ laziness, this mechanism cannot apply to energy conservation since it requires the energy consumer to take active measures. The mediation analysis showed that defaults influence energy consumption by nudging energy consumers toward higher savings goals. It seems that the default goal communicates normative information to the consumer, indicating which goal is regarded as achievable by the initiator of the energy efficiency intervention. In line with this, Meyer and Gellatly (1988) suggest that defaults have a normative character that informs people of the savings they are likely to achieve. With this normative character, default goals could also have negative effects on behavior if they communicate a detrimental norm. Indeed, the results show that if defaults are set too low, people set low goals and save less energy since low goals produce low discrepancies between the actual and the desired energy consumption [154], resulting in low motivational levels. Detrimental effects were also observed when default goal levels were too high. This can be attributed to the negative effect of high goals on self-efficacy. Goals have to be high but still realistic; if they are perceived as being too high, people will not believe that they are able to achieve them, which results again in low motivational levels [188]. The study further shed light on how goals and feedback interact as opposed to previous studies that did not test goal setting strategies with and without feedback in a longitudinal study design. Feedback was indeed
used to adjust behavioral strategies; however, consumers adjusted the goal level downward, instead of increasing effort to achieve the goal in the future. It is likely that the high levels of goal discrepancies resulted in lower levels of self-efficacy which lead energy consumers to doubt that they were able to achieve their intended goal.

8.2.2 Goal setting and identity signaling
The study on goal setting and identity signaling (Ch. 5) extends the knowledge of identity signaling theory by showing that identity signaling is an important motivator for curtailment behaviors. By definition, these behaviors, as opposed to efficiency behaviors, require continuous effort to achieve energy savings. Identity signaling seems to be regarded as a benefit that compensates for the effort associated with energy conservation since energy consumers choose higher saving goals than usual when they perceive an opportunity to signal their green identity to others. However, energy conservation can also be perceived as a costly and non-beneficial identity signal if energy conservation sends undesirable signals about one’s identity. The results indicate that it seems to depend on the identity signaling desires of a specific person in this particular domain (domain relevance) whether an image of energy conservation is perceived as beneficial or costly. Both people with high versus low domain relevance rate a trendy person as being more likeable and more similar to themselves. However, a sympathy effect is only found for people who rate domain relevance low, indicating that they perceive a trendy image as beneficial and a
non-mainstream image as costly. For people with high domain relevance, a trendy image is costly because it reduces the possibility to send clear identity signals. Recipients of the signal may interpret it as being sent for non-authentic, purely signaling purposes. A non-mainstream image, in contrast, is perceived as beneficial for these reasons. The findings are in accordance with research that has shown that people abandon their original tastes when the signal is poached by dissociative groups [39,41]. The study results further extend identity signaling theory by showing that the “cost effort” assumption by Berger and Heath [41] seems not to be correct, since the relation between effort and goal choice is not positive linear but instead shows an inverse u shaped pattern. That is, people do not set high goals if they want to engage in identity signaling, but choose medium goals since they allow energy consumers to send clear signals at a moderate level of effort. This finding supports a modification of the “Low-cost hypothesis” by Schahn and Möllers [254], which assumes that people choose measures requiring medium effort as opposed to low effort (“Low-cost hypothesis” [82]) or high effort (“Cost effort” [41]).

8.2.3 Feedback and social norms

The study on feedback and social norms (Ch. 6) shows that social normative feedback is effective in motivating electricity conservation. It replicates previous studies on the effect of descriptive and injunctive feedback and shows that social normative feedback is also applicable to IS-based interventions. While Schultz and colleagues used manually drawn smileys to
indicate social approval or disapproval [259], that is, injunctive normative feedback, the study in this thesis delivered the two types of social normative feedback via a web portal that is capable of exerting social influence according to Fogg [107] but that is likely to be weaker than social influence within personal interactions. Another difference consisted of the type of injunctive feedback that was used. While Schultz and colleagues used a smiley, this study used the European energy efficiency scale, with efficiency levels ranging from A (“high efficiency”) to G (“low efficiency). However, the effects of descriptive and injunctive feedback for below and above-average energy consumers were the same as in Schultz et al.’s study, which increases the validity of the results. In addition to testing the applicability of social norm interventions for IS, the study also shed light on how the two types of norms interact with each other. While literature and prior research proposed three contradictory mechanisms for the buffering effect of injunctive normative feedback, this study is the first to test the underlying mechanism empirically by including a condition that provides energy consumers with injunctive feedback only. The results provide support for an ordinal interaction; that is, injunctive normative feedback alone has a buffering effect and overshadows the detrimental effect of descriptive normative feedback for below-average energy consumers. Thus, injunctive norms are dominant over descriptive norms if presented in combination.
8.2.4 Feedback and reference groups

The study on feedback and reference groups (Ch. 7) contributes to social norm theory by showing that the choice of the reference group largely determines the effectiveness of descriptive normative feedback. Only if the reference group is relevant and salient to the energy consumers will they orient themselves around the behavior of that group and save electricity. Theories such as the “social comparison theory” [102] or ‘social learning theory’ [26] have suggested that comparison targets should be similar to the person addressed by the behavioral intervention; however, the researchers have not specified the meaning of similarity. Previous studies have primarily defined similarity in terms of personal characteristics or abilities [121,200], while only a few studies have focused on similarities with regard to contextual factors [2,121,179]. This study confirms that contextual factors are relevant for the salience and the perceived importance of a group norm and extends prior research by systematically varying the closeness of a reference group in terms of geographical proximity. The fact that only close reference groups achieve significant electricity savings shows that energy consumers regard those norms of groups as beneficial that most closely match one’s immediate settings, situations, and circumstances [121]. This is because such norms most reliably inform about which behavior is adequate in a specific context. Energy consumers in both rural and urban areas are equally affected by descriptive normative feedback and respond most strongly to close reference groups. The superiority of close reference groups can be explained by a
higher salience instead of a higher relevance. If the manipulation would have varied the relevance, energy consumers in rural areas should have responded more strongly to the norm interventions since social ties are stronger there.

8.2.5 Choice architecture and Nudging
The results of the four studies presented in this thesis have several implications for choice architecture and nudging. The design of the four behavioral interventions was based on the idea that residential consumers’ decisions on whether and how much electricity to conserve depends on the way consumption feedback and energy saving targets are presented (i.e. choice architecture. The idea of choice architecture and libertarian paternalism is to design the decision context in a way that supports the individual energy consumer’s decisions more effectively than if he or she were not bound in rationality. The decision context should provide little details that nudge the energy consumer in the right direction while at the same time not restricting his or her freedom of choice. Some researchers critically observe that the normative standard of libertarian paternalism is somehow fuzzy, since it is empirically not possible to determine what the individual would choose under perfect conditions, and libertarian paternalism seems to be rather oriented towards political trends [257]. Schnellenbach says that libertarian paternalism necessarily includes an institution that claims to know what is best for the individual. He proposes a decentralized solution instead, where individuals who realize that they have a self-control problem (e.g., know that they
should save electricity) can use a commercial service that supports them in overcoming their self-control problem. However, this approach requires that people be aware that their energy-related decisions are sometimes suboptimal. But research has shown that most people believe that they behave in an energy-conscious manner [113]. In addition, choice architecture does not seem to be unethical given that it is very pervasive that decisions are being made on our behalf. For example, when designing a feedback system, the system designer has to choose from an almost infinite set of possibilities which features to implement and how to frame behavioral choices to achieve the highest possible energy savings. Choice architecture and its effects therefore cannot be avoided. Consequently, every effort should be made in order to base these design decisions on empirically proven guidelines instead of implicit hypotheses about human decision making.

The goal of this thesis was therefore to empirically identify how the two behavioral nudges, social influence and defaults, should be designed so that they are most likely to help make good decisions (high goals, high savings) and least likely to inflict harm (increased consumption) [291]. The results of this thesis show that the two nudges – social influence and defaults – have the potential of nudging energy consumers toward higher savings. Specifically, close reference groups and injunctive norms have proven to be effective in supporting energy consumers in conserving electricity. Some nudges are only effective if they are tailored to the energy consumers’
characteristics and can lead to boomerang effects if there is a mismatch between nudge and energy consumer. For example, descriptive normative feedback leads to savings for energy consumers with high a priori consumption levels but increases consumption if provided to energy consumers who are better performing than a reference group. In addition, if energy conservation is presented as a mainstream activity, individuals who are actually motivated to conserve electricity refuse to take conservation measures because it would send non-desirable identity signals to other people. The study results also show that certain nudges have negative effects that cannot be buffered by tailoring them to the energy consumer. For example, if default goals are set too high or too low, they lead to savings that are smaller than those achieved by self-set goals. To summarize, the study results confirm that choice architecture has a significant effect on energy savings and needs to be considered in the design of feedback systems. However, nudges have to be used with deliberation and need to be tailored to the energy consumer to exert positive effects on behavior.

8.3 Practical implications

This section discusses the implications of the thesis’ results for Smart Metering, households, and society. In addition, recommendations for feedback systems design and for the design of energy efficiency campaigns are provided.
8.3.1 Implications for Smart Metering, households, and society

The results of this thesis show that the goal setting and feedback interventions presented here are powerful measures to change residents’ electricity consumption. By providing energy consumers with the right default goal level, type of social normative feedback, and reference group in social comparative feedback, consumers were able to achieve savings between 4.02% and 8.02% compared to their baseline consumption. Due to the emergence of Smart Metering, these savings are scalable to millions of households. In the following, the impacts of the behavioral interventions on savings in kilowatt hours, reductions of CO$_2$ emissions, monetary benefits for residential energy consumers, and net benefits of the Smart Metering infrastructure are presented (see Table 12 and Table 13). The effects are exemplarily calculated for Germany and Switzerland to demonstrate how effects differ based on number of households, average annual electricity consumption in the residential sector, costs per kilowatt hour, and fuel mix (see Table 11). The calculations are based on the assumption that the intervention effects that were found in the thesis’ field experiments are applicable to all German and Swiss households. The assumption is justified given the high external validity of the experimental setup, which did not interfere with utility consumers in any way besides the feedback system Velix itself. However, not all households are likely to use the feedback systems such as web
portal or in-home display, even if they were available for free. Therefore, the analyses are based on an expected adoption level of 50%. In addition, the extrapolation considers two distinguished scenarios with 0% (scenario 1) and 50% reversion of behavior (scenario 2) in the long run since meta-reviews have shown that effects of feedback are not always persistent [95].

Table 11. Overview of Swiss and German electricity-related statistics

<table>
<thead>
<tr>
<th>Country</th>
<th>Residential electricity consumption (in kWh/a)</th>
<th>CO₂ emissions (in kg CO₂/kWh)</th>
<th>Costs for electricity (in Euro/CHF/kWh)</th>
<th>Costs for Smart Metering (in bio Euro/CHF)</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>3,500²²</td>
<td>0.566²³</td>
<td>0.257²⁴</td>
<td>3.8*²⁵</td>
</tr>
<tr>
<td>CH</td>
<td>3,500²⁷</td>
<td>0.122²⁸</td>
<td>0.197²⁹</td>
<td>1.0**²⁰</td>
</tr>
</tbody>
</table>

Impact on energy savings

In the first scenario, the potential energy savings for Germany with 40.3 million households range between 2.84 billion and 5.66 billion kilowatt hours per year assuming an adoption rate of 50%. In Switzerland, the number of households as of 2009 was 3.3 million\(^3\) which leads to potential savings between 0.23 and 0.47 billion kWh per year (Table 12). In the second scenario, savings range between 1.42 and 2.83 billion kWh for Germany and between 0.12 and 0.23 billion for Switzerland. The most effective intervention in terms of electricity savings is comparing a resident’s electricity consumption to the neighborhood’s average electricity consumption (Ch. 7). The results show that behavioral interventions significantly contribute to a more sustainable usage of electricity. Improved energy efficiency hence is indeed a fruitful avenue toward securing the future generations’ energy supply as acknowledged by European policies [89].

Impact on CO\(_2\) emissions

Germany and Switzerland differ very much in their fuel mix. While German electricity is to a large extent produced from fossil resources such as stone coal and brown coal, Swiss


\(^{31}\) http://www.bfs.admin.ch/bfs/portal/de/index/themen/01/04/blank/key/haushaltstypen.html [accessed on 23.07.2012]
electricity is mainly generated from hydro and nuclear power.32,33 Hence, the CO₂ emissions per kilowatt hour of electricity are relatively lower in Switzerland than in Germany (Table 11). While the behavioral interventions investigated in this thesis have the potential of cutting up to 3.20 billion tons of CO₂ emissions in the first and 1.60 billion tons of CO₂ in the second, the potential CO₂ reductions in Switzerland are lower but still amount to 0.06 and 0.03 billion tons, respectively (Table 12 and Table 13). Again, neighborhood comparisons are most effective in reducing CO₂ emissions. The results show that in both scenarios an improved energy efficiency through changes in behavior actually result in a better environmental quality for societies, in that it reduces the emission of hazardous substances.

**Impact on monetary savings for residents**

In Germany, residential energy consumers pay on average about 25.47 euro cents per kilowatt hour electricity. In Switzerland, electricity is cheaper. On average, Swiss residential energy consumers pay 19.7 Rappen (= 16 euro cent) per kilowatt hour. Consequently, absolute savings per household are higher in Germany than in Switzerland. German households can save between 0.73 and 1.46 billion euros a year in the first scenario and up to 0.73 billion a year in the second scenario, while Swiss

households can achieve savings up to 0.09 billion CHF in the first scenario and 0.05 billion CHF in the second scenario. This illustrates that households can save significant amounts of money every year just by changing their energy consumption behavior. These savings remain significant even if effects decrease over time by 50%.

**Impacts on cost-efficiency of Smart Metering**

Introducing a Smart Metering infrastructure is very costly, since it requires investments in smart electricity meters, in-home communication infrastructure, IT-systems for energy data management, power grids, and distribution grids. In Germany, expected costs for a full roll-out range between 3.8 and 5.7 billion Euro, depending on the features of the Smart Meters [112]. In Switzerland, a full roll-out is estimated to cost about one billion Swiss francs [16]. The energy reduction potentials of 4.02% to 8.02% (or 2.01% and 4.02% in the second scenario) amount to large benefits, which increase the cost-effectiveness of the Smart Metering infrastructure drastically. The yearly energy savings obtained by carefully designed interventions have the potential of paying off the costs quickly. Even if only 50% of all households adopt the smart feedback systems, the costs for the infrastructure will pay off in three to six years for Germany and in ten to twenty years for Switzerland in the first scenario. If energy savings diminish by 50% over time, pay-off times are twice as long for both Germany and Switzerland. While the pay-off time is still acceptable for Germany, the pay-off time in Switzerland exceeds the economic lifetime of Smart
Meters of 18 years [16]. Hence, utility companies and public institutions such as the BfE should take measures to promote the adoption rate of feedback systems to achieve a faster pay-off of the Smart Metering infrastructure.

*Table 12. Savings of the behavioral interventions investigated in this thesis in kilowatt hours, CO₂, and Euro/CHF in the first scenario*

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Country</th>
<th>kWh</th>
<th>CO₂</th>
<th>Euro/CHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal setting with medium default level</td>
<td>D</td>
<td>2.84</td>
<td>1.60</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.23</td>
<td>0.03</td>
<td>0.05</td>
</tr>
<tr>
<td>Descriptive and injunctive feedback</td>
<td>D</td>
<td>4.89</td>
<td>2.77</td>
<td>1.26</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.4</td>
<td>0.05</td>
<td>0.08</td>
</tr>
<tr>
<td>Neighborhood comparisons</td>
<td>D</td>
<td>5.66</td>
<td>3.20</td>
<td>1.46</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.47</td>
<td>0.06</td>
<td>0.09</td>
</tr>
</tbody>
</table>

All numbers in billion Euro (D) or CHF (CH) per year

*Table 13. Savings of the behavioral interventions investigated in this thesis in kilowatt hours, CO₂, and Euro/CHF in the second scenario*

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Country</th>
<th>kWh</th>
<th>CO₂</th>
<th>Euro/CHF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goal setting with medium default level</td>
<td>D</td>
<td>1.42</td>
<td>0.80</td>
<td>0.36</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.12</td>
<td>0.01</td>
<td>0.02</td>
</tr>
<tr>
<td>Descriptive and injunctive feedback</td>
<td>D</td>
<td>2.44</td>
<td>1.38</td>
<td>0.63</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.20</td>
<td>0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Neighborhood comparisons</td>
<td>D</td>
<td>2.83</td>
<td>1.60</td>
<td>0.73</td>
</tr>
<tr>
<td></td>
<td>CH</td>
<td>0.23</td>
<td>0.03</td>
<td>0.05</td>
</tr>
</tbody>
</table>

All numbers in billion Euro (D) or CHF (CH) per year
To conclude, the analyses above indicate that the Smart Metering infrastructure should include smart feedback systems to increase the effects of the Smart Metering. Designing smart feedback systems comes at essentially no extra costs since they represent a mandatory part of the infrastructure. However, the design of the feedback systems determines the effects of Smart Metering on energy savings, CO₂ emissions, and monetary savings for energy consumers. It also determines how quickly the infrastructure pays off. Hence, utility companies and public institutions should spent great care with the design of such feedback systems and promote their adoption by energy users. The approach presented here, that is, shifting the focus from technology to people and respecting that individuals are not acting fully rationally, helps to make Smart Metering smarter and can be understood as a paradigm shift. The interventions can serve as a blueprint for feedback system designers and managers at governmental institutions and utility companies (see 8.3.2 and 8.33).

8.3.2 Implications for feedback system design

The study results presented in this thesis have a number of implications for feedback system designers. As shown above, feedback and goal setting interventions have proven to be effective in stimulating energy savings and hence should be implemented in the system. In addition, social influence and defaults as behavioral nudges affect energy savings significantly, which shows that the decisions of a system designer on how he designs the choice context determine
whether or not the feedback system actually achieves energy savings. However, it is sometimes not sufficient to choose an empirically proven intervention and combine it with a successful behavioral nudge to obtain energy savings. The results of this thesis have shown that combining successful interventions and nudges may still produce undesirable effects for certain energy consumers. To prevent this, the behavioral interventions need to be tailored to the characteristics of the energy consumers. These characteristics refer to attributes that are relevant with regard to the behavioral nudge to be employed.

The following framework (Figure 39) can be understood as an attempt to support the automatic tailoring of goal setting and feedback interventions. If the system designer wants to implement a goal setting functionality and use default goals, he should provide a medium default goal level, since default goals that are too low or too high produce no savings at all. The study of defaults and goal setting did not test whether certain consumer characteristics moderate the effect of default goals. Therefore, it is not possible to give recommendations on how to tailor this intervention. Since feedback has proven to have a negative effect on subsequent goal setting if defaults goals are too high, a system designer should think about testing different default goal levels to find out which levels are seen as realistic and are still ambitious. In addition, the system designer should test different strategies on how to provide feedback on goal attainment that encourages the consumer not to adjust his or her goal downwards, but to increase effort to achieve the savings
goal in the future. For example, they could pair energy consumers with similar characteristics so that one could support the other in achieving his or her energy savings goals. In doing so, self-efficacy can be improved which in turn increases the likelihood that the goal will be attained in the future. If the system designer wants to use identity signaling to nudge consumers toward higher goals and savings, he needs to tailor the image that is associated with energy conservation with regard to the identity signaling desire of the energy consumer in this domain. Specifically, individuals who want to project their green identity toward others should perceive that energy conservation is not a main-stream activity. Conserving energy should give them the opportunity to send clear identity signals. In contrast, people for whom energy signaling is less important should perceive energy conservation as an attractive and popular activity. Since data on that personal characteristic are sparse, the system designer should either incorporate a short survey into the feedback system to subsequently tailor the intervention, or he or she should use historical data of the utility company to infer which people want to signal their identity. For example, the utility company often tracks people participating in their efficiency campaigns. Customers highly involved in such activities are very likely to consider energy conservation as an important part of their identities. If the two possibilities for data acquisition are not feasible, the system designer could alternatively implement a functionality that allows identity signalers to show their green behavior to others. For example, the campaign could include a reward system that rewards and
exhibits people who are putting much effort into energy conservation. When combining feedback with social norms, the system designer should use information on baseline consumption to tailor the intervention to the energy consumer. These data can be easily obtained since the utility company stores historical consumption data in their data-base or the data can be easily measured by the feedback system. For below-average consumers, the system designer can either use injunctive normative feedback or a combination of injunctive and descriptive normative feedback; however, he should never use descriptive normative feedback only. For above-average consumers, he can use any kind of feedback. When using descriptive normative feedback, the system designer should use a close reference group such as neighbors. Since utility companies have information on both consumption and address data, the provision of this kind of feedback is highly feasible. However, the system designer has to respect the privacy of the energy consumer, for example by providing feedback on a higher aggregation level, if the number of households in a street is below a certain threshold. This approach assures that anonymity is respected. The study on reference groups has shown that it is not necessary to tailor the intervention to the location of a consumer. That is, energy consumers in rural as well as urban areas all respond well to neighborhood comparisons.
8.3.3 Implications for campaign management at utility companies and governmental institutions

The results of this thesis not only provide specific guidelines on how to design effective feedback systems but also have more general implications for managers at utility companies or governmental institutions with regard to energy efficiency campaigns for residential energy consumers. First, the success of the goal setting and feedback interventions that were presented in this thesis underline that behavioral interventions are actually effective in achieving energy savings. They achieve savings up to 8.02% which amounts to 11.31 billion saved kilowatt hours, a reduction of CO2 emissions by up to 6.4 million tons and money savings of up to 2.91 billion Euro in Germany (Table 12). The interventions all exceed the savings targets that utility companies both in Europe and the U.S. need
to achieve to fulfill their regulatory obligations and also help to increase the cost-efficiency of Smart Metering infrastructures. The interventions presented here are also more effective than the mass media campaigns that are usually initiated by governmental institutions [5]. Hence, it is worth using behavioral interventions. The thesis’ results further show that the behavioral interventions need to be tailored to the characteristics of the energy consumer. For example, the study on goal setting and identity signaling showed that energy consumers respond very differently to the image that is associated with energy conservation depending on whether or not they want to show their green attitudes to others. In addition, energy consumers respond differently to neighborhood comparisons depending on whether they are performing better or worse than these reference groups. Extensive meta-reviews in the area of health campaigns have shown that tailored campaigns outperform non-tailored similar campaigns [223]. The results of this thesis further imply that it is advisable to find strategies to reward energy consumers who are already consuming on a low level and to prevent them from assimilating to the (higher) average consumption. One strategy could be to incorporate social approval. In using IS, this is as simple as providing a smiley or an energy efficiency level. Other non-IS related strategies include publicizing good behavior, or providing them with a special status that is associated with additional privileges. To achieve significant savings, it is not only relevant to prevent “good consumers” from adjusting saving targets downward but also to encourage energy
consumers to continuously try to save energy even after having received negative feedback. This may be achieved by allowing energy consumers to build support teams for information exchange and motivation. To make tailoring possible, utility companies and governmental institutions should gather information on the energy customers that is relevant for tailoring. In using IS, this can be easily done by including short surveys or data input fields. As opposed to governmental institutions, utility companies often already have the relevant information in their customer data-bases. For example, they have historical consumption data, which helps to tailor normative feedback, and they also know which customers participated in previous campaigns. This information could be used to infer how important energy conservation is to a given customer, supporting the tailoring of identity signaling approaches. To make sure that a new energy efficiency campaign actually achieves the desired effects for all customer groups, the campaign should be pretested with lead users before it is made available to the whole customer base. Modern IT companies like facebook have predefined subsets of users which they use as a test sample to gauge the desirability of a new application. Campaign managers should further consider using IS to conduct energy efficiency campaigns because they facilitate tailoring and pretesting. Tailoring with IS is easy, since small modifications of the decision context can be achieved very quickly. Customers can be automatically assigned to different interventions based on predefined characteristics, which also allows for testing novel energy efficiency interventions with a
small subset of customers. Lastly, the results of this thesis show that the design of behavioral energy efficiency interventions require competencies from different areas such as psychology, energy efficiency, information technology, and user interface (UI) design: Psychologists are experts in behavior change, energy efficiency experts know how to identify and realize energy efficiency gains, IT experts know how to build the infrastructure that is necessary to deliver large-scale energy efficiency interventions, and UI designers know how to build interfaces that are easy to understand and use. Therefore, energy efficiency campaigns will profit from interdisciplinary collaborations, especially because these competencies are often not available in one company or institution. The implications for utility companies and governmental institutions are summarized in Table 14 below.

Table 14. Implications for campaign managers at utility companies and governmental institutions

<table>
<thead>
<tr>
<th>Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Use behavioral interventions</td>
</tr>
<tr>
<td>2 Tailor the interventions to the energy consumers</td>
</tr>
<tr>
<td>3 Reward good customers and encourage those with a low performance</td>
</tr>
<tr>
<td>4 Gather and use customer information to tailor interventions</td>
</tr>
<tr>
<td>5 Test campaigns with lead customers</td>
</tr>
<tr>
<td>6 Use IS to conduct, tailor, and test campaigns</td>
</tr>
<tr>
<td>7 Look for interdisciplinary collaborations for the design of energy efficiency campaigns</td>
</tr>
</tbody>
</table>
8.4 Limitations and future research

Even though every effort has been made to ensure the validity of this thesis’ findings, the presented studies come with limitations that provide opportunities for future research. First, the studies were conducted with energy consumers who registered voluntarily for Velix (Ch. 4, 6, 7) or took part voluntarily in the online-experiment (Ch. 5). A selection bias can therefore not be ruled out. Participants who volunteer to participate in a study tend to be more environmentally conscious and more motivated, which might have biased the treatment effects [10,111]. However, the goal of this thesis was to test the relative effectiveness of the different behavioral interventions instead of their absolute effects. If researchers wish to test absolute affects, they should use an opt-out approach instead of the applied opt-in approach. For example, they could use electricity bills, emails, or mailings as a channel to cost-efficiently test different interventions. Second, since the studies were all, except for one, field studies, there was no possibility to obtain processing data. To elucidate the underlying mechanisms for the effects presented earlier, future research should also include lab studies, which allow for testing the effects of various interventions in a highly controlled environment and hence with a high internal validity. For example, a lab study could test if injunctive and descriptive feedback induce different emotions or cognitive processes which explain the dominance of injunctive norms over descriptive norms. Alternatively, if lab studies are not feasible, focus groups or questionnaires could be applied. For example, it
could be tested whether the two types of normative feedback induce different conservation strategies than can explain the differential effects. A third limitation concerns the experimental design of the studies. Some of the presented studies did not include control groups in which customers did not receive any treatment at all because, as mentioned above, the studies aimed at testing the relative effectiveness of various interventions. Hence, it is not possible for all studies to conclude that interventions applying nudges are actually more effective than interventions that do not use a nudging approach. However, the first study on goal setting and default did include a control group. For that intervention it could be shown that default goals are at most as effective as self-set goals. In contrast, for the study on feedback and reference groups, it is not possible to conclude that feedback is more effective when using social influence as a nudge than using feedback alone since the study design did not include a control group that just received individual consumption feedback. Including a real control group where customers do not receive any treatment at all is sometimes difficult to realize when using real customers as a study sample. Hence, if researchers are interested in testing whether interventions with nudges are more effective than the interventions alone, they should consider using a different sample, such as college students. Another opportunity for future research involves testing the combined effects of multiple interventions and nudges on electricity conservation. The studies in this thesis combined two interventions at most and were restricted to one nudge per intervention. However, the effects of
the interventions could differ if they were applied with other interventions (e.g., rewards, competition). To rule out negative interaction effects, future research should test the combinations of multiple interventions and nudges [222,310].

Beyond the research opportunities than result from the thesis’ limitations, this thesis opens a window to considerably more research opportunities surrounding the new approach that combines traditional behavioral interventions with tailored nudges to account for human irrationality and differences in motivation. First, the research approach itself – that is, the combination of hypotheses rooted in the behavioral sciences and design-oriented IS research – can serve as a powerful tool to fundamentally extend the understanding of individual’s decision-processes in the energy context. The information systems within the Smart Metering infrastructure make it easy to combine goal setting, feedback, or other types of behavioral interventions with behavioral nudges and to assess the interventions’ effects on behavior. Future research could focus on other intervention strategies and test different nudges (for an overview see [5,291]). For example, rewards that inform individuals similar to feedback about their performance and progress could be combined with social influence. Specifically, a social reward system could be designed in a way that individuals would not keep the rewards that they received based on their own energy consumption but they would give it away to friends [7]. By doing this, the effects of rewards would be increased by adding social pressure from friends. Since people
respond differently to social rewards, it should be tested whether the intervention needs to be tailored with regard to the energy consumers’ personality traits. For example, it is likely that people who believe that they actually control their energy consumption (= internal locus of control) respond stronger to rewards than people who believe that they cannot control their consumption (= external locus of control) [172]. In addition to investigating other intervention strategies and nudges, it is also worth testing different other strategies than tailoring to buffer potential detrimental effects of behavioral interventions for certain consumer groups. There could be interventions that work for energy consumers with different characteristics, similar to providing injunctive normative feedback for both below-average and above-average energy consumers. For example, it could be tested whether a ranking would motivate both energy consumers who aim at identity signaling as well as those who do not.

Furthermore, future research should test the effect of a certain intervention strategy on more energy uses than just electricity. Research found that individuals sometimes can respond to an intervention by reducing their water use and increasing their electricity use simultaneously34. This effect is called “moral licensing”: If people already behave well in one area, they take this as a moral excuse to behave less morally correct in other domains.35 The emerging Smart Metering infrastructure also

facilitates the measurement of water and gas on a very granular level which allows for detecting negative side effects. Lastly, it would be worth investigating the long-term effects of the behavioral interventions tested within this thesis. Since the effects usually diminish over time, future research should test different strategies for maintaining the effects over time. Since external factors such as situational barriers play an important role in whether a certain behavior is shown [294,315], prompts and reminder could be effective in continuously engaging energy consumers in energy conservation.

8.5 Conclusions

To conclude, the results of this thesis show that the new approach that was presented in this thesis, that is, combining traditional behavioral interventions with tailored nudges, is successful in motivating residential energy consumers to reduce their electricity use. The interventions contribute on the micro-level by supporting energy consumers to reduce their electricity bills, on the meso-level by helping utility companies to meet their regulatory obligations and by making Smart Metering more cost-effective and on the macro-level by improving environmental quality and securing future generations’ energy supply. Hence, it is important to account for human irrationality when designing feedback systems for Smart Metering and to provide little nudges that help energy consumers to take the right measures to save electricity. Social influence is especially effective in directing human behavior and is thus worth being
considered in the design of feedback systems or energy efficiency campaigns. The results of this thesis further indicate that combining effective interventions with nudges does not assure energy savings unless the nudges are tailored to the characteristics of the energy consumer. To prevent negative effects and increase energy efficiency gains, the interventions should always be pretested with a subset of energy consumers. Information systems in this context play a significant role because they support pretesting, tailoring, and finally delivering the interventions cost-efficiently to energy consumers. The combination of information systems and behavioral interventions hence holds the potential of playing a significant role in the energy supply of the future.
9 Bibliography


56. Brown, C.L. and Krishna, A. The Skeptical Shopper: A Metacognitive Account for the Effects of Default Options


77. Deci, E.L., Koestner, R., and Ryan, R.M. A meta-analytic review of experiments examining the effects of extrinsic
rewards on intrinsic motivation. *Psychological Bulletin* 125, 6 (1999), 627-668.


90. EC. *Starke Impulse für Energiesparen und Energieeffizienz*. 2011.


121. Goldstein, N.J., Cialdini, R.B., and Griskevicius, V. A Room with a Viewpoint: Using Social Norms to Motivate


149. van Houwelingen, J.H. and van Raaij, F.W. The Effect of Goal-Setting and Daily Electronic Feedback on In-Home


International Conference on Information Systems, (accepted), 1-14.


218. Mizerski, R. The relationship between cartoon trade character recognition and attitude toward product


222. Nielsen, L. How to get the birds in the bush into your hand: Results from a Danish research project on electricity savings. *Energy Policy* 21, 11 (1993), 1133-1144.


233. Perkins, H.W., Haines, M.P., and Rice, R. Misperceiving the college drinking norm and related problems: A


239. Petty, R.E. and Cacioppo, J.T. *Attitudes and persuasion: Classic and contemporary approaches*. Brown, Dubuque, IA, 1891.


244. RWE. *Market Data*. Essen, Germany, 2008.


246. Reeves, B. and Nass, C. *The media equation: How people treat computers, television, and new media like real
people and places. CSLI Publications, Stanford, CA, 1996.


267. Scott, M., Barreto, M., Quintal, F., and Oakley, I. Understanding Goal Setting Behavior in the Context of


274. Shilts, M.K., Horowitz, M., and Townsend, M.S. Goal setting as a strategy for dietary and physical activity


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