Energy conservation through behavioral change

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Chapter 1
Introduction

As soon as seasonal temperatures start to drop significantly in the Netherlands, some time in the autumn, advertisement campaigns advocating the benefits of energy conservation tend to crop up. These advertisements aim to encourage households to save energy, by emphasizing that energy conservation activities can be fairly effortless and do not necessarily entail a loss of comfort or quality of life, as illustrated by the use of terms like 'comfortable living', 'cozy home base' and 'enjoy'. As soon as spring has set in, the advertisements cease. The question remains whether interventions, such as the advertisement campaigns referred to in the above example, are in fact successful in enticing households to reduce their energy use. Do households start adopting energy-saving measures, and why (not)? And, do these efforts to conserve energy actually make a difference? In other words, what is the environmental impact of these behavioral changes in terms of energy conservation or CO_2 emission reductions?

A number of important issues need to be taken into account when developing, implementing and evaluating interventions aimed at encouraging energy conservation among households. If the aim is to successfully encourage households to reduce their energy use, it is necessary to examine the effectiveness of interventions in terms of changes in energy use (i.e. energy savings), changes in energy-related behaviors and changes in behavioral antecedents. Interventions aimed at energy

conservation will be more effective if they target behavioral antecedents. This provides additional insight into why interventions were (in)effective, which can subsequently serve as input for their further improvement. The main objective of this dissertation is to develop better understandings of the effectiveness of interventions aimed to encourage households to reduce their energy use via behavioral changes, and to enhance our understandings of the psychological factors related to household energy use and conservation by means of the application of various social-psychological theories.

Household energy use: facts & figures

Energy use is an important driving force in modern, industrialized societies; supporting most, if not all, economic activity. Energy is used for many day-to-day behaviors, such as home heating, the use of household appliances and car use. And insofar as this energy is derived from fossil fuels, it contributes to increased concentrations of greenhouse gases (e.g. carbon dioxide) in the atmosphere. Current energy consumption levels are intensive in terms of resource use and lead to various adverse environmental effects such as global warming, air pollution and depletion of natural resources (Daly, 1996; Dutch Ministry of Economic Affairs, 2005; EIA, 2005; OECD, 2001). Such developments call for measures to substantially reduce our impact on the environment, by reducing the usage of fossil fuels and/or increase the use of alternative sources of energy such as solar or wind energy. In view of this, the Netherlands has committed itself to reducing its CO_2 emissions by 6% in the period 2008-2012, which requires annual energy savings of 1.3% by industry, agriculture and households (Dutch Ministry of Economic Affairs, 2005).

Household energy use – through the combustion of fossil fuels - accounts for a significant proportion of total greenhouse gas emissions. For OECD countries, average percentages range between 15 and 20% of total emissions (OECD, 2001). In the Netherlands, households are responsible for 17% of total greenhouse gas emissions in relation to gas, electricity and fuel use (RIVM, 2005), and this residential share is rapidly growing. When viewed in this light, households can be considered an important target group for energy conservation. By targeting energy-related behaviors, household energy use and its impact on the environment may be reduced.

Gas, electricity and fuel use are the most salient forms of household energy use. The use of gas to regulate in-home temperature, the use of electric appliances and the use of a car are all examples of what is labeled direct energy use. These forms of energy use are directly visible from meter readings. Approximately one quarter of

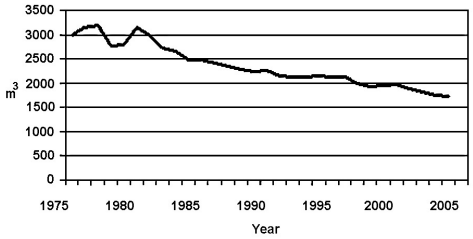

Figure 1. Average annual gas use of Dutch households for the period 1975-2005 (in m^3; corrected for temperature). Source: EnergieNed (2006).

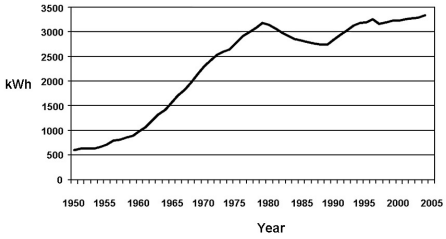

Figure 2. Average annual electricity use of Dutch households for the period 1950-2005 (in kWh) Source: EnergieNed (2006).

total energy requirements of Dutch households is accounted for by gas use, 13% by electricity use, and 10% by the use of fuel (Kok, Benders, & Moll, 2006). On average, approximately 74% of gas use is used for home heating, 22% for the use of warm water, and 4% for cooking (MilieuCentraal, 2006). During the last few decades, average gas use of Dutch households has steadily declined (see Figure 1), mainly as a result of better in-home insulation. On the other hand, average household electricity use has increased (see Figure 2) due to increased appliance ownership and an increased usage of appliances. Average (Dutch) household electricity use is distributed in the following manner: 22% is used for washing/drying, 17% for cooling, 15% for lighting, 14% for home and water heating and the remaining 32% for the use of various electric appliances (MilieuCentraal, 2006).

Indirect energy is a rather more inconspicuous form of energy use, as it is embedded in the production, transportation, and disposal of consumer goods and services (Vringer & Blok, 1995). To illustrate, the production of fruit and vegetables requires energy for packaging, distribution and disposal purposes. Households may generally not be aware of the fact that energy is embedded in the products and services they consume, i.e. they may not realize that fruit and vegetables imported from overseas have higher energy intensities (in terms of energy use per product or unit) than locally grown counterparts. A study revealed that for an average Dutch household in 1994, approximately half of total household energy requirements consisted of indirect energy use (Reinders, Vringer, & Blok, 2003). As a comparison, in Finland and Spain, the share of indirect energy use was found to be 36%, in the UK it was 51% and in Portugal 66%. It is important to design and implement energy policies aimed at reducing indirect energy use. Households can make an important contribution to energy conservation by consuming products with lower energy intensities.

Households may reduce energy use by adopting efficiency and/or curtailment behaviors (Gardner & Stern, 2002; Geller, Winett, & Everett, 1982). Efficiency behaviors

are one-shot behaviors, typically involving the adoption of new technologies, such as purchasing energy-efficient equipment (e.g. energy-saving light bulbs). Curtailment behaviors, in contrast, involve changing energy-related behaviors, such as lowering thermostat settings. The adoption of these kinds of behaviors requires a certain amount of conscious effort, at least until new habits have been formed. The energy-saving potential of efficiency behaviors is considered to be greater than that of curtailment behaviors (Gardner & Stern, 2002), and this also reflects the perception of consumers (Steg, Dreijerink, & Abrahamse, 2006). It should be noted that the adoption of new technology (such as the purchase of an energy-saving appliance) does not necessarily result in energy savings. When this appliance is subsequently used more often, perhaps because it is considered to be environmentally friendly, this may result in a so-called rebound effect (Berkhout, Muskens, & Velthuijsen, 2000, see Box 1). It is therefore important to monitor technological innovations as well as subsequent usage of these innovations.

Box 1. On the Rebound

Households can save energy, but this may not always materialize in terms of reduced environmental impact, because of the occurrence of so-called rebound effects. A rebound effect refers to an (unanticipated) counterbalancing or even a complete disappearance of initial energy efficiency gains (cf. Hertwich, 2005). One type of rebound effect occurs when households spend the money they have saved by reducing their energy use on energy-intensive goods and services, e.g. on a holiday requiring air travel. A second type of rebound effect is related to the implementation of technological innovations. To illustrate, when using energy-saving light bulbs, it may well be that householders leave them burning for longer periods of time, or they may install additional lighting; hereby counterbalancing initial efficiency gains. Rebound effects are therefore important to take into consideration.

Shaping factors of household energy use and conservation

It has widely been acknowledged that household energy consumption contributes significantly to global energy-related problems and that attempts should be made at reducing household energy use. However, households' use of fossil fuels keeps increasing and their environmental impact accordingly. This begs the question of why households continue to consume energy at such increasing rates. Both societal-level as well as individual-level variables may be identified as contributing to this trend.

Societal determinants: the TEDIC factors

Various societal factors contribute to the increase in household energy consumption. These may be summarized as technological developments, economic growth, demographic factors, institutional factors and cultural developments (also known as the TEDIC factors, see Gatersleben & Vlek, 1998; Vlek, 2000). First, developments in technology have provided households with a broad and continuously growing range of appliances (see Table 1). For instance, since its introduction about two decades ago the microwave oven has found its way into 80% of Dutch kitchens (as of 2001). In 1981, 13% of all Dutch households owned a clothes dryer and 10% owned

Table 1. Average annual electricity use of a number of household appliances (in kWh), taking into account electric capacity, average annual use and stand-by functions.

	Electricity use (kWh/year)		Electricity use (kWh/year)
Waterbed	734	Washing machine	231
Clothes dryer	599	Computer	146
Lighting	540	TV	138
Cooking equipment	55-530	Video recorder	10
Refrigerator (2-doors)	462	Coffee maker	80
Refrigerator (1-doors)	286	Vacuum cleaner	5
Dishwasher	305	Whirlpool	21

Source: Milieu Centraal (2006); BEK (1997).

a dishwasher; two decades later, this had amounted to 55% and 40% respectively (CBS, 2003). Over the years, appliances have become more energy-efficient. However, households posses and use more electronic appliances than ever before - a trend that has outweighed initial efficiency gains. Overall, human activities have become motorized whilst the purchase and use of these material goods puts a strain on sustainable development.

Second, the last few decades have seen - in developed countries at least - a steady rise in economic welfare. Nowadays, households have more means to spend on goods and services. Households with higher incomes use more energy than households with lower incomes and this relationship is most marked for expenditures on indirect energy use (Moll et al., 2005; Vringer & Blok, 1995). Compared to households with an average income, households who earn twice as much tend to spend three times as much on indirect energy, in the form of leisure activities, clothing and home furnishings (RIVM, 2001). Potentially, households with higher incomes also have more means to finance environmentally-friendly alternatives. For instance, they have the means to purchase in-home insulation, to buy energy-efficient appliances, or to finance alternative ways of leisure travel (e.g. a train journey from Amsterdam

to London is generally more expensive than flying). In sum, economic growth is intricately related to household energy requirements.

Third, demographic factors, such as population growth, are related to the rise in energy consumption. Since the 1950s, the number of inhabitants in the Netherlands has increased substantially. As a result of the decrease in average household size (from 4.4 persons in 1956 to 2.3 in 2002) and the increase in the number of single-person households, the total number of households has increased (CBS, 2003). And since average household energy use has increased over the years, these developments in household demographics have resulted in increased environmental impact per person.

Fourth, institutional factors, such as governmental policies, play an important part in household energy consumption patterns. Energy policies may be designed to discourage the use of fossil fuels (e.g. by means of implementing a tax on the use of energy), or to encourage the use of renewable energy sources (e.g. by means of subsidies; see also Box 2). Regulatory measures may be implemented, restricting ecologically harmful consumption. On the other hand, governmental policies also encourage energy consumption, as is illustrated by policies maintaining relatively low kerosene duties and policies sustaining energy-intensive agriculture and horticulture (the latter profiting from a quantity rebate for the use of gas). The extent to which governments encourage or discourage the use of energy may be a shaping factor for household energy use and may provide a signal to the public as to the eminence of this issue.

Fifth, and finally, cultural developments shape individual (household) decision-making processes. Households are part of larger social and cultural structures, ultimately influencing the choices they make. That is to say, prevalent social norms

Box 2. Renewable, or not? The case of energy from animal manure

Renewable energy sources, such as solar and wind energy, are used as viable alternatives to fossil fuels. A new source of energy has recently been discovered: animal manure. Animal manure can be transformed into biogas by means of a fermentation process, and can subsequently be transformed into thermal and electric energy. This type of energy is marketed as renewable energy: rather than dumping the manure surplus on farmlands, it is used to generate gas and electricity. In fact, the Dutch government generously subsidizes green electricity from animal manure. A closer look at its ingredients, however, reveals that the electricity is not as green as one might think. To facilitate the fermentation process, corn is added to the mixture. Per fermentation installation, 1,000 tons of corn is needed annually, and the production of this amount of corn requires 22,000 liters of diesel oil (for harvesting, use of fertilizers, etc.). Maybe not so renewable after all.
Source: Abrahamse (2006).

influence individual preferences (Shove, 2003; Spaargaren, 2003). The past decades have witnessed a shift towards a so-called 'consumer culture', including a strong increase in the number of products and services offered to, and demanded by households, with accompanying changes in consumer lifestyles (Cross, 1993). The goods people own do not only have a material value, but they also have a symbolic value. They are an expression of a certain social status and in this sense convey a message to other people (Dittmar, 1992). These goods require the use of energy (fossil fuels) and in the long run, this consumer culture may turn out to be environmentally unsustainable.

It has been argued that, consumers are locked in by structural circumstances, governing individual consumer behavior (Sanne, 2002). In this view, environmentally-relevant behaviors are regulated by contextual factors, such as governmental policies How then can individual consumers adapt their behavior in a more sustainable direction when governments or industries do not offer and facilitate the use of environmentally-friendly behavior options? Structural factors are indeed important, but there seems to be more to it than that. For instance, not every consumer will switch from 'grey' (non-renewable) to 'green' (renewable) electricity as a result of energy policies that promote the use of renewable energy. That is, given the societal circumstances, individual consumers generally have a choice to act pro-environmentally or not (Ölander & Thøgersen, 1995). In other words, individual-level factors are important to consider in relation to energy use and conservation. In this dissertation, the focus is on these individual-level factors. That is, given the current context, which individual-level factors are related to energy consumption and conservation?

Individual-level factors: The psychology of energy use and conservation

Individual-level factors refer to a range of cognitive and motivational factors, that govern individual behavioral choices, such as awareness, beliefs, values, attitudes and knowledge. Individual-level factors may be important driving forces behind consumption choices. To illustrate, research has shown that households may not be aware of the energy use associated with household appliances, or may have misconceptions about it (Baird & Brier, 1981). Households tend to base their estimates of energy requirements on both visibility and size of appliances. That is, large appliances were presumed to use large amounts of energy, whereas small appliances were believed to use small amounts, even if the reverse was true. To illustrate, energy requirements of a whirlpool were largely overestimated, whereas those of a coffee maker were highly underestimated (Schuitema & Steg, 2005). A similar point can be

made for behaviors related to indirect energy use. Households may not be aware of the energy use associated with daily purchase decisions (e.g. seasonal vegetables have lower energy-intensities than vegetables flown in from abroad). It is therefore important to encourage households to make purchase decisions at a lower cost to sustainable development. If it is known which factors form barriers for households to change their behavior, interventions can then be designed that specifically target these barriers.

Various social-psychological theories can be applied to explain environmentally relevant behaviors. To date, such theories have been applied to behaviors such as car use (e.g. Bamberg & Schmidt, 2003), recycling (Hopper & Nielsen, 1991; Guagnano, Stern, & Dietz, 1995) and environmental activism (Stern et al., 1999), whilst far less attention has been devoted to the application of these theories to household energy use and conservation. A widely used framework is Ajzen's (1985) theory of planned behavior (TPB). Its main assumption is that behavior is a resultant of an individual's positive and negative evaluations of the behavior in question (reflected in attitudes), an individual's perception of the prevailing opinion of important others (reflected in a social norm), and an individual's perception of his or her capabilities of performing the behavior (reflected in perceived behavioral control). The TPB has been successfully applied to explain a range of environmentally relevant behaviors, such as car use (Bamberg & Schmidt, 2003) and bus use (Heath & Gifford, 2002).

Another theory that has received extensive attention is the norm activation model (Schwartz, 1977). This theory was developed to explain pro-social and altruistic behavior. It is in this sense that it has been applied to pro-environmental behavior, as both types of behavior may entail giving up personal benefits for the sake of collective considerations. From a NAM perspective, engagement in pro-environmental behavior is determined by the extent to which people feel a moral obligation to do so (reflected in so-called personal norms). The degree to which people feel morally obliged to adopt pro-environmental behaviors is believed to be determined by the extent to which they are aware of the environmental consequences attached to their behavioral choices, and by the extent to which they assume responsibility for these problems. The NAM has been found to successfully explain various environmentally-relevant behaviors, such as recycling (e.g. Guagnano, Stern, & Dietz, 1995; Hopper & Nielsen, 1990).

More recently, the value-belief-norm (VBN) theory of environmentally significant behavior (Stern, 2000) has been put forward. This theory extends the NAM with general values emanating from value theory (Schwartz, 1992; 1994), and the new environmental paradigm (NEP; Dunlap, Van Liere, Mertig, & Jones, 2000). The VBN theory postulates that core values (viz., guiding principles in people's lives, Rokeach,

1976) are related to how people perceive the relationship between humans and the environment (NEP), which influences environmentally specific beliefs and norms, which in turn are assumed to be related to environmentally relevant behaviors. These assumptions make the VBN theory a relevant framework for explaining household energy use. The VBN theory has been successfully applied to car use (Nordlund & Garvill, 2003), environmental activism (Stern et al, 1999), and acceptability of energy policies (Steg, Dreijerink, & Abrahamse, 2005).

It has been suggested that household energy conservation can be framed in terms of a social dilemma (Samuelson, 1990). The dilemma arises from the conflict that exists between individual and collective outcomes of energy conservation behavior. While it would seem that energy use has many individual benefits (e.g. increased comfort and well-being), the negative side of the equation is, however, that it leads to negative environmental consequences (e.g. depletion of energy sources, environmental degradation). To the extent that households are aware of this dilemma, their behavior may be determined not only by individual considerations, but also by concern for environmental consequences (Samuelson, 1990). This calls for a more integrative approach, incorporating variables related to individual considerations (i.e. TPB) and environmental considerations (i.e. NAM, VBN). Some attempts have been made at such integrations. Harland, Staats, and Wilke (1999) for instance found personal norms (a NAM concept) to add significantly to the explanation of various environmentally related behaviors, over and above the power of the TPB variables.

Three issues stand out in psychological research examining household energy use and conservation. First and foremost, many psychological studies focus on examining the effectiveness of interventions aimed at reducing energy use, while far less attention has been devoted to (theoretically) examining its behavioral antecedents. Thus, relatively little is known of the factors that are related to household energy consumption and factors related to changes in these consumption patterns (i.e. savings). To reiterate a point that has been made previously, interventions will be more effective when they target behavioral antecedents. It is therefore important to not only look at what makes households reduce their energy use but to also examine the reasons why they do so (or not). Second, studies to date have mainly focused on changing gas, electricity and fuel use (direct energy use), while energy use that is embodied in the goods and services households purchase (indirect energy use) has rarely been the focus of intervention studies (with some notable exceptions, e.g. Staats, et al. 2004). It would be interesting to look at the extent to which these different kinds of energy use and energy savings are related to different types of variables. Third, many studies tend to focus on relating energy use and conservation to socio-demographic variables, while only a few psychological variables are included.

The general consensus seems to be that energy use is strongly related to socio-demographic variables such as income and household size (see Brandon & Lewis, 1999; Gatersleben, Steg, & Vlek, 2002; Poortinga, Steg, & Vlek, 2004). Energy savings on the other hand appear to be mainly related to attitudinal variables, and not to socio-demographic variables (e.g. Brandon & Lewis, 1999; Gatersleben, et al., 2002; Poortinga, et al., 2004). This may be explained by the fact that socio-demographic variables shape households' opportunities for energy consumption, while changes in energy use on the other hand require a certain amount of conscious effort and decision making, for instance to adopt certain energy-saving measures rather than others. This thesis aims to examine a wider ranger of psychological variables, including variables reflecting environmental considerations - in addition to attitudes – and linking this to not only direct but also indirect energy consumption patterns.

This dissertation aims to fill these gaps, first, by examining the effectiveness of interventions in terms of (i) changes in energy use, (ii) behavioral changes and (iii) changes in behavioral antecedents. Second, it aims to theoretically examine the relationships between direct and indirect energy use and conservation on the one hand and socio-demographic variables and individual-level variables on the other. Against the backdrop of various social-psychological theories (TPB, NAM, and VBN), this thesis examines the relative importance of variables reflecting both individual and environmental considerations in relation to household energy use and energy savings.

Strategies for behavioral change

Various types of strategies can be implemented to encourage consumers to reduce energy use. In Chapter 2, an overview is given of such strategies. Some energy conservation initiatives are aimed at maintaining the same behaviors with greater efficiency by means of technological innovations, while others intend to foster curtailment of these behaviors (Gardner & Stern, 2002). Two categories of interventions may be distinguished: (i) structural and (ii) psychological interventions (Steg, 2003; for a detailed taxonomy see also Vlek, Jager, & Steg, 1997 and Vlek, 2000). Structural interventions aim to change the (social) context in which behavioral decisions take place. The general idea behind these types of interventions is that by altering the conditions in which behavior takes place, behavior will change accordingly. Generally, three structural strategies are distinguished (Steg, 2003): financial-economic measures, physical/technical alternatives and legal regulation.

First, energy conservation may be encouraged by means of financial-economic measures, aimed to make energy-intensive behaviors relatively more expensive

and environmentally-friendly alternatives relatively less expensive. To illustrate, increasing the costs of energy use by means of a tax on the use of gas and electricity may entice households to reduce their energy use. Furthermore, increasing the prices of products that require much energy may encourage households to choose less energy-intensive alternatives. These kinds of measures are only effective to the extent that consumers take prices into account when making such choices.

Second, physical/technical alternatives involve changes to already existing infrastructure and equipment; such as the introduction of energy-efficient appliances, or hydrogen fuel cell technology. It has been acknowledged that efficiency improvements are necessary for sustainable development (Hinterberger, Kranendonk, Welfens, & Schmidt-Bleek, 1994). However, technological innovations can only offer partial solutions, as the effectiveness of technological measures hinges upon the adoption of new technology by consumers and the extent to which consumers know how to use these technologies efficiently. Possible rebound effects may occur (see Box 1), in that consumers may increase the use of efficient appliances, counterbalancing initial efficiency gains.

Third, legal regulation entails the introduction of legislation by the government, such as speed limits for cars in order to reduce carbon dioxide emissions. Generally, behavior that deviates from these regulations is met with some form of punishment. The assumption is that these rules and regulations will eventually become internalized. Regulatory measures may be an effective strategy for behavioral change, provided the monitoring and enforcement system works properly.

Psychological interventions are aimed at changing already existing perceptions, knowledge, attitudes, norms and values (i.e. individual-level variables). The underlying assumption here is that by changing these perceptions, behavior will change accordingly. Typically, a distinction is made between antecedent interventions and consequence interventions (Geller et al., 1990, see also Chapter 2). Antecedent interventions are focused on changing one or several determinants before behavior takes place. Examples of antecedent interventions are commitment, goal setting, modeling and information. To illustrate, the provision of information about energy-saving measures at home is presumed to lead to an increase in households' knowledge of energy conservation, which in turn should - ideally - result in the adoption of energy saving behaviors (see Box 3).

Consequence interventions are based on the assumption that when positive or negative consequences are attached to a certain behavior, this will subsequently lead to an alteration of this behavior. Feedback is an example of a consequence intervention. For instance, when households receive feedback about their efforts to reduce energy use, they may, as a result of the positive consequences attached to

Box 3. Households' involvement in energy conservation issues

Households respond differently to energy-saving measures they receive. Some households ignore it altogether, some households start adopting them, and some households… scrutinize them.
Households participating in the intervention study (see Chapter 3), received a package of tailor-made energy-saving options they could apply at home. In one particular household, this caused quite a stir. One of the option they had received was to reduce their showering time. They however sincerely doubted whether this would result in significant energy savings. To examine this, they kept a log of the amount of cubic meters gas they used each time they had a shower. A distinction was made between showers that involved washing their hair and those that did not. As it turned out, a positive relationship was found between showering time and hair length. For a time reduction of one minute, their estimated savings amounted to an annual 1.3% (showers including shampooing), and 1.2% (for showers excluding shampooing). They doubted whether this could make a contribution to energy conservation, in view of the energy-saving potential of other sectors (i.e. the industry). As this example illustrates, some households are very much actively involved in energy conservation issues, and critically examine the advice they receive.

their behavior, be motivated to conserve energy.

Structural and psychological interventions have been employed to encourage household energy conservation, with varying degrees of success. From our detailed review of intervention studies (see Chapter 2), it appears that when determining the effectiveness of interventions aimed at behavioral changes, it is important to examine the extent to which the intervention results in energy savings, behavioral changes and changes in behavioral antecedents because these measures provide a suitable basis for the further development of effective intervention planning.

A multidisciplinary approach to household energy use and conservation

Environmentally relevant behavior, such as household energy use and conservation, are related to a broad range of factors. As has been argued above, household energy use is related to structural variables, such as economic growth and to individual-level variables, such as individual perceptions and knowledge. Considering its multifaceted nature, it is necessary to address the issue of promoting pro-environmental behavior from a multidisciplinary viewpoint, covering different disciplines, such as economics, sociology, environmental sciences and behavioral sciences. Multidisciplinary research can be defined as research that combines theoretical knowledge and methodological approaches of different disciplines (Max-Neef, 2005). Each discipline carries out their own strand of the research in question,

and these different perspectives are combined to form a coherent understanding of the issue at hand and to provide possible solutions. The issue of encouraging households to reduce their energy use has been predominantly examined from a mono-disciplinary perspective, generally from either a natural science or a social science perspective (Robinson, 2004). There are however some exceptions (e.g. Gatersleben, 2000; Gatersleben, Steg, & Vlek, 2002; see also Schoot Uiterkamp & Vlek, 2006). A mono-disciplinary perspective is not sufficient to effectively address sustainability issues (Schoot Uiterkamp & Vlek, 2006; Robinson, 2004; Stern, Dietz, Ruttan, Socolow, & Sweeney, 1997). Rather, combining different approaches seems necessary to encompass the multifaceted nature of environmentally relevant behaviors and to effectively encourage consumers to adopt a more sustainable behavior pattern with reduced impact on the environment.

The empirical studies presented in this dissertation were conducted from a multidisciplinary perspective, in which environmental scientists, social scientists, and computer engineers were represented. The environmental scientists examined household energy consumption patterns with a focus on the actual impact of energy-related behaviors. They calculated how much direct and indirect energy use is associated with a broad range of energy-related behaviors and selected energy-related behaviors that would have a significant impact on household energy conservation (i.e. in terms of potential energy savings). The social scientists focused on the role of human behavior in relation to energy consumption, by focusing on the effectiveness of strategies for behavioral change whilst examining behavioral antecedents. Lastly, computer scientists were responsible for the implementation of a user-friendly interface (by means of an Internet site). It is important to convey information about energy-related behaviors in a user-friendly way, as this will affect how households deal with the information. This approach required a collaborative effort, so as to integrate the input from the various disciplines. The disciplines did not work in isolation, but each strand required input from the others at various stages in the process (detailed information about the multidisciplinary focus is given in Chapter 3).

A multidisciplinary approach such as this has the benefit of combining insights regarding environmental impact of various energy-related behaviors with knowledge about encouraging behavioral changes as well as knowledge about how to develop and implement a user-friendly interface. In addition, energy conservation studies have mostly focused on reducing direct energy use (gas, electricity and fuel use). However, energy use is also embedded in the products and services households consume, which implies that a much wider range of behaviors is relevant for achieving overall energy reductions than is normally included in studies on

household energy conservation. This requires input from environmental scientists about energy requirements associated with behaviors related to indirect energy use. This way it is possible to target energy-related behaviors that make a significant difference in terms of energy savings as well as being feasible for households to adopt.

The present dissertation

The purpose of this dissertation is twofold. First, it examines how households can be encouraged to reduce their (direct and indirect) energy use through behavioral changes by means of (a combination of) intervention strategies. This topic is covered in Chapters 2 and 3. Second, this thesis aims to examine which factors underlie household energy use, households' intention to reduce energy use and actual energy savings, against the backdrop of various social-psychological theories (Chapters 4 and 5). The emphasis will be on the relative influence of socio-demographic variables and individual-level variables, such as attitudes and awareness. This dissertation starts with an extensive overview of the intervention literature in the area of household energy conservation and then moves on to a discussion of the results of two multidisciplinary field studies. The one field study is discussed in Chapter 3 and Chapter 5, the other field study is discussed in Chapter 4. Both studies aimed to encourage households to reduce their energy use through behavioral changes and to examine behavioral antecedents. The multidisciplinary focus of these studies allowed for a broad insight into how households can effectively be encouraged to adopt various energy-saving measures whilst educating them about the actual impact of (changes in) energy-related household behaviors on their energy use. A wide range of energy-saving options was included, encompassing direct as well as indirect energy use. Chapters 2 - 5 are based on journal articles that have either been published or submitted for publication. There is some overlap between those chapters, especially in the method sections (i.e. explanation of the intervention, sample description). However, this overlap allows the reader to read each chapter independently, without cross-referencing to other chapters.

In Chapter 2, a thorough literature review is given of intervention studies aimed at promoting energy conservation among households. This review provides an evaluation of the effectiveness of various types of interventions in terms of changes in energy use (i.e. energy savings), of changes in energy-related behaviors (i.e. adoption of energy-saving measures), of changes in behavioral antecedents (e.g. did knowledge levels increase as a result of the intervention?). It also evaluates the long-term effects of interventions.

Chapter 3 discusses the results of a multidisciplinary field study, which was aimed at encouraging households to reduce (direct as well as indirect) energy use through behavioral changes. More specifically, this Internet-based study tested the effectiveness of tailored information (about energy-saving measures), goal setting and feedback in relation to changes in energy use, changes in energy-related behaviors and changes in behavioral antecedents. For this purpose, energy use, energy-related behaviors and knowledge of energy conservation were monitored over a period of five months. It was examined whether, as a result of the intervention, households had reduced their direct and indirect energy use, whether households had adopted the energy-saving measures they had been provided with, and whether households had gained more knowledge about energy conservation

In Chapter 4, results of a second multidisciplinary field study are presented, which was aimed at examining the relationships between both socio-demographic and psychological factors and household energy use and householders' intention to conserve energy. In particular, variables from two social-psychological theoretical frameworks (the value belief norm theory and the theory of planned behavior) were compared with respect to their explanatory power.

In Chapter 5, it is examined whether different types of energy use are related to different behavioral antecedents. For this purpose, both socio-demographic variables (e.g. income) and individual-level variables (e.g. attitudes) are examined in relation to direct and indirect energy consumption and direct and indirect energy savings. In particular, variables reflecting the individual advantages of energy use (stemming from the theory of planned behavior) as well as variables related to environmental considerations (stemming from the norm activation model) were taken into account.

The dissertation concludes with a general discussion of the reported findings, in Chapter 6. The results are integrated and discussed, with an emphasis on theoretical, research and policy implications.