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Energy Policy 34 (2006) 3612–3622

ENERGY POLICY

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New approaches for household energy conservation—In search of personal household energy budgets and energy reduction options

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Available online 12 September 2005

Abstract

Large-scale energy reduction campaigns focusing on households generally have two shortcomings. First, an energy reduction campaign is either personalized but time intensive or time extensive but generalized. Second, because only the direct energy requirements are addressed, only 50% of the total household energy requirement is subject to reduction. The other 50%, the indirect energy requirement, is much more difficult to calculate and address and therefore not subject to reduction.

In this paper, we describe a web-based tool that has the potential to overcome both of these shortcomings. The tool addresses direct as well as indirect energy requirements. By means of a simple expert system participants obtain personalized reduction options and feedback on the energy reduced. The tool was tested in Groningen (the Netherlands) with a sample of 300 households, resulting in a direct energy reduction of about 8.5% compared to a control group. The reduction in indirect energy was not statistically significant.

Keywords: Household energy reduction; Indirect energy; Personalization and feedback

1. Introduction

After the report of the Club of Rome (Meadows et al., 1972) and the energy crises of 1973 and 1979 energy conservation became an issue on the political agenda. In the 1970s and 1980s, the focus was mainly on sectors and functions with high energy demand (electricity production, transport, space heating). During the 1990s it was increasingly acknowledged that households are relevant for reducing long-term energy impacts (Noorman and Schoot Uiterkamp, 1998). Consumer activities can be linked to input–output (IO) patterns in the economy and hence to the accompanying energy requirements due to economic activities. Many activities take place within households so a large part of the accompanied energy requirements can be imputed to these households. Together, the direct energy requirements (energy for space heating, electricity, and motor fuel) and the indirect energy requirements by households make up about 80% of the total energy flows throughout society in the Netherlands (Wilting, 1996). The indirect energy requirement is defined as the energy needed for the production, distribution, and waste disposal of consumer goods and services (e.g., the production of food).

Households are thus an important group when addressing energy conservation. Another reason for focusing on households is that, in contrast to other sectors, and in spite of various information campaigns conducted over many years in the Netherlands, energy consumption in households continues to rise. This is especially true of electricity consumption and motor fuel (EnergieNed, 2002; Bouwman, 2000). The main determinant for this increase is the rise in incomes (Cohen et al., 2005; Moll et al., 2005; Pachauri, 2004; Weber and Perrels, 2000). The energy needed for space heating is declining due to insulation measures and regulation (EnergieNed, 2001).

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0301-4215/$ - see front matter © 2005 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enpol.2005.08.005

Both the direct and the indirect energy requirements per household have increased. Wilting calculated that in 1990 Dutch households were using on average about as much direct energy as indirect energy (Wilting, 1996; Vringer and Blok, 1995). Although the indirect energy requirement is important when looking at household energy conservation (Bin and Dowlatabadi, 2005), most research on changing household energy requirements focused only on direct energy requirements (Abrahamse et al., under review; Dwyer et al., 1993; Wood and Newborough, 2003). The reason for this omission lies in the difficulty of determining the indirect energy requirement as compared to the direct energy requirement (Kok et al., in press).

The main determinants behind the differences in the energy requirement are income and household size (Moll et al., 2005; Biesiot and Noorman, 1999; Biesiot and Moll, 1995; Vringer and Blok, 1995). While the lowest income classes require relatively more direct energy, higher income classes require more indirect energy in relative and absolute terms (Moll et al., 2005). For example, the energy requirement for holidays is very sensitive to rises in income. On a household level there is a large spread in the energy requirement even within a group with the same income and household size. There is a large spread in the energy requirement for different categories between individual households (e.g., space heating, transport, food, holidays) (Biesiot and Moll, 1995; Vringer and Blok, 1995; Schipper et al., 1989).

On the one hand this diversity shows that high income groups can be low energy consumers. On the other hand it shows that the average household does not exist. This diversity makes it hard to address households effectively by means of information in a generic way. Personalization of information could be a solution but is often very labor intensive and time consuming. The potential for a personal approach (information and feedback) is illustrated in a Dutch experiment (the so-called "Perspectief" project) (Novem, 2000). This experiment shows that an energy reduction of up to 40% (compared to other households) was achievable due to personal information, diverse types of feedback, freedom of choice, and social pressure. In this experiment that lasted from 1996 to 1998, a small group of households (12) in the Netherlands committed themselves to reducing their total energy requirements (direct + indirect). They achieved an average reduction of 31% (compared to their own situation) while receiving an increase in income of 20%. After the experiment was finished a regression took place, mainly in the energy requirement for transport and holidays, but a large part of the lifestyle changes were partially (50%) or almost fully sustained (25%). Because of the intensity of the contacts, such an experiment is only suitable for small groups, but the personal approach and the feedback appeared to be a powerful strategy.

This leads to the following research questions: (1) Is it possible to develop a tool that can be applied on a large scale and that supplies households with personalized energy reduction options? (2) Is it possible to aim such a tool at both the direct and indirect energy requirement? The findings described above generate new research questions and possible solutions worthwhile investigating.

In the present project, we developed a tool for addressing households on the subject of energy conservation in such a way that:

- participants were approached more personally (reduction options and feedback),
- the approach was not labor intensive for the researchers,
- besides direct energy indirect energy was also taken into account.

The tool was tested and evaluated in a field experiment. The main questions in the evaluation were: Does the tool stimulate the participants to reduce their total energy requirement? Is it possible to address the indirect energy requirement and reductions?

The research was carried out as a field experiment with a group of 300 households in the city of Groningen (the Netherlands).

2. Research background

In this section, three items, personalization, indirect energy, and scalability, already raised in the research question, are further discussed and/or explained.

2.1. Personalization, tailoring, and feedback

There are several ways of persuading households into a more energy extensive consumption pattern. From several review articles (Abrahamse et al., under review; Dwyer et al., 1993; Wood and Newborough, 2003) it can be deduced that information programs on energy reduction are rarely effective (Dulleck and Kaufmann, 2004). Another important conclusion in these reviews is that the information that is given should appeal to the consumer: when the information given is personalized, the results are better. This holds for reduction options given to the consumers as well as for the feedback on their changed behavior.

Here are some examples of successful experiments:

- Wilhite and Ling (1995) found that by giving a more informative energy bill more frequently (six times instead of 1/year) to about 600 households in Oslo, an energy reduction of about 10% was achieved as compared to the control group (Wilhite and Ling,

1995). The extra information comprised a simplification of the bill, a comparison with last year's energy bill, and some energy-saving tips.
- Brandon and Lewis (1999) measured an average energy reduction of 1.36% as compared to a 7.78% increase for the control group. In this experiment, a group of 120 households (divided into seven groups) received different forms of feedback on their gas and electricity consumption. The researchers noted consumer disappointment about the lack of personalized information.
- An example of personal information in an energy conservation context is the home energy audit. This audit is a home visit by an expert on home energy savings. This expert gives personal advice for reducing energy in several ways, often focused on energy for space heating. Winett et al. (1982) measured a 21% average reduction compared with the control group in an energy audit study.

These three examples can be characterized as the personal approach. By a personalized approach in the context of energy reductions in households we mean that information will be offered to a household which is based on specific characteristics of that household. This information can be reduction options to change the household's energy requirements or feedback on their changed behavior.

It is obvious that these personalized reduction options can only be given if the household's hardware (ownership of appliances, etc.) and behavior (how are the appliances used) is known. The advantage of the personalization is that households get only that information which is relevant to them, so they will be safeguarded from an overload of non-relevant information.

Feedback is the other form of personalized information. In this study, it is defined as personalized information concerning the obtained change in energy requirements due to change in ownership of hardware and/or behavior. The advantage of feedback in this context lies in the chance for households to see the relationship between their behavior and their energy requirements.

Tailoring is a term often used in the context of personalized information. In our definition, tailoring goes one step further. Where the personalized approach is a ready-to-wear suit, tailoring is a made-to-measure suit which fits perfectly. With tailoring, the households concerned are offered those reduction options which best suit the preferences of the household itself. For example, within the personalized approach a household that owns a car is always offered car related reduction options. Through the tailored approach these car related reduction options are not offered if the household has indicated reduction in car mobility is not a feasible option for them. The options that are indicated as feasible can be worked out more detailed than in a personalized approach. In the health care sector (computer), tailoring intervention has already proven to be a successful methodology (Brug et al., 1996; Campbell et al., 1994; Dijkstra et al., 1999; Etter and Perneger, 2001).

In general, it is concluded (Abrahamse et al., under review; Dwyer et al., 1993; Wood and Newborough, 2003) that not all experiments carried out on energy reduction in households are successful, but that those in which feedback and a more personalized approach are used give the best results.

The successful examples mentioned here and those discussed in the reviews (Abrahamse et al., under review; Dwyer et al., 1993; Wood and Newborough, 2003) are all relatively small-scale experiments (<1000 participants) and focus on household energy consumption (space heating and electricity).

2.2. Indirect energy

In none of the articles described in the three reviews mentioned in Section 2.1 did indirect energy play a role. This is remarkable as indirect energy is about 50% of total energy requirements. The probable reason for this is that the indirect energy requirement is much more difficult to determine than the direct energy one. In this section, the methodology for calculating indirect energy requirements in households is briefly described.

Given the definition of indirect energy (see Section 1), all energy embodied in the expenditure of households, except that for direct energy (electricity, motor fuel, natural gas, etc.), are seen as indirect. In Fig. 1, the division into energy categories is given for the Netherlands in 1996. The indirect part is about 50% (the right-hand side of the pie: 121 GJ) of the total energy requirements (243 GJ) of an average household.

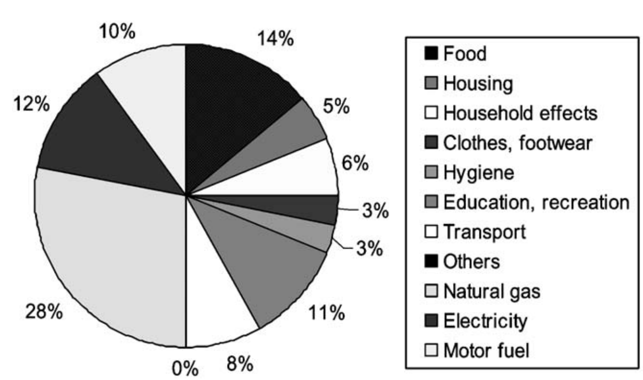

Fig. 1. Relative energy requirements by category for an average household in the Netherlands in 1996. The left half of this pie contains the direct energy categories (natural gas, electricity, and motor fuel) and the right half the indirect energy categories (data derived from Kok et al., in press, Table 5).

To calculate the indirect energy requirement of an expenditure, the whole life cycle (the so-called 'from cradle to grave' approach) for this expenditure should be calculated. One method for calculating the whole energy life cycle that is characterized as bottom-up with a high level of detail (Kok et al. in press) is the so-called hybrid method as defined by Engelenburg et al. (1994).

We used the so-called hybrid method as developed by Bullard et al. (1978) and worked out in a practical step-by-step method by Engelenburg et al. (1994). This hybrid method is a combination of IO analysis and process analysis. In process analysis, the processes in the life cycle of a product are described in physical terms. Process analysis is more accurate but more time consuming than IO analysis. However, process analysis suffers from a truncation error, caused by the infinity of the tree structure of the inputs of the product. IO analysis deals with the complete input tree structure of a product, but suffers also from uncertainties mainly due to the aggregation level, e.g., multiple products in one sector, multiple prices to one product, and multiple producers of one product (Hondo et al., 2002). To minimize the uncertainties from both methods, a hybrid approach is used taking best from both methods (Bullard et al., 1978).

The step-by-step method as was mentioned above was implemented in the energy analysis software program (EAP) developed by Wilting at the Center for Energy and Environmental Studies, IVEM (Wilting, 1996; Wilting et al., 1999; Benders et al., 2001; Kok et al., 2001). This EAP program contains a set of databases with production data, energy statistics, and an IO table. By entering some crucial product information (e.g., price, basic materials, producer, transport waste handling) in EAP, energy intensities (MJ/€) for 350 household expenditures have been determined. These 350 household expenditures match those present in the national consumer expenditure survey. By combining the energy intensities with the national consumer expenditure survey data the total indirect energy requirements for an average Dutch household can be determined. For a complete description of the methodology we refer to Benders et al. (2001), Engelenburg et al. (1994), and Wilting (1996).

2.3. Scalability

In Section 2.1, it was concluded that experiments in the literature were relatively small-scale experiments (<1000 participants). When, e.g., the national government wants to persuade households on a large scale toward a more energy extensive life style, a mass media approach is needed to reach them. In Section 2.2, it was concluded that traditional mass media campaigns do not work (Dulleck and Kaufmann, 2004). Personalization could be very effective but has thus far only been used in labor-intensive experiments (Winett et al., 1982; Novem, 2000). We searched for a method that:

- would be easily expandable to a large group,
- could be personalized or even tailored,
- would be user friendly by looking attractive and not be time consuming for participants.

Computer supported tools meet these requirements (Leeuw et al., 2003). Because we needed the response of the participants in an easy way, stand-alone software was not a viable option. Therefore, we chose the Internet (a website) that demonstrates some unmistakable advantages:

- information can be personalized by a simple expert system,
- the results of the survey can be stored in a central place and thus be examined later,
- it can be adjusted more easily than stand-alone software,
- because a website is a bi-directional medium, feedback based on the answers in the questionnaire can be directly given to the participants.

Of Dutch households, 68% already have an Internet connection (in 2003), and this group is still growing, and 75% people have access to the Internet so it represents good opportunities for expansion (Department EA, 2004).

3. The tool

Based on the reasons given above, it was decided to use the Internet to communicate with the participants. A World Wide Web-based tool, interactive and scalable, was developed. The tool consists of three parts: a questionnaire measuring the energy requirement at the start of the experiment, information provision on how to reduce energy options, and a feedback section showing the effect of the changed behavior. The tool was aimed at reducing direct and indirect energy requirements in participating households. The design features (see Section 2.3) for this web tool were:

1. it must be personalized,
2. it must be user friendly by looking attractive and having a moderate fill-in time,
3. it must be expandable to fit a large group.

Re 1. A simple expert system was built to make the questionnaire more personalized. To question relevant behavioral aspects and to offer relevant (personalized) reduction options, we had to know which appliances were present in each household and how they were used.

First, participants were asked to indicate whether or not they possess each of the listed 32 appliances. This information was used to personalize the information on behavioral questions and reduction options. For instance, a household that does not own a cloth dryer did not get any questions on related behaviors and was also not informed about reduction options clothes dryer.

Re 2. A user-friendly website is important for two reasons. First, it will reduce dropout among participants. Second, the number of problems that will arise should be limited in order to be manageable. To cope with problems that could arise when working with the tool, a helpdesk, which could be contacted by phone and by mail, was installed. The tool was thoroughly tested, quantitatively as well as qualitatively, and online help was available. The number of questions was limited because of time constraints, it was decided that it must be possible for the questionnaire to be filled in within 45 min.

To keep the feedback understandable, it was decided to show the energy reduction as a percentage of the total energy requirements.

Re 3. During the experiment user input, generation of the energy reduction options, and feedback all worked automatically.

In this experiment, the direct as well as indirect energy requirements were subject to reduction. To determine the indoor direct energy requirements, the natural gas and electricity requirements on the last annual bill was requested and corrected for the outdoor temperature for that year, in case it had been much colder or warmer than the average year. The indirect energy requirement was more difficult to determine. Because of time constraints due to questionnaire fill-in time, not all energy related behavior could be addressed in the experiment. We defined six criteria for energy related behavior that should be addressed in the experiment:

- options for change must be present, realistic, and feasible,
- it must contribute substantially to the energy requirements of households (about 0.3% of the direct or indirect energy requirements, respectively),
- alternatives should be present,
- it must be an object for change during the experiment,
- questions must be phrased in a simple and unambiguous way,
- only options with regards to behavior (also shopping behavior) are offered.

For this reason, e.g., clothing was left out because there are no real alternatives, furniture was left out because it is not subject to change during the experiment; the option of eating more seasonal vegetables was left out because the question about how often people eat seasonal vegetables needed too much explanation in order to clarify what seasonal vegetables are and in which season certain vegetables grow. The indirect energy requirements for which questions are present is called the compliant part. To get a complete picture of households' total energy requirements, we also calculated the non-compliant part; energy related behaviors that were excluded by the six criteria resulted in no questions in the questionnaire. The energy calculations for the non-compliant part were based on previous research (Moll et al., 2005; Biesiot and Moll, 1995; Vringer and Blok, 1995) in which it was concluded that the main characteristics which determine the indirect energy requirement are income and household size. To determine the non-compliant indirect energy requirement for each household, the average indirect energy requirement per income group (4) and per number of household members (1, 2, 3, 4, and more) was calculated so that all participants were divided among this 4×4 matrix. The compliant part covers about 53% of the total indirect energy requirement. The sum of the compliant and the non-compliant part is the total indirect energy requirement. In this way, a personal energy requirement was calculated for each household. In total about 77% $(1.0 \times 50\% + 0.53 \times 50\%)$ of the energy requirements, direct and indirect were inquired. All changes during the research period were related to this personal energy requirement at starting point.

4. The experiment

Participants were selected on a voluntary basis through an advertisement in a local newspaper and through direct mailing. The participants were asked to test a website about energy reduction. Five thousand letters were sent out to a random sample of households in the city of Groningen obtained via the customer's file of the energy company. Limiting factors for participation were: a personal energy bill (which excluded a large part of the student population of about 25% of the total city population) and an Internet account. Furthermore, participants who had taken part in a recently concluded experiment initiated by the city of Groningen on energy saving in households were also excluded. In total, 443 households responded positively to the mailing, but only 347 started the experiment.

The participants were divided randomly into two groups:

- an experimental group that received information about the (personal) energy-saving objective, personalized reduction options, and personalized feedback,
- a control group which received no energy-saving objective, no personalized reduction options during the experiment, and no feedback. This group received

Table 1
Intervention time scheme and parts present in the intervention for both experimental and control group

	Experimental group	Control group
First intervention October 2002	Questionnaire to determine energy requirements at the start of the experiment. Information about options for energy reduction.	Questionnaire to determine energy requirements at the start of the experiment.
Second intervention December 2002	Questionnaire to determine change in appliance ownership and behavior. Feedback on the adjusted behavior. Information about options for energy reduction.	
Last intervention February 2003	Questionnaire to determine change in appliance ownership and behavior. Feedback on the adjusted behavior.	Questionnaire to determine change in appliance ownership and behavior. Information about options for energy reduction.

the personalized reduction options after the experiment had finished.

Both groups got the same instruction to test the website. Of the 347 households which started the experiment in the first place, 190 (experimental group 137, control group 53) completed the experiment. Those who did not finish the experiment had various reasons for not doing so (see Section 5.1).

For the participants, the project started in October 2002 and ended in February 2003. During this period there were three surveys. The control group only received the first and the last intervention and no reduction options and/or feedback were offered. The three interventions had three goals: to determine the energy requirements, to give reduction options, and to provide feedback on changed behavior. Table 1 shows the time scheme which parts of the interventions were present for both groups.

In the first intervention, participants had to fill in a list with questions about their natural gas and electricity requirements, their ownership of energy-consuming appliances, and about their behavior. This in-take questionnaire was used to determine the total energy requirement of a household.

The goal of the questionnaire was to provide an energy reduction option list generated automatically by the website. This option list contained personalized energy reduction options.

In the second questionnaire, participants were asked to enter relevant changes in household composition, possessions (appliances, car, etc.), and behavior. After filling in this second questionnaire, the participants received feedback on how their energy requirements had changed.

The third questionnaire was less similar to the second one but had some extra questions about holiday plans. Participants obtained feedback on how their energy requirements had changed compared to those at starting point. An example of the feedback given to the participants is presented in Fig. 2. The percentages are the savings (pos. or neg.) related to the household energy requirements at the start of the experiment.

5. Results and discussion

5.1. Results

Of the 347 households that actually started the experiment, 190 completed it. This means that 157 households were excluded during the experiment for several reasons:

- Many participants quit prematurely for several reasons, including ‘no time’, ‘computer broken’, ‘no Internet connection’ (103).
- In several cases during the experiment, after a thorough test procedure, we found some errors in the calculations of the feedback. In cases where the participant received the wrong feedback due to these miscalculations, the participant was excluded (44).
- There were changes in the number of household members between the start and end of the experiment (5). Such changes have such impact on energy requirements that no conclusions can be drawn on the behavioral change of the households.
- Essential parts of the answers were missing; e.g., households entered a zero for their natural gas and/or electricity requirements (5).

One hundred and thirty-seven were left in the experimental group and 53 in the control group. Of the 5000 randomly selected potential participants, 347 started the experiment. The small response and the large group of persons who dropped out necessitate

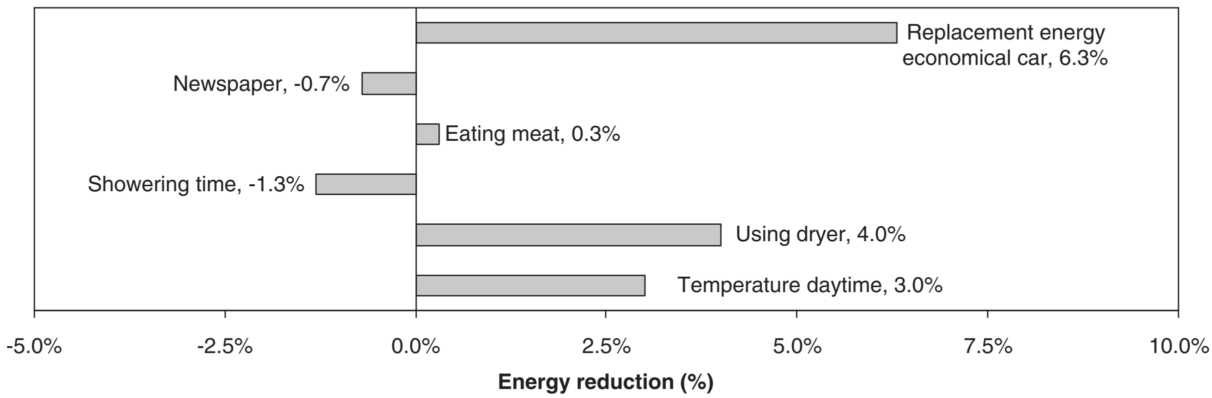

Fig. 2. Example of feedback on the savings (pos. = energy reduction or neg. = energy increase) given to the participants. The values are percentages compared to the total energy requirements. In this example, the replacement of the old car by a new more energy-efficient car has the highest energy reduction. The extension of the showering time compared to the time at the start of the experiment has the highest energy increase.

Table 2
Characteristics of the participating households

Average requirements of	Experimental group (137)	Control group (53)	The Netherlands
Natural gas (m^3)	1660	1865	1965
Electricity (kWh)	3160	3450	3230
Motor fuel (GJ)	32	33	25
Indirect (GJ)	113	116	121
Total (GJ)	233	248	243
Household size	2.3	2.4	2.3
Income	>1845[a]	>1905[a]	1930

Sources: EnergieNed (2001), EnergieNed (2002), CBS (2004), and Kok et al. (in press).
[a]Because income categories were asked, this figure is only an approximation.

reservations as to whether the results can be generalized. The 347 households who actually started were, as far as could be examined, a representative group (see Table 2). The withdrawn participants did not differ from those who finalized the project as far as their energy requirements and general characteristics are concerned.

To get an indication of whether the participating households are more or less representative of an average group of Dutch households, the experimental and control groups were compared on certain indicators with an average Dutch household (see Table 2).

Because of the large spread in natural gas, electricity, motor fuel, and indirect energy requirements, these data are not statistical significant. The differences between the experimental group, the control group, and the average Dutch household fit within the statistical spread. The higher consumption of motor fuel by the experimental group and the control group can partly be explained by higher car ownership (83% versus 77%) and a higher average travel distance in the participating households as compared to the Dutch average (CBS, 2004).

The results of the experiment are presented in Table 3. The total average energy reduction of the experimental group compared to the control group is almost 6%. Although this is a substantial amount, the difference is not statistically significant. The percentages in Table 3 are the energy reductions compared to the total energy requirements.

When the total reductions are split up into indirect and direct reductions, it becomes clear that a large part of the energy reduction can be ascribed to savings in direct energy. The reduction for the direct part is very significant ($F = 18.1$; df = 1, 188; $p < 0.001$). Although there is difference between experimental and control groups for indirect energy of 4%, it is not statistically significant. A possible explanation is the large variability in the energy reduction of holidays. All energy requirements for holidays were defined as indirect energy. There are households that went on several trips abroad last year but had no plans for the coming year (or the other way around). This can make a difference in absolute terms of more than 300 GJ, while the total energy requirement of an average Dutch household is about 240 GJ (see Table 2). When leaving out the options concerning holidays, the total energy reduction also became significant ($F = 4.45$; df = 1, 188; $p = 0.04$). Although the indirect energy reduction is not statistically significant it clearly points in the same direction as the direct energy reduction.

The obtained reductions, as presented in Table 3, are the result of savings within an extensive list of options. The length of the list offered to the participants depended on the personal circumstances. The most successful 15 options (out of 75) with the largest energy reductions realized are listed in Table 4.

An increase in the energy requirement occurred with some options, e.g., the purchase of a new dryer or different accommodation during holidays. In the top 15 (75 possible options were defined) of the most selected reduction options, five (out of 21 indirect energy

Table 3
Average savings at a household level

Reduction	Experimental group	Control group[a]	ANOVA p-value
Total energy (MJ)	11,951 (+5.1%)	−1730 (−0.7%)	0.15
Direct energy (MJ)	9143 (+8.3%)	−972 (−0.4%)	<0.001
Indirect energy (MJ)	2809 (+3.8%)	−757 (−0.3%)	0.69

[a]The negative values for energy reductions for the control group mean that the energy requirements increased during the experiment.

Table 4
Top 15 of the most successful savings options (out of 75)

Savings options[a]	Average saving (MJ) per household	Standard deviation
Total	11,950	
Other transport mode during holidays (D, I)[b]	1450	50,980
Less motor fuel due to car change or ownership (D)	1290	11,540
Shorter showering (D)	1250	4040
Room temperature lower during day hours (D)	1250	2570
Less eating of meat (I)	980	1650
Using energy extensive commuter traffic (D, I)[b,c]	780	6000
Room temperature lower during night hours (D)	720	2290
Less food thrown away (I)	620	680
Less frequent shower taking (D)	510	1180
Fewer rooms heated (D)	350	970
Appliances not on stand-by (D)	350	480
Closing inner doors (D)	350	850
Less dryer use (D)	310	1280
Using energy efficient light bulbs (D)	290	460
Sharing the newspaper (I)	253	2400

[a](D) and (I) behind an option indicate whether this option refers to Direct or Indirect energy reduction.
[b]Energy required for public transport, planes, and touring cars is defined as indirect energy.
[c]The indirect part in driving a car is the energy needed to build and maintain the infrastructure.

options) were at least partly indirect energy reduction options.

To get an idea how the participants judge the website, the website was evaluated by the participants after the experiment. In general, the participants were positive about the design, about how the website worked and about the information given to them (see Table 5).

From remarks participants were able to make, it became clear that it was sometimes difficult to estimate their own behavior (e.g., how long a shower takes). Not all options were judged as realistic, e.g., a participant mentioned "Not flying is not very realistic for holidays".

5.2. Discussion

Whether our findings may be generalized to the general (Dutch) population depends—among other things—on the representativeness of the study's sample. In view of the voluntary participation, the rather low response rate (5000 invitation letters resulted in only 346 participating households) and the high dropout percentage (45% of the 347 households did not finish the experiment), it is conceivable that the people with an above average interest in environmental and energy reduction issues are overrepresented in the sample. On the other hand, a comparison of the sample with the general population on several energy relevant characteristics (Table 2) revealed no major differences.

One of the research questions was is it possible to create a tool that is scalable? Such a tool should at least be labor extensive. In our experiment, the automatically generated reduction options and feedback all worked without problems. To be scalable, users should be able to find their way through the website without problems. A good indication of this is the frequency of contacts with the installed helpdesk (mail and telephone). This helpdesk was not contacted very often and most of the contact concerned complicated technical problems.

6. Recommendations and conclusions

6.1. Conclusions

The main question to be answered here is did the tool work? This question can be split up into four sub-questions. The answers to these four questions will be discussed below.

1. Was energy conservation realized?

As was concluded in Section 5, conservation in direct energy of 8.7% was realized as compared to the control group. The results for the total energy reduction were not significant. When looking at the indirect energy requirements, the conclusion is that the reduction is not significant, largely due to the wide spread in the energy requirements for holidays. When leaving out the options concerning holidays, the total energy reduction also became significant.

Table 5
Results of the evaluation of the website

Questions	Yes definitely + yes (%)	No not much + not at all (%)
Does the website give you more insight into your energy requirements?	73.1	26.9
Were the saving options given clear and understandable?	95.3	4.7
Did you receive sufficient options for reduction?	66.3	33.7
Was the information given in the feedback concerning the energy reduction clear and understandable?	96.3	3.7

2. Did the tool (experiment) reach the public?

As stated above, a large number of the participants who started the experiment quit or were excluded from the experiment for various reasons. So, of all the people who were invited to participate, less than 9% (experimental + control group) started the experiment and less than 4% finished it successfully.

From the evaluations it became clear that participants were very positive about the website. So from a quantitative perspective we did not reach a broad public, but from a qualitative perspective we reached out goals.

3. Was the tool successful in addressing the indirect energy issue?

Although it is a more difficult subject for inquiry, and although it is not certain that households will reduce their indirect energy requirements, it was demonstrated in the experiment that it is possible to successfully address indirect energy issues. In the top 15 of the most selected reduction options, four were indirect energy reduction options.

The questionability factor was limiting in some of the indirect energy items. Items that were interesting were left out because it was very difficult to pose questions about them in a simple and unambiguous way (e.g., the option of eating more seasonal vegetables was left out).

4. Is the tool suitable for up-scaling from an experiment to a mass media campaign?

In general, it can be said that the developed tool is suitable for scaling up to a mass media campaign level. During the experiment the user input, the generation of the savings options, and the feedback all worked automatically. Some of the elements in this experiment presented in the form of manual assistance (by mail and telephone) can be automated, e.g., by a list of frequently asked questions and through an automatic password recovery system.

The main conclusion is that personalized large-scale approaches are possible and at least for the direct energy part are also potentially successful. Although the reduction in indirect energy was not significant, we showed that it is possible to address indirect energy without compromising the scalability. Table 4 shows a wide variety in reductions, options chosen by households. This underlines the need for more personalized solutions, as was already found by Nonhebel and Moll (2001).

6.2. Recommendations

Not all the questions related to personalized large-scale energy reduction approaches could be answered by the experiment described here. More research is needed on certain points like the fall back behavior and the rebound effect, which are explained below.

6.2.1. Is it possible to reduce indirect energy requirements in households?

Although there is difference between experimental and control groups for indirect energy of 4%, the statistically insignificance of this reduction precludes an unambiguous answer. To answer this question with certainty, experiments with larger groups are needed.

6.2.2. What about the long-term use and behavioral effects?

From the literature it can be concluded that at least part of the energy-reducing behavior will not last because people will fall back into their old habits (Wilhite and Ling, 1995). Our experiment lasted only 5 months that is not long enough to study this effect. Another long-term effect is the rebound effect. This effect is the mechanism by which energy reduction due to energy efficiency improvements is compensated for by energy increase due to behavioral changes (Berkhout et al., 2000; Schipper and Grubb, 2000). This effect in relation to this experiment also needs further study.

6.2.3. Recommendations for the website

Although the website worked properly in this experimental setting, some things should be adjusted and others can be omitted when this kind of tool is made available for a very large number of households. For example, the site as it was used in the experiment was not suitable for continuous use, since participants had to log in and answer the questionnaire over a period of a few weeks. After these weeks feedback was generated and put on the website. This should be made continuous with direct feedback. To make it worth more than a one-time visit, the content of the website should be renewed frequently. This has three advantages: it is kept interesting for the users, not all information has to be given at once with the risk that it become overwhelming, and the website can be kept up to date with new insights entered on the website. Although personalization of the information given to participants, as was done in the experiment described here, is a big step in the right direction, it is not the final step. Personal information can be made more personal by taking a step toward tailoring: focusing on those subjects the participant indicates as being important, as has been done in the health care sector.

Acknowledgments

The authors want to thank Laurie Hendrickx for his help with the statistical analyses and comments on the draft version of this article. We thank our co-workers on the project: Wokje Abrahamse and Linda Steg of the faculty of the psychology department of our university for their advice and insights. We also would like to thank the anonymous referee for the suggestions and comments.

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