Influencing electricity consumption via consumer feedback: a review of experience

Dr. Corinna Fischer
Forschungsstelle für Umweltpolitik
Freie Universität Berlin
Germany
cofiffu@zedat.fu-berlin.de

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Abstract
Improved feedback on electricity consumption may provide a tool for customers to better control their consumption and ultimately save energy. This paper asks which kind of feedback is most successful. For this purpose, a psychological model is presented that illustrates how and why feedback works. Relevant features of feedback are identified that may determine its effectiveness: frequency, duration, content, breakdown, medium and way of presentation, comparisons, and combination with other instruments. The paper continues with an analysis international experience in order to find empirical evidence for which kinds of feedback work best. In spite of considerable data restraints and research gaps, there is some indication that the most successful feedback combines the following features: it is given frequently and over a long time, provides an appliance-specific breakdown, is presented in a clear and appealing way, uses computerized and interactive tools, and may involve historic or normative comparisons.

Sustainable Electricity Consumption: A Herculean Task?

Electricity seems a particularly difficult area within which to promote sustainable consumption. And households seem a particularly difficult target group. In Germany, for example, the household sector is the one with the fastest growing end energy consumption. Electricity consumption, especially, is rising even faster than total end energy consumption.

Sustainable electricity consumption, in this context, comprises different things. First, it may mean choosing electricity from renewable or other less environmentally detrimental sources (which will not be addressed in this article). Secondly, it means a conscious choice of appliances and of their duration and modes of use with the ultimate goal of curbing overall consumption[1] - in short, electricity conservation. Stimulating electricity conservation is a difficult task, because electricity differs in significant ways from other consumer goods. It is abstract, invisible and untouchable. It is not consumed directly but indirectly via various energy services. Electricity consumption is therefore not perceived as a coherent field of action. Rather, it involves activities as diverse as listening to music, cooking meals, working with the computer, or making a phone call. Moreover, electricity conservation is not limited to the act of using electricity but starts with choosing and purchasing energy-using appliances like a TV set, washing machine, computer equipment or electric heater. In each of these activities, conservation means a different set of behavioural modifications. It is difficult for the consumer to link all these various activities and develop a coherent, comprehensible and concise cognitive frame of what "electricity conservation" could mean in everyday life.

The invisibility of electricity also means that the consumer usually receives little feedback on her consumption – she does not experience the "diminishing stock" and does not find herself in control of her consumption. Also, electricity's qualities

1. All energy scenarios, e.g. for Germany, agree that a sustainable energy system is impossible without significant cuts in overall consumption (Enquete-Kommission 2002, DLR et al. 2004, DIW et al. 2005).

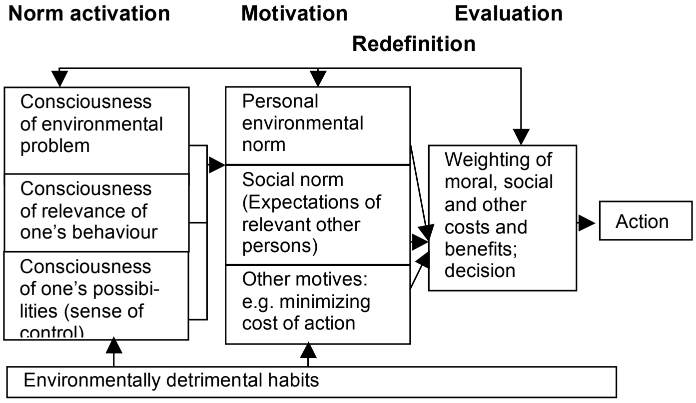

Figure 1: Heuristic model of environmentally relevant behaviour. Source: Matthies, 2005 (Own translation)

– including its ecological features – cannot be directly perceived, making it hard for the consumer to develop an emotional involvement. It is hardly a product to be proud of, to show around, or to worry about. Consumers regard electricity as a necessary, but unspectacular everyday product of which security of supply is important, but specific features do not matter much. In contrast to products like organic food or sustainable housing, sustainable electricity consumption can therefore not easily become an element of lifestyle (Birzle-Harder and Götz, 2001). And neither do its costs usually make up for an important share of a household's budget. Thus, all in all, electricity turns out to be a "low interest" product.

Consumer Feedback as a Road to Sustainable Consumption?

One idea for supporting sustainable electricity consumption is to improve feedback on consumption, on its cost, and its environmental impacts. Today, such feedback is far from what it could be. Kempton and Layne (1994) equate consuming electricity to shopping in a grocery store in which no individual item has a price marking, and the consumer receives a monthly (or, in many countries, even annual) bill on an aggregate price for "food consumption". She has no idea how, when, or by which appliances electric current was used. Nor is she informed whether her consumption is relatively high or low (which could stimulate a search for reasons), or whether it has increased or decreased (and thus, whether her actions had any effect).

Feedback may be improved in various ways. Possibilities include increasing the frequency of feedback, providing a time-, room- or application-specific breakdown, improving the visual design, or adding further information, for example time series, comparisons with an average, or information about environmental impact.

As shown by a number of international model projects and scientific studies, such improved feedback can help to repair the problems associated with electricity conservation. In an excellent review of experience, Darby (2006) has found that improved feedback may reduce consumption by up to 20 %. Recently, EU policy has been taking on such encouraging experience: EU Directive 2006/32/EC on energy end-use efficiency and energy services, dating from April 2006, calls for informative billing and other types of feedback, "where appropriate" (see the conclusions).

The present article builds on existing review work on feedback (Darby 2001, Roberts and Baker 2003, Abrahamse et al. 2005, IEA 2005). It re-analyses relevant projects and studies reviewed by these articles as well as some additional literature not yet covered. Its aim is threefold. First, it wants to contribute to a more theoretically guided understanding of why and how feedback works. For this purpose, a psychological model of environmentally relevant behaviour is presented and tentatively linked to the topic of feedback. Secondly, the article would like to shed some light on the question why results of individual studies on feedback differ so much and what it is that causes feedback to succeed (or fail). To achieve that, relevant dimensions are identified that differ between the various studies. The differences relate to the context of the respective project, but more importantly, to design features of the feedback itself. Linking these features to the psychological model, some hypotheses are derived on how feedback needs to be designed in order to achieve optimum results. Empirical evidence is sought from the studies, and research gaps are identified. In doing so, the paper pursues its third, methodological, objective: to comment more critically and in more detail on the available database than existing articles do, allowing the reader to judge results more carefully.

Some Theory

Environmental psychology has developed various models to explain environmentally relevant behaviour and provide a basis for successful behavioural change. Matthies (2005) has reviewed theory and findings from all over the discipline and integrated them into a heuristic model of environmentally relevant behaviour (see fig. 1). This model can be helpful for explaining why and how feedback on electricity consumption can reduce consumption.

First, the model highlights *habits* that might be environmentally detrimental and need to be broken up in order to stimulate more sustainable behaviour. Secondly, it points to several aspects of *consciousness*: One needs to be conscious about environmental problems, about the relevance of one's own behaviours and about one's possibilities for changing behaviour (the latter often being labelled as a "sense of control"). Furthermore, *norms* are relevant as well as *other, sometimes conflicting motives* (like convenience, or monetary savings). In an evaluation phase, people evaluate various (moral, environmental, personal…) costs and benefits in order to come to a decision on how to act.

Thinking in these categories enables us to detect in which ways feedback can operate. First, it can direct attention towards electricity consumption, demonstrating to the consumer how much electricity everyday activities consume. This way, *habits* are broken up and a door is opened for reflecting one's behaviour and taking conscious decisions. Secondly, it can raise *consciousness* in various ways. It can highlight environmental impact and one's own contribution to it. It can also give the consumer a sense of control of her behaviour: With the help of feedback, she can detect how a certain appliance or a certain way of using it affect the amount of electricity consumed and the money spent, and she can determine how changes in behaviour or appliance stock affect the outcome. Finally, improved feedback can activate *other motives* conducive to electricity conservation: it can, for example, point to cost savings achievable by electricity conservation, or stimulate a sense of competition. To improve the incentive character even more, feedback could be combined with other instruments, like price incentives, goal setting or a contest.

A Review of International Experience

DATABASE

The review presented here covers five review studies (Darby 2001, Roberts and Baker 2003, Abrahamse et al. 2005, IEA 2005, Darby 2006) and 19 original papers on the effects of feedback on electricity consumption and on consumers' reactions, attitudes and wishes concerning such feedback. The criteria for the choice of papers were as follows: In order to retain some topicality, I restricted myself to papers dating from the last 20 years, that is, from 1987 onward. I also confined the analysis to projects that were explicitly designed for giving feedback (e.g. via the meter, displays, or the bill) and excluded broader approaches where feedback may come indirectly as a by-product (e.g. energy advice or community learning). Finally, feedback solely designed for the purpose of load-shifting (usually as a complement to time-of-use pricing), was also excluded, focusing instead on feedback designed to have (also) an effect on overall consumption. Insofar as they fulfil these criteria and were available (which was a problem sometimes), the papers discussed in the five reviews were included[2]. They have been complemented by some additional papers not yet covered by those reviews, mainly from German-speaking or Nordic countries. A list of the papers analysed is included in the references list.

All in all, the original papers cover 26 projects from 11 countries: the USA (2x), Japan (2x), Hungary (1x), and many Northern and Western European countries (Denmark (5x), Finland (2x), Germany (1x), the Netherlands (1x), Norway (3x), Sweden (5x), Switzerland (1x), UK (3x)). Thus, there is a remarkable lack of knowledge from Southern European and Accession countries. Many of the papers are reports about model projects or field experiments. Very few comment on real-life experience, and some report on surveys or interviews about consumers' attitudes towards feedback.

PROJECT DESIGN FEATURES

Project results depend on a number of design features, including a project's context, location, size, goals, and the different features of the feedback itself, such as frequency, content, breakdown, presentation, inclusion of comparisons, and combination with additional information and other instruments. In the following sections, I will systematize the projects according to these design features, and give a preliminary evaluation of their results, together with an appraisal of the interrelationship between results and design features. While the systematization builds on the original literature reviewed, the discussion of results also includes the results of existing review articles.

Overall Project Design

Context. Thirteen of the reviewed projects are research projects, trying to test the implication of a theory / theories or to fill knowledge gaps left open by earlier research. Four of them explore consumer preferences towards feedback: two in the form of a survey (Henryson et al. 2000, Sernhed et al. 2003), one in the form of focus group discussions (Soós and Ürge-Vorsatz 2003), and one (Egan 1999) combines interviews, a survey and the evaluation of a real-life project. The others try to explore the effects of feedback. One takes the form of a laboratory experiment (McCalley and Midden 2002), the others are field tests employing a design with a control group and one or more experimental groups that are exposed to one or more types of feedback. They therefore allow for comparisons between different treatments, at least *within* a study.

Eleven are model projects, meaning that a specific type of feedback is tested "in the field", usually in order to find out about its specific merits and its possibility for broader application.

- Only two evaluations of "real life" projects are included, one in Denmark (Karbo and Larsen 2005), and one in Norway (Wilhite and Ling 1995, Wilhite et al.1999).[3]
- This means that many project designs will not necessarily be fit for application in the real world, for example regarding cost efficiency or technical requirements. The lack of reported real-life projects indicates potentially severe problems with putting existing knowledge about feedback into practice. Potential reasons and remedies will be discussed in the conclusions.

Goals. With providing feedback on electricity consumption, one may pursue different goals. Motivating and enabling households to lower overall consumption is the most prominent one, but feedback is also given with other goals. This must be kept in mind when evaluating results, as different methods of feedback may have different success with respect to the various goals.

Of the 26 projects reviewed, 23 explicitly state goals. The main reasons for giving feedback were:

- to enable and motivate households to conserve energy, or to "stimulate ecological behaviour" (18 projects)
- to increase customer satisfaction or service (5 projects, three of which in combination with energy conservation)
- to achieve load shifting or peak shaving (two projects, both in combination with energy conservation)
- to raise consumers' "consciousness" (one project)
- to explore consumer preferences, trying to detect what kind of feedback households would like to have on their electricity bills (three projects)

2. Due to language constraints, only English and German papers could be considered. As the paper by Darby (2006) became available only recently, some of the references cited there could not be considered. I am planning a fuller coverage of material for the final paper.

3. The latter emerged from a research and pilot phase into the everyday billing practice of a Norwegian electric utility and has later even become the basis for binding legislation: As of July 1997, a new regulation required all Norwegian utilities to provide billing based on actual use, at least each quarter, and a bar-chart showing a 12 month historic self-comparison. (I thank, my panel leader, Ms. Anita Eide, for the information on the legislation).

- or, less specifically, to test any "effects" of improved feedback (two projects).

Size and Location. Knowing the projects' size and location is important to assess the degree to which the results can be generalized. Especially, the location points to potential cultural, social or political differences to be taken into account. For example, there are indications that feedback works very differently in different social milieus (Nielsen 1993).

The sample of projects covers quite a range of different household types in terms of household size, features of the building, appliance stock, ownership, income and social status. In a number of projects, this mixing is deliberately done in order to achieve a representative sample. This broad array allows some assessment of the generalizability of results. On the other hand, with regard to project size, the situation is not as good. Many model projects and field experiments include no more than 10-44 households. This leads to sub-groups being very small (around 10 households) and raises questions about the significance of results. Three studies (Haakana et al. 1997, Brandon and Lewis 1999, McCalley and Midden 2002) include around 100-120 participants, but by splitting them into several subgroups, again arrive at rather small subgroups. Seven big field experiments with over 1000 participants are not reported in great detail (Henryson et al. 2000). This leaves us with only five well-documented projects with big samples for analysis: two field experiments (Sexton et al. 1987, Nielsen 1993), and three implementation studies (Egan 1999, Wilhite et al.1999, Karbo and Larsen 2003).

Types of Feedback

The feedback described in the papers differs in various aspects which, according to the psychological model, are probably relevant for its success.

Frequency and duration. From the model it would follow that feedback is the more effective, the more directly after an action it is given because the direct link with the action would increase consciousness about the action's consequences. Furthermore, persistent effects would be more likely if feedback is given over a longer time, because new habits can form during that time. In the reviewed projects, the frequency of feedback ranges from continuous to bimonthly with ten projects giving feedback more often than monthly, four projects giving it monthly and seven projects giving it less often (it is not reported for all projects). With respect to duration, there is a very clear-cut division: Six projects last less than three months (usually 4-6 weeks)[4] and thirteen (including all of the billing projects) last at least nine months (up to one or several years).

Content. Feedback may be given on electricity consumption alone (e.g. kWh), on cost, or on environmental impacts of consumption. The model would suggest that these different contents activate different motives, personal and social norms. It remains an open question which motives and norms would be strongest in which target groups. In the projects reviewed, all three kinds of information are used, though the emphasis is on consumption and cost. Eighteen projects fed back consumption and cost, three consumption only (McCalley and Midden 2002, Mack and Hallmann 2004, Mosler and Gutscher 2004). Only two projects (Jensen 2003, Brandon and Lewis 1999 in one experimental condition) test the effects of environmental information, one (Soós and Ürge-Vorsatz 2003) discusses the desirability of such information in focus groups.

Breakdown. Feedback may become more informative if a breakdown, e.g. for specific rooms, appliances or times of the day is provided. This is almost the only way of establishing consciousness of the relevance of *individual* actions (as required by the model). However, only five of the reviewed projects provide some sort of breakdown while two restrict themselves to a single appliance type anyway (cooking appliances in Mansouri and Newborough 1999, Wood and Newborough 2003, and washing machines in McCalley and Midden 2002). Sexton et al. (1987) provide a breakdown for all big appliances. Wilhite et al. (1999) test a breakdown for typical uses (lighting, heating…), based on interview data. Karbo and Larsen (2005) use a daily load curve, based on measured data, and an appliance-specific breakdown, based on interview data, both upon request. And Ueno et al. (2005 and 2006) provide appliance- and time-specific breakdowns (daily and 10-daily load curve) upon request, based on real consumption data.

Medium and mode of presentation. Our model does not directly alert us to the relevance of the medium and way of presentation. However, it has long been clear from communication sciences and learning theory that the way information is presented is crucial for its adoption (Roberts and Baker 2003). Two basic media may be used: electronic media and written material. Electronic media is used in eight studies, taking different forms. One relatively unique approach is to install an electronic display directly at an appliance, which can provide information about the consumption of this particular appliance (Mansouri and Newborough 1999, McCalley and Midden 2002, Wood and Newborough 2003). Also, an electronic, maybe interactive, meter may show the total consumption of a household, provide additional information such as time-specific breakdown or cost (Sexton et al. 1987, Jensen 2003). Another approach is to use computer and internet as interactive tools. A computer program is supplied with data that may stem from user input (e.g. on household size, appliance stock) and / or from metering of actual consumption data, and can provide the user upon request with a broad range of information, e.g. load curves, appliance-specific breakdown, comparisons, or energy-saving tips (Brandon and Lewis 1999, Karbo and Larsen 2005, Ueno et al. 2005 and 2006). Advantages of electronic feedback are its flexibility (being able to react to users' demands, and showing different kinds of information upon request), and its ability to quickly process and present actual consumption data. Interactive tools may also stimulate users' curiosity and experimenting. On the other hand, electronic feedback may be difficult to access for users not used to electronic media, and interactive tools require more user involvement.

Written material may come on its own in the form of direct mailings, brochures, etc. This is done in four projects (Haakana et al. 1997, Brandon and Lewis 1999, Jensen 2003, Mack and Hallmann 2004). Another possibility, used by nine projects, is to use the electricity bill as a carrier of feedback information. This approach seems promising because it can be expected that

4. The projects by Ueno et al. (2005, 2006) actually lasted longer, but have been evaluated only at one early point of time, namely after they had been running for four weeks (or six weeks, respectively).

the bill is read more carefully and raises more interest than additional material. Such efforts are described in Wilhite and Ling (1995), Wilhite et al. (1999), Egan (1999), Henryson et al. (2000).

Equally important is the way of presentation. Much depends on the comprehensibility and appeal of text or graphics. The projects apply numerous variants of presentation, the most common being text, load curves, bar charts or pie charts (for an application-specific breakdown or comparisons in time and with other households), and horizontal lines or bell curves (for comparison with other households). Here, the devil is very often in the details. Most projects do not seem to reflect these problems: the choice of a specific design is usually not discussed at all nor are reasons given for a specific choice. Only two projects test design variations systematically (Egan 1999, Wilhite et al. 1999).

Comparisons. Comparisons are said to stimulate energy conservation, first, by stimulating competition and ambition (motivational aspect), and secondly, by making transparent if consumption (e.g. in a certain period or of a certain household) is "out of the norm", activating the search for reasons and redress (consciousness and problem awareness aspect). There are two basic types: Historic comparison relates actual to prior consumption (often, temperature-corrected, with the same period in the previous year). Almost all reviewed studies present, or deal with, historic comparison (with the exception of Soós and Ürge-Vorsatz 2003).[5] Normative comparison compares consumption to that of other households (e.g. with a national or regional average, households in the neighbourhood, or households that are in some way similar, e.g. in size, type of house, application stock). Ten studies also take up this option.

Additional information and other instruments. Feedback is very often combined with other instruments which makes a lot of sense from a theoretical point of view. Information on consumption will not work without a motivation to conserve, which may be provided by other instruments like financial incentives (Sexton et al. 1987, Nielsen 1993), goal setting (McCalley and Midden 2002, Mosler and Gutscher 2004) or personal commitment (Mack and Hallmann 2004, Ueno et al. 2005 and 2006.) On the other hand, feedback will not work if households have no idea on what they can do about their consumption. This problem may be remedied by additional information on how to save energy, ideally closely connected to the appliance or situation on which feedback is given. Most projects use or explore such additional information (with the exception of Egan 1999, Jensen 2003, Sernhed et al. 2003, and two studies reported in Henryson et al. 2000).

RESULTS

Does feedback work?

One result, at least, seems clear: Feedback stimulates energy (and specifically, electricity) savings. Not all studies discuss actual savings, some concentrate on customer preferences or on satisfaction with feedback schemes. But those who do generally find savings ranging from 1.1 % to over 20 %, depending on the treatment. Usual savings are between 5 and 12 %.[6]

However, in a few instances, no savings were found. To look carefully at these examples teaches us something about the preconditions for feedback to work. In the study of Sexton et al. (1987), the main purpose was load shifting. Feedback accompanied the test of a tariff structure where peak and off-peak tariffs differed considerably (between 3:1 and 9:1). Feedback informed consumers about their current use and projected cost per hour, and a light signal alerted them to the switch between peak and off-peak hours. Apparently, the feedback showed to customers that electricity was unexpectedly cheap in off-peak hours, and stimulated heavy load shifting activities. Thus, the savings that occurred in peak periods were cancelled out by increased off-peak consumption.

Nielsen (1993) found that almost no savings occurred in a working class area with small flats, low income and low consumption. Other studies also show that households with a previously low consumption do not feel encouraged to conserve if they receive feedback – they might even increase their consumption (Bittle et al. 1979-1980, Brandon and Lewis 1999). On the one hand, there might just be no saving potential. On the other, the findings point to a relevant precondition for feedback to work: There must be an – implicit or explicit – motivation. Without a motivation to conserve, information about how well you perform in this discipline is useless. It may even be counterproductive, for example, when comparative or historical feedback shows that your consumption is relatively low (or has been dropping), signalling that there is space for improvement on comfort.

Which types of feedback work best?

However, we do not only want to know whether feedback is effective in general, but how it must be designed to work best. Answering this question is much more difficult. Studies can only be compared with the greatest care. First, results are not always reported quantitatively or in sufficient detail to make a comparison. Secondly, studies use very diverse reporting schemes. They vary in baseline, in time and duration of measurement, and in the unit for which savings are reported. Table 1 summarizes those studies that report savings, giving an overview of the reporting schemes used. Schemes that allow at least a rough comparison are grouped next to each other.

To arrive at some conclusions, I first checked "best cases". As such, I defined projects and experimental conditions seeming to provide highest savings within their group of at least roughly comparable studies. These were: Ueno et al. (2005), Haakana et al. (1997), McCalley and Midden (2002).[7] Where there was no comparable study, I identified as "best cases" the experimental conditions providing highest savings *within* their study. These were: Group 2 (feedback only) in Mansouri and Newborough (1999) / Wood and Newborough (2003), and group 6 (computerized feedback) in Brandon and Lewis (1999). I

5. For five of the seven studies reported in Henryson (2000) historical feedback is not reported, but because those are generally under-reported, this does not necessarily mean it was not present.

6. Information on statistical significance of the findings is often lacking, but the sheer number of studies which report savings is a good indicator for the general effectiveness of feedback.

7. Mosler and Gutscher (2004), who found high savings in the posttreatment period (but not during the treatment), were excluded because the posttreatment period was in a warmer season and there was no weather correction

Table 1: Reporting schemes of reviewed literature

Source	No. of projects covered	What is reported?	Unit for which savings are reported	Baseline	Measurement period and time(s)	Results
Wilhite et al. 1999	1	Customer satisfac-tion, attitudes, understanding of bill, activity: lowering room temperature	No. of persons who lowered room temperature	One survey before treatment	One survey after treatment	Rising customer satisfaction and understanding of bill. Historical comparison leads to an 6-8 % rise in the number of people who lowered room temperature. High Interest in normative feedback, it is seen as motivating for conservation. High interest in appliance-specific breakdown.
Mansouri 1999, Wood and Newbo-rough 2003	1	Electricity consumption, satisfaction	No. of households that saved more than a certain amount (total and within experimental groups)	Baseline interval: average of 56-89 days immediately before treatment (temperature corrected)	Average of treatment period (56-84 days)	Households appreciated feedback. Fourteen of 31 households saved more than 10 %, six of those saved more than 20 %. Group 1 "Information only": Three of twelve saved > 10 % Group 2 "Feedback only": Seven of ten saved >10 % Group 3 "Information and feedback": Four of ten saved >10 %.
Jensen 2003	1	Electricity consumption	Reduction in selected cases (=blocks of flats); number of cases that follow the tendency	Baseline interval: yearly average before begin of treatment	Yearly average during the first year of treatment	Best case: 22 % reduction, two others in that size, five others (of nine toatal) follow the tendency
Brandon and Lewis 1999	1	Electricity consumption	No. of households in each experimental group who increased vs. decreased consumption. Each group's average change.	Baseline interval: yearly average before begin of treatment	Average of 8 monthly readings during treatment and one final reading after treatment	Only in experimental group 6 (computerized feedback) there was a significant effect: 12 participants decreased consumption (by 31 % on average), only 3 participants increased it (by 4 % on average). In the other groups, about half of the participants increased and half decreased.
Mack and Hallmann 2004	1	Electricity consumption Conservation activities	Average reduction of participants (and control group) Average number of conservation activities in participating households.	Baseline interval: average of 6 measurements during 3 months before treatment (temperature corrected) Control group	4 weekly measurements during intervention, 30 measurements over 10 months after treatment, divided in 5 intervals with 6 measurements each	Reduction during treatment period as compared to baseline period: 15 %, temperature corrected: 2.9 %. Reduction during five posttreatment intervals (altogether 10 months): between 1.5 and 3.6 %. No reduction in control group. In average 4.8 conservation activities during treatment, 4.4 after treatment.
Ueno 2005	1	End energy, gas and electricity con-sumption, conser-vation activities	Average reduction of participants (and control group). Percentage of participants that took conservation activities.	Baseline interval: average of 28 weekdays before begin of treatment Control group	Average of 28 weekdays before begin of treatment	End energy consumption reduced by 12 %, electricity consumption by 17.8 % (control group 4.7.) Sixty per cent of households reduce standby consumption and 70 % electrical heating.
Ueno 2006	1	Electricity consumption	Average reduction of participants. Percentage that took conservation activities.	Baseline interval: average of fourty weekdays before begin of treatment	Average of fourty weekdays after begin of treatment	Electricity consumption reduced by 9 % (appliances with feedback 12 %, appliances without feedback 5 %). Various activities are reported.

Haakana et al. 1997	1	Electricity consumption, conservation activities, satisfaction	Average and median reduction in each experimental group. Percentage of households that took certain activities. Percentage who are satisfied	Baseline interval: 3 months before beginning of feed-back (temperature corrected). Control group	Monthly averages during the 17 month feedback period	Average reduction in first half of feedback period: "feedback plus video information" group: 21 % , "feedback plus written information" group: 19 %, "feedback only" group: 17 %, control group: 14 %. Second half (also compared to baseline): 7 %, 5 %, 5 %, 1 %, respectively. Eighty-one to eighty-four per cent in exp. groups and 77 % in control group took conservation activities. Ninety-eight per cent were satisfied with the feedback, 83 % desire normative comparisons.
Mosler and Gutscher 2004	1	Electricity consumption	Average reduction in each experimental group	Baseline interval: 4 weeks before intervention Control group	1 (or 4?) measurements during each phase: 4-week baseline, 4-week treatment and 4-week posttreatment	Treatment period: Group 1 ("information, feedback and commitment"), group 2 (" information and feedback") and group 3 ("information only") reduced by 10.2 – 10.9 % each. Group 4 ("information and commitment") reduced by 1.1 %. Control group reduced by 4.8 %. Posttreatment period: Group 1: 18.1 %; group 2: 21.7 %, group 3: 21.9 %, group 4: 13.3 %, control group:7.5 %.
Nielsen 1993	1	Electricity consumption	Average consumption in each experimental group during each treatment year and total average	Baseline interval: 1 year before treatment	Monthly during the three treatment years	Reductions in Jütland and Kokkedal (middle class, detached houses): Group 1 ("information, feedback, energy audit, financing audit, increased tariffs"): 8-10 % savings Group 2 ("information, feedback, financing audit, increased tariffs): 7-9 % savings Group 3: ("information, feedback, energy audit, financing audit"): 6-8 % savings Reductions in Odense (working class, flats): Group 1: -1-2 %, Group 2: 3-6 %, Group 3: 0-4 %
McCalley and Midden 2002	1	Electricity consump-tion per wash in a computerized mashine washing simulation	Average reduction over 20 washes in each experimental group	Baseline "interval": Average of 6 pre-treatment washes Control group	Twenty times (each wash)	Average reduction: Group "Feedback and self-chosen goal": 21.9 % Group "Feedback and assigned goal": 19.5 % Groups "Feedback only" and "control group": about 10 % each.
Sexton et al. 1987	1	Electricity consumption	Average consumption of participants (and control group)	Control group that received ToU pricing but no feedback	Monthly averages during the 10 months feedback period	During nine of the ten months, HH with feedback consumed more than HH without feedback. This was due to heavy load shifting: The rise took place in off-peak periods, while in peak periods, feedback HH consumed on average 1.2 % less than control group (reduction was significant during 6 of the 10 months).
Wilhite and Ling 1995	1	Electricity consump-tion, customer satisfaction, under-standing of bill	Average reduction in each experimental group during each treatment year	Control group	Yearly average during each of the three treatment years	Seven point six per cent reduction in second year and 10 % reduction in third year in all groups ("increased frequency only", "increased frequency and historic comparison, "increased frequency, historic comparison, and energy tips"). Customer satisfaction and understanding of bill rose markedly
Henryson et al.	7	Electricity consumption	Average reduction of participants	Not reported	Not reported	0-12 %
Karbo 2005	1	Electricity consumption	Results not yet available	Results not yet available	Results not yet available	Results not yet available

found that, with regard to the design features discussed above, at least two (and usually at least three) of the following features were present in the best cases:

- multiple options for feedback available at the user's choice through computerized feedback (e.g. consumption over various time periods, comparisons, additional information like environmental impact or energy saving tips)
- an interactive element that engages households – through computerized feedback or required activities like meter reading
- feedback given more often than monthly (continuously, daily load curves, or immediately after the action)
- a detailed, appliance-specific breakdown
- comparisons with previous periods.

However, results are not too clear, because there are also less successful cases exhibiting the same features. The only feature that appears exclusively in the best cases (but not in all of them) is computerized feedback. Therefore, as a second step, I compared, for each design feature, the performance of cases that include it with the performance of those that don't.

Frequency. I grouped projects into those that provided feedback monthly, more often than monthly, or less often than monthly. It emerges that one of the four "monthly" projects (Haakana et al. 1997) and two of the ten "more than monthly" ones (McCalley and Midden 2002, Ueno et al. 2005) are among the best performing projects, but none of the "less than monthly" ones. However, there are also quite low performing projects among the "more than monthly" ones. This indicates that frequent feedback is helpful, but not sufficient for best performance on its own.

Duration. There is no clear indication that long term projects provide higher (initial) savings than short term ones. However, it seems sensible to assume that long term projects contribute to habit formation and can therefore engender more persistent savings (during, but possibly also after treatment).

Content. As almost all projects combine consumption and cost information, there is no basis for separating the effects of both kinds of information. However, one may look separately at the two projects that test the effects of environmental feedback. Jensen (2003) delivers eco-information to nine housing blocks in a Copenhagen working class quarter. He reports savings in the order of 20 % against baseline for three cases, but unfortunately no figures for the remaining ones. In Brandon and Lewis (1999), there is no significant difference between the "environmental information" group and other experimental groups. The findings at least suggest that environmental information may be as effective as other kinds of information. Our model would suggest tailoring the kind of information given to the potential motives and norms of the target group.

Breakdown. Reliable data for the effectiveness of appliance-specific breakdown, again, is difficult to find. Of the seven breakdown projects, three (Mansouri and Newborough 1999, Wilhite et al. 1999, Karbo and Larsen 2005) provide no or no comparable data on savings. One (Sexton et al. 1987) is unsuccessful in promoting conservation due to its focus on load shifting. However, of the three remaining ones, two (McCalley and Midden 2003, Ueno 2005) are among the most successful ones – a good indication of the potential usefulness of detailed, appliance-specific data.[8] Also, appliance-specific data is appreciated by consumers (Wilhite et al. 1999).

Medium and mode of presentation. We have already seen that interactive, computerized feedback is very stimulating. Interactivity and the possibility of choice involve customers, raise their attention and allow for tailored solutions. It is less clear, however, what exactly the presentation must look like. Surprisingly, very few studies have considered the relevance of graphic design or formulation of text at all. Roberts and Baker (2003) suggest that the presentation should be simple but not simplistic, that it should not involve additional paper, and that a combination of text, diagrams and tables is more effective than single-format presentations. This is a start, but there is not enough detail yet. The only two comparative studies show convincingly that households' reactions to graphical designs depend very much on the exact choice of diagram or chart type, labels, scale, symbols, and wording of the explanation. Designs may range from the completely unintelligible to the highly motivating (Egan 1999, Wilhite et al. 1999).

A special case is the use of the bill as a medium. None of the billing projects are among those yielding the highest scores. They show quite a range of savings, from 0 % (only one case) to 12 %. However, billing projects have other advantages. They can typically be implemented with little additional effort, and can be long term projects, forming energy-conscious habits over time. They are therefore worth exploring for practical reasons (see for political implementation the discussion of the EU energy end use directive in the conclusions).

Comparisons. As almost all projects use some form of historical comparison, it is only worthwhile to look separately at normative comparison. It shows that none of the ten studies dealing with normative comparison could demonstrate an effect on consumption so far. A simple reason presents itself: While it stimulates high users to conserve, it suggests low users that things are going not so bad and they may upgrade a little. These effects probably tend to cancel out each other. A similar argument may hold for historical feedback: it stimulates conservation only when consumption has risen.

Additional information and other instruments. The theory postulates that motivating instruments (like goal setting, commitment, or financial incentives) and information on "how to" conserve must be present in order to make feedback work. The empirical evidence, though, is less clear. With regard to motivation: On the one hand, Katzev and Johnson as early as 1987 highlighted the role of a commitment to save when they analysed successful and unsuccessful examples of feedback. McCalley and Midden (2002) confirm in a laboratory experiment that feedback alone does not induce savings if it is not combined with a savings goal. However, in many studies, feedback alone seems to work. One project involving commitment delivers very small savings (Mack and Hallmann 2004), and one field experiment that explicitly tests the additional effect of commitment can find no such effect (Mosler and Gutscher 2004). In Nielsen (1993), financial incentives have very little

8. It remains unclear, though, why the project by Ueno (2006), which is a very similar project to Ueno 2005, resulted in much lesser savings. Uncertainties due to the very small sample surely play a part.

effect. With regard to additional information, results are also very mixed. There are a number of studies in which it is of no use or even counterproductive. (Mansouri 1999, Brandon and Lewis 1999, Mosler and Gutscher 2004, Wilhite and Ling 1995) and only one in which it was explicitly helpful (Haakana et al. 1997).

One methodological reason may be the small size of experimental groups. A possible substantial explication is that motivation and knowledge about energy saving possibilities is already present to some degree in participating households, and can be activated by giving feedback. In this situation, additional information or tools may rather complicate the situation for participants and cause an "information overload". Other reasons lie in the design of specific studies (for example, a too unambitious goal rather discourages households from making further efforts, see Mosler and Gutscher (2004)) Finally, as already reported, the usefulness of information depends strongly on how it is presented, and whether it is specific to the needs of the target group.

How would households prefer their feedback?

Some studies (Egan 1999, Wilhite et al. 1999, one study reported in Henryson et al. 2000, Sernhed et al. 2003, Soós and Ürge-Vorsatz 2003) do not focus primarily on quantitative effects of feedback, but on households' understanding, preferences, and needs concerning feedback. These are important for building up customer satisfaction, but also for laying a fertile ground for motivating households to conserve electricity.

One unanimous finding is that households in all countries approve more detailed and more frequent feedback, based on actual consumption (while electricity bills in many countries come in the form of estimates). It gives them a sense of control and, if delivered with the bill, of being valued and well informed by their utility. Furthermore, there is usually an interest in comparisons with own previous consumption. A number of studies also report that consumers are interested in normative feedback and that it would motivate them to conserve energy if they consumed more than average. It is equally clear that households prefer information that is easy to understand and that they find their current electricity bills often hard to understand. Easy-to-understand information includes (the list is not exhaustive):

- feedback based on actual consumption in a given period (instead of offsetting with previous periods, prepayments, or estimates)
- clear labelling and explanation of labels, acronyms and technical terms
- clear indication of the various components of the electricity price
- support by graphic presentations which are also clearly labelled. For purposes of breakdown, pie charts are preferred. For comparisons with previous periods, households like vertical bar charts. And for comparison with other households, horizontal bars or lines ranging from lowest to highest consumption are the design of choice, with the various levels of household consumption indicated as data points on the line.

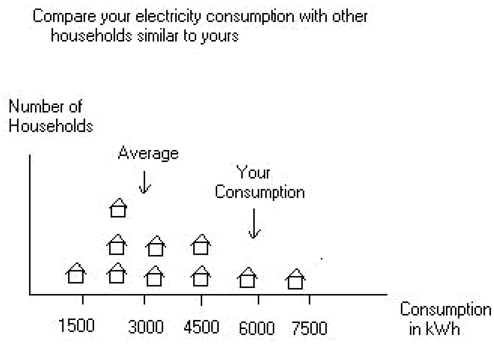

Figure 2. Distribution graph with little houses, as tested in Wilhite et al. (1999) and Egan (1999).

Other preferences vary highly between nations and, probably, cultures. One instructive example is a comparison between Egan (1999) and Wilhite et al. (1999) which have tested the same four graphic designs for presenting a between-household comparison in Delaware, USA, and in Norway. The design that ranked highest in the USA was a distribution graph with the horizontal axis spanning from lowest to highest consumption, and the vertical axis showing the number of households on each level of consumption. The individual data points were represented by little houses (see fig. 2). The same design bombed completely in Norway, being characterized as childish on the one hand, and difficult to interpret on the other, because it remained unclear whether the houses represented individual households or aggregate data.

For the UK (IEA 2005, p.10) and for Sweden (Sernhed et al. 2003), it is reported that citizens exhibit an interest in comparison with their own previous consumption, but are much less interested in comparisons with other households. On the contrary, the Japanese customers in Ueno et al.'s study (2005, p.1293) were highly interested in comparisons with others, much more than with own previous consumption.

In countries where the idea of a liberalized electricity market is relatively new, citizens are not yet accustomed to thinking about electricity as a product about which they would like to know more. Soós and Ürge-Vorsatz (2003) report from Hungary that citizens are poorly prepared for the idea of getting any other information than price and amount consumed on their electricity bill. They just can't imagine what additional features electricity might exhibit and what kind of information might be of use to them. When prompted, they discuss that they might like to receive information on voltage, security of supply, price stability, customer service and maybe energy conservation tips. When heavily prompted, they also discuss the potential inclusion of environmental impact information. In this case, they would like to have some aggregate index rather than detailed data on emissions or nuclear waste.

Research Gaps

From the current state of affairs, a number of gaps can been identified that should be explored for useful consumer feedback to be implemented widely. First, many studies and projects use rather small samples. There is a lack of well-documented large-N studies which could provide reliable data on which kind of feedback will stimulate electricity conservation the most. Such studies should cover a representative sample of households, and vary systematically the kind of feedback given, ideally only one feature of feedback at a time. Actual consumption should be measured during and some time after the feedback phase, and data should be provided on average savings within the experimental groups, on the range of savings that occurred, and on differences between different target groups (e.g. "high" and "low" users). Consumption data should be complemented with survey data on motivation, preferences regarding the feedback, and types of action taken.

Another research gap is the lack of international comparative studies. As this short review already shows, there may be wide cultural and national differences not only in preferences, but also in the kind of information that is effective in stimulating conservation. As long as comparative studies are not available, one must be careful about applying results from other countries to a specific national situation.

Furthermore, specific information on some countries is completely missing. Especially for EU accession countries and for Southern Europe, the effects and preferred types of feedback still remain to be investigated.

Conclusions: Chances and Challenges for Implementing Consumer Feedback

We have seen that, though many details remain to be resolved, a relatively sound body of evidence indicates the usefulness of feedback for promoting electricity conservation in households. With all due care because of data restraints, there are reasons to identify some likely features for successful feedback (meaning both effective in stimulating conservation, and satisfying to households). Such feedback:

- is based on actual consumption
- is given frequently (though this alone is not sufficient)
- involves interaction and choice for households
- involves appliance-specific breakdown
- is given over a longer period
- may involve historical or normative comparisons (although these are appreciated by households, the effects are less clear)
- is presented in an understandable and appealing way (designs should be based on sound consumer research, as has been done in Wilhite (1999) and Egan (1999) and recommended by Roberts and Baker (2003)).

Especially the first three characteristics point to the advantages of electronic metering and data procession.

However, it is important to check whether the recommendations hold for all target groups. There is probably not "the" perfect feedback for everybody. As we have seen, high users react differently from low users, and middle class groups from working class groups. Similar considerations hold for computerized and interactive feedback: An overly complex tool requiring much understanding and initiative from users may not be the tool of choice for households with lower education, lower technical interest (e.g. many elderly people) or less spare time.

Sadly, implementation of useful feedback is lagging way behind knowledge. Implementation usually is not governed by scientific findings but by political interest, power constellations, opportunities, and incentives. Firstly, many variants of improved feedback hinge on technical preconditions that are not always met. For example, continuous electronic feedback requires "smart", two-way metering technology. A similar argument applies to more frequent (e.g.monthly) feedback, if meter reading should not become overly expensive. (However, there could be ways out of the dilemma, like self-reading of the meter). Appliance-specific breakdowns would need even more sophisticated technology which is at the moment unlikely to be installed widely. Comparisons with similar households rely on adequate data bases which need to be built up.

Other forms of feedback, however, are less demanding. Comparisons to a previous period, presented in a graphic form, for example, should be feasible as well as the inclusion of environmental impact information or energy saving tips. In some countries, advanced metering technologies are currently being introduced, providing a better basis for improved feedback (e.g. in Denmark, 25 % of all meters will be replaced by remote metering and two-way communication technology by 2010. Norway is conducting pilots with smart meters. Italy has decided to implement them widely.[9]). In general, it would be advisable to rely on a little less effective forms of feedback that can be more easily implemented. This points, for example, to the potential of improved electricity bills.

The biggest hurdle, of course, is energy utilities' motivation. In situations of overcapacities, cheap electricity available on the market, or oligopolies with little competition, there is little interest in demand side management. And if conservation is not very important to customers, feedback is not the tool of choice for customer retention.

Here, EU legislation will provide a window of opportunity. Directive 2003/54/EC (concerning common rules for the internal market in electricity) obliges suppliers to disclose certain product features (fuel mix, carbon content, nuclear waste) in the bill. Therefore, utilities need to reconsider their bill format anyway. Even more important, Directive 2006/32/EC on energy end-use efficiency and energy services (Energy Services Directive), requires Member States to introduce informative billing and other types of feedback, including more frequent billing, historic and normative comparisons, and contact details for obtaining further information on energy efficiency (Art.13). Several Member States have already started acting on the Directive. Denmark has a legal obligation to provide an "informative electricity bill" showing environmental impact as well as historic and normative comparisons. Companies are free to include further information and to choose the mode of presentation (IEA 2005, p.15). In Sweden, legislation foresees that by July 2009, all consumers will have monthly reading of their consumption based on actual use.[10]

The Directive will also provide a favourable framework for systematic comparative large-N studies of various forms of

9. I thank my panel leader, Ms Anita Eide, for information on Norway and Italy.

10. I thank an anonymous reviewer for providing this information.

feedback (which are expensive and technically challenging, so normally there would be few actors with an interest in conducting them). For example, in the UK, the government has earmarked 9.75 million for a pilot study containing various trials of different sorts of feedback. A tender has been held by OFGEM and first trials start early 2007 (OFGEM 2006).

However, the Energy Services Directive leaves ample space for Member States to define which measures they deem "appropriate", and how stringently they will implement the measures. Therefore, it is up to national actors to push for changes, promote interest in sustainable energy consumption, and introduce experiments with feedback. National energy agencies could be such actors. Where they are lacking, weak or disinterested, NGOs, research institutions, consumer advocacy groups and innovative utilities could take up the same role. Without them doing so, widespread implementation of helpful feedback will probably not stand any chance.

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