THE EFFECTIVENESS OF FEEDBACK ON ENERGY CONSUMPTION

A REVIEW FOR DEFRA OF THE LITERATURE ON METERING, BILLING AND DIRECT DISPLAYS

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EXECUTIVE SUMMARY

Most domestic energy use, most of the time, is invisible to the user. Most people have only a vague idea of how much energy they are using for different purposes and what sort of difference they could make by changing day-to-day behaviour or investing in efficiency measures. Hence the importance of feedback in making energy more visible and more amenable to understanding and control. This review considers what is known about the effectiveness of feedback to householders. The focus is on how people change their behaviour, not on the detail of the technology used.

There is considerable variety in the feedback literature, but common themes emerge. The first studies, in the 1970s, established that feedback (mostly via display monitors) has measurable effects and was worth pursuing, on its own or in combination with other processes. Feedback came to be seen in terms of a learning tool, allowing energy users to teach themselves through experimentation. Overall, the literature demonstrates that clear feedback is a necessary element in learning how to control fuel use more effectively over a long period of time and that instantaneous direct feedback in combination with frequent, accurate billing (a form of indirect feedback) is needed as a basis for sustained demand reduction. Thus feedback is useful on its own, as a self-teaching tool. It is also clear that it improves the effectiveness of other information and advice in achieving better understanding and control of energy use.

Scope of the review

The literature reviewed here mostly consists of primary sources, with a few review papers. Most of it comes from the USA, Canada, Scandinavia, the Netherlands and the UK. The focus is on feedback on gas and electricity consumption, with some reference to the literature on advice and information. There are not many studies of the use of feedback in the UK, or on feedback for low-income households, but these have been sought out where possible.

Savings from feedback

The norm is for savings from *direct feedback* (immediate, from the meter or an associated display monitor) to range from 5-15%. The role of the meter is to provide a clearly-understood point of reference for improved billing and for display. If there is no separate, free-standing display then the meter must also be clearly visible, within the building. There is some indication that high energy users may respond more than low users to direct feedback.

Indirect feedback (feedback that has been processed in some way before reaching the energy user, normally via billing) is usually more suitable than direct feedback for demonstrating any effect on consumption of changes in space heating, household composition and the impact of investments in efficiency measures or high-consuming appliances. Savings have ranged from 0-10%, but they vary according to context and the quality of information given (see below). Historic feedback (comparing with previous recorded periods of consumption) appears to be more effective than comparative or normative (comparing with other households, or with a target figure).

Feedback that is *disaggregated by end-use* at the electricity meter is relatively expensive and complicated to supply. An instantaneous, easily accessible display may give the consumer adequate information on different end-uses, by showing the surge in consumption when the kettle is switched on, or the relative significance of a radio, vacuum-cleaner or toaster. Information on how energy use is disaggregated among end-uses in an average home can also be given on the bill, as a general guide. Accurate, frequent billing will give the householder a much better sense of the heating load at different times of year than can be gained from a direct debit statement.

Pay-as-you-go systems with some form of display allow customers to be more in charge of their electricity use. Savings of 10-20% are quoted for North American systems. A full evaluation of the keypad pay-as-you-go meter in Northern Ireland is under way; figures from small-scale earlier studies show savings of around 3% compared with previous usage.

While online billing can provide a useful interactive feedback service and can incorporate analysis and advice, it is unlikely to be an adequate substitute for a direct display. Ideally, every household needs to be able to see what is happening to consumption without having to switch on an optional feedback service.

Time-of-day pricing

The case for time-of-use electricity pricing or real-time pricing for the residential sector is not yet made for the UK. Opportunities for reducing peak usage are limited and there are equity concerns. But time-of-use or real-time pricing may become important as part of more sophisticated load management and as more distributed generation comes on stream.

Persistence of effect

Persistence of savings will happen when feedback has supported 'intrinsic' behaviour controls – that is, when individuals develop new habits – and when it has acted as a spur to investment in efficiency measures. People may need additional help in changing their habits – this is where well-thought-out energy advice can be of use. Where feedback is used in conjunction with incentives to save energy, behaviour may change but the changes are likely to fade away when the incentive is taken away. As a rule of thumb, a new type of behaviour formed over a three-month period or longer seems likely to persist - but continued feedback is needed to help maintain the change and, in time, encourage other changes.

The future of feedback

Important factors influencing the effectiveness of feedback are

- General context, eg social, educational and historical factors, energy infrastructure
- Scale and timing of usage. Indirect feedback is most likely to give a compelling picture of what is happening to the heating load, while instantaneous direct feedback illustrates the impact of smaller end-uses.
- Synergies between feedback and other forms of information. It is not always easy to separate out these effects, even in relatively small-scale and intensive studies.
- Timing. Billing or other periodic feedback (eg via a PC) will show up longer-term effects best, eg investment in insulation, use of new appliances, replacement of heating systems and appliances, home extensions, new members of the household. Direct displays will show up the significance of moment-to-moment behaviour best.

Any development of 'smart metering' needs to be guided by considerations of the quality and quantity of feedback that can be supplied to customers. Direct displays in combination with improved billing show promise for early energy and carbon savings, at relatively low cost. They also lay the foundations for further savings through improved energy literacy.

CONTEXT

The scale of the challenge facing the UK in reducing carbon emissions and maintaining adequate, reliable energy for the future is set out in the recent energy review paper (DTI 2006). There is clearly an enormous task ahead in terms of developing more sustainable ways of living and there is a growing recognition that energy efficiency alone is inadequate to achieve the aims of a major reduction in carbon emissions (see Boardman et al. 2005 for a discussion of issues for the residential sector). Many Energy Conservation Authorities are behind schedule on progress towards their targets under the Home Energy Conservation Act and the indications are that their reporting arrangements are unreliable, overestimating levels of improvement in the energy efficiency of the housing stock (New Perspectives 2004). In spite of professed public concern about climate change, improved appliance efficiency and information campaigns, domestic electricity consumption rose by 6% in the third quarter of 2005 (DTI press release, 5.1.06).

Energy supply and consumption are sociotechnical in nature: technology and behaviour interact and co-evolve with each other over time. It is well established that technical and physical improvements in housing are not enough to guarantee reduced energy consumption. Consumption in identical homes, even those designed to be low-energy dwellings, can easily differ by a factor of two or more depending on the behaviour of the inhabitants (Sonderegger 1978; Curtis 1992-93; Keesee 2005). Any attempts to change the patterns of supply and consumption therefore have to take into account the interfaces between supplier, technology and consumer and the ways in which these can be improved. This is where feedback issues enter the debate.

> *Energy and power are not terms within the natural language of mainstream householders. Gas and electricity operate at the level of the subconscious within the home... Whilst there does seem to be some latent cultural guilt about the notion of waste... there appeared to be virtually no sense of being able to actively and significantly reduce energy consumption in the household.*
>
> - Dobbyn and Thomas 2005, p6

'Smart metering' or 'advanced metering' is proposed as a promising way of developing the UK energy market and contributing to social, environmental and security-of-supply objectives. Five years ago, the Smart Metering Working Group estimated that meters offering more information to consumers could help reduce household consumption of gas and electricity in addition to other potential benefits (SMWG 2001). A new European Directive requires a substantial improvement in the information given to energy consumers (see box) and there has been a considerable debate on the future of metering in the UK, with Ofgem carrying out consultation on domestic metering innovation at the time of writing. The Ofgem consultation in 2005 on the regulatory implications of domestic-scale microgeneration is also relevant: increasingly, householders are becoming generators as well as consumers of energy.

EU Energy end-use efficiency and energy services directive (2005)

Preamble

- In defining energy efficiency improvement measures, account should be taken of efficiency gains obtained through the widespread use of cost-effective … innovations, eg electronic metering…
- to enable final consumers to make better-informed decisions … they should be provided with a reasonable amount of information … consumers should be actively encouraged to check their own meter readings regularly.

Article 11
… Member States may establish a fund… to subsidise the delivery of energy efficiency improvement programmes and … measures… These shall include the promotion of energy auditing … and, where appropriate, improved metering and informative billing.

Article 13
Member States shall ensure that, in so far as it is technically possible, financially reasonable and proportionate in relation to the potential energy savings, final customers … are provided with competitively priced individual meters that accurately reflect actual energy consumption and that provide information on actual time of use.

- … Billing on the basis of actual consumption shall be performed frequently enough to enable customers to regulate their own energy consumption.
- MS shall ensure that, where appropriate, the following information is made available to final customers in clear and understandable terms … in or with their bills…:

Current actual prices and actual consumption of energy;

Comparisons of the final customer's current energy consumption with consumption for the same period in the previous year, preferably in graphical form;

Wherever possible and useful, comparisons with an average normalised or benchmarked user of energy of the same user category …

This paper sets out general issues that are relevant to the debate on the future of energy in the residential sector and how it is understood and controlled. It revisits a review of feedback carried out six years ago (Darby 2001), updating it with some more recent findings from the literature and supplementing it with what has been learned since then about the nature and possibilities of different types of feedback. The review does not look at the detail of technology, but concentrates on principles of feedback, basic types of feedback and responses to it. The focus is on the energy user rather than the supplier.

THE LITERATURE ON ENERGY FEEDBACK

The early studies on energy feedback, carried out in the 1970s and 1980s, were carried out mostly by psychologists. Feedback was mostly seen as an 'intervention', an interruption in the normal order of things. For example, a typical early feedback experiment would involve a note posted on the consumer's kitchen window each morning, telling him or her how the previous day's consumption compared with some reference level. It was also often interpreted in terms of behaviour reinforcement, motivating individuals who were seen as relatively passive and motivated by reward and punishment. These studies established that feedback can have measurable effects on behaviour, at least in the short term.

> Feedback: *Information about the result of a process or action that can be used in modification or control of a process or system … especially by noting the difference between a desired and an actual result.*
>
> - Oxford English Dictionary

Some researchers began to emphasise that feedback is part of a learning process, in which people are information processors who actively make sense of the world around them (Ellis and Gaskell 1978). Another early review pointed out that interventions tended to focus too narrowly on the control of 'target behaviours' at the expense of viewing them within a systems context (Winkler and Winett 1982). The wide-ranging study by Hutton et al (1986), carried out in three North American cities, 'cautions against saying that any type of feedback, under any conditions, directed at any population, will produce positive results' – context is important. It was not always easy to set boundaries to the scope of a study of feedback or to establish a theoretical basis for studying it. For example, a review of the effectiveness of feedback as demonstrated in experimental conditions concludes that 'Feedback research is…marked by a simultaneous lack of concern with theory and overemphasis on application. As a result our understanding of *how* feedback does or does not work remains unexplored or untested' (Katzev and Johnson 1987). One answer to this rests with learning theory (Ellis and Gaskell 1978; Darby in press).

More recently, the focus has shifted to more 'ecological' studies, carried out on a longer timescale and with larger samples. These are typically funded by energy suppliers, regulators or government. There is less danger of a 'Hawthorne effect' in these conditions (that is, of participants behaving differently because they know they are being observed).

Qualitative work has also become more significant in feedback studies. For example, van Houwelingen and van Raaij included interviews in their work on the effect of goal-setting and daily electronic feedback on gas use (1989). These give some additional insight into how the householders actually used their feedback, 'mainly as a permanent check on the effects of energy conservation efforts'.

The consumer's 'energy analysis environment' under traditional billing was shown to be inadequate for decision making, lacking the detail which would make sense of the bill and allow for effective experiments in reducing it:

> *…consider groceries in a hypothetical store totally without price markings, billed via a monthly statement… How could grocery shoppers economise under such a billing regime?*
>
> - Kempton and Layne 1994

Informative billing initiatives in Norway showed how customers appreciated improved accuracy and extra information (historic and comparative feedback, a guide to which end-uses were the highest consuming), began to read their bills more frequently and with more understanding, and began to alter their behaviour (Wilhite 1997; Wilhite et al, 1999). Various qualitative studies (eg Egan 1999, Roberts et al 2004) give more detail on how customers respond to different billing designs. The latter deals with UK billing and shows some distrust of comparative feedback: customers were suspicious about the validity of their comparison group but appreciated feedback that compared their recent consumption with that in previous billing periods.

As the literature on feedback expanded, so did that on energy use and on measures to reduce consumption and promote efficiency. In my earlier review, I described five main categories of feedback with various degrees of immediacy and control by the energy user, ranging from the home energy audit (carried out very infrequently, often by a professional) to the glance at a display panel (carried out at any time by the householder). Those that are relevant to this review are shown in the box below.

Direct feedback: available on demand. Learning by looking or paying

- *Self-meter-reading*
- *Direct displays*
- *Interactive feedback via a PC*
- *Pay-as-you-go/keypad meters*
- *'Ambient' devices*
- *Meter reading with an adviser, as part of energy advice*
- *Cost plugs or similar devices on appliances*

Indirect feedback – raw data processed by the utility and sent out to customers. Learning by reading and reflecting

- *More frequent bills*
- *Frequent bills based on readings plus historical feedback*
- *Frequent bills based on readings plus comparative/normative feedback*
- F*requent bills plus disaggregated feedback.*
- *Frequent bills plus detailed annual or quarterly energy reports.*

Inadvertent feedback – learning by association

- *With the advent of microgeneration, the home becomes a site for generation as well as consumption of power.*
- *Community energy conservation projects such as the Dutch 'Eco-teams'.*

Utility-controlled feedback – learning about the customer

- *Utility-controlled feedback via smart meters, with a view to better load management.*

Energy audits – learning about the 'energy capital' of a building

Audits may be

- *undertaken by a surveyor on the client's initiative*
- *undertaken as part of a survey for the Home Information Pack*
- *carried out on an informal basis by the consumer using freely available software, eg carbon calculators.*

Feedback covers a wide range of practices and these are best analysed and understood in context. The overall idea here is to look at feedback in terms of its contribution to the building up of a body of 'tacit knowledge' or know-how about the supply and use of energy. In this, people take in information concerning their energy use, they act (change their behaviour in some way) and they gain understanding of what has happened by interpreting any feedback that is available. These three elements do not always happen in a neat sequence but all are involved when a person learns about energy use (Figure 1).

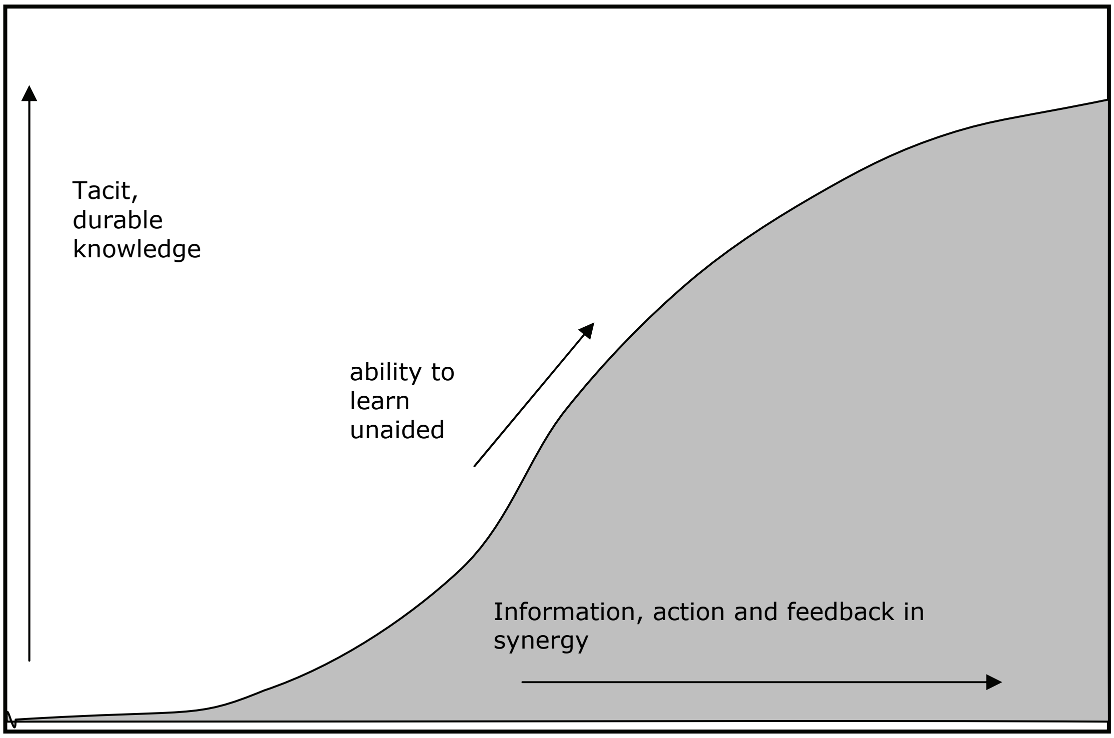

Figure 1: A model for the development of tacit, durable knowledge

EFFECTIVENESS OF DIFFERENT TYPES OF FEEDBACK

This section of the report refers frequently to studies which are summarised in the attached Tables 1 (direct feedback), 2 (indirect) and 3 (time of use).

It is worth saying at the outset that savings from feedback will always vary according to the technology under consideration, whether the main heating fuel is under consideration or a subsidiary fuel, and the institutional and cultural background against which the study takes place. In addition, the quality of feedback information and the way in which the study was conducted will affect the recorded outcomes. However, the studies reviewed below do show, consistently, the usefulness to households of having feedback information that is specific to them and allows them to control their energy use more effectively.

The savings presented here challenge the estimated 1% savings from 'more accurate billing and more sophisticated pricing' and 0.5% from 'the simple meter which provides more accurate billing information' in the recent Ofgem consultation document (Ofgem 2006, p18). The consultation document appears to confuse potential savings from indirect feedback (when the customer does not have easy, direct access to the meter and consumption data and relies mainly on bills or statements) with the higher potential savings from direct feedback, where customers have easily-accessible displays.

Basic metering without separate direct display monitors

The standard gas or electricity meter can be used to give a very basic form of energy consumption feedback. A painstaking householder can chart consumption from one meter reading to the next and use the meter to check the accuracy of bills or statements, but there is no obligation to do either and the meter is normally hidden out of sight. Nonetheless, over a quarter of householders appear to check their meters fairly regularly (Attan 1985; Darby in press). There is an association between the level of energy awareness of householders, the likelihood that they have installed efficiency measures, and whether they check their meters (Darby, ibid.).

Using feedback in this way requires a level of commitment to reading the meter regularly, but it has been effective as a tool in advice programmes, in conjunction with information on how to save energy, and in 'eco-team' conservation programmes (eg Sluce and Tong 1987; Gaskell et al. 1982; Nielsen 1993; Staats and Harland 1995). The potential savings, with motivated participants, can be in the region of 10-20% (see Table 1). The advice programme run by West Lothian District Council has asked clients to phone in their meter readings over a number of weeks in order to check that they are making progress, with encouraging results. Savings have been in the region of 10% after three months from behavioural change alone and mostly from fuel-poor clients. There may be further savings after efficiency measures have been installed (WLEAP), and the advisers estimate that habits formed over three months or more are likely to stick. A US energy advice evaluation showed savings in the third year after weatherisation and advice visits that were 85% of the 26% saved in the first year. This was comparable with the persistence of savings from weatherisation alone (Harrigan and Gregory 1994)

The standard meter cannot however establish *when* energy was used and cannot be activated remotely.

Key meters and keypad meters

Approximately 85% of electricity consumers and 90% of gas consumers in Great Britain pay for their energy in arrears (NEA 2004). This is not conducive to conservation, or to control of costs. A study of British householders on prepayment tariffs (mostly low-income households) showed that over 80% of electricity customers and 70% of gas users wished to continue with this method of payment although most of them knew that it was more expensive than payment in arrears (Waddams Price 2001).

Key meters are 'semi-smart' in that they allow transfer of information such as tariff-changes and meter reading data to and from the keycode at the payment point/shop. When keypad meters were introduced as an option to low-income customers in Northern Ireland they proved extremely popular and have now been made available to all customers. There is a 2% discount for electricity bought in this way – a regulatory decision. Around 25% of NI households now use keypad meters, buying credit from a nearby outlet and keying a 20-digit code into their meter, which looks something like a telephone and is situated in a room of their choosing. Savings to date for all keypad customers are estimated at 3% (reported in Owen and Ward 2006). A fuller evaluation is due in 2006.

Utilities in towns in Ontario have experimented with 'pay as you go' systems successfully (these are similar to the keypad meters in operation). The local utility Woodstock Hydro claims that the 25% of their customers who use the system are using between 15 and 20% less energy than they were doing under the traditional system of payment, because the display unit makes them aware of what they are consuming. (http://www.ec.gc.ca/pp/en/storyoutput.cfm?storyid=109; http://www.energyprobe.org/energyprobe/index.cfm?DSP=content&ContentID=9838) The disparity between North American and Northern Ireland figures may be partly due to differences in what is displayed to customers.

You need three pieces of equipment to use the pay-as-you-go system. First, there is an electronic meter. Then, there's an in-home display unit, which resembles a thermostat and plugs into any electrical outlet.

The in-home display unit communicates constantly with the … meter, relaying how much energy you're using at the moment. For example, if you have the washing machine, dishwasher and dryer running at the same time, the meter might read 25 cents an hour, as opposed to late at night, when nothing is running, when the meter shows lower rate of eight cents an hour.

Lastly, there is the smart card. Like a prepaid phone card, users go to select stores and purchase electricity on their card. At home, you swipe the card through the in-house meter to keep the electricity flowing.

-description of pay-as-you-go system in Ontario
http://www.melaniechambers.ca/pay-as-you-go.html

Direct displays on monitors separate from the meter
Direct displays are a supplement to the meter. Almost all show electricity consumption, though there is one recorded trial of a display that showed the previous day's gas consumption in relation to a weather-adjusted target, producing savings of 10% against controls (van Houwelingen and van Raaij 1989). Over half of those interviewed during the trial said that they would like to have such a display permanently.

With a free-standing display, the meter can be left alone once a transponder is attached. Householders can look at the displays for instantaneous information and/or information on previous consumption. On some displays, they can also set an alarm to go off when the load rises above a level chosen by them.

Savings are typically of the order of 10% for relatively simple displays (McLelland and Cook 1979; Dobson and Griffin 1982; Mountain 2006). These are small panels that can be carried around the home, typically showing instantaneous electricity consumption along with cost per hour at the current rate. The most recent displays also show carbon dioxide emissions for a given rate of consumption. They cost £15-£80. Trials are under way in the UK at the time of writing.

Use of TVs and PCs for display
More complex displays are also being developed, such as a complex interactive online display tested in Japan that cost around $5000, showing historic consumption, daily and 10-daily costs, living room temperatures and comparisons with other homes. Over a nine-month trial, this gave electricity savings of 18% and gas savings of 9% compared with controls, for the 10 householders who took part in the trial (Ueno et al. 2005). Benders et al. (2005) report 8.5% savings from the use of an interactive web page by 137 Dutch households. This helps analyse consumption and establish relevant conservation measures. Money saved by using less energy was invested in efficiency measures, contributing to the persistence of the savings. Brandon and Lewis, in one of the few British feedback trials, found interactive display via a PC the most promising method (1999). A major trial of feedback on gas, electricity and water via digital TV is scheduled to begin in the autumn of 2006, carried out for the Market Transformation Programme.

Disaggregated feedback

Information on which end-uses consume most energy is seen as useful by customers (Harrigan et al. 1995). When 1000 Norwegian households were given a pie-chart on their bill showing a typical breakdown of six main domestic end-uses, 81% of respondents thought it useful and 38% appeared to have learned something new from it. A direct display can convey the same information provided the response to the signal from the meter shows up instantaneously. Customers can then see immediately what happens when they switch on the kettle or vacuum cleaner, or when the central heating pump goes on. Portable end-use monitor plugs are on sale in the UK for £25 and serve the same function, one appliance at a time.

End-use disaggregation can be carried out by identifying appliance 'signatures' (Sidler and Waide 1999), but this is likely to be unfeasibly expensive for everyday use by householders in the foreseeable future (IEA-DSM 2005, subtask 2).

There are no data on persistence of effect for this type of feedback. The argument for it rests on the educational effect in raising awareness of the relative demand from different appliances.

Ambient displays

Ambient displays rely on 'pre-attentive' processing of information. They do not show text or numbers, but simply alert the householder to the fact that something relevant to their electricity supply has changed or is about to do so. Some direct displays can be programmed to sound an alarm when load has exceeded a given level (a more user-friendly version of the load-limiting trip switch). A flashing light was used to alert a sample of American householders that the outdoor temperature had dropped below 68°F and it was time to turn off the air-conditioning and open windows for cooling instead. This gave savings of 16% over a three-week period (Seligman et al. 1979).

Martinez and Geltz (2005) describe the testing of an 'energy orb' which changes colour according to the time-of-use tariff in operation. The orb flashes during the two hours before a 'critical peak' with high unit costs, and users who tried it out tended to reduce consumption well in advance of the peak and to continue with the reduction for some time afterwards. As a consequence, there was some overall saving as well as load-shifting.

The Design Council's recent 'Future Currents' project has come up with some innovative and attractive designs for displays that do not necessarily show numbers but give a clear impression of electricity demand in the home (http://www.designcouncil.org.uk/futurecurrents/).

INFORMATIVE BILLING

A [standard] *utility bill is a form of feedback in which the feedback loop is too far removed from the use of inputs to have any information value'* (Gaskell et al, 1982). But bills can be adapted to show broad trends in consumption over time. First, they can demonstrate how the heating load is spread over the year – something that direct debit payers may be completely unaware of. They can also show how consumption has changed relative to the same period of the previous year, giving the energy user the chance to work out what might have caused the change: a new person in the household, a new boiler or appliance, insulation or the addition of an extension to the house. Bills can also include an annual 'energy report', compare the household's consumption with that of a comparable household (though this is not straightforward), or give a breakdown of how consumption is distributed between end-uses in an average home (Wilhite et al. 1999; Kempton 1995).

The minimum requirement at present in the UK is for a meter reading every two years, so that most bills and statements are based on estimated consumption – the source of endless queries and complaints to the suppliers. With some suppliers, customers can phone or email their meter readings as an alternative, but this is not a guarantee of regular, accurate billing. Since October 2005, UK suppliers have begun to disclose the generation fuel mix of electricity supplied to the customer.

> *We can't be using that much…It's just the two of us in this two-bed flat. I am out all day …and we are on income support. I just don't know how the bills are so high… I think there is something wrong with them.* - Londoner in her 30s, whilst in broad daylight lights were on in most rooms, a TV and radio were playing in an unoccupied bedroom, and all appliances in the sitting room were on standby.
>
> - Dobbyn and Thomas 2005, p26

Table 2 (see Appendix) indicates the range of savings that have been achieved through informative billing – from 0-12% - with comments on characteristics of each study.

The Norwegian informative billing studies show persistence of savings over several years. Wilhite and Ling (1995) reported savings averaging 10% for customers of Oslo Energi who received bills based on electricity meter readings at 60-day intervals (as opposed to the usual single meter reading a year and four bills, three of which were estimates). The figure rose to 12% when the frequent bills were supplemented by feedback comparing the consumption with the same period of the previous year and all periods in between. Interestingly, advice tips did not appear to add to the impact of the frequent bills and feedback. 79% of customers showed an interest in continuing with the new billing system at the end of the project. Eventually, the government made quarterly informative billing mandatory.

A further Norwegian study (Wilhite, 1997) involved customers in Stavanger reading their own electricity meters and sending the readings to the utility. They were helped to understand their new informative energy bills by a well-designed brochure in simple language. Increases of 15-20% in claimed awareness and understanding of billing information resulted over a period of just over a year. Consumer reaction to this project was also very positive. Both studies involved a representative cross-section of households, with roughly 25% using all-electric space heating and 50% some electric space heating.

Three years after the start of the Stavanger trial, the customers who read their meters and received informative bills were consuming 8% less electricity than the general population in the area who were receiving quarterly bills that were mostly based on estimates (Wilhite, pers comm). Their consumption had fallen by 4% compared with that before the new bills were introduced, while that of the control population had risen by 4%. These Norwegian findings are highly relevant to a discussion of Automated Meter Reading.

A review of billing in the Nordic countries found that the longer the duration of a trial and the more information available to the customer, the more persistent the effects were likely to be (Henryson et al, 2000). It seems that the regular reminders of consumption can be a continuing influence, as well as reducing consumption in the first instance. These findings support those of van

Houwelingen and van Raaij (above), that savings fell off when the gas consumption display monitor was removed from homes. Persistent feedback promotes persistent conservation behaviour and also has implications for the development of technology. The regulatory requirement for monthly, accurate bills in Sweden drove the move to smarter (and remote) metering.

Wilhite and Ling found that the single most effective change was from quarterly estimated bills (only one meter reading per year) to bimonthly, accurate bills. They set out what they saw as the chain of causation from bimonthly, accurate bills with historic feedback to savings:

Increased feedback – increase in awareness or knowledge – changes in energy-use behaviour – decrease in consumption

On the basis of qualitative work carried out by the Bristol Centre for Sustainable Energy, historic feedback is likely to be more popular than comparative feedback in the UK (Roberts et al. 2004). Studies using comparative feedback by Haakana et al. (1998) and Egan (1999) show that, while householders are interested in comparisons, they do not necessarily make savings when shown them. The choice of comparison groups is problematic (people may be unhappy with the validity of the group they are assigned to) and the response to comparisons may not be positive. In one study, over 70% of respondents said that they would take conservation action if they were shown to be over the 80th percentile of their comparison group (Iyer et al. 1998). But what if they found themselves at the frugal end of a high-consuming comparison group? It is questionable whether that would provide much motivation to reduce consumption further.

TIME-OF-USE PRICING

Time of use pricing, critical peak pricing and real-time pricing have been major concerns mostly in those parts of the world with summer and winter peaks in demand allied with supply constraints: California, Ontario, the northeastern states of the USA and parts of Australia.

There is evidence of reductions of up to 30% of peak demand through a variety of reduction programmes involving some sort of time-sensitive pricing, with or without direct load control by the supplier. Automatic Meter Management, a likely next step in UK metering, allows for time-sensitive tariffs to be used and communicated remotely to the consumer. But the business case is not yet made for time of use pricing in the UK (Owen and Ward 2006). Moreover, domestic customers are not usually enthusiastic about real time pricing, in which prices are based on utilities' short-term marginal costs and risk is transferred to the customer (IEA-DSM 2005, subtask 2; Barbose et al 2005). There is little scope for load-shifting among domestic consumers. 80% have gas heating, while almost all the rest use off-peak electricity, oil or solid fuel for their heating. There is also a danger that it would penalise some low-income householders with lifestyles that make it very difficult to alter their consumption patterns. This picture could change as the proportion of demand that is met by building-integrated renewables and distributed generation increases, but that is a subject for further research.

Electricity tariff structures do not have to be based on time of use in order to have an impact on load: for example, progressive block pricing offers an incentive to conserve and could be combined with informative billing and displays of how close the customer is to reaching a threshold above which the unit cost will be higher.

COMPARISON WITH OTHER 'SOFT' DEMAND REDUCTION MEASURES

Information on its own has a poor track record in achieving energy conservation. While people may appreciate the message, few are likely to be spurred into action (Heberlein 1975; Condelli et al. 1984; COI 2000; Valente and Schuster 2002). The problems with large-scale information campaigns are those of giving information relevant to people's circumstances at the same time as convincing them that they can achieve change and that it is worthwhile. Learning to use energy more effectively is not possible unless the consumer experiments with the system.

Evaluations of energy advice supplied by the EEAC network show estimated savings of around 5% of annual energy bills following the installation of efficiency measures – that is, capital investment (New Perspectives and NFO BJM). New Perspectives/Energy Inform (2004) give estimated cost savings of around 9% for advice on day-to-day behaviour via the EEAC network. Those on lower incomes are estimated to save more than those on higher, while client-led and 'opportunistic' advice programmes, with personal interaction with an adviser, are able to achieve higher levels of savings than paper-based advice programmes. There are examples of advice programmes that incorporate feedback from meter readings into their procedure achieving measured savings of around 10% in gas and/or electricity (Darby 1999).

Energy education in schools can be a powerful resource (eg, the NP/NFO Utilities evaluation of the 'Energy Matters' course in schools, 2003). Home audits are a part of the course, 76% of pupils' families took some action and the level of behavioural change appeared to be higher than that achieved by advice services such as the EEACs. However, we do not have figures for savings arising from education programmes and they would be difficult to isolate.

PERSISTENCE OF SAVINGS

The main general points to make are the importance of internal motivation as opposed to external incentives and controls (de Young 1993; Dwyer et al 1993) and the need for feedback to be maintained over time in order to allow householders to monitor the impact of any changes in their lifestyles, housing and appliances.

The 3-year trial of informative billing in Oslo found that the effect lasted throughout the trial. Post-experiment interview of the householders showed up no uniform pattern of behavioural changes or purchase/investment decisions to account for the savings. The interviewees rarely remembered any specific changes unless prompted, and the authors of the study state that '*Our impression from the interviews is that after three years the changes people made had become so routine that they had trouble identifying them*' (Wilhite and Ling 1995 p151).

In the West Lothian energy advice programme, the measured savings were made solely from behavioural change. An adviser commented that '*If someone was going to return to their old inefficient habitual ways they would do so within three months. In our experience, if they have adopted a change in behaviour for over three months they have changed for at least a year.'* This does not contradict the need for continuing feedback to keep the householder informed as his or her circumstances change, and as a constant teaching aid for all members of the household.

MICROGENERATION

With energy production as with consumption, it is important to make the whole process as visible as possible. Microgeneration will need to become widespread if the government's renewables and carbon dioxide emission targets are to be met. ECI research shows that most households with solar PV expect a fair payment for their own-generated electricity and would like to be able to see, separately, the amounts of electricity that they are importing and exporting. In spite of the cost of installation of solar PV, displays of this sort are optional and not part of any standard package. In households where this information is visibly displayed, increased awareness has led to a conserving behavioural effect, reducing total electricity consumption by as much as 20% from pre-microgeneration levels (Keirstead and Boardman, 2005).

Some solar water heating installations have associated display units showing water temperature and/or the amount of energy absorbed from the sun in a given period. Again, there are no norms as yet, but such displays do have a powerful effect in raising awareness of the potential for cutting carbon emissions and saving gas or electricity.

> *Beyond the sheer excitement and pleasure of DIY energy generation, the impact is seen in householders' shifting attitudes to energy conservation and consumption ... there starts to develop a strong sense of which behaviours are free and self-provided, versus ones that cost money and are supplier-dependent.*
>
> - Dobbyn and Thomas 2005 p6

SYNERGIES

The literature shows clear evidence of synergies between different types of feedback and between feedback and other types of information. The value of different types of information will obviously vary between individuals and social groups. For some, feedback may jolt them into considering energy for the first time. For others, it complements what they have learned from other sources. The study by Gaskell et al (1982) illustrates both these points. It showed that the most effective means of achieving savings came from supplying groups of householders with information on energy use and at the same time asking them to read their meters daily. Daily monitoring without information, though, led to *increased* consumption (5% gas and 11% electricity), possibly because of an overzealous approach: daily meter readings, temperature readings and keeping an energy diary would be tiresome for most of us unless we could see a clear point to the exercise. The highest savings came from relatively young high consumers.

The clearest indication of the positive role of feedback in energy advice … comes from the West Lothian programme [where clients are encouraged to phone in meter readings to their adviser until they are reaching their target consumption]. WLEAP believe that the method *'gives the customer ownership of the problem. They can see right away the positive effects of the energy advice - they can see an immediate drop in consumption without having to wait for a bill to come in and compare it with a bill from the previous year'*. The majority of the fuel savings recorded come from behaviour changes, before any energy efficiency measures have been installed. Of 999 enquiries in 1996/97, 421 clients are recorded as having made savings: these ranged up to €1500 per year, although the bulk (279) fell between €75 and €450 (WLEAP 1997).

The West Lothian approach is supported by other projects studied. A component of two advice projects was the encouragement of tenants to read their own meters and to keep a record of their consumption, while a third project involved monthly meter readings by a project worker (EEO 1988; Sluce and Tong 1987; Hill 1991).

- Darby 1999

There is also the potential to link feedback at various levels, from the household upwards. Learning about energy from daily usage in homes can connect with learning in the community, or with learning by utilities and government.

There needs to be a common language in which the information is expressed. For example, a web page with a graph of current load and available capacity plus forecasts for the Californian electricity system received more than 2m hits each day during the 2000/01 electricity crisis (LBNL 2001). The page was a simplified version of data that had previously only been available to the state's energy policy makers and utilities. The authors stated that their impression from limited interactions with visitors to the site was that many people were modifying their actions as a result of observing what was happening on the grid.

SUMMARY AND CONCLUSIONS

Domestic energy consumption is still largely invisible to millions of users and this is a prime cause of much wastage. Feedback on consumption is necessary for energy savings. It is not always sufficient – sometimes people need help in interpreting their feedback and in deciding what courses of action to take – but without feedback it is impossible to learn effectively.

Immediate direct feedback could be extremely valuable, especially for savings from daily behaviour in non-heating end-uses. In the longer term and on a larger scale, informative billing and annual energy reports can promote investment as well as influencing behaviour. Savings have been shown in the region of 5-15% and 0-10% for direct and indirect feedback respectively.

User-friendly display is needed as part of any new meter specification. Monitors would be most useful if they showed instantaneous usage, expenditure and historic feedback as a minimum, with the potential for displaying information on microgeneration, tariffs and carbon emissions (linked to disclosure in the bill of the emissions factor of their supply).

Feedback is of value in itself as a learning tool and must be seen in context. The outcomes from feedback will vary according to circumstances, but they can also sometimes be improved by using feedback in conjunction with advice and information.

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APPENDIX: SUMMARY OF QUANTITATIVE FINDINGS

1: Direct feedback studies

Study	Date	Savings	Persistence	Sample size	Control	Location	Energy source	feedback type	Other change	Comments by authors [and by SD]
Seligman, Darley and Becker	1979	16% against controls for feedback+light or light alone	4-week study, summer	10 with blue light and feedback, 10 blue light, 10 feedback	10	USA	electricity	Flashing light went on as outdoor temperature cooled beyond 68F; feedback 3 times/ week, giving ratio of actual:predicted consumption		The feedback was ignored because it jumped around and did not seem credible.
McClelland and Cook	1979	12%	11 month study, Sep-Jul	25	75	USA	electric, in new, insulated, all-electric homes	Fitch energy monitors with display of cents/hr.	none	Displays 'may have served more to teach residents what activities consume the most energy than simply to draw attention to the cost of energy.' Homes with monitors had lower consumption than controls in all 11 months (Sept -July) with greatest differences in months with moderate weather. Suggests that conservation actions taken by households with monitors primarily affected energy uses other than heating and cooling.
Gaskell, Ellis and Pike	1982	9% from feedback, 11% from fb + info	4 weeks	80 had fb/fb + info	80 had info alone/nothing	UK	electricity	Meter readings	weekly visits, daily diaries	information alone gave 8% saving
Gaskell, Ellis and Pike	1982	5% and 22%	4 weeks	80 had fb/fb + info	80 had info alone/nothing	UK	gas	Meter readings	weekly visits, daily diaries	information alone gave 9% saving
Winett et al	1982	15% against controls for feedback and/or video	3-week baseline + 5-week intervention, winter and summer	85 winter, 53 summer	yes	USA	electricity	Daily, plus weekly visits from experimenters	Videos demonstrating alternatives for comfort	Feedback alone and feedback+video were more effective than video alone. The video showed ways of being comfortable without recourse to overheating or air-conditioning, using positive language.
Hutton, Mauser, Filiatrault and Ahtola	1986	up to 7% over controls, depending on context	unclear	3x25 (I city in US and 2 cities in Canada): ECI + education	3x75: education only, experimental control, blind control	USA + Canada	gas + electricity	Energy Cost Indicator (ECI)	Education materials for 2 groups	Consumer response influenced by situation, eg all-electric homes, extreme weather=high motivation. Quebec, the coldest area, gave strongest behavioural effect and had highest levels of knowledge about usage and savings. 'It does appear that the ECI enhances learning in low-knowledge situations' - California. No evidence from Quebec and BC that the ECI made a significant difference to knowledge about energy-saving actions. For Quebec, ECI+info gave 4.1% savings over exptal control; BC, 5% less increase in consumption than control. In California, only middle-class, educated consumers made savings, 7% over control.
Sluce and Tong	1987	13%	5-month study	31	25	UK	gas + electricity	Fortnightly advice visits including meter readings by adviser	Energy diaries	Low-income households in town houses. All received draughtproofing in the course of the study
van Houwelingen and van Raaij	1989	12% compared with previous; 10% with control; 7% with self-monitoring; 4% with external feedback	1 year experiment. 1 year later, differences between groups ceased to be significant	50	5x 55	Netherlands	gas	Indicator showing daily gas use along with reference figure (agreed norm), adjusted for weather. Signal light to show when heating was on.	None	Supports view that commitment in combination with feedback leads to greater savings than external feedback or self-monitoring alone. Cumulative daily feedback via a display/indicator better than monthly external feedback or self-monitoring. 'People seem to need a permanent reminder and a regular check in their home in order to save energy' [savings lessened when the indicator was taken away]. Interviews with participants showed growing awareness of energy use. Self-monitoring did not work, perhaps because people could not distinguish between weather-related change and other change.
Dobson and Griffin	1992	13% compared with controls and compared with weather-adjusted baseline	a persistence of conservation behaviour... with electrical consumption declining by approx 5% over the 60 days' [for the households with displays]	25, random sample	75, randomly selected	Canada	electricity in all-electric homes	Residential Electricity Cost Speedometer, showing cost on hourly, daily, monthly and annual basis; also breaks down by end-use	No change	A post-test interview indicates that households with the RECS 'began thinking about their electricity usage in ways not possible without specific feedback. Two contacted the supplier for information on heat pumps. The group reported increasing their use of the RECS over the period of the test.
Harrigan and Gregory	1994	26% over controls for feedback+education+ weatherisation. 26% for education+ weatherisation. 14%, weatherisation only	14-month study, then reevaluation in 3rd year. Persistence of 84% of 1st-year savings for the education+feedback+ weatherisation group in year 3, comparable with weatherisation-only group (90%).	47 x 3	39 in yr 1; 13 in yr 3	USA	gas	Energy Log display	Weatherisation+education sessions+ electric DSM measures+ payment plan	No significant difference between education and education+feedback: the difference was between the groups that did or did not have three intensive in-home sessions on energy and money management. The educational focus had been on space and water heating (both gas);
Nielsen	1993	1% (flats), 10% (houses)	3-year study	approx 1500		Denmark	electricity in non-electrically heated homes	meter reading	written information	Savings were low in the flats - relatively low-income householders.
Staats and Harland	1995	27%	savings were measured 6-9 months after the 6-month project was over.	93		Netherlands	electricity	Householders read their meters and compared readings with the others in their 'Eco-team'		Social factors and commitment a key element. Savings persisted/ increased 6-9 months after programme ended. Participants installed more low-energy lights and low-flow showers than Dutch population
Staats and Harland	1995	23%	savings were assessed bewtween Jan-Feb and Oct)	144		Netherlands	gas	Householders read their meters and compared readings with the others in their 'Eco-team'		Social factors and commitment a key element in the Eco-teams
Brandon and Lewis	1999	12% for PC feedback over baseline for those who saved; 3% increase for those who did not.	9 months	120 in 7 groups, including control group	yes	UK	gas and electricity	Written or via the PC	various information materials for some groups	Income and demographics predicted historic consumption but not changes during the study, where environmental attitudes and feedback were influential. The only feedback form the authors are confident about is interactive via the computer (smart metering and household-specific systems may do away with need for a PC).'Visibility may be the key to change.'
McCalley 2000	2000	Up to 21% over baseline, according to experimental conditions.		1	25	Netherlands	washing machines	Simulation using a copy of washing machine control panel	various items of information	Emphasises the importance of goals and social or self-orientation as determinants of effectiveness of feedback.
Wood and Newborough	2003	14% over baseline for ECI only; 12% for ECI+information; 3% for information only	12-month baseline, then 2-months+ for trial of display. No data on persistence after experiment	10 with Energy Consumption Indicator; 10 with ECI+ information pack	12 with information pack only, 9 in no-action control	UK	electric cookers	Direct, through ECI attached to cooker		The use of electronic feedback indicators deserves further attention and optimisation. The units that the ECI displayed were cenbtral to the user being able to understand the display.
NIE	2002?	11% compared with previous usage		former prepayment customers		UK	electricity	Keypad display, pay-as-you-go	no bills; induction/advice	Keypad fitted in room of customer's choice.
NIE	2003?	4% compared with controls	12 months	26 former credit customers	national consumption	UK	electricity	Keypad display, pay-as-you-go	no bills; induction/advice	Keypad fitted in room of customer's choice.
Mountain	2006	6.5% against baseline (adjusted for weather, appliances, demographics)	2.5-year study. Response was persistent across the study period.	505	52	Canada	electricity	Portable monitor with instantaneous feedback, consumption in kWh, $ and CO_2, per hour, in total and predicted		Only 2% of the selected customers refused to have one in their house for the study. Highest savings (16.7%) came from homes with electric WH but not SH (air-conditioning made no difference to this figure) . Separating feedback from the heating load and the rest of the load would be needed to encourage conservation in this sector.'
Benders et al	in press	8.5% over control	5months	137 households, Groningen	53	Netherlands	gas and electricity	Web-based tool, using billing data	information as well as feedback	Quite a high drop-out due to lack of time, computer difficulties, lack of Internet connection. Those who persevered were +ve about the website.

2: Indirect feedback studies (billing)

Study	Date	Savings	Persistence	Sample size	Control?	Location	Energy source	feedback type	Other change	Comments
Bittle, Valesano and Thaler	1979	Mixed effect	2-month study, summer	353	delay group' with no feedback from days 18-28. 16-day baseline study	USA	electricity	6 days/week, historic feedback, 4 types, from the experimenters. kWh/day, cumulative kWh since start of month, cost/day and cumulative cost..		Feedback led to 18% reductions by high consumers but had opposite effect for some med and low consumers. Baseline study was not a true baseline - it involved experimenters coming to the house to read the meter.
Seligman, Darley and Becker	1979	10%	3-week study, summer	15	14	USA	electricity	Almost daily from the experimenters, giving ratio of actual:predicted consumption		Providing homeowners with feedback about their rate of consumption can be an effective strategy for conservation.
Seligman, Darley and Becker	1979	13%	4-week study, summer	80 in 4 groups	20	USA	electricity	3 times/week from the experimenters	householders asked to set a difficult or easy conservation goal	Feedback especially effective if the homeowners are motivated to save a considerable amount of energy. Controls also had a notice in their kitchen window that was ticked each time the meter was read - ie, likely Hawthorne effect.
Arvola et al	1994	3% against controls for feedback; 5% for feedback+ advice tips	2 year study	525	175	Finland	all-electric	Bills every 36 days; in the 2nd year, historic feedback was added to the bills.		Frequent billing seemed to have the largest single effect. The experiment had most influence on families with lower incomes and those with high baseline consumption.
Garay and Lindholm	1995	A 'tendency of red. consumption in electrically heated homes', but an inc in district heating. .	15 month project	600	600	Sweden	electricity+ district heating	Monthly bill with measured energy use + historic and comparative feedback		Through interviews, discovered that the new bill improved householders' control over their energy costs. 96% satisfaction. Treatment and control groups were not similar enough to give good comparisons.
Haakana et al	1998	7% over internal controls	2.5yrs after end of study, almost 1/2 h/holds still making savings. Monitoring still frequent; most freq in h/holds which had made savings.in electricity and water.	105		Finland	electricity, no electric heating	H/holds sent monthly form with meter readings. Utility sent monthly comparative+ weather-adjusted historic feedback .		Advice after feedback had no further effect. The 7% may be an underestimate - it comes from comparing monthly consumption from Dec-March with monthly consumption April-November.
Haakana et al	1998	4-5% over blind control	2.5yrs after end of study, almost 1/2 h/holds still making savings. Monitoring still frequent; most frequent in h/holds which had made savings.in electricity and water.	79 with fb	26 w no fb or info; 650 blind controls	Finland	gas	H/holds sent in mnthly form from meter readings. Utility sent monthly comparative+ weather-adjusted historic feedback.	advisory material as requested - video or written - for 2 exptal gps.	Savings were not necessarily according to the written advice recd.Internal controls made almost as many beh changes as exptal gps. Type of (video, written. Meter) made no diff.
Wilhite and Ling	1995	10% over controls	3 years. 'our impression from interviews is that after 3 years the changes people made had become so routine that they had trouble identifying them.'	191 with frequent bill;209 with feedback; 211 with feedback+tips	675, matched for ownership status, size of home and stage in family cycle	Norway	electricity	6 bills/year based on meter readings, with simplified text and a graphic showing each period compared with the previous year, temperature-corrected.		Wasteful habits linked to misunderstandings about where energy is used in the home. Recipients of the new bills paid more attention to them, were more likely to discuss them and wanted to continue with the new system. Costs minimal in relation to savings - about $0.01/kWh saved. A small amount of saving may have been achieved by fuel-switching. Younger customers more likely to reduce consumption than older.
Wilhite	1997	8% (see next column)	The project ran from March 1995-Dec 1996. In April 1998, consumption of the participants had fallen by 4% compared with baseline, while that of customers in surrounding areas had risen by 4% (Wilhite, pers. comm).	2000	comparison made after the study was over	Norway	electricity	Customers read their meters and sent in the figure to the utility, every 60 days. After a year, they were sent historic feedback.	transfer of meter-reading from utility employee to customer	Good results in terms of customer satisfaction and loyalty. 18% more customers read their bills often or always; 19% more were satisfied with the information; 20% fewer of the younger customers said they did not know whether their consumptioh had changed over the past 2 years; 8% more customers reduced temperatures at night. The costs of billing doubled but the supplier expanded the recipient group from 2000 to 25,000 households in 1997.
Henryson et al	2000	0, 2, 2, 3, 2-4, 10 and 12%		7 studies, samples of 600-1500 inc. Wilhite&Ling		Scandinavia	electricity	Increased energy awareness and customer satisfaction in 6 of the 7 studies. One reports that increased information did not change attitudes.	With and without additional information	The longer the duration of a trial or the larger the quantity of information, the more prolonged the effects.

3: Electricity feedback with time of use pricing

Study	Date	Savings	Sample size	Control?	P:OP ratio	Location	feedback type	Comments
Kasulis et al	1981	some rescheduling of consumption	30			USA	written, with bill: use + cost, peak and offpeak	Participation was mandatory
Sexton et al	1987	26% savings at peak when p:op at 9:1	480	120	various	USA	monitor showing peak, offpeak and total consumption	Customers were informed that the exercise was to do with load-shifting, not conservation
CPUC pilot of DR to CPP with sms cited in Owen and Ward	2003-4	27% peak reductions with automated response at highest CPPs to 5-10% without automated response				USA		Information about peak periods without a price signal gave no savings. No impact on overall demand - just shifting. Though an IEA study cited, which showed 4% average conservation effect
Crossley for IEA, cited in Owen and Ward	2005	12-14% peak reductions	1200					
NIE	2005	11% reduction in evening peak when price signal is applied	100 price message gp - 4 keypad ToD bands+ 3 tariffs	100 - 4 keypad ToD bands + flat tariff	5.8p:8.6p: 15.4p	UK	keypad display	93 in each group finished the trial. Best prospects for load management = wet appliances (12%). Also lighting at 24%. Functionality of meter has changed little - just added display giving real time cost data.
Puget Sound Energy (from IEA DSM subtask 2)	2005	5% peak reduction	300,000		14 Euro-cents, reduced to 12 after a year	USA		Customers left the programme when the P:OP ratio was reduced and they realised they were paying slightly more by participating than they would by not participating.
Gulf Power Company (from IEA DSM subtask 2)	2005	22% reduction against controls at peak periods; 37% in critical peak periods	3000		8:5, with CPP = 3x peak price	USA		Customers were given a thermostat that could be programmed to control their major end-uses when prices exceeded a preset level
SWALEC (in IEA DSM subtask 2)	2005	25% reduction in peak - enough to avoid reinforcing a rural distribution network	100+			UK		Demand control algorithm scheduled charge and release of energy from storage heating based on half-hourly price message 24 hours ahead. No customer override - but acceptable to customers. Could not be used with profile settlements and was not rolled out because of additional cost needed for TOU metering and processing of the data.
Martinez and Geltz	2005	some overall reduction	32 residential, 29 commercial		up to 4:1	USA	ambient - the Energy Orb. Notification the day before a Critical Peak Pricing event	4-month trial. Many reduced consumption well in advance of peak pricing time. Resdential customers more interested in real-time information than commercial