Energy feedback in buildings: improving the infrastructure for demand reduction

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The concept of market transformation is being widened to include a range of processes, including information flows. The paper argues that feedback to energy users on their consumption (via improved metering, billing and displays) complements other tools such as energy labelling and minimum standards, increasing the likelihood that decisions on built fabric and equipment will be grounded in the realities of daily usage. Different types of feedback to energy users, mostly in the residential sector, are considered for their impact in the short- and long-term. Implications are examined for energy policy in relation to feedback, including the relative importance to different actors of load control and demand reduction, as well as the question about how priorities should be set in debates over the future of metering.

Keywords: behaviour, billing, demand management, feedback, inhabitants, intelligent buildings, market transformation, metering, socio-technical systems

Energy demand and energy information

Technologies and materials are available that can dramatically reduce the energy demand from buildings in temperate climates and many of them, such as improved building insulation and more efficient cold and wet appliances, have been deployed for some time and are becoming more prevalent (Boardman et al., 2005; Utley and Shorrock, 2006). Yet aggregated energy statistics for Organisation for Economic Co-operation and Development (OECD) countries rarely show a decline in the overall delivered energy. In the UK, for example, overall delivered energy to homes has remained roughly stable between 1996 and 2006, with residential electricity consumption rising by 8% during that period (Department of Trade and Industry (DTI), 2007a). There is a mismatch between expectations for energy efficiency and outcomes, all the more serious because a failure to stem growth in fuel consumption and carbon emissions is not something that can be managed solely by recourse to supply-side
solutions and carbon sequestration. This is recognized in current policy documents: for example, direct demand reduction (including energy efficiency) accounts for 37–47% of the estimated drop in carbon emissions between present and 2020, with supply-side developments (including carbon capture and storage) accounting for only 3–9% (DTI, 2007b, table 10.1).

The growth in the numbers of households is an important factor in cancelling out efficiency gains. But there are many other factors driving up demand, such as changing perceptions of what constitutes thermal comfort and desirable lighting, along with the proliferation of consumer electronics (Shove, 2003; Boardman et al., 2005; Boardman, 2007; Cole et al., 2008; Shove et al., 2008). Many studies over the past few decades have pointed out the importance of including social and behavioural considerations in the analysis of energy use in buildings (e.g. Sonderegger, 1978; Palmborg, 1986; Dall and Toft, 1996; Bin and Dowlatabadi, 2005), leading to the view of energy systems as socio-technical in nature, both socially constructed and society shaping. In such systems, information plays a crucial role.

At the simple end of the spectrum, an energy system may comprise a source of wood that is maintained by hand, a fireplace and a residue of ash that can be used as fertilizer. The scale of the woodland resource, the management regime, the comfort requirements of the energy users, and the type and number of fireplaces will all have an effect on final consumption, but it will be relatively easy to establish how the system works and to see the entire fuel cycle in action. In an industrialized society, though, it is far more likely that energy needs will be supplied by gas or electricity travelling long distances through a complex transmission and distribution network, with the associated management systems. There will be many end-users with a wide range of equipment and appliances; there will also be the rules by which they and their suppliers act, whether explicit or implicit (Wilhite and Shove, 1998; Marvin et al., 1999; Lebot et al., 2005). Few people understand such systems in their entirety and they are not designed to be clear to the end-users. For example, day-to-day usage of domestic central heating controls reveals how designers and users of the controls fail to understand each other (Bartram et al., 1985; Leaman, 2000; Pett and Guertler, 2004). This matters because design, testing and installation of the controls can ‘write the script’ for energy wastage or for thrift. Yet testing of controls typically takes place in standardized surroundings rather than in real-life situations, while heating installers are often not well suited to prepare householders for life with a new system. An example is given by an energy adviser who described what he called ‘plumber setting’ – the situation that he and colleagues had often observed after a plumber had installed a new central heating system:

... The hot water tank thermostat will be at 90°C, boiler thermostat will be at Max. ... [Plumbers have] got to check everything before they go. ‘So we’ll test it at High. And we’ll leave it at High. Put the heating on Constant, put the water on Constant and if it’s too hot, Missis, turn it down. And if it’s too cold, turn it up.’ And they walk away. ... The tenant thinks the [thermostat] on the wall is an on-off switch, which leads to over-heating, under-heating, over-heating. ... (interviewed in Darby, 2003, ch. 7)

Installers do not normally stay around to see the effects of their handiwork and advice (and neither do they wish to make return visits); once the controls are in use, the outcomes are not fed back adequately to designers and installers so that they can make realistic improvements.

There are continuing failures to design ‘reality checks’ into buildings in order to inform energy and climate policy. Post-occupancy evaluations – a rare phenomenon – point to the need for ‘a culture of feedback with better benchmarking and constant review against client and design intentions’ (Bordass et al., 2001, p. 144). Such evaluations can be used in the short- and long-term, to inform day-to-day behaviour of the people using a building and to improve design, materials, construction, installation and commissioning practices (Bordass and Leaman, 2005). There are also strong arguments for improving the infrastructure of metering and/or billing in order to promote better understanding and control (Williams et al., 1985; Henryson et al., 2000; Strengers, 2008). As a first requirement, all households need their own meters: a shift from master-metering to individual metering or submetering can lead to reductions in demand of the order of 30% (Lutzenhiser, 1993). Second, there is plenty of room for more visible, accessible information on energy use, in real time and retrospectively; some of the evidence for such feedback information as a tool for energy literacy1 and changed behaviour is discussed below.

This paper argues that it is reasonable to think of improved feedback through energy systems as an element of market transformation in buildings, and that the formal incorporation of feedback arrangements into policy (for example, in the recent European Energy End-use Efficiency and Energy Services Directive (EC, 2005)) is a welcome development. It looks at some options for developing the feedback infrastructure for energy in buildings, at the interests of different actors and the issues raised, and concludes with some policy recommendations.
Market transformation

There does not seem to be a single accepted definition of market transformation, but it is acknowledged as a strategic approach to energy policy that embraces several elements. An early reference to the concept describes the task of transforming the market for cold appliances in the European Union as a mix of initiatives, comprising information and advice (including product labelling), financial incentives, procurement, and minimum standards (Boardman et al., 1995, appendix D).

The concept is being developed in various contexts. One example is the market transformation strategy of the California Energy Commission, which emphasizes continual learning, with new initiatives piloted and evaluated in an iterative manner. It aims to build knowledge about regulatory dynamics, organizational networks, business practices, consumer–vendor interactions, and other physical and relational aspects of changing markets (Blumstein et al., 2000). In the UK, recent work carried out for the Market Transformation Programme proposes a redefinition of market transformation as:

a detailed process of transforming the rules, resources and institutions that mediate between lifestyle goals, commercial interests and social policy goals. (Jackson, 2005, p. 40)

This makes market transformation a broadly-based project for energy policy, going beyond what are usually considered to be ‘market’ considerations. How valid is it to incorporate feedback information flows into the project? There is a case for doing so because such flows affect both the physical and the relational aspects of markets; they are part of the process of transforming ‘rules, resources and institutions’. Arguments for the significance of feedback in the short- and the longer-term are summarized below and rehearsed in more detail elsewhere, as indicated in the references. But before looking at the scope for developments in feedback, the next section defines and discusses some terms related to energy feedback, gives a little theoretical background, and indicates the range of mechanisms available to end-users.

Energy feedback to end-users: some general considerations

‘Feedback’ is:

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, s.v.)

The term can, of course, be used in relation to purely mechanical or electronic processes (for example, heating, cooling and ventilation systems in buildings will normally rely on feedback mechanisms), but here it is used in connection with systems that directly involve humans. In a ‘building–energy–user’ system, feedback can be received in a number of ways. For example, what is on view (on a meter or on an associated display); what a bill or statement shows and how it is interpreted; or what energy users perceive as changes in comfort or satisfaction from their energy services, following changes in building fabric, equipment, or behaviour. This last may not show up in statistics but will inevitably affect the acceptability of attempts to reduce demand.

While a surprisingly high proportion of residential energy users may check their bills and meters, the quality of feedback from these is usually very limited (Kempton and Layne, 1994; Darby, 2006a). Meters typically only show a series of digits or dials representing cumulative consumption, while bills and statements are very unlikely to disaggregate consumption by end-use, even in the most general way. Individuals paying for fuel by direct debit spread their payments evenly over the year with no indication of how heat load or lighting consumption vary with time. Bills based on estimated consumption prevent customers from having realistic data on which to base decisions about their behaviour and purchases.

Yet the literature on energy feedback and conservation (and, increasingly, the literature on building management and emissions reduction) points to the importance of accessible, specific information in building awareness of consumption in order to experiment and to manage it more effectively. Feedback on its own is not always sufficient to bring about change, but it is necessary for this learning process (Darby, 2006b). There is ample scope for learning in the average home, where there is huge variability in terms of the acquisition, default setting and day-to-day use of heating systems and appliances, and where ‘behaviour’ is central to consumption levels (Lutzenhiser, 1993).

A relatively new consideration is the potential for feedback on building-integrated electricity generation. A recent study of system change for domestic micro-generation in the UK concludes that the advent of microgeneration is an ‘ideal opportunity to kick-start the modernisation of the UK’s meter stock …’. (Watson et al., 2006, p. 3). More advanced metering does not in itself guarantee effective feedback to consumers (see below), but it does offer an opportunity to improve it, if ‘smart’ meters are deployed along with effective displays. Advanced metering can also facilitate feedback on consumption and generation at the same time, to give...
householders an overview of what is happening from moment to moment. There is already some evidence that building-integrated electricity generation, especially when installed with feedback displays, is associated with demand reduction as well as with building awareness about generation (e.g. Keirstead, 2005; Dobbyn and Thomas, 2005). Own-generators will require metering for overall consumption, on-site generation and exports if they are to have a clear picture of what is happening in their premises and if they are to be able to take part in wholesale electricity markets (Keirstead et al., 2006).

The range of savings achieved through feedback-related innovations points to the significance of the mode, content, and timing of feedback in promoting learning and change. It also means that there is a need for thorough testing before widespread adoption of a particular application. From the literature to date, though, energy savings of the order of zero to 10% have been achieved when householders were given better indirect feedback (usually billing or statements), and of 5–15% from direct feedback (via the meter or an associated display). The variation in savings has also been attributed to factors such as social and cultural context, the characteristics of the households sampled, climate, and housing type (Wood and Newborough, 2003; Darby, 2006b; Mountain, 2006). The few feedback studies carried out over a year or more show that participants did not just change their behaviour in the short-term but formed new habits (Darby, 2006b). The shorthand way of describing this is to say that the ‘savings’ persisted in comparison with control households.

At this point, though, it is worth questioning the use of the term ‘savings’ in the policy debate. However appropriate it might be when considering short-term changes, it loses some of its usefulness over longer time periods. For example, if a household uses 10% less fuel than its neighbour in 2006 following some intervention or specific change in the energy system, and is still using 10% less fuel than the neighbour in 2012, but more fuel than in 2006, does that represent a continued ‘saving’, or a failure to learn from the intervention or change? Both, presumably, but the latter is likely to be more significant than the former in the long-term. It is arguably more productive to think in terms of transformation to a low-fuel, low-carbon way of life than to centre the debate on ‘savings’, which so often turn out to be steps taken down an upward-moving escalator. The ‘learning’ aspects of any planned change in the system need to take a more central place in the evaluation of its effects.

Interpretations of feedback from psychology and learning theory

The early experiments with feedback on energy consumption in the 1970s were mostly conducted by psychologists and concentrated on immediate responses to what was seen as a ‘stimulus’ or ‘intervention’, but over time they became more ‘ecological’ in nature, being carried out in more easily-replicable conditions, on longer timescales, with more participants and with due attention to the need to minimize possible ‘Hawthorne effects’ (that is, of participants behaving differently because they know they are being observed).

There have also been changes in terms of interpretation of the significance of feedback. After a few years of experimentation, researchers began to appreciate that feedback has an educational impact as well as directly behavioural effects (Ellis and Gaskell, 1978). This is backed by educational theory that argues that individuals find ways of adapting themselves to their environment, and of shaping that environment, by using feedback (Piaget, 1972; Wadsworth, 1996).

Both learning theory and psychology have been used to give pointers about how energy feedback ‘works’ (Darby, 2006a). They support the proposition that improved feedback will not just produce short-term results but will alter the way in which people think of energy, control usage, and are able to adapt to changes in energy systems. That is, it will have impacts on the development of these systems by allowing energy users to experiment and develop their own methods of energy management, based on data that are specific to them and that they trust. It allows them to interrogate their own ‘building–energy–user’ system: ‘What happens if I turn the thermostat up a degree/insulate the walls/switch off the computer whenever it is not in use?’ A number of possible channels for energy feedback are discussed briefly below, in relation to recorded outcomes and potential for learning.

Informative billing

Informative billing is billing that is accurate (based on readings rather than estimates), frequent, and that provides useful information in addition to total consumption and cost over the billing period. This may include a comparison with previous periods (historic feedback), or comparison with other energy users (comparative feedback). Bills can be adapted to show trends graphically, such as how heating demand is spread over the year. They can show how consumption has changed relative to the same period of the previous year, giving the energy user the opportunity to work out what might have caused the change, such as new patterns of occupancy, a new boiler or appliance, insulation or an extension to the building. Bills can also include annual ‘energy reports’, or give a breakdown of how consumption is distributed between end-uses in an average home. For useful overviews of the issues, see Roberts and Baker (2003) and Iyer et al. (2006).
The most comprehensive informative billing studies to date are those carried out in Norway during the 1990s, which gave savings of 10% relative to a control group by those with more frequent and accurate bills, which were maintained over at least two years (Wilhite and Ling, 1995). A second, larger study, in which 2000 customers telephoned in their meter readings six times a year as the basis for accurate bills with historic feedback, was showing savings of 8% over a control group, more than a year after the end of the experimental period, accompanied by increased energy awareness (Wilhite, 1997). The learning from these trials extended beyond the households and the utilities to government, when the changes in procedure (more frequent meter readings and the insertion of a feedback graph into the bill) were institutionalized as mandatory quarterly informative billing for the whole of Norway. A further development in Scandinavia has been the Swedish regulatory requirement for monthly, accurate bills for all customers by 2009, which is now driving the business case for automated meter reading (Siderius and Dijkstra, 2006).

**Advanced metering and displays**

The term ‘advanced’ or ‘smart meter’ is used to cover a range of meter specifications, but it is generally accepted that smart meters are able to measure consumption over representative periods to legal requirements, store the data for multiple time periods, and allow ready access to data by consumers as well as suppliers and their agents (having two-way communications and allowing automated meter reading). The interface between consumer and supplier is a crucial component of the system, affecting the extent of learning and control by either. There is the potential for smart electricity meters to be used by the supplier for direct load control, for example, by switching off water heaters or freezers for short periods at times of peak demand; or they can be used to enable householders to manage load themselves, in response to signals from the supplier – an ‘interval’ electricity meter can store and communicate consumption data by time of use, paving the way for more complex tariffs designed to reduce peak demand. Customers can be incentivized to shift their consumption away from peak times, being informed via a display about when those peak times occur and what their rate of expenditure is at any point during the day. Owen and Ward (2006) cover these and many related issues in their assessment of costs and benefits of smart metering in the UK.

*Internet metering* combines the functionalities mentioned above with the ability to communicate with the Internet, allowing online transactions and related services.

It is important to note that the demand for smart metering came in the first instance from energy suppliers, not from their customers: it has been developed primarily as a tool for load management/peak reduction, and for reducing the costs of customer service, rather than for overall demand reduction. Some of the claims made for it need to be treated with caution: so much depends on design and implementation. However, advanced metering makes accurate, frequent billing much more viable and so it improves the prospects for better billing feedback. If the customer interface (display) allows, it can also improve the prospects for demand reduction from direct feedback.

Direct displays\(^3\) are typically small panels giving information about electricity consumption (although multi-utility displays are now starting to appear and a gas display was first developed some time ago for the study described in Van Houwelingen and Van Raaij, 1989). They can be used in conjunction with both advanced and standard (‘dumb’) meters and are developing rapidly at the time of writing. ‘First-generation’ displays show real-time consumption (or own-generation); the second generation also gives historic information over specified time periods; and the third generation has web interfaces, allowing for a wide range of interrogations, access to advice, and membership of user groups. They are designed to answer questions varying from the simple ‘How much electricity am I using right now?’ and ‘Have I left anything switched on as I leave the house/go to bed?’ to the more complex: ‘Are we consuming more today than yesterday?’, ‘More this month than last month?’; ‘How does our in-house generation compare with our consumption?’, ‘How much are we exporting to the grid?’ and ‘How much are we consuming compared with other households?’ Consumption may be indicated in terms of kilowatts (kW), cost or carbon dioxide units. Some displays can be programmed to show an alarm when the electricity load in the building exceeds a given level, or if credit is running out.

Displays do not have to show consumption or generation in the form of numbers, although that is the most common mode. There have been experiments with analogue display and with *ambient feedback*, showing consumption or current cost (for time-of-day pricing or critical peak pricing) through the colour of a light or the size of a graphic (Lockwood and Murray, 2005; Martinez and Geltz, 2005).

**Pay-as-you-go metering**

This can be seen as a transitional form of metering, between the ‘dumb’ and the fully ‘smart’ meter. An example is in operation in Northern Ireland, where there are now over 155 000 residential customers using keypad meters, a ‘pay-as-you-go’ system (Office of Gas and Electricity Markets (Ofgem), 2006). The keypad meter has the benefits of being portable and programmable with new tariffs. It replaces the old
prepayment meter, but has also been taken up by many former credit customers. Customers buy electricity using a plastic card at a local shop or filling station, or via their debit card over the telephone. They then key in their code on the key pad, which displays how much electricity they have bought and the total credit. There is some protection against self-disconnection, with an alarm when credit is close to running out and an emergency supply that can be extended if it runs out during evenings or weekends. The meter can show instantaneous electricity usage and give historic feedback, showing how much has been spent on electricity during the previous day, week and month. Some meters display the previous 13 months’ usage (Northern Ireland Electricity (NIE), 2001) and a ‘power-shift’ option now also allows for time-of-use pricing (NIE, 2006). Ninety per cent of a sample of 500 customers stated that the meter helped them to manage their consumption better (Consumer Council, 2005); an earlier survey showed electricity savings of 4% among customers compared with the previous, pre-keypad, year (NIE, 2003). The comparable Salt River Project in Arizona, US, claims savings of over 12% among its pay-as-you-go customers (American Council for an Energy-Efficient Economy (ACEEE), 2007).

Collective feedback
During the California electricity supply crisis of 2000, the Lawrence Berkeley Laboratory set up a website with a graph of current demand and available supply for the whole region. It was widely consulted (with up to two million hits a day) and credited with increasing the level of energy-conserving behaviour (LBNL/ceeee, 2001). Now this has been extended to http://current energy.lbl.gov/, which shows real-time demand in six areas of the US along with forecast demand, net electricity imports, and the potential cap on load. This makes it possible for all online consumers to see the ‘big picture’ easily and quickly, taking feedback to a new level. Through this type of feedback, individuals can see themselves graphically as agents in a complex, dynamic energy system. A similar action is reported from the Western Cape in South Africa, where electricity customers are shown a colour-coded bar on their television screens every 15 minutes during periods of tight supply margins and are asked to turn off appliances according to the likelihood of blackouts (Gosling, 2006).

The impact of feedback on relationships within energy systems
The above descriptions show something of what is already possible in terms of transforming the ‘information infrastructure’ of energy systems. The relationship between suppliers and consumers is also changed by altering the type and quantity of information passing between them; each technical specification for a metering system will have its own impact. For example, a conventional meter allows for monitoring and a ‘limited’ relationship, whilst a smart meter with an interactive display can allow greater user control and a more ‘devolved’ relationship with the utility (Marvin et al., 1999). Table 1 summarizes some characteristics of advanced metering, indicating how the benefits may be distributed.

Feedback and the European Union Energy Services Directive
The European Union Directive on Energy End-use Efficiency and Energy Services (often referred to as the Energy Services Directive, or ESD) was signed in May 2006 with the stated aims of improving the efficiency of energy markets, managing demand, contributing to environmental objectives and improving energy security.

The preamble to the Directive broadens the concept of energy-efficiency measures to include the metering infrastructure:

In defining energy efficiency improvement measures, account should be taken of efficiency gains obtained through the widespread use of cost-effective ... innovations, e.g. electronic metering.

(preamble, para. 28)

and specifically aims for well-informed decision-making by consumers:

In order to enable final consumers to make better-informed decisions as regards their individual energy consumption, they should be provided with a reasonable amount of information thereon ... consumers should be actively encouraged to check their own meter readings regularly.

(preamble, para. 29)

In this way, the familiar concept of energy efficiency is extended in a way that has already been seen in the extension of the concept of market transformation. Not only does efficient technology need to be promoted: the people responsible for energy end-use need to have the information to manage their technologies more effectively and they need the infrastructure that will allow for that. But the document stops short of moving from the language of efficiency (a ratio) to the language of demand reduction (an absolute). And, judging from the content of the many conferences held over the past few years on the theme of advanced metering, utilities are mainly interested in the potential for smart metering to assist in reducing peak electricity
demand, to reduce the costs of billing and customer service operations, and to allow movement into new areas of business. The relationship between these objectives and that of overall demand reduction is still uncertain as utilities prepare for massive investments in new metering and billing and as they watch the progress of those who are already implementing major changes. Article 13 of the Directive gives some guidance, requiring that:

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.

Member States 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;

Comparison 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 normalized or benchmarked user of energy of the same user category. . . .

However, while Article 13 requires accurate, frequent measurement and billing, information on time of use, and clearly presented feedback information, it still leaves considerable room for interpretation. Judgements on technical possibility, potential energy savings and ‘reasonable’ cost are left to Member States, which were given two years within which to enact their own legislation in compliance. That period is almost over at the time of writing, but there is still plenty to resolve.

Policy issues

The extent to which regulators should hold utilities responsible for improving feedback to their customers and reward them for any savings attributable to such improvements is still under intense discussion. More generally, there is increasing debate about the role of suppliers in relation to their customers – ‘consumers’, some of whom are becoming ‘co-generators’ – and about the acceptable uses of new technologies. For example, how much power should an electricity

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<td>Function</td>
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| Automatic meter reading | Supplier: reduces the cost of reading, enquiries, complaints and call outs  
Energy user: more accurate bills, not having to be available when the meter reader calls |
| Analysis of data and local display | User: improved understanding and control, partly dependent on the quality of display |
| Transfer of consumption data to the supplier for accurate billing without requiring access to the home | User plus the supplier |
| Facilitating payment | User plus the supplier |
| Measurement and recording of data on continuity and the quality of supply | District Network Operator (DNO) plus the supplier |
| Remote control of consumer circuits or equipment for agreed load management | Supplier: who pays less for peak-load generation  
Users: should also benefit from reduced tariffs |
| Display of price signals for different time periods as part of demand–response/load-control programmes | Supplier: who can facilitate load management; there might be equity issues for customers; also confusion by multiple tariffs |
| Remote change of tariff, debt or other rates (if allowed by the regulator) | Supplier: primarily |
| Remote disconnection and reconnection | Supplier: primarily (contentious) |
| Measurement of electricity export and/or generation from the building | User plus the supplier plus the DNO |
supplier have to control load, change tariff or to disconnect customers remotely? Who should have access to detailed information on consumption: are advanced meters, in effect, ‘spies in the home’? The technical specification of metering systems and their associated communications, the subject of so much urgent debate, is far from being socially neutral.

A further set of issues centres on the distribution of quantitative risks and benefits from implementing different types of metering (for an overview for the UK, see Owen and Ward, 2007). As the technology for implementing more complex pricing regimes becomes widely available, there is debate about the amount of ‘shiftable’ load and the distribution of risk between supplier and customer in paying for electricity generated at different times of day at varying marginal cost. There is a risk of confusing customers with a plethora of competing tariffs, and there are also equity concerns: is the ability to shift load linked with income in any consistent way? How does time-of-use electricity pricing affect demand and the ability to pay in all-electric buildings, especially as these are often the homes of customers on low incomes?

These are some of the main concerns from the customer’s perspective, but there are further difficult decisions to be faced by government and suppliers in planning for gas and electricity distribution in the future and for the integration of renewable supply into networks. There is also the need for clear standards for smart meter interoperability in liberalized markets, so that customers can switch supplier without needing to change their meter. Should the aim be for single or multi-utility meters? Where should the ‘smartness’ (the communications technology) reside – in the meter or alongside it? The more liberalized the market, and the more complex the technologies involved, the greater the need for clarity.

In all this it needs to be remembered that feedback systems for demand reduction do not have to be complex to be effective. The basic requirements for good information flows through an energy system, for a better understanding of the system by end-users, and above all for continuing demand reduction, are in danger of being lost in the arguments over equipment specification.

Summary and conclusions
Large energy systems are highly complex and the concept of market transformation is developing to reflect this fact, including infrastructures of demand and the ways in which these are configured and adapted. The paper has concentrated on information infrastructures, with an emphasis on improved feedback on energy use to gas and electricity consumers and to own-generators. The literature indicates significant demand reduction in the short- to medium-term and a continued ability to develop energy literacy in the longer-term. The latter is the most important ‘transformational’ characteristic of feedback.

However, there are many issues related to the extent to which feedback technologies can be used to control energy end-users or to empower them. The European Union Energy Services Directive is an example of a policy move towards improved feedback, but it offers a wide scope for interpretation. There is still much to be done to ensure that feedback to end-users is recognized as part of market transformation – not only as a method of achieving ‘savings’ – and that it effectively complements other policy tools such as energy labelling and minimum standards that apply at the design stage and at point of sale or point of lease.

If there is a single salient lesson from experience so far, at this stage of the debate it is that feedback does not need to be complex to be effective. There is a danger that the debate over the future of metering, with all its complexity, overshadows the need to test and build up feedback mechanisms as and where possible, with a view to incorporating them within smart meter systems as these evolve.

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References


Endnotes

1. Energy literacy is: ‘a dimension . . . reflecting different patterns of beliefs and knowledge about energy conservation . . . [those with low energy literacy] lack the decisional freedom typical of the more energy literate, who through greater knowledge have more options available with which to respond to new situations’ (Gaskell et al., 1982, p. 2).

2. A number of trials are under way at present, and findings are being collated by the European Smart Metering Alliance.

3. While the term ‘smart meter’ is often used to describe a display, it is important to note that the two are not the same.