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Re-materialising energy use through transparent monitoring systems ☆

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ABSTRACT

This paper reviews the effect of transparent energy monitoring systems on the purchasing, production and energy use behaviour of consumers and producers. Relevant literature is explored on the linkages between feedback, risk and responsibility, knowledge, economic drivers, and sustainable energy consumption. Drawing on international as well as UK-specific experiences, the paper focuses on the prospects for current and future energy monitoring systems to 're-materialise' energy use in economic and environmental terms that are more meaningful, and thus more behaviourally significant, to a substantially wider range of energy users than today's. Appliance labelling, smart metering and carbon footprint analyses are explored as case studies.

1. Transparent energy monitoring: current issues and pathways to success

The need to engage the public in mitigating climate change through a shift to less energy-intensive lifestyles has never been more urgent. The recent Stern report estimates that if current emissions trends continue, average global temperatures are likely to rise by 2–3 °C within the next 50 years (HMT, 2006). Domestic emissions form about 30% of the current UK energy footprint (Defra, 2006) and offer significant potential for carbon reductions. The Government has recognised the importance of reducing the energy draw from the domestic sector in recent Climate Change Programmes through measures such as supply-side Energy Efficiency Commitments. However, it is becoming increasingly apparent that some sort of intervention in consumer demand for energy may also be necessary to reduce the environmental impacts of domestic consumption (Darby, 2001; Fawcett et al., 2000).

Encouraging energy conservation will not be easy. By its nature, 'energy' is an abstract and invisible force that is conceptualised or commonly defined in a number of different ways, for example as a commodity, as a social necessity, as an ecological resource, or as a strategic material (Sheldrick and Macgill, 1988, p. 563). The invisibility and abstract nature of energy is particularly relevant for the domestic sector, in which the effect or extent of energy use is not always readily apparent in the form of chimneys belching smoke or myriads of office windows lit against the night sky. Research shows that many consumers exert considerable effort to understand their energy use levels from the information that is available to them on energy bills or meters (Kempton and Layne, 1994). However, it may be difficult for the average consumer to connect their daily activities to energy use levels and energy expenditure without more transparent cues to energy use. Recent research on the relationship between social practices, lifestyles, consumption and the environment (Burgess, 2003, Gilg et al., 2005; Hobson, 2002; Shove, 2004) suggests that environmentally significant behaviours should be understood as relatively inconspicuous actions performed in the context of everyday life. In this sense, the environmental effects of energy use may be doubly invisible to the domestic consumer. The impact and amount of energy use are not readily apparent, or are largely abstract concepts, and it may be difficult to link these values to daily energy-using activities. We will return to this idea, and its significance for the potential of transparent energy monitoring systems, in more detail in Section 5.

In the discussion that follows, we review the achievements of a selection of current appliance labelling programmes and then explore the potential of emerging technological advancements in smart metering and carbon labelling and analysis. Impacts on the consumer, in terms of ergonomics, behavioural effectiveness, perceived transparency and other factors are explored alongside producer buy-in and environmental benefits. We conclude with a discussion of the key issues associated with advances in information technology and consumer energy use behaviour.

2. Energy labelling for appliances: current programmes and achievements

Energy labelling for white goods and appliances is the most common and well-established form of energy monitoring and

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display for predicted energy in use. The format of energy labels varies by country and by product category. But, in general, energy labels take either an endorsement (seal of approval) or comparative (ranking or scale) form. Whatever the specific format chosen for a label, it is important to recognise that it conveys much more than an evaluation of cost or energy use to the consumer. 'Labels are not just messages about a product or a service, but *claims* stating that it has particular properties or features' (de Boer, 2003, p. 255). These multi-faceted claims not only affect the choices consumers make at the point of sale, but can also encourage manufacturers and retailers to produce and stock more efficient products, so that labelling schemes have important supply-side influence as well as affecting consumer behaviour (Weil and McMahon, 2001).

2.1. *Criteria for success*

Energy labels are an important point-of-sale source of consumer information about the hidden costs of white goods or appliances over their useful life (de Boer, 2003). But they must compete for attention with a variety of other informational and experiential information sources such as media advertising, word of mouth and education programmes (Caswell and Padberg, 1992). Consumers have a limited cognitive capacity for processing information relevant to purchase decisions (Magat and Huber, 1988) and tend to use information 'shortcuts' to make on-the-spot decisions (Anderson and Claxton, 1984; Hutchinson and Alba, 1991).

It is generally recommended that labels should be credible, should be applied to every product in a particular range of appliances so to avoid free-riding, and should be easy to understand and eye-catching (Boardman, 2004; Paulos, 1998). Labelling energy use in both monetary and energy-based terms can be an effective method of connecting energy use to familiar measurements from everyday life, and helps meet many of these criteria (see Anderson and Claxton, 1984, for a thorough discussion of this idea). Our review of literature on energy and appliance labelling reveals several examples of successful energy labelling programmes in action around the world. Most notable among these are the US Energy Star Programme, the EU Energy Label scheme and the Australian Energy Label, which are summarised below.

2.2. *Energy labelling programmes in action*

The voluntary US Energy Star labelling programme was initiated in 1992 and now covers a wide variety of energy-intensive products, including office equipment, windows, refrigerators and houses, which incorporate energy-saving settings or features. Energy Star-labelled office products save anything from 10% to 70% of the energy used by comparable non-labelled goods (Weber et al., 2000). A recent brand audit of Energy Star by Brown et al. (2002), revealed that consumers who report an understanding of what the label represents also report that it has a strong influence on purchasing decisions. The annual energy savings associated with Energy Star are forecast to reach 1.6 exaJ of electricity, or 444 billion kWh, in 2010, with associated carbon savings of 20 million tonnes.

It is now estimated that Energy Star products account for about 99% of all printers sold in the USA, and 80% of all computers. However, the figures are dramatically lower for white goods; for example 20% for central air-conditioning units. This suggests that a mandatory labelling scheme may be more appropriate than a voluntary one such as Energy Star in encouraging supply-side innovation in markets for more infrequent, high value purchases.

The European Community Energy Label programme began in 1995. The label consists of a set of coloured bars supplemented by lettered rankings of efficiency (Waide et al., 1997). The label must be displayed on most domestic white goods including refrigerators and freezers, washing machines and air conditioners. The mandatory nature of the scheme appears to have encouraged manufacturers to produce more efficient products. The sales-weighted energy efficiency of refrigerators increased by about 10% across the EU between 1992 and 1999 when accompanying mandatory efficiency standards are controlled for (Bertoldi, 2000). In the UK, the average efficiency of refrigerators/freezers increased by about 8% in the first 2 years of the labelling scheme (1995–1996) as compared with 1994 models (EES, 1998). However, a report by researchers at the Environmental Change Institute in Oxford (Boardman et al., 1997) found that UK energy consumption from refrigerators and freezers decreased by only 0.75% during the same period, due to the rising popularity of more energy-intensive frost-free freezers at this time. If frost-free purchases are controlled for, energy savings are in the region of 4% in this period (Boardman et al., 1997, p. 102). These disappointing figures probably reflect consumer preferences for larger refrigerators, which, despite better efficiency ratings, consume more energy in absolute terms than smaller ones with a worse efficiency rating.

The Australian Energy Label also takes a comparative format, although the presentation consists of a series of stars (more stars = more efficient). Harrington and Wilkenfield (1997) note that because of the mild Australian climate, appliances, such as freezers and air conditioners, account for a greater share of the Australian consumer energy draw than they do in Europe or the USA. Energy labelling became mandatory in most Australian states in 1986, leading to savings of approximately 5 million tonnes of carbon dioxide, about 1.5% of total emissions, between 1992 and 2000 (Holt and Harrington, 2003). Over the past decade or so, energy consumption from labelled refrigerators and freezers has decreased by approximately 3% per year even as the use of frost-free freezers has increased (Harrington and Brown, 2007). The energy consumption has continued to decline at around 3% per annum despite increases in the market share of frost-free freezers and increases in size. A survey of Australian consumers by Harrington and Wilkenfield (1997) reveals that recognition of the label and its intended meaning is high (about 65%). Approximately 45% of those surveyed indicated that the label influenced them to make more sustainable purchasing decisions.

2.3. *Accounting for the rebound effect*

The preceding examples demonstrate that consumer preferences for white goods and office equipment can be influenced by transparent energy labelling. However, as the case of the European Energy Label shows, such changes may not always be positive in terms of environmental impact. Advertisers can target environmentally aware consumers with the promise of more energy-efficient goods. Increased sales volumes, even of energy-efficient products, may ultimately outweigh, or 'rebound' beyond, the benefits of a pro-environmental shift in consumer preferences (e.g. Greening, 2000). This perverse linkage between green advertising and higher volumes of consumption could be amplified in a period of sustained economic growth and rising affluence.

3. Immediate feedback displays and smart meters: current technology and key advances needed to unlock full potential

Energy monitoring through metering is perhaps the most obvious and direct point of intervention into domestic energy demand. Feedback from a meter serves as a reference point from which to evaluate, or ideally to adjust, energy behaviour. Because it offers the potential to couple daily activity with energy use and its economic or environmental impacts, such feedback could be a particularly powerful driver of more sustainable energy use. For the sake of brevity, this discussion does not differentiate between metering technology for different types of energy (e.g. gas or electricity), although there are clear differences in use patterns and monitoring needs between the two (see Baldock, 2006).

3.1. Criteria for success

Most meters currently in use in the UK are over 20 years old (Energy Watch, 2005). They present the consumer with a single measure of energy flow in kWh that may be incomprehensible or irrelevant (Kempton and Layne, 1994, p. 857). This information is not benchmarked against past energy use trends, energy prices, or daily activity. Such an aggregate number is essentially useless as a reference point for energy use, unless the consumer makes the effort to collect and compare meter readings over time.

The Energy Review (DTI, 2006) and the Energy White Paper (DTI, 2007) both emphasise the potential of immediate feedback devices and 'smart metering' for reducing domestic energy demand. Although the installation of smart metering technology in the domestic sector is currently cost-prohibitive (DTI, 2007), the Government is currently consulting on a new policy requiring all new and replacement meters to include real-time energy use displays. In terms of demand reduction, the key advantage of these systems lies in the provision of real-time information that is directly linked to energy use. Such immediate feedback has been shown to be an important driver of changes in energy consumption habits and in attitudes towards consumption—with the proviso that feedback be provided in a format relevant to the consumer's needs and easy to comprehend such as pounds and pence rather than kilowatt hours (Van Houwelingen and Van Raaij, 1989).

Recent research into the energy savings that could be achieved by smarter meters or real-time displays suggests a 5–10% reduction in consumer energy demand, which equates to a reduction of about 2.5–3.5 million tonnes of carbon dioxide per year for the UK and an overall saving of about 2% of UK energy use (DTI, 2001).[1] A more comprehensive review of several different feedback programmes indicates that the highest savings, of around 20% in some cases, were achieved through smart metering technology (Darby, 2001).[2]

3.2. Looking towards the future: smarter meters and key advances necessary for successful implementation

'Smarter meters' with two-way communication capabilities offer the potential to combine feedback with other demand-side interventions such as on and off peak tariffs (Energy Watch, 2005). Estimated carbon savings from such interactive demand-side measures are in the region of 2.5–3.5 million tonnes per year (DTI, 2006, p. 10), and a 2.5% reduction in peak demand for electricity and gas (Baldock, 2006, p. 18). Such two-way communication technology could also reduce consumer uncertainty about billing, facilitate microgeneration, and reduce the need for more expensive pre-payment meters, which could be an important step in combating fuel poverty (Baldock, 2006; DTI, 2001; Energy Watch, 2005; 2006).[3] The two-year, £20 million Ofgem/BERR trial for smarter energy meters in the UK, which began in autumn 2007, should provide some firm evidence about the benefits and disbenefits of real-time energy displays for energy consumption patterns (see Ofgem, 2007, for more details).

However, important technological hurdles remain for the widespread roll-out of smarter metering. The 2007 Energy White Paper encourages the installation of smart meters within the next 10 years for homes, and within 5 years for most businesses. But the successful implementation of this technology is dependent on advances in other areas, particularly communications technologies to accommodate increased network traffic between utilities and users. A recent report by Datamonitor (2007) notes that telephony technology, such as that commonly used in current smart metering applications in the USA and Scandinavian countries, may not be robust enough to handle the high volumes of data traffic necessary for a large-scale roll-out of two-way metering devices. Current experience with a government mandate for smart meters in all domestic and industrial premises in Ontario, Canada, suggests that 'ubiquitous' high-speed internet connections are a vital prerequisite for the successful installation of such a system (Ontario Energy Board, 2005). In the UK, the Energy Retail Association raised similar concerns, noting that 'one of the most complicated standards to achieve will be that required to address remote metering communications, particularly to enable cost-effective solutions and to provide future flexibility' for the 45 million meter points likely to be covered by such a system (ERA, 2006, p. 4, see also ERA, 2007). Domestic use would account for 26 million of these. Recent surveys on computer ownership in the UK indicate that about 75% of households own a computer (Pew Research, 2007). However, only about 55% of homes have a broadband connection (Point Topic, 2007). These figures suggest that increasing domestic broadband penetration is an important technological prerequisite for the widespread roll-out of two-way metering systems.

Several other managerial and legislative barriers must be overcome before two-way smart metering could be seen to be attractive to energy providers, even if it is technically feasible. Ofgem's report on smarter metering suggests that the voluntary adoption of smarter meters is 'unlikely' (Baldock, 2006, p. 20). The problems it cites include consumers switching suppliers, which might leave expensive meter assets stranded, changing technology, legal requirements for on-site meter reading, and the higher costs of installing and maintaining such meters (see also Energy Watch, 2005). If metering costs, ownership patterns and regulatory environments were to change over time, smart meters could become more attractive as a voluntary option. However, it is more probable that only compulsion could provide the level of standardisation and market penetration necessary to discourage free-riding, stabilise costs, and shift economies of scale to favour smarter meters.[4]

4. Looking towards the future: carbon labelling and energy monitoring systems

This final section explores the technology of carbon footprinting and its potential application for carbon labelling of products. Such technology could be an important method of communicating

[1] Energy Watch (2005) reports slightly higher figures, with an uppermost reduction of 15% in consumer demand (Energy Watch, 2005, p. 2).

[2] The reliability of these figures is debatable because the study conditions vary and are not always directly comparable (Baldock, 2006).

[3] Experiments with smart metering by E.On (see E.On, 2006) and EDF Energy/National Energy Action should provide more concrete, UK data in this area in coming years.

[4] Ofgem notes that one method of compliance with the metering goals of the EU Energy Services Directive could be a standardised system of mandatory smart meters (Baldock, 2006).

the embodied energy of products in the form of a basket of greenhouse gases expressed as CO_2e, embodied CO_2. Recent reports by organisations such as Best Foot Forward (2002), the Stockholm Environment Institute (Wiedmann et al., 2003) and the WWF (WWF-UK, 2005) have investigated the potential of component-based Ecological Footprinting for analysing the embodied energy of specific product groups. The Carbon Trust is developing a more detailed carbon analysis methodology that seeks to evaluate the total embodied energy and carbon content of specific brands, so that carbon labelling can be made a viable form of consumer information for sustainable product choice. The label is currently being trialled by Boots, Walkers Crisps and Innocent Juices (Carbon Trust, 2007a, b).

A holistic carbon-monitoring system offers great potential for encouraging consumers to purchase products that are less resource and energy intensive. Previous examples suggest that such changes in consumer behaviour would put pressure on producers to create more efficient supply chains and to offer products with lower carbon footprints. A renewed focus on total product management and resource efficiency along the supply chain could signal a dramatic shift in the carbon footprint of UK business, particularly in the retail sector where embodied energy is often hidden in excessive product packaging or in foods transported over large distances. But, as with metering, such a major transformation is only likely to occur within a context of mandatory labelling.

4.1. Mandatory carbon labelling: technological requirements and likelihood of consumer/producer buy-in

A mandatory carbon labelling system can only be implemented fairly and credibly if the calculations behind the label conform to a credible and universal standard. The Carbon Trust is currently working with the British Standards Institution to develop a standardised carbon labelling methodology (Carbon Trust, 2007a, b). This project may prove exceedingly difficult. There is wide variation in manufacturing and production processes between product groups and even between similar products from different manufacturers. This problem is exacerbated by fundamental inconsistencies and gaps in the availability of data for energy inputs and outputs in specific commodity chains (Boardman et al., 2007; Carbon Trust, 2007a). A recent report by researchers at Stockholm Environment Institute (Cherrett et al., 2005) illustrates the enormous complexity of gauging the embodied energy of specific textiles. Extending the analysis from these largely intermediary goods to final products would prove even more difficult. Fig. 1 illustrates the challenge of accounting for the inputs into a carbon label as compared with the relatively straightforward calculation behind an energy label.

The use of CO_2 (or more formally CO_2e) as an indicator of embodied energy is also problematic. While the general public is probably familiar with the more rhetorical concept of carbon footprinting, the idea of CO_2e is unfamiliar to the British consumer and is meaningless or opaque as a comparison tool. This problem is likely to ease with time, but may hinder the scheme's ability to shift consumer preferences at the outset.

Industry groups are likely to oppose the adoption of a mandatory carbon labelling scheme because it raises competitiveness issues by claiming that one product is environmentally better than another. No matter how credible the scheme is perceived to be by consumers, carbon labelling is economically dangerous unless the numbers behind it are accurate, reliable and verifiable. There is no room in a mandatory labelling scheme for the assumptions that are used to fill the gaps in current energy input/output studies.

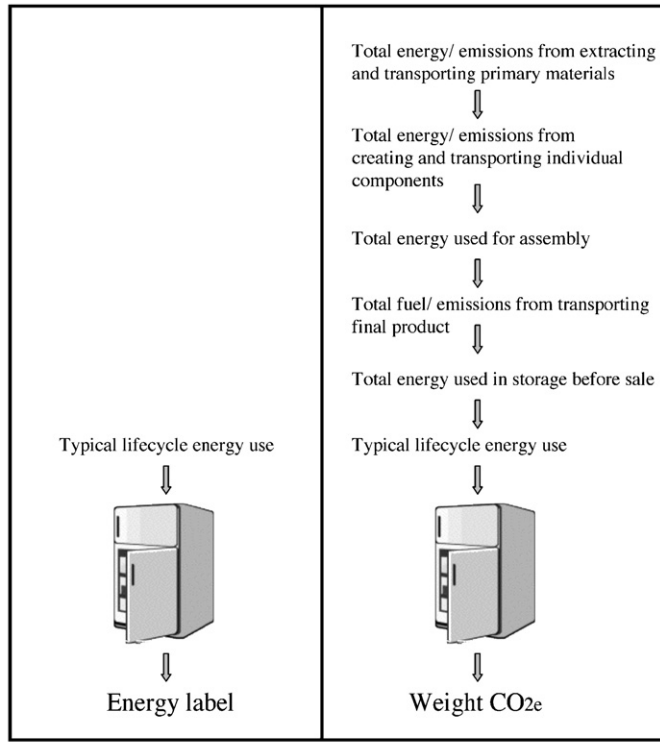

Fig. 1. Energy labelling versus carbon labelling inputs.

5. Summary and conclusions: focus on the interface between consumers and information technology

The energy monitoring systems and associated literature reviewed here reveal that demand-side energy reductions are certainly achievable with properly designed metering or labelling systems. Significant reductions in energy use and carbon emissions have been observed and projected for both energy labelling (4% for energy from refrigeration equipment, Boardman et al., 1997) and smart metering (up to 20% reduction in total domestic energy use according to Darby, 2001) in a variety of contexts. Mandatory energy labelling systems also seem to pressure manufacturers to produce more efficient products, in some cases beyond mandated standards.

This review suggests that two factors are critical to the success of an energy monitoring system in changing behaviour. First, a transparent energy monitoring system is one in which the costs and extent of energy use are made more apparent to the consumer and so more relevant to behavioural adjustment or product choice. Second, a transparent energy monitoring system is one that is credible or trustworthy. It will ideally be mandated and overseen by government authorities, so as to add a degree of legitimacy to the information or data provided.

5.1. Impacts and potential for shifting consumer preferences

The programmes and issues discussed in this review demonstrate that the technologically mediated relationship between users and energy offers several productive entry points for shifting consumer preferences towards more energy-efficient products or services. The linkage between two-way smarter meters and microgeneration is perhaps the most promising and potentially productive intervention point here. Green microgeneration allows former net consumers of energy to become net producers, with the potential for significant financial gains as well as environmental benefits. This could significantly alter the relationship between individuals and energy, signalling a supply-side transformation of energy markets towards lower carbon solutions.

However, this review also indicates that the relationship between consumers and energy use is a potentially fragile one. Positive technological advances can be unbalanced by wider shifts in consumer demand or preferences, as in the case of energy labelling and the rebound effect. More generally, a lack of reliable data or of the technological infrastructure for measuring energy inputs and outputs can damage the feasibility and credibility of an energy monitoring system.

Finally, it is important to bear in mind that the relationship between energy, technology and consumer behaviour is complex and multi-faceted. In addition to the well-understood economic drivers of consumption, evidence is accumulating that consumer goods play major roles in individuals' identity formation and social status, as well as providing structure for conventional routines and habits (Nye and Burgess, 2008; Sanne, 2002; Shove, 2004). Our contention in this paper is that re-materialising energy use patterns through more transparent energy monitoring technology gives consumers the opportunity to question both the inconspicuous nature of their energy consumption and the lifestyle choices that underpin their energy use. A transparent energy monitoring system should mediate the relationship between daily activities and energy use in such a way that 'invisible' energy use becomes connected to a more considered frame of consciousness. This connection between energy and lifestyles could be a powerful driver for a change in the way individuals understand and define themselves, and their relationship to the Earth and its energy resources. This change may in turn signal pervasive and lasting reductions in domestic energy use.

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