Can consumers save energy? Results from surveys of consumer adoption and use of low and zero carbon technologies

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Abstract
This paper presents results from a UK Open University research project which surveyed consumers' reasons for adoption – and non-adoption – of domestic energy efficiency measures and renewable energy systems – collectively called low and zero carbon (LZC) technologies. Data was gathered during 2006 via an on-line questionnaire with nearly 400 responses, mainly from 'green' consumers, supplemented by 83 in-depth telephone interviews. These consumer surveys also identified problems and benefits experienced by adopters of these LZC technologies.

The paper outlines some results of these surveys, for four established energy efficiency measures – loft insulation, condensing boilers, heating controls, and energy-efficient lighting – and for four renewable energy technologies – solar water heating, solar photovoltaics (PV), micro-wind turbines and wood stoves. These consumers typically adopted the energy efficiency measures and renewable energy systems to save energy, money and/or the environment, which many considered they achieved despite some rebound effects. The reasons for considering but rejecting these LZC technologies include the familiar cost barriers, but there were also other obstacles that varied according to the product or system concerned. An important finding is that most adopters of renewable energy systems have previously adopted two or more energy efficiency measures. Thus one conclusion is: sell energy efficiency first, then renewables. Whilst in the UK very few people have adopted household renewable energy systems, about a third of the consumers in our on-line survey said that they seriously considered adopting a renewable energy technology, although, only about 20 % of these actually did so. There seems to be considerable interest in household renewables in the UK, especially among older, middle class green consumers, but so far only relatively few pioneer adopters (notably retired couples) have managed to overcome the barriers of cost, time and effort involved in planning, installing and using them.

Introduction
This project by the Open University Design Innovation Group surveyed the factors influencing UK consumer adoption – and non-adoption – of established energy efficiency measures and of more innovative renewable energy technologies – collectively termed low and zero carbon (LZC) technologies. There is already a considerable body of work on the drivers and barriers to consumer adoption of energy efficiency measures. For example, a survey for the UK's network of Energy Efficiency Advice Centres (EEACs) showed that the main reasons given by a random sample of 200 UK householders for installing energy efficiency measures, was saving money or to increase comfort, while the main barrier to installing additional measures was cost (Central Office of Information 2001). A 1,000 household interview survey and analysis for the UK Department of the Environment Food & Rural Affairs (DEFRA) showed that perceived cost far outweighs expected energy savings in consumer decisions to install energy efficiency measures, especially insulation (Oxera 2006). DEFRA's Energy Efficiency Action Plan stated 'In the household sector, there are different barriers to improving energy efficiency, and three predominate: lack of information, high upfront costs, and hassle and disruption... Even relatively well informed consumers are often more interested in

renewable energy.' (DEFRA 2004). Another EEAC survey did find that a quarter of clients were very interested in receiving advice on renewables (Energy Saving Trust 2002). But despite this consumer interest, less is known about drivers and barriers to adoption of renewables. One survey for the Department of Trade and Industry of enquirers to a solar water heating (SWH) promotion scheme in London with 380 responses showed that the main drivers for installing SWH systems were environmental concern and saving money, while the main barriers were capital cost and lack of trustworthy information or reliable brands (SEA/RENUE 2005). Existing research on LZC technologies, at least that conducted by and for UK government, has tended to focus on the financial and informational drivers and barriers to household energy saving. However, there is another body of research (e.g. Veitch and Gifford 1996; Guy and Shove 2000) which suggests that people's motivations and actions on energy are more complex than suggested by a rational model of decision-making based on information and economics. For example, consumer diffusion of compact fluorescent lamps has been slow despite their clear financial benefits and some householders install SWH even though the likely payback period is longer than expected system life. Presentations at the 2005 ECEEE summer study used household surveys that showed there is no clear cut relationship between energy efficiency practices and environmental motivation, and that the social context is all important (Bruel and Hoekstra 2005; Moreau and Wibrin 2005; Bartiaux and Gram-Hanssen 2005). The lessons were that policy makers need to target different audiences with different messages. As the leaders of the Panel on the Dynamics of Consumption pithily summed up '…the "general public" is not one unified group. What works for one group does not fit another group' (Bartiaux and Selnæs 2005: 1188). Likewise, the National Consumer Council responding to the UK Government's 2006 energy policy consultation said 'a better understanding is needed of the key motivations and influences of different groups of consumers... In this way, energy efficiency messages can be targeted and made more effective' (NCC 2006: 2).

Our research therefore attempted to examine consumer decisions to adopt, or reject, energy efficiency measures and renewable energy technologies in more detail. We considered that the reasons for adopting or rejecting LZC technologies whose function is improving energy efficiency, such as loft insulation, may differ from those also involving user interaction, such as heating controls, or are part of interior design, such as lighting (Stokes et al 2006), or those with symbolic value such as solar energy systems (SEA/RENUE 2005). The research also examined how consumers who adopted them used these products and systems. This is important because even if people adopt LZC technologies, they may not use them in an energy-saving manner. For example, many people fail to understand, or could not be bothered, with controls such as thermostatic radiator valves or central heating programmers. SWH system adopters may not know how best to use solar heated water to minimise back-up fossil fuel consumption. There may also be rebound effects, such as taking some or all of the benefits of insulation in higher room temperatures; leaving energy efficient heating and lighting on for longer, or installing extra lighting in the home or garden (Herring 2005).

OVERVIEW

The paper starts with an outline of the methodology of the project. Then – first for energy efficiency measures and second for renewables – it examines the characteristics of the adopters and non-adopters, the drivers and barriers to adoption and the benefits, problems and any rebound effects experienced by consumers who installed these products or systems. The paper ends with a summary of conclusions and recommendations for improving the up-take of LZC technologies.

Methodology

The project comprised an exploratory study and a main phase. The exploratory study involved a literature review and pilot interviews with volunteer consumers, plus a survey of 50 energy professionals such as local authority housing officers, architects and energy consultants via an on-line energy newsletter, to develop the methodology for the main phase. A more detailed discussion of the development of the research, including the consumer decision-making model of adoption process developed for the project may be found in Roy, Caird and Potter (2007: 51).

For the main phase an on-line questionnaire was linked to the websites of a 2006 BBC TV programme on climate change and the UK's Energy Saving Trust. This produced 390 responses from consumers who since mid 2002 had adopted – or seriously considered but rejected – one or more of the energy efficiency measures (loft insulation, etc), and/or renewables (solar water heating, etc) listed above (Roy and Caird 2006).

The research team then conducted 83 telephone interviews in 2006, each lasting 30 to 60 minutes, in order to uncover more detailed information on reasons for adoption or rejection and experience of use. The interviews were conducted with:

- clients who sought advice between late 2004 and end 2005 from two of the UK's network of EEACs and who adopted, or considered but rejected, one or more of the four chosen energy efficiency measures; and
- people who had advice from a renewable energy charity, the National Energy Foundation, in 2005-6 on solar water heating; about half of whom went on to install a system.

The respondents to the on-line survey were self-selected and not unexpectedly were 'greener' and from higher socio-economic groups than the UK population as a whole. Almost all the energy efficiency and solar water heating enquirers we contacted agreed to be interviewed. They claimed similar levels of 'greenness' to the on-line respondents. This is therefore a purposive rather than a representative survey; necessary when investigating the pioneer adopters of innovative technologies such as household renewable energy, and to a lesser extent also for established energy efficiency measures many of which are still at the early adoption stage in the UK.

It should be pointed out that we did not investigate how seriously respondents had considered a particular technology before rejecting it. Neither did we measure the household energy use of consumers, but relied on their responses and estimates. Thus we are not able to verify the magnitude, or even the existence of, savings following installation of LZC technologies

Table 1. Adoption and non-adoption of energy efficiency measures

Energy efficiency measures	Installed	Seriously considered but decided against.
New or additional Loft insulation of up to 250 mm depth (LI)	229 (59 %) 28 interviews	59 (15 %) 7 interviews
Central heating timer/programmer (HC/T)	286 (73 %) 21 interviews (HC/T or TRV)	13 (3 %) 0 interviews
Thermostatic radiator valves (TRVs)	214 (55 %) (interviews: see above)	53 (14 %) 0 interviews
Condensing central heating boiler (CB)	109 (28 %) 7 interviews	97 (25 %) 0 interviews
Compact fluorescent lamp(s) (CFLs)	275 (71 %) 17 interviews	23 (6 %) 3 interviews
Light emitting diode (LED) lighting	28 (7 %) 0 interviews	62 (16 %) 0 interviews
Number on-line responses	390	390
Number interviews	73	10

Notes: 1. Some multiple adoptions 2. Total on-line responses include adoptions and non-adoptions of energy efficiency measures + renewables. Adoptions or non-adoptions of energy efficiency measures are percentages of total responses.

and treat 'energy savings' as a consumer belief rather than an actuality.

Energy efficiency technologies

Table 1 provides details of the numbers adopting, and considering but rejecting, the energy efficiency measures we investigated (the larger numbers refer to the on-line survey responses).

CHARACTERISTICS OF ENERGY EFFICIENCY ADOPTERS AND NON-ADOPTERS

The respondents to the on-line survey who adopted the chosen energy efficiency measures typically come from:

- Two-person adult households (about twice the UK national average of 34 % of such households);
- A middle class household, where the main earner belongs to the occupational category of professional/senior or middle management, or education/medical services, or are retired;
- Semi-detached or detached houses with three or four bedrooms.

The characteristics of the interviewed adopters was similar, but with a higher proportion of retired people (36 %).

The non-adopters' characteristics in the on-line survey are very similar to those of the adopters.

Most adopters – and non-adopters – of the various energy efficiency measures in the on-line survey are 'green' consumers. Over 80 % of adopters, and over 70 % of non-adopters, were fairly or very concerned about reducing their environmental impacts. Almost all recycle household waste; most adopters (75 % to 87 %, depending on the measure) and non-adopters (62 % to 85 %) attempt to save energy; while 57 % to 79 % try to cycle, walk or use public transport when possible. While this was not surprising for the self-selected on-line respondents, the adopters we interviewed claimed similar levels of 'greenness' (65 % to 81 % being very or fairly concerned about the environment) with most recycling waste, trying to economise on energy, water and car use.

The majority of the on-line respondents had adopted at least two energy efficiency measures for their home. For example, half of the total sample adopted both loft insulation and timer/programmers, and at least half adopted three energy-efficiency products, including programmers, TRVs and CFLs. However, as will be discussed below, very few people (less than 10 %) adopted both energy efficiency and renewable energy technologies. Nevertheless, a sizable number of energy efficiency adopters (about a third) seriously considered but rejected renewable energy systems, such as solar water heating and wood burning stoves.

DRIVERS FOR ADOPTION

The adopters of energy efficiency measures do so for many reasons, but in the on-line survey reducing fuel bills, saving energy and concern for the environment were the three most frequently cited reasons. An exception is loft insulation, where these drivers are still important but equalled by the desire for a warmer home (*Table 2*).

EXPERIENCE OF ENERGY EFFICIENCY ADOPTERS

Loft insulation

The majority (58 %) of adopters of loft insulation in the on-line survey said its main benefit was a warmer house, (compared to the 77 % who said they adopted LI for this reason) while nearly a third said they also had lower fuel bills and/or energy consumption. There is thus, not unexpectedly, evidence of a rebound effect for loft insulation, with a small minority (4 %) saying they took the entire benefit of greater energy efficiency in higher room temperatures, heating more of the house or heating for longer periods. However, over 40 % of adopters (both on-line respondents and interviewees) said that they were more concerned about saving energy since installation. A few also mentioned that loft insulation helped keep their home cooler in summer; a benefit likely to become increasingly important with climate change, but not generally mentioned in insulation programmes. 10 % of the on-line sample complained about the loss of storage space in their loft as a result of installing insulation and this has led some to remove insulation or compress it under boarding. These actions would reduce the energy savings of loft insulation.

Table 2. Main drivers for adopting energy efficiency measures

Main driver	New or extra loft insulation (250 mm or more)	Heating Controls		Condensing boiler	Energy efficient lamps	
		Timer/ programmer	TRVs		CFLs	LEDs
Save energy/ reduce fuel consumption	200 (84 %) 12 (43 %) interview	220 (78 %) 6 (29 %) interview	154 (59 %) 6(29 %) interview	75 (77 %)	242 (91 %)	20 (57 %)
Reduce fuel bills/save money	192 (81 %) 20 (71 %) interview	210 (74 %) 5 (24 %) interview	148 (57 %) 5 (24 %) interview	68 (69 %)	217 (82 %)	12 (34 %)
Increase comfort/ warmth/retain heat	182 (77 %) 20 (71 %) interview	104 (37 %)	83 (32 %)	34 (35 %)	n/a	n/a
Concern for environment/ global warming/reduce emissions	161 (68 %) 6 (21 %) interview	162 (57 %)	117 (45 %)	59 (60 %)	218 (82 %)	4 (11 %)

Notes: 1. Multiple reasons for adoption given 2. On-line percentages calculated from number respondents who answered at least two questions about an energy efficiency measure 3. n/a = not applicable

Energy-efficient lighting

Some compact fluorescent lamp (CFL) adopters pointed out the labour-saving advantages of these energy efficient, long life lamps, as well as associated financial savings, because of less need to spend time purchasing and replacing them. Adopters liked CFLs' long life, but several expressed annoyance if a lamp failed after one to three years rather than the advertised eight to ten years. The life of CFLs thus acted as a driver, but also a barrier if it failed early. Although about a quarter of CFL adopters in the on-line survey noticed reduced electricity bills, there were some rebound effects, as about 10 % of users chose to leave CFLs switched on longer than incandescent lamps and/ or installed additional CFL lighting in the home, in the garden or for security. However, a third of users said they were more concerned about saving energy since adopting their CFLs.

Although about 70 % of on-line respondents had one or more CFL lamps and over 80 % were satisfied with them, many rejected CFLs for certain locations because of problems associated with colour quality, brightness and brightening time, and incompatibility with light fittings and lampshades.

Only about 7 % of the on-line respondents had bought light emitting diode (LED) lighting, a newer technology. The main problem reported by LED users concerned insufficient brightness, making existing LEDs mainly suitable only for (additional) decorative lighting.

Central heating controls and condensing boilers

About 40 % of the on-line adopters of improved heating controls – timer/programmers and thermostatic radiator valves (TRVs) – and condensing boilers noticed reductions in fuel bills and/or energy consumption, but a third also noted a warmer house and a quarter (23 %) of heating control users and about 5 % of condensing boiler owners said they took the main benefit in heating more of their house, for longer, or used more hot water. These energy efficiency products thus also appear to involve some rebound effects. However, over third of heating control and condensing boiler users said they were more concerned about saving energy since their adoption.

A few users (about 10 % in the on-line survey) said they find electromechanical timer/programmers with adjuster tabs fiddly to adjust, others, especially the elderly, find complex electronic programmers with LCD displays difficult to see and find the user interface difficult to understand. As a result settings are often not changed and some users said they turn heating on and off using the thermostat because it is easier. Adopters also mentioned difficulties using TRVs effectively because they are fiddly with small markings difficult to see and set to achieve a desired room temperature.

BARRIERS TO ADOPTION

The reasons given in the on-line survey for considering but rejecting energy efficiency measures, and backed up by the interviews, include the familiar issues of capital cost and anticipated payback, but often other barriers specific to the particular technology were more important (see *Table 3*).

Loft insulation

For loft insulation, available to UK households under subsidised or free installation schemes, the most frequently cited deterrents to installation to the recommended 250 mm thickness or more were loss of storage space and/or trouble clearing the loft. These were mentioned by about a third of non-adopters in the on-line survey. In open comments a few adopters and non-adopters mentioned they were deterred by the irritant effects of the glass or lava fibre normally used for loft insulation, some mentioning their preference for eco-friendly materials such as recycled paper not available in subsidised schemes. An important insight gained from interviews with non-adopters is that there is a critical timing for installing loft insulation, before any boarding is laid. Thus any delay by the homeowner to install loft insulation may lead to boarding with the result that the insulation may never be laid.

Table 3. Main reasons for non-adoption of energy efficiency measures (on-line survey)

Barrier to adoption	New/ extra loft insulation (250 mm)	Heating Controls Timer/ programmer	Heating Controls TRV's	Condensing boiler	CFL	LED
Fuel savings not worth cost.	11 (20 %)	6 (26 %)	6 (20 %)	23 (26 %)	3 (13 %)	11 (19 %)
Too expensive	n/a	n/a	n/a	61 (70 %)	8 (33 %)	22 (39 %)
Trouble in clearing loft	18 (33 %)	n/a	n/a	n/a	n/a	n/a
Loss of loft storage space	20 (37 %)	n/a	n/a	n/a	n/a	n/a
Disruption in home.	12 (22 %)	n/a	n/a	8 (9 %)	n/a	n/a
Too much trouble to install	n/a	4 (17 %)	14 (47 %)	n/a	n/a	n/a
Reputation for unreliability	n/a	n/a	n/a	37 (43 %)	n/a	n/a
Don't fit existing light fittings.	n/a	n/a	n/a	n/a	8 (33 %)	22 (39 %)
Unpleasant or unsuitable quality or colour of light	n/a	n/a	n/a	n/a	8 (33 %)	8 (14 %)
Ugly and/or too large	n/a	n/a	n/a	n/a	10 (42 %)	n/a
Not widely available	n/a	n/a	n/a	n/a	4 (17 %)	23 (40 %)

Notes: 1. Multiple reasons for non-adoption given
2. Percentages calculated from number respondents who answered at least two questions about an energy efficiency measure
3. n/a = not applicable

Energy-efficient lighting

About 40 % of non-adopters of CFLs in the on-line survey mentioned disliking their size and perceived ugliness, while about a third mentioned deterrents of cost, incompatibility with existing fittings and dimmers, their light quality and/or lack of brightness. The cold colour of CFLs may be unacceptable in rooms required for relaxation, since lighting is used to create mood, atmosphere and décor. One CFL non-adopter who preferred halogen spot lamps said 'I'm very fussy about my lighting'.

LEDs are a relatively new technology and some 40 % of non-adopters of LEDs mentioned lack of availability and high cost. About a third of non-adopters of LEDs also said they were deterred by their incompatibility with existing fittings and/or their light quality and lack of brightness. But many people do not know what LED lighting is and would like more and better information about it.

Central heating controls and condensing boilers

Since April 2005 condensing boilers are virtually mandatory under UK Building Regulations; hence non-adopter responses reflect their experiences before this date or post 2005 decisions against early replacement of a conventional boiler. The majority of non-adopters (70 %) considered them too expensive compared to the then conventional (non-condensing) boilers or as an early replacement option. The reputation of condensing boilers for unreliability and having a shorter life was the second most frequently cited deterrent for nearly half (43 %) of non-adopters. Other important deterrents affecting about a third of non-adopters were problems connecting to existing heating systems and the negative attitude of installers to condensing boilers at the time they considered getting one. Apart from consumers' doubts whether the fuel savings of new or upgraded heating controls were worth their cost, the 'hassle' factor was the most important deterrent to installing them.

Renewable energy technologies

In the UK in 2005 there were some 82,200 domestic micro-generation and renewable energy systems, with solar water heating (SWH) accounting over 95 % of them. Although a typical flat plate or evacuated tube SWH system can provide about half of a household's hot water, they are still rare in Britain compared to other European countries. Even rarer are domestic micro-generation/renewable energy technologies, including micro-CHP, ground source heat pumps, wood pellet stoves and boilers, solar PV and micro-wind. It is estimated that there were only 3,750 such systems in 2005 in the UK (DTI 2006).

Table 4. Adoption and non-adoption of renewable energy technologies

Renewable energy systems	Installed	Seriously considered but decided against.
Solar water heating (SWH)	39 (10 %) 15 interviews	151 (39 %) 13 interviews
Solar photovoltaics (PV)	12 (3 %)	130 (33 %)
Micro-wind turbine (MWT)	7 (2 %)	128 (33 %)
Biomass (wood fuelled) stove	63 (16 %)	65 (17 %)
Number on-line responses	390	390
Number interviews	15	13

Notes: 1. Some multiple adoptions 2. Total on-line responses include adoptions and non-adoptions of energy efficiency measures + renewables. Adoptions or non-adoptions of energy efficiency measures are percentages of total responses.

Table 4 provides details of the numbers adopting, and considering but rejecting, the renewable energy technologies investigated in our surveys.

CHARACTERISTICS OF RENEWABLES ADOPTERS AND NON-ADOPTERS

Based on our small on-line survey sample, the respondents who adopted the renewable energy systems typically come from:

- Two-person adult households. Only about a quarter of renewables' adopters come from households with children under 16 years, except for wood stoves nearly half of which were adopted by families;
- A middle class household where the main earner belongs to the occupational category of professional/senior or middle management, or education/medical services, or are retired;
- Semi-detached or detached houses with three or four bedrooms;

Table 5. Main drivers for adopting renewable energy technologies

Main driver	Solar water heating (SWH)	Solar Photo Voltaic (PV)	Micro-wind	Wood stove
Save energy/ reduce fuel consumption	43 (83 %) 7 (47%) interview	5 (31 %)	39 (65 %)	39 (65 %)
Reduce fuel bills/save money	40 (77 %) 8 (53 %) interview	4 (25 %)	5 (28 %)	37 (62 %)
Concern for environment/ global warming/ reduce emissions	41 (79 %) 11 (73 %) interview	9 (56 %)	6 (33 %)	31 (52 %)
Had funds available to invest	22 (42 %)	7 (43 %)	2 (11 %)	19 (32 %)
Received a grant/special offer	16 (31 %)	4 (25 %)	3 (17 %)	n/a
Like warmth/appearance of a real fire	n/a	n/a	n/a	49 (82 %)

Notes: 1. Multiple reasons for adoption given 2. On-line percentages calculated from number respondents who answered at least two questions about a renewable technology 3. n/a = not applicable

Table 6. Main reasons for non-adoption of renewable energy technologies (on-line survey)

Barriers to adoption	Solar water heating system.(SWH)	Domestic PV system.	Micro wind turbine (MWT)	Wood stove
Too expensive	109 (73 %)	104 (85 %)	67 (53 %)	24 (35 %)
Likely fuel savings not worth the cost	53 (36 %)	49 (40 %)	26 (21 %)	n/a
Likely system life to pay back	36 (24 %)	34 (28 %)	9 (15 %)	n/a
New technology with uncertain performance and reliability	35 (23 %)	23 (19 %)	27 (21 %)	n/a
Gaining planning permission	19 (13 %)	16 (13 %)	46 (37 %)	n/a
Difficulty finding space or suitable location for unit	26 (17 %)	20 (16 %)	42 (33 %)	24 (35 %)
Insufficient electricity produced	n/a	35 (28 %)	24 (19 %)	n/a
Lack of space to store fuel.	n/a	n/a	n/a	31 (45 %)
Difficult to control heat output	n/a	n/a	n/a	30 (43 %)
More dust/ dirt in home	n/a	n/a	n/a	28 (41 %)

Notes: 1. Multiple reasons for non-adoption given 2. Percentages calculated from number respondents who answered at least two questions about a renewable technology 3. n/a = not applicable

- Environmentally concerned households (depending on the technology, 83 % to 90 % of adopters were fairly or very concerned about reducing their environmental impacts).

The characteristics of the interviewed SWH adopters was similar, but with a higher proportion of retired people (45 %).

Based on a larger sample, the non-adopters' characteristics in the on-line survey are very similar to those of the adopters.

DRIVERS AND BARRIERS TO ADOPTION AND EXPERIENCE OF RENEWABLES USERS

The adopters of renewable energy systems do so for many reasons, but in the on-line survey the three most frequently cited reasons were reducing fuel bills, saving energy and concern for the environment (i.e. the same drivers as for the energy efficiency measures). An exception is wood burning stoves where these drivers are still important, but mainly adopted by people wanting the warmth and appearance of a real fire, which adds to room decor (*Table 5*).

The responses from the on-line survey revealed that just 20 % of those who considered getting a renewable energy system actually installed one. Half of these adopters bought a wood stove; a third SWH; 10 % a solar PV system; and just 5 % a micro-wind turbine. Interestingly half of those who seriously considered getting a wood stove actually installed one, compared to 20 % for SWH, 8 % for PV and 5 % for micro-wind. These results reflect the high cost, uncertainty about suitability of the site and perceived unpredictability of performance of these items. Whereas a wood stove is an established product costing about 500 euros (although if you need to have your chimney lined this can triple the cost), SWH and micro-wind systems are more innovative and typically cost 3,000-7,500 euros, while PV panels might cost 15,000 euros or more. Wood burning stoves (as opposed to automated pellet stoves and wood boilers) are not eligible for UK government grants, although householders can apply for grants to recoup part of the cost of installing solar and wind systems.

There are grants available in the UK for household micro-generation/renewable systems – currently up to 600 euros for SWH; 30 % of the cost up to 7,500 euros for wind; and 50 % of the cost up to 22,000 euros for PV. While these grants were mentioned by some of the renewables adopters, they were not the most frequent driver and having funds available to invest was mentioned more often for solar systems.

Whilst high capital cost, and hence long payback times, of renewable energy systems are the main barrier to adoption, the survey found that there were other major obstacles (Table 6). These include uncertainty about the performance and reliability of domestic solar and wind systems, getting planning permission, and compatibility with electrical or plumbing systems

in the home. There were also concerns about maintaining often inaccessible components of solar thermal or PV systems in lofts or on roofs.

As well as helping to save money, energy and the environment, people who had installed SWH, solar PV or a wood stove said that using renewable energy or fuel gave them great pleasure, and focused their attention on saving more energy. Some also saw it as a green status symbol: one user said of his solar panels 'it is like flying a flag saying "we're green"' – see Jensen 2005 on energy saving as a form of conspicuous consumption.

There are similarities as well as differences in the influences on adoption of different household renewables and their benefits and problems in use. Therefore, we next consider the technologies investigated in more detail.

Solar water heating

In our on-line survey SWH was the most commonly adopted renewable energy technology with 39 installations (10 % of the sample, compared to approximately 0.3 % of UK households with SWH). Our findings for SWH come both from this survey plus additional information from our 28 in-depth interviews.

The major hurdle after deciding to adopt SWH is finding a good installer. Many asked their local authority and were recommended installers in their area either directly or via the National Energy Foundation's 'Energy for Good' scheme. In general the recommended installers gave quotations for installing one model of SWH system. Most accepted the recommendation of installers, usually without understanding much about the technology. The issue of trust in the installer is crucial. One adopter recounted how the Council put him in contact with two local installers, who quoted similar prices, so he chose the one who inspired trust for advice, installation and maintenance.

Only 20 % of people we interviewed chose the installer offering the cheapest quote and accepted the SWH system that they recommended. About a third of adopters approached friends or neighbours who already owned a system for advice. About two thirds of people chose evacuated tube, with the rest going for flat plate SWH. Only one person, an electrician, did not accept the installer's recommendation. Instead he bought a flat plate DIY kit because it was a simple and well designed, efficient, at a good price and he had the expertise to fit it himself.

Overall two-thirds (67 %) of on-line and nearly half (47 %) of interviewed SWH adopters were satisfied with their system. However about 80 % of interviewed adopters reported problems with leaks, pumps and valves sometimes leading to several installer recalls for repairs. Another issue (31 % on-line and 53 % interviews) was whether solar heated water could be used in their dishwasher or washing machines. Often it could not due to plumbing constraints or because most new appliances are cold-fill only, a disappointment for some, although some were aware of this in advance.

Despite such problems, two thirds (65 %) of adopters in the on-line survey mentioned their pleasure in using solar heated water. Other benefits mentioned by about half of SWH adopters were lower fuel bills (54 %), greater energy efficiency (46 %) while about third (35 %) mentioned having a greater concern about saving energy since adoption. Some rebound effects were admitted by the on-line sample; 21 % were less concerned about using hot water and 8 % were aware that they used more, a potential rebound effect – while not consuming extra energy if the water is solar heated, at least using more water. The interviews showed that nearly half (47 %) tried to use solar hot water when it was available, giving examples of showering or using their (hot-fill) washing machine in the afternoon or evening when the water is hot, rather than the morning. But more than half (53 %) had made no changes to their habits. One potential adopter said that it was difficult to get good advice about the system and how to use it efficiently. He commented: 'I think that if you move to solar you need to rethink your use of hot water; you need to change your washing habits to the evening and reset the boiler so you are not heating the water...'.

Micro-wind

Only seven people in our on-line survey had installed a micro-wind turbine mainly to save energy and/or the environment, but a third had seriously considered this technology but decided against it. The main barriers to installation are cost and payback; one non-adopter stating 'I checked wind levels for my postcode to work out a payback period of over 15 years'. The other main obstacles are getting planning permission; finding a suitable location for the unit; and this new technology's uncertain performance and reliability. Towns and cities were considered unsuitable for wind because of worries about noise and visual intrusion, with one non-adopter saying 'I live in a suburban area: imagine if everyone had one! Chaotic visual impacts and noise pollution'.

Four of the seven micro-wind adopters reported their difficulty in gaining planning permission. Other problems mentioned by individual adopters were the difficulty in finding a good installer, insufficient electricity from the system and the experience that wind-generated electricity is not available when required. However, three reported being fairly or very satisfied with their system and only one was dissatisfied; even the person whose turbine was destroyed in a lightning strike would still recommend micro-wind to anyone living in a suitable area.

Solar photovoltaics

Only 12 people in our on-line survey had installed a domestic PV system, mainly for environmental reasons or because they had the funds but, as for micro-wind, a third had seriously considered this technology but decided against it. The main barriers to the installation of PV is capital cost, and/or too long payback, but other deterrents included insufficient output, difficulties connecting to the National Grid; finding an installer, or a suitable location. One non-adopter stated, 'The cost per kWh hideously expensive; smaller systems would barely charge a car battery and to be useful would need to have a larger system integrated with 230 V mains, with all the expense and issues with connecting to the grid. This type would require far too much roof space for me to consider'.

The satisfaction with PV is mixed and below that for SWH. Only a third of adopters were fairly or very satisfied, with about half of adopters unsure. This lack of satisfaction is probably due to not enough electricity being produced or available when required and the poor feed-in tariffs available. One non-adopter stated 'apparently you have to sell all your electricity to your supplier for say 3 p per unit and buy back for 9 p per unit, you cannot use your own electricity first then top up from supplier'. However, installing PV can have a beneficial influence on energy consumption. In our survey half said they were more con-

cerned about saving energy after installing PV, while a quarter tried to use their own solar electricity when available, getting considerable satisfaction from doing so. One adopter reported a 40 % energy saving, 'Installation caused me to monitor the daily electricity which when I started was an average 25 units a day. With a combination of the solar PV and energy saving actions… the average electrical usage has reduced to 15 units a day'.

These observations from a small number of respondents are supported by results from much larger surveys of PV users presented at the 2005 ECEEE summer study. Based on an Austrian study, Keirstead reported that 'PV can indeed reduce the consumption of a household, although there is a consumption threshold of about 3,500 kWh/year below which consumption increases and above which it decreases.' Quoting Haas et al, he noted that PV is an 'energy conservation tool for the rich', being the culmination of investment in energy efficiency (Keirstead 2005: 1251).

Wood burning stoves

Wood burning stoves were the most widely adopted renewable energy device in our on-line survey (63 installations, 16 % of the total). We did not distinguish simple wood stoves from automatic pellet stoves and boilers, but it is unlikely that (m)any of the automatic type were included. Wood stoves' popularity is due to their relatively modest cost, but also due to fitting existing fireplaces and offering benefits other than using a renewable fuel. However, not all fireplaces or houses are suitable. One non-adopter stated 'We were replacing an open fire and considered a stove, but that required a flue liner and substantial remodelling to the hearth and chimney breast area - which made it several times the cost of a coal-effect gas fire'. Also wood stoves do involve physical work, the storage and carrying of fuel, the removal of ashes, and extra house cleaning. This can be a drawback for older or disabled people. As one stated 'As you get older you don't want the downside of this form of heating – or for an automatic system the cost is too high'.

However, most (82 %) wood stove adopters are very satisfied and two-thirds (65 %) mentioned the pleasure of using a renewable fuel. Other benefits mentioned by about a third of adopters were lower fuel bills (37 %) and greater energy efficiency (33 %), while 30 % of wood stove users mentioned having a greater concern about saving energy since adoption. The main problems cited were; more dust and dirt in the home, connecting the stove to radiators and/or the hot water system and controlling heat output. Also, there were rebound effects, due to the greater difficulty of controlling the output of wood stoves; some 60 % of users said their wood stove heated one or more rooms to a higher temperature.

Not everybody, however, considered wood stoves as a desirable or renewable system. A few respondents remarked that they are not environmentally friendly as they pollute the atmosphere. One stated, '*Surely a wood-burner emits carbon dioxide and particulates. Hardly clean!*' One respondent remarked that in New Zealand the local council is giving grants to remove wood stoves because of pollution. However, in this case the person is referring to older types of wood stove rather than modern smokeless designs.

Conclusions

Our surveys show that each LZC technology has different drivers, barriers, benefits and problems. Some of the findings support previous work, with its emphasis on financial drivers and barriers, but these surveys of mainly green consumers also reveal a more complex picture.

DRIVERS FOR ADOPTION OF LZC TECHNOLOGIES

The adopters of energy efficiency measures do so for many reasons; but in the on-line survey the main drivers were saving energy; reducing fuel bills and concern for the environment. For LI adopters these three drivers are matched by the desire for a warmer home.

Adopters of renewable energy technologies do so for similar reasons. Reducing fuel bills, saving energy and the environment were each cited by about 80 % of on-line SWH adopters. Three quarters of SWH interviewees were also influenced to adopt by friends, etc. who already owned a SWH system. For solar PV, environmental concern, and for micro-wind saving energy, were the main drivers for adoption. Despite the existence of UK government grants, having funds available to invest was a crucial adoption factor for SWH and solar PV, For wood stoves saving energy, money and the environment are important, but they are mainly bought by people wanting the warmth and appearance of a real fire.

BARRIERS TO ADOPTION OF LZC TECHNOLOGIES

The barriers that deterred non-adopters of energy efficiency measures depended on the technology. For example, those who rejected LI did so mainly because of losing loft storage space and/or having to clear the loft, the hassle factor identified in previous research. Most non-adopters of condensing boilers, at least before high efficiency boilers became mandatory, considered them too expensive, unreliable and/or short-lived. People decided against installing TRVs mainly because of the trouble involved, the hassle factor again. These barriers prevent many people from replacing conventional boilers and upgrading controls until absolutely necessary. The biggest deterrent to installing new or additional CFLs was their size and perceived ugliness, followed by their cost, incompatibility with existing fittings and/or dimmers and/or their light quality. Except for LED lighting as a new technology, lack of information did not feature very strongly as a barrier to adoption of energy efficiency measures in our survey of green consumers, although other studies cite information a major issue for the general population.

The deterrents to adoption of renewables also varied with the technology. However, high capital cost was the universal reason for rejecting SWH (on-line and interviewed respondents) as well as solar PV and micro-wind. Wood stoves were more often rejected because of difficulties in controlling their output and the extra dirt and labour they involve rather than their cost. There were several other obstacles to installing renewables. These include finding a trustworthy installer for SWH and PV; the installer problem plus finding a suitable location, getting planning permission, and worries about noise, vibration and visual intrusion for micro-wind; and having the space to install and store fuel for wood stoves. Although both adopters and non-adopters said they would like more independent ad-

vice and information about choosing, financing, installing and using renewables, surprisingly few non-adopters cited lack of information as the major barrier to purchasing a system.

BENEFITS, PROBLEMS AND REBOUND EFFECTS OF USING LZC TECHNOLOGIES

About a third of those who installed one or more energy efficiency measures said they noticed reduced fuel bills, despite rising energy prices. Some of this saving could be due to the greater energy awareness claimed by many users following installation. However, some 60 % of LI, a third of condensing boiler and heating controls adopters felt they took at least some of the energy savings in more warmth while 10 % of CFL adopters felt they used or installed additional lighting. Energy efficiency technologies caused few operational problems apart from the difficulties some people had in operating timer/programmers and in using programmers and TRVs to optimise energy efficiency.

Many adopters of renewables, also reported reduced fuel bills. This again could be partly due to their increased awareness of household energy use after installing a renewable system. However, the main benefit mentioned by owners of SWH, solar PV, micro-wind and wood stoves was the pleasure they got from using renewable energy.

Users of renewables, however, experienced various problems. For example, many SWH users did not know how to operate their system most effectively to save fossil fuel, while some were disappointed that they could not use solar heated water in cold-fill washing machines or dishwashers. Only a third of solar PV users were fairly or very satisfied, with about half of adopters unsure; compared with two-thirds of satisfied SWH owners. Over 80 % of wood stove adopters were very satisfied, the main problems being extra household cleaning and the difficulty of controlling the output of wood stoves leading to over-heating one or more rooms, a possible rebound effect.

THE MARKET FOR LZC TECHNOLOGIES

This project showed that only about 10 % of adopters of energy efficiency measures adopted renewables, even though about a third of our respondents said they seriously considered doing so. In contrast adopters of renewables typically installed other energy efficiency measures, such as loft insulation and CFLs. Thus the first step to installing SWH or other renewables may be getting some CFLs and insulating the house, then installing new heating controls. Such measures, our respondents said, increased energy awareness, and then interest in renewables may be translated into action – see Darby (2005) on the idea of 'tipping-points'. So one conclusion is: sell energy efficiency first, then renewables. However, this project found, like other surveys (e.g. SEA/RENUE 2005) that in the UK solar water heating and other household renewables is currently largely confined to a niche market of mainly older, environmentally concerned middle class consumers. How the markets for both energy efficiency and renewables might be expanded is explored in the next section.

Recommendations

As well as investigating the drivers for, and barriers to, adoption and the experiences of users of LZC technologies, this project solicited consumers' technical and non-technical ideas for improving these products and systems. These improvement ideas, together with the other findings of the project, suggest that promoting the widespread adoption and effective use of energy efficiency measures and household renewables requires different actions and policies by government, manufacturers, energy suppliers and retailers tailored to the specific markets and technologies.

GOVERNMENT

In open comments, many of our on-line respondents observed that there was a need for a stronger government role in promoting energy efficiency and renewables, mentioning various measures they would like to see implemented. These included:

- financial incentives to reduce costs, such as tax breaks, increased subsidies and grants, and lower council tax bills;
- better regulation to control 'cowboy' installers of solar water heating systems; and
- mandatory standards for product performance, reliability and durability, especially of condensing boilers and domestic solar energy systems.

People would also like more financial penalties, such as higher taxes on inefficient technologies, or even their prohibition as proposed for incandescent lamps in Australia.

Respondents also commented that all new housing should integrate solar water heating or other renewable energy technologies in their design, enforced by tighter building regulations. New buildings, some said, are the best place to apply these technologies, since costs would be less than for retrofitting. It would help the industry to develop skills and the infrastructure for supporting sales, installation and servicing, and would help bring costs down for retrofit through economies of scale, as well as helping to develop societal norms of energy saving. Also, a few believed that, wider adoption would be achieved if renewables were installed more in public buildings, since this would inspire consumer confidence.

Despite numerous existing government energy efficiency and renewables promotion and support schemes some consumers still want better information and advice, with comparisons of manufacturers' ratings, independent assessments of performance, payback, etc. to help them make the best energy investment decisions on a budget. Homeowners want better information on using LZC products and systems effectively, including information on compatibility with other household systems; suitability of their location; as well as using controls and making changes to energy use habits. A single body to guide people through all the details of technology choice, grant applications, planning permission, installation, use and maintenance were suggested ways of promoting adoption, especially of renewables.

DESIGNERS AND MANUFACTURERS

A key challenge for designers is to offer low cost user-centred designs that guarantee efficiency, reliability and payback as well as achieving carbon reductions. Designers need to think beyond individual LZC products or systems to how they interconnect with existing systems and the building structure, overcoming problems such as a lack of compatibility between SWH systems and cold-fill appliances. Designers have a role in creating aesthetic LZC products and systems, overcoming the stark contrast between people who regard renewables, like solar panels as monstrosities and those pleased with their symbolic display of environmental credentials. Another challenge for design is to reduce ineffective use and rebound effects with better feedback to users influencing changes to energy using habits that help to achieve the expected savings.

The barriers to adoption and the improvement ideas suggested by consumers indicated a number of technical and design improvements that could improve the uptake of different LZC technologies. These are the subject of another paper (Roy and Caird 2007), but some of the most frequently requested improvements include:

- heating controls designed for all users that provide feedback and automatically optimise energy efficiency and comfort;
- dimmable CFLs and LEDs suitable for general lighting;
- building-integrated solar water heating panels and wind turbines;
- more user-friendly controls for solar water heating and PV systems that provide feedback on energy and money saved; and
- wood stoves whose heat output is easier to control.

It was clear from respondents' comments and design ideas such as the above that many were unaware of improvements and innovations in the design and technology of LZC products and systems that have taken place. Where products are changing, consumers need to be kept informed by manufacturers and other of developments if they are not to reject technologies based on their outdated perceptions or experience; for example, that CFLs are still bulky, insufficiently bright and slow to warm-up or that irritant-free thin loft insulation materials are available.

ENERGY SUPPLIERS

Energy suppliers could offer better methods of financing to move household renewable energy beyond the niche market of the environmentally concerned middle classes. In particular, the majority of non-adopters of solar water heating, solar PV and micro-wind systems said they would be encouraged to adopt if energy suppliers offered finance packages to install to be repaid via fuel bills, while half of the non-adopters of PV wanted better feed in tariff for surplus electricity exported to the National Grid.

A specific recommendation arising from the barriers to adoption of loft insulation would be for subsidised schemes to offer a wider range materials of than the glass and lava fibre insulation which some consumers wish to avoid for health reasons. A loft clearing and storage service as part of the installation process and better methods for providing post-installation storage would help overcome two of the main barriers to adoption.

RETAILERS AND INSTALLERS

As noted in the introduction, application of good marketing principles, i.e. targeting different energy efficiency measures and renewables at receptive market segments, is vital to ensure their more rapid uptake. Our surveys indicate that installing one or more energy efficiency measures is likely to raise consumers' energy consciousness and could pave the way for interest and eventual commitment to renewable energy systems. However, for renewables, despite the existence of grants, having funds available to invest is crucial and this is perhaps why retired middle class consumers are one group worth targeting. Other research indicates that the over 50s have the highest carbon footprint of all UK age groups, are most concerned about climate change and are motivated to take action (Haq et al. 2007). They may have a retirement lump sum and are willing to invest some of it on a green, money saving system. Retired people are also more likely to have the time needed to plan, apply for grants, install and operate renewable energy systems.

Retailers also need to be aware that there is a critical timing for adopting energy efficiency measures and renewables since they are often installed when moving house or as part of other home improvements. Where retailers or installers are slow to respond, this may lead to homeowners going ahead with their plans with the result that the LZC product or system may not be included as part of the improvements.

Promoting the widespread citizen adoption and carbon-saving use of energy efficiency measures and renewable energy systems requires a multiple approach that needs to be tailored to the different technologies concerned. Policies and actions need to go beyond addressing the financial barriers to adoption, important as these are. Policies and action should include improving the design and technology of some existing products and systems; improved communications about improvements to established energy efficiency measures; detailed practical advice about the installation and use of renewable energy systems and guarantees regarding their performance, reliability and maintenance.

References

Bartiaux, F. and Gram-Hanssen, K. 2005, Socio-political factors influencing household electricity consumption: A comparison between Denmark and Belgium, ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1313-25.

Bartiaux, F. and Selnæs, G. 2005, Introduction to Panel 6, ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1187-9.

Bruel, R. & Hoekstra, J. 2005, How to stimulate owner-occupiers to save energy? ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1197-1204.

Central Office of Information 2001, The 2000/2001 Energy Efficiency Advice Centre Survey UK Report, NFO BJM, London, November.

Darby, S. 2005, Learning about energy – how will low-impact energy use become a way of life?, ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1335-42

DEFRA 2004, Energy Efficiency: The Government's plan for action, Department of Environment, Food & Rural Affairs, London, April.

DTI 2006, Micro-generation strategy: Power from the people, Department of Trade and Industry, London, Report 06/993.

Energy Saving Trust 2002, EEACs Savings Study, Research Findings – South East Report. Jigsaw Research Ltd.

Guy, S. and Shove E. 2000, A Sociology of Energy, Buildings and the Environment: Constructing knowledge, designing practice, Routledge, London.

Haq, G., Minx, J., Whitelegg, J. and Owen, A. 2007, Greening the Greys. Climate change and the over 50s, Stockholm Environment Institute, University of York, February.

Herring, H. 2005, Energy Efficiency: A Critical View? Energy: the International Journal 32 (1), pp. 10-20.

Jensen, O. M. 2005, Consumer inertia to energy saving, ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1327-34.

Keirstead, J. 2005, Photovoltaics in the UK domestic sector: a double-dividend? ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1249-58

Moreau, L. & Wibrin, A.-L. 2005, Energy-related practices, representations and environmental knowledge: A sociological study. ECEEE Summer Study 2005 Proceedings, Volume 3 pp. 1301-12.

NCC 2006, A sustainable energy policy for all, NCCs response to DTI's consultation, Our Energy Challenge. National Consumer Council, London, April.

Roy, R, Caird, S. and Potter, S., 2007, People Centred Eco-design: Consumer adoption and use of low and zero carbon products and systems, in Murphy, J. (ed.), Governing technology for sustainability. Earthscan, London, pp. 41-62.

Roy, R. and Caird, S. 2006, Designing low and zero carbon products and systems – adoption, effective use and innovation, In Proceedings, Sustainable Innovation 06 International Conference, Chicago 23-24 October, Centre for Sustainable Design, University of the Creative Arts, Farnham, UK, pp. 216-224.

Roy, R. and Caird, S. 2007, Designing low and zero carbon products and systems: Improvements based on consumers' experience of adoption and use. Paper for the International Conference of Engineering Design 2007, Paris, 28-31 August.

SEA/RENUE 2005, Barriers to installing domestic solar hot water systems, Sustainable Energy Action/Renewable Energy in the Urban Environment, London, September.

Stokes, M., Crosbie, T. and Guy, S. 2006, Shedding light on domestic energy use: A cross-discipline study of lighting homes. Paper to the RICS (Royal Institute of Chartered Surveyors) Annual Conference, Cobra 2006, London, 7-8 September.

Veitch, J.A. and Gifford, R. 1996, Assessing Beliefs about lighting effects on health, performance, mood, and social behaviour, Environment and Behaviour, 28 (4) pp. 446-470

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