Consumer adoption and use of household renewable energy technologies, Report DIG-10

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Consumer Adoption and Use of Household Renewable Energy Technologies

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People-centred ecodesign project:
Renewable Energy study

Consumer adoption and use of household renewable energy technologies

Sally Caird and Robin Roy
with Stephen Potter and Horace Herring

Final Report

DIG-10 December 2007

Acknowledgments

We should like to thank all the individuals and organisations that helped us undertake the renewable energy part of the People-centred ecodesign project, especially the following:

Ian Byrne, Gareth Ellis and Saffron Myhill-Hunt, National Energy Foundation, Milton Keynes.

Angus Murchie , Milton Keynes Energy Agency.

Mike Tofts, National Energy Services Ltd., Milton Keynes.

Ellen Matschke, editor *NHER E-info*

Jennie Abelman, Energy Saving Trust.

Donna Phillips and Nick Haycox, Survey Research Department,
Institute of Educational Technology, The Open University.

Julia Burrows, Open Broadcasting Unit, The Open University.

Sally Boyle, Department of Design and Innovation, The Open University.

The many respondents to our surveys, including: the members of the National Home Energy Rating scheme who responded to the energy professionals online survey; the volunteers and the National Energy Foundation's 'Energy for Good' clients interviewed for the exploratory and main studies; and the members of the public who responded to the online survey on the BBC/Open University and Energy Saving Trust websites.

Funding

The research for this report was partly supported from funding provided through the Open University's Research Committee's Strategic RAE Initiative and partly from funds from the Faculty of Technology.

The Research Team

Robin Roy, Professor of Design and Environment, The Open University. r.roy@open.ac.uk
Stephen Potter, Professor of Transport Strategy, The Open University. s.potter@open.ac.uk
Dr Sally Caird, Research Fellow, Department of Design and Innovation, The Open University. s.caird@open.ac.uk
Dr Horace Herring, Visiting Research Fellow, Energy and Environment Research Unit, The Open University. h.herring @open.ac.uk
Georgy Holden, Lecturer in Design and Innovation, Department of Design and Innovation, The Open University.
Karen Yarrow, Research Consultant, Cheltenham, Glos.

Cover design: Sally Boyle, Department of Design and Innovation, The Open University.
Photos: Robin Roy.

Design Innovation Group
(part of the Sustainable Technologies Group)
Faculty of Mathematics, Computing and Technology
The Open University
Milton Keynes MK7 6AA
United Kingdom

Tel: +44 (0)1908 652944 Fax: +44 (0)1908 654052

http://design.open.ac.uk

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Abbreviations

Abbreviation	Definition
LZC	Low and zero carbon (technologies)
LI	Loft insulation
HC/P	Heating control timer/programmer
TRV	Thermostatic radiator valves
CB	Condensing boiler
CFL	Compact fluorescent lamp
LED	Light emitting diode (LED) (lighting)
STWH	Solar thermal water heating
PV	(Solar) Photovoltaic
Micro-CHP	Micro combined heat and power
MWT	Micro wind turbine
WS	Wood burning stove

EXECUTIVE SUMMARY

Why a report on UK household renewable energy technologies?

Household adoption of low and zero carbon (LZC) technologies, including microgeneration and domestic renewable energy systems, is a key element of the UK Government's energy and climate strategy to reduce the carbon footprint of homes, which in 2005 were directly responsible for 28% of total UK carbon dioxide emissions (DTI, 2005). The Department of Trade and Industry's Microgeneration Strategy report *Our Energy Challenge* suggests that microgeneration could reduce domestic carbon emissions by up to 6.5% by 2030 and by up to 15% by 2050, i.e. a quarter of the 60% household reduction target (DTI, 2006). Microgeneration is defined as 'the small scale production of heat and/or electricity from a low carbon source' and encompasses domestic renewables such as solar thermal water heating and micro-wind turbines plus low carbon technologies such as heat pumps and micro combined heat and power (micro-CHP) systems.

However, despite UK government support for microgeneration, through grant schemes such as Clear Skies and the successor Low Carbon Buildings Programme, household adoption of renewables, such as solar thermal water heating, solar photovoltaics (PV) and biomass stoves and boilers, has been slow. In the UK in 2004 there were some 82,200 microgeneration installations (i.e. only about 0.3% of UK households), with solar thermal water heating (STWH) systems accounting for over 95% of them (DTI, 2006).

In a report commissioned by the DTI, significant potential was identified for market growth, and carbon saving of microgeneration technologies; including solar PV, micro-wind, micro-CHP, heat pumps, solar thermal and biomass heating systems. However, this depended on the barriers to widespread consumer adoption of microgeneration and renewable energy technologies being overcome. The report found that,

> 'Microgeneration could deliver significant efficiency and CO_2 benefits, through increased use of renewables… or renewable heating fuels, and avoidance of losses in the electricity transmission and distribution system…. For microgeneration to have an impact on the UK electrical system, units must be installed by consumers in their millions…. In addition, a new understanding of the likely interaction between microgeneration technology and its multitude of potential end users (the general public) must be developed.' ((EST/E-Connect/Element Energy, 2005 p.3)

According to this EST report, slow adoption is due to three main barriers – the high costs of microgeneration technologies, partly alleviated in the short term by grants, the low value of exported electricity and lack of targets and incentives for renewable heat; legislation, especially planning permission; and the low level of awareness. Financial mechanisms and a centrally co-ordinated programme to improve information and advice to installers and end users of these technologies are recommended to address these barriers. Similar barriers were identified, and recommendations made, in a Parliamentary Trade and Industry Committee report on *Local energy* which stressed the importance of renewable heat as well as electricity production (House of Commons, 2007). The report also pointed to the considerable effort and knowledge involved in deciding whether to invest in a renewable energy technology or in choosing between alternative renewable energy systems.

> '…individuals face a number of hurdles when it comes to the purchase, installation and operation of local energy systems. As one witness put it, for households to overcome these barriers they are "likely to require the entire skill set found in a specialist renewable project development company"'. (House of Commons, 2007, p. 20)

An ESRC-funded study of the potential of solar PV, micro-CHP and micro-wind for household energy generation also identified high upfront costs, long payback times and lack of information and knowledge as barriers to their widespread adoption. The study also noted that these new technologies need to overcome scepticism by consumers regarding their technical reliability and performance, given the lack of operational experience and wide variations in the actual and predicted performance of these technologies (Watson et al., 2006).

However, sociological and anthropological research (e.g. Guy and Shove, 2000, Wilhite, 2005) has shown that people's motivations and actions concerning energy are often more complex and socio-culturally embedded than these practical and financial barriers suggest. As the *Local Energy* report observed,

> …most households that have purchased solar panels or wind turbines have tended to be early adopters who are not necessarily motivated by a rational cost benefit-analysis…. They are instead motivated by other factors. For example, they may be technology enthusiasts who are keen to own the latest environmental innovation.....Also, those consumers who install microgeneration technologies are rather proud of them, they do like to show them off to their friends …. (House of Commons, 2007, p. 29)

Furthermore, few studies evaluate whether in-situ use of domestic renewable energy systems deliver the expected reductions of carbon dioxide emissions. Even when householders adopt renewables, they may not use them in an energy-saving manner because they lack understanding of the system, experience problems in controlling it, or find it difficult to make adjustments to their lifestyle. There may also be rebound or take-back effects, such as using more solar heated water than previously or heating rooms with wood-burning stoves to higher temperatures. Most existing studies of household adoption of renewables take little account of user behaviour and whether widespread adoption will actually deliver the predicted carbon reductions.

This report presents the results of a study carried out by the Design Innovation Group at the Open University (OU) that aimed to investigate in more detail UK householders' decisions to adopt, or decide against adopting, selected renewable energy technologies, and adopters' experiences and use of the systems once installed. It presents the views of a group of householders interested in energy efficiency and renewable energy rather than a representative sample of the UK population.

What this report is about

This report presents results of research which surveyed UK householders' reasons for adopting – or considering but rejecting – four domestic scale renewable energy systems:

- solar thermal water heating;
- solar photovoltaics (PV);
- micro-wind turbines;
- wood-burning stoves.

The surveys also identified the benefits and problems experienced by those householders who had installed one or more of these technologies, including their views regarding the extent of rebound or take-back effects. In addition the surveys asked householders to respond to ideas suggested by energy experts for improving the installation, design or technology of these renewable energy systems and to suggest their own improvement ideas.

The sources of data

The data on the factors influencing adoption and rejection of the selected renewable energy technologies, and adopter experiences of their use, was gathered during 2006 via an online questionnaire linked to the websites of the Energy Saving Trust (EST) and a BBC/OU television series on climate change, which produced nearly 400 responses. The online survey responses were supplemented by the results of twenty eight in-depth telephone interviews with householders seeking information about solar thermal water heating from an information and advice scheme called 'Energy for Good', managed by the National Energy Foundation (NEF), a charity that promotes renewable energy. The online questionnaire and interview schedules were developed following exploratory interviews with volunteer consumers which provided insights on adoption and non-adoption of both energy efficiency measures and household renewables. An online survey of energy efficiency professionals, including local authority housing officers, architects and energy consultants provided an expert perspective on the factors affecting adoption, non-adoption and design improvement of LZC technologies, including the four renewable energy technologies examined in this report.

The survey respondents

The respondents to the online questionnaire linked to the EST and BBC/OU websites were self-selected and, not unexpectedly, were 'greener' and from higher socio-economic groups than the general UK population. The Energy for Good clients interviewed expressed similar levels of general environmental concern and were also mainly middle class householders, but with a higher proportion of retired people.

This is therefore a 'purposive' rather than a representative survey of mainly environmentally concerned householders. Our respondents' reasons for rejecting renewable energy systems, and any problems experienced by those who did adopt them, thus represent significant barriers and issues that need to be addressed before the less wealthy, less 'green' general UK population will decide to install renewables and thus achieve the worthwhile carbon reduction benefits that their widespread adoption is estimated to bring.

The People-centred ecodesign project

The surveys of household adoption of renewable energy systems presented in this report form part of a larger project entitled 'People-centred ecodesign' (Roy, Caird and Potter, 2007). As well as investigating renewable energy systems, this project also examined the drivers and barriers to UK household adoption and use of the following four domestic energy efficiency measures and one microgeneration technology:

- loft insulation – new or top-up to 270mm thickness, as required under 2005 Building Regulations;
- condensing boilers – before and after they became virtually mandatory under 2005 Building Regulations;
- heating controls – focusing on central heating programmers and thermostatic radiator valves (TRVs);
- energy-efficient lighting – compact fluorescent lamps (CFLs) and the more recently introduced light emitting diode (LED) lamps;
- micro-CHP – a microgeneration technology under development and trial for domestic application.

The findings of the survey of household energy efficiency measures are the subject of a separate report.

The renewable energy survey results presented in this report are based on the responses to the same online questionnaire that was used for the energy efficiency study reported separately (Caird and Roy et al, 2007; Herring, Caird and Roy, 2007).

In the following sections key findings of the renewable energy study are provided in summary tables and as a more extended text discussion.

Key findings – summary tables

Table A summarises the main drivers for, and barriers to, household adoption of the four renewable energy systems covered in the online survey and interviews, together with the main benefits and problems experienced by the householders who adopted one or more of these technologies.

Table A. Main drivers for, and barriers to, household adoption of renewable energy systems and main benefits and problems experienced during their use

	Solar thermal water heating	Solar photovoltaics (PV)	Micro-wind turbines	Wood-burning stoves
Drivers for adoption (percentage adopters – online survey)	**Saving energy** (83%; Also 47% interviewees) **Saving money** (77%, Also 53% interviewees) **Positive communications from friends/ relatives/ neighbours** (75% interviewees) **Environmental concern** (79%; Also 73% interviewees) *Funds available* (42%; Also 27% interviewees) Affordable after grant/special offer (31%) To try out an innovative technology (22%)	***Environmental concern*** (56%) *Funds available* (43%) Saving energy (31%) Saving money (25%) Affordable after grant/special offer (25%) To try out an innovative technology (19%)	*Saving energy* (39%) *Environmental concern* (33%) Saving money (28%) To try out an innovative technology (22%) Affordable after grant/special offer (17%)	**Pleasure of having a real fire** (82%) **Saving energy** (65%) **Attractive appearance** (65%) **Access to free/low cost fuel** (63%) **Saving money** (62%) ***Environmental concern*** (52%) *Alternative heating system* (48%) Funds available (32%) Adds value to property (28%) Part of home improvements (27%)
Barriers to adoption (percentage *non-adopters* – online survey)	**Too expensive** (73%; Also 69% interviewees) *Likely fuel savings not worth cost* (36%) Difficulty finding a reputable installer (25%) New technology with uncertain performance and reliability (23%) System not likely to last long enough to payback (24%; Also 46% interviewees) Incompatibility with heating/hot water systems (19%) Difficulty finding suitable location for unit (17%) Expected disruption in home (16%)	**Too expensive** (85%) *Likely fuel savings not worth cost* (40%) Insufficient electricity from system (28%) System not likely to last long enough to payback (28%) Difficulty finding a reputable installer (24%) Problems connecting to existing electricity systems (24%) New technology with uncertain performance and reliability (19%) Difficulty finding suitable location for unit (16%)	***Too expensive*** (53%) *Difficulty getting planning permission* (37%) *Difficulty finding suitable location for unit* (33%) Noise/vibration (26%) Difficulty finding a reputable installer (25%) Unattractive visual appearance (22%) Likely fuel savings not worth cost (21%) New technology with uncertain performance and reliability (21%)	*Lack of space to store wood (45%)* *Difficulty controlling heat output (43%)* *More dust/dirt in the home (41%)* *Too frequent refuelling/ash removal required (39%)* *Difficulty finding suitable location for unit (35%)* *Too expensive* (35%) Incompatibility with heating/hot water systems (28%) Continued……

	Solar thermal water heating	Solar photovoltaics (PV)	Micro-wind turbines	Wood-burning stoves
Benefits experienced in use (percentage adopters – online survey)	**Satisfied or very satisfied** (67%;Also 47% interviewees) ***Pleasure of using a renewable energy*** (65%) ***Lower fuel bills*** (54%) *Greater energy efficiency/ lower energy use* (46%; Also 60% interviewees) *Greater concern about saving energy* (35%; Also 46% interviewees)	*Greater concern about saving energy* (38%) Satisfied or very satisfied (31%) Pleasure of using a renewable energy (31%) Greater energy efficiency/ lower energy use (25%) Lower fuel bills (19%)	Satisfied or very satisfied (17%) Pleasure of using a renewable energy (11%) Greater energy efficiency/ lower energy use(11%)	**Satisfied or very satisfied** (82%) **Pleasure of using a renewable fuel** (65%) *Lower fuel bills* (37%) *Greater concern about saving energy* (37%) *Greater energy efficiency/ lower energy use* (33%)
Problems experienced in use (percentage adopters – online survey)	**Poor reliability of components** (80% interviews) Solar hot water not usable in cold-fill appliances (31%: Also 53% interviewees) Insufficient solar heated water (12%)	[Few adopters experienced problems]	[Few adopters experienced problems]	*More dust/dirt (35%)* Not possible to connect to radiators and/or hot water system (28%)
Rebound effects (percentage adopters – online survey)	***No behaviour change to use available solar hot water*** (50%; Also 47% interviewees) Less concerned about using hot water (21%)	[Few adopters noted rebound effects]	[Few adopters noted rebound effects]	***Rooms heated to higher temperature*** (60%) Heat more of home (17%) Heating on for longer periods (13%)

The information in Table A (adapted from Roy and Caird, 2007) is classified according to the frequency of responses in the relevant sub-sample, mainly from the EST/BBC/OU online survey, as follows:

Bold = 66% or more responses
Bold Italic = 50% or more responses
Italic = 33% or more responses
Normal = Other responses (less than 33%)

Table B lists technical, organisational and communication ideas and policies survey respondents considered would encourage householders to adopt renewable energy systems and address the problems experienced in use.

Table B. Ideas and policies to encourage household adoption and effective use of renewable energy systems

	Solar thermal water heating	Solar photovoltaics (PV)	Micro-wind turbines	Wood-burning stoves
Design improvements/ technical innovations (percentage adopters – online survey)	***Lower cost systems*** (60%; Also 62% interviews) *Integration of solar panels with roof (48%; Also 46% interviews)* *Guaranteed reliability, durability and payback* (47%; Also 54% interviews) *Packaged systems (43%)* *System designed to give user feedback on money/energy saved* (41%; Also 38% interviews) Installation of system from inside house (30%) Designs for installation without scaffolding (26%) Impressive visual appearance (23%)	**Lower cost systems** (80%) *System designed to give user feedback on money/energy saved* (46%) *Guaranteed reliability, durability and payback* (46%) Installation of system from inside house (34%) Impressive visual appearance (17%)	**Lower cost systems** (82%) ***Roof-integrated systems*** **(***60%) *Guaranteed reliability, durability and payback* (48%) *System designed to give user feedback on money/energy saved* (42%) Impressive visual appearance (30%)	*Better control of heat output (41%)* *Produce less smoke/pollution (48%)* *Produce less dust/dirt (41%)* *Require less frequent refuelling/ ash clearance (41%)* *Lower cost systems* (41%)
Organisational/ marketing changes (percentage adopters – online survey)	***System financed by energy suppliers and paid back via fuel bills*** (56%)	***System financed by energy suppliers and paid back via fuel bills*** (55%)	***System financed by energy suppliers and paid back via fuel bills*** (59%)	

The information in Table B (adapted from Roy and Caird, 2007) is classified according to the frequency of responses in the relevant sub-sample, mainly from the EST/BBC/OU online survey, as follows:

Bold = 66% or more responses
Bold Italic = 50% or more responses
Italic = 33% or more responses
Normal = Other responses (less than 33%)

Key findings – in more detail

Drivers for installing household renewables

Householders who install renewable energy systems do so for many reasons; but the key drivers most frequently cited by our survey group of mainly 'green' consumers were saving energy and/or reducing fuel bills and/or concern for the environment. For people buying wood-burning stoves, saving energy, money and the environment are important, but they are mainly bought for the pleasure of the warmth and appearance of a real fire.

The online survey found that household renewable energy systems were not widely adopted even among this group of largely middle class, green consumers – only 10% of the 390 online respondents had installed solar thermal water heating, 3% had solar photovoltaics (PV), 2% a micro-wind turbine and 16% a wood-burning stove. However, these adoption rates are considerably higher than among UK households in general. This study, in common with other British, American and Australian studies (Guagnano et al.,1986, Foster, 1993, SEA/Renue,

2005), found that the early adopters of household renewables are mainly from environmentally concerned, higher income, professional and managerial groups. Older environmentally concerned consumers (the 'grey-greens') are a group especially likely to be early adopters (Herring, Caird and Roy, 2007).

The drivers of saving energy, reducing fuel bills and/or concern for the environment were most frequently cited by the adopters of solar thermal water heating, solar PV, micro-wind and wood-burning stoves. For solar thermal water heating and wood-burning stoves these key drivers were cited by half to three-quarters of online survey respondents. There were too few adopters of solar PV and micro-wind turbines to provide conclusive results, but for those who responded, environmental concern and saving energy were the main adoption drivers.

For wood-burning stoves the key drivers mentioned above were important, but more important was the wish to have the warmth and appearance of a real fire (82%) which preferably also adds to room décor (65%). Many respondents bought wood-burning stoves because they have access to free/low cost supplies of fuel (63%) and like these stoves as an alternative or backup to gas or electric heating (48%).

Another important driver mentioned in three-quarters of interviews with solar thermal water heating adopters was recommendations from friends, relatives or neighbours who owned a system and often allowed potential purchasers to view it. Having the funds to buy a system was also an important factor for solar thermal water heating adopters (42% online respondents and 27% interviewees). Many of this group were retired (18% online respondents and 45% interviewees) and were willing to invest some of their savings or retirement lump sum in a green, money saving system. Retired people usually have more spare time to plan, apply for grants, install and operate renewable energy systems. Other responses suggest that the interest in adopting renewables was often related to jobs, such as farming or engineering; or the experience of living in countries that use renewable energy more widely.

Most adopters of solar thermal water heating systems had also installed home energy efficiency measures. Although only a few solar thermal water heating users had installed other renewables, about one third said they seriously considered them before deciding against adoption. Adopting a low or zero carbon technology may thus prime people to install or consider purchasing other LZC technologies.

Solar thermal water heating adopters were the largest sub-group of adopters of renewables. Most had adopted energy efficiency measures, such as compact fluorescent lamps (74%) and/or up to 270 mm of loft insulation (59%). Some solar thermal water heating adopters had also installed other renewables (18% had a wood-burning stove, 15% a PV system and 8% a wind turbine) while about one third said they had seriously considered but decided against purchasing solar PV or a micro-wind turbine. This supports the findings of the survey of household energy efficiency measures reported separately (Caird, et al, 2007) that installing energy efficiency measures increases energy awareness and may prime people at least to consider purchasing other low and zero carbon technologies. Solar thermal system users are thus potential adopters of the full range of home LZC technologies.

The importance of environmental concern, especially climate change and nature conservation, as a key driver was probably due to the 'greenness' of the majority of our respondents.

The majority (83% to 90%) of adopters of the four renewables in the online survey described themselves as 'concerned' or 'very concerned' about reducing their impacts on the environment. Over 90% said that they recycled household waste; over two-thirds saved energy and water and shopped for environmentally friendly products; and over half tried to reduce transport impacts. Almost all (95%) of the solar thermal water heating adopters we interviewed also described themselves as concerned or very concerned about reducing their environmental impacts. For example, one observed,

> 'I believe that we are stewards of the earth. I object to people who live as if there is no tomorrow and knowingly leave future generations with huge environmental problems to solve.' (Solar thermal water heating adopter)

The role of information and advice schemes

Renewable energy information and advice schemes provided by councils, local authorities and specialist organisations, and that recommend reputable local installers, help to build the consumer trust that is essential for widespread adoption of household renewables.

The interviews with householders interested in adopting solar thermal water heating systems were all clients of the 'Energy for Good' information and advice scheme managed by the National Energy Foundation (NEF), which advises householders and SMEs on adoption of a range of LZC technologies. The interviews showed that people are reassured by schemes such as Energy for Good, especially as this scheme operates in partnership with local authorities, County Councils and local Energy Efficiency Advice Centres (EEACs).

Several of the interviewed adopters of solar thermal water heating were very pleased when approved installers brought demonstration models to their home or introduced them to neighbours to view their systems, and several mentioned the need for a trusted official source of advice.

> 'I think it is important to be able to trust an organisation like the Council to recommend reputable installers rather than respond to ads or leaflets through the door.'
> (Solar thermal water heating adopter)

With high pressure sales techniques being employed by some 'cowboy' solar thermal water heating installers, trust in installers is vital for householders considering this technology or other renewables. Schemes like Energy for Good help built trust by providing a complete programme to deliver renewable energy installations, including recommending reputable installers via local authorities, councils and EEACs.

> 'A salesman came around and wanted me to sign on the spot, a kind of double glazing salesman. I refused saying that I never made decisions like that. I received a brochure from Suffolk Council about grants for solar thermal water heating and I was happy to pursue this.'
> (Solar thermal water heating adopter)

Some solar thermal water heating non-adopters we interviewed wanted further development of renewables advice centres and support schemes to provide more detailed, independent information and advice, for example on:

- The costs, performance and payback time of different manufacturers' systems;
- The suitability of the home, its existing appliances, heating and electrical systems, and the compatibility of renewables with the building structure;
- How to operate systems and/or change lifestyles to maximise carbon reductions.

This suggests the need for a one-stop shop for all renewables and microgeneration technologies , building on schemes like Energy for Good, to assist householders in the process of technology choice, grant applications, planning permission, installation, use and maintenance.

Renewable energy information and advice schemes would support more widespread consumer adoption if developed to provide a one-stop shop assisting the process of technology choice, grant applications, planning permission, installation, use and maintenance.

General barriers to installing household renewables

A majority (80%) of our sample of 'green' householders who considered installing a renewable energy system decided not to go ahead with the purchase. These consumers did not adopt renewables for many reasons; but the key barrier for the majority of non-adopters of solar thermal water heating, solar PV and micro-wind turbines is that the system was considered too expensive. For these three technologies capital cost was a major determinant of adoption rates. For wood burning stoves, given their relatively modest capital cost, other barriers to adoption were more important.

Overall 20% of all respondents to the online survey who said they seriously considered installing a renewable energy system decided to go ahead with the purchase. Of the 80% who decided not to purchase, 95% of those considering micro-wind, 92% considering solar PV, 80% considering solar thermal water heating and 51% considering wood-burning stoves, decided against adopting these technologies.

Unsurprisingly – and in line with previous research (e.g. EST/E-Connect/Element Energy, 2005; House of Commons, 2007) – the most significant barrier is the cost of installing the system, cited as a deterrent by non-adopters of solar PV (85%), solar thermal (73%) and micro-wind (53%). With PV the most expensive technology, the deterrent effect is thus proportional to the capital cost of the system. As wood-burning stoves are relatively lower cost products, expense was given as a barrier by only a third (35%) of non-adopters, and other barriers (e.g. lack of space to store wood fuel) were more significant.

The role of grants and subsidies

Most of the minority of online respondents who had installed a renewable energy system did so without assistance from grants or subsidies. The interviews with solar thermal water heating adopters showed that while most purchases involved grant aid, this was not a key driver for adoption. Although this may suggest that grants or subsidies are not essential to household adoption of renewables, their effect is restricted by their modest value, and take-up may be limited by the bureaucracy they can involve. For most respondents to our online survey the available grants, etc. are insufficient to overcome the cost barrier for those considering adoption.

Less than a third of online adopters of solar thermal water heating (31%) and very few interviewed adopters (80% of who had a grant) cited grants, subsidies or special offers as a reason for installing their system. Likewise, only a quarter (25%) of solar PV and 17% of micro-wind turbine adopters said they installed because of grants or subsidies.

This suggests that financial support that makes domestic renewables more affordable is not a key driver for adoption, although grants, etc. may encourage some consumers who otherwise would not adopt to do so. However, this result is due to the fact that grants, subsidies and special offers often only cover a relatively small proportion of the capital cost of installation, can involve considerable bureaucracy, and are not available for all renewables. Until March 2007, under the Clear Skies and successor Low Carbon Buildings Programme (LCBP) generous UK government grants were available to householders to install solar PV and micro-wind, but the high capital cost of PV still limited its uptake, and after May 2007 the grants were severely reduced. Grants for solar thermal water heating typically cover only about 10-15% of system cost, while simple wood-burning stoves are not eligible for grants.

The process of obtaining a grant could be a deterrent for some, who may not consider the amount involved worth the effort. Some 10% of solar thermal water heating adopters mentioned that they had difficulty obtaining a grant and some interviewed adopters complained that different grants operated in different parts of the UK. Some open comments included:

> 'The grant process is absolutely chock full of bureaucracy, and all for £400. Government needs to do a whole lot better here' (Solar thermal water heating adopter)

> The grant process is 'impenetrable/random'… 'confusing'…. 'failing to stimulate the market' (Solar thermal water heating adopters)

Barriers to installing, using and improving specific household renewables

As noted above, the drivers for adopting household renewables were broadly similar for the different technologies – namely saving energy, money and the planet. But, apart from capital cost, the barriers to adoption, plus the benefits enjoyed and any problems experienced by those who adopted them, as well as householders' responses to ideas for improvement, varied for the different technologies. Therefore, in the rest of this summary the findings concerning barriers, user experiences and improvement ideas are considered separately for

the four renewable energy technologies surveyed. The most important findings are highlighted in bold.

Solar thermal water heating

Although a typical solar thermal water heating system can provide about half of a UK household's hot water, they are still rare in Britain compared to other European countries with only 78,470 installations in 2004, 0.4% of the potential 19 million suitable UK homes (DTI, 2006). It is estimated that installing systems in all these homes could save 1.7m tonnes carbon per year (DCLG, 2006).

Barriers to adoption

Respondents to both the interviews and online survey decided against adopting solar thermal water heating systems mainly because they were considered too expensive and offered a poor payback on the investment. Other deterrents for a quarter of non-adopters were the difficulty finding a reputable installer and uncertainty about the technology's performance and reliability.

A fifth of online respondents who seriously considered solar thermal water heating actually purchased a system. As noted above, and in line with other research (SEA/Renue, 2005), the overwhelming reason was capital cost and other reasons were also cost related; namely that likely fuel savings were not considered worth the investment (36%), and payback may exceed system life (24%) or even the life expectancy of the owner!. Similar views were expressed by interviewed non-adopters, who also mentioned that systems were too expensive (69%) and may not last long enough to payback the investment (46%).

> 'Current cost is £1000's when hot water consumption might be around a £100 of which you save a percentage e.g. half, which means a long payback.' (Solar thermal water heating non-adopter)

Other deterrents cited by about a quarter of non-adopters in the online survey included difficulty finding a reputable installer (25%) and uncertainty of the technology's performance and reliability (23%).

In open comments, a few non-adopters mentioned concerns about maintaining often inaccessible components in lofts or on roofs, the weight of solar thermal panels on their roof, and inadequate hot water storage capacity. In contrast to people who installed solar thermal water heating to display their green credentials ('*it's like flying a flag saying we're green*'), a few non-adopters were put off by such visible green symbolism, saying that solar energy is '*not for "normal" households'* or associated with '*left wing hippy types'*.

Benefits and problems in use

Most interviewed and online solar thermal water heating adopters were satisfied or very satisfied with their system. The main benefit was the pleasure of using solar heated water in the home. The most frequent disappointments were not being able to use solar heated water in their dishwasher or washing machine and insufficient capacity to store the water heated on sunny days for later use.

Overall two-thirds (67%) of online and nearly half (47%) of interviewed solar thermal water heating adopters were satisfied with their system ('*Fantastic – every home should have one'*). The benefits included lower fuel bills (54% online adopters) and energy use (46%). However, the most frequent benefit (65%) was the pleasure of using solar heated water (one mentioned the '*spiritual experience'* of showering with solar heated water). The most frequent disappointment was not being able to use solar heated water in the dishwasher or washing machine (31%), due to plumbing constraints or because most new appliances are cold-fill only; and insufficient tank capacity to utilise the solar input on sunny days (12%).

Although only a minority of online adopters experienced problems with their systems, most interviewed adopters (80%) experienced problems with leaks, faulty pumps and/or valves. Most (73%) interviewed adopters regarded their solar thermal system as easy to use, although many (60%) mentioned there was a need to monitor gauges and adjust valves to prevent overheating, and a few mentioned difficulties understanding the controls and operating the system to minimise back-up water heating.

> 'The main problem is we don't know how much solar heated water the system produces. It would be nice to be able to switch the immersion heater off during suitable days and to know that all hot water is free, in theory.' (Solar thermal water heating adopter)

About half of solar thermal water heating adopters noticed reduced fuel bills post-installation. Nearly half of adopters changed their pattern of water use to make optimum use of available solar heated water, while over half made no changes, probably because of convenience or lack of information.

The benefits of solar thermal water heating for about half the adopters in the online survey included lower fuel bills and reduced energy use. However, there was some indication of a small rebound effect – a fifth of online adopters agreed they were less concerned than before about their usage of hot water. But any extra water used could be mainly solar heated and so involves no additional fossil fuel use.

The interviews showed that nearly half (47%) tried to use solar heated water when it was available, giving examples of showering or using their (hot-fill) washing machine in the afternoon giving time for water to reheat for evening or morning use. But more than half of interviewees had made no changes to their patterns of hot water use. This was a matter of habit or convenience, but inadequate instructions or feedback from the system as to how to use it most efficiently was probably another factor in unchanged behaviour.

Improvement ideas

Apart from lower cost systems, the most popular improvements to solar thermal water heating technology among the householders surveyed are systems integrated with the roof and systems with controls that provide feedback on money and energy saved. Some people would be encouraged to adopt solar thermal water heating systems given new financing packages from energy suppliers.

Not surprisingly, both adopters and non-adopters would like lower cost systems (44% adopters and 60% non-adopters). For instance a 'solar lilo' was mentioned, but such ideas would only work in areas receiving high annual solar radiation.

Both groups, especially non-adopters, liked the idea of having solar thermal water heating systems financed by an energy supplier and paid back via their fuel bills (44% adopters and 56% non-adopters). More adopters, having experienced solar thermal water heating, felt that systems integrated with the roof (69% adopters and 48% non-adopters), and/or controls that give feedback on money and energy saved (56% adopters and 41% non-adopters), were good ideas. A few respondents were aware of more technically advanced systems available in other countries such as Germany and the U.S., including systems with controls linked to Internet weather forecasts to inform the user when solar hot water was likely to be available.

More adopters (48%) than non-adopters (43%) would like to see integrated systems, such as a solar thermal water heating and condensing boiler package which is already marketed by a major manufacturer. Such systems could help avoid interconnectedness problems such as experienced when one interviewee installed a combination boiler (which does not require a hot water tank) not realising it was incompatible with most UK solar thermal systems. Both

adopters and non-adopters would like systems with guaranteed reliability, durability and payback (48% adopters and 47% non-adopters).

> 'I would like at least a 10 year guarantee, 5 year payback and 20 year product life.' (Solar thermal water heating non-adopter)

In open comments, ideas for technical improvements included designs for larger, better insulated tanks to store hot water overnight for days when the system is not collecting solar energy. Some would like systems designed for easier monitoring, better instruction manuals and a diagnostic system to warn about component failure – with existing controls users are often unaware if their system is not functioning.

This reinforces the importance of more informative and easier to understand solar thermal water heating system controls, possibly integrated with central heating controls and linked to Internet monitoring for optimal solar energy utilisation.

Solar photovoltaics (PV)

Household solar PV systems are not considered cost-effective at present given an average payback of 50 years or more, but if installed in the 9 million potentially suitable UK homes could save an estimated 2.5m tonnes carbon per year (DCLG, 2006). It is estimated that by 2050 household PV could contribute up to 4% of UK electrical demand and a 3% reduction in domestic carbon dioxide emissions (EST/E-Connect /Element Energy, 2005).

Barriers to adoption

Most householders considering solar PV, decided against purchase mainly because systems are too expensive and considered to offer inadequate fuel savings for the investment. Other deterrents for non-adopters were expectations of insufficient electrical output and difficulties connecting to the National Grid, and finding a reputable installer.

Only twelve (3%) of all respondents to the online survey had adopted solar PV. However, a third of respondents to the online survey (130 householders), said they had seriously considered this technology but decided against installing it. Only 8% of those who considered getting PV actually went ahead with the purchase. The main barriers were capital cost (85%); fuel savings not worth the investment (40%); and/or too long payback (28%); insufficient output (28%); connecting to the Grid (24%) and finding a reputable installer (24%). Less cited deterrents were difficulties finding a suitable location for the solar modules (16%); getting planning permission (16%); and poor availability of solar generated energy (11%). Some thought that too much roof space would be required for PV to generate sufficient electricity.

> '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… with all the expense and issues with connecting to the grid. This type would require far too much roof space for me to consider.' (Solar PV non-adopter)

Benefits and problems in use

Satisfaction with solar PV among the few householders who had installed a system was mixed, probably due to not enough electricity being produced or available when required and the poor feed-in tariffs.

User satisfaction with PV among the twelve householders who adopted this technology was mixed and below that for solar thermal water heating. Only a third of these PV users were fairly or very satisfied, with about half unsure. This mixed satisfaction is probably due to not enough electricity being produced or available when required and the poor feed-in tariffs available in the UK. Nevertheless, about a third mentioned the pleasure of generating and using their own renewable electricity and a quarter tried to use it when available. Nearly half said they were more concerned about saving energy in the home after installing PV and a fifth noticed reductions in electricity bills, one adopter reporting a 40% saving,. There were few problems reported with PV and this very small sample of adopters noticed no obvious rebound effects.

> 'The primary shift I have had to make is in my own awareness of what pulls an electrical load, however small. This has made me painfully aware of how much electricity is wasted by the countless tiny lights in an average grid home'. (Solar PV adopter)

Improvement ideas

> **Unsurprisingly, most householders surveyed would like lower cost solar PV systems, while new financing methods and a better price for exported electricity would encourage more people to purchase. Most users would like PV controls to provide feedback on energy and money saved by the system.**

Apart from financial measures – lower cost PV systems (80%), systems installed by energy suppliers paid back via fuel bills (55%); and better feed-in tariffs (50%) – the main improvements the 130 PV non-adopters thought would encourage adoption were: guaranteed reliability, durability and payback (46%); and PV control system feedback on electricity generated and money saved (46%). The visual appearance of PV systems was an issue for only 17% of non-adopters. In open comments, other improvement ideas mentioned were PV modules integrated with south facing windows, roof lights or conservatories and semi-transparent PV film for windows. Suitable semi-transparent PV cells exist but have yet to be used to any extent in domestic buildings because of their cost.

Micro-wind turbines

Micro-wind turbines with outputs of 0.5kW to 6kW are established products for remote use on farms, etc. However, 1kW to 1.5kW grid-connected household micro-wind turbines are an emerging technology being marketed to UK consumers to generate an estimated 10% to 30% of domestic electricity. Many engineers are very sceptical about the value of these micro-wind systems for urban and suburban areas, given that the power output of a wind turbine is proportional to its swept area and the cube of the wind speed and that air turbulence around buildings greatly reduces useful wind speeds. Hence estimates of micro-wind's carbon saving potential vary widely or are not stated (DCLG, 2006) while in mid 2007 the results of EST monitoring of micro-wind in Britain are yet to be published.

Barriers to adoption

About half of householders decided against installing micro-wind turbines because they were considered too expensive. About a third also mentioned difficulties getting planning permission and finding a suitable location for the unit.

Only seven people in our online survey had installed a micro-wind turbine, two-thirds saying they did so mainly to reduce mains electricity consumption. However, a third of online respondents (128 householders) said they had considered this technology but rejected it. Only 5% of those who considered getting a turbine actually went ahead with the installation. The main barrier was cost, mentioned by 53% of non-adopters, even though 1kW turbines costing under £2000 are available. The other important deterrents included getting planning permission (37%); finding a suitable location for the unit (33%); noise and vibration (26%); unattractive appearance (22%); uncertainty about this new technology's performance and reliability (21%); and problems connecting to existing electricity systems (21%). Many considered towns and cities unsuitable for micro-wind because of worries about noise and visual intrusion.

> 'I live in a suburban area: imagine if everyone had one! Chaotic visual impacts and noise pollution'. (Micro-wind turbine non-adopter)

Benefits and problems in use

Of the seven householders who had installed a micro-wind turbine, three reported being 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. Other problems mentioned included that wind-generated electricity was not always available when required.

Improvement ideas

Most householders would be encouraged to adopt micro-wind if lower cost systems were available financed by energy suppliers and paid back via fuel bills. Most householders would like micro-wind turbines designed to be integrated with the roof or building.

The main design improvements our respondents agreed might get more people to adopt micro-wind were: lower cost designs; roof-integrated systems; feedback on energy and money saved and visually attractive turbines. One non-adopter wanted *'an attractive, quiet wind turbine that does not arouse objections from neighbours or planners'*. All these requirements provide challenges for engineers and designers. In particular there is active development of building integrated wind systems in which the building acts to channel the wind flow.

Wood-burning stoves

Wood-burning stoves were the most widely adopted renewable energy device with 63 installations (16% of respondents to the online survey). We did not distinguish simple wood-burning stoves from automatic pellet stoves and wood-fuelled boilers, but open comments indicated that it was unlikely that our respondents had considered any of the latter two types. There were only 150 biomass boilers installed in the UK in 2004 (DTI, 2006) and their principal market is among Britain's 1.1 million rural homes (EST/E-Connect/Element Energy, 2005), although automatic pellet stoves and simple wood burning stoves have a broader potential market in domestic housing.

Wood stoves' popularity is due to their relatively modest cost and their contribution to saving fossil fuels and the environment, but they are mainly bought for the pleasure of having a real fire, their contribution to the décor of the home and access to a supply of free or low cost wood fuel.

Barriers to adoption

Householders surveyed decided against installing a wood-burning stove because of lack of fuel storage space, difficulties controlling the stove's heat output, and the labour involved in refuelling, ash removal and extra house cleaning.

A similar number (65 householders or 17% of the online sample) had decided against buying a wood-burning stove as had installed one. The main deterrents for the non-adopters were: lack of fuel storage space (45%); difficulties controlling heat output (43%); extra dust and dirt (41%); the labour of refuelling and ash removal (39%); difficulty finding a suitable location (35%), and cost (35%) particularly if the chimney required lining. Less common deterrents include incompatibility with an existing hot water/heating system (28%) and a belief that the environmental benefits are not worth the cost (14%).

> 'I have a small terraced house now, with limited room to install. It is impractical to plumb into my existing heating system. There is very little storage space. I am now disabled so it is not very practical.' (Wood-burning stove non-adopter)

Not everyone considered wood-burning stoves as a desirable technology, a few respondents considered that these stoves are not environmentally friendly.

> 'Surely a wood-burner emits carbon dioxide and particulates. Hardly clean!' (Wood-burning stove non-adopter)

Benefits and problems in use

Most adopters were satisfied with their wood burning stove, particularly the pleasure of using renewable wood fuel. Problems experienced are extra dirt in the home and difficulties connecting the stove to an existing heating/hot water system.

Most (82%) wood-burning stove adopters are very satisfied with their purchase and two-thirds (65%) mentioned the pleasure of using a renewable fuel. The main problems cited by users were; more dust and dirt in the home (35%) and connecting the stove to radiators and/or the hot water system (28%). Although a relatively inexpensive technology not all houses are suitable and adapting fireplaces, lining chimneys and connecting to an existing heating system can be expensive.

About one third of wood-burning stove adopters have reduced energy consumption and fuel bills. But most adopters are enjoying a warmer house, indicating a rebound effect associated with this renewable energy product.

About a third (37%) of adopters mentioned lower fuel bills. However, there were rebound effects – 60% of users said their stove heated one or more rooms to a higher temperature than before and others admitted heating more of the house (17%) and/or heating rooms for longer periods (13%) – some of these rebound effects may be due to the greater difficulty of controlling the output of wood-burning stoves.

Improvement ideas

About half of householders would like lower cost, less polluting wood-burning stoves. About half would be encouraged to adopt wood-burning stoves with a more controllable heat output.

As with other renewables, non-adopters felt that lower cost designs would help adoption (41%), but other improvements were considered more important, including wood burning stoves with better control of heat output (49%) and stoves that produce less dirt and require less frequent refuelling/ash clearance (both 41%). About half of both adopters (55%) and non-adopters (48%) thought less polluting wood-burning stoves needed to be developed, despite modern smokeless designs. Other ideas included a multi-fuel stove designed to recycle combustible household waste and ducts for heat transfer between rooms from a stand-alone wood-burning stove.

1 Introduction

In order to address the problem of climate change, the UK Government set a legally binding target of reducing the nation's carbon emissions from their 1990 levels by 26% to 32% by 2020 and by 60% by 2050 (HM Government, 2007) and is expected to exceed its commitment under the Kyoto Protocol to reduce greenhouse gas emissions by 12.5% between 2008 and 2012 (DTI, 2006). The development and rapid adoption of 'low and zero carbon' (LZC) products and systems, including microgeneration and renewable energy technologies, to reduce the 28% of all UK carbon dioxide emissions that arise from direct energy consumption by households, is a key element of the UK Government's Energy and Climate Strategy (HM Treasury, 2005).

Many LZC products and systems are now available for household installation. These range from: established energy efficiency measures such as loft insulation, condensing boilers and compact fluorescent lamps (CFLs), to low-carbon technologies, including micro combined heat and power (micro-CHP) units, ground and air source heat pumps and fuel cells; and zero-carbon renewable energy technologies, such as solar thermal systems, biomass stoves and boilers for heating, and solar photovoltaic (PV) systems and micro-wind turbines for electricity generation. However, consumer adoption of LZC products and systems has been slow, particularly of the more innovative microgeneration and renewable energy technologies.

This report considers consumer adoption and non-adoption, use and improvement of selected domestic renewable energy technologies, while a separate report (Caird et al., 2007) is concerned with household energy efficiency measures.

There is already a considerable body of work on the drivers and barriers to consumer adoption of energy efficiency measures. For example, a 1000 household interview survey and analysis for the UK Department of the Environment Food and Rural Affairs (DEFRA) showed that perceived cost far outweighs expected energy savings in consumer decisions to install energy efficiency measures (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 promotion scheme for solar thermal water heating (STWH) in London, with 380 responses, showed that the main drivers for installing STWH 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). In a report commissioned by the DTI, significant potential was identified for market growth and carbon saving of renewable and microgeneration technologies; including solar PV, micro-wind, micro-CHP, heat pumps, solar thermal and biomass heating systems. However, this depended on the barriers to widespread consumer adoption of these LZC technologies being overcome. According to this EST report, slow adoption is due to three main barriers – the high costs, partly alleviated in the short term by grants; the low value of exported electricity and lack of targets and incentives for renewable heat; local planning obstacles; and the low level of awareness (EST/E-Connect/Element Energy, 2005). Similar barriers were identified in a UK Parliamentary Trade and Industry Committee report on Local Energy (House of Commons, 2007). This report also pointed to the considerable technical knowledge required to decide whether to invest in a renewable energy technology or in choosing between alternative renewable energy systems. Another UK study of the potential of solar PV, micro-CHP and micro-wind for household energy generation also identified high upfront costs, long payback times and lack of information and knowledge as barriers to their widespread adoption. The study also noted that these new technologies need to overcome scepticism by consumers regarding their technical reliability and performance, given the lack of operational experience and wide variations in the actual and predicted performance of these technologies (Watson et al., 2006). Such findings are not confined to the UK. For example a number of earlier studies of the consumer adoption and rejection of solar energy technologies in the USA and Australia identified similar drivers and barriers (e.g. Guagnano et al, 1986; Foster, 1993),

Existing research on LZC technologies, at least that conducted by and for UK government, has tended to focus on the addressing the financial, regulatory and informational drivers and barriers to household energy saving. However, there is a body of sociological and anthropological research (e.g. Guy and

Shove 2000, Wilhite, 2007) which suggests that peoples' motivations and actions on energy are more complex than suggested by a rational model of decision-making based on information, regulations and economics. For example, householders who install STWH or other renewables often do so for non-economic reasons, given that the likely payback period is longer than the expected system life. As the Local Energy report observed,

> *'...most households that have purchased solar panels or wind turbines have tended to be early adopters who are not necessarily motivated by a rational cost benefit-analysis…. They are instead motivated by other factors. For example, they may be technology enthusiasts who are keen to own the latest environmental innovation....'* (House of Commons, 2007: 29).

Similar motivations were found among pioneer adopters of fuel cell micro-combined heat and power (micro-CHP) systems for home heating and electricity generation in Germany (Fischer, 2004).

Our research therefore attempted to examine consumer decisions to adopt, or reject, 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 with symbolic or status 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 STWH 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 leaving renewable space heating on for longer or using more solar heated water (Herring 2005). Such rebound or 'comfort taking' effects are recognised in estimating the energy saved by home insulation, but are not generally understood or taken into account for household renewables (DEFRA, 2007).

2 Methodology

The project comprised an exploratory study followed by main phase consumer interviews and surveys that aimed to identify:

- Key factors influencing consumer adoption, and non-adoption, of household renewable energy systems;
- The problems and benefits which adopters of these systems experience during installation and use; and whether they use the products in a way that reduces carbon emissions, including rebound or take-back effects;
- Specifications, ideas and concepts for improvements to, or innovations in, the systems that would make them more desirable to consumers and effective in reducing carbon emissions;
- Policies and actions by designers, manufacturers, service providers and government that would promote the more widespread adoption of these renewable energy systems.

2.1 The exploratory study

The exploratory study involved a literature review, pilot interviews with volunteer consumers, and an online survey of energy professionals to develop the methodology for the main phase.

In the exploratory study a model of consumer adoption and use of LZC products and systems was developed (Figure 1). It identified four groups of variables that influence consumers' adoption decisions and use behaviours:

- The socio-economic context (e.g. fuel prices, regulation);
- Communication sources (e.g. professional, interpersonal);
- Consumer variables (e.g. attitudes, lifestyle);
- The properties of the product or system itself – its functional utility, interconnectedness with other systems, symbolic value, and price.

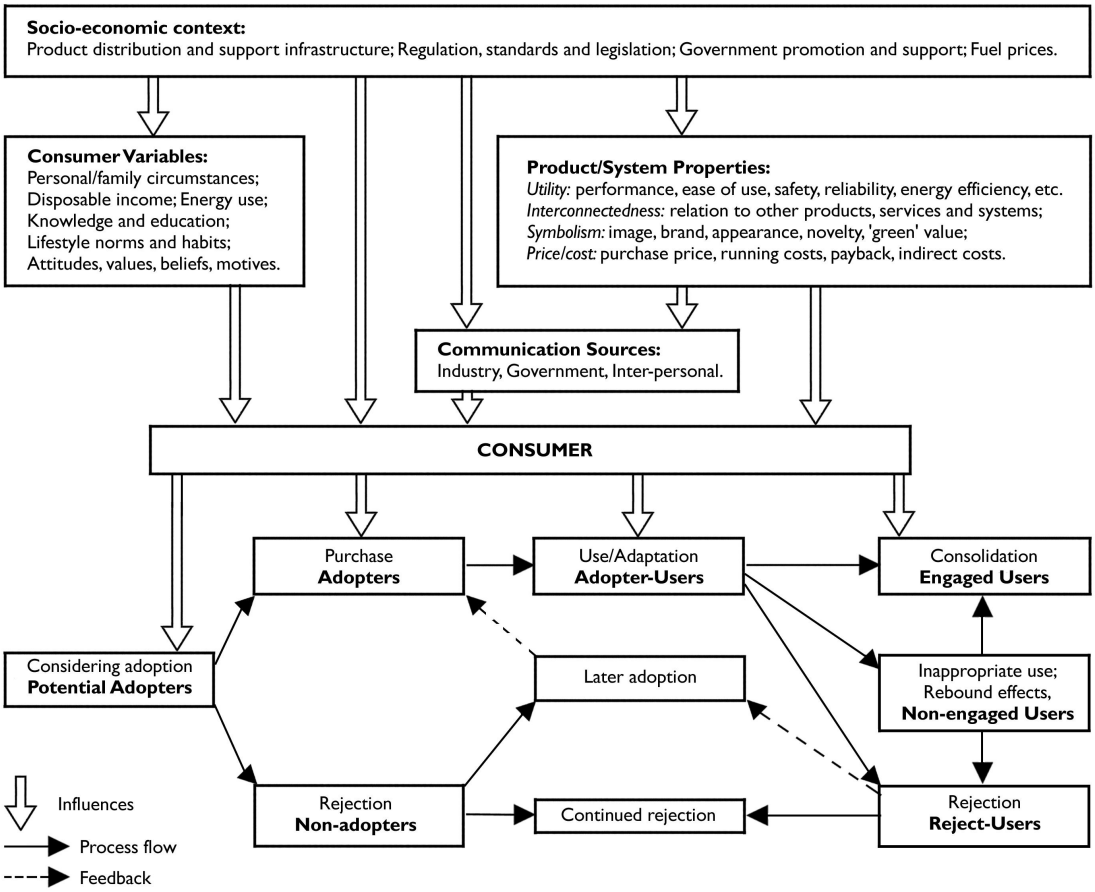

Fig.1. Model of adoption and use of LZC products and systems (Roy, Caird and Potter, 2007)

In the 14 exploratory interviews different consumer categories were identified and incorporated into the model. These included:

- *Potential adopters* (i.e. those considering adoption);
- *Adopter-users* (those who installed and used a LZC product or system);
- *Non-adopters* (those who seriously considered but decided against adoption i.e. rejectors);
- *Reject-users* (those who rejected a product or system *after* using it).

The adopters were further categorised into *engaged users* (those who adapted their behaviour to use the LZC product or system effectively e.g. to avoid rebound effects) and *non-engaged users* (those who did not use the product or system effectively).

For the main phase we focused principally on adopter-users and non-adopters.

The exploratory interviews and survey showed that the influences on the adoption and use of different LZC technologies varied, but all could be classified within our research model, giving confidence in its validity (see Roy, Caird and Potter, 2007).

The exploratory study also obtained the views of 50 energy professionals, e.g. local authority housing officers, architects and energy consultants, via a questionnaire linked to the *NHER E-info* online energy newsletter, on the factors influencing on consumer adoption of various energy efficiency measures (loft insulation, heating controls, condensing boilers and CFLs) plus micro-CHP, solar thermal water heating and other renewables. Most of these professionals said they had good knowledge of energy efficiency measures and solar thermal water heating systems, but not micro-CHP or other household renewables. The survey specifically sought professionals' technical and other ideas for improving the products and systems to facilitate their more widespread consumer adoption and, together with the influencing factors identified in research model, helped to develop the surveys for the main phase.

2.2 The main phase surveys

For the main phase we surveyed the factors influencing consumer adoption – and non-adoption – of solar thermal water heating and solar PV systems, micro-wind turbines and wood-burning stoves. Apart from micro-hydro, these are the renewables identified in the DTI Micro-generation Strategy and supported by the Low Carbon Buildings Programme. We also surveyed adopters' experience of installation and use of these products and gathered their responses to ideas for improving them. The research was conducted in two ways:

via structured telephone interviews, each lasting 30 to 60 minutes, with householders who had sought advice from the 'Energy for Good' scheme managed by the National energy Foundation (a charity which promotes renewables and other low carbon technologies) in partnership with local authorities, County Councils and Energy Efficiency Advice Centres. We randomly selected clients from those who had sought advice about solar thermal water heating between 2004 and 2006 (excluding those receiving state benefits) and interviewed those willing to participate and offered the option of a £10 incentive. The interviews were conducted with 15 adopters and 13 householders who had considered but decided against adopting solar thermal water heating. At the time Energy for Good had few clients who had installed renewables other than solar thermal water heating and therefore it was not possible to extend the interviews to other technologies.

via an online questionnaire accessible to the general public posted in Spring/Summer 2006 on the website of the Energy Saving Trust (EST) and on a website linked to the BBC/Open University *Climate Chaos* TV series. This questionnaire produced 390 responses which included both adopters and non-adopters over the past four years of energy efficiency measures (loft insulation, central heating controls, a condensing boiler, compact fluorescent or LED lamps and micro-CHP), and/or household renewables (solar thermal water heating, solar PV, micro-wind turbines and wood-burning stoves).

Table1 details the numbers adopting and deciding against adoption of the four selected renewables.

Table 1 Numbers adopting and rejecting household renewables

Renewable energy technology	Installed (Mainly online survey)	Seriously considered but decided against. (Mainly online survey)	Installations as % considering adoption (Online survey)
Solar thermal water heating (STWH)	39 (10%) 15 interviews	151 (39%) 13 interviews	39/190=20%
Solar photovoltaic (PV)	12 (3%)	130 (33%)	12/142=8%
Micro-wind turbine (MWT)	7 (2%)	128 (33%)	7/135=5%
Wood-burning stove (WBS).	63 (16%)	65 (17%)	63/128=49%
Total adoptions and non-adoptions	121 (total number of respondents=390)	474 (total number of respondents =390)	121/595=20%

Note: some multiple adoptions

2.3 The respondents' characteristics

The respondents to the online questionnaire were self-selected and, as is detailed below, were 'greener' and from higher socio-economic groups than the general UK population. This is the result of these respondents reaching our questionnaire from websites concerned with energy efficiency and climate change, as is required in order to include the early adopters of innovative technologies such as domestic renewables.

This is therefore a 'purposive' rather than a representative survey. Our respondents' reasons for non-adoption, and the problems of adopters, thus represent important barriers that need to be addressed before the less wealthy, less 'green' general population will consider adopting renewable energy technologies.

2.3.1 The Energy for Good scheme interviewees

The characteristics of interviewees who had adopted, or had considered but decided against adopting, solar thermal water heating systems is shown in Table 2.

Table 2 Characteristics of the majority of interviewed adopters and non-adopters of solar thermal water heating systems

Variable	Adopters N=15	Non-adopters N=13
House size	47% live in 3 and 27% in 4-bedroomed homes	38% live in 4 and 23% in 3-bedroomed homes
Type of house	47% live in detached homes and 40% in bungalows	46% semi-detached and 23% bungalows and 23% detached
Household size	73% from household of 2	42% from household of 4
Main earner's occupation	45% retired 40% had technical background	77% not retired 42% had technical background
Level of concern about reducing impacts on environment	95% fairly or very concerned	92% fairly or very concerned

Note: Some non-adopters remained potential adopters, although only a minority 4 (31%) were fairly or very likely to adopt a solar thermal water heating system.

2.3.2 The online survey respondents

The online survey produced 390 responses from people who had adopted – or seriously considered but rejected – one or more of the renewable energy systems listed in Table 1 over the past four years. **However, its is important to note that this online group also included a number of people who had adopted, or considered but rejected, one or more household energy efficiency measures and which are the subject of a separate report (Caird and Roy et al. 2007)**.

Table 3 Characteristics of the majority of online survey respondents

Variable	Majority responses
Geographical location of home	347 (89%) live in UK 292 (75%) live in England
House size	162 (42%) live in 3-bedroomed homes 102 (26%) live in 4 bed roomed houses
Age of house	152 (39%) houses built before 1930, 89 (26%) houses built after 1965
Type of house	134 (34%) live in semi-detached, 131 (34%) live in detached 44 (12%) live in mid-terrace houses
Main heating system in home	312 (80%) have central heating boiler and radiators 106 (27%) have a condensing boiler 215 (55%) don't have a condensing boiler
Main heating fuel	278 (71%) use mains gas 39 (10%) use oil
Hot water provision	201 (52%) from central heating system, 105 (27%) from gas instant/combi boiler
Existing insulation	345 (89%) have some loft insulation 166 (43%) have 100- 270mm loft insulation 162 (42%) have cavity wall insulation 237 (61%) have double glazing on most windows
Size of household	253 (65%) live in 2 adult households 132 (34%) households include children under 16 years
Main earner's occupation	111 (29%) Professional/senior management 52 (13%) Retired 46 (12%) Education/medical services 22 (6%) Middle management 21 (5%) Crafts/ tradesperson 15 (4%) Office/clerical worker

N= 390 (Percentages are of the total sample which includes other responses and missing data)

Table 4 (Appendix 1) presents some more detailed characteristics of the online adopters and non-adopters of renewable energy systems.

2.3.3 Environmental attitudes and behaviour of respondents

Table 2 above showed that most *interviewed* adopters were 'green' consumers who said that they were fairly or very concerned to reduce their impacts on the environment. For example,

> *'I like to see birds in the garden and there are less of them than there were before. We love animals and you have to think of grandchildren growing up. There are too many cars on the road and too many pesticides being used; I love greenery and clean air.'*
> (Solar thermal water heating adopter)

> *'I have been interested in the environment since the 1970s (when friends thought I was mad) because I used to live on a barge for years with a wind turbine and batteries to provide electricity. Environmental problems have become more critical in recent years.'*
> (Solar thermal water heating adopter).

Table 5 Environmental concern of adopters of household renewables (online survey)

Environ-mental concern	Unconc-erned	Quite unconcerned	Neither	Fairly concerned	Very concerned	Total	Missing data	% Fairly and very concerned
STWH	0	1	1	11 (39%)	24 (62%)	39	2	90%
PV	0	0	1	3 (25%)	7 (58%)	12	1	83%
MWT	0	0	0	1 (14%)	5 (71%)	7	1	85%
WBS	0	3	1	10 (16%)	45 (71%)	63	4	87%

The results presented in Table 5 show nearly as high levels of 'greenness' amongst the adopters of renewable systems who responded to the online survey, with at least 83% saying they were fairly or very concerned to reduce their environmental impacts.

Perhaps surprisingly, Table 6 shows that non-adopters who responded to the online survey had as strong green attitudes as the adopters, with at least 84% expressing environmental concern. Tables 5-6 show that a higher percentage of non-adopters report were quite unconcerned about their environmental impacts, including 7% of non-adopters of solar thermal water heating.

Table 6 Environmental concern of non-adopters of household renewables (online survey)

Environ-mental concern	Uncon-cerned	Quite unconcerned	Neither	Fairly concerned	Very concerned	Total	Missing data	% Fairly and very concerned
STWH	0	10 (7%)	3	28(19%)	101 (67%)	151	9	86%
PV	0	8 (6%)	1	28 (22%)	85 (65%)	130	8	87%
MWT	0	8 (1%)	3	18(14%)	92 (72%)	128	7	86%
WBS	0	4 (6%)	3	10 (15%)	45 (69%)	65	3	84%

Table 7: Actions taken by respondents to reduce their impacts on the environment (online survey)

Actions to reduce environmental impacts	Total	STWH	PV	MWT	WBS
Number	390				
Adopters (A)		39	12	7	63
Non-adopters (N)		151	130	128	65
Reduce, reuse, or recycle waste	354 (91%)	35 (90%) A 138(91%)N	10 (83%) A 119 (92%) N	4 (57%)A 118 (92%)	57 (90%) A 61 (94%) N
Save energy	333 (85%)	35 (90%) A 128 (85%) N	9 (75%) A 109 (84%)N	5 (71%) A 108 (84%) N	54 (86%) A 55 (85%) N
Reduce transport impacts	214 (55%)	20 (51%) A 85 (56%) N	9 (75%) A 70 (54%)N	5 (71%) A 71 (55%) N	37 (57%) A 41 (63%) N
Save water	268 (69%)	30 (77%) A 113 (75%) N	9 (75%) A 97 (75%) N	5 (71%) A 86 (67%) N	41 (65%) A 52 (80%) N
Shop for environmentally friendly products	247 (63%)	27 (69%) A 92 (61%) N	9 (75%) A 78 (60%) N	3 (43%) A 74 (58%) N	43 (68%) A 39 (60%) N
Reduce environmental impacts on home and garden.	272 (70%)	27 (69%) A 110(73%) N	9 (75%) A 91 (70%) N	4 (57%) A 87(68%) N	50 (79%) A 48 (74%) N
Community or political environmental action	71 (18%)	9 (23%) A 30 (20%) N	5 (42%) A 22 (17%) N	2 (29%) A 30 (23%) N	15 (24%) A 13 (20%) N

Note: percentages given for adopter (A) and non-adopter (N) sub samples.

Table 7 shows that the majority of both adopters and non-adopters of renewable energy technologies are taking environmental actions as follows:

- **Reduce, reuse, or recycle waste** – depending on the technology concerned 83% to 100% of adopters and non-adopters, i.e. almost all (except only 4 of 7 MWT adopters);
- **Save energy** – 71% to 90% of adopters and 84% to 85% of non-adopters;
- **Reduce transport impacts**, e.g. cycling, walking, using public transport – 51% to 75% of adopters and 54% to 63% of non-adopters;
- **Save water** – 65% to 77% of adopters and 67% to 80% non-adopters;
- **Shop for environmentally friendly products** – 43% to 75% of adopters and 58% to 61% of non-adopters;
- **Reduce environmental impacts when looking after home and garden** – 57% to 79% of adopters and 68% to 74% of non-adopters;
- **Community or political environmental action** – 23% to 42% of adopters and 17% to 23% of non-adopters.

There is no clear trend of adopters taking more environmental actions than non-adopters, and the numbers of solar PV and micro-wind adopters are too small for comparative purposes. It is interesting that non-adopters are recycling more than adopters of the renewable systems.

2.3.4 Summary of respondents' characteristics

Using SPSS to cross tabulate adoption data with characteristics of the sample reveals a strong profile reflecting the most typical characteristics of the adopters of renewables in the online survey (although there were too few solar PV, and micro-wind adopters to provide conclusive results for these technologies).

- **At least two–thirds are from two-person adult households** (65% to 79% depending on the technology, except smaller percentages of the small groups of micro-wind turbine and PV adopters), only about a fifth of solar thermal water heating adopters and 42% wood-burning stove adopters come from households with children under 16 years;
- **A middle class household** where the main earner belongs to the occupational category of professional/senior or middle management (33% to 34%), education or medical services (8% to 10%) or are retired (10% to 18%). It is notable that 13% of all adopters of renewables are retired, including 18% of solar thermal water heating adopters;
- **Living in detached** (44% to 49%) **or semi-detached houses** (28% to 33%) with three (29% to 30%) or four bedrooms (27% to 49%).

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

The non-adopters' characteristics in the online survey, i.e. those who seriously considered adopting renewable energy systems but decided against, are similar to those of the adopters, typically coming from:

- Two adult households (66% to 71% depending on the technology), with about a third (30% to 38%) not adopting renewable energy systems from households with young families;
- Middle class occupations of professional/senior or middle management (30% to 34%) or education/medical services (10% to 14%) or retired (up to 15%);
- Living in semi-detached (37% to 46%) or detached houses (23% to 33%) with three (44% to 48%) or four bedrooms (21% to 28%).

The characteristics of the interviewees who decided against adoption of solar water adopters was similar, but with a lower proportion of retired people (13%) and fewer living in detached homes (23%).

Those considering adoption of renewables, both adopters and non-adopters appear to come from similar backgrounds, i.e. households with 2 adults and from professional, managerial, education or medical occupational categories, although higher numbers of adopters are retired and come from detached homes. Few households with young children consider renewables and even fewer adopt them.

3 Results

The results presented in this report are mainly based on an analysis of the 390 responses to the online consumer survey. The online responses for solar thermal water heating are augmented by data from telephone interviews with the Energy for Good clients. The online survey of energy efficiency professionals provides supplementary and illustrative information. The results are summarised in Tables 8-17 below.

The tables cover multiple adoptions, drivers and barriers to adoption, problems in use, and the benefits and impacts experienced by adopters. **The results also include ideas and policies for improving renewable energy systems** agreed with, or independently cited by, more than 20% of the online survey respondents, by the 50 energy efficiency professionals and in the 28 solar thermal water heating interviews.

3.1 Multiple adoption of energy efficiency measures and renewable energy technologies

Analysis of the online-survey data for adopters and non-adopters given in Table 8 (using SPSS to cross tabulate adoption of LZC technologies) shows that **the majority of online respondents had adopted at least two energy efficiency measures** for the home. However, Table 8 shows that **very few online respondents have adopted both energy efficiency measures and renewable energy technologies**. For example, only 11% of the total sample has heating controls or loft insulation and a wood-burning stove; only 6% have loft insulation and solar thermal water heating (STWH) and 3% have a central heating programmer (HC/P) and solar PV.

Table 9 shows the results of a further analysis of the extent to which the adopters of energy efficiency measures and renewables consider but decide against adopting other energy efficiency measures and/or

renewables. Using SPSS to cross tabulate data on adoption and non-adoption of LZC technologies, the results show that almost a third of the 390 online respondents, a sizable proportion, who adopted an energy efficiency measure also considered but decided against adopting other LZC technologies. For example, about one fifth of the sample adopted loft insulation but following consideration decided against STWH (23%), solar PV (20%) and a micro-wind turbine (21%). More than one third of loft insulation and heating controls adopters considered but decided against solar thermal water heating, solar PV or a micro-wind turbine.

Table 8 Multiple adoption of LZC technologies (energy efficiency measures and/or renewables – online survey)

Adopters LZC technologies	LI	HC/P	TRV	Cond. boiler (CB)	CFL	LED	Micro-CHP	STWH	PV	MWT	WBS
Loft Insln (LI) N=229 (59%)		194 (50%)	147 (38%)	75 (19%)	165 (42%)	25 (6%)	2 (1%)	23 (6%)	9 (2%)	5 (1%)	44 (11%)
STWH N =39 (10%)	23 (6%)	31 (8%)	23 (6%)	13 (3%)	29 (7%)	5 (1%)	2 (1%)		6 (2%)	3 (1%)	7 (2%)
Programmer (HC/P) N =286 (73%)	194 50%		196 50%	103 26%	207 53%	24 6%	3 1%	31 8%	11 3%	5 1%	43 11%
TRV N =214 (55%)	147 38%	196 50%		83 21%	156 40%	22 6%	2 1%	23 6%	8 2%	5 1%	43 11%

Percentages given for total sample = 390

Table 9 Adopters of LZC technologies who decided against adopting other LZC technologies (energy efficiency measures and/or renewables – online survey)

Non-adopters of LZC technologies	LI	HC/P	TRV	Cond. Boiler (CB)	CFL	LED	Micro-CHP	STWH	PV	MWT	WBS
Adopters Loft Insln (LI) N =229 (59%)		5 (1%)	31 (8%)	58 (15%	11 (3%)	31 (8%)	32 (8%)	88 (23%)	79 (20%)	83 (21%)	42 (11%)
Adopters STWH N =39 (10%)	5 (1%)	2 (1%)	7 (2%)	12 (3%)	1 (0%)	6 (2%)	3 (1%)		12 (2%)	13 (3%)	6 (2%)
Adopters programmer (HC/P) N=286 (73%)	47 12%		43 11%	76 19%	19 5%	54 14%	52 13%	118 30%	107 27%	105 27%	56 14%
Adopters TRV N=214 (55%)	33 8%	43 11%		52 13%	13 3%	37 9%	31 8%	90 23%	73 19%	72 18%	36 9%

Percentages given for total sample = 390

In our sample STWH was the most commonly adopted renewable with 39 installations (10% of the sample, compared to approximately 0.3% of UK households with STWH). Focussing on this small sub-sample, more than 70% had adopted other energy-efficiency measures, such as CFLs (74%) and central heating programmers (HC/P, 79%), and 59% have adopted both loft insulation (LI) and TRVs. This suggests that adopters of renewables, such as STWH, have typically installed other energy efficiency measures, although the reverse is not true. Fewer adopters of STWH have adopted other renewables: 18% have adopted wood-burning stoves; 15% have adopted solar PV; and 8% have adopted a micro-wind turbine. Although fewer STHW adopters have adopted other renewables (Table 8) about one third have considered but decided against purchasing solar PV (31%) and micro-wind (33%), and 15% considered but decided against a wood-burning stove. (Percentages in Tables 8-9 are based on the total sample; percentages for the sub-sample of STWH adopters can be ascertained from statistics provided).

What emerges from this analysis is that many adopters of energy efficiency measures say that they are seriously considering adopting renewables, even if they have decided against doing so for now. Most adopters of solar thermal water systems have adopted energy efficiency measures and many have considered adopting other renewables.

3.2 Drivers for adoption of household renewables

3.2.1 Primary drivers

Table 10 shows that the online respondents installed solar thermal water heating, solar PV, micro-wind turbines and wood-burning stoves for the following most frequently cited reasons:

- **Saving energy and/or reducing fuel consumption**. This reason was given by 83% adopters of solar thermal water heating, and 65% adopters of wood-burning stoves, and about one third of small sample of adopters of solar PV and micro-wind turbines;
- **Concern for the environment**. This was the second most frequently cited reason given by adopters of solar thermal water heating (79%) and micro-wind turbines (33%) and the top reason for solar PV (56%). This was the second most frequently given reason in interviews with solar thermal water heating adopters (73%).

'*I am very concerned about climate change and in particular the lack of concern by governments. I think that it is difficult for the individual to do anything about it. I even feel cynical about the actions I have taken; about how much good they are likely to do. More needs to be done to make it easier for people to take eco-friendly actions.*'
(Solar thermal water heating adopter)

'*I have always cared about nature. When we moved we had lovely heath land around us and now this is covered by buildings. We have lost a lot of birds and butterflies (Suffolk Blues are very rare now). I am very sorry about this and want to do my bit to protect the environment and do something about my grandchildrens' future*.' (Solar thermal water heating adopter)

- **Saving money and/or reducing fuel bills**. This reason was given by 77% adopters of solar thermal water heating, about half adopters of solar PV (56%) and wood-burning stoves (52%), and about one third of adopters of micro-wind turbines.

'*I chose this system because it was simple with little to go wrong, and providing lower cost for the given output. It had a polycarbonate panel, solar powered pump on roof, an auto drain back so no antifreeze is needed, and a single hot water tank designed with the solar coil at the bottom of the tank and the boiler coil at the top.*'
(Solar thermal water heating adopter undertaking a DIY installation)

Some key reasons for adoption were specific to particular renewables, as follows

- **Having funds available to invest.** This was the second most frequently cited reason for solar PV adopters (43%) and given by a similar percentage of solar thermal water heating adopters (42%). Sometimes having funds was as a result of moving house or having a retirement lump sum to invest;

'*I do not expect payback in my lifetime because I am 73 years old, although rising gas prices may reduce the time it takes to achieve payback from 7-10 years to 4 years….I believe that I*

have a moral obligation to do something about climate change. I can afford it so I should!' (Solar thermal water heating adopter)

'*We got an opportunity to relocate to Suffolk from London. We had always been aware of green issues but had not done a lot about it, so we decided to get a solar thermal water heating system when we had an extension built on the house*.'.(Solar thermal water heating adopter)

- **Because it was affordable or free/low cost/got a grant/special offer.** This reason was given by less than one third of adopters: solar thermal water heating (31%), solar PV (25%) and micro-wind turbines (17%).
- **To try an innovative technology**. This reason was given by up to quarter of adopters: solar thermal water heating (27%), solar PV (19%) and micro-wind (22%).
- **Enjoying the warmth and appearance of a real fire and having a stove that adds to the room décor** were the top reasons for adopting wood-burning stoves mentioned by 65 to 82% of these adopters**.**
- **Having access to free/low cost supply of wood fuel** (63%) and an **alternative source of heating** (48%) were important reasons given by adopters of wood-burning stoves.

'*The wood burner is one of the best things purchased - if only from the aesthetic point of view - but its fuel efficiency and clean burn of a renewable energy source makes it a very worthwhile installation.*' (Wood-burning stove adopter)

'It is essential to have alternative energy/heating supplies at this rural UK location.' (Wood-burning stove adopter).

Table 10 Drivers for consumer adoption of renewables (online survey and solar thermal water heating interviews)

Drivers for adoption	Solar thermal water heating (STWH)	Solar PV	Micro-wind	Wood-burning stove
Sample – online survey adopters	39	12	7	63
Sample – online responses	52	16	18	60
Sample – interviews	15	0	0	0
Save energy/reduce fuel consumption.	43 (83%) 47% interviews **Rank 1**	5 (31%) **Rank 3**	7 (39%) **Rank 1**	39 (65%) **Rank 2 =**
Reduce fuel bills/save money.	40 (77%). 53% interviews **Rank 3**	4 (25%)	5 (28%) **Rank 3**	37 (62%) **Rank 3 =**
Concern for the environment/global warming/reduce emissions.	41 (79%). 73% interviews **Rank 2**	9 (56%) **Rank 1**	6 (33%) **Rank 2**	31 (52%)
Had funds available to invest	22 (42%) 27% interviews	7 (43%) **Rank 2**	2 (11%)	19 (32%)
Because it was affordable or free/low cost/got a grant/special offer.	16 (31%)	4 (25%)	3 (17%)	†
Adds value on property/would help sell it.	10 (19%)	2 (13%)	2 (11%)	17 (28%)
Doing building work anyway/part of other home improvements.	4 (8%) A DIY job. 20% interviews	2 (13%)	2 (11%)	16 (27%)
To try an innovative technology	14 (27%)	3 (19%)	4 (22%)	†
To make my/our environmental credentials visible	7 (13%)	2 (13%)	2 (11%)	6 (10%)
Like warmth and appearance of a real fire.	†	†	†	49 (82%) **Rank 1**
Attractive appearance of stove/part of room decor	†	†	†	39 (65%) **Rank 2 =**
Have access to free/low cost supply of wood fuel	†	†	†	38 (63%) **Rank 3 =**
Alternative to gas or electricity for heating	†	†	†	29 (48%)
Additional drivers *	Opportunity to observe friends/relatives/neighbours positive experience. 10 (75%) interviews **Rank 3 =** Long term interest linked to job and education. 4 (27% interviews) Moral obligation to do something to halt climate change A growing trend in the county		Ideal location	Enjoy exercise associated with collecting and using wood

† = not asked, * Additional drivers were open-ended responses to the online survey and interviews.

3.2.2 Additional drivers

These additional drivers are open-ended comments made by interviewees or a few online respondents and thus provide anecdotal evidence (Table 10). The interviews with householders considering and adopting solar thermal water heating showed that people are reassured by schemes such as the 'Energy for Good' information and advice scheme managed by the National Energy Foundation (NEF) in partnership with Local Authorities and local Energy Efficiency Advice Centres. Several of the interviewed adopters of solar thermal water heating mentioned that the local Council was the most helpful source of advice, some being happy to trust their Council's recommendation of installers.

'*I think it is important to be able to trust an organisation like the Council to recommend reputable installers rather than respond to ads or leaflets through the door.*'
(Solar thermal water heating adopter)

'*A salesman came around and wanted me to sign on the spot, a kind of double glazing salesman. I refused saying that I never made decisions like that. I received a brochure from Suffolk Council about grants for STWH and I was happy to pursue this*.'
(Solar thermal water heating adopter)

'*I received a quote for each sort of solar water system but decided to choose one installer, who inspired trust and made me feel that he would look after us should we have any problems following installation. That installer quoted for the evacuated tube sort but said that he could give us the other sort if we liked. But we accepted his recommendation not being sure about the respective merits of each. I am aware that this system collects indirect light very well and solar energy in winter*.' (Solar thermal water heating adopter)

Several were delighted when installers brought **demonstration models** to their home or introduced them to neighbours to view their operating solar thermal systems.

'*The installer came and laid out the evacuated tube and flat plate types in garden. This demonstration showed that the feed was hotter on the evacuated tube type*.'
(Solar thermal water heating adopter)

'*I have a strong interest in sciences and had read about black radiators used to heat water and knew that they were not efficient. The installer demonstrated with a demonstration model of solar tubes, that they were capable of picking up rays on a cloudy day. I did research on internal solar tubes and found that they were capable of picking up rays on a cloudy day*.'
(Solar thermal water heating adopter).

Several were pleased when installers introduced them to neighbours to view their operating solar thermal systems. The most frequently cited reason given in 75% interviews with solar thermal water heating adopters was the **opportunity to observe the positive experience of friends, relatives or neighbours,** an important driver that was not incorporated into the online questionnaire.

'*The installer put me in touch with a household with a solar thermal water heating installation. I found I knew the family when I visited and was pleased to hear their evaluation of the system. …They told me that they had had the system for 14 years and that all their hot water was now free*.' (Solar thermal water heating adopter)

'*It is a trend; lots of people are doing it in Suffolk. I have many friends with solar thermal water heating. I am also receiving lots of phone calls from people interested in it. My installer is very busy with installations in homes and schools and council offices*.'
(Solar thermal water heating adopter)

Several mentioned that their interest in renewables was a long-term interest related to their job, such as in farming and engineering; lifestyle, such as experience of living in countries that use renewable energy more widely; and interests in environment issues and low carbon technologies.

'*I became interested in renewable energy many years ago at Technical School when I was learning about buildings maintenance. I saw an item in the local press published by SEAL (Suffolk Energy Action Link). … I was the first to install with Suffolk Coast District Council and so have received a lot of media interest and have been on local radio several times to discuss it.*' (Solar thermal water heating adopter)

3.3 Barriers to adoption of household renewables

This section presents the barriers to adoption of renewables by these mainly 'green' consumers.

3.3.1 Primary barriers

Table 11 shows the barriers to adoption of renewable energy systems from analysis of the responses to the online consumer survey. Also shown is some data on solar thermal water heating adoption issues from the interviews with Energy for Good clients and the survey of the energy efficiency professionals. The table shows that there are some common reasons why consumers seriously considered but rejected solar thermal water heating, solar PV and micro-wind; although the importance of these barriers varied for each system. Other barriers are specific to each of the renewables.

Capital cost

Unsurprisingly, capital cost was a barrier to adoption of most of the renewable energy systems we surveyed. The majority of non-adopters of solar thermal water heating (73%), solar PV (85%) and micro-wind turbines (53%) considered these technologies too expensive. Other reasons common to all renewables were also cost related; namely the view that the likely fuel savings or the price paid for home-generated electricity are not worth the investment (21% to 40% adopters).

> While only 35% non-adopters of wood-burning stoves mentioned cost as a barrier, several non-adopters were concerned that there may be additional costs of remedial work to modify their property, such as installing a flue liner for the chimney and/or a new hearth.
>
> '*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*' (Wood-burning stove non-adopter).

System will not last long enough to payback

Payback was an issue for a quarter of non-adopters of solar thermal water heating (24%), solar PV (28%), but less of a barrier for non-adopters of micro-wind (15%).

> '*The payback period proved to be vastly longer than my remaining life expectancy*.'
> (Solar thermal water heating non-adopter)
>
> Payback is not static and is influenced by fuel costs, effective use of the system, reliability of renewable energy source, costs of maintenance, as well as technological improvements to the efficiency of comparative systems delivering the same functionality.
>
> '*As boilers get more efficient, payback on solar water heating gets even longer*.'
> (Energy efficiency professional)

Expected disruption in the home

About 40% of non-adopters of wood-burning stoves mentioned concerns about dust and dirt in the home and the requirement for frequent refuelling and ash removal. This was an issue for only 16% non-adopters of solar thermal water heating and related to installation rather than use.

> '*We have a three-storey house so lots of disruption from pipe-work and big costs were major factors*.' (Solar thermal water heating non-adopter)

Difficulty in gaining planning permission

More than one third (37%) non-adopters of wind turbines had difficulty in gaining planning permission, compared with only 13% non-adopters of both solar thermal and solar PV.

Difficulty finding space/suitable location for unit

33% non-adopters of micro-wind turbines and 35% wood-burning stove non-adopters were put off by the difficulty finding sufficient space or a suitable location for the equipment. Some micro-wind non-adopters mentioned it is especially difficult for terraced, urban, suburban and some modern house designs to find space and a suitable location for a turbine. Wood stove non-adopters have additional space issues with nearly half (45%) put off by the lack of space to store wood fuel.

Difficulties in finding a reputable installer

This was an issue for a quarter non-adopters of solar thermal water heating (25%), solar PV (24%) and micro-wind turbines (25%).

Problems connecting or incompatibility with existing systems

This was an issue for about a quarter non-adopters of wood-burning stoves (28%), solar PV (24%) and micro-wind (21%). Although 56% energy professionals thought that this was a barrier to adoption of solar thermal water heating, only 19% of STWH non-adopters agreed.

> '*We need more information about how to do it and how to connect the electricity generated to our electrical supply*.' (Solar PV non-adopter)
>
> 'The increase in water storage tanks may require the floor joisting to be increased.'
> (Solar thermal water heating non-adopter)

New technology with uncertain reliability and performance

This was an issue for about a fifth non-adopters of solar thermal water heating (23%), solar PV (19%) and micro-wind turbines (21%).

> '*It's a big one off purchase and you can't do it again if it's a failure. Perhaps delay is better, wait for better systems; I don't want to be a guinea pig. I want to view real [working] systems and have recommendations and feedback on performance.*'
> (Solar thermal water heating non-adopter).

> '*There are no independent performance tests such as in the 'Which?' report. I'm not happy to rely on manufacturers' ratings or reliability figures.*' (Solar PV non-adopter)

> '*I accepted a cheaper quotation to have a new model installed, designed by Sydney and Beijing universities. Unfortunately, this system blew up during an installation due to a design fault, before the company came to me. I had to have an older model installed which was more expensive but I did not have to pay the extra because a contract had been signed.*'
> (Solar thermal water heating adopter)

> '*All wind turbines need to import electricity continuously simply to hold the system in readiness for when the wind blows at over 10 mph and they do not generate full power until the wind speed reaches 20 mph. Due to the vagaries of the winds in the UK they all only generate full power for 25% of the time- The capital costs per Kw installed make them dearer than nuclear stations.*' (Micro-wind non-adopter)

Insufficient electricity produced from system

This was a deterrent for non-adopters of solar PV (28%) and micro-wind turbines (19%).

Energy is not available when required

Some non-adopters are concerned that the energy is not available when required: micro-wind (17%), STWH (13%) and solar PV (11%).

> '*They work best when hot water is least required.*' (Solar thermal water heating non-adopter)

> '*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. As a household we will need to think about soaking dishes used during the day for washing in the evening and having evening washes. This is a personal issue and I'm not sure if my household will change their habits.*' (Solar thermal water heating non-adopter)

Barriers specific to solar thermal water heating

High pressure sales techniques

A quarter of energy efficiency professionals (24%) regarded the use of high pressure sales techniques as a major problem; however only 11% of STWH non-adopters surveyed online had a problem with this.

> '*Some companies using high pressure sales techniques also make unrealistic claims (indicate it saves on heating which customers interpret as space heating whereas it only saves on domestic hot water) and charge extortionate prices, potentially damaging the reputation of the industry.*' (Energy efficiency professional)

Barriers mainly specific to wood-burning stoves

Difficulty controlling heat output from system

This was a unique barrier for 43% non-adopters of wood-burning stoves.

> '*I need more info about how many "watts" output one needs to get a room of a given size to a particular temperature. If I only want a little warmth occasionally, I don't need something that "efficiently" gives me ten times that for several hours.*' (Wood stove non-adopter)

Barriers specific to micro-wind turbines

Noise and vibration from unit

This was a unique barrier for 26% non-adopters of micro-wind turbines.

Unattractive visual appearance

This was an issue for a fifth of non-adopters of micro-wind (22%), but only cited by a minority of non-adopters of STWH (9%) and solar PV (9%).

Table 11 Barriers to adoption of household renewables (online survey and consumer interviews plus views of energy professionals)

Barriers to adoption	Solar thermal water heating (STWH)	Solar PV	Micro wind (MWT)	Wood-burning stove (WBS)
Sample – online survey	151	130	128	65
Sample – online responses	149	123	126	69
Sample – interviews	13	0	0	0
Sample – professionals	50	0	0	0
Too expensive	109 (73%) non-adopters 47 (94%) professionals 9 (69%) interviews **Rank 1**	104 (85%) non-adopters **Rank 1**	67 (53%) non-adopters **Rank 1**	24 (35%) non-adopters **Rank 3**
Likely fuel savings not worth the cost	53 (36%) non-adopters **Rank 2**	49 (40%) non-adopters **Rank 2**	26 (21%) non-adopters	†
A new technology with uncertain performance and reliability	35 (23%) non-adopters 6 (12%) professionals	23 (19%) non-adopters	27 (21%) non-adopters	†
Difficulty in gaining planning permission	19 (13%) non-adopters 13 (26%) professionals	16 (13%) non-adopters	46 (37%) non-adopters **Rank 2**	†
Difficulty finding reputable installer	37 (25%) non-adopters 19 (38%) professionals **Rank 3**	29 (24%) non-adopters	32 (25%) non-adopters	†
Difficulty finding space/ suitable location for unit	26 (17%) non-adopters 20 (40%) professionals	20 (16%) non-adopters	42 (33%) **Rank 3**	24 (35%) non-adopters **Rank 3 =** Lack of space to store wood fuel. 31 (45%) non-adopters **Rank 1 =**
Expected disruption in the home.	24 (16%) non-adopters	†	†	More dust and dirt in the home. 28 (41%) non-adopters **Rank 2 =** Frequent refuelling/ash removal required. 27 (39%) **Rank 2 =**
Incompatibility with existing heating/ hotwater system	29 (19%) non-adopters 28 (56%) professionals	†	†	19 (28%) non-adopters
Not available when required	Solar water 19 (13%) non-adopters	Solar-electricity 14 (11%) non-adopters	Wind-electricity 21 (17%) non-adopters	†

System not likely to last long enough to pay back	36 (24%) non-adopters 47 (94%) professionals 6 (46%) interviews	34 (28%) non-adopters **Rank 3 =**	9 (15%) non-adopters	†
Unattractive visual appearance	14 (9%) non-adopters 17(34%) professionals	11 (9%) non-adopters	28 (22%) non-adopters	†
Doesn't add to house value/saleability	6 (4%) non-adopters and professionals	5 (4%) non-adopters	7 (6%) non-adopters	†
Insufficient electricity produced from system	†	35 (28%) non-adopters **Rank 3 =**	24 (19%) non-adopters	†
Problems connecting to existing electricity system	†	30 (24%) non-adopters	26 (21%) non-adopters	†
Reasons specific to each technology	High pressure techniques used to market STWH 17 (11%) non-adopters 12 (24%) professionals		Noise / vibration. 33 (26%) non-adopters	Difficult to control heat output from stove**.** 30 (43%) non-adopters **Rank 1 =** Environmental benefits not worth the cost. 10 (14%) non-adopters

† = not asked.

3.3.2 Additional barriers

These additional barriers are open-ended comments made by a few online respondents or interviewees and thus only provide anecdotal evidence. Some *technical concerns* were mentioned, for example several non-adopters of solar thermal water heating, solar PV and micro-wind turbines were concerned about the impact of the installed system on the building structure. Related to this are concerns about maintaining system components that are in locations inaccessible for users. Other technical concerns of non-adopters of solar thermal water heating include the adequacy of tank hot water storage capacity and possible freezing. Indeed several had doubts that solar energy is viable in the UK, while others were put off by poor experience with other solar powered products, even those that worked on completely different principles.

> '*I tried lots of solar lighting/fountains etc for outside and none of it has worked*.'
> (Solar thermal water heating non-adopter)

Some non-adopters mentioned *environmental concerns***,** for example, the effects of micro-wind turbines on birds or pollution from wood burning stoves.

> '*Surely a wood-burner emits carbon dioxide and particulates. Hardly clean!*'
> (Wood-burning stove non-adopter)

Others dislike the green symbolism of renewable energy systems, and one non-adopter of micro-wind turbine mentioned concern about possible adverse impacts on relations with neighbours.

> '*The image would not encourage people to adopt being …not ordinary and everyday but associated with left-wing hippy types*' (Solar thermal water heating non-adopter).
>
> '*The view is it is not for "normal" households.*' (Energy efficiency professional)

Several non-adopters of wood-burning stoves are concerned about whether there is an adequate supply of good quality wood or wood pellets and a reliable delivery. Non-adopters of micro-wind turbine and PV are concerned about receiving a fair price for electricity generated.

> '*Apparently you have to sell all your electricity to your supplier for say 3p per unit and buy back for 9p per unit, you cannot use your own electricity first then top up from supplier*.'
> (Solar PV non-adopter)

Several non-adopters complain of the lack of demonstration installations on public buildings to inspire confidence, since this would inspire consumer confidence in renewables some of which are still regarded as innovative and untried. Several would like to see government taking a lead to ensure that all new housing should integrate energy-efficiency and renewable technologies in their design, enforced by tighter Building Regulations. This would help bring costs down for retrofit through

economies of scale and would help the industry to build the infrastructure for supporting sales, installation and servicing.

Finally, several were concerned about the lack of *impartial advice and information* to help them evaluate available systems and use them effectively, including: independent information on prices, cost effectiveness and payback time; suppliers, installers and maintenance; reliability, durability and efficiency of different renewables; suitable location, impact on roof and house structure and compatibility with appliances; and advice on effective use to minimise carbon emissions. For example, consumers interested in micro-wind turbines complained about the lack of information about wind-speeds, suitability for urban/suburban location, potential damage to the house structure, and the effect on migrating birds. Several believe that the information provided by existing advice bodies is too generalised with the details on domestic installations of renewable systems left up to the installers.

3.4 Benefits of adopting household renewables

Although very few adopters of renewables were dissatisfied, Table 12 shows that the levels of satisfaction were highest amongst wood-burning stove adopters (82%) and solar thermal water heating adopters (67% of online and 47% of interviewees). Some two-thirds of wood-burning stove and STWH adopters were very satisfied with their purchase.

> '*Fantastic – every home should have one – Government regulations should incorporate solar thermal water heating in all new homes.*' (Solar thermal water heating adopter)

> '*The wood-burning stove has exceeded expectations in regards to the amount of heat generated, I'm also finding it a godsend to cook on as we have a lot of power cuts in this area and I have four under 5s to feed and keep warm.*' (Wood-burning stove adopter)

User satisfaction with solar PV is mixed and below that for solar thermal water heating. Only a third of PV adopters were fairly or very satisfied, with about half of adopters unsure, although about a third (31%) mentioned the pleasure of using renewable energy. This mixed reporting of satisfaction is probably due to not enough electricity being produced or available when required and the poor UK feed-in tariffs available.

Although few benefits were reported by wind turbine adopters which may reflect the small sample, attitudes were positive, for example, one adopter lost his turbine when struck by lightning but would still recommend micro-wind to anyone who lives in a suitable coastal area.

> '*Three years ago my small wind turbine was struck by lightning and I have been financially unable to repair/replace it but would recommend it to anyone. It's not for all locations, but would be ideal for coastal locations. It has a small visual footprint, unlike the massive wind farms.*' (Micro-wind turbine adopter)

Other benefits mentioned by about half of solar thermal water heating adopters and one third of wood-burning stove adopters were lower fuel bills, and energy use.

> '*I costed this improvement at 13 years for pay back, but achieved it in 10 years.*' (Solar thermal water heating adopter)

> '*It is early days, but I'm quite impressed. Doesn't seem to provide enough oomph on its own but makes a valuable contribution.*' (Solar thermal water heating adopter)

> '*I moved into a new home with three water heating systems oil, electric and STWH. We found that the STWH was so efficient in providing hot water that it was only during colder months that we realised that the oil-fired back up for water heating was not working.*' (Solar thermal water heating adopter)

About a third of STWH (35%), solar PV (38%) and wood-burning stove (30%) adopters said they had a greater concern about saving energy since adoption.

> '*The primary shift I have had to make is in my own awareness of what pulls an electrical load, however small. This has made me painfully aware of how much electricity is wasted by the countless tiny lights in an average grid home.*' (Solar PV adopter)

Few rebound effects were admitted by STWH, micro-wind and solar PV adopters. Some 60% of wood-burning stove adopters admitted heating rooms to a higher temperature. This rebound effect may be partially due to the greater difficulty of controlling the output of wood-burning stoves. However, few

wood-burning stove users admitted heating more of the house (17%) or leaving the heating on for longer periods (13%).

Although half of STWH adopters tried to use solar heated water when it was available, 21% were less concerned about using hot water and 8% were aware that they used more, a rebound effect, if not for energy if the extra was mainly solar heated, then for water use. The interviews showed that nearly half (47%) tried to use solar heated water when it was available, giving examples of showering in the afternoon or using their (hot-fill) washing machine in the afternoon thus allowing the water to reheat. But more than half (53%) had made no changes to their habits when efficient use may depend on washing in the afternoon or evening, and setting the boiler to minimise fossil fuel use. Some had not been advised in advance that their patterns of water use should change to get the best efficiency from the STWH, and although some were aware that it would be advisable to wash in the afternoon or evening, they continued with their preference for washing in the morning.

> '*I prefer to shower in morning when it would be more energy saving to shower in evening.*' (Solar thermal water heating adopter)

Table 12 Benefits and effects of adopting household renewables

	Solar thermal water heating	Solar PV	Micro-wind turbine	Wood-burning stove
Sample - online adopters	N=52	N=16	N=18	N=60
Sample - interviewed adopters	N=15	0	0	0
Positive appraisal – satisfied or very satisfied	35 (67%) online adopters 7 (47%) interviewees	5 (31%)	3 (17%)	49 (82%)
Dissatisfied	0 online adopters 3 (20%) interviewees	2 (13%)	1 (6%)	2 (3%)
Benefits				
Pleasure at using renewable energy	65% online adopters **Rank 1**	5 (31%) **Rank 2**	2 (11%) **Rank 1 =**	39 (65%) **Rank 1**
Lower fuel bills	54% online adopters **Rank 2**	3 (19%)	1 (6%)	22 (37%) **Rank 2**
Greater energy efficiency, lower fuel consumption	46% online adopters 60% interviewees	4 (25%) **Rank 3**	2 (11%) **Rank 1 =**	20 (33%) **Rank 3**
Greater concern about saving energy since adoption	35% online adopters	6 (38%) **Rank 1**	1 (6%)	18 (30%)
Try to use when available	50% online adopters 47% interviewees **Rank 3**	3 (19%)	2 (11%) **Rank 1 =**	†
Rebound effects (admitted by users)	Some online adopters No interviewed adopters	none	some	some
One or more rooms are heated to a higher temperature	2 (1%) online adopters	†	†	36 (60%)
Heat more of the house	†	†	†	10 (17%)
Heating is on for longer periods	†	†	†	8 (13%)
Less concerned about saving energy or hot water	21% online adopters (hot water)	0	1 (6%)	2 (3%).
Use more hot water	8% online adopters	†	†	1 (2%)
Leave lights on more	†	0	1 (6%)	†
Leave electronic equipment on for longer	†	0	0	†

† = not asked

3.5 Problems for adopters of household renewables

This section reports on some of the problems experienced by adopters during purchasing, installation and use of their renewable energy systems. Such problems can add useful insights to the key influences on their adoption and effective use.

The results in Table 15 are given for problems agreed with, or cited by the online survey respondents who adopted renewable energy systems. The small sample of online adopters of solar PV and micro-wind turbines experienced few problems and the results are thus anecdotal. Special attention is given to

the experience of adopters of solar thermal water heating using additional data from the interviews. The problems cited by STWH users are compared with the views of the online survey of energy professionals on the problems they expected consumers to experience.

3.5.1 Problems experienced while purchasing renewables

Difficulties finding a reputable installer

This was mainly a problem for 12% STWH adopters and a few adopters of other renewables.

> '*I felt that installers looked at you thinking about how much money they could make. With better information on components, I would have purchased a different solar thermal water heating system, i.e. a bigger tank, 2 panels, possibly a seal system (not atmospheric) and not be so focused on price*.' (Solar thermal water heating adopter)

> *'It was difficult and expensive to find someone to install it; we also had to have the chimney lined as the pipe from the stove seemed to be heating up the chimney breast too much, which was also quite expensive*.' (Wood-burning stove adopter)

Obtaining grants

This was mainly a problem for 10% solar thermal water heating adopters and relates to different grant systems being in operation in parts of UK, with some claims met post-installation and others not, so the adopter may need to be able to afford to pay upfront.

> '*The solar heating market is a nightmare, there are too many poor companies in the business. The grant process is absolutely chock full of bureaucracy, and all for £400. Government needs to do a whole lot better here*.' (Solar thermal water heating adopter)

> '*Even getting the grant back was difficult. It was very slow and I had to supply a lot of documentation to prove that I had the installation*.' (Solar thermal water heating adopter)

Difficulty in gaining planning permission

This was mainly problem for micro-wind turbine adopters (22%) and a few solar thermal water heating adopters. There appeared to be confusion about whether planning permission is needed, particularly for listed buildings.

> '*The installer was unclear if I needed planning permission and that it was up to the householder to find out. When I contacted the Local Authority Planning Section, they said that it was unusual to inquire about this; it was a grey area depending on whether the panel is erected above the tiles or installed on the rafters…. The installer said that he would remove tiles so that we did not require permission, but then changed his mind during the installation. I had to apply for permission retrospectively although the installer accepted responsibility for the costs*'. (Solar thermal water heating adopter)

3.5.2. Problems experienced during installation of renewables

Problems connecting to existing systems

Difficulties connecting to existing heating, plumbing and electrical systems was mainly a problem for wood-burning stove adopters (28%) and a few adopters of STWH, micro-wind and PV systems. Some 28% of wood-burning stove adopters mentioned integration with existing systems as difficult or expensive. Although a relatively inexpensive technology, not all houses are suitable and lining chimneys and connecting to an existing heating/hot water system can be expensive.

> '*It would have been too expensive to connect to existing radiators/ hot water system*.' (Wood stove adopter)

A few adopters of STWH mentioned problems in connecting to the existing plumbing system and the requirement to have plumbing alterations, such as radiators overhauled and gravity feed water system changed to direct mains.

3.5.3. Problems experienced during use of renewables

Unable to use solar heated water for all requirements

The most frequent disappointment for users of STWH was not being able to use solar heated water in their dishwasher or washing machine, due to plumbing constraints or because most new appliances are cold-fill only; or due to insufficient solar storage capacity. 31% of online survey, and 53% interviewed users were either unsure or not able to use solar heated water in these appliances. Less than one third of interviewed users had dishwashers or washing machines with a solar water feed. (This was also a deterrent for nearly 20% of non-adopters STWH.)

> '*I cannot find a dishwasher that will take the high temperature of water supplied by the solar system*.' (Solar thermal water heating adopter)

> '*I enquired before the installation, but all the suppliers recommend cold fill for hot water-using appliances. I even enquired with 'Which' but the consensus is that coldfill is best – shame*.' (Solar thermal water heating adopter)

> '*I do not mind (that I cannot use the solar heated water) because the utility area is a long way from the tank, and if connected to the solar water tank the water would have cooled by the time it reached the appliances, and this would not be the best use of the solar heated water*.' (Solar thermal water heating adopter)

Extra labour when using wood-burning stoves

Wood-burning stove users are concerned with the extra dust and dirt in the home (35%), the requirement for frequent refuelling and ash removal (10%), and difficulties controlling the heat output from the stove (13%). These have all been cited as barriers to adoption of wood-burning stoves.

> '*The thermostat in living room cuts off heating to rest of house – the fire makes living room hot but rest of house cold!*' (Wood-burning stove adopter)

> '*We tend to heat the lounge (the room where the stove is) to a higher temperature and then leave doors open so that the heat can travel through the house*.' (Wood-burning stove adopter)

Insufficient output from the system

This was mainly a problem for STWH and a few PV and micro-wind adopters. A few adopters were also concerned solar-heated water or solar or wind generated electricity is not available when required. The main reasons for insufficient solar hot water is lack of storage capacity or poor design of the system.

> '*I found it very difficult to talk to the installers who I believe sold me the wrong tank leading to a significant loss of heat over night. The hot water area in the tank is miniscule and so the water may be largely used up by morning. Another problem is the immersion heater being fed from the bottom of the tank rather than the top*.' (Solar thermal water heating adopter)

> '*There is significant cooling overnight with the tank losing 25% efficiency despite a new cylinder with circuits for both the boiler and solar*.' (Solar thermal water heating adopter)

System unreliability

Only a minority of online solar thermal water heating adopters experienced problems with their systems post installation, although most interviewed adopters experienced problems with leaks, pumps and/or valves (80%).

> '*I had continuous problems from the beginning with leaks (5 on the knuckle joints) and pressurisation which meant I had to have a new pump and valve. I have had the installer back 15 times!*' (Solar thermal water heating adopter)

A few adopters of micro-wind, solar PV and wood-burning stoves also experienced problems with reliability and breakdown of system components.

> '*One of three inverters is faulty and under-performing (shortly to be replaced).*' (PV adopter)

Table 13 Problems experienced by adopters of renewable energy systems

Note: results on solar thermal water heating adoption compared between online survey, interviews and views of energy professionals

	Solar thermal water heating	Solar PV	Micro wind	Wood-burning stove
Sample - online	52	16	18	63
Sample – interviews	15	0	0	0
Sample - professionals	50	0	0	0
Problems purchasing system				
High pressure techniques used to market STWH	7 (13%) adopters- **Rank 2**	†	†	†
Difficulty in finding a reputable installer	6 (12%) adopters- 19 (38%) professionals **Rank 3 =**	0 adopters	Few adopters	†
Obtaining finance for the system	5 (10%) adopters. Different grant systems in parts of UK with only some claims met post-installation	†	†	†
Difficulty in gaining planning permission	2 (4%) adopters. Confusion over planning permission requirement	Few adopters	4 (22%) adopters **Rank 1**	†
Problems during installation				
Difficulty in finding space/suitable location for the unit	4 (8%)adopters 20 (40%) professionals	0 adopters		A few agreed with this and with difficulty finding space for wood storage
Poor installation by installers	Few adopters 3 (6%) interviews	0 adopters		†
Greater than expected disruption in the home	Few adopters	Few adopters	0 adopters	Few agreed
Problems in connecting to existing systems	Few adopters	Few adopters	Few adopters	Not possible to connect to radiators and or/ hot water system 17 (28%) adopters. **Rank 2**
Problems during Use				
Cannot use solar heated water for all hot water requirements	16 (31%) adopters 8 (53%) interviews **Rank 1**	†	†	†
More dust and dirt	†	†	†	21 (35%) adopters **Rank 1**
Insufficient output from system	Insufficient solar heated water 6 (12%) adopters **Rank 3 =**	Few adopters (Insufficient electricity)	Few adopters (Insufficient electricity)	†
Difficult to control heat output from stove	†	†	†	8 (13%) adopters **Rank 3**
Too frequent refuelling/ ash removal required	†	†	†	6 (10%) adopters
Unreliability.	12 (80%) interviews problems post installation e.g. leaks, pumps and valves	(Faulty under-performing inverters)	(Durability issue due to exposure to elements)	

Additional issues for use				
Visual appearance	7 (47%) interviewees were not concerned 17 (34%) professionals thought it an issue	0 adopters	(Neighbours worried about appearance)	†
Noise	Few adopters (Noise from pump)	0 adopters	Few adopters (Noise/ vibration)	†
System not likely to last long enough to pay back investment	Few adopters	Few adopters	0 adopters	†
Poor service/ maintenance provision	Few adopters	0 adopters	0 adopters	

† = not asked. Online results used for ranking. Additional reasons were responses given by few adopters or in addition to presented suggestions

3.5.4 Additional issues for users of renewables

Visual Appearance

Although a third of energy professionals thought that the unattractive appearance of the solar panels was a deterrent for solar thermal water heating adoption, in practice few adopters were concerned, half of interviewed adopters were not concerned about the appearance; indeed several liked the way the solar panels visibly advertised their household's environmental credentials.

'*It is like flying a flag saying "we're green*"' (Solar thermal water heating adopter)

'*A visitor to the house asked "*What is that monstrosity on the wall?*"(laughed) ...and a neighbour complained that it reflected on her kitchen.*' (Solar thermal water heating adopter with a wall mounted panel)

Noise and vibration

There were some concerns about noise and vibration, mainly expressed by adopters of a micro-wind turbines, but also by at least one STWH user.

'*The wind generator made a "whispering" sound that I had to become accustomed to, but only because it is otherwise very quiet where I live. It is installed on a 45ft tower approximately 100ft from my house. It could be attached directly to the house but I was told that some vibration would occur.*' (Micro-wind adopter)

'*…my neighbours are worried about the noise and appearance.*' (Micro-wind adopter)

'*The pump is over my daughter's bedroom and disturbs her.*' (Solar thermal water heating adopter)

Feed-in tariffs

Several solar PV adopters were concerned that they were not receiving a fair price for electricity generated.

'*The ROC tariff currently set at only £0.045 per kWh generated, far below standard / daytime cost of grid power.*' (PV adopter)

Service and maintenance

Maintenance was an issue for only a few solar thermal water heating adopters, indeed most interviewed adopters were very positive about the service from installers. A few solar thermal water heating and wood-burning stove adopters experienced difficulty accessing services and getting replacement parts for maintenance.

'*I have only a 2 year guarantee for the system and I would not know where to go to get replacement parts.*' (Solar thermal water heating adopter)

'*The installer is brilliant; he always comes the next day when there is a problem. The installer says that he has installed solar thermal water heating for hundreds of people without problems.*' (Solar thermal water heating adopter)

3.5.5. Specific issues for users of STWH systems

Three quarters (73%) of interviewed STWH adopters regarded their system as *easy to use*.

> '*There is no real use involved because there are no specific controls. I can check the pressure and temperature on the indicators which are easy to see because they are located in the airing cupboard. If the pressure is wrong I need to call the installers and if it leaks there is a collection container for the leakage which could be re-used. There is no need to go up to the roof to check like many of my friends and acquaintances with older STWH systems*.' (Solar thermal water heating adopter)

However, some complained about poor or inadequate instructions

> '*The 3 sheets of paper I got as a manual was inadequate in describing the equipment fitted and how to monitor the system. The manual had pictures of a system which did not match the system I have*.' (Solar thermal water heating adopter)

> '*There is no after sales instruction on how to use the system, no proper instruction manual or what to do if it goes wrong*.' (Solar thermal water heating adopter)

Moreover, 60% thought there was a need to *check for leaks, monitor gauges and adjust valves to prevent overheating*, and a few mentioned *difficulties understanding the controls***.**

> '*It (the system) is not designed tidily. I cannot understand why it is not designed so you can see the bits (the flow gauge and pressure gauge) you need to see in one place*.' (Solar thermal water heating adopter)

> '*I do not bother with the controls or displays and just leave the system to run itself. But the system seems a bit Heath Robinson – there are gauges in airing cupboard to check, I have to top up the water if the gauge falls below a certain level and I can check through the inspection window if glycol/water mixture is circulating ok. I am supposed to check the pumps in the loft but don't know what to look for and the user manual is too complicated*.' (Solar thermal water heating adopter)

> '*The main problem is understanding the controls and displays, which are too complicated and even my husband who works with engineers can't understand the controls and displays. There are two dials in cupboard and an electronic display with meaningless numbers. All we do is switch the system immersion heater off if it is sunny*.' (Solar thermal water heating adopter)

> '*If I had known in advance that the solar thermal water heating system was a complex pressurised system requiring monitoring and maintenance and possibly getting up to the loft to release air locked in the valve, (which would be difficult to do if I was very old or disabled), I would not have had one installed.*' (Solar thermal water heating adopter)

> '*The installer says that he has installed solar thermal water heating for hundreds of people without problems. I asked him "Do they check the pressure gauge? You need to check the valve and flow meter and release air if necessary". I suspect that there may be elderly who don't go and look. As a retired engineer and technically aware I believe that other people would not know how to monitor the system to ensure that it is working properly*.' (Solar thermal water heating adopter)

All interviewed STWH adopters mentioned a reduced use of the boiler or immersion heater to back-up the household hot water supply. Two-thirds (67%) changed their use of the back up water heating systems following adoption of a STWH system, for example by manually boosting them when required in the evening, or switching off on sunny days. A few mentioned having *difficulties operating the system to minimise back-up water heating***.**

> '*The main problem is we don't know how much solar heated water the system produces. It would be nice to be able to switch the immersion heater off during suitable days and to know that all hot water is free, in theory*.' (Solar thermal water heating adopter)

> '*I use the indicators to decide on whether to boost the boiler. The green light shows when it is collecting solar energy. The dial provides information on the amount of solar energy received and the temperature of the water allows a decision to be made to boost if necessary*.' (Solar thermal water heating adopter)

3.6 Promoting more widespread adoption of household renewables

The drivers, barriers, problems and benefits of renewable energy systems discussed above suggested several improvement ideas and design challenges, including technical, marketing, financial and regulatory improvements for promoting more widespread adoption and effective use of household renewable energy systems.

Online respondents and interviewees were asked to respond to a list of possible improvements to the technology, design, installation, marketing, etc. of renewable energy systems (generated by the research team following the exploratory survey of energy professionals) and also to suggest their own ideas.

This section summarises the responses mainly from the online sample, but with some of the additional ideas provided by the interviewees and energy efficiency professionals, focusing in detail on the design improvements for each renewable energy technology.

3.6.1 The role of Government

In open comments, 13% of our online 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;

'A wider variety of financing schemes need to be available to householders, i.e. low interest loans, mortgage 'bolt-on' extensions for energy saving installations, greater government subsidies, lower council tax bills according to the extent to which people invest in energy saving systems and products. This could be tied in with the proposals for carbon allowances.' (Online respondent)

- simpler, more consistent grant systems throughout the UK and higher levels of grant;
- better regulation to control 'cowboy' installers of solar thermal water heating systems;
- mandatory standards for product performance, reliability and durability;

9% of the online sample and 40% of interviewed respondents also commented that all *new housing should integrate 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:

'*I find it amazing, with all the current building regulations that it is not compulsory to install renewables, and other energy saving measures, in new build*.'

'*There should definitely be no VAT on any renewables and all new houses or renovated houses should have to have a renewable system fitted. It is much cheaper to install when building than having to put it in later*.'

'*I think that all new homes should have some form of renewable energy source installed automatically which should have the added benefit of bringing the cost down for the rest of us, making it more attractive for us to install something*.'

3.6.2 Information and advice

Despite numerous existing government energy efficiency and renewable energy promotion and support schemes, some 8% of online respondents 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.

'*Poor information from the turbine provider led us to use wrong batteries so the machine performed poorly…we had such poor results we got rid of it*.' (Micro-wind turbine adopter)

'*Advice on changing habits is not mentioned in the literature and if people do not change their habits there is no point in getting solar thermal water heating. I think that if you move to solar you need to change your washing habits to the evening and reset the boiler so you are not heating the water. As a household we will need to think about soaking dishes used during the day for washing in the evening and having evening washes*.' (Solar thermal water heating non-adopter)

Several believe that the information provided by existing advice bodies is too generalised with the details on installations of household renewables left up to the installers. 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.

3.6.3 Technical and design improvements

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. Many suggestions for design improvements to renewable energy systems were suggested by respondents to the online surveys and in the interviews – some of these ideas are presented in the following sections.

Improvement ideas for solar thermal water heating systems

Both adopters (online 44% and interviewees 47%) and non-adopters (online 60% and interviewees 62%), would like lower cost systems perhaps using simpler technology or supported by more financial incentives to reduce costs, such as more grants, reduction in council tax, VAT incentives, and cheaper servicing. Both groups, especially online non-adopters, liked the idea of having solar thermal water heating systems financed by an energy supplier and paid back via their fuel bills (44% adopters and 56% non-adopters), although some interviewed non-adopters were concerned that they would pay more this way.

More online adopters and energy efficiency professionals, having experienced solar thermal water heating, than non-adopters felt that systems integrated with the roof (69% adopters, 62% professionals and 48% non-adopters), and/or involving installation from inside the house (44% adopters, 50% professionals and 30% non-adopters), and/or which give feedback on money and energy saved (56% adopters, 60% professionals and 41% non-adopters), were good ideas. Some interviewees were concerned that additional complexity may impact on costs and efficiency of the system, although interviewed adopters and non adopters liked the idea of systems integrated with the roof (40% adopters and 46% non-adopters) and/or which give feedback on money and energy saved (40% adopters and 38% non-adopters).

More adopters (48%) and professionals (50%) than non-adopters (43%) would like to see integrated packaged systems, e.g. a STWH and condensing boiler package, already on offer by a major manufacturer. Such systems could help avoid interconnectedness problems such as experienced when an interviewee installed a combination boiler (which does not require a hot water tank) not realising it was incompatible with solar thermal systems.

Nearly half of adopters (48%), non-adopters (47%) and professionals (44%) would like systems with guaranteed reliability, durability and payback adopters and non-adopters). Some 54% energy efficiency professionals thought that systems should be developed to established standards with published performance figures. Interviewed adopters (33%) were less concerned than interviewed non-adopters (54%) about system performance, perhaps reflecting their greater experience with solar thermal water heating.

'*I would like at least a 10 year guarantee, 5 year payback and 20 year product life*.' (Solar thermal water heating non-adopter)

Only about a quarter of adopters (27%) and non-adopters (23%) and a few interviewees were concerned about the visual appearance of solar panels. In open comments (Table 14), some ideas for technical improvements included designs for larger, better insulated tanks to store hot water for days when the system is not collecting solar energy; different standard sizes for solar panels; remote control for monitoring inaccessible components, such as valves. A few respondents were aware of more technically advanced STWH systems available in other countries such as Germany or the US, including

systems with controls linked to Internet weather forecasts to inform the user when solar hot water was likely to be available.

Some would like systems designed for easier monitoring, including a tidier presentation of gauges and indicators and a diagnostic system to warn about component failure and to locate leaks in pipes. With existing controls, users can be unaware if their system is not functioning, and one idea was a pressure gauge needle monitor that could communicate faults. Some users appear to have to guess how much boiler boosting of hot water is required when using solar heating systems and would like better controls to fine tune the time/ temperature required for topping up water so that they use the boiler only when needed. This reinforces the importance of more informative and easier to understand STWH controls integrated for efficient use with boiler and timer controls.

Table 14 Solar thermal water heating – improvements considered good ideas/would encourage adoption

Improvement ideas	Adopters	Non-adopters
Sample – online-survey	52	149
Lower cost STWH systems	23 (44%)	89 (60%) **Rank 1**
Solar panels integrated with the roof	36 (69%) **Rank 1**	72 (48%) **Rank 3**
Packaged systems e.g. plus condensing boiler	25 (48%) **Rank 3 =**	64 (43%)
System financed by energy supplier paid back via fuel bills	23 (44%)	84 (56%) **Rank 2**
Installation of solar panels from inside the house	23 (44%)	44 (30%)
STWH systems designed for installation without scaffolding	18 (35%)	39 (26%)
System giving user feedback on money and energy saved	29 (56%) **Rank 2**	61 (41%)
Guaranteed reliability, durability and payback	25 (48%) **Rank 3 =**	70 (47%)
Impressive visual appearance of the solar panels.	4 (27%)	34 (23%)
Additional ideas*		
Technical improvements.		
Systems developed to established standards with published performance figures. 27 (54%) **e**nergy professionals.		
Most advanced technology should be available in UK: Some perception that technology is antiquated in UK compared to US and Germany, where the emphasis is more on efficiency than lower-cost systems.		
More energy-efficient solar panels designed with different standard size to integrate with roof.		
Reduce tank cooling and make full use of solar energy e.g. by installing a larger insulated tank or two tanks.		
Solar panels that track the angle and height of sun to maximise gain.		
Black hose-pipe coiled on roofs, along line of gutters etc. to provide low cost STWH system.		
'Solar lilo' in areas receiving high annual solar radiation.		
Greater integration of STWH with other systems.		
Greater integration of solar energy with central heating.		
Better availability of water-using appliances that can use solar heated hot water.		
An integrated approach to roofing and retrofitting STWH		
Design for easier monitoring.		
Tidier presentation of gauges and indicators designed and located together		
Diagnostic system for warning about component failure**,** problems with pump or the vacuum in evacuated tubes and for locating leaks in pipes		
Manual should provide idiot proof instructions on how the system operates and easy to use manuals with pictures that match the system installed.		

* Additional improvements are open-ended ideas mentioned by online respondents and interviewees

Improvement ideas for solar PV systems

Apart from financial measures, such as lower cost solar PV systems (80%), available finance from energy suppliers paid back via fuel bills (55%); and better feed-in tariffs (50%); the main improvements wanted by online non-adopters were: long-term performance guarantees for reliability, durability and payback (46%); systems feedback on electricity generated and money saved (46%) and

the option for installation from inside house (34%). The visual appearance of PV systems was an issue for a minority of 17% non-adopters.

As well as lower cost PV systems (69%), most online adopters of PV systems would welcome feedback on energy and financial savings. In open comments, other improvement ideas included PV panels integrated with south facing windows, roof lights or conservatories and semi-transparent PV film for windows.

Table 15 Solar photovoltaic systems – improvements considered good ideas and would encourage adoption

Improvement ideas	Adopters	Non-adopters
Sample – online-survey	16	123
New types of PV system that cost less	11 (69%) **Rank 1**	99 (80%) **Rank 1**
PV system financed by electricity supplier paid back via electricity bills	5 (31%) **Rank 3=**	68 (55%) **Rank 2**
Installation of PV panels from inside the house (like Velux windows).	5 (31%) **Rank 3=**	42 (34%)
System designed to give user feedback on money and energy saved	9 (56%) **Rank 2**	56 (46%)
Guaranteed reliability, durability and payback	5 (31%) **Rank 3=**	56 (46%)
Attractive visual appearance of the PV panels	3 (19%)	21 (17%)
Better price for electricity exported to National Grid	†	62 (50%) **Rank 3**
Additional ideas*		
Greater efficiency in conversion of solar energy to electricity		
Semi-transparent PV film for windows		
An integrated approach to roofing and solar PV		
Solar panels integrated with south facing windows or new conservatory		

† Not asked. * Additional improvements are open-ended ideas mentioned by online respondents

Improvement ideas for micro-wind turbines

Online non-adopters who have considered micro-wind turbines would like lower cost systems (82%); turbines integrated with the roof (60%); systems financed by an energy supplier and paid back via energy bills (59%); guaranteed reliability, durability and pack back (48%); feedback on energy and money saved (42%); and attractive visual appearance (30%). Although there were very few online adopters, the favoured improvements to micro-wind turbines are similar.

Table 16 Micro wind turbines – improvements considered good ideas and would encourage adoption

Improvement ideas	Adopters	Non-adopters
Sample – online-survey	18	126
New types of micro-wind systems that cost much less	12 (67%) **Rank 1**	103 (82%) **Rank 1**
Financed by electricity supplier paid back via electricity bills	7 (39%)	74 (59%) **Rank 3**
Building integrated wind turbine(s).	9 (50%) **Rank 2**	76 (60%) **Rank 2**
System designed to give user feedback on money and energy saved	6 (33%)	53 (42%)
Guaranteed reliability, durability and payback	8 (44%) **Rank 3**	60 (48%)
Attractive visual appearance of the wind turbine	6 (33%)	38 (30%)
Additional ideas *		
Smaller, more discreet units suitable for more locations.		
More visually attractive wind turbines that do not arouse objections from neighbours or planners		
Reduced vibration and noise.		

* Additional improvements are open-ended ideas mentioned by online respondents

Improvement ideas for wood-burning stoves

As with the other household renewables, non-adopters would like lower cost wood-burning stoves (41%), but more popular improvements suggested by about two fifths of non-adopters included better control of the heat output (49%), less polluting (48%), less dirt producing (41%) and systems requiring less frequent refuelling and ash clearance (41%). Interestingly, about half of both online adopters (55%) and non-adopters (48%) wanted less polluting wood-burning stoves, despite modern smokeless designs. Other improvement ideas included a multi-fuel stove designed to recycle combustible household waste; a duct system designed to transfer heat from a stand-alone wood-burning stove between rooms; and ventilated storage systems to provide properly seasoned wood fuel.

Table 17 Wood-burning stoves– improvements considered good ideas and would encourage adoption

Improvement ideas	Adopters	Non-adopters
Sample – online-survey	60	69
Lower cost wood-burning stoves	32 (53%) adopters **Rank 2**	28 (41%) **Rank 3=**
Wood-burning stove with more controllable heat output.	22 (37%)	34 (49%) **Rank 1**
Wood-burning stove that does not require frequent refuelling/ash clearance.	25 (42%) **Rank 3=**	28 (41%) **Rank 3=**
Wood-burning stove that produces less dust and dirt.	25 (42%) **Rank 3=**	28 (41%) **Rank 3=**
Wood-burning stoves that produce less smoke/pollution.	33 (55%) adopters **Rank 1**	33 (48%) **Rank 2**
Additional ideas*		
Easier integration with central heating system		
Recycle combustible household waste by burning in multi-fuel stove (with pollution control)		
Design a means to dispose ash, other than in domestic rubbish, if ash cannot be composted		
Ventilated fuel storage systems to provide properly seasoned fuel and therefore improve efficiency of stove.		
Ducts from one room to another to allow the heat from the stove to heat more rooms		

* Additional improvements are open-ended ideas mentioned by online respondents.

4 Conclusions

Our surveys show that each renewable energy technology has different drivers, barriers, benefits and problems. Some of the findings support previous work, with its emphasis on financial, informational and regulatory barriers including, high capital costs, lack of information and advice and planning permission (EST/E-Connect/Element Energy, 2005). However, our surveys, and interviews with a sample of mainly 'green' consumers reveal a more complex picture.

The adopters of renewable systems do so for many reasons; but in the online survey the main drivers were saving energy; reducing fuel bills and concern for the environment (especially climate change and nature conservation). For wood-burning stove adopters especially, these three drivers are matched by the pleasure in using a renewable energy system that adds to the decor of their home. The results show that many adopters of renewable energy technologies come from similar backgrounds, namely households with two adults rather than larger family households, with professional or senior managerial occupations, at least 10% of whom are retired. The characteristics of the non-adopters were similar.

The barriers that deterred non-adopters of renewable energy systems depended on the technology and go beyond the well-known financial issues. However, even for environmentally concerned citizens, capital cost is a major barrier to adoption of household renewables, and other reasons were also mainly cost related; namely inadequate fuel savings, and views that the system may not last long enough to payback the investment. This was less a deterrent for wood-burning stoves where the biggest deterrents were lack of fuel storage space, difficulties controlling heat output, and the labour associated with the extra dust, refuelling and ash removal. Non-financial barriers for those deciding against solar thermal water heating systems include difficulties finding a reputable installer and uncertainty of whether the system would perform reliably. Additional barriers to the installation of solar PV include finding a reputable installer and concerns that the system would not produce sufficient electricity, as well as problems connecting to the Grid and the poor feed-in tariffs available in the UK. Potential adopters of

micro-wind turbines are deterred by difficulties getting planning permission; finding a suitable location; noise/vibration from the unit; and finding a reputable installer.

Many of those who had considered adopting renewables had many questions that they found difficult to answer because much of the available information and advice is of a generalised nature. For example, solar thermal water heating non-adopters wanted to know: how to maintain components in lofts or on roofs, or whether the tank hot water storage capacity is adequate for household requirements. Wind turbine non-adopters wanted to know about how wind-speeds affect this source of renewable energy; whether wind turbines are suitable for urban/suburban locations; and whether installation would damage the house structure. Lack of information and advice on the adoption process that involves technology choice, grant applications, planning permission, installation, use and maintenance is a major barrier to adoption. Despite existing schemes such as 'Energy for Good'; consumers still want more independent information and advice, allowing comparisons of manufacturers' ratings, assessments of payback and making carbon reduction decisions on a limited household budget.

About a half of solar thermal water heating users, one third of wood-burning stove users, one quarter of solar PV users, but very few (of the small sample) of micro-wind users reported reduced fuel bills and/or energy consumption. There was some evidence of a rebound effect associated with solar thermal water heating use; for example one fifth of adopters were less concerned than before about using hot water, although the extra could be mainly solar heated. The interviews showed that more than half had made no changes to their habits of water use although efficient use may depend on using solar heated water when it is available and minimising use of back-up water heating. Solar PV users mentioned no obvious rebound effects, but more than half of wood-burning stove users (60%) said their stove heated one or more rooms to a higher temperature than normal probably due to the problem of controlling the stove's heat output.

User satisfaction with solar thermal water heating, micro-wind turbines and wood-burning stoves is high, but more mixed for solar PV adopters. Some solar thermal water heating users were concerned that their solar heated water was under utilised when they found that they could not use it for all their hot water requirements, due to plumbing constraints or because new water using appliances are cold-fill only; and some had insufficient storage capacity on sunny days when their system could be delivering more solar hot water. Most interviewed solar thermal water heating users experienced post-installation problems that undermined their trust in the reliability and performance of the system, leading some to want better controls for system monitoring and effective use. The main problems of wood-burning stove users were increased dust and dirt, while connecting the stove to radiators and the hot water system proved too expensive for some.

This project shows how important it is to research user requirements for low cost, aesthetic, user-centred designs that interconnect with existing electrical and/or hotwater systems and building structures; with guaranteed efficiency, reliability and payback; affordable support for maintenance; and with improved user controls that provide feedback to help the user develop energy saving habits and achieve the expected carbon reductions.

More widespread consumer adoption of renewable energy systems would be facilitated if renewable energy technologies were integrated in all new buildings and displayed more often on public buildings, since this would inspire consumer confidence in technologies still regarded as innovative and untried. This would boost the industry and stimulate the development of a supportive infrastructure, helping to bring costs down for retrofit installations through economies of scale, and help to build societal norms of greater energy efficiency. Policies and actions need to go beyond addressing the financial barriers to adoption, important as these are, and requires a multiple approach that needs to be tailored to the different technologies concerned, such as:

- Installers offering integrated packaged solutions to householders;
- Providing greater simplicity and consistency in the planning and grant application process;
- Establishing standards that guarantee the performance of household renewables;
- New financing schemes e.g. council tax rebates, finance packages and repayment loans through energy suppliers, and better prices for renewable electricity exported to the National Grid;
- One-stop shop offering detailed practical advice on technology choice, grant applications, planning permission, installation, use and maintenance, and carbon-saving use.

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Appendix 1 Detailed characteristics of the online survey respondents

Table 4 Detailed characteristics of the majority of adopters and non-adopters of household renewables (online survey)

Variable	Total sample	STWH adopters	STWH non-adopters	Solar PV adopters	Solar PV non-adopters	Micro-wind adopters	Micro-wind non-adopters	WBS adopters	WBS non-adopters
Sample size (N)	390	39	151	12	130	7	128	63	65
House size									
1-bed						3 (43%)	4 (3%)		
3-beds	162 (42%)	12 (30%)	72 (48%)	4 (33%)	62 (48%)	1	56 (44%)	18 (29%)	30 (46%)
4 beds	102 (26%)	16 (49%)	33 (22%)	2	27 (21%)	1	35 (27%)	17 (27%)	18 (28%)
Other house sizes (eg. 1,2,5,6 bedrooms)		10 (26%)	37 (25%)	5 (42%)	33 (25%)	1	26 (20%)	23 (37%)	14 (22%)
Missing data on house size		1	9 (6%)	1	8 (6%)	1	7 (5%)	5 (8%)	3 (5%)
Type of house									
semi-detached	134 (34%)	11 (28%)	61 (40%)	4 (33%)	55 (42%)	2	47 (37%)	21 (33%)	30 (46%)
detached homes	131 (34%)	19 (49%)	39 (26%)	2	34 (26%)	2	42 (33%)	28 (44%)	15 (23%)
Mid-terrace and bungalow		6 (15%)	36 (24%)	4 (33%)	29 (22%)	1	28 (22%)	7 (11%)	15 (23%)
Other house types (flat, maisonette)		2	7 (5%)	1	6 (5%)	1	6 (5%)	2 (3%)	4 (6%)
Missing data on house type		1	8 (5%)	1	6 (5%)	1	5 (4%)	5 (8%)	1
Size of household (adults and children)									
Size of household (1)		4 (10%)	20 (13%)	4 (33%)	14 (11%)	3 (43%)	13 (10%)	7 (11%)	7 (11%)
Size of household (2)	253 (65%)	31 (79%)	99 (66%)	7 (58%)	89 (68%)	3 (43%)	85 (66%)	41 (65%)	46 (71%)
Size of household (3)		3	13 (9%)	0	11 (8%)	0	14 (11%)	9 (14%)	3 (5%)
Other size households (4, 5, more)		0	8 (5%)	0	8 (6%)	0	9 (7%)	2 (3%)	7 (11%)
Missing data on household size		1	11 (7%)	1	8 (6%)	1	7 (5%)	4 (6%)	2 (3%)
Households with children (<16 years)	132 (34%)	9 (23%)	48 (32%)	2	39 (30%)	2	45 (35%)	26 (42%)	25 (38%)

Variable	Total sample	STWH adopters	STWH non-adopters	Solar PV adopters	Solar PV non-adopters	Micro-wind adopters	Micro-wind non-adopters	WBS adopters	WBS non-adopters
Main earner's occupation									
Crafts/ tradesperson	21 (5%)	2 (5%)	6 (4%)	0	9 (7%)	1	8 (6%)	10 (16%)	4 (6%)
Education/ medical services	46 (12%)	3 (8%)	18 (12%)	2	13 (10%)	1	14 (11%)	6 (10%)	9 (14%)
Middle management	22 (6%)	3 (8%)	12 (8%)	0	11 (8%)	0	8 (6%)	2 (3%)	3 (5%)
Office/clerical worker	15 - 4%)	1	9 (6%)	0	7 (5%)	0	7 (5%)	1	6 (9%)
Professional/ senior management	111 (29%)	10 (26%)	39 (26%)	2	29 (22%)	1	37 (29%)	19 (30%)	18 (28%)
Retired	52 (13%)	7 (18%)	23 (15%)	3 (5%)	20 (15%)	1	16 (13%)	6 (10%)	10 (15%)
Other occupations (housewife/ husband, manual/factory worker, shop worker, student, unemployed, other)		2 (5%)	13 (9%)	1	11 (8%)	1	11 (9%)	5 (8%)	4 (6%)
Missing data on main earner's occupation		11 (28%)	31 (21%)	4 (33%)	30 (23%)	2	27 (21%)	14 (22%)	11 (17%)

Note: Results are for the majority of sampled adopters and non-adopters of household renewables.
Percentages are given for total sample, which includes some missing data