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# Adoption and Use of Household Microgeneration Heat Technologies

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## ABSTRACT

*The development and rapid household adoption of smallscale, low and zero carbon microgeneration technologies are key elements of UK and EU strategies to meet the challenge of climate change. Microgeneration heat technologies, including solar thermal hot water, heat pumps and biomass heating systems, have an especially important role in reducing the carbon emissions from buildings. But despite government policies to promote microgeneration, adoption by UK householders is very slow. Surveys by the Open University and Energy Saving Trust examined why over 900 UK householders decided to adopt these technologies and why many do not. These surveys describe the niche market for microgeneration heat as largely confined to environmentally concerned, older, middleclass householders, mainly living in larger properties off the mains gas network. Although these pioneer adopters are generally highly satisfied, for microgeneration heat to expand beyond its market niche, several issues need to be addressed, including: price reductions and subsidies; independent information on the suitability, performance, payback and effective use of equipment; 'onestop' support from consideration to operation; improved system compatibility with smaller properties and existing buildings and heating systems; and more userfriendly and informative controls.*

***Keywords***: *Microgeneration, Domestic Heating and Hot Water Systems, Renewable Energy, Consumer Surveys, Usercentred Design and Marketing, Energy Policy*

## 1. Introduction

### 1.1. The Importance of Low and Zero Carbon Heat

Increasing the supply of renewable sources of energy is a key element of the UK Government's strategy to help address key challenges of tackling climate change and securing energy supplies [1]. In 2007 the European Commission set the UK a target that 15% of energy (electricity, heat and transport) should come from renewables by 2020, including smallscale, lowand zero-carbon microgeneration systems in domestic and other buildings.

Tackling the heat demand is particularly important because heating (both domestic and nondomestic) accounts for the largest single proportion of the UK's final energy demand at approximately 49%. Households alone contribute 27% of UK carbon emissions with approximately 75 per cent of these domestic emissions arising from space and water heating [2,3].

A number of recent reports on the potential of local or distributed energy stressed the importance of microgeneration heat technologies–the smallscale production of heat from a low carbon source–to achieve the UK's renewables and carbon emission reduction targets [4,5]. The government's microgeneration strategy suggested that widespread adoption of solar thermal hot water (STHW) systems, heat pumps, biomass stoves and boilers, and microCHP technologies, could reduce domestic carbon emissions by up to 6.5% by 2030 and up to 15% by 2050 [6]. Microgeneration heat could therefore play a small but significant contribution to meeting the challenges of the 2008 Climate Change Act, in which the UK government set demanding targets to reduce CO2 and other greenhouse gas emissions by 34% by 2020 and by 80% by 2050 on 1990 levels [7].

But household adoption in the UK of microgeneration technologies is slow compared to other EU countries such as Germany despite UK government support through grant schemes, such as the Low Carbon Build-

 

ings Programme. A recent detailed report by Element Energy on the potential for microgeneration estimated that by 2007 that there were only 95,00098,000 installations in UK homes, including about 90,000 solar thermal hot water (STHW) systems (over 92% of total installations), less than 2,000 ground source heat pumps (GSHPs), and 500 to 600 biomass boilers [8]. Element Energy calculated that the UK market for domestic microgeneration could reach 9 million installations by 2020 given an ambitious policy support framework, such as a subsidy of 2 p per kWh for microgenerated heat and prohibiting all offsite (nonrenewable) electricity for zero-carbon homes, except for low carbon systems such as heat pumps [8]. Under the UK Government's Renewable Heat Incentive, planned for introduction in 2011, more generous financial incentives for householders are proposed depending on the technology concerned, ranging from 5.5p per kWh for small biogas systems and 7p per kWh for ground source heat pumps to 18 p per kWh for small solar thermal systems [9]. If implemented, this policy could lead to more widespread adoption of microgeneration heat technologies than forecast by Element Energy.

Given the slow rate of takeup, UK reports tend to focus on the barriers to household adoption of microgeneration, especially those of high cost, lack of consumer information and restrictive regulations such as planning laws [5,8,10]. Some studies also include consumerrelated barriers, such as the considerable technical knowledge involved in purchase decisions [4], lack of trust in unfamiliar technologies and scepticism regarding the performance of technologies like solar PV, microCHP and microwind [11].

But additional reasons for the slow takeup of microgeneration, especially beyond the enthusiast 'early adopters', is that often equipment and systems have been designed and installed without taking sufficient account of user requirements and usability [12]. This paper moves beyond the view of microgeneration systems as purely functional, energy saving devices to consider user issues, including equipment ergonomics and aesthetics, the symbolic value of generating your own energy, and compatibility with existing buildings and heating systems. Understanding the ways people *use* microgeneration systems is also important because energy and carbon savings are not guaranteed by their adoption.

Consumers may reduce or cancel out carbon saving benefits through 'rebound Effects' such as increasing room temperatures [13] or because they lack understanding of the equipment, find it difficult to make adjustments in their lifestyle, or simply do not use the technologies as expected [14]. On the other hand adopting microgeneration may produce 'double dividend' benefits, such as consumers improving their home's energy efficiency or their household energy saving behaviour.

### 1.2. Project Aims

To better understand how consumers perceive and experience low and zero carbon heating systems, the Open University (OU) and Energy Saving Trust (EST) conducted some of the largest surveys to date of UK householders in the process of considering or purchasing microgeneration technologies for providing space heating and/or hot water [10]. Two surveys, which together produced over 900 responses, revealed why UK consumers purchase or decide against adopting these systems; and provide insight into experiences of using low carbon heat. The surveys covered four technologies, all eligible for UK government grants under the householder stream of the Low Carbon Buildings Programme (LCBP), which ran from 2006 to 2010:

- Solar thermal hot water (STHW systems);
- Ground source heat pumps (GSHPs);
- Woodfuelled boilers (WFBs);
- Automatic pellet feed biomass room heaters or stoves (BS systems).

The questions addressed in the project were:

1) Why do householders adopt, or decide against adopting, microgeneration heat technologies for domestic use?

2) What is the householder experience of purchase, installation and use of microgeneration heat systems?

3) What ideas for improvements to domestic microgeneration heat systems would make them more desirable to consumers and effective in reducing carbon emissions?

4) Do the 'rebound' and/or the 'double dividend' effect influence the carbon emission reductions achieved with microgeneration heat systems?

5) What actions would encourage more householders to install microgeneration heat technologies?

Findings for the surveys of the four selected microgeneration heat technologies are presented below with special attention to the most popular technologies; solar thermal hot water systems and ground source heat pumps.

## 2. Methodology

The two OU/EST surveys that were conducted provide a purposive investigation of a sample of 924 'pioneer' adopters and potential adopters of microgeneration heat technologies, mainly living in England and Wales plus a small number in Scotland and Northern Ireland. The first survey was conducted with self-selected visitors to an

 

online questionnaire on the Energy Saving Trust and Open UniversityBritish Broadcasting Corporation websites. Two groups of consumers from the general public responded, comprising: 314 householders who were considering purchase of one of these technologies (named 'considerers' of which 221 were considering a STWH system; 50 a GSHP; 28 a WFB and 15 a BS); and 64 householders who had considered but decided against any purchase (called 'nonadopters').

A second survey was conducted via email and weblink with 546 UK householders who were randomly selected from the LCBP database as a representative sample of householders who had been awarded a government grant to install a microgeneration system. This group was named 'adopters', of whom 413 had chosen to install STHW; 89 a GSHP; 36 a WFB and 8 a BS and who included 285 households with a system already installed and with experience of using microgeneration space and/or water heating.

The major study by Element Energy, mentioned above, which examined the growth potential for microgeneration in the UK surveyed a representative sample of 1279 UK residents and established that only a minority (about 13%) had considered adopting microgeneration technologies [8]. The OU/EST surveys provide an indepth study of the interest, motivations and experience of this minority group. Only a fifth of the considerers in the Element Energy study went on to obtain quotations from installers with only 3040% of these proceeding to purchase, thereby suggesting that less than 1% British residents actually adopt a microgeneration technology [8]. This finding is consistent with the number of domestic systems installed which represent less than 1% of the 26 million UK households. The second OU/EST survey offers a unique insight into a representative sample of LCBP grant holders from the niche market of UK households who have actually adopted a microgeneration system.

The online questionnaires were designed to obtain both multiplechoice and open ended responses with questions about the purchase, installation and experience of using different microgeneration heat technologies, plus questions about nonadoption of seriously considered but rejected technologies. The surveys also included questions on household and property demographics.

We relied on users' responses and estimates of household energy use rather than actually measuring carbon and fuel bill savings following installation of a microgeneration system. The survey results were analysed to provide descriptive statistics and crosstabulations using 'Questback' survey solutions software (http://www.questback.com/) and Excel software.

# 3. Results

## 3.1. Pioneer Households Considering, Adopting or Rejecting Microgeneration Heat

**Table 1** provides some of the household characteristics of the survey samples, including considerers, adopters and nonadopters. The table shows that the sample comprised households more than half of which included a main earner that has (or is retired from) a professional or senior managerial occupation and about a quarter of which had an annual household income more than twice the £30,000 (US$48,000) UK average. Over 60% of respondents live in households without children or where children have left home. In addition, not shown in the table, up to half of respondents from all groups were environmentally conscious and said that they usually took actions to reduce their energy and transport environmental impacts, such as cycling, walking and using public transport whenever possible instead of driving.

A striking characteristic of the adopters of microgeneration heat is that over half live in larger detached homes with 4 or more bedrooms and large gardens (over 300 $m^2$), located in rural areas, and off the UK's mains gas network. By comparison, though considerers and nonadopters have similar occupational characteristics and environmental attitudes, more live in suburban, semidetached or terraced homes with smaller gardens in areas on the mains gas network. They were also more often considering retrofitting rather than installing a system in a newbuild property.

The main fuels displaced when microgeneration heating is installed are mains gas (42%), followed by oil (29%) and electricity (8%). More specifically STHW systems displace mains gas (54%) and oil (27%) while GSHP systems mainly displace oil (33%) and electricity (11%) with only 6% GSHP installations displacing mains gas. Although there were too few biomass heating installations for statistical analysis, almost all were in rural areas off the mains gas network.

This contrasted with only about half of STHW installations that were rural and offgas, confirming the wider applicability of STHW systems.

More than a third of adopters were retrofitting microgeneration heat systems in an older (pre 1919) property, while a tenth installed the system when first moving into a converted older property or into a newbuild (post 2006) home. A higher percentage of GSHPs (about a third) were installed in new buildings.

Unsurprisingly, GSHPs were typically installed in properties with larger gardens than other systems; three quarters were installed in gardens/land of over 300 $m^2$, and 57% were installed in large plots of at least 1,000 $m^2$.

 

**Table 1. Household and property characteristics: considerers, adopters and nonadopters of microgeneration heat technologies.**

| Household and property Characteristics | Total considerers | Total nonadopters | Total adopters |
|---|---|---|---|
| Professional or senior managerial occupations [(1)] | 59% | 78% | 69% |
| Total annual household income (of all earners, before tax) > £60,000 [(2)] | 24% | 20% | 28% |
| Households with no children (< 18 years normally resident) | 57% | 63% | 64% |
| Live in detached house/bungalow | 47% | 44% | 73% |
| 4+ bedrooms house | 42% | 40% | 62% |
| House built before 1919 | 29% | 20% | 38% |
| Live in newbuild house built post 2006 | 3% | 0% | 10% |
| With medium/large garden or land (over 300 $m^2$) | 39% | 44% | 65% |
| Properties OFF mains gas network | 12% | 6% | 54% |
| Live in rural location | 46% | 44% | 65% |
| Live in urban/suburban areas | 54% | 56% | 34% |
| **Number of responses** | 314 | 64 | 546 |

[(1)]4% adopters did not provide occupational information; [(2)]8% adopters did not provide their household income and 4% adopters responded 'don't know'.

## 3.2. Why Householders are Interested in Microgeneration Heat

**Table 2** shows that the main reasons why UK householders are considering or decide to adopt microgeneration heat technologies are that they wish to reduce their household carbon emissions and fuel bills. But these consumers also want to own a microgeneration system for the anticipated pleasure of using a low or zero carbon energy source and/or to demonstrate their environmental commitment. A fifth of these microgeneration pioneers have a job or hobby related to the environment or low carbon technology and hence many are enthusiasts, motivated by an interest in the technologies themselves or the desire to be a technology pioneer. A fifth of adopters are also using the opportunity of a new build or other major home improvement projects to install a microgeneration heat system.

## 3.3. Why Householders Decide against Adopting Microgeneration Heat

**Table 3** shows that financial barriers–high initial cost, long or uncertain payback, and relatively small grants–were the major deterrents for nonadopters. This led more than half of nonadopters to respond that there are more cost effective ways to reduce carbon emissions, such as installing home insulation. Microgeneration heat has also to overcome perceptual barriers such as lack of confidence in the performance and reliability of unfamiliar technologies, as well as practical barriers, especially lack of suitable space and locations to install equipment, and the frequent need to adapt existing properties and heating systems to be compatible with microgeneration.

Specific deterrents for 43 GSHP nonadopters included concerns that installation of ground loops in trenches or a borehole would involve great disruption to the garden (51%) and the possibility of the system freezing or causing dryness to the soil (28%). A specific deterrent for most of the 29 nonadopters of biomass heating systems was the effort involved in sourcing fuel, refuelling and ash removal.

## 3.4. The Purchase of Microgeneration Heat Systems

Our survey results show that when choosing between microgeneration heat technologies householders generally adopt the one perceived to be less risky (40%); more compatible with their property (37%), with better established information (26%); lower priced and with faster payback (25%).

When householders consider buying microgeneration heat technologies they usually seek impartial information on the internet, in manufacturers' or other literature, as well as advice from family, friends and installers. Potential purchasers often review more than one technology before making their choice. On average the 546 households who proceeded to purchase a microgeneration heat system organised two to three installer visits and typically

 

**Table 2. What drives people to seriously consider or adopt microgeneration heat technologies?**

| Reasons given | Percent |
|---|---|
| To reduce carbon dioxide emissions | 75% |
| To save money on fuel bills | 72% |
| I wanted to use low carbon energy and will get pleasure from doing so | 61% |
| Allows me to visibly demonstrate my environmental commitment | 34% |
| The low carbon technology forms part of a heating system replacement or upgrade | 23% |
| Related to my job, hobby or interests in the environment/low carbon technologies | 21% |
| Being innovative, a pioneer in using low carbon energy technology | 21% |
| The low carbon technology forms part of other home improvements e.g. home extension; loft conversion, new build | 20% |
| Had funds available to help purchase the system | 20% |
| Had confidence in the performance and reliability of this technology | 19% |
| **Total responses: Considerers and Adopters** | n = 859 |

**Table 3. Barriers to adoption of microgeneration heat technologies.**

| Nonadopters saying this issue was 'very' or 'fairly important' in deterring adoption | Total nonadopters[(1)] |
|---|---|
| Purchase price | 86% |
| Pay back on the investment is uncertain or long | 68% |
| Grant(s) only 1020% of the purchase price | 60% |
| Performance and reliability uncertainties | 58% |
| More cost effective ways to reduce carbon emissions | 56% |
| Possible major modifications to my existing heating, hot water or electrical systems | 54% |
| Difficulties finding space or suitable location | 50% |
| Time and effort involved in investigating and installing | 47% |
| **Total responses: Nonadopters** | 132 |

[(1)]Our surveys with 132 nonadopters included a special group of 70 LCBP grantholders who had rejected a microgeneration heat technology in favour of another LCBP microgeneration heat or electricity generating technology.

choose installers who appear to be knowledgeable, trustworthy and reliable (49%), local (32%), and (preferably) with a personal recommendation (21%). Since installers tend to specialise in specific technologies they typically cannot offer specialised advice to householders trying to choose between alternative microgeneration and other heat technologies. This places the onus on adopters to understand their choices, leading to over a quarter (28%) mentioning the time and effort involved in investigating microgeneration technologies.

## 3.5. Users' Experience of Using Microgeneration Heat

Only 285 households had actually installed and were using microgeneration heat, including 217 STHW systems and 48 GSHP systems. **Table 4** shows that householders who adopt microgeneration heat systems are generally very satisfied with their performance and reliability and

 

**Table 4. Adopters' satisfaction using microgeneration heat system.**

| Satisfaction indicator[1] | Total adopters with experience of use[2] | STHW adopters | GSHP adopters |
|---|---|---|---|
| System meets household demands for heating and/or hot water | 74% agree<br>3% disagree | 71% agree<br>3% disagree | 83% agree<br>2% disagree |
| System performs reliably | 86% agree<br>3% disagree | 88% agree<br>2% disagree | 85% agree<br>0% disagree |
| Get pleasure from using low carbon energy | 92% agree<br>0% disagree | 93% agree<br>0% disagree | 87% agree<br>0% disagree |
| Satisfactory appearance | 87% agree<br>3% disagree | 86% agree<br>1% disagree | 94% agree<br>4% disagree |
| Satisfactory instructions on operating and using system | 64% agree<br>6% disagree | 65% agree<br>6% disagree | 52% agree<br>8% disagree |
| Controls provide feedback on efficient system use | 44% agree<br>20% disagree | 47% agree<br>19% disagree | 30% agree<br>30% disagree |
| Satisfactory costs of running and maintaining the system | 70% agree<br>2% disagree | 72% agree<br>0% disagree | 58% agree<br>6% disagree |
| Reductions in fuel bills are as expected | 46% agree<br>4% disagree | 47% agree<br>3% disagree | 40% agree<br>6% disagree |
| **Total responses** | 285 | 217 | 48 |

[1]'agree' and 'disagree' responses include strongly agree/strongly disagree. [2]responses from 15 woodfuelled boiler adopters and 5 biomass stove adopters are included in the total.

92% say they get considerable pleasure from using them. However, less than half of all users (46%) said that the reductions in their fuel bills were as great as expected (although this was before major fuel price rises in the UK).

Not shown in the table is the result that many of these adopters (59%) required unexpected modifications to their existing heating and hot water system during installation. This particularly affected twothirds (67%) of STHW adopters, while twothirds (69%) of GSHP adopters complained about the disruption to their property or garden during installation.

A small percentage (12%) of all users complained that their system provided less than expected of their household's heating and/or hot water requirements. A few GSHP adopters (10%) also complained about the slow warmup of their heating and/or inability to heat rooms to the required temperature. GSHPs produce lower flow temperatures than a boiler and so response times can be slow.

A specific complaint, made by a third (32%) of STHW users, is disappointment at not being able to use solar-heated water in their coldfill washing machine and/or dishwasher. This problem may be attributed to plumbing constraints or modern coldfill only appliances. It appears that the adapter valves available in Germany and elsewhere to allow use of solar heated water in coldfill appliances are not supplied by UK installers.

The most common problems experienced by over a third of all users was uncertainty about how best to operate the system to make most efficient use of fuel or energy (37%) and difficulties understanding the system's controls (28%). **Table 4** shows that less than half of the users are satisfied with the feedback they get from the system's controls on the energy and money they are saving, and a fifth are strongly dissatisfied. Poor usability was a particular problem for GSHP users, with nearly one third of them very dissatisfied with feedback provided by their system's often sophisticated and computerised controls.

## 3.6. Users' Ideas for Improving Microgeneration Heat

The main system improvements desired by microgeneration heat adopters arose from the problems they experienced in use. The improvements include more user-friendly controls, better instructions on use of controls, and improved feedback displays showing energy generated and carbon and money saved. This would help users understand how to make the most efficient use of fuel and maximise carbon and financial savings. Adopters would also like improvements to the compatibility of microgeneration technologies with existing buildings and heating systems.

Over half (57%) of 413 STHW adopters would like systems improved to provide space heating as well as hot water, probably not realising that such systems are available but are not usually costeffective in the UK cli-

 

mate. Nearly half (48%) wanted easier to understand STHW controls that minimise backup water heating use and provide feedback on money and energy savings.

Over half 89 GSHP adopters (53%) would like controls that give more feedback on operating efficiency (e.g. electrical energy in and heat energy out) and energy saved–rather like a car computer. Almost a quarter would like higher heat pump efficiencies with existing radiator and hot water systems (24%), and more compact designs for ground collectors (22%) to allow GSHPs to be installed in smaller house sites.

Nearly half (44%) of the woodfuelled boiler (WFB) system adopters would like more compact designs matched to smaller homes and 17% would like automatic fuelling and ash removal. Most of the automatic biomass stove (BS) adopters would like improvements to the infrastructure to provide a reliable supply of fuel pellets. However, with samples of only 36 adopters of WFB and 8 BS systems, these desired improvements are only indicative.

### 3.7. Carbon Reductions with Microgeneration Heat

Although over threequarters of adopters say their system meets their heating and hot water needs, as noted in Table 4 only 46% were satisfied that their fuel bills have reduced much as expected. This questions whether these technologies are performing as well as designed.

When asked if the installation of a low carbon energy system had led to changes in home energy use some users described 'rebound' effects. Thus a quarter of 272 users admitted that they were heating more of the home and/or for longer periods, and 8% said they used more hot water. But most users responded that they were not heating rooms to higher temperatures or using more hot water.

However, there was also some evidence of 'double dividends' or additional carbon reductions that followed installation of a microgeneration system, including increased general household energy awareness and adoption of additional home energy efficiency measures. Three quarters of 272 microgeneration users said that they are more aware of their energy use, make greater efforts to save energy than before the installation, and have adapted their patterns of use of space heating and/or hot water to make most efficient use of the system.

The findings also show that although most of the 546 adopters had already installed energy efficiency measures before applying for a LCBP grant to help pay for the system, the grant stimulated up to a quarter of adopters to install extra insulation, new energysaving lights and/or heating controls. A fifth of all adopters went further and installed additional energy saving measures over and above the grant's requirements, including underfloor insulation (13%); hot water cylinder thermostats (19%); Arated domestic appliances (10%); and lowemissivity double glazing (10%), while 2% also installed solar PV.

### 3.8. Encouraging UK Householders to Adopt Microgeneration heat

Reducing the initial cost of microgeneration heat systems, thus addressing the biggest barrier to adoption, is probably the main way of widening appeal. Our survey found price thresholds below which many more microgeneration considerers and nonadopters said they would probably purchase a system. For example, £2500 to £3,000 was the maximum most microgeneration considerers were prepared to pay for a retrofit STHW system, rather than the £4000 average price in the UK. The maximum price threshold for those considering a GSHP installation was about £10,000, while many GSHP systems cost more than that to install.

Other than directly reducing the price, the most popular financial support measure for microgeneration is local council tax relief following system installation; favoured by over half of all respondents (53%), while the least popular measure was lowcost, long term loans for purchase, favoured by only 18%.

Over twothirds of all respondents would support new building regulations that required householders in the UK, as in some other countries, to install low carbon energy technologies when undertaking major refurbishments, extensions or conversions to their home.

Increasing consumer understanding and confidence in microgeneration technologies is also needed to promote wider adoption. **Table 5** shows some of the information and advice measures and support wanted by consumers to help with the complex process of choosing and installing a system.

## 4. Conclusions

The UK microgeneration heat market is still at the early phase of the adoption curve with significant barriers to widespread market penetration [8]. The OU/EST surveys show that microgeneration space and water heating systems currently mainly attracts 'pioneers' interested in innovative green technologies and able to pay the upfront installation costs, who are also driven by a desire to reduce their carbon emissions coupled with the hope to save money and enjoy the pleasure of using low or zero carbon energy. These findings reinforce our previous research on the drivers for UK consumer adoption of household renewables [15], as well as that of similar research in Germany, Austria, Australia and the USA [16-18]. Our surveys identify those considering or adopting microgeneration–estimated to be limited to 13%

 

**Table 5. Desired information and advice measures: all respondents.**

| Support measure | Percent |
|---|---|
| Independent information on the performance and payback of different manufacturers' systems | 71% Rank 1 |
| 'Onestop shop' assisting process of technology choice, grant applications, planning permission, installation, use, maintenance, and effective use | 69% Rank 2 |
| Online information to help assess suitability of home for low carbon energy technologies | 50% Rank 3 |
| More opportunity to see low carbon energy technologies installed in people's homes and public buildings | 46% Rank 4 |
| Multiskilled installers who supply different low carbon energy technologies and advise on the most suitable | 41% Rank 5 |
| **Total respondents** | n = 924 |

of British householders [8]–as currently largely confined to a niche market of environmentally concerned, middle class householders, and mainly those living in larger rural properties off the UK's mains gas network. This description of the typical UK microgeneration adopter applies especially to adopters of ground source heat pumps, woodfuelled boilers and biomass stoves. These technologies are more typically installed in larger, rural, offgas properties because they are costly; currently only costeffective in properties previously heated by oil, electricity or solid fuel; while GSHPs and WFBs are better suited to properties with sufficient space for the equipment, ground heat collectors or wood fuel stores.

Solar thermal hot water accounts for over 90% of existing UK installations and was also the most frequently adopted system in our surveys. Compared with other microgeneration heat technologies, STHW has a wider appeal because it is a lower cost, more compact and familiar technology, with a faster payback, worthwhile for properties with or without mains gas, and suited both to rural and urban/suburban dwellings.

For microgeneration heat to expand beyond the current market niche, the views and concerns of the householders seriously considering purchase of a microgeneration system need first to be addressed followed by lowering the barriers that are deterring adoption by the wider population. These include:

- Cost reductions: **Table 3** shows that purchase price and payback issues are the barriers most cited by nonadopters. Microgeneration has already benefitted from UK purchase tax reductions (to 5%), and prices could be brought down further by larger grants, through lowercost production (e.g. from the rapidly expanding Chinese microgeneration industry) or by subsidies from energy suppliers as is required under the UK government's Carbon Emissions Reduction Target (CERT). A new renewable heat incentive proposed by the UK government for introduction in 2011 should also help overcome the payback barrier, but was not available at the time of these surveys, when the most popular financial support measure was local council tax relief for households with microgeneration.
- Independent information: This would reduce the requirement for consumers to rely on manufacturers' claims about the reliability and performance of microgeneration technologies. Consumer confidence would be increased by greater availability of independent information on the suitability, performance, payback and carbon savings of different manufacturers' microgeneration systems. The need for greater consumer confidence to invest in unfamiliar technologies may be partly addressed with the introduction in 2008 of a UK government Microgeneration Certification Scheme [19].
- Better advice and support: Consumers would like 'onestop', independent, trustworthy advice and support covering the whole process of technology choice, grant applications, planning permission, installation, maintenance, and effective use. The 'Act$On CO_2$' advice service offered by the Energy Saving Trust seeks to address difficulties UK consumers have finding trustworthy, multiskilled installers.
- Less disruptive installations: More than half microgeneration heat users required unexpected modifications to their existing heating and hot water systems. In some cases this led to additional cost and pressures on microgeneration users to take a strong installation coordination role.
- Design improvements to controls to make them more userfriendly: with improved feedback displays showing the energy generated, carbon and money saved. These improvements should help

 

overcome the difficulties some users experience in understanding and operating their system effectively.

There will always be some homes that are unsuitable for microgeneration heat. For example STHW systems suit properties with a mainly southoriented, unshaded roof and a GSHP requires sufficient land to install the ground collectors and space inside or outside the house to accommodate the equipment. Likewise woodfuelled boilers and biomass room heaters/stoves require suitable locations for equipment and space for storing fuel. However, greater use of borehole GSHPs (which need less space) and designing more efficient air source heat pumps (which need no ground loop) would allow such systems to be installed in more urban and suburban homes. Similarly, more compact wood boilers and biomass room heaters would encourage wider uptake.

The survey shows that householders who purchase these technologies are generally very satisfied and derive considerable satisfaction from using them (**Table 4**). However, less than half of adopters were satisfied that their fuel bill reductions were as great as expected, which raises the question of whether the energy and carbon savings predicted for microgeneration heat systems are being achieved in practice. This may be partly due to the fact that the way that people use microgeneration systems affects their performance. Also there may be 'rebound effects' if people use more heat or hot water as a result of installing low or zero carbon energy technologies [13]. Although these surveys did not attempt to measure carbon savings actually achieved (which is the subject of the Energy Saving Trust's field trial to monitor the performance of domestic heat pumps[1]), the results showed that adopting a microgeneration heat system often produces 'double dividend' benefits, such as householders deciding to install additional home insulation measures as well as encouraging greater energy saving awareness and behaviour in the home. This supports findings from other qualitative studies of the positive impact on household attitudes to energy use of the adoption of microgeneration technologies like solar water heating, microwind turbines and air source heat pumps [21].

The OU/EST surveys provide evidence from a representative sample of adopters and a purposive sample of potential adopters and nonadopters of microgeneration heat technologies that can inform government policies, industry strategies, and specifications for usercentred design improvements that should encourage the uptake of microgeneration heat and so make a significant contribution towards achieving the UK's carbon reduction targets.

[1]The Energy Saving Trust in partnership with the Open University and industry and government stakeholders, is undertaking the UK's largest independent field trial to evaluate the technical performance, user experience and carbon emissions of domestic heat pumps in private and social housing, with initial results published in September 2010 [20].

## 5. Acknowledgements

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