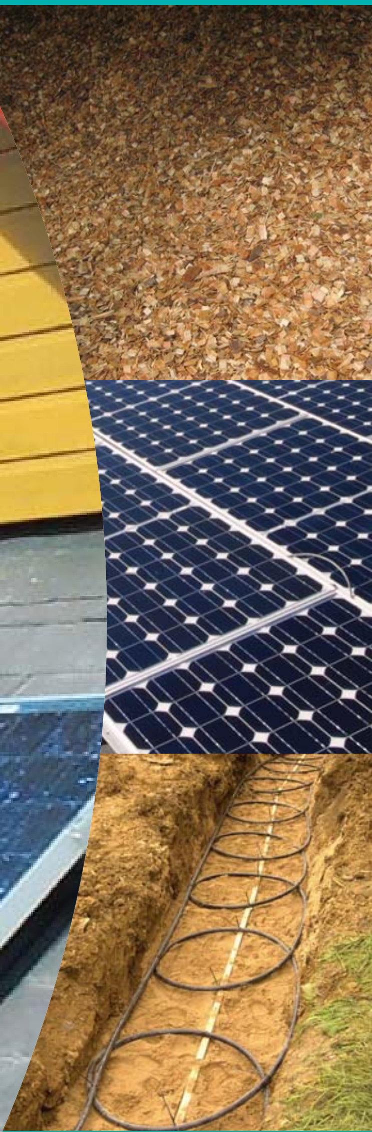


Generating the Future: An analysis of policy interventions to achieve widespread microgeneration penetration

energy saving trust®

Contents

Executive Summary

Can microgeneration help the UK hit its carbon targets?

Saving energy is one thing. But unless the energy that we use is cleaner, Britain will be hard-pressed to hit its aggressive CO_2 reduction targets. 'Macro' renewable projects for electricity generation – like wind farms and tidal schemes – are on the up, thanks to the 'Renewables Obligation', which forces suppliers to buy a certain fraction of their energy from renewable sources. But despite this, only 4.6 per cent of the UK's electricity came from renewable sources in 2006. There is still a long way to go. However, electricity-generation is only a small part of the problem: three-quarters of the energy we use at home is for heating and there is currently no way of creating a large-scale, carbon-neutral solution for home heating.

Microgeneration – producing energy at a domestic level – has huge potential for CO_2 reduction. It could create a more diverse energy supply, in an age when energy security is a major worry. It creates none of the waste that happens when energy is transported long distances (centralised power stations lose over 60 per cent of their 'primary' energy as waste heat and in transmission losses). And microgeneration can help to tackle fuel poverty, particularly in 'hard to treat' properties.

The problem with microgeneration is adoption. How do you get consumers to invest in technologies whose full benefits they find difficult to appreciate or realise, whilst others find it difficult to afford them? For most people, microgeneration is a lifestyle choice rather than a hard-headed commercial decision.

This report explores the different ways in which policy could help this crucial carbon-saving technology to develop – and it makes a series of pragmatic recommendations. In conclusion, we find that a judicious blend of policies and incentives could deliver huge carbon savings for a fraction of the 1 per cent of GDP that the Stern review suggests is needed.

Where is microgeneration now?

100,000 installations out of a potential tens of millions

Grant systems like the Low Carbon Buildings programme are helping microgeneration to grow – but at a painfully slow pace. Despite rising interest in solar PV and thermal, micro-wind and ground source heat pumps, there are currently only 100,000 installations out of potential millions.

Two-thirds favour renewable electricity

Consumer attitudes are in the right place. A survey of over 6,000 individuals revealed that two-thirds favoured renewable electricity, 44 per cent opting for 'macro' and 24 per cent for microgeneration – and with wind and solar the preferred sources. Most respondents to this survey thought that government was responsible for ensuring energy sustainability and should subsidise renewable energy.

Barriers still high

However, the barriers to microgeneration ensure that this public enthusiasm does not translate into action. Most technologies are expensive; many are hemmed in by red tape, like the planning laws and the complexities of selling electricity back to the grid. Consumer understanding of the technologies is low. And developers and suppliers have few incentives to invest and commit.

The solution – a careful blend of policies

The detailed modelling that underpins this report shows that no single policy will encourage the kind of mass adoption of microgeneration that is needed to get results. However our research shows that a combination of different policies, providing incentives to both consumers and providers, could drive massive carbon savings from microgeneration.

Investing for the future

A successful policy scenario:

- Mandate for one heating microgeneration technology to be installed (instead of a conventional boiler) at time of replacement
- Make wind, solar or PV compulsory on new builds
- Offer a 30 per cent grant to retrofit renewable technology into existing buildings
- Provide 10-year, low-interest loans on all microgeneration technologies
- Make sure that electricity from renewable sources can be sold back at the same price consumers pay for grid electricity
- Apply a carbon tax of £20 for each tonne of CO_2

When this combination of policies is applied, micro-CHP (combined heat and power), currently an emerging technology, becomes the heating system of choice by 2050. Air-and ground-source heat pumps would be installed in large numbers, along with biomass boilers and solar thermal, wind and PV. All of which would add up to national CO_2 savings of more than three-quarters of the way to the 80 per cent target suggested by the IPCC (Intergovernmental Panel on Climate Change). A direct subsidy cost of £200 million and a total annual cost of around £3 billion (excluding all benefits) by 2020 is a small price to pay compared to the £13 billion cost implied by Stern's recommendation that 1 per cent of GDP is needed to mitigate climate change.

13 steps to make microgeneration succeed

1. Regulation – take the least efficient heating products off the market and make low-carbon replacements compulsory. Our research suggests that regulation has huge potential to encourage microgeneration. It is the only policy that would work on its own and the most effective way to apply it is at specific points in the life of a building. In the longer term, more radical measures mandating installation at sale or re-roofing should be applied.

2. Carbon pricing – price carbon at least £20/tonne of CO_2. A carbon price that reflects its social cost would not work in isolation but would help microgeneration as part of a package of measures.

3. Change consumer decision-making – provide 'soft loan' purchasing options that offer real savings to consumers. These could apply to equipment bought directly or via energy supply companies.

4. Raise awareness, change attitudes – run an awareness programme that motivates consumers to include environmental factors when making investment decisions. 'Forward-looking' consumers who currently buy microgeneration are prepared to invest out of concern for the environment and accept long payback times.

5. Provide information and advice – set up an independent advice service on microgeneration. The subject is fraught with technical and regulatory complexity, which frightens off potential adopters. Practical, usable guidance is needed.

6. Help householders to understand the Energy Performance Certificate (EPC) process. The value of a house will one day reflect its energy performance, encouraging home-owners to take action. Raising awareness of EPCs will help his process along.

7. Subsidies – increase their value, particularly in the early years. Subsidies need to be at considerably higher levels than presently planned (post current grant support) to encourage mass-market take-up of microgeneration.

8. Heat measures – give heat-microgeneration technologies an 'uplift' under the Carbon Emissions Reduction Targets (CERT). A subsidy of 30 per cent is required for substantial carbon savings.

9. Electricity measures – provide a guaranteed 'feed-in' tariff; or create a 'Microgeneration Obligation'. The former gives an attractive price for microgenerators to sell at and the latter will help to incentivise technology developers and suppliers, in the same way that the 'Renewables Obligation' has boosted 'macro' renewable schemes such as wind farms.

10. Technology development – use the Environmental Transformation Fund to support household generation too; and support early commercialisation measures such as field trials. Grant support is all very well, but it tends to support the lowest-cost technology rather then helping others to develop. Field trials are essential to refine microgeneration technologies before they are released to a wider market.

11. Provide a clear framework – set out plans that encourage companies to invest. Without certainty of the direction government policy will take, businesses will be reluctant to commit to microgeneration technologies.

12. Invest in peripheral technology issues – using existing technologies more carbon-efficiently, exploring energy storage and looking at ways of rewarding peak demand reduction: Investment in these areas, perhaps through the Environmental Transformation Fund, will help to support microgeneration too.

13. Link into grid de-carbonisation – create a unified policy for domestic microgeneration. Linking together the grid, community scale solutions and microgeneration will ensure that CO_2 savings are achieved at lowest cost.

Microgeneration holds out huge potential for revolutionising the way the UK produces energy and for carbon savings. But without a carefully considered policy approach, we could miss the important – and extremely cost-effective – way of hitting the UK's CO_2 obligations.

Introduction

The Energy Review[1] states that 'Cost-effective ways of using less energy will help move us towards our carbon reduction goal. But on their own they will not provide the solution to the challenges we face. We also need to make the energy we use cleaner.' An increase in use of renewable energy is vital to cut CO_2 emissions, diversify supply and help tackle fuel poverty.

Whilst the Renewables Obligation has undoubtedly increased the supply of renewable electricity, this is still at a very low level – 4.6 per cent of the total in 2006[2]. It is also important to remember that three-quarters of energy used in the typical home is in the form of heat. More localised forms of generation are far more efficient for heating.

In this report we explore different policy mechanisms for supporting microgeneration[3]. If we want these technologies to be a significant part of the UK's[4] future energy mix, they need support. We look at the forms this support could take and present the results from our modelling. We then analyse these results alongside consumer research and political considerations.

This report builds on a model developed for the Energy Saving Trust by Element Energy[5], which uses a simple, robust but highly flexible framework to determine which policies enable microgeneration to achieve its full potential in terms of energy supply and CO_2 reduction. Although most technologies are predicted to be cost-effective by 2020, intervention to promote microgeneration is likely to be expensive in the early years. So it is important that the likely effects of any interventions are evaluated as carefully as possible.

Clearly, in forecasting new technologies and hard-to-predict consumer behaviour, any model is subject to uncertainties. The reader is therefore cautioned against over-interpreting specific numeric results from this model: it is not a forecasting tool, nor does it analyse the likelihood of each scenario. Instead, the results of the study are intended to allow policymakers to estimate the relative impacts of different market interventions.

The model focuses on the domestic sector only and looks at the contribution that household-scale technologies could make to the energy requirements and CO_2 reduction targets. It does not attempt to model the whole energy system or look at community-scale technologies. There are models that have already attempted this – see, for example, the World Alliance for Decentralised Energy (WADE) model.[6]

The model makes certain assumptions about which technologies will be available. It cannot predict as yet un-invented technologies, although there is no doubt that new technologies will develop. And some of the technologies analysed may never become commercially viable. The model simply looks at the characteristics of the various technologies currently available and shows which types of technology are likely to be affected by different

1 DTI, 2006, Energy Review

2 BERR, July 2007, UK Energy in Brief

3 Microgeneration is defined in Section 82 of the Energy Act (2004) as the small-scale production (usually below 50/100kW electric and 45kW thermal) of heat and/or electricity from low carbon sources. This definition encompasses all small-scale renewables, such as solar thermal and PV, heat pumps, micro-wind and biomass. It also includes small-scale combined heat and power devices, which may use fossil fuels as an energy source. Most domestic installations will be below 3kWe, though thermal systems could be larger.

4 This report covers the UK. A separate Scottish report is also available.

5 http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1122

6 The WADE (World Alliance for Decentralised Energy) Economic Model: Previous Results and Future Application, 20 February, 2006)

policy interventions. If, for example, fuel cells never reach full commercialisation, then these will obviously not be part of the mix: but the model does predict that a technology with these types of characteristics could do very well in the future.

We have concentrated on mass-market technologies in the domestic sector. For this reason, we have not included micro-hydro products within our modelling, because whilst it has great potential, it is not applicable for most households. Similarly, in the case of wind power, we have looked only at very small-scale applications. Whilst there is a market for turbines in the range of 6-20kW, for example, in this report we are looking at mass-market applications with possible uptake in the millions.

For microgeneration technologies to play a significant role in the UK energy mix, they must achieve widespread penetration. Each microgeneration unit represents only a few kW of heat or electricity generating capacity, compared to the tens of GW required by the UK population as a whole. As a result, uptake of microgeneration technologies in the millions is required to have an effect on the carbon content of our overall energy supply.

"The efficiency of generation from power stations is at best 40 per cent before transmission losses whereas home generation can achieve efficiencies as high as 90 per cent."
[Senior Marketing Manager, Utilities]

"Microgeneration could produce all UK electricity but we are currently going to struggle to meet our Kyoto targets. If every south-facing roof was covered in solar this would be enough on its own without considering the other renewables. The size of the resource is enormous."
[Marketing Manager, Supply & Installation]

Quotes are from Project Renew[7]

The approach

The approach used for this research is as follows:

- We built a model based on principles of consumer behaviour and used it to analyse specific policy interventions. The results are presented in this report.
- Allegra Strategies undertook a major piece of consumer research called Project Renew, in which the Energy Saving Trust was a funding partner. The research involved over 6,000 members of the general population in the UK.
- The Energy Saving Trust undertook a lifecycle analysis[8] which analysed existing studies that have considered energy and carbon payback times for microgeneration technologies.

7 Allegra Strategies, October 2006, Project Renew: UK Consumer Perspectives on Renewable Energy – Strategic Analysis

8 Energy Saving Trust, June 2007, Review of Existing Life Cycle Assessment Studies of Microgeneration Technologies, undertaken by Simon J. Bennett http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1160

9 Open University and Energy Saving Trust Carbon Connections Scoping Project, 2007, Surveys of UK householder adoption, non-adoption and use of Low and Zero Carbon heat technologies. This was undertaken under the University of East Anglia's Carbon Connections project. The report is unpublished at time of writing.

- Using applicants and enquirers of the Low Carbon Building Programme (LCBP), we surveyed[9] 1,000 adopters and non-adopters of low- and zero-carbon technologies.

Chapter 1 of this report explores why we should support small-scale renewables, outlining the current status and consumer views on microgeneration technologies.

Chapter 2 describes the modelling methodology and Chapter 3 presents the results of the modelling.

Chapter 4 goes on to summarise the modelling results and presents results of policy combinations.

Finally, Chapter 5 makes recommendations on policy interventions to increase uptake of microgeneration technologies in the domestic sector.

Chapter 1:
Why support small-scale renewables?

Energy policy in the UK is currently guided by the four long-term goals set out in the Energy White Paper 2003[10]. These goals cover four major themes:

- greenhouse gas emissions
- energy security
- competition
- energy poverty

The 2007 Energy White Paper reaffirmed the goal of reducing UK emissions by 60 per cent relative to 1990 levels by 2050[11].

The Stern Review[12] set out in detail how economic and social costs of climate change will mount over the coming century and concluded that stabilising greenhouse gas concentrations in the atmosphere and avoiding dangerous warming was not only possible at a cost of 1 per cent of global GDP, but is an investment with benefits that will far outweigh the costs.

Oil prices have risen in recent years[13], particularly because of geopolitical issues in the Middle East, and gas prices have risen too, driven by concerns about shortages. Alongside declining production of oil and gas in the UK, this has highlighted our reliance on imports to attain our energy needs, and the fragility of this in the political context. Coupled with ageing energy generation capacity in the UK, it has led to a widely predicted 'energy gap' with uncertainty about how to provide for energy demand in the coming decades.

Large-scale renewable generation, such as onshore and offshore wind farms, has significant potential to decarbonise the electricity grid. But despite recent growth, renewables still account for only 5 per cent of the UK electricity mix, with an aspiration for electricity from renewables of 20 per cent by 2020[14]. The substitution of gas for coal-fired generation is generally projected to continue, but gas is also set to replace nuclear power as the decommissioning of the current generation of reactors continues. It is likely therefore that grid electricity will remain the most carbon-intensive form of energy for the medium-term.

The UK's centralised electricity system has served well to date, but there are questions over its suitability to provide for a future low-carbon economy. The system was based on the economies of scale afforded by large power stations. But the low generating costs of centralised plant have hidden the fact that such a system suffers from a fundamental inefficiency. The average thermal efficiency of UK coal power stations is 36.3 per cent and combined-cycle gas turbines (CCGT) 48.9 per cent[15]. Once transmission and distribution losses are included, the system only delivers, on average, one third of the primary energy input to end-users. WADE estimates that between 5 and 10 per cent of the grid losses are caused by transmitting electricity large distances[16]; and it is even more inefficient to ship heat over any distance. So decentralised energy offers benefits by using the energy that would have been wasted in centralised plant.

In 2007, European heads of state signed up to a binding EU-wide target to source 20 per cent of their energy needs from renewables. Specific national targets within this overall figure will be

10 DTI, 2003, Energy White Paper 2003: Our Energy Future – Creating a Low Carbon Economy

11 DTI, 2007, Energy white paper: meeting the energy challenge

12 Cabinet Office – HM Treasury, Nicolas Stern, 2007, The Economics of Climate Change: The Stern Review

13 The price of standard crude oil on NYMEX was under $25/barrel in September 2003, but by August 11, 2005, it had risen to over $60/barrel, through most of 2006 showed a bumpy plateau, with a summer peak, falling for the early part of 2007 to between $50 and $60/barrel, before rising again from May to September 2007, to be traded at over $80 in the autumn, by October 2007 prices had reached $96.24 per barrel.

14 DTI, May 2007, Reform of the Renewables Obligation

15 BERR, 2007, Digest of United Kingdom Energy Statistics – http://stats.berr.gov.uk/energystats/dukes07.pdf

16 http://www.localpower.org/deb_how.html

agreed, taking into account each country's starting point and potential; the minister has recently confirmed that the UK is negotiating for a target of 10-15 per cent[17] Crucially, the requirement covers all types of energy (i.e. not just electricity). There are no easy solutions to achieve this level of renewables, therefore all options for technologies and their scale need to be kept open.

Microgeneration can help reduce carbon emissions, diversify supply, reduce wasted energy from transmission and distribution losses and help tackle fuel poverty, particularly in hard-to-treat and off-gas network properties. The 2005 report for DTI entitled 'Potential for microgeneration study and analysis' concluded that many of the technologies needed will be cost-effective before 2020. The report also suggested that substantial network reinforcement is unlikely to be required up to an installed capacity of 500W/household on a typical piece of network – and this should not therefore be a significant constraint on the timescales for mass rollout. Any issues appear to be financial (hence, generally, regulatory) rather than technical[18].

UK policy needs to provide sufficient support and a more favourable market framework to deliver the potential offered by microgeneration. The Renewables Obligation (RO) is already delivering substantial growth in large-scale renewable generation capacity, but it does nothing to encourage renewable heat and provides very limited support in practice to renewable microgeneration technologies. Recognising the potential of these technologies, the government has published a microgeneration strategy that sets out how it will support the industry and allow it to realise its potential[19].

Current status of microgeneration

Underpinned by support from government grants, there is a growing number of microgeneration installations across the UK, with the largest markets being photovoltaics (PV) and solar water heating. Numbers of ground source heat pumps and wind turbines are also increasing rapidly from a low starting point, with microCHP (small-scale combined heat and power) an important new entrant with significant technology investment. There are currently around 100,000 installations[20] of the various technologies, which is a small fraction of the market potential. The Environmental Change Institute[21], for example, estimates the technical potential at around 53.6 million installations by 2050 in the domestic sector alone, equating to 1.7 installations per dwelling.

Short-term opportunities include heat pumps and biomass, which are already competitive when installed off the gas grid, as is micro-wind at high (generally above 12 m/s) windspeed sites. Current predictions for gas microCHP are that it is likely to be available by 2010, however this technology has been anticipated for some time and has not yet reached commercialisation for the domestic sector. PV can be viable off-grid in commercial applications, but without a major cost or technology breakthrough it is unlikely to be

17 http://www.guardian.co.uk/environment/2007/oct/24/renewableenergy

18 See the E-Connect appendix to the DTI report at http://www.berr.gov.uk/files/file27558.pdf

19 DTI, 2006, Our energy challenge: power from the people. Microgeneration strategy

20 The 2005 report 'Potential for Microgeneration' commissioned by the DTI (Energy Saving Trust, E-Connect and Element Energy, 2005, Potential for Microgeneration Study and Analysis) found that there were approximately 82,000 microgeneration installations in 2004. There is no ongoing collection of this data, so estimates below are based on grant-funded installations added to this. Therefore the data below is the minimum number of confirmed installations. Discussions by BERR with industry experts suggest there could be approximately 100,000 installations, although this cannot be verified.

21 Environmental Change Institute, University of Oxford, 2005, 40 per cent house

cost-effective on a householder scale until at least 2020. Solar thermal is currently popular, as it is one of the cheapest investments in terms of capital cost, but has one of the lowest returns in terms of carbon saving (assuming it continues to be used primarily for water heating in gas-connected homes).

The consumer view

UK consumers are greatly in favour of renewable energy. According to research carried out on over 6,000 individuals[22], two-thirds of respondents would like their electricity to be generated from renewable sources, either large-scale (44 per cent) or via micro-generation (24 per cent), with wind and solar power the most-preferred sources. Respondents considered these sources to be environmentally friendly, clean, natural, infinite, and, in the long-term, cost-effective. Nearly 50 per cent of the sample stated that they would be prepared to pay more for their electricity bills to ensure that the energy comes from a renewable source, compared with 32 per cent who would not pay more.

More than 70 per cent of respondents thought the government should be responsible for ensuring future energy sustainability, because of its authority to legislate on the use of renewable alternatives. 80 per cent agreed that renewable energy should be subsidised by the government and 73 per cent thought that all new houses/constructions should, by law, be powered by renewable energy.

This shows significant support amongst the general population to implement policies that boost renewable energy.

"Microgeneration is the way forward as it results in no [transmission] losses by delivering generation at the point of use and has the advantage of Joe Public being a part of that."
[Solar UK Sales & Marketing Manager, Consulting Services]

"People with microgeneration immediately begin behaving differently, realising that if they use less energy they can export more."
[Head of Offshore, Industry Association]

If you start to see how you generate, sort of take responsibility for generating power, it's somehow not remote, it creates a link between people and energy that doesn't usually exist."
[Director Renewable Energy Section, Government]

Quotes are from Project Renew [23]

Cost-saving is the main motivation for adopting energy-saving behaviour, cited by more than 55 per cent of respondents in the Allegra research.

When consumers were prompted to say what they were most likely to do to reduce their carbon emissions, 40 per cent said they would change their consumption, 31 per cent would install renewable measures in their home and 27 per cent would install energy-saving measures.

More than two-thirds of the sample had never seriously considered renewable energy measures for their home. 12 per cent had seriously considered alternatives but not

22 Allegra Strategies, op. cit

23 Allegra Strategies, op. cit

installed, mainly because of the high installation costs. And only 1.4 per cent had actually installed renewable energy measures in their home – typically solar PV and solar water heating.

Those who had considered renewable measures cited mainly ethical motives: 44 per cent – women in particular – wanted to prevent climate change; 24 per cent planned to save energy costs in the long term (especially male consumers); 22 per cent hoped to become self-sufficient.

Consumers believed that the best way to encourage the use of renewable energy would be through lower costs (subsidies) for renewables (33 per cent) or financial incentives (32 per cent). 10 per cent of respondents saw compulsion as the most effective way to establish the use of renewables.

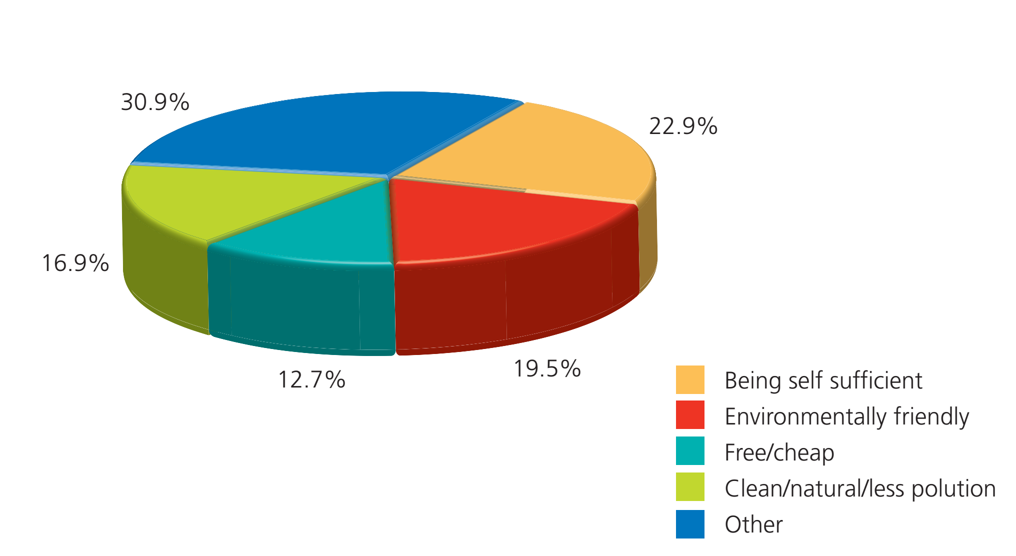
"I'd ideally like to have a micro-renewable source of electricity so that I can be self sufficient without having to rely on anyone else."
[M, 35-44, Taxi Driver, Folkestone]

"I know someone who has solar panels and they seem to be paying less than I am, so in the long run micro-renewable sources are cheaper and more environmentally friendly."
[F, 25-34, Builder, Tonbridge]

"With a micro-renewable, I am in control of it and I wouldn't have to pay towards the profits of the large energy companies. There would be no worries about harmful gases being emitted."
[F, 65+, Tunnel Miner, Glasgow]

Quotes from Project Renew[24]

Figure 1: Analysis by reasons for preferring micro-renewables



* 'Other' includes: available, won't run out, not using fossil fuel, don't like nuclear, efficient, can monitor yourself, not affect landscape, everyone's responsibility

24 Allegra Strategies op. cit.

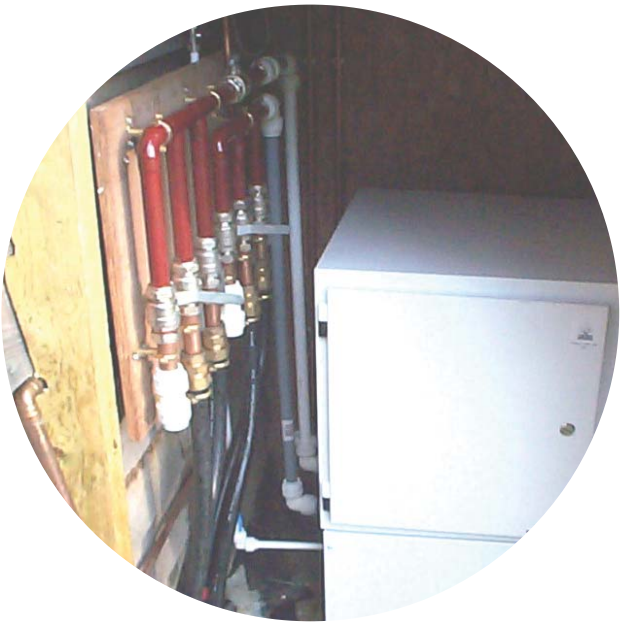
Familiarity with fuels

The Allegra research shows that familiarity is extremely important. The typical age of the respondents here also suggest that loyalty to a fuel may be less of an issue with future consumers.

Some respondents chose gas as their preferred source of electricity generation out of habit and familiarity. They perceived it to be cost-efficient and cleaner and more environmentally friendly than other sources such as nuclear, coal or oil.

A few consumers would like their energy to be derived from coal-fired power stations because they believed there were still enough resources available. They consider coal to be a traditional, conventional and also natural source of energy.

A small number of interviewees would like their homes to be powered by oil-fired powered stations – out of habit and because they saw oil as a cost-efficient source that is less harmful to the environment than coal.



"We have over three hundred years' worth of untouched coal. Not only would it help the environment but it could provide employment opportunities as well."
[F, 65+, Component Packer, Towcester]

"I'm used to using oil and have found that it works quite well for my purposes."
[F, 55-64, Builder, Northern Ireland]

"My father used to be a miner, so coal power is what I was brought up on and what I know."
[F, 45-54, Retail Outlet Owner, Swansea]

"Gas is the only one I know much about."
[F, 65+, Local Government Officer, Glasgow]

"I'd ideally like my energy to come from coal, which is a natural source to use."
[M, 35-44, CarRe-Management, Dudley]

"We have always used gas and I'm not changing"
[F, 65+, Painter and Decorator, Swansea]

"I think oil would be ideal because our supplies of coal are running out."
[M, 55-64, Process Operator, Swansea]

"I don't know anything other than coal. It's what we have always had."
[F, 65+, Waitress, Handforth][25]

25 Allegra Strategies, op. cit.

Who do consumers hold responsible for investment in renewable energy?

The majority of consumers hold government ultimately responsible for ensuring sufficient energy supply in the future because it is government's role to legislate on the subject[26].

Consumers expect more initiatives from Government to ensure sufficient and environmentally friendly energy. Over 80 per cent of respondents agree that renewable energy should be subsidised by government.

There were strong opinions regarding legislation for new buildings: 73 per cent of interviewees believed that all new houses/constructions should by law be powered by renewable energy, while only 13 per cent disapproved of this kind of legislation[27].

17.9 per cent of the population see energy providers as responsible for renewables investment because of the nature of their business: they are paid for the supply of energy. Respondents felt that providers should offer clean, alternative energy and invest more in renewable sources because they are energy experts and profit from the supply of energy.

Only 15.6 per cent of consumers felt that individuals should share the responsibility by reducing waste and using less energy in order to ensure sufficient energy supplies for the future. Some consumers felt that 'public pressure' should be used to influence the Government.

"Major responsibility falls on the Government to teach people how to use energy better. They should also be investing in the technology surrounding renewable energy so that it can be made more affordable down the road."
[M, 55-64, Diesel Engineer, Market Deeping]

"The Government must take energy efficiency seriously and educate people about the effects that our behaviour is having on the environment. They need to take the lead as they have the influence to make something happen. They could offer grants for renewable energy use or legislate to ban the use of non-renewable fuels."
[F, 25-34, Post Office, Watford]

"Energy suppliers are the people actually providing the energy, so they should use the source of energy that is best for society and not be so concerned with their profits."
[F, 25-34, Accountant, Kettering]

"Energy suppliers should be responsible because they are the experts and they control the buying and selling of energy."
[F, 45-54, Builder, Stowmarket]

"We are the ones that are using energy, so we should be more aware of how we are using it so that we have sufficient supplies in the future."
[F, 35-40, Barmaid, Hounslow]

Quotes from Project Renew[28]

26 Allegra Strategies, op. cit.
27 Allegra Strategies, op. cit.
28 Allegra Strategies, op. cit.

Barriers to microgeneration

The key barriers to microgeneration are well documented[29] and summarised below:

- costs – many technologies currently rely on grant support to achieve even small markets
- regulatory issues – planning permission, the low value of exported electricity and high transaction costs for accessing rewards for renewable generation
- lack of long-term incentives for renewable heat
- lack of awareness, independent information and advice, negative perceptions about the technologies or installers
- inadequate skills base
- lack of targets and framework for positive environment for investment
- lack of long-term rewards and carbon price signal

This report analyses the most effective strategies to overcome these barriers and provide a policy framework that encourages high uptake of microgeneration.

Keeping future options open

There is a need to keep options open as technologies may evolve faster, more slowly, or even come to a dead end. New technologies may appear, too – and the policy framework

needs to be flexible enough to include them. Crucially, new technologies must be quickly included in certification programmes such as the new Microgeneration Certification Scheme[30] and government-supported schemes (e.g. SAP[31] and the Energy Efficiency Commitment (EEC)[32]) in order to get them to the mass market as fast as possible.

It is also important to be prepared to respond to a changing climate. For example, it is uncertain if we will have more or less insolation (sun resource) and wind resource by 2050. Therefore it is important at this stage to support a wide range of technologies, focusing support on those that have mass-market potential.

29 See, for example, Energy Saving Trust, E-Connect and Element Energy, 2005, Potential for Microgeneration Study and Analysis: http://www.dti.gov.uk/files/file27558.pdf

30 http://www.redbooklive.com/page.jsp?id=135

31 SAP is the Government's Standard Assessment Procedure for Energy Rating of Dwellings and is used to demonstrate compliance for dwellings with Part L of the Building Regulations (England and Wales) and to provide energy ratings for dwellings. SAP 2005 Appendix Q allows the energy performance of new technologies and advanced versions of existing technologies to be evaluated for inclusion in SAP assessments. For further information see http://projects.bre.co.uk/sap2005/

32 Under the Energy Efficiency Commitment (EEC), electricity and gas suppliers are required to achieve targets for the promotion of improvements in domestic energy efficiency. In May 2007, Government published its consultation on the Carbon Emissions Reduction Target (CERT), previously referred to as EEC3. The Government proposes to impose the CERT mechanism to 2011 at around double the level of activity of the current EEC 2005-08. It proposes to extend its scope to include, in addition to energy efficiency measures, microgeneration and other measures for reducing the consumption of supplied energy. See http://www.defra.gov.uk/environment/climatechange/uk/household/eec/index.htm. EEC/CERT applies to Great Britain, in Northern Ireland a broadly equivalent scheme operates under the name of the Energy Efficiency Levy.

This does not necessarily mean that the UK has to support the whole chain from research through to mass take-up for each technology. The Carbon Trust[33] suggests four specific circumstances in which the UK should play an active role:

- existence of sufficient resources in the UK to support or fuel the technology
- ability of the technology to make an important contribution to UK energy demands
- existence of a comparative advantage for UK against other countries
- ability to derive economic benefits for the UK

Lifecycle analysis and sustainability

As energy efficiency and better design reduces energy use in buildings, 'embodied' energy (the energy expended in manufacture) takes a more significant part of the total energy footprint. So in the medium-term it will become more important to consider the 'whole life energy' of technologies[34]. All of the technologies considered have payback times that are lower than their expected lifetimes. The potential savings depend to a large extent on two things: the conditions into which they are installed; and the existing system that they are due to replace. In the calculations, the systems are compared with the average electricity mix imported from the grid and an efficient modern (condensing) natural gas heating and hot water system. The estimates may therefore be very conservative for installations in windy or sunny areas that currently rely on diesel generators or electric heating.

33 Carbon Trust, 2006, Policy frameworks for renewables: Analysis on policy frameworks to drive future investment in near and long-term renewable power in the UK

34 An desk-top study was undertaken for the Energy Saving Trust, analysing 43 different studies on lifecycle analysis. Where possible, peer-reviewed academic studies have been used. In some cases other corporate, governmental and non-governmental figures have been included. These results are presented as a range for each technology. The study can be found at: http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1160

Table 1: Summary of lifecycle payback times		
System	Energy payback time (years)	Carbon payback time (years)
Micro-wind	1.6 – 2.5	1.1 – 1.7
Solar PV	5.0	6.0 – 8.0
Solar Water Heating	2.0 – 3.8	2.4 – 4.4
Ground Source Heat Pump	2.1	6.0
Biomass (pellet) boiler	N/A	0.6-1.1

Energy payback time (EPBT) – Microgeneration has the potential to reduce the amount of primary energy that is needed to meet a given annual domestic energy demand. The number of years of energy savings from microgeneration using a given technology, under UK conditions, that are required to equal the amount of energy expended in its production, installation, maintenance and decommissioning, is defined as the EPBT. Once the EPBT has been reached the annual energy saving is realised for the remaining life of the installed plant.

CO_2 payback time (CPBT) – As with EPBT, but equated to the quantity of carbon dioxide (or carbon dioxide equivalents) released during production, installation, maintenance and decommissioning. Once the CPBT has been reached the microgeneration system provides a net-positive effect on CO_2 emissions.

Where ranges are specified this is because different assumptions have been used about wind resource, for example.

The technologies considered here all have short payback times compared to their expected lifetimes. Choosing the best domestic electrical generator should ultimately be dependent on location and economics. Both microwind and solar PV can deliver high greenhouse gas emissions savings. Biomass boiler CPBTs appear highly sensitive to delivery distances, but since the payback time is so short, even long transport distances would not compromise the ability of a biomass system to pay back embodied CO_2. The long EPBT for solar PV is due to the energy required to process the silicon, which has become more necessary as supplies of silicon from the electronics industry are increasingly scarce, although this constraint should be lifted in coming years.

Chapter 2:

Developing a model for analysis of the long-term potential

This report has been compiled using a sophisticated modelling tool that has been designed as an aid to policy makers. We cannot predict the future – amongst many other uncertainties, technologies may stagnate or new technologies may appear; other technologies may advance more quickly than predicted; oil prices may go in an unexpected direction. The one certainty is that the future will not look exactly as predicted here; but the model does give an indication of what is required to establish mass markets for different types of technology, 'orders of magnitude' of action required and which actions are likely to have more impact than others. It can also analyse whether the technologies we have today are sufficiently attractive to consumers in order to achieve a mass market in microgeneration.

A brief summary of the modelling methodology is included at Appendix 2 with a full methodology report on the Energy Saving Trust website[35].

This model extends the previous study, 'Potential for Microgeneration: Study and Analysis' published by DTI in 2005[36]. The main difference between the two studies is the increased resolution in the modelling of consumer behaviour, which has been achieved by analysing consumer choice when purchasing new technology. This allows a complete model of all technologies (including conventional heating systems) in front of the consumer at the point of purchase and hence all technologies compete for market share.

Whereas almost all homes currently require heating of some form, PV, wind or solar thermal are not required for a building to function, so are installed on a discretionary basis, like any other household purchase such as a conservatory or a plasma-screen TV. As discretionary and 'essential' purchases represent very distinct consumer choices which result in different buying behaviour, two parallel models are created – one for technologies replacing the main heating system and one for discretionary purchases.

The heating technologies considered in this study include condensing boilers, fuel cell CHP, Stirling engine CHP, biomass, ground source heat pumps, air source heat pumps, as well as conventional gas, oil and liquid petroleum gas (LPG) boilers and pure electric heating. Assumptions about the characteristics of these technologies can be found in Appendix 3.

The consumer model has been run to 2050, using a peer-reviewed dataset of the likely development of the microgeneration technologies available. Further details on the assumptions and the peer review process can be found in the appendices of this report and in the full methodology report[37].

The model selects which technologies are worth considering for each household by defining how they apply to house type and location. It then considers how well they match consumer priorities, and – when multiplied by the number of each type of household making the decision each year – how many consumers might purchase each technology. By varying assumptions about the policies to support microgeneration and hence changing the characteristics of the purchase decision, it is possible to explore a range of policy options.

35 http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1122
36 http://www.energysavingtrust.org.uk/download.cfm?p=4&pid=872
37 http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1122

How is consumer behaviour modelled?

This model is designed to consider the likely behaviour of the mass market with respect to new microgeneration technologies.

How do consumers choose which heating systems to install? Why do some consumers choose to install measures that are unlikely to pay back in their lifetime? The answers to these questions are fundamental to predicting the future uptake of microgeneration, but they are largely unknown. There is a paucity of data on consumer priorities relating to microgeneration – any data tends to be from early adopters. Reliable sales numbers for different types of consumer are not available, although consultations with industry experts and publications provide estimates of the overall sales of each technology. Since overall sales are low, errors in historic data are more significant than, for example, in the case of heating systems.

For these technologies to make a significant contribution to a lowering of CO_2 emissions from the UK domestic sector, they must be adopted by millions of households. How the priorities of the early adopters of PV, wind and solar thermal differ from those of the mass market is unclear at present. Clearly, the mass market is more focussed on cost saving rather than an interest in new technologies per se or on the environment or self-sufficiency. So simply calibrating the model using historic uptake data is insufficient.

To overcome the lack of quantitative data on consumers, a number of sources have been used to quantify likely consumer behaviour:

- past behaviour from 1995 to 2005 with respect to condensing boilers and other heating technologies is used to calibrate the heating model. Consumer coefficients have been calibrated for heating technologies using historic data on the uptake of condensing gas boilers, the split between oil, electric and LPG heating, and consumer behaviour when installing loft or cavity wall insulation[38].
- the very limited historic uptake of discretionary technologies is also used.
- observations from previous large scale roll-outs of energy efficiency appliances, which suggest consumers have very high discount rates (up to 20 per cent) and evaluate decisions over short discount periods.
- calibration of coefficients from parameters such as ‘value of time’.

These analyses lead to a definition of coefficients representing consumer behaviour and a model which correctly reflects past technology choices by consumers. However, it is important to recognise that the coefficients used in the model are based on significant assumptions about the behaviour of consumers and the model results should be interpreted accordingly. A consumer survey to support these assumptions is a priority for future research. This research is now being

38 See Oxera, 2006, Policies for energy efficiency in the UK household sector: report prepared for Defra

undertaken by a consortium including the Department for Business Enterprise and Regulatory Reform (BERR) and the Energy Saving Trust and should report by Spring 2008[39]. These results will help refine the model inputs used in this work.

The model assigns different coefficients to reflect different consumer priorities for the following attributes:

- up-front cost (for device and installation)
- ongoing fuel cost (£/kWh demand – scaled according to heating demand of consumer)
- offset electricity savings (£/kWh offset electricity – the attribute is scaled for each consumer according to annual output)
- exported electricity savings (£/kWh exported electricity – the attribute is scaled for each consumer according to annual output)
- annual maintenance charges
- (un)familiarity of technology
- CO_2 emissions (relevant for specific policies that place a value on £/t CO_2)
- space required
- consumer time required

With consumer behaviour simulated based on these assumptions, there is very limited microgeneration uptake in our reference scenario. Past behaviour suggests that left to their own devices, consumers will assess energy efficient appliances with high effective discount rates and short lifetimes. This behaviour strongly discourages microgeneration uptake, as microgeneration economics are dominated by capital costs, which can only be paid back by their savings over long periods.

39 See details of project at: http://www.berr.gov.uk/energy/sources/sustainable/microgeneration/research/page38208.html

Chapter 3:
Results of the modelling

What will happen with no intervention?

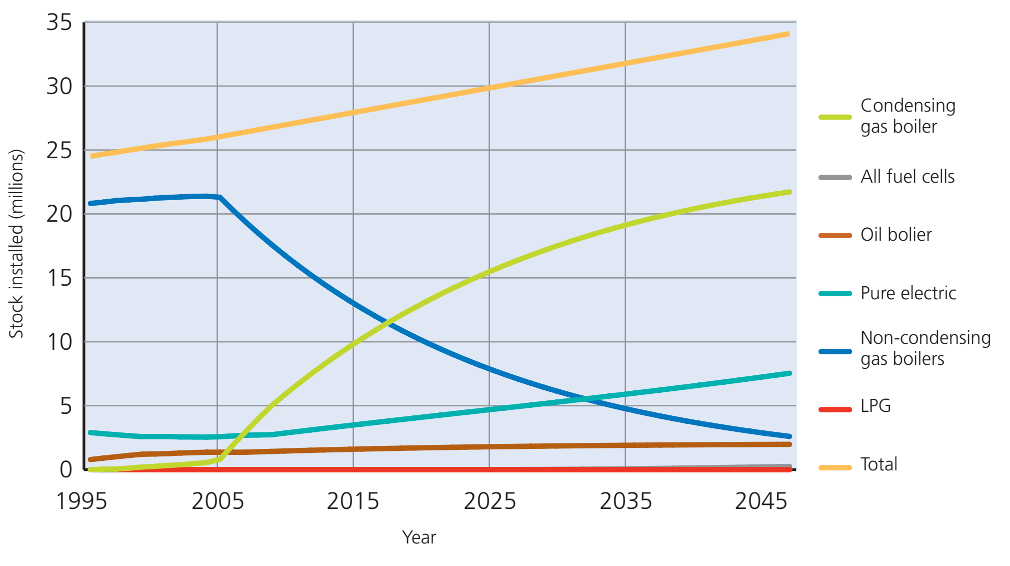
The model has been run using a reference scenario which assumes no further policy intervention beyond 2005 building regulations and no further subsidy beyond the current Low Carbon Buildings Programme[40] (and devolved administration support programmes). The results of this modelling show that without any further intervention, microgeneration technologies are likely to play a very limited role in the UK energy mix to 2050.

Heating technologies

The biggest change to the overall stock on a business-as-usual scenario is the replacement of non-condensing boilers with condensing boilers. What is interesting from this graph is the length of time taken for the stock to change. Even with regulation – the most dramatic policy intervention and in this case the current regulation in England and Wales to require boilers above 90.7 per cent efficiency[41] (essentially condensing boilers) – it is around 2020 before there are more condensing boilers in the UK housing stock than non-condensing boilers.

This gives a clear indication of the scale of policy intervention required to encourage a change in this market.

Figure 2: Total heating stock installed to 2050 under reference scenario[42]



40 http://www.lowcarbonbuildings.org.uk/home/

41 In Scotland, the requirement is 86 per cent

42 NB. Uptake of air source and ground source heat pumps and biomass is too low to show on the graph

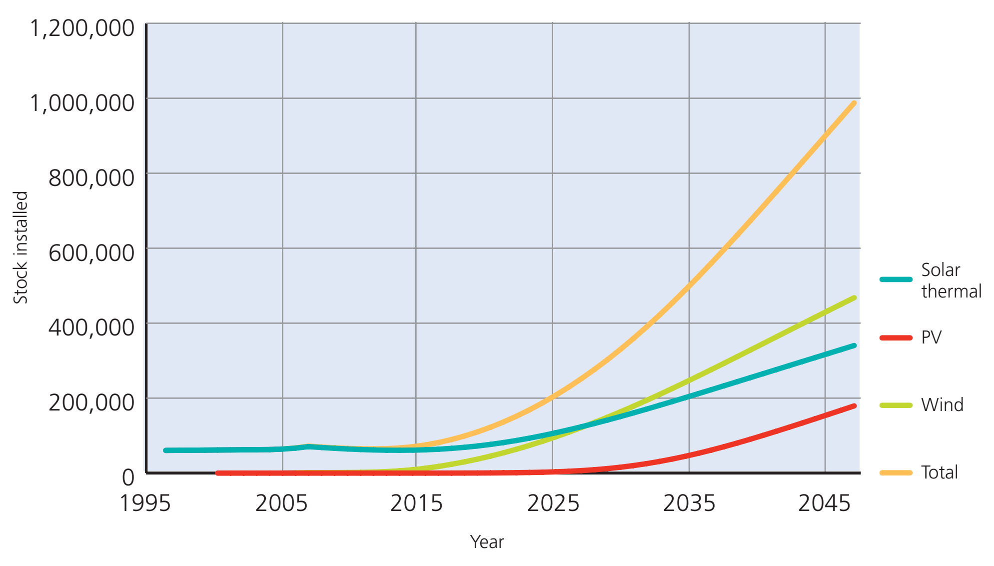
Uptake rates of microCHP and other low-carbon heating technologies are too small to lead to significant penetration of the domestic housing stock[43]. Without supportive intervention, the heating demand in 2050 will instead be met mostly by condensing gas boilers, followed by oil and electric systems.

However a minority of consumers are predicted to purchase fuel cell CHP units, particularly after 2030. Under this scenario, the cumulative generating capacity of these units is predicted to be 245 MW in 2050 – the size of a typical power station, producing 1.3 TWh electricity per year.

With no further intervention, the total CO_2 output from primary heating technologies in the domestic sector is predicted to be 160 Mt CO_2/year in 2050. There is little change from 2007, because modest improvements due to improved boiler efficiencies and lower energy requirements of new housing will be offset by the growth in overall stock.

Discretionary technologies

Figure 3: Total stock of discretionary measures installed to 2050 under scenario with no urban wind



43 modelled at circa 34m million homes in 2050, with a total heating demand of 581 TWh.

Under the reference scenario, the discretionary technologies – PV, wind and solar thermal – each present a 'net disutility' to consumers in the early years, because the ongoing energy generated does not repay upfront and maintenance costs (using the assumptions on consumer discount rates and technology costs). So the vast majority of consumers choose not to purchase.

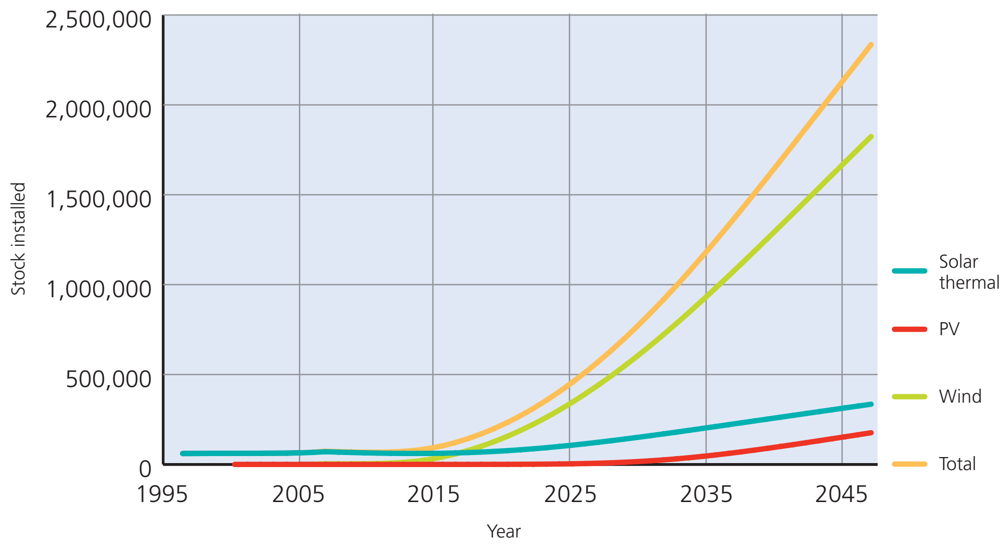
The uptake of microgeneration resulting from cost reduction is likely to begin after 2015. And by 2050, almost 500,000 homes are predicted to install wind, 200,000 PV, and 350,000 solar thermal, with the majority of all installations taking place in the later years. This baseline scenario predicts the CO_2 saving from the installation of discretionary microgeneration to be 0.6 Mt CO_2/year by 2050, largely coming from rural micro-wind.

Since solar thermal mainly offsets heating by gas, this technology contributes only a small amount to avoided CO_2. Although solar thermal has historically been the most popular technology with householders, the model predicts that microwind will be the most popular in the medium and long-term, assuming it develops as anticipated. However, the scenario above assumes that wind technology does not perform well in urban locations and is not installed in these situations. The Energy Saving Trust is currently conducting field trials to verify the actual performance in consumers' homes.

If microwind turbines do perform well in urban areas, then the potential is much higher. The graph below shows the results when we have assumed that a 1kW system will produce around 876 kWh per year (i.e. a 10 per cent loading) on urban sites.

In this case, by 2050, up to 1.8 million homes are predicted to install wind. PV and solar thermal installations are predicted to be slightly lower in this case – 160,000 and 300,000 respectively, as wind turbines would be competing for market share. In this case, the total represents approximately 7 per cent of the households and corresponds to a generating capacity of over 2 TWh/year by 2050, i.e. the output of one or two large power stations. This scenario predicts the CO_2 saving from the installation of discretionary microgeneration to be 1.25 Mt CO_2/year by 2050.

Figure 4: Total stock of discretionary measures installed to 2050 with urban wind allowed



Summary of reference scenario

There is substantially higher potential for CO_2 saving in this reference scenario. But without support, the market for both heating technologies and for domestic wind, PV and solar thermal will not lead to significant CO_2 savings. Carbon savings are delayed well into the future. Therefore the baseline of no support represents a wasted opportunity for the household sector to contribute to reducing UK CO_2 emissions and, on the basis of Stern's view[44] of investment in carbon saving outweighing the costs, intervention appears warranted.

44 Cabinet Office op. cit.

Policy options

This section looks at different types of option available to policy-makers, under the following sections:

- Regulation
  - Requiring a microgeneration technology at point of heating system replacement
  - Requiring a discretionary technology at point of roof replacement
  - Requiring a microgeneration technology at point of house sale
- Carbon pricing
  - Carbon tax
  - Consumers valuing carbon
- Changing consumer decision making
  - Alternative models of purchase (Energy Service Companies[45] (ESCOs), leasing, soft loans)
  - Education/publicity/culture change
  - Energy Performance Certificates
- Subsidy
  - Renewables Obligation Certificates
  - kWh subsidies (feed-in tariffs, export tariffs)
  - CERT/Microgeneration Obligation
  - Tax breaks (council tax reduction, stamp duty, income tax reductions)
  - Grants
- Technological development
  - Research and development
  - Field trials
- Fossil fuel price changes

Regulation

Regulation for new buildings

The model suggests that it is possible to make substantial CO_2 savings by compelling all new buildings to have some form of microgeneration technology for the heating system. This could be achieved by building regulations or mandatory renewables measures enforced by local authorities. Savings of around 2 per cent CO_2 are available by 2020 and 5 per cent by 2050.

Interestingly, compulsion on new build does not increase the total microgeneration stock in a linear fashion to 2050. This is because when a consumer comes to replace the technology on their new building after its useful life, they retain the option of making no purchase (i.e. not replacing their microgeneration unit) or replacing the heating system with a conventional one. By the time consumers come to decide about microgeneration replacement, the model predicts that in the majority of cases, microgeneration options are less attractive to consumers than conventional technologies or no purchase. As a result, with no further support, most ‘new build’ consumers will choose not to replace their microgeneration technology at the end of its life, leading to only a slow increase in the microgeneration stock. This does assume that consumer attitudes have not changed during this period and that Energy Performance Certificates[46] (EPCs) have no impact.

Compulsion linked to other events in a building’s life

The penetration of microgeneration can be increased well above that of the new build-based policies by linking a microgeneration purchase to ‘trigger events’ in the life of a house. In the boiler model, this could mean compelling a microgeneration technology on replacement of the existing heating system. Banning conventional and condensing gas, oil, LPG and electric boilers from 2008 could lead to over 11 million lower-carbon heating systems

45 ESCO is used in the loosest sense – the energy supplier or third party owns the equipment installed but ownership may transfer at the end of a specified period, the owner may or may not be responsible for maintenance and the savings may be entirely with the owner or the householder, or shared.

46 Energy Performance Certificates tell you how energy efficient a home is on a scale of A-G. The most efficient homes – which should have the lowest fuel bills – are in band A. Better-rated homes should have less impact through carbon dioxide (CO_2) emissions. See http://www.homeinformationpacks.gov.uk/consumer/17_Energy_Performance_Certificate.html

installed by 2020, mostly Stirling CHP. This regulatory requirement could lead to savings of 29 Mt CO_2/year (20 per cent) by 2020 and 62 Mt CO_2/year (40 per cent) by 2050. It is unlikely to be politically acceptable to impose the current cost of microgeneration technologies on householders at the moment. But, as has happened with condensing boilers, once the cost approaches that of conventional boilers, this may be a real option for future years.

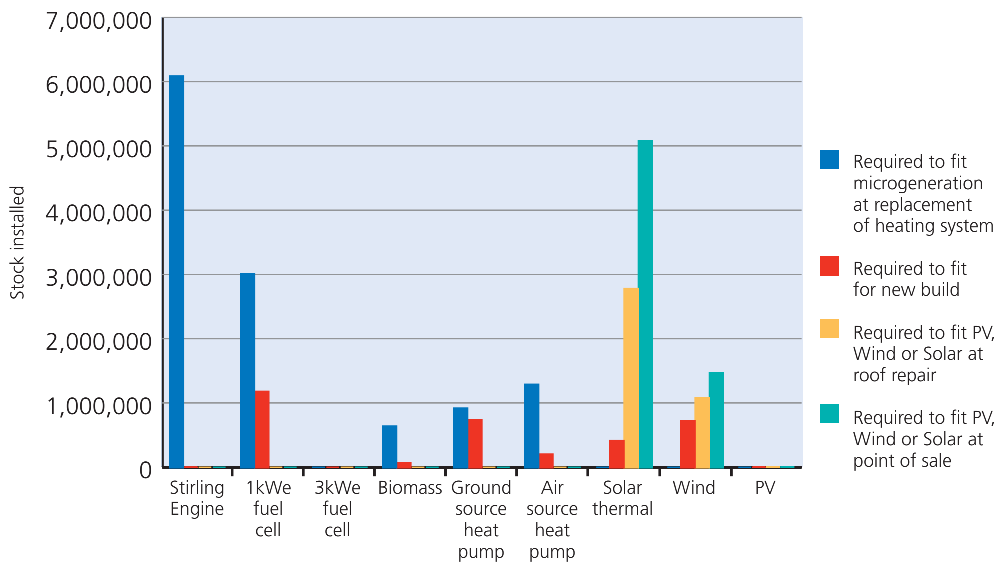
In 'discretionary' purchases, a trigger related to re-roofing or a house sale could also be an effective measure for increasing installations. Again, there is a question about how cost-effective and/or carbon-efficient a technology must be before a consumer is compelled to buy it. With a plan that looks 20+ years ahead, industry would be able to prepare for this.

Innovative policies to compel existing home owners to install microgeneration technologies at such trigger points will save more carbon than policies for new-builds only. Mandating the installation of a microgeneration technology whenever a property is re-roofed will lead to the uptake of nearly 4 million units of solar thermal, wind and PV combined by 2020; and 13.5 million units by 2050. This will save 1.9 and 7 Mt CO_2/year by 2020 and 2050 respectively.

Compelling the installation of either wind, PV or solar thermal at point of sale of a house is even more attractive. The model predicts 6.6 million additional units by 2020 and 20.6 million by 2050, with CO_2 savings of over 3.2 Mt CO_2/year by 2020 and 10.5 Mt CO_2/year by 2050.

Showing results for 2020, the graph below illustrates the effectiveness of policy measures that apply to all building stock, rather than just new build. Looking ahead to 2050, compulsion during roof repair or at house

Figure 5: Microgeneration technologies installed by 2020 under regulatory scenarios



sale could lead to the majority of homes having at least one measure installed by 2050.

The graphs below show the impact of the assumptions made on urban wind. Without urban wind, the dominant discretionary technology in 2020 is solar thermal, reaching almost 5 million units (where one technology is required at point of sale) whilst wind sells just 1 million units. With urban wind, these figures are pretty much reversed.

Figure 6: Discretionary technologies installed by 2020 under regulatory scenarios with urban wind allowed

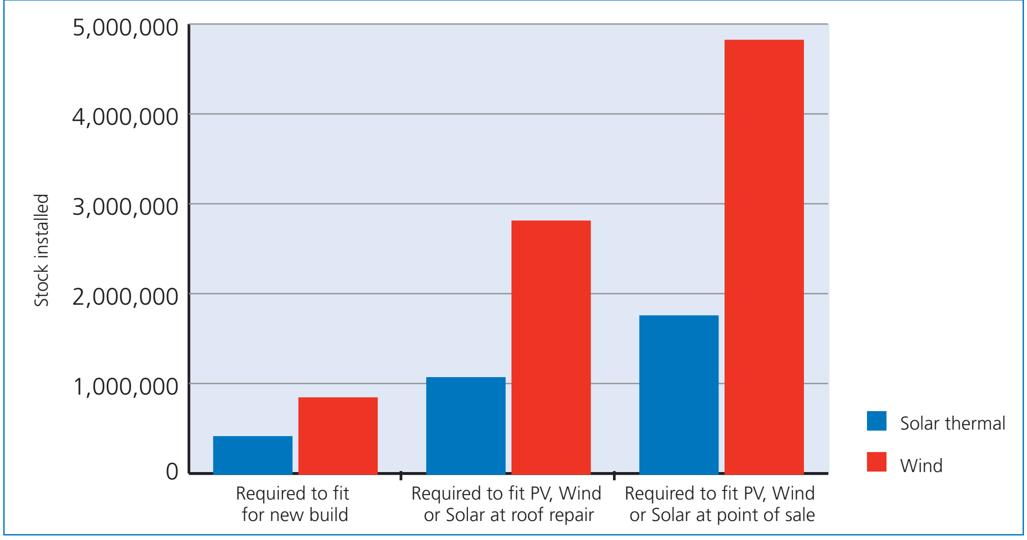
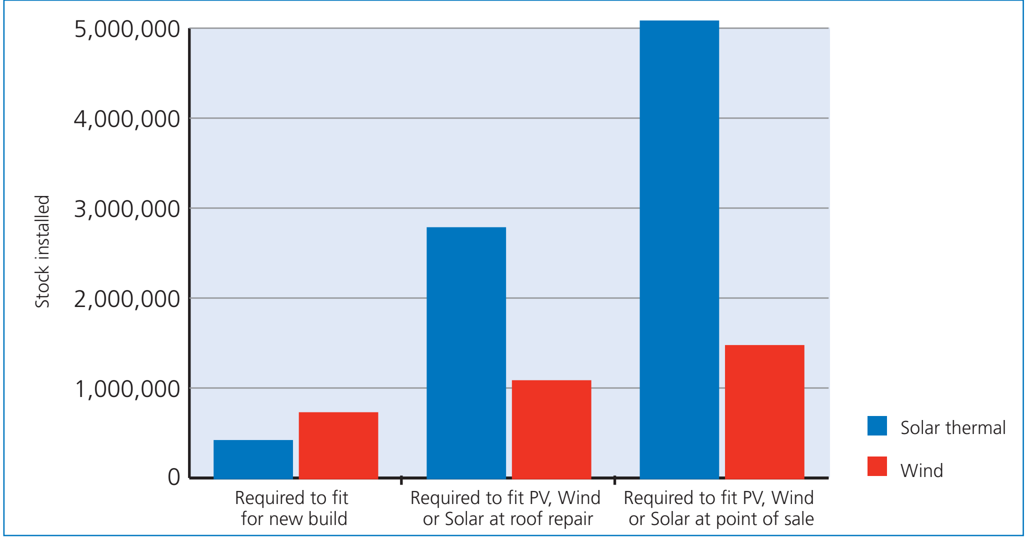


Figure 7: Discretionary technologies installed by 2020 under regulatory scenarios with urban wind disallowed



By 2020, PV does not represent an attractive choice for consumers when faced with the choice of one of the discretionary technologies, even with no urban wind as a scenario. But by 2050, significant numbers of consumers are predicted to buy PV – 1.3 million units are installed where there is compulsion at house sale; and 0.9 million where there is compulsion during roof repair. However, if no urban wind technology is assumed to be available, this increases to 4.8 million PV units at house sale and 3.2 million at roof repair.

Placing a value on carbon

Valuing carbon is a policy being promoted by a number of environmental organisations and one which is under consideration in Government policy making. Stern valued the social cost of carbon around the order of \$85/tonne CO_2[47] (approx £43/t CO_2), a Defra/Treasury report in 2002[48] valued carbon at £70/tC within a range of £35-£140 (approx £10-38/t CO_2). Our recent consumer research estimates that the amount people are willing to pay to reduce emissions by 25 per cent (approx 1 tonne CO_2) is around £23/tonne CO_2[49].

The model has been run for various consumer values for CO_2, ranging from just over today's market value (2008 contract is currently €21.50/tonne C) to a significantly larger £2000/tonne of CO_2, without pre-judging what might be acceptable levels. The model treats an actual carbon value (e.g. a carbon tax of £100 per tonne of carbon) in exactly the same way as if people intrinsically gave carbon a value (e.g. if they were willing to pay £100 in order to avoid emitting a tonne of carbon).

The results suggest that a CO_2 value of £200/tonne would be sufficient to stimulate considerable biomass boiler uptake by 2020 (1.5 million units installed) and significant 1 kWe fuel cell uptake by 2050 (>9.6 million FC units and 4 million biomass boilers). CO_2 savings of 12 per cent of total domestic CO_2 by 2020 and 36 per cent by 2050 are possible.

The £200t/ CO_2 level would lead to 1.5 million installations of PV by 2050, almost 3/4 million solar thermal installations and 2 million wind installations. (This assumes no urban wind. If it is allowed in the model, this would increase to 5.6 million wind installations.)

This illustrates well the carbon-saving potential of discretionary microgeneration technologies. There could be large CO_2 savings from the uptake of micro-wind and PV by 2050 (3Mt CO_2 at £200/t CO_2 or 15 MtCO_2 at £500/t CO_2 (4.5Mt CO_2 and 18Mt CO_2 respectively where urban wind is allowed in the model), but at current price projections it would be necessary to increase society's value of CO_2 (by education or a change in culture for example) in order for these technologies to be installed through consumer choice alone.

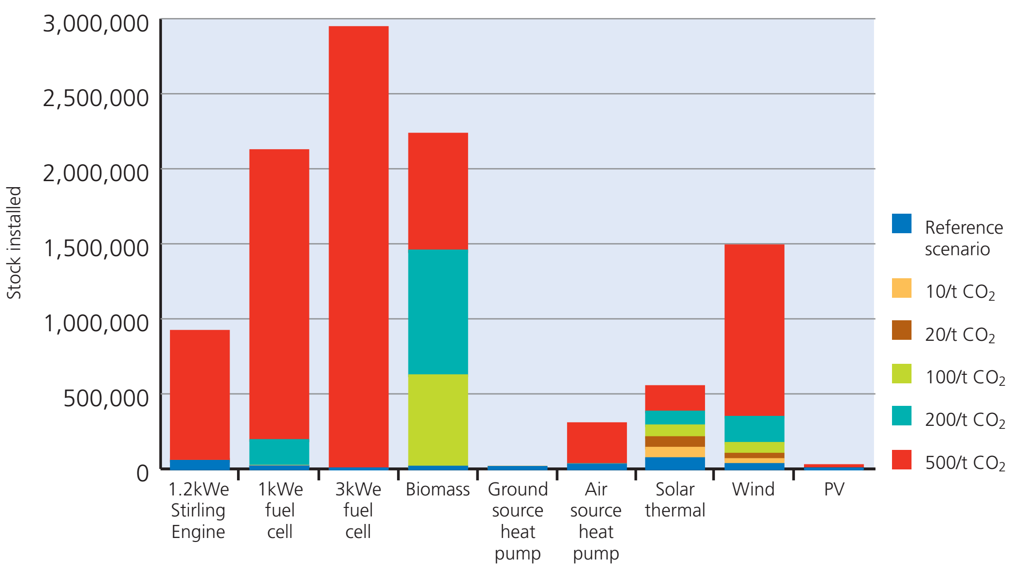
By 2020, a sustained value of £500/t avoided leads to 30 per cent of all dwellings installing microgeneration and by 2050, an average household would have 1.3 technologies installed. At this price, the model suggests consumers will favour the 3 kWe fuel cell option, which is oversized for their own electricity demand, but is valuable for its lower carbon electrical output.

47 Cabinet Office op. cit.

48 Defra and Treasury, 2002, Government Economic Service working paper 'Estimating the Social Cost of Carbon Emissions'.

49 Using a conjoint analysis, consumers were asked to choose between different heating systems with different characteristics. From this the figure of £83/tonne of carbon (£23/CO_2) was derived.

Figure 8: Technologies installed by 2020 under various carbon value scenarios



Changing consumer decision-making

If the government is to stimulate the uptake of microgeneration technologies successfully, it must first help consumers to evaluate the economics of them and, if necessary, change the economics of the purchasing decision. There are three mechanisms identified for this:

- **Alternative models of purchasing**, for example where Energy Services Companies (ESCOs) or leasing companies own and operate the microgeneration equipment and provide a commercial return to the consumer. Two alternatives are considered. A standard ESCO arrangement is simulated as an 8-year discount period, with a 12 per cent interest rate. Alternatively a benevolent ESCO with a lower rate (5 per cent) and longer payback (10 years). Soft loans – loans with a longer life than commercial loans – on the purchase of microgeneration technologies are the other possibility. These were used successfully to support photovoltaics in Germany, where soft loans were a key component in early uptake. This is modelled using a loan with an interest rate of 3 per cent over 5 years.
- **Education/publicity/culture change –** aimed at educating consumers about the economic benefits of microgeneration and the need to look at the economics over the long term. The effect of any publicity campaign is very difficult to quantify, but is represented in the model as a lengthening of the discount period (to 20 years) and a reduction in the discount rate to 5 per cent. Consumers

could be prompted to make more frequent decisions about microgeneration with more marketing, for example mailshots, advertising campaigns, campaigns by utilities with each electricity bill, or through a general culture change. The Oxera 2005 study into energy efficiency measures[50] suggests that a reason for the success of the Energy Efficiency Commitment has been the direct consumer access enjoyed by the utilities responsible for implementing EEC. This gives them a channel to increase decision-making frequency through marketing activities.

- **Energy Performance Certificates (EPCs)**

Figure 9 shows the results of interventions to affect consumer decision-making – represented in the model by varying the consumer discount rate and periods.

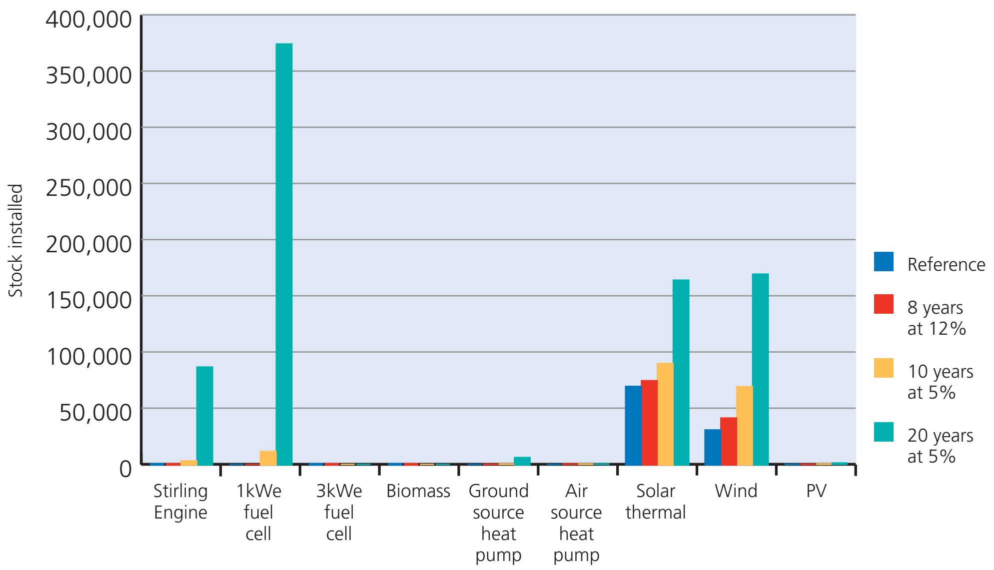
With an ESCO model for ownership, the boiler model suggests a substantial uptake of microgeneration technologies, dominated by fuel cells. This could lead to a significant additional CO_2 saving of up to 14 per cent of domestic heating CO_2 emissions by 2050. In the discretionary model, the effect of improved consumer economics is much smaller, as the technologies are further from being economic at ESCO rates. This suggests policy efforts to promote the ESCO model should first be focussed on the microCHP market.

Adopting ESCO models for purchasing heating is insufficient to make any impact by 2020. Only with a significant change amongst consumers is there any significant uptake. If the market changes to become dominated by forward-looking consumers (represented by 20 year discount period and 5 per cent discount rate), annual CO_2 savings of over 23 per cent are possible by 2050 without subsidies or other interventions. So encouraging consumers to switch from short- to long-sighted behaviour is clearly important. However, only when market behaviour is radically altered will high uptake rates be possible in the short term. A radical change to the domestic primary heating system market, equivalent either to a scenario of forward-looking consumers, or where capital can be provided at Government discount rates (e.g. 5 per cent at 20 years) would encourage mass adoption of fuel cells.

Figure 9 shows the results for the various discount rate scenarios for 2020, covering ESCOs, benevolent ESCOs, soft loans and consumer behaviour change. This graph assumes no urban wind. With urban wind, the predicted uptake by 2020 rises from 170,000 installations to 335,000. There is little impact on the other discretionary technologies in this case.

50 Oxera, op. cit

Figure 9: Technologies installed by 2020 under various discount rates and discount periods



Energy Performance Certificates

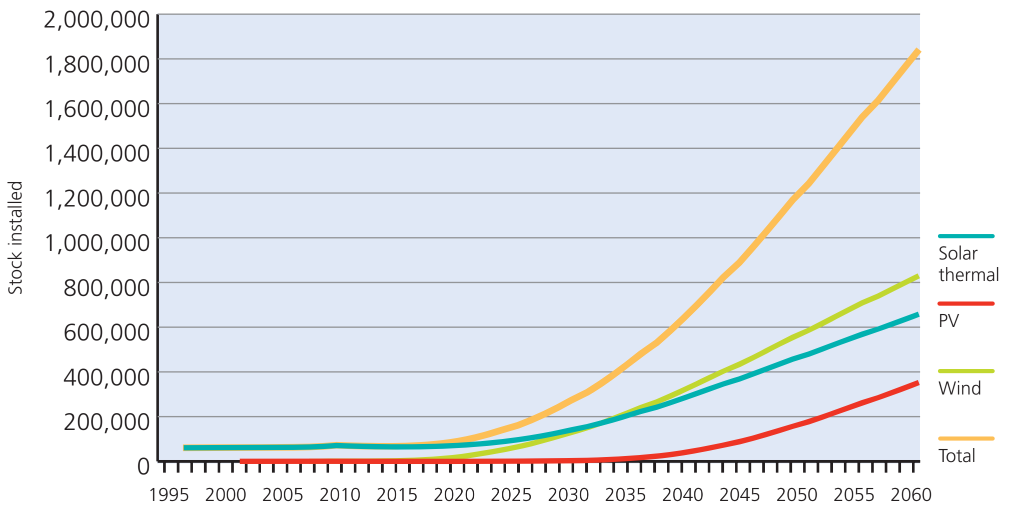
Energy Performance Certificates (EPCs) are represented in this model by an increase in consumer decision-making frequency for discretionary technologies from once every 13 years[51] to once every 7 years.

Results show a significant uptake of discretionary technologies from this increase in decision-making frequency to over 1.8 million units by 2050. This suggests that getting consumers to think about these technologies more often is very important.

A compulsory element of EPCs could also be modelled – see regulatory scenarios where a microgeneration technology is required at the point of house sale (Figure 5: Microgeneration technologies installed by 2020 under regulatory scenarios).

51 The rate at which a consumer considers the purchase of a discretionary technology could be increased by increasing the frequency of marketing either through mailshots or advertising campaigns, for example. The Oxera 2005 study (see footnote 38) into energy efficiency measures suggests that a reason for the success of EEC has been the direct access of the utilities to consumers and their ability to increase decision making frequency. A reference value of 13 years has been adapted from insulation uptake data.

Figure 10: Impact of EPCs on uptake of discretionary technologies



Subsidies

What level of support is required?

When considering different support options, the issue of support should be separated from the question of how the support is delivered. For example, 'feed-in tariffs' (paying consumers for the power they generate) are often quoted as being the most effective form of subsidy, because of superior results in countries such as Germany where they have been applied. However, the value of subsidy in those countries is also significantly higher. It is not clear whether the higher uptake is due to the extra value of support, the mechanism itself (e.g. more secure rates of return for investors), or other factors altogether (e.g. the planning regime).

Post 2011, it is likely that a Suppliers' Obligation would provide significant support for microgeneration. Beyond that, carbon pricing is likely to play a major part. However, for the period following current grant support, there will be a lack of financial support. General consensus appears to be that CERT (carbon emissions reduction target scheme) will not provide the support required to underpin the microgeneration industry, because the value of the incentive itself and the fact that most investment over the next few years is likely to continue to go into energy-efficiency measures.

A number of different subsidy options have been considered in our modelling:

- Grant support
  - Expressed as a percentage of capital cost – implying that the size of the subsidy decreases with the cost of the technology. Options of 20 per cent, 30 per cent and 50 per cent are considered, together with the option of capping the total subsidy at various levels. Two scenarios have been modelled – one that offers grant support for all microgeneration technologies, and one for renewables only (i.e. excludes gas-based CHP).
- kWh subsidies
  - Renewable obligation certificates (ROCs)
  - Feed-in tariff (on all generated electricity)
  - Export tariff (on exported electricity only)
- CERT, or a separate obligation on energy suppliers for microgeneration, operating in a similar manner to CERT
- Tax breaks or some other form of fiscal incentive (council tax or stamp duty related for example)

Grant support (capital subsidies)

To date, grants have tended to be government's favoured measure for stimulating the microgeneration sector. Currently support is extended to microgeneration technologies through the UK's Low Carbon Buildings Programme (LCBP), the Scottish Community and Householder Renewables Initiative (SCHRI) and Northern Ireland's Environment and Renewable Energy Fund (EREF).

However, the most significant conclusion from subsidy modelling is that with the assumptions about consumer behaviour and predicted technology developments, subsidies have a limited effect on the market if they are limited in their total scope (i.e. have a funding cap).

Also, a poorly designed scheme (e.g. a blanket subsidy at 50 per cent of capital cost, with a £100 million cap) promotes technologies with lower immediate capital cost (Stirling engines) but which may have limited long term potential, compared to, for example, fuel cells. In this example, the grant is exhausted before fuel cells are able to achieve their potential. And as long as there is a subsidy cap, penetration will always be limited. Consumers become dependent on the subsidy and do not continue to adopt the technology once the grant is removed.

A limited subsidy scheme's main value is in helping to commercialise technologies which would not otherwise reach the market at reasonable costs. In order to provide maximum benefit, support of this type needs to be carefully targeted at promising technologies. It should avoid subsidising technologies which are currently cheaper but have limited long-term potential for cost reduction and market penetration. It may be better to encourage commercialisation through policies which will support the long-term uptake of microgeneration (thereby encouraging private investment) rather than the limited, short- term uptake offered by a subsidy scheme.

For a subsidy scheme to be effective the total cap must be very large, well over £1 billion: this is the same order of support which has gone into PV in Germany.

An effectively uncapped subsidy offers significant potential for uptake of microgeneration. With an uncapped subsidy at 50 per cent of the capital cost of boiler-replacement microgeneration, the uptake of fuel cell and Stirling CHP systems and ground source Heat Pumps could exceed 8 million by 2020. Air source heat pumps and biomass boilers would also benefit, with over 200,000 of each installed by 2020. Annual CO_2 savings of over 10 per cent of domestic heating emissions (20 Mt CO_2/year) would be available with an uncapped 50 per cent subsidy to 2020. This is primarily from CHP penetration. However, the cost of such an uncapped subsidy is very large (cumulative cost of the 50 per cent cap by 2020 is £28.1 billion) and potentially unpalatable. This type of scheme over-rewards the most cost-effective technologies, because it applies a blunt percentage subsidy to all technologies. It may be considered that only renewable technologies should be eligible for such a grant.

Figure 11: Subsidy scenarios for heating technologies – numbers of installations in 2020. All subsidies capped at £200m total

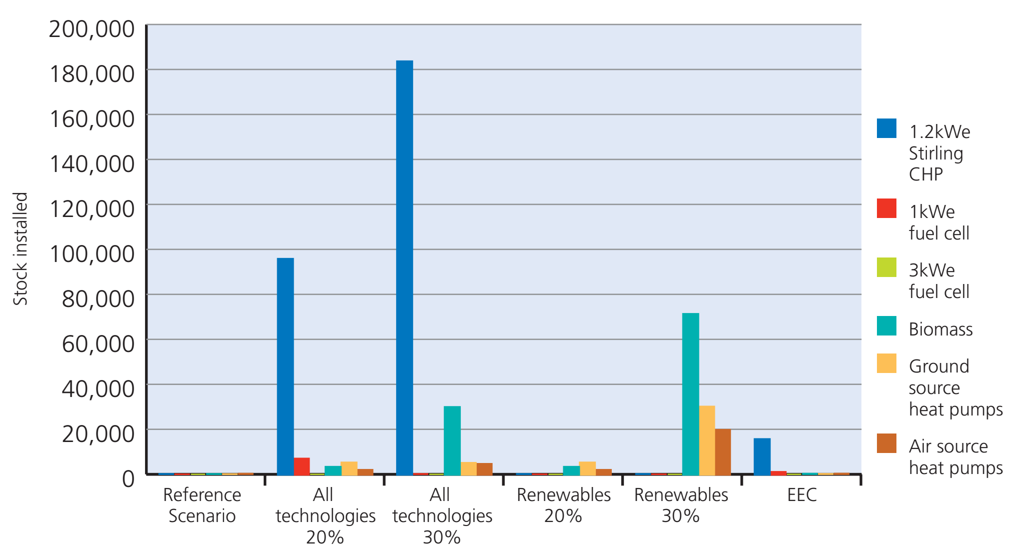


Figure 12: Subsidy scenarios for heating technologies – numbers of installations in 2050

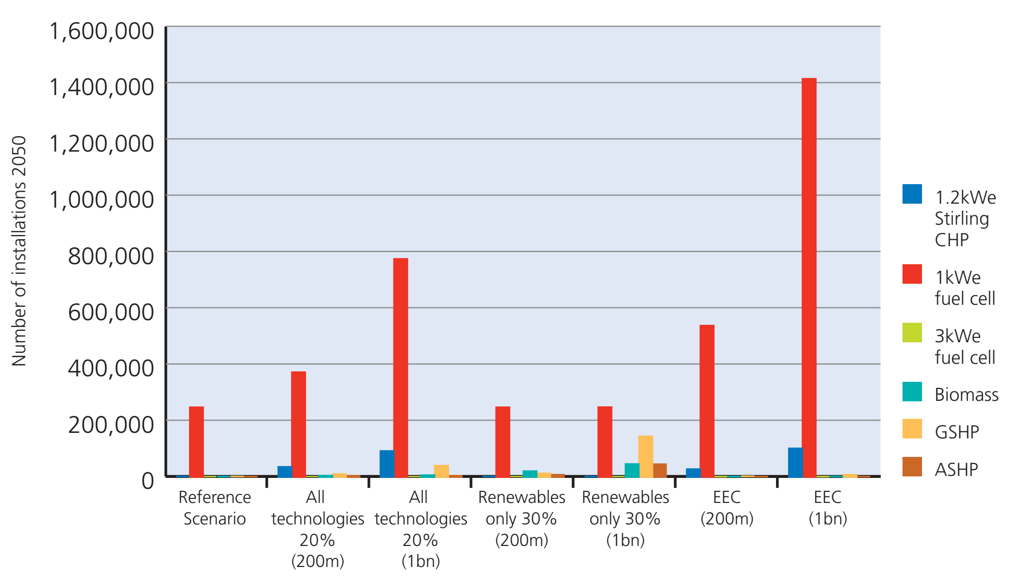
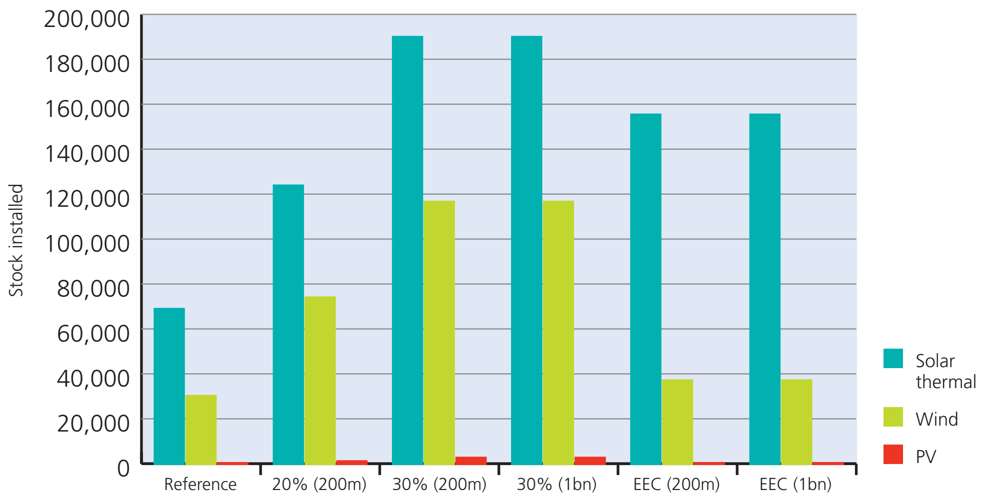


Figure 11 shows various grant scenarios, all with a total cap of £200 million. Scenarios were run at a cap of £1 billion as well, but for the renewables-only case no further uptake was seen, because the limit of uptake was already reached – i.e. the limiting factor is the number of consumers willing to buy at that cost by 2020, not the total grant money available.

By 2050 (Figure 12) a 20 per cent grant on all technologies only has an impact if there is a cap larger than £200m. Where £1 billion is available, microCHP has a large uptake – almost 800,000 installations in total. At the 20 per cent grant level, there is no further uptake for renewable technologies under a programme which supports renewables only, rather than including microCHP. Again, the limiting factor is the number of people willing to buy, rather than all the money being taken by microCHP. In order to have a significant uptake for renewables, a 30 per cent grant, on renewables only, is required, otherwise the majority of funding is taken up by microCHP technologies. EEC only has an impact on microCHP (at the levels of subsidy currently likely – based on no additional uplift for renewable technologies and the microCHP being eligible under EEC). Current levels of EEC subsidy, even when no subsidy cap is present, are insufficient to stimulate millions of houses to adopt Stirling CHP, biomass, or ground- or air-source heat pumps for their primary heating system.

Figure 13: Subsidy scenarios for discretionary technologies – numbers of installations in 2020

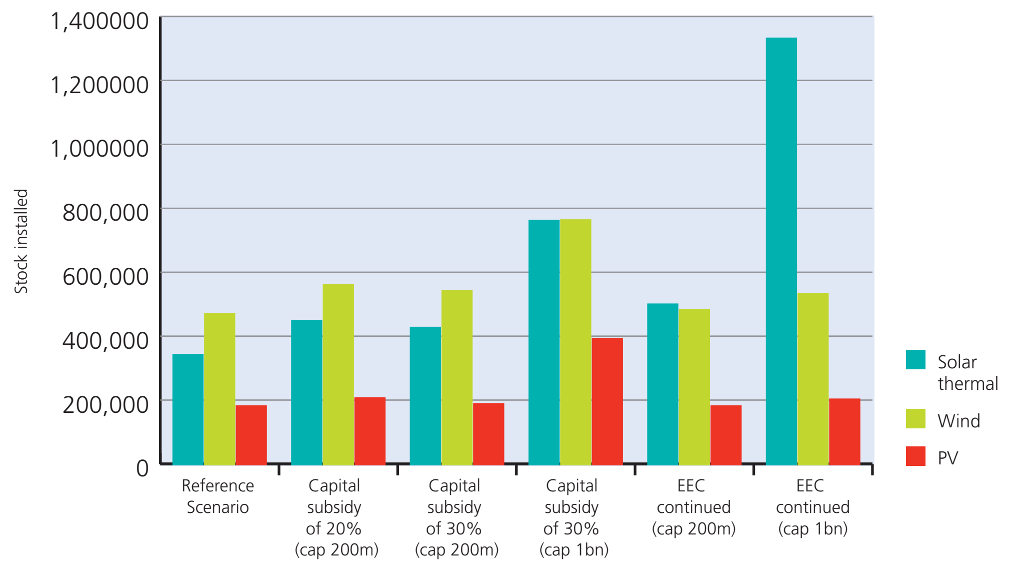


For discretionary technologies a 30 per cent grant encourages both solar thermal and wind by 2020. With a £200m cap, over 180,000 units of solar and almost 120,000 units of wind would be installed by 2020. A much higher cap of £1 billion is not used up, because the limiting factor is the number of consumers willing to buy at that price. EEC grant levels do encourage some uptake, particularly of solar thermal.

By 2050, a larger cap on funding does allow much higher take-up – the model predicts significant take-up with a £1billion cap and 30 per cent grants, including almost 400,000 installations of PV, which is cost-effective by 2050.

These graphs have assumed that microwind is not available in urban situations. However, if the technology does prove itself here, over 4 million installations of microwind could take place with a £1billion cap and 30 per cent grants.

Figure 14: Subsidy scenarios for discretionary technologies – numbers of installations in 2050



EEC/CERT or microgeneration obligation

Subsidies based on the current levels of support available under EEC (and likely under CERT) do show a small increase in the penetration of microgeneration-based boiler replacements, however, the support is not sufficient to increase uptake substantially by 2020, and total penetration is limited to only thousands of units. By 2050, a £1 billion EEC scheme available for all microgeneration technologies would stimulate fuel cell uptake, creating approximately 1.4 million additional units over the base case, costing over £500 million.

For the discretionary technologies, an EEC-type mechanism tends to favour solar thermal technology because of the nature of the support calculations. Significant extra solar thermal uptake can be expected (double by 2020 and up to 5 times more by 2050 if EEC continued in its current form). PV and wind uptake is limited with EEC support.

Of course, the EEC mechanism does not determine the subsidy offered to the consumer on each technology. The energy suppliers themselves determine this according to the carbon credits received for installations. Varying the assumptions made about what might be offered affects the outcome quite dramatically and we have made assumptions about what these levels of subsidy may be. If there was an uplift (i.e. a higher carbon credit) for microgeneration technologies, this would also encourage suppliers to offer higher subsidies.

The 'Illustrative Mix' is an analytical tool used by Defra to explore the implications of various options and to explain the underlying assumptions in setting the overall target and other key elements of the CERT framework. It thus demonstrates the feasibility of achieving the target. Looking at the Illustrative Mix[52] and assuming a continuing level of support at the same level to 2020, the model calculates that the grant amounts need to be, approximately:

- £1300 each for biomass, ground source heat pumps and air source heat pumps.
- £600 for solar thermal
- £700 for PV
- £300 for wind

However, these levels would not result in an even uptake between now and 2020. There would be more installations in the later years, so to reach these levels for the first 3 years would require much higher levels of grant. This has not been modelled, because the model is not designed for short-term predictions. But the grant levels above can be seen as a minimum for achieving the illustrative mix.

Valuing electricity production – kWh subsidies

Increasing the value of electricity generated would support the adoption of electricity-producing technologies in the home.

Exporting surplus power from a small embedded generator is easily done, provided the appropriate regulations are observed. The question is: how much should owners of domestic generation equipment be paid for this? From 2003, it has been possible under the Balancing and Settlement Code[53] for owners of small generators to meter their exports with a simple kWh meter, the same as for the import meter. To tell the supplier when the power was exported, an 'assumed profile' is used. In order for these profiles to be fair, BEAMA have been working on export values for each type of microgenerator[54]. One thing the project has established is that typical microgeneration units export 50-60 per cent of the total electricity generated, because consumption is not concurrent with generation. This shows how vital it is that exported electricity is rewarded fairly, otherwise more than half the value of the electricity generated could be lost to the consumer, significantly damaging the economics of these technologies.

Three options for increasing the value of electricity export are considered.

- Energy Export Equivalence (EEE) – where exported electricity is valued at the same rate as imported electricity
- Subsidy on each unit of electricity generated (often called a 'feed-in' tariff)
- Renewable Obligation Certificates (ROCs)

52 Defra, May 2007, Carbon Emissions Reduction Target April 2008 to March 2011 Consultation Proposals contains the following figures for the Illustrative Mix: Wood burning stoves (secondary) 12,000; Wood chip boilers (primary) 30,000; Photovoltaic panels (2.5 kWp) 2,000; Solar Water Heater (4mÇ) 40,000; mWind (1 kWp, 10 per cent LF) 7,000; Heat pumps 28,000.

53 The Balancing and Settlement Code contains the rules and governance arrangements for electricity balancing and settlement in Great Britain and all licensed electricity companies must sign it. Like most commodities, electricity is produced, sold into a wholesale market and then resold to consumers. Contracts are made for each half hour between Generators who produce the electricity and Suppliers who sell it on to commercial and domestic consumers. These contracts are notified into central systems so that any difference between the amount of electricity contracted for and delivered by Generators or sold on by Suppliers, must be bought or sold through the systems managed by ELEXON. See http://www.elexon.co.uk/AboutElexon/default.aspx

54 http://83.217.99.100/cfide/beamaprj/index.cfm

Figure 15: Number of installations for wind and PV for ROCs and EEE

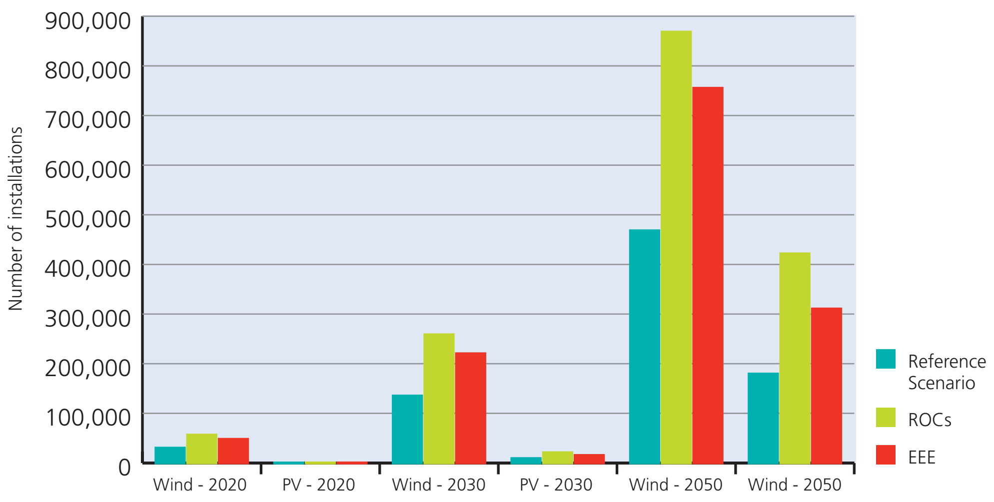


Figure 15 illustrates the modelled number of wind and PV installations under ROC and EEE scenarios.

It shows that uptake by 2020 would be minimal with these low levels of reward (ROCs have been modelled at 4p/kWh electricity generated and EEE at 10p/kWh exported). By 2050, there is some additional uptake – almost double the number of installations than would take place under the reference scenario, but these figures fall well under the potential that could be achieved.

Feed-in tariffs (reward for all electricity generated) have been modelled for all electricity-producing technologies (wind, PV, microCHP) and then separately for just renewable-based technologies (i.e. excluding gas-based microCHP). Figure 16 and Figure 17 show the results for renewable-only feed-in tariffs in 2020 and 2030.

Feed-in tariffs for all the electricity-producing technologies have a limited effect on increasing consumer uptake by 2020, though the effect by 2050 is marked. By 2020, a 10p/kWh feed-in tariff increases fuel cell uptake to 0.9 million installations. By 2050, the same tariff leads to over 13 million installations and CO_2 savings of 31 per cent.

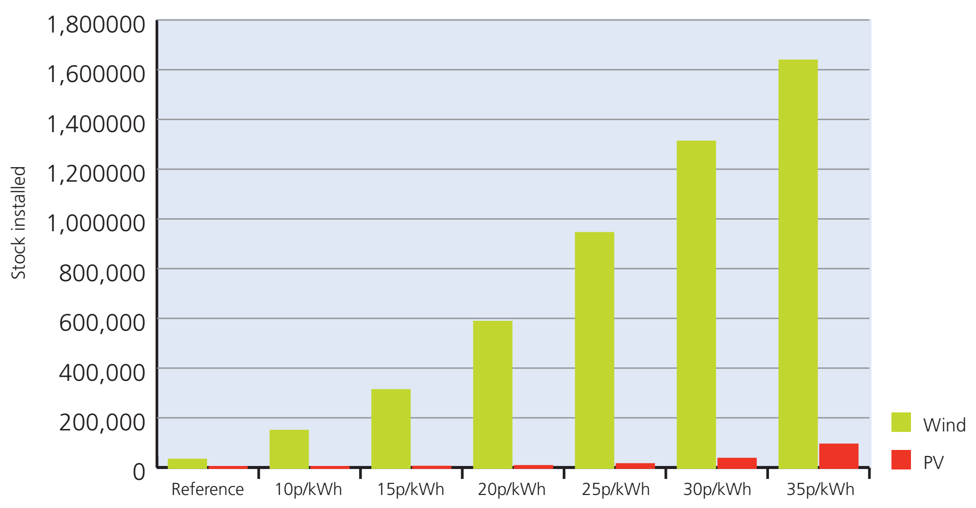
The model shows that a feed-in tariff of 5p/kWh will have encouraged 8.5m houses to install 1kWe fuel cells by 2050, with CO_2 savings of 2.8 per cent.

It is worth noting without additional support for heating measures, a feed-in tariff slows biomass uptake, because it favours electricity-producing technologies.

Feed-in tariffs for just renewable technologies have also been modelled. The banded ROCs[55] suggested by the 2006 Energy Review are one mechanism to introduce a type of feed-in tariff that supports discretionary microgeneration technologies.

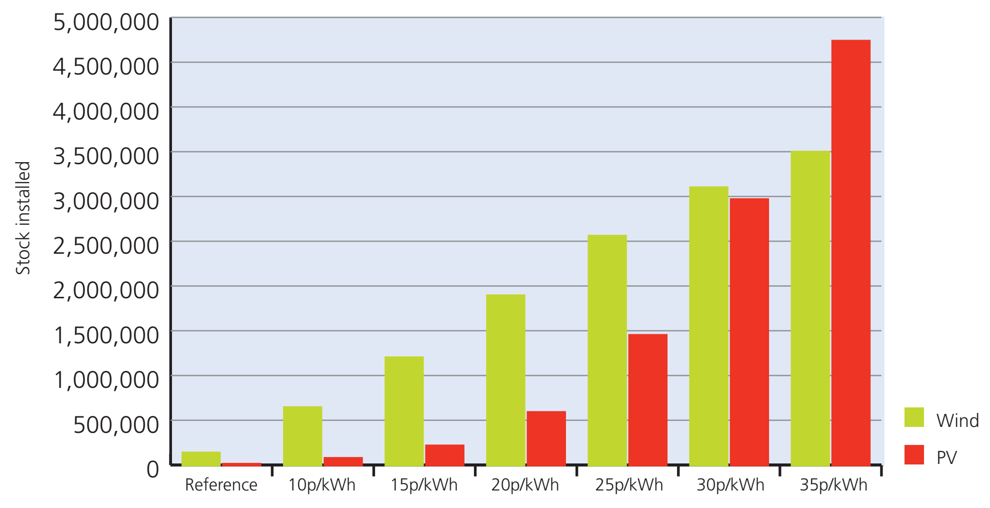
The feed-in tariffs are particularly effective at boosting uptake of micro-wind by 2020, even assuming urban wind technologies are not installed. PV appears to need a higher tariff. By 2030, feed-in tariffs strongly support PV, because the price will have dropped significantly. Savings of up to 1.8 and over 8 Mt CO_2 are available by 2020 and 2030 respectively.

Figure 16: Stock installed by 2020 for wind- and pv-specific feed-in tariffs



55 4 bands are proposed: technologies in the Established Band will receive 0.25 ROCs/MWh; technologies in the Reference Band will receive 1 ROC/MWh; technologies in the Post-Demonstration Band will receive 1.5 ROCs/MWh; technologies in the Emerging Technologies Band will receive 2 ROCs/MWh. Microgeneration projects will be placed in the same bands as large scale generation using the same technology.

Figure 17: Stock installed by 2030 for wind and pv specific feed-in tariffs

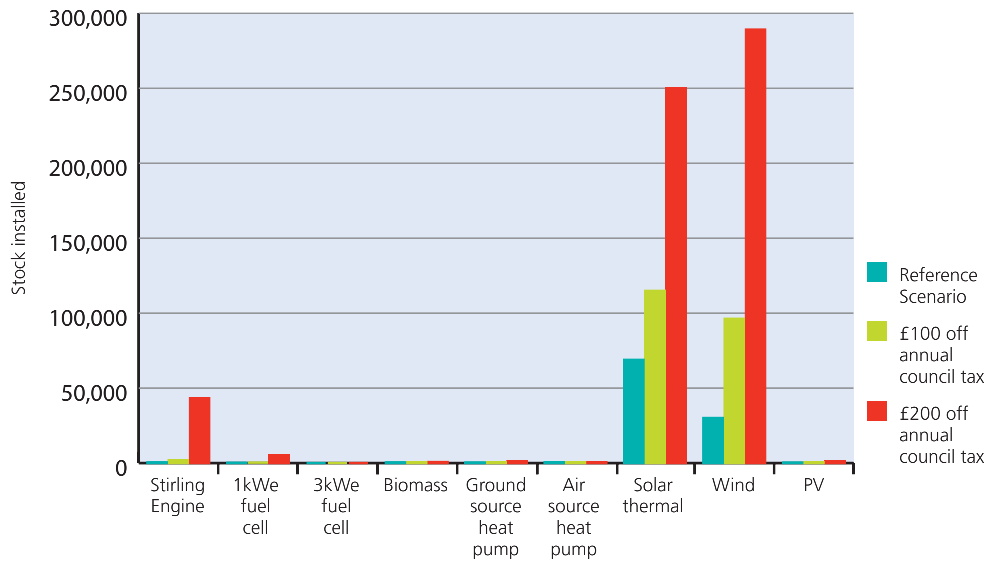


Tax breaks

Annual subsidies in the form of a council or income tax reduction are an effective mechanism. Annual tax reductions of between £100 and £200 for the lifetime of the technology appear to be enough to stimulate the uptake of wind and solar thermal. Such a mechanism could be introduced either as a council tax reduction, or as a reduction on income tax as part of the annual tax forms – a 'green' page within the tax return could include carbon-saving equipment installed. Although not everyone submits one of these as a matter of course, anyone wanting to claim this benefit could request one.

The model predicts that even by 2020, tax reductions of £200/device/year would stimulate uptake of almost 250,000 solar thermal and almost 300,000 rural wind installations.

Figure 18: Number of installations by 2020 for annual council tax reductions



Technological development

The model assumes a level of technological development and cost reduction established by historical data, research with the industry and assessment of the current level of investment. It is impossible to predict the long-term development of these technologies, but by looking at patterns of cost reduction and increases in efficiency, we can make an assumption about the speed and direction of improvement. Examples of likely types of improvement include: better materials cost and performance, reliability, efficiency, manufacturing economies of scale, distribution, and installation economies of scale.

There are also assumptions in the model about the efficiency performance of each technology. These should be seen as long-term averages rather than what would be achieved today. This would tend to slightly over-estimate the uptake in early years, but since the majority of uptake is in future years, this should not be significant.

The graphs below show the sensitivity analysis for learning rates[56], which shows the cost reduction that is predicted with a doubling of volume. The reference scenario is represented by 100 per cent and scenarios were modelled which looked at a learning rate of half this (50 per cent) and a third higher (130 per cent). The graphs below show that the model is not very sensitive to heating technologies, but for discretionary technologies, this is key. It is clear that cost reduction is vital to increased take-up of these technologies and that policy intervention should include measures to ensure this is achieved.

56 Learning curves describe the change in price as volume of sales increase. This indirect relation can include the effects of economies of scale, technological improvements, and other cost cutting measures. A doubling of cumulative volume (units, systems or installed capacity etc) provides a cost reduction expressed as a percentage –the learning rate, for example, the PV learning rate was historically 18 per cent.

Figure 19: Sensitivity of 2020 stock to reductions in the installed cost for heating technologies

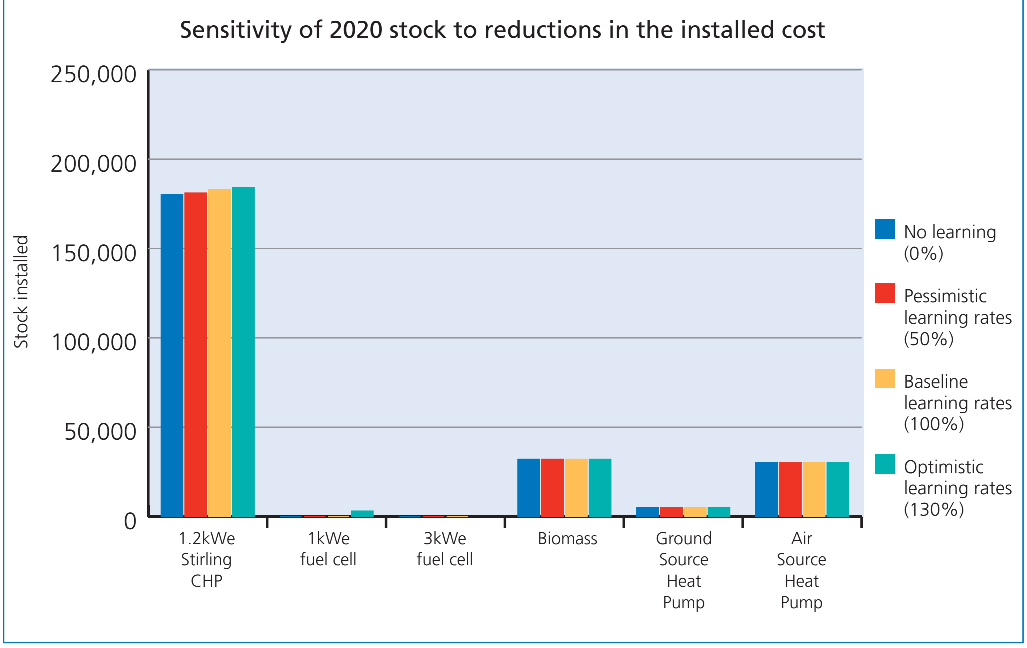
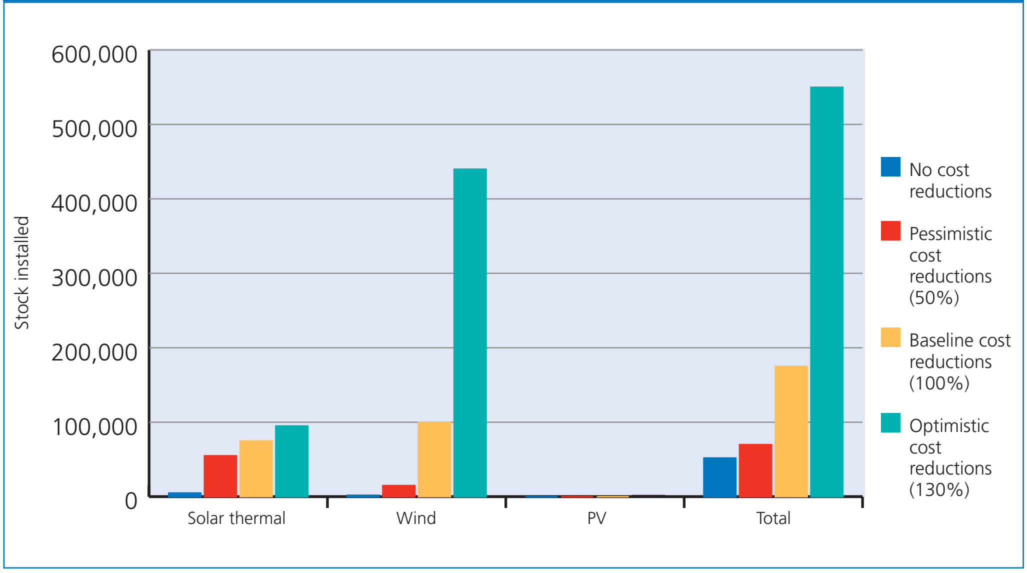


Figure 20: Sensitivity of 2020 stock to reductions in the installed cost for discretionary technologies



Fossil fuel prices

Fossil fuel price increases could come about through shortages in global production or from Government policies targeted at domestic fossil fuel costs. The model has explored the effect of variations in fossil fuel costs (electricity, LPG, heating oil and natural gas). Three mechanisms for fossil fuel/electricity price rises are considered:

- a step change in price (a doubling in 2008)
- a gradual increase year-on-year
- or an increase in VAT on fuel to 17.5 per cent

The results suggest that a doubling of fossil fuel prices in 2008 would only affect the uptake of biomass[57] boilers by 2020, with an increase of 600,000 units installed over the reference case. A tripling of the fossil fuel price would lead to the installation of significant (> 1million) fuel cell units and nearly 2 million biomass boilers. Biomass units take off more rapidly than the fuel cell because they are already available in the market at a known price, whilst fuel cells still need to undergo their final commercialisation phase.

By 2050, the model predicts that fossil fuel price increases would embed the fuel cell as the dominant heating technology and push biomass boilers into the majority of off-gas homes. Ground source and air source heat pumps are penalised by the high electricity costs under this scenario.

CO_2 savings available from heating technologies that would result from a doubling of fossil fuel costs are 5 per cent in 2020 and 30 per cent by 2050, relative to the reference case.

High fossil fuel prices also appear sufficient to cause very significant uptake of the discretionary microgeneration technologies. Increases in fossil fuel prices tend to stimulate each discretionary technology equally. Even by 2020, a doubling of fossil fuel prices in 2008 doubles the uptake of wind and solar thermal, with over 300,000 discretionary microgeneration units installed.

By 2050, either a doubling of the fossil fuel/electricity price or an annual 2 per cent rise would be sufficient to double the CO_2 saving from discretionary microgeneration technologies. This corresponds to an additional annual CO_2 saving of more than 1 Mt CO_2/year.

Small changes to the fuel price (e.g. increasing VAT on fuel to 17.5 per cent) has a limited effect on uptake of either the heating technologies or the discretionary measures, causing only a 4 per cent decrease in CO_2 over the reference case by 2050.

Policies to deter fossil fuel use, and an underlying increase in the price of oil, will support microgeneration, but it is recognised that an increase in fossil fuel price is unlikely to be driven by a microgeneration-specific policy. However, anything which increases the effective cost of fossil fuels to consumers would all improve consumer attitudes to microgeneration. This could be significant if fossil fuel prices double.

57 For the purpose of this scenario, biomass prices are assumed constant

Chapter 4:
Summary of modelling results and possible policy combinations

This chapter reviews the modelling results and highlights the successful policies for each technology. It concludes by analysing the impact of combining a number of policies in order to maximise take-up.

Several policies promote microgeneration uptake by 2050, including:

- a 30 per cent capital subsidy
- compulsion (e.g. during roof repair)
- a feed-in tariff of 10p/kWh or more
- change in consumer attitude
- benevolent ESCOs or soft loans

The model shows that some policies – e.g. grants capped at £100m, or a CO_2 price of only £10/t, have no negligible effect on the number of technologies installed in 2050.

Different technologies require different types of support

As the market begins to move beyond its early stages, it has become clear that different technologies require different types of support in order for them to achieve mass markets in the long term. In order to retain maximum flexibility, at this stage we believe it is prudent to encourage the development of all the existing technologies, as well as continuing to invest in future technologies.

MicroCHP

Stirling engines and fuel cells represent opposite extremes of domestic CHP, in terms of technology and heat:power ratios. The modelling shows that the technology attributes of Stirling CHP are more favourable than fuel cells in the short term (up to 2020), but fuel cells have the potential for greater cost reductions and are more favoured in the long term (up to 2050). The lower heating demand for new homes is better served by fuel cells with low heat:power ratios.

In the boiler model, most supportive policy measures lead to stimulation of the 1kWe fuel cell in all gas-connected properties, with either biomass or ground source heat pumps favoured where no gas connection is present. One of the reasons that the technology could be so significant is that in many ways, it looks and works like a conventional boiler and does not have some of the perception hurdles that many of the other technologies have.

Stirling engine CHP

Currently, the technology is not far from being cost-effective in domestic situations. Uptake depends strongly on achieving lifetime and maintenance costs close to those of the incumbent, the condensing gas boiler. Following likely commercial introduction sometime after 2010, this sector is likely to grow quickly as costs reduce further.

One this technology becomes cost effective, it could be another 10-15 years before a significant proportion of domestic energy is generated by Stirling engine CHP.

Mass market-uptake could be accelerated through energy supplier programmes and then by a carbon-related requirement for boilers within the Building Regulations.

Fuel cell CHP

There is currently no affordable small fuel cell CHP unit on the market. Numerous companies are at the pre-commercial phase, but no system has yet been introduced and there is

substantial uncertainty in the future development of the technology. Commercialisation is strongly dependent on achieving lifetime and maintenance costs close to condensing boilers. Cost-effective introduction is expected around 2015, with costs predicted to reduce significantly thereafter.

This technology is more suited to smaller dwellings with below-average heating loads. Future reductions in domestic heating loads, for example through higher building standards, would increase the market for this technology.

As with Stirling engines, mass-market uptake could be accelerated through energy supplier programmes and then by the inclusion of a maximum carbon emission requirement within the Building Regulations.

Microwind

Microwind systems are generally not cost effective at present, except in very windy sites (e.g. above 12 m/s). However, a number of new products have recently come to market with potential for significant volume-related cost reductions. As a result, mass commercialisation could occur around 2015.

The potential for micro and small wind is significant – there are several UK developers, a suitable UK market of significant size and near-term potential for significant cost reductions, mainly through supply-chain efficiencies and mass production. Electrical contractors can be used as distributors and the skills required are transferable. Note that the projections are, like for all the discretionary technologies, highly dependent on the cost reductions anticipated.

In the short term, this technology will need to be supported by subsidy through the period of time until commercialisation is achieved. Projections suggest a capital grant of circa 25-50 per cent could be sufficient to support uptake levels until this time. Commercial viability is highly dependent on acquiring sufficient reward for electrical production. This would be the single most important market change for microwind.

Poorly informed planning decisions could increase costs and reduce the market quite significantly. An objective assessment of the environmental impact of domestic micro wind systems is required to provide clarity on this issue, followed by guidance to planners on the key issues.

Photovoltaics

Short-term cost reductions in this technology are possible – from standardisation, building industry capability and the scaling up of production. Prices in continental Europe are already significantly lower than in the UK, in part because of these factors. If PV is incorporated into building products such as roof tiles and glazing, this will also reduce costs, because these would replace conventional materials. The skills for installation already exist within the building industry. PV is not expected to be cost-effective until 2030: however, a technology breakthrough could reduce capital costs and bring this forward towards 2020 or even earlier.

At the moment, PV is not generally cost effective. In many countries, including the UK, significant incentives are needed to maintain the market for small grid-connected systems.

There are small markets where PV is cost-effective, for example remote power and in prestige facades. Lack of planning issues means the long-term market potential for PV is amongst the largest of those studied.

Significant incentives will be required to maintain the market until commercialisation is reached. If regulations for new builds mandated on-site electricity generation, this would significantly increase the uptake of PV. The alternative is to stop support and allow the technology to develop abroad until costs reach a point where it becomes viable in the UK climate. In the medium to long term, a reward for electricity production will be needed to ensure commercial viability.

Biomass heating and heat pumps

Renewable heating has significant potential for CO_2 reduction. Both biomass heating and heat pump technologies can already be commercially viable when compared to electric or LPG heating. However these technologies are not currently competitive with natural gas or oil-fired heating. Half the cost of ground source heat pumps is the installation of the ground loop. This cost will come down if a number of boreholes are drilled on the same site – and costs are estimated to halve in future once installers become more familiar with the technology, and if builders plan ahead to minimise disruption. Plumbers can undertake heat pump installation, as the process is similar to fitting a boiler. Ground loop pipes require additional training and installation is currently undertaken by specialists. Vertical boreholes require specialist skills, found in well-drilling businesses.

Although only a small proportion of the housing market uses electric heating, and only a fraction of these will be suited to biomass or ground source heat pumps, the CO_2 savings are disproportionately large (due to the high CO_2 emissions of electric/LPG heating displaced). These applications would also contribute disproportionately to alleviating fuel poverty in low-income households living in the hard-to-treat homes off the gas grid.

In the short-term, support through CERT should help these technologies significantly, particularly if there was an uplift element within the mechanism (i.e. a bonus payment for developing technologies). For low-income households, it may be appropriate to use direct grant support through Warm Front and its devolved counterparts.

These technologies both rely on wet heating systems (i.e. using hot-water radiators) to be installed instead of electric and LPG. This could be a significant barrier, because consumers and developers perceive electric heating systems in particular to be simple. In the short to medium term, regulation could improve uptake in preference to electric or LPG in appropriate regions (especially off the natural gas grid). This could take the form of incentives in the Building Regulations or in local or national planning guidelines.

Solar water heating

Solar water heating is most cost-effective when it replaces electric heating systems. Where gas is available, it is not generally cost-effective. Basic plumbing skills are needed, although many installations are currently done by specialists. Plumbers could help drive demand by raising the option whenever a boiler is replaced, or even installing twin-coil cylinders as standard so that solar heating could be added on to the system in future.

While capital costs are projected to reduce – volume efficiencies could deliver 20-30 per cent cost reduction[58] – the rate of reduction appears low and it is not likely that solar water heating will provide cost-effective water heating over the timescales of the study. At least half the costs are for scaffolding and installation. If done at time of re-roofing, or with new build, costs come down.

Although it has been the most popular technology to date, this is unlikely to continue beyond a niche market without continued substantial (of the order of 50 per cent) grant support in order to attract the 'normal' consumer. Lower levels of grant funding, or access to EEC would assist somewhat but installation levels would be significantly lower than their potential.

There is, however, real potential for solar heating for space heating, indeed 62 per cent of those installing solar thermal would like to have had space heating provided by their solar thermal system as well as hot wate[59].

Policy combinations

The model suggests that a number of measures which are thought to support low CO_2 technology (e.g. Energy Export Equivalence, ROCs and personal CO_2 credits) would not stimulate consumer uptake of microgeneration at their current levels. For example, CO_2 would need to be valued over £100/tonne to cause a noticeable effect in the uptake of even fuel cell CHP systems by 2050.

The previous results have highlighted that for single policies to be effective, substantial intervention is required. This could result in a distortion in the market (e.g. by a very high CO_2 price or subsidy applied to specific technologies). Combinations of policies offer several advantages over single policy interventions. Using multiple policies allows flexibility to adjust the components of each policy to respond to market conditions (e.g. the introduction of new technologies) or shifting government priorities. It also means elements of each policy can be phased in and out over time.

In addition, combinations of policies may be more cost efficient in reducing overall barriers, and reach a wider overall market, than mechanisms that target only one technology attribute or one market failure. From a practical point of view, it may be easier to develop and implement combined small interventions than to create a single large scale intervention.

For example:

- Combining an ESCO model with a regime which values exported electricity at the same rate as that imported leads to over 7.7 million fuel cell CHP sales by 2050, and a 18 per cent CO_2 emission reduction
- Combining an ESCO model with personal CO_2 credits at £100/tonne would lead to over 32 per cent CO_2 savings
- The combination of ESCOs, EEE and a CO_2 price of £100/t encourages nearly 9m homes to install micro-wind or PV by 2050
- A combination of EEE, ESCO and a price of £100/t CO_2 promotes savings of 6 Mt CO2/year, mostly from wind and PV

58 Green Alliance, September 2004, A micro-generation manifesto by Joanna Collins

59 Open University and Energy Saving Trust, op.cit.

Based on the support required for the various technologies, the policy combination modelled below illustrates what a comprehensive package could achieve.

The combination consists of:

- regulation of heating systems – one heating microgeneration technology is required at time of boiler replacement
- one discretionary microgeneration technology is required at time of new build
- 30 per cent grant for renewable measures for retrofit into existing buildings
- low interest loan – 5 per cent over 10 years
- EEE at 10p for renewable measures only (i.e. not micro-CHP)
- £20 per tonne/ CO_2

Figure 21: Total heating measures installed under policy combination

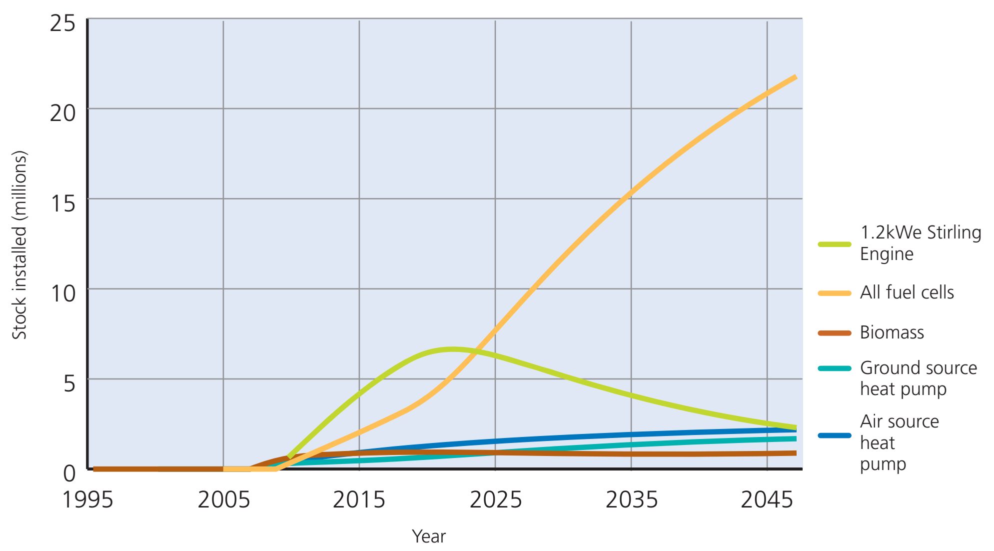
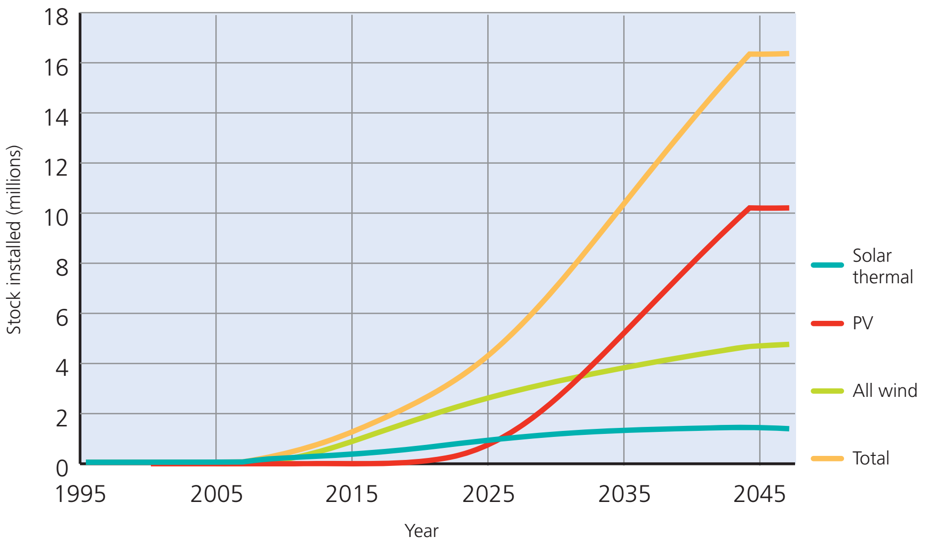


Figure 22: total discretionary measures installed under policy combination



The heating results show that this policy combination is successful for microCHP, with dramatic take-up by 2020 and this being the heating system of choice by 2050. In the earlier years, Stirling CHP is the dominant technology, but this is overtaken by fuel cells by 2025. Over 2 million air source heat pumps are installed, 1.7 million ground source heat pumps and almost 900,000 biomass boilers.

Carbon savings are impressive for this policy combination – 35 Mt CO_2 (22 per cent) by 2020, 53 Mt CO_2 (34 per cent) by 2030 and 84 Mt CO_2 (53 per cent) by 2050.

The discretionary technologies also do well under this policy combination, with over 16 million units installed in total and a total of 12 Mt CO_2 saving per year by 2050. In order to achieve a higher uptake, regulation on roof replacement or at point of sale would be required.

Total carbon savings available under this scenario equate to more than three quarters of the total savings required to reach an 80 per cent saving by 2050 (assuming an equal contribution from the domestic sector). With energy efficiency savings on top of this, this target looks entirely achievable.

Chapter 5: **Conclusions**

The model suggests that, if well supported, microgeneration technologies could make a combined saving of 96 Mt CO_2/year by 2050. The potential for savings by 2020 are more limited: Even with supportive scenarios (including some form of compulsion) a saving above 35 Mt CO_2/year (22 per cent) appears unlikely by 2020. This is still significant compared to other carbon-reduction efforts – for example, CERT is expected to deliver savings of 4 Mt CO_2 per year by the end of the programme (2011)[60].

Unlike primary heating technologies which compete with each other, discretionary microgeneration (such as PV, solar thermal and wind) compete with the option of no purchase. This strongly retards uptake in the absence of policy support – and potential CO_2 savings from the discretionary technologies are lower than from primary heating technologies.

A number of different policies are capable of supporting discretionary microgeneration uptake, however in all cases (including when combinations of policies are used) substantial intervention is required to promote uptake and achieve significant CO_2 savings.

Principles of support

The traditional role of government is to intervene in market failures and provide alternatives to market solutions. Government has a role to protect ‘public goods’, which are indivisible in consumption and are accessible to everyone (e.g. the environment). Public policy should take account of externalities – a cost which is not reflected in the price of a product but on other people (e.g. pollution).

Microgeneration products can reduce carbon dioxide emissions so have a societal benefit that is not reflected in the price of the product. According to public policy theory, Government should therefore intervene and ensure that the benefits of these products are taken into account.

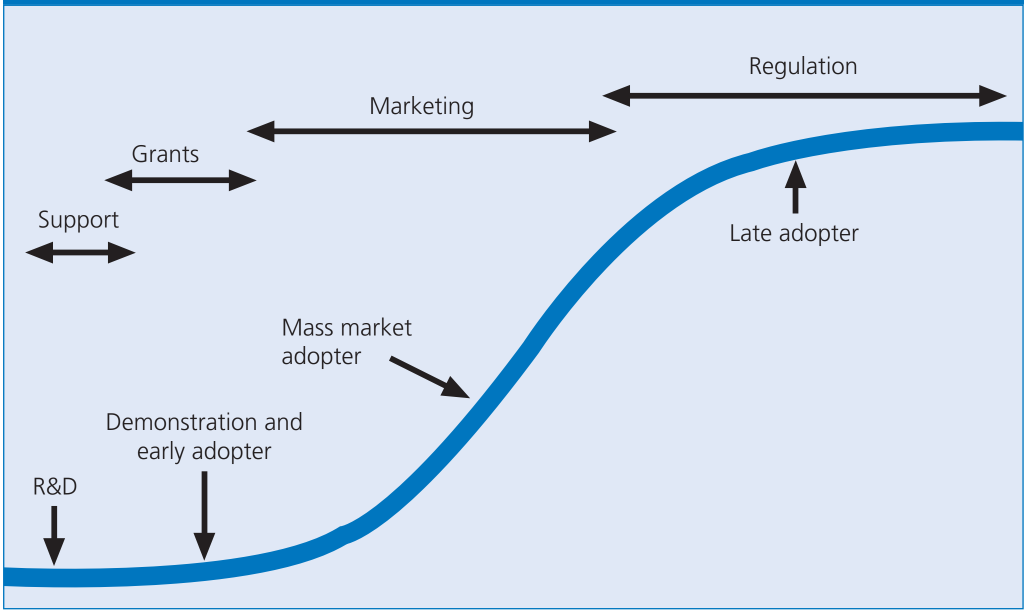
Any support in this market should be:

- aimed at overcoming the barriers identified
- differentiated to allow support of technologies with different characteristics
- not cause perverse incentives
- promote the most energy/carbon-efficient use of the technology

Different support is required at various stages of a market. In the early years, it may be appropriate to use subsidies, raise awareness, provide information/advice, demonstrate technologies, remove any barriers that hinder take-up and set up voluntary codes. As the market matures, a more enduring support mechanism is needed. Targeted incentives and penalties, and mandatory standards could be introduced. In a mature market, there would ideally be full capture of carbon value and regulation to outlaw inefficient alternatives.

60 Defra, May 2007, Carbon Emissions Reduction Target April 2008 to March 2011: Consultation proposals.

Figure 23: Market transformation curve



The graph above shows a typical market transformation curve for a new technology. Based on experience, the most effective forms of support are highlighted at each stage. Taking the penetration of condensing boilers as an example, this graph shows the transformation from R&D through to late adopters. In the early years, innovators and early adopters started using the technology and the Energy Saving Trust ran a cashback grant programme to encourage them. Once the boilers were established in the market and performance data available, the mass market was encouraged by dispelling myths (removing barriers) and marketing the availability of these more efficient boilers. Eventually, the boilers were mandated by building regulations, encouraging the 'late adopters' to purchase them.

Recommendations

The following recommendations are designed to encourage mass market uptake of microgeneration. It is important to see them as a package of measures. The results of the modelling show that one policy measure alone cannot easily achieve significant uptake, just as a four-wheeled vehicle cannot move forward with only one wheel.

Recommendations are grouped into the following categories:

- regulation
- carbon pricing
- changing consumer decision making
- subsidy
- technological development

Regulation

The modelling shows that the most effective mechanism is a compulsion to procure microgeneration at certain trigger points. Compulsion for new buildings has a substantial effect, but the most effective compulsion occurs at periodic ‘trigger points’ relating to the building. Examples include re-roofing (for discretionary technologies) and boiler replacement for heating technologies. Compulsion has the advantage of causing significant uptake by 2020. It is the only policy measure that does so.

However, any compulsion scenario should bear in mind the high cost imposed on householders whilst also considering the benefits to consumers and the environmental imperative. For most microgeneration technologies, it is probably too early to consider compulsion. But policy should be clear on including new technologies as they develop. It would be helpful for the industry to know that such measures could be introduced over, say a 20-year period.

For maximum effectiveness in mass-market transformation, the higher energy performance levels of the Code for Sustainable Homes in England should be made a requirement for new homes wherever possible, and similar measures should be taken in the devolved nations. The government has already announced that all publicly funded homes in England must be compliant with the Code. In a climate where more new homes are being planned, it is essential that planners at both regional and local level know that climate change remains a priority – and that they do have the power to do something about it by requiring higher Code levels. This should be backed by a consumer awareness campaign, linked to the A-G Energy Label to be introduced for new homes.

The definition of on-site renewables is critical to microgeneration uptake in new builds. The assumption in the modelling here is that new build Code level 6 requirements force the purchase of at least one new microgeneration technology, but community-scale solutions may turn out to be more attractive and/or cost-effective to developers (and hence purchasers).

Recommendations

As microgeneration technologies approach conventional technologies in cost-effectiveness, regulation should ensure that the least efficient heating products are taken off the market so that only low-carbon options are available for householders wishing to replace their heating system. Communities and Local Government (CLG) should publish clear plans on timetables for delivering this in relation to building regulations for England and Wales. Equivalent action should be taken by the Scottish Government and the Northern Ireland Executive.

In the longer term, more demanding regulation should be considered, for example a requirement to install measures at point of sale or at point of re-roofing.

Further research is required on community-scale solutions for new-build requirements.

Placing a value on carbon

It is unlikely that a carbon price that reflects the current social cost of carbon (in the range of £10 – £43 per tonne of CO_2 – see references in the Modelling Results chapter) would, in isolation, have a significant impact on uptake of microgeneration as a policy. However as part of a package of measures, even a price of £20/tonne CO_2 would aid uptake. To be effective in isolation, a much higher carbon price (£200/tonne CO_2 or more) would be required – at this level, it could be the only form of ongoing financial support.

Recommendation

A carbon price that reflects the social cost of carbon should be implemented as part of a package of policy measures to encourage microgeneration (and energy efficiency). A carbon price at this level will not have much impact in isolation but could work in tandem with other financial support measures.

Changing consumer decision-making

Access to alternative purchasing tools

There is a real need to ensure that consumers have access to tools for purchasing and operating microgeneration technologies: This implies providing relevant incentives such as low-cost loans; or situations where Energy Service Companies own and operate the microgeneration technology. Another possibility is a green mortgage, in which money is lent up front and paid back on the sale of the house. All these tools aim to overcome the barrier of high capital costs.

The model shows that a purely commercial ESCO has limited impact. Indeed, it is speculated that consumers are unlikely to be willing to sign up to a long-term contract without significant savings being achievable. Comparisons with the mobile phone market are instructive: there, substantial discounts have to be offered in order to get customers to sign up to 18-month contracts instead of 12-month contracts. It is therefore likely that any such purchasing tool would need to be supported financially by government, at least in the early years. Such a tool could look like a soft loan scheme, in which government in effect subsidies interest rates and provides for the marketing and administration of the scheme.

Recommendation

Until the market delivers ESCOs, Government should help consumers to overcome the high capital costs of microgeneration technologies. This could be done effectively through a soft loan scheme.

Awareness-raising and attitude changing

The modelling shows that one of the key variables in predicting uptake is how much consumers are willing to pay compared to the alternative (grid electricity or gas). This can be changed, for example, through a shift in attitude to carbon emissions, and promotion of the idea that microgeneration technologies are something to aspire to. For example, 45 per cent of people are already willing to pay more for a home that's environmentally friendly – up to £10,000 more. And 64 per cent of people say they would steer clear of buying a poorly insulated, poorly glazed home[61] This kind of attitude can be strongly influenced by messages from government and estate agents, for example.

Persuading consumers to view microgeneration technologies positively and encouraging them to consider carbon emissions has the effect of lowering discount rates and lengthening discount periods. A consumer who is concerned about carbon emissions will be more willing to make an investment now that may take longer to pay back, and have a lower ultimate payback, that an alternative investment made purely for financial reasons. The modelling shows that 'forward-looking consumers' result in much higher uptake of these technologies.

Awareness-raising and changing attitudes is also important to ensure that consumers accept and support new, more radical policies like some of the regulatory measures discussed above.

The Energy Saving Trust's recent report 'The role of education and schools in shaping energy-related consumer behaviour'[62] concludes that education has the potential to put in place the necessary foundations for delivering energy-related behaviour change. In addition, the work highlights the potential role that educating children and indeed schools more generally could play in delivering community-wide behaviour change.

Recommendation

An awareness programme is needed so consumers value the environmental benefits of microgeneration technologies and make investment decisions that include environmental factors.

Information and advice

Consumers should be able to find reliable sources of information regarding microgeneration technologies easily and the process of installation, and the action in the Microgeneration Strategy to 'assess the feasibility of a communications/information campaign' should be implemented without further delay.

The Energy Saving Trust has piloted the Sustainable Energy Network concept with the creation of Energy Saving Trust Advice Centres in three parts of the UK (two in England and one in Northern Ireland). These build upon the existing infrastructure provided by the Energy Efficiency Advice Centre (EEAC) network. The next stage of rollout is currently taking place with new centres in Wales, Scotland and London. Subject to Government funding, these will become the key local delivery element of the Energy Saving Trust's carbon-saving activities for UK citizens, including advice on microgeneration. The EEACs currently focus on the provision of home energy efficiency advice, which has proven extremely successful. They now advise 770,000 people annually. In 2005/6 the advice led to actions saving 1MtC over their lifetime at an average cost of just £6/tC.

61 Statistics sourced from consumer research commissioned by the Energy Saving Trust and carried out by IPSOS Mori and ICM in January and February 2006.

62 Energy Saving Trust, 2007, The role of education and schools in shaping energy-related consumer behaviour

The rules for distributed generation are daunting, and people need guidance on technical, commercial and regulatory issues. Non-technical audiences (like householders and new industry players) would benefit enormously from advice and written information on the practical requirements of microgeneration.

Recommendation

A fully-functioning, consumer-facing independent information and advice service on microgeneration is required.

Energy Performance Certificates (EPCs)

EPCs should allow householders to recoup investment even if they do not remain within a house after a microgeneration/energy efficient product has been installed. If the value of the house reflects the cost of running the house, then investments would be worthwhile regardless of time left in the property. Also, landlords would be more likely to invest, particularly where they are investing for capital value rather than just rental income.

EPCs would also increase the decision-making frequency of microgeneration/energy efficiency purchase as householders would be reminded of them at every house sale, and they would serve as a regular reminder to portfolio landlords. They could also be linked to a degree of compulsion in the future, for example, requiring installation of a microgeneration technology at the time of a house sale.

Without wider awareness raising and support, EPCs are likely to make little difference on their own. This is because people moving home can easily miss the EPC in the hustle and bustle of the home moving process. There is a need for more systematic follow-up and hand-holding of householders through the process.

Recommendations

EPCs should be implemented on all properties without delay and an awareness-raising campaign should be put in place to encourage buyers and sellers to take notice of the energy performance of their house.

Detailed advice should be freely and easily available to all buyers and sellers.

Government should consider the possibility of linking EPCs to a degree of compulsion in the future.

Subsidies

For a financial subsidy measure to be effective in increasing uptake of microgeneration amongst householders, it must have the following features:

- low transaction cost
- maximisation of delivery/subsidy to customer rather than intermediaries, whilst ensuring sufficient incentive is in place to encourage investment in the industry
- focus on reduction in capital cost, rather than ongoing subsidy
- subsidy outwith public expenditure
- simple to access and understand
- minimisation of ‘free riders’
- support should be at an appropriate level for each technology

The support mechanism(s) should be compatible with the anticipated longer-term framework that enables all low- and zero-carbon technologies to capture the underlying value of avoided carbon emissions (and diversity of supply).

Further, microgeneration should be integrated into a common framework with energy efficiency so that the policy:

- promotes the delivery of cost-effective, carbon-saving measures at least cost, but also
- supports innovation and early markets for technologies with future benefits, and
- addresses barriers faced by individual technologies.

Regardless of the type of subsidy mechanism used, the value of the support needs to be significantly larger than current levels (once LCBP and equivalent programmes in the devolved nations come to an end) in order to cause a substantial increase in the deployment of microgeneration. The size of existing support mechanisms (e.g., ROCs, CERT or CO_2 value) are not yet sufficient to cause mass-market uptake of any of the microgeneration technologies. To make these schemes supportive towards microgeneration, they need to be increased in value, particularly in the early years.

Grant support is shown to have very limited value when the total level of support available is capped – for example at £100 million. This is because the technology remains too expensive even after the subsidy program is finished. In some cases, for example PV, cost is almost completely dependent on global rather than UK developments and a short-term subsidy programme has very little impact on price reduction. If a limited subsidy program is to be made available, it would be better deployed on bringing technologies to market and assisting firms to commercialise their technology – to ensure consumers get access to microgeneration at the cost projected in the modelling. This would be preferable to the current subsidy situation, where the subsidy simply supports the lowest cost technology and has a very limited effect on its long-term cost. There also remains a question about the perceived value of an item with a grant attached to it. It is possible that grants could actually de-value these products in the minds of some consumers.

Heat measures

A Renewables Heat Obligation (RHO) would be more complicated than the existing RO (for electricity). The GB electricity market is governed by the British Electricity Technical and Trading Arrangements (BETTA) with electricity suppliers, generators, distributors and the transmission company being regulated by Ofgem through their licenses. It was therefore possible to introduce new powers under the Utilities Act for the RO. It does not appear to be feasible to impose an obligation on 'heat suppliers' in the same way, because the generation of heat is far more decentralised than for electricity. Further, even if an RHO is deemed to be workable, renewable heat microgenerators may encounter the same administrative problems under an RHO as experienced by renewable electricity microgenerators under the RO.

As such, all heat microgeneration technologies should be eligible to receive an uplift under the CERT as 'innovative technologies'. The uplift should provide subsidy to a level of around 30 per cent of the capital cost. CERT is likely to become more important in the medium term but in the short term, higher levels of capital grant are required. We do not believe that support under CERT without an appropriate uplift should be seen as an alternative to the provision of continued grant funding for technologies that are not yet cost effective. CERT should continue to concentrate on those measures which have the largest carbon impact in the short and medium term. In order to achieve the highest carbon savings possible, higher incentives could be given where heat measures are replacing electric heating.

Recommendation

If CERT is to replace LCBP and equivalent devolved programmes as the financial support mechanism for renewable microgeneration heat measures, an uplift will be required to provide subsidy at a level of around 30 per cent of the capital cost.

Electricity measures

For electricity-producing technologies, the value that would be available under CERT is too low to encourage significant uptake, without a very large uplift.

RO support could in theory replace grants; indeed, except for PV, the value of ROCs would be similar to grants currently available under LCBP. However, the RO was not designed with microgeneration in mind and does not serve individuals well; they are not used to dealing with such mechanisms and the administrative requirements are a barrier to accessing the value of ROCs. In most cases, the administration overhead and transaction costs simply outweigh the potential benefits. Furthermore, allowing agents to act on behalf of small generators will not add significantly to the value, since they will need to take some of the value to cover their operating costs. This will further reduce what is already a very low level of reward. As a consequence, renewables microgeneration is at a major disadvantage to larger renewables despite the embedded benefits.

If the RO is retained for microgeneration, a separate band is needed for renewable microgeneration with a higher uplift, because technologies are further from commercialisation compared to their larger-scale counterparts. For example, micro wind is far behind onshore wind farms and should receive a higher benefit.

The measures proposed by BERR to increase the certainty of long-term ROC prices[63] are critical for investment decisions. This does however illustrate the intrinsic problem of the RO, in that prices and investment decisions carry a high degree of risk under this mechanism. So private investors want a higher rate of return to compensate for the risk. A more suitable mechanism would be a guaranteed tariff. Evidence from other European countries suggests that this is more effective in bringing forward renewable capacity than the RO (See for example 'Communication from the Commission, 2005, The support of electricity from renewable energy sources'[64]).

63 E.g. moving to a ski-slope mechanism instead of cut-off price and implementing targets on a headroom basis, as proposed in DTI, May 2007, Reform of the Renewables Obligation

64 http://ec.europa.eu/energy/res/legislation/support_electricity_en.htm

For renewable microgeneration, it may be more efficient to put in place a different support mechanism that is more suited to the size of technology and the competencies of the individuals who would be installing and operating it. The supporting policy framework needs to be cheaper, simpler and easier for householders. One such option would be to remove the RO for microgeneration and replace it with a supplier's Microgeneration Obligation, as part of, or separate to, CERT, and ultimately, the Supplier Obligation (the proposed programme that would follow on from CERT in 2011).

A Microgeneration Obligation (MO) would allow suppliers to claim the value of ROCs for all microgeneration amongst their customers. In return, the supplier should be obligated to ensure a certain capacity of microgeneration is built within their customer base. This would incentivise suppliers to encourage consumers to install systems, but would remove direct access to ROCs from consumers. Whilst this may initially seem counterintuitive from the consumer's perspective, it would be administratively easier for both the consumer and Ofgem, and would boost value to the consumer and increase growth in renewable microgeneration.

The targets could be reached through any means desired by each supplier, as they have historically been for EEC. Suppliers could, for example, give grants as a contribution to upfront capital costs, develop an ESCO approach that could include energy efficiency measures alongside domestic renewables, or offer a higher tariff on exported electricity. An MO would have the advantage of encouraging the development of energy services, which are likely to be a major requirement under the proposed Supplier Obligation. It would be up to suppliers to decide whether they reward microgenerators on a type approval[65] or on generation. Type approvals would reduce the administrative burden on small generators by removing the requirement to collect meter data, and on suppliers and Ofgem to process that data. The important principle is that it would be up to the market to decide what is required to achieve targets, whilst allowing suppliers to differentiate their offerings and operate in a competitive market. Suppliers would be required to report on total capacity rather than electricity generated.

The value of ROCs for microgenerators would be on average around 4p per kWh, based on current ROC prices. The model shows that this is not high enough to encourage significant renewable generation, so the target should be set at a level which requires suppliers to make a higher investment. This could either be funded by suppliers (through their customer base) or subsidised by government.

This Obligation would replace the need for long-term capital grants and would provide a strong signal and a stable, long-term initiative to help industry invest in these technologies. Such an obligation should be easy to fit with a Supplier Obligation from 2011. The exact form of the SO is currently being consulted on, but

56 BERR has previously ruled out the option of rewarding microgeneration on a type approval (un-metered) basis. However, the following observations are made with regards to type-approvals:

- One ROC is currently equivalent to generation between 500 and 1499 kWh in any period. It is hard to see how type approval would be any less accurate than this.
- BERR suggests that this approach would not offer a guarantee that equipment which is awarded ROCs will be properly installed or will be fixed if it breaks, or that it is sited in the best location. We would suggest that the installer accreditation scheme and product certification should offer protection to consumers from poor quality and inappropriate systems and siting. We also note that customers who install microgeneration have made a substantial capital investment and most are motivated to do so by the value of the energy and the desire to reduce environmental damage rather than to simply secure a ROC income stream.

we believe that a MO would fit with either of the main options being considered i.e. an evolution of CERT, with the ability to trade energy savings amongst third parties; or a cap and trade approach, which will incentivise the development of energy services packages.

This solution does not necessarily require a regulated minimum price (a 'feed-in tariff'), but, as a minimum, there should be a requirement to publish tariffs, in order to allow consumers to make an informed choice. In addition, the recommendations of the Electricity Network Strategy Group[66] should be taken forward (to increase the value of exported electricity through changes in the regulation and metering charges).

Recommendations

Electricity-producing technologies should be supported by some form of kWh subsidy. One way of achieving support would be through a separate Microgeneration Obligation as a ring-fenced part of CERT or as a separate mechanism, eventually incorporated into the proposed Supplier Obligation.

There must be action on the provision within the Climate Change and Sustainable Energy Act 2006 which allows for government to impose a scheme to reward exporters 'fairly' if industry does not come up with such a scheme itself. The recommendation to implement a Microgeneration Obligation could include a reward for electricity. Alternatively, a feed-in tariff of some kind would achieve similar ends.

Adopting Fiscal Incentives

'Consumer research[67] undertaken by Accent Marketing & Research indicated that consumers felt tax incentives to encourage energy efficiency were, in general, "a good idea" and quotes from consumers included "Everyone wants to pay less tax", and "I would certainly take notice of it if it came with the council tax…" The report went on to note: "Many consumers said that lower-than-expected costs of installation plus savings on energy bills were enough to encourage them to consider installing energy saving measures. While there was no evidence that a tax rebate would be more motivating than a grant, the research did indicate that fiscal incentives are likely to act as a trigger to stimulate consumer action'. Recent research on LCBP applicants showed that council tax reductions would have been more popular than a grant – 41 per cent supported an annual reduction in council tax compared to 25 per cent supporting the grant programme[68].

The modelling shows that an ongoing rebate on council tax can have a significant effect on uptake of microgeneration technologies.

Recommendation

Consideration should be given to a scheme whereby those installing microgeneration measures are given a rebate on their annual council tax bill.

Technological development

For the boiler-based scenarios, the most significant technology is the 1kWe fuel cell CHP, particularly in the long term. Without this technology, CO_2 savings without compulsion

66 Jade Energy, 2007, Scheme to reward microgenerators exporting excess electricity (A report to the DWG Work Programme 4 – Microgeneration Project P02)

67 Energy Saving Trust 2005, Changing Climate Changing Behaviour, Delivering Household Energy Saving through Fiscal Incentives, see: http://www.energysavingtrust.org.uk/uploads/documents/aboutest/fiscalupdate.pdf

68 Open University and Energy Saving Trust, op. cit.

would be minimal. However, there are currently no affordable small fuel cell CHP units on the market. Numerous companies are at the pre-commercial phase, but no system has yet been introduced and there is substantial uncertainty in the future development of the technology.

For the CO_2 savings implied by microgeneration technologies to be realised, it is essential that the technologies reach the market as assumed here using the baseline technology cost projections. The cost of technology, particularly those which have a long way to go in cost reduction before they become cost-competitive with the incumbents, can be crucial in dictating uptakes. The assumption in the base case assumes a learning rate for the installed cost of the technology and the model has been iterated with more optimistic and pessimistic learning rates.

It is a political reality that subsidy programs are likely to be capped or limited in time. As a result, they do not provide a long-term support mechanism which will increase microgeneration uptake. Where subsidies are provided, they should be targeted towards technology development and cost reduction. Criteria for determining levels of support could include: nearness to market, carbon savings, potential numbers of applications, innovation, benefit to UK plc, and security of supply. For example, subsidies aimed at bringing fuel cell microCHP to market (i.e. supporting initial commercialisation) are likely to have a longer term CO_2 benefit than limited grants provided to PV, whose cost is controlled by a global PV industry. Government should concentrate more effort on the deployment of those microgeneration technologies which have the potential to become commercially available and reduce carbon emissions significantly.

This implies increasing spend on R&D targeted at the key CO_2-reducing technologies; and dedicated support at the early stages of commercialisation (e.g. through a government program to guarantee a certain number of sales from a give supplier or specific technology). An approach targeted at specific technologies which have genuine mass market potential would be more effective in the long term than blind subsidy programs which simply support the lowest-cost technology at any given time.

Over the period 2005-2008, £320 million is available to businesses in the form of grants to support research and development in new and emerging technologies, however under the April 2004 call, fewer than 3 per cent of the total funds available supported various microgeneration projects. This is insufficient support for microgeneration technologies in comparison to large-scale technologies.

The recently announced Energy Technologies Institute provides an opportunity to address the lack of support for domestic scale technologies, as does the proposed Environmental Transformation Fund.

Field trials are essential in taking lab-tested technologies to the field and investigating how they operate once they are installed in real homes and householders are in charge of operating them: These can provide very different results from lab-testing. The Energy Saving Trust is currently running a microwind trial, but this was very much as an emergency measure in reaction to the sudden interest amongst retailers, the media and consumers. Our research has shown that of those who have already installed measures, 74 per cent would have liked to have better information on performance and payback[69]. It is important to anticipate new technologies sufficiently far ahead so that equipment is fully tested – and consumers can be given advice on siting and suitability – before technologies are released to the mass market. The Energy Saving Trust is now in the early stages of setting up a heat pump trial.

Early commercialisation is also important, because new technologies take time to become familiar and institutional barriers, such as the dominance of installers on consumers' decision-making, take time to move.

BERR is currently consulting on a set of route-maps for the various sectors of the microgeneration industry and these should provide more detailed recommendations on a technology-specific basis.

Perhaps most significant of all though is establishing a clear and supportive framework for microgeneration. This will allow technology companies themselves to invest in the technology, driving cost reduction through technology improvement and through initiating volume manufacture. The key to long-term cost reduction is mass production and deployment: there is a well-established link between production volume and cost. Long-term targets for microgeneration will help to give industry confidence that market transformation will occur. A piece of research investigating the impact of targets is currently being carried out as a joint initiative between BERR, Energy Saving Trust, industry representatives, and other interested parties.[70]

Recommendations

Government should ensure that any subsidy is evaluated on a set of criteria which includes nearness to market, carbon savings, potential numbers of applications, innovation, benefit to UK plc, and security of supply.

Government should redress the current imbalance of R&D investment by using the Environmental Transformation Fund to support household measures.

Government should support early commercialisation measures, including field trials.

Government should establish a clear and supportive framework for microgeneration in order to encourage investment in companies delivering these technologies. Without pre-empting the results of the BERR consortium research, consideration should be given to targets for this sector on the basis of evidence collated from that work.

Product standards

In a nascent market, it is crucial to instil confidence amongst consumers, particularly in light of reports about rogue traders within the solar thermal industry, for example. Customer confidence in installers is paramount and attracting companies with good trading reputations is essential to the development of the industry.

69 Open University and Energy Saving Trust, op. cit.

70 See details of project at: http://www.berr.gov.uk/energy/sources/sustainable/microgeneration/research/page38208.html

The most effective way that Government could support the development of a set of robust product standards for all microgeneration technologies is to work with industry and learn lessons from other sectors such as the gas boiler industry (CORGI's codes of practice).

This approach is being used develop a set of product standards for microCHP. The Energy Saving Trust is developing a Publicly Available Specification (PAS) 67 facilitated by the BSI (British Standards Institute) to provide an agreed basis for 'Laboratory Test Conditions' to determine the thermal and electrical performance of microCHP units with max capacity below 70kW. The test results are intended to feed into a higher-level procedure being developed by the BRE, sponsored by Defra, to determine a Seasonal Performance Index for microCHP.

In addition, the British Wind Energy Association is developing guidance notes on health and safety for microwind with industry and the Health and Safety Executive. The notes will provide guidance on the manufacturing, installation, maintenance and decommissioning for both free-standing and building-mounted turbines. BWEA are also reviewing product standard development.

Recommendation

Government should actively work with other sectors of the microgeneration industry to encourage them to follow suit.

Other technological issues

There is a need for parallel investment in other technological issues, not just the technologies themselves.

For example:

- How do the technologies work together when more than one is installed in a household?
- Are there more carbon-efficient uses of existing technologies – for example, using wind energy for heating water rather than generating electricity and wasting energy in the inverter? Using solar thermal for space heating?
- One of the fundamental problems of renewable energy is the inability to predict supply on a short-term basis. Therefore storage solutions (heat sinks, thermal storage, phase-change materials that take advantage of latent heat released as they change from solid to liquid) and demand management are vital to ensure a fully functioning and efficient system.
- Regulatory instruments, such as pricing structures and ability to meter exports should be explored further. This could include ways of charging and rewarding people based on use of peak load electricity; for example, consumers could be paid to reduce peak demand either through behavioural change or through

'smart' appliances that can decrease the amount of power used at times of low grid frequency (i.e. at high demand) and people with storage could be paid for that benefit.

- There is a more urgent need to look at embodied energy as building fabric improves and in-use energy comes down

Recommendation

Investment should be made in the peripheral technological issues as well as in the technologies themselves. The Environmental Transformation Fund could be one source of funding for this type of activity.

Grid de-carbonisation

As the grid decarbonises, the CO_2-reduction benefits of certain technologies becomes less significant – in particular all gas-based CHP technologies, whose CO_2 advantage is based on the higher CO_2 of grid electricity displaced by CHP electricity generation compared to the input fuel (natural gas). Electric boilers, ground source and air source heat pumps benefit from reduction of grid CO_2 intensity. However, the model does not consider the additional cost of grid electricity in high de-carbonisation scenarios, so will underestimate the impact of microgeneration in this case.

It is clear that any policy developed in support of microgeneration needs to be developed in tandem with an overall grid decarbonisation policy. It may also be prudent to concentrate on off-grid and heat-producing technologies – there are 4.4 million homes off the gas network in the UK and this could be a focus for early activity concentrating on heating technologies. This is particularly important where there are targets for significant electricity de-carbonisation, as in Scotland (which has a target to source 40 per cent of its grid electricity from renewables by 2020). However, if a market developed for renewable electricity tariffs, all of this renewable electricity could be taken up by those wanting to buy into large-scale renewable generation and microgeneration would provide genuinely additional carbon savings, displacing the higher-carbon content of the rest of the grid.

Recommendation

Government to create a unified policy for domestic microgeneration and grid decarbonisation, so that overall CO_2 savings are achieved at lowest cost.

Appendix 1:
Glossary

ASHP	Air Source Heat Pump
BERR	Department for Business, Enterprise and Regulatory Reform (formerly DTI)
CERT	Carbon Emission Reduction Trading scheme (formerly EEC)
(micro)CHP	(micro) Combined Heat and Power
CO_2	Carbon dioxide
CPBT	Carbon Payback Time
Defra	Department for Environment, Food and Rural Affairs
DTI	Department of Trade and Industry (now BERR)
EEC	Energy Efficiency Commitment
EPBT	Energy Payback Time
EPCs	Energy Performance Certificates
ESCO	Energy Service Company
GSHP	Ground Source Heat Pump
LCBP	Low Carbon Building Programme
LPG	Liquid Petroleum Gasoline
MO	Microgeneration Obligation
PV	Photovoltaic
RO	Renewables Obligation
ROCs	Renewable Obligation Certificates
SAP	Standard Assessment Procedure for Energy Rating of Dwellings
SCHRI	Scottish Community and Householder Renewable Initiative

Appendix 2:
Brief description of modelling

The full methodology report can be found on the Energy Saving Trust website[1].

Background: results from the 2005 DTI report 'Potential for Microgeneration: Study and Analysis'

Key findings from the DTI study were:

- Timely regulation of cost-effective technology is important to achieving significant microgeneration capacities and CO_2 reductions by 2030.
- A fair value on exported electricity is vital to achieving significant CO_2 savings by 2050 from microgenerators.
- Stirling CHP units could be a major contributor to UK domestic energy requirements.
- Once commercialisation is achieved, fuel cell CHP could be the dominant microgen electricity generator.
- Small wind commercialisation could be achieved near term, with a significant contribution to CO_2 reduction.
- Photovoltaics have significant potential, but the cost of energy is likely to remain high for some time.
- Biomass heating and ground source heat pumps have potential for CO_2 reduction, particularly when competing with oil or electric heating, though their potential is limited by the lack of appropriate housing.
- Solar water heating – limited cost reduction potential results in low growth.
- Numerous microgeneration technologies could produce cost-competitive energy after 2020.
- A substantial percentage of UK electricity demands could be supplied by microgenerators, with >15 per cent domestic CO_2 reductions possible, following intervention.

Limitations of a lifetime cost model

The DTI study used a simple lifetime cost-reduction model to drive uptake of selected microgeneration technologies. Though this is a rational engineering approach to determining uptake, in practice most consumers do not measure whole-life costs and instead make their purchases using their individual time horizons. As examples, the historic uptake rates for loft and cavity wall insulation and installation of energy-efficient light bulbs have been much lower than their lifetime benefits would suggest.

The failure to consider lifetime costs can arise for a variety of reasons: the inability for private landlords to recoup their investments, insufficient awareness of costs and benefits (extending to an inability or lack of interest to calculate, accurately, net present values and asymmetry in valuing costs and savings).

Since house prices (or rents) do not, in general, currently reflect energy efficiency, those who move early do not realise the full cost benefits of their investments. Therefore there is merit in developing a model which allows flexibility in consumer discount rates and periods with respect to microgeneration purchase.

1 http://www.energysavingtrust.org.uk/download.cfm?p=0&pid=1122

The new model

Introducing LOGIT calculations for consumer decision-making.

Evaluating what are the best ways of accelerating the growth of preferred technologies requires an understanding of consumer decision making.

A popular method to predict technology uptake using consumer data is to determine (or postulate) consumer priorities, and develop a measure of the 'utility' of each technology according to how well it satisfies the priorities of the consumer. Typical priorities in the context of energy purchase are up-front costs and running costs. The consumer explicitly or implicitly compares the utilities of different alternatives. The technology with the greatest utility (or lowest disutility) then has the highest probability of purchase.

Clearly, different consumers may have different priorities and therefore have different preferred choices. Where these differences are known (e.g. householders with different heating demands) it is possible to develop separate models for each consumer group.

Numerous models have been developed to reflect the lack of knowledge (or error) in the exact parameters affecting each consumer's evaluation of utility. One of the most widely used models is the LOGIT model. This applies a Gumbel probability distribution (similar to the normal distribution) to the error in variations between individual consumers' priorities.

Note that unlike epidemic diffusion models, a LOGIT model does not inevitably predict sigmoidal growth of technologies. Rather, any resulting S-shaped behaviour derives from relative improvements of a new technology (e.g. cost reductions) relative to its competitors over time.

The new model:

- models the choices in front of consumers when evaluating a microgeneration purchase;
- incorporates non-cost attributes of technologies, such as the time required by the consumer and the space required by the technology;
- updates technology and fuel cost and CO_2 assumptions in light of recent market developments;
- allows a wide range of technologies to be examined with the ability to resolve different costs for different consumers;
- allows combinations of microgeneration options to be explored together; and
- is capable of examining a diverse mix of policy interventions, including combinations of policies, that affect technology, fuel and CO_2 prices, consumer awareness and behaviour, suitability of technologies for different dwellings and regulations on new and existing build, boiler replacement and more innovative regulations such as linking microgeneration installation with other critical trigger points for homes.

Consumer coefficients have been calibrated for heating technologies using historic data on the uptake of condensing gas boilers (slow until regulation imposed), the split between oil, electric and LPG heating, and consumer behaviour when installing loft or cavity wall insulation.

A three-pronged approach was used to calibrate consumer coefficients:

- Initially, an 'engineering' approach was taken to provide reasonable estimates for consumer coefficients, using estimates of value of time.
- These coefficients were then revised in line with literature on consumer discount rates and priorities (notably those obtained recently in the DEFRA/Oxera study of insulation uptake).
- Finally the model was calibrated against historical uptake rates and trends, particularly of condensing gas boilers, and the ratios of gas:oil:electric:LPG heating systems.

As with any model, a number of assumptions and approximations must be made. On the technology side, assumptions include the choices of technologies considered, their technical specifications (e.g. size, lifetime, heat:power ratios of CHP systems, efficiencies, capacity factors), and how they differ in the attributes that consumers are expected to care about (e.g. installed cost, running costs, cost savings). Importantly technology attributes are forecast until 2050 which inherently brings uncertainty.

With respect to fuels, the model considers only gas, oil, biomass LPG, and electricity (with different options for premium rate, economy, and exported electricity). Other fuels, for example hydrogen, are not considered. The model requires forecasting prices and CO_2 /kWh forecasts up to 2050. Fuel prices are volatile as shown by recent history. The CO_2 content of electricity may change depending on fuel security and supply for coal and natural gas, and in response to concerns on climate change.

To provide high resolution and accuracy, the model uses 72 different consumer groups. These groups allow technology uptake to be related to the characteristics of the purchaser and the property itself. The 72 groups are made from combinations of:

- New build during year of construction or pre-existing (e.g. it is easier to install ground source heat pumps, PV and solar thermal during construction than fitting onto an existing dwelling). There are 24 'existing build' consumer groups pre-2005. These have replacement/retrofit prices and attributes for technologies. The 'new build' post-2005 dwellings become 'existing' post-2005 dwellings in the subsequent year in the stock model.
- Compliance with 2005 Part L building regulations (e.g. post-2005 dwellings have lower heating demand than pre-2005 dwellings).
- Tenure (3 choices – owner occupier, private landlord, registered social landlords (RSLs). e.g. RSL and owner occupiers care more about fuel costs than private landlords).
- Gas connection (yes/no – e.g. Stirling and fuel cell CHP are relevant when there is a gas connection).
- House/flat (e.g. houses have more storage space for biomass, GSHP and roof-borne technologies).
- Urban/rural (e.g. wind capacity factors are higher in rural than in urban areas).

Technologies and technology attributes

The technologies are divided into 'primary heating' systems (boilers, CHP units and heat pumps), and 'discretionary' systems (active solar water heating, PV and wind).

Technology 'attributes' represent the underlying differentiable properties of technologies that consumers are expected to compare when evaluating the usefulness (or utility) of each technology. In the heating and discretionary purchase models, the common attributes are:

- Up-front cost – calculated by multiplying standard device costs/kW by size, adding installation costs and VAT, and subtracting subsidies where appropriate. The costs of all technologies have been updated from the 2005 DTI report on microgeneration with information from suppliers for 2007 prices. Median technology learning curves are prepared as in the 2005 DTI report.
- Annual maintenance cost – calculated as the typical price of a maintenance contract (including VAT) where available, or a percentage of upfront cost (as in the 2005 microgeneration report).
- Familiarity – lack of consumer familiarity is widely accepted to retard the growth of novel technologies. In both models a simple penalty is applied that depends logarithmically on the total number of units installed in the UK.
- Other attributes are described for each model in their appropriate sections. These other attributes include cost savings from offset and exported electricity, cost savings from lower heating bills, the physical space required to install the technology, the time required by consumers.

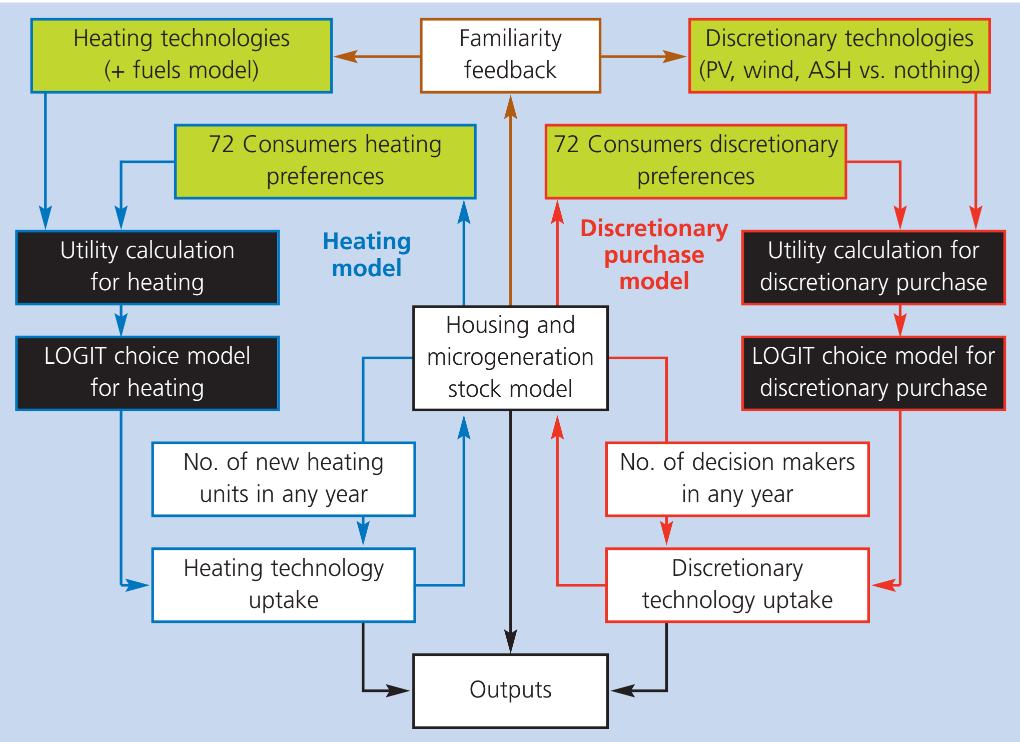
The familiarity of a technology is an attribute that acts as a feedback. It is postulated to depend logarithmically on the number of units installed.

Familiarity is recognised as an important feedback that helps or retards sales of specific technologies. In the two models, familiarity is modelled as a high penalty (equivalent to £500 on-cost) at low penetration (<1000 units installed), decreasing to zero if one million are present in the market. Technologies are modelled as benefiting in the utility calculation if more than one million units are present in the market (reflecting inertia or risk avoidance).

Development of two models for microgeneration technology purchase

When simulating possible purchases of microgeneration technologies, the choices offered should be exhaustive and relevant. The approach taken in this report recognises the important distinction between the purchase of a heating system, which is essential for all homes, and purchases of wind, PV and solar thermal which are optional. Though a subset of homes may receive heating from additional sources (for example the use of fires to heat living rooms in winter as well as central heating), in general each home has one 'Primary Heating' Technology. Primary heating technologies are installed at the time a home is built, or as replacements in the event of or in anticipation of boiler failure. The primary heating microgeneration technologies must compete with conventional heating technologies. An advantage is that typical new build and boiler replacement rates are well known and historic calibration is possible between modelled and observed data.

It is helpful to separate the essential and optional purchases. Consumer priorities and resulting purchasing behaviour for their primary heating system are not necessarily similar to those for optional purchases (at present, the purchase of PV, wind or solar thermal is essentially a lifestyle choice). Although consumers choose between a range of primary heating technologies, they ultimately pick one to use. In contrast, when deciding whether to install PV, wind or solar thermal, consumers also have the option of not purchasing. Also the date and frequency of decision making will be different between for primary heating and discretionary purchase decisions. A simplifying feature is that typical new build and boiler replacement rates are well known for heating technologies. Historic calibration of consumer behaviour is relatively straightforward for heating technologies – the penetration of condensing boilers in the UK offers a model for how consumers will adopt other new primary heating technologies. In contrast the flexibility to calibrate consumer behaviour separately with respect to discretionary purchase may be expected to be useful.



Stock model and outputs

The model is capable of generating the following outputs for any given year, with resolution by consumer type and technology type: Sales, numbers installed, heat generated, total fuel consumed, electricity generated (offset and/or exported), CO_2 emissions (or avoided), and amount spent (£). In addition the utilities of each technology can be compared for each consumer, allowing detailed understanding of what are the benefits and hurdles that need to be overcome for each technology.

The heating technologies

Ten distinct Primary Heating Technology types are modelled. Each option is assigned two sets of attributes (primarily differing in costs), one for retrofit and one for installation during construction of new build. The appropriate values are used for the utility calculation depending on the consumer.

A set of rules are developed so that consumers are only presented with the most relevant primary heating technologies for their homes.

As examples, it is recognised that:

- Biomass and ground source heat pumps are more appropriate for houses than flats and in the case of retrofit installation on an existing property, more appropriate for rural than for urban.
- Condensing gas boilers, Stirling engines and fuel cells are not relevant for homes without gas connection.
- All homes have the option of electric heating.
- Stirling engines, with high heat to power ratios, are best suited to houses built prior to 2005.
- Only homes without gas connections consider oil and LPG-fired boilers.
- Installations are cheaper (particularly for GSHP) for new build than for existing build – in the model only 'new build during construction' consumers calculate utilities from a distinct set of technology attributes.

Taken together, rules on suitability of homes for specific technologies are used to build up a matrix which eliminates irrelevant options from the utility calculation. In the base case, the suitability of properties for specific technologies is assumed constant up to 2050 (though this restriction is removed for specific policy interventions where necessary).

As a simplifying assumption, the cost of completely removing any existing central heating system is not included. A future refinement to allow for the cost of switching between wet radiators, electric storage heaters, and underfloor heating systems may be worthwhile.

For each CHP system, both heat and electricity power ratings are specified. Stirling CHP engines have intrinsically high heat to power ratios, and are usually sized according to the heating demand of a property. In contrast fuel cell CHP units can have heat to power ratios as low as 1:1, and are typically scaled for their electricity output. A 1kW fuel cell is well sized to meet many homes' electricity consumption.

3kW fuel cells are really only relevant in the case where electricity export is an important component of the business model.

The model considers four distinct options for fuel cells, based on electrical power rating options of 1kWe, with three effective average heat to power ratings between 1.5 and 5.5:1, and a 3kWe operating at a heat:power at 2.2.5:1, as shown in the table below.

Fuel cell power ratings and average heat:power ratios	Pre-2005	Post-2005
Flat	1kWe at H:P of 3:1	1kWe at H:P of 1.5:1
House	1kWe at H:P of 5.5:1 3kWe at H:P of 2.25:1	1kWe at H:P of 1.5:1 3kWe at H:P of 2.25:1

Discretionary technologies

Technologies considered in the discretionary model are solar thermal, PV and wind. Each technology is assigned two sets of attributes – allowing different costs for retrofit and in new build.

The two wind options allow resolution from wind speeds. Urban wind is modelled with 10 per cent capacity factor, whereas rural wind is assigned 17 per cent capacity factor.

The possibility of installing microgen is estimated at 50 per cent of houses and 10 per cent of flats. This determines how many consumers make a decision each year.

Under the base case, the option of making 'no purchase' has the highest utility and as such is favoured in the majority of cases.

A utility calculation shows that, using standard consumer discounting behaviour, the value of the energy generated from solar thermal, wind or PV does not offset the upfront costs. Lack of familiarity with the technology and installation remains an important penalty even in 2020.

Appendix 3:
Technology assumptions

Condensing Gas Boiler	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Capital cost/kWp	£/kWp	64.36	61.79	59.06
Heating efficiency		0.9	0.91	0.91
Up front capital+installation cost	£	2,499.55	2,439.04	2,374.89
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.211111	0.208791	0.208791
Annual maintenance cost	£	67.58	64.88	62.01
Consumer time required (inc. no. of days of installation)	days	2	2	2
Land required (m3)	m3	1	1	1

1.2kWe Stirling Engine	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	10.08	10.08	10.08
System Rated Power (ELEC)	kWp	1.2	1.2	1.2
Heat:Power Ratio		8.4	8.4	8.4
Export Proportion		0.33	0.33	0.33
Efficiency		0.9	0.9	0.9
Heating efficiency		0.804255	0.804255	0.804255
Up front capital+installation cost	£	3,710.04	3,416.11	3,309.72
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.169843	0.171061	0.175325
Annual maintenance cost	£	226.86	100.27	95.51
Consumer time required (inc. no. of days of installation)	days	5	3	3
Land required (m3)	m3	1	1	1

1 kWe FC (H:P=3, pre-2005 flats)	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	3	3	3
System Rated Power (ELEC)	kWp	1	1	1
Heat:Power Ratio		3	3	3
Export Proportion		0.33	0.33	0.33
Efficiency		0.88	0.88	0.88
Heating efficiency		0.66	0.66	0.66
Up front capital+installation cost	£	5,957.40	3,497.32	3,185.61
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	0.101957	0.105368	0.117308
Annual maintenance cost	£	428.05	207.81	179.91
Consumer time required (inc. no. of days of installation)	days	5	3	3
Land required (m3)	m3	1	1	1

3 kWe FC (H:P=2.25, pre-2005 houses)	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	6.75	6.75	6.75
System Rated Power (ELEC)	kWp	3	3	3
Heat:Power Ratio		2.25	2.25	2.25
Export Proportion		0.75	0.75	0.75
Efficiency		0.88	0.88	0.88
Heating efficiency		0.609231	0.609231	0.609231
Up front capital+installation cost	£	9,782.52	5,354.38	4,793.29
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	0.063973	0.068521	0.084441
Annual maintenance cost	£	577.87	280.55	242.88
Consumer time required (inc. no. of days of installation)	days	5	3	3
Land required (m3)	m3	1	1	1

Biomass	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.9	0.9	0.9
Up front capital+installation cost	£	4,652.65	4,299.59	3,843.61
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.003444	0.003444	0.003444
Annual maintenance cost	£	173.21	158.40	139.26
Consumer time required (inc. no. of days of installation)	days	5	4	4
Land required (m3)	m3	3	3	3

Ground source heat pump (GSHP)	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	5	5	5
Efficiency		3.16	3.16	3.16
Heating efficiency		3.16	3.16	3.16
Up front capital+installation cost	£	5,580.30	4,251.26	3,767.22
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.176508	0.173269	0.161934
Annual maintenance cost	£	108.43	75.71	63.79
Consumer time required (inc. no. of days of installation)	days	6	6	6
Land required (m3)	m3	2	2	2

Oil Boiler	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.852	0.855	0.855
Up front capital+installation cost	£	3,039.76	2,944.36	2,746.55
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.305164	0.304094	0.304094
Annual maintenance cost	£	89.89	85.99	81.89
Consumer time required (inc. no. of days of installation)	days	9	9	9
Land required (m3)	m3	3	3	3

Pure Electric	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	15	15	15
Heating efficiency		1	1	1
Up front capital+installation cost	£	1,988.13	1,914.74	1,762.58
Ongoing fuel costs/kWh heat output	£/kWh	0.06	0.06	0.06
Net kg CO_2/kWh heat	kg/kWh	0.56	0.55	0.51
Annual maintenance cost	£	39.70	38.12	36.43
Consumer time required (inc. no. of days of installation)	days	0	0	0
Land required (m3)	m3	0.8	0.8	0.8

Air source heat pump (ASHP)	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	8	8	8
Heating efficiency		2.8	2.8	2.8
Up front capital+installation cost	£	5,315.00	4,438.77	4,438.77
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.199202	0.195547	0.182754
Annual maintenance cost	£	117.50	117.50	117.50
Consumer time required (inc. no. of days of installation)	days	3	3	3
Land required (m3)	m3	2	2	2

1 kWe FC (H:P=5.5) pre-2005 houses	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	5.5	5.5	5.5
System Rated Power (ELEC)	kWp	1	1	1
Heat:Power Ratio		5.5	5.5	5.5
Export Proportion		0.33	0.33	0.33
Efficiency		0.88	0.88	0.88
Heating efficiency		0.744615	0.744615	0.744615
Up front capital+installation cost	£	5,957.40	3,497.32	3,185.61
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.153753	0.155614	0.162127
Annual maintenance cost	£	428.05	207.81	179.91
Consumer time required (inc. no. of days of installation)	days	3	3	3
Land required (m3)	m3	1	1	1

LPG	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.9	0.9	0.9
Up front capital+installation cost	£	2,921.58	2,852.42	2,779.09
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	0.233333	0.233333	0.233333
Annual maintenance cost	£	135.13	135.13	135.13
Consumer time required (inc. no. of days of installation)	days	5	5	5
Land required (m3)	m3	3	3	3

Condensing gas boiler in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Efficiency		0.88	0.88	0.88
Heating efficiency		0.9	0.91	0.91
Up front capital+installation cost	£	2,170.55	2,110.04	2,045.89
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.211111	0.208791	0.208791
Annual maintenance cost	£	67.58	64.88	62.01
Consumer time required (inc. no. of days of installation)	days	2	2	2
Land required (m3)	m3	1	1	1

1kWe FC (H:P=1.5, post-2005) new bld	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	1.5	1.5	1.5
System Rated Power (ELEC)	kWp	1	1	1
Heat:Power Ratio		1.5	1.5	1.5
Export Proportion		0.33	0.33	0.33
Efficiency		0.88	0.88	0.88
Heating efficiency		0.528	0.528	0.528
Up front capital+installation cost	£	5,663.40	3,203.32	2,891.61
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	-0.012	-0.00517	0.018707
Annual maintenance cost	£	428.05	207.81	179.91
Consumer time required (inc. no. of days of installation)	days	5	3	3
Land required (m3)	m3	1	1	1

3 kWe FC (H:P=2.25, post-2005) new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	6.75	6.75	6.75
System Rated Power (ELEC)	kWp	3	3	3
Heat:Power Ratio		2.25	2.25	2.25
Export Proportion		0.75	0.75	0.75
Efficiency		0.88	0.88	0.88
Heating efficiency		0.609231	0.609231	0.609231
Up front capital+installation cost	£	9,488.52	5,060.38	4,499.29
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	0.063973	0.068521	0.084441
Annual maintenance cost	£	577.87	280.55	242.88
Consumer time required (inc. no. of days of installation)	days	5	3	3
Land required (m3)	m3	1	1	1

Biomass in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.9	0.9	0.9
Up front capital+installation cost	£	4,652.65	4,299.59	3,843.61
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.003444	0.003444	0.003444
Annual maintenance cost	£	173.21	158.40	139.26
Consumer time required (inc. no. of days of installation)	days	4	4	4
Land required (m3)	m3	3	3	3

GSHP in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	4	4	4
Heating efficiency		3.16	3.16	3.16
Up front capital+installation cost	£	4,992.30	3,663.26	3,179.22
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.176508	0.173269	0.161934
Annual maintenance cost	£	108.43	75.71	63.79
Consumer time required (inc. no. of days of installation)	days	2	2	2
Land required (m3)	m3	1	1	1

Oil boiler in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.852	0.855	0.855
Up front capital+installation cost	£	2,170.26	2,074.86	1,877.05
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.305164	0.304094	0.304094
Annual maintenance cost	£	89.89	85.99	81.89
Consumer time required (inc. no. of days of installation)	days	8	8	8
Land required (m3)	m3	3	3	3

Electric boiler in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	15	15	15
Heating efficiency		1	1	1
Up front capital+installation cost	£	1,492.28	1,418.89	1,266.73
Ongoing fuel costs/kWh heat output	£/kWh	0.06	0.06	0.06
Net kg CO_2/kWh heat	kg/kWh	0.557766	0.547532	0.511712
Annual maintenance cost	£	39.70	38.12	36.43
Consumer time required (inc. no. of days of installation)	days	0.5	0.5	0.5
Land required (m3)	m3	0.6	0.6	0.6

ASHP in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	8	8	8
Heating efficiency		2.8	2.8	2.8
Up front capital+installation cost	£	5,052.50	4,176.27	4,176.27
Ongoing fuel costs/kWh heat output	£/kWh	0.03	0.03	0.03
Net kg CO_2/kWh heat	kg/kWh	0.199202	0.195547	0.182754
Annual maintenance cost	£	117.50	117.50	117.50
Consumer time required (inc. no. of days of installation)	days	2	2	2
Land required (m3)	m3	2	2	2

LPG in new build	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	20	20	20
Heating efficiency		0.9	0.9	0.9
Up front capital+installation cost	£	2,386.96	2,317.80	2,244.47
Ongoing fuel costs/kWh heat output	£/kWh	0.04	0.04	0.04
Net kg CO_2/kWh heat	kg/kWh	0.233333	0.233333	0.233333
Annual maintenance cost	£	135.13	135.13	135.13
Consumer time required (inc. no. of days of installation)	days	4	4	4
Land required (m3)	m3	3	3	3

Solar Thermal	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	2.1	2.1	2.1
Capacity Factor		0.073	0.073	0.073
Annual heat generated per KWp	kWh/kWp	639.48	639.48	639.48
Up front capital+installation cost	£	2,650.24	1,677.71	1,458.10
kWh heat generated/year	kWh/year	1342.908	1342.908	1342.908
Carbon dioxide saved	kg CO_2/year	318.9407	318.9407	318.9407
Annual maintenance cost	£	32.93391	25.16023	23.40489

Micro-Wind (urban 1kWe)	Units	2007	2020	2050
System Rated Power (ELEC)	kWp	1	1	1
Export Proportion		0.6	0.6	0.6
Capacity Factor		0.1	0.1	0.1
Annual electricity generated per kWp	kWh/kWp	876	876	876
Up front capital+installation cost	£	3,140.89	1,180.69	1,002.22
Value of offset electricity	£/year	31.47	30.99	32.12
Income from exported electricity	£/year	21.02	20.43	21.18
Carbon dioxide saved	kg CO_2/year	488.6028	479.6376	448.2595
Annual maintenance cost	£	69.20	26.01	22.08

PV	Units	2007	2020	2050
System Rated Power (ELEC)	kWp	2	2	2
Export Proportion		0.5	0.5	0.5
Capacity Factor		0.097	0.097	0.097
Annual electricity generated per kWp	kWh/kWp	849.72	849.72	849.72
Up front capital+installation cost	£	7,718.74	2,899.26	1,746.19
Value of offset electricity	£/year	76.32	75.14	77.90
Income from exported electricity	£/year	33.99	33.03	34.24
Carbon dioxide saved	kg CO_2/year	947.8895	930.497	869.6234
Annual maintenance cost	£	76.21	26.01	13.95

Micro-Wind (rural 1kWe)	Units	2007	2020	2050
System Rated Power (ELEC)	kWp	1	1	1
Export Proportion		0.6	0.6	0.6
Capacity Factor		0.17	0.17	0.17
Annual electricity generated per kWp	kWh/kWp	1489.2	1489.2	1489.2
Up front capital+installation cost	£	3,140.89	1,180.69	1,002.22
Value of offset electricity	£/year	53.50	52.68	54.61
Income from exported electricity	£/year	35.74	34.73	36.01
Carbon dioxide saved	kg CO_2/year	830.6248	815.384	762.0411
Annual maintenance cost	£	61.84	23.24	19.73

Solar Thermal (New Build)	Units	2007	2020	2050
System Rated Power (HEAT)	kWp	2.1	2.1	2.1
Capacity Factor	%	0.073386	0.073386	0.073386
Annual heat generated per KWp	kWh/kWp	642.8571	642.8571	642.8571
Up front capital+installation cost	£	2,271.64	1,438.03	1,249.80
kWh heat generated/year	kWh/year	1350	1350	1350
Carbon dioxide saved	kg CO_2/year	320.625	320.625	320.625
Annual maintenance cost	£	32.93	25.16	23.40

Wind (urban) new build	Units	2007	2020	2050
System Rated Power (ELEC)	kWp	1	1	1
Export Proportion		0.6	0.6	0.6
System Lifetime	years	10	10	10
Capacity Factor		0.1	0.1	0.1
Annual electricity generated per kWp	kWh/kWp	876	876	876
Up front capital+installation cost	£	2,748.28	1,033.10	876.94
Value of offset electricity	£/year	31.47	30.99	32.12
Income from exported electricity	£/year	21.02	20.43	21.18
Carbon dioxide saved	kg CO_2/year	488.6028	479.6376	448.2595
Annual maintenance cost	£	58.89	22.14	18.79

PV (new build)	Units	2007	2020	2050
System Rated Power (ELEC)	kWp	2	2	2
Export Proportion		0.5	0.5	0.5
Capacity Factor		0.097	0.097	0.097
Annual electricity generated per kWp	kWh/kWp	849.72	849.72	849.72
Up front capital+installation cost	£	6,848.19	2,447.52	1,392.26
Value of offset electricity	£/year	76.32	75.14	77.90
Income from exported electricity	£/year	33.99	33.03	34.24
Carbon dioxide saved	kg CO_2/year	947.8895	930.497	869.6234
Annual maintenance cost	£	76.21	26.01	13.95

Wind (rural) new build	Units	2007	2020	2050
System Rated Power	kWp	1	1	1
Export Proportion		0.6	0.6	0.6
System Lifetime	years	10	10	10
Capacity Factor		0.17	0.17	0.17
Annual electricity generated per kWp	kWh/kWp	1489.2	1489.2	1489.2
Up front capital+installation cost	£	2,748.28	1,033.10	876.94
Value of offset electricity	£/year	53.50	52.68	54.61
Income from exported electricity	£/year	35.74	34.73	36.01
Carbon dioxide saved	kg CO_2/year	830.6248	815.384	762.0411
Annual maintenance cost	£	58.89	22.14	18.79

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