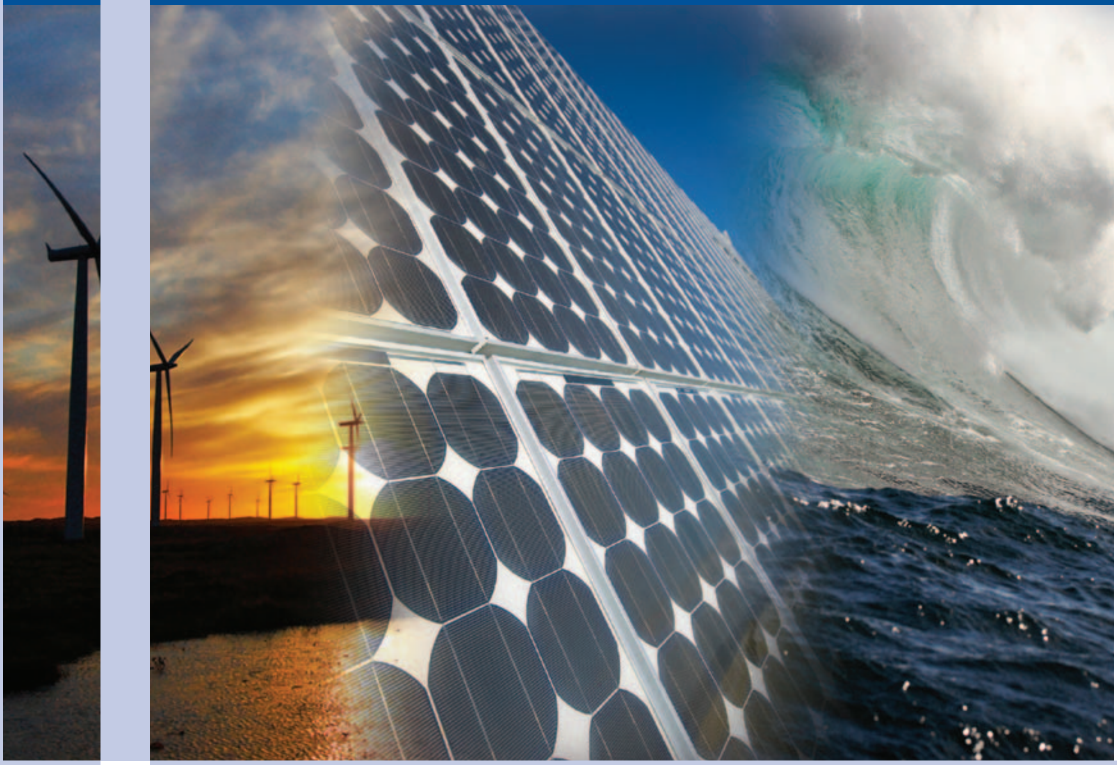
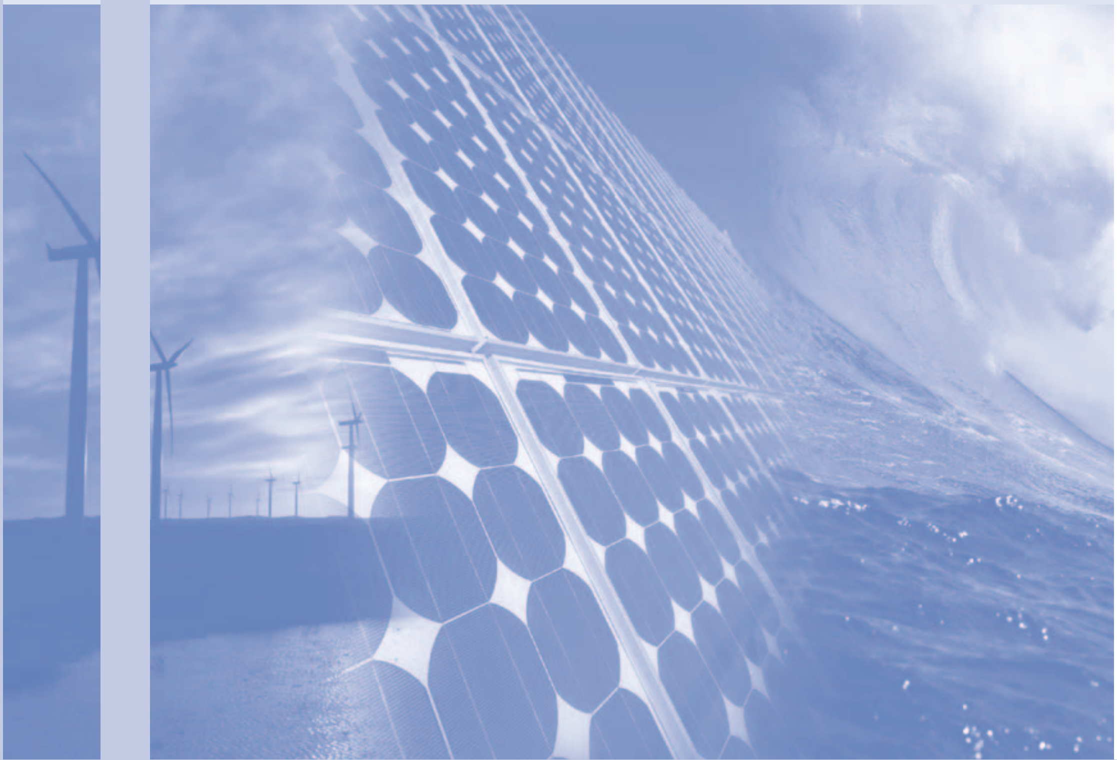


A review of microgeneration and renewable energy technologies

NHBC Foundation
Housing research & development in partnership with BRE Trust



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January 2008

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FOREWORD

As the industry plans to move towards the government's ambitious 2016 zero carbon homes target, one of its most pressing challenges is the use of microgeneration and renewable energy systems. The strict definitions of zero carbon, as laid out in the Code for Sustainable Homes, include appliances and lighting. With around 45% of the total UK energy output used to heat, light and power homes and buildings, the need to address energy consumption is fundamental to producing zero carbon homes.

Although the industry has nearly 10 years within which to make the necessary changes to construction systems and processes, the use of renewable and microgeneration systems is very much in its infancy. So this review is both timely and pertinent. The review assesses a variety of the current technologies for their likely capability, impact, payback periods and suitability for use in the domestic sector. In addition, it considers the legislative framework and the mechanisms local authorities are implementing to drive the uptake of these technologies.

For each type of system, detailed analysis is provided including potential carbon savings, capital costs, likely lifetime, barriers to use, risks and other essential data. The scope of the review encompasses cutting-edge innovations such as fuel cells and small hydrogeneration systems, alongside the more familiar technologies such as solar, wind and biomass generation.

Additional factors, such as daylight and thermal mass, also impact on heating requirements: this review discusses how these affect the design process and suitability of technologies. Taking into account the use of energy and water resources and the production of waste at the design stage will be crucial. The review provides much needed guidance to enable builders and developers to start this design process for renewable energy and microgeneration systems.

This review provides invaluable information for builders and developers on the road to zero carbon and will hopefully encourage wider debate and meaningful dialogue between industry, parliament and stakeholders.

Rt. Hon. Nick Raynsford MP

Chairman, NHBC Foundation

CONTENTS

Abbreviations and glossary of terms

Term	Definition
ASHP	Air-source heat pump
BERR	Department for Business, Enterprise & Regulatory Reform (formerly DTI)
CCL	Climate Change Levy
Daylight factor (DF)	Calculated by dividing the amount of indoor illuminance at a point on the working plane by the outdoor illuminance under overcast conditions
DCF	Discounted cash flow
ECA	Enhanced Capital Allowances Scheme – www.eca.gov.uk
EPBD	European Energy Performance of Buildings Directive
EST	Energy Saving Trust – www.est.co.uk
Fenestration	Windows and glazing products
GJ	GigaJoule
GSHP	Ground source heat pump
HECA	Home Energy Conservation Act
HTHW	High temperature hot water or steam
IRR	Internal rate of return. The interest rate, which, when used as the discount rate for a series of cashflows, gives a net present value of zero
kW_e	1000 Watts of electrical output
kWp	Kilowatt peak
kW_{th}	1000 Watts of thermal (heat) output
LEC	Levy Exemption Certificate
LPHW	Low pressure hot water
LTHW	Low temperature hot water
Monovalent system	In the context of this review, the heating system uses only one type of heat source
MTCE	1×10^6 tonnes of carbon equivalent
MW_e	1 000 000 Watts of electrical output
Oil equivalent	Tonnes of oil equivalent saving (TOE)
Organic Rankine cycle (ORC)	A non-superheating thermodynamic cycle that uses an organic working fluid to generate electricity
PJ	PetaJoule (1 × 10 to the power of 15)
PV	Photovoltaic (solar panel producing electrical energy)
REGO	Renewable Electricity Guarantees of Origin
ROC	Renewable Obligation Certificate
SAP	Standard Assessment Procedure for the energy rating of dwellings
SMEs	Small and medium-sized enterprises
Stirling engine	Also known as the hot air engine – a heat engine of the external combustion piston engine type
TWh	Terawatt hours
U-value	A measure of thermal performance of building components, measured in $W/m^2/K$
V_{ave}	Average velocity (ms^{-2})

1 Introduction

Many microgeneration and renewable energy technologies for domestic use are available on the market. However, it is not known how local authorities are prioritising the uptake of these technologies or how they are allocating priorities to ensure maximum uptake and improved cost-effectiveness. In order to address this knowledge gap, the NHBC Foundation asked BRE to identify and report on the most appropriate available technologies at the building scale for reducing carbon emissions cost-effectively, and the issues associated with them.

This review:

- Identifies the legislative instruments currently used by local authorities to promote the uptake of these technologies, and evaluates how these are currently being used.
- Identifies those technologies that are appropriate for UK domestic buildings and the barriers to their uptake.
- Quantifies the costs and carbon benefits associated with the technologies under investigation, their current market penetration and their state of development.
- Considers some likely developments in future policy, legislation and markets and how these may affect the technologies under consideration.

In this review, BRE has considered the following issues:

- Descriptions of the technology with some of the issues surrounding it and the carbon saving benefit.
- Future developments and trends, barriers and routes to market.
- Policy makers, implementers and influencers involved with the technology.
- Current and future legislative impacts.

Each technology has been addressed in turn with its own datasheet provided to make the presentation of relevant information as concise as possible.

2 Methodology

The first step of the research was to liaise with the NHBC Foundation to agree a list of technologies to be assessed, following which a standard template was developed to capture the overview information to be provided within this review.

This template was completed using a combination of the individual knowledge of the experts and desk-based research. Findings from previous studies conducted by BRE and others were also used. References to previous research have been included.

Technologies reviewed:

1. Biomass systems
2. Solar photovoltaic (PV) systems
3. Solar hot water systems
4. Wind power systems
5. Ground source heat pumps
6. Air source heat pumps
7. Absorption heat pumps
8. Small-scale hydroelectric systems
9. Micro combined heat and power (CHP) systems
10. Renewable combined heat and power (CHP) systems
11. Fuel cells.

The desk-based research was undertaken on the following issues:

- Whole-life environmental impact of the technologies.
- Issues including the site constraints, technical issues, safety, perception and costs.

- Local authority planning requirements for microgeneration and renewable technologies.
- A summary of the Department for Business, Enterprise & Regulatory Reform's (BERR's) Microgeneration Certification Scheme developed by BRE for products and installers.

  The Microgeneration Certification Scheme underpins BERR's grant scheme, the Low Carbon Buildings Programme, under which grants are available to applicants using products and installers certified under the scheme. The scheme evaluates products and installers against robust criteria for each of the microgeneration technologies, and aims to help build a rapidly growing microgeneration industry based on quality and reliability, which will make a substantial contribution to cutting the UK's dependency on fossil fuels and its CO_2 emissions.
- BERR's Microgeneration Strategy

The template covers information such as:

- Typical annual energy, carbon and cost savings
- Expected lifetime energy, carbon and cost savings
- Cost-effectiveness expressed as simple payback
- Capital costs
- Current state of market development
- Spin-off benefits that might arise from the technology
- Particular market barriers and risks associated with the technology
- Legislative and policy issues relating to the technology.

3 Domestic energy use

In 2005 the UK used 172 000 000[1] tonnes of oil equivalent (7206 PJ or 2002 TWh). Of this, 27% or 540 TWh was used in the domestic sector. Using DEFRA conversion factors, this resulted in the release of nearly 224 million tonnes of CO_2 and cost householders around £21 billion.

In contrast to the variety of methods used to build institutional and commercial buildings, all domestic properties tend to have similar construction processes and similar installed energy services, which make predictions of energy use and potential energy savings simpler and more reliable.

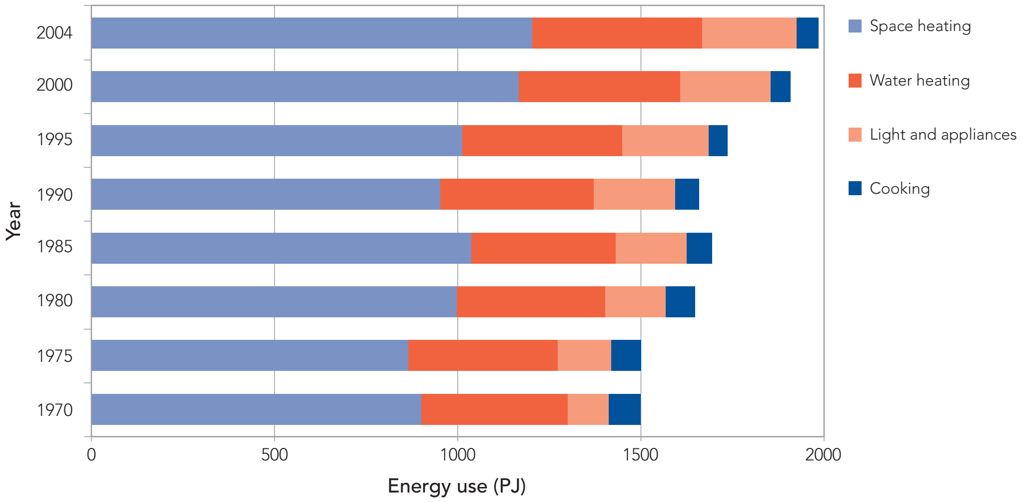

Figure 1 Energy use in domestic properties (from the Domestic Energy Fact File 2006, BRE).[2]

As shown in Figure 1, the energy used for heating continues to rise despite a reduction in 20-year average degree-day data. This is likely to be due to the increasing ownership of central heating and higher controlled internal temperatures. The use of hot water has seen significant increases from 1990 onwards, as a result of changed lifestyles. Electrical (lighting and appliances) use has more than doubled since 1970 and has seen a consistent increase year on year throughout the period. Cooking is the only identified energy end use that has decreased slightly over the period. This is for the domestic sector as a whole.

The total energy use per household has not been affected significantly, and the overall increase is mainly due to the increasing numbers of properties in the sector (Figure 2).

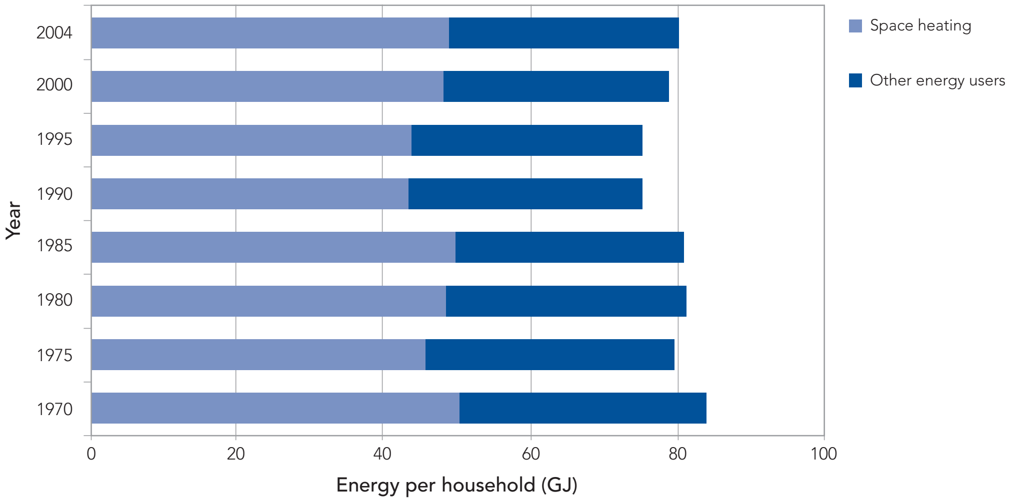

Figure 2 Energy use per household from 1970 to 2004. (Source: Domestic Energy Fact File 2006, BRE).[2]

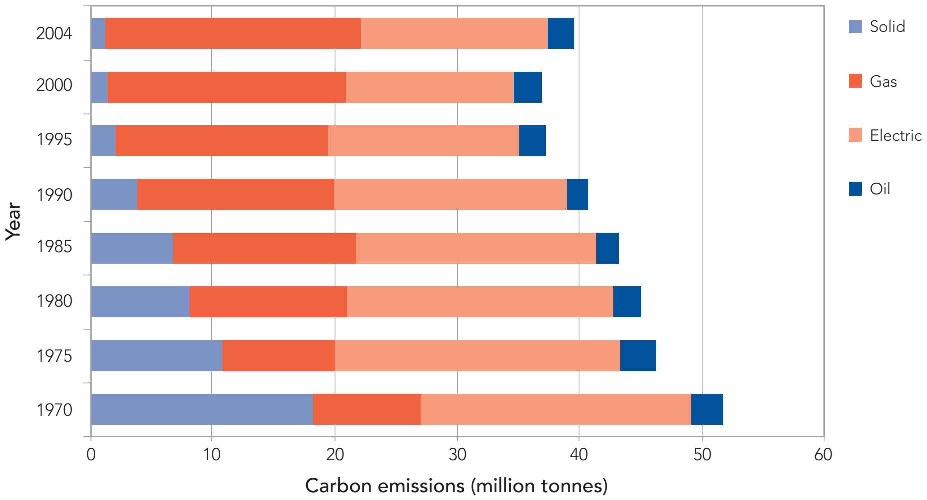

Figure 3 Carbon emissions for the domestic sector from 1970 to 2004. (Source: Domestic Energy Fact File 2006, BRE).[2]

Increases in the efficiency of electricity production together with a switch from coal to gas for heating have resulted in overall carbon emissions being reduced in the 30 years to 2000. However, recent gas price rises have led to an increase in the use of coal fired power stations to generate electricity, and the continuing increase in electrical use has resulted in this trend being reversed in 2004.

4 Energy implications of building design, fabric and services

Energy to directly heat, light and power our buildings accounts for around 45% of the total UK energy use, but if the energy used to manufacture and transport materials to site for construction purposes and the general transportation of building occupants between buildings is added, energy use attributable to the domestic sector will greatly exceed half the UK total.

Operating a building has a higher environmental impact than its construction and demolition. This is due to the extended length of time for which these buildings will be operating – often exceeding 50 years, and in some cases extending over a number of centuries. Much of this impact is built in at the design stage, and improving the efficient use of resources (including energy, water and waste) at this stage can make an enormous difference to overall running costs. Speculative developers generally do not consider running costs when these are to become the responsibility of the owner.

New buildings are expected to have at least a 60-year design life, and it is commonly expected that the installed services will be replaced within 10 to 20 years. In reality, many new buildings will have to improve on these figures, as much of the existing stock currently does. Many buildings in our towns and cities are over a hundred years old, and some still have inefficient boilers that pre-date the 1950s. The assumption that upgrades and replacement will take place within current predicted lifetimes is misleading and potentially costly for the bill payer and the environment.

Many of the significant energy-saving opportunities are available only at the initial design stage. For example, decisions regarding a building's orientation (say, to maximise daylight) and the thermal mass of the building fabric will have an impact on the choice of heating systems installed throughout the building's life. A north–south-facing orientation reduces the need for electric lighting, which reduces energy costs (as well as the associated heat gains from lighting) and at the same time provides a roof surface ideally aligned to maximise the opportunities for solar renewable technologies (PV and thermal).

However, this orientation can increase solar gains, which can cause uncomfortable over-heating and result in the installation or retrofit of an energy-consuming mechanical cooling system to overcome this. These effects can be reduced. Some advanced glazing systems can filter out the infra-red energy from sunlight. External shading can also be used to prevent direct penetration of sunlight during peak summer periods.

The construction materials used will affect the heating strategy to be employed. Heavy buildings have slower response times to heating and cooling (from both internal and external sources), allowing the building to use slow response heating systems such as under-floor heating and benefit from night cooling techniques.

Lightweight buildings can experience relatively large variations in internal temperature and require faster responding heating such as wet central heating systems (radiators). They may also require a cooling strategy such as air conditioning, which is becoming an increasing common feature in many high-density urban residential developments. During hot weather when the overnight temperature fails to drop below 12°C both construction types may experience uncomfortable over-heating, but the heavyweight construction will show a delayed response, which may allow it to 'ride out' the hot spell if it does not occur over an extended period.

Increasing airtightness and insulation levels and greater quantities of electrical equipment being used within dwellings can further increase the risk of over-heating. This is the reason for the increasing need within the Building Regulations to demonstrate how over-heating will be tackled at the design stage of a building to prevent the retrofit of mechanical cooling systems (often over-sized and inefficient) during the building's operational life.

Smaller heating systems may be required as a result, and specifying the most efficient lighting and appliances together with good controls could reduce the need for mechanical cooling to a level that allows passive cooling techniques to be feasible. Such techniques include secure night cooling, cross ventilation and passive stacks.

But in order to ensure that the dwelling operates as it is designed to, occupants need to understand and use the building's features and controls. Information to enable them do this forms part of the Home Information Pack.

Although the majority of the operational energy spend will be dictated by the design features of a dwelling, it is possible to improve energy use during refurbishment or during minor works. During refurbishment, the building fabric can be upgraded, insulation levels can be improved, and the heating needs re-evaluated and the system sized accordingly. During minor works, the following may be considered:

- Installing draught proofing and seals around windows, loft hatches and so on.
- Replacing some windows and upgrading to 'advanced' glazing.
- Fitting external shades to the building on the most exposed sides.
- Installing or upgrading heating and lighting controls.
- Replacing older inefficient systems – eg replace boilers over 15 years old.

5 Technology overview

When specifying these technologies it is recommended that only installers and products certified by the Microgeneration Certification Scheme are used (www.uk-microgeneration.org.uk).

5.1 Biomass systems

5.1.1 General description of the technology

'Biomass' in the domestic sector nearly always refers to wood fuel, as wood chip is rarely suitable at this scale. Remember, biomass is only a renewable resource if the trees are replaced once felled for fuel:

Logwood – derived from coppiced, pollarded, or felled trees with minimum processing, but which does need prolonged seasoning to reach the desired moisture content.

Wood pellets – which are formed from dry seasoned wood waste (eg from furniture factories) and which suit fully automated fuel handling and combustion control.

The technologies available for the domestic sector include:

Log stoves – manual feed; they provide radiant and convective heating or may be fitted with a back boiler to provide water and/or space heating. Clean burn and catalyser models produce less smoke than ordinary models. **Efficiencies: typically 70% – compared with open hearths at 15%.**

Ranges – manual feed; they have hob tops and usually roasting and baking ovens. Back boilers for water and/or space heating are optional. **Efficiencies: typically 60%–70%.**

Pellet stoves – automatic control of operation, including air supply (via fans) and fuel delivery to burner from integral fuel hopper, allows efficient operation and extended periods between refills (typically every 24h). Some are fitted with back boilers for water and/or space heating. They need a mains electricity connection for the fuel feeder, combustion and convection fans, and control system. **Efficiencies: typically 80%.**

Log boilers – automatic control of operation including air supply (via fans) allows efficient operation and extended periods between refills (typically every 12h). They are plumbed into the LPHW (low pressure hot water) circuit, which heats the radiators (or underfloor heating) and the hot water cylinder. Most need electricity connection for the combustion fan and control system. **Efficiencies: typically 80%.**

Pellet boilers – automatic control of operation, including air supply (via fans) and fuel delivery to burner from integral fuel hopper, allows efficient operation and extended periods between refills (typically every 24h). They are plumbed into the LPHW circuit which heats the radiators (or underfloor heating) and the hot water cylinder. A mains electricity connection for the combustion fan and control system is required. **Efficiencies: up to 90% claimed – can lead to deposition of tar and acids.**

Points to remember:

- Not all biomass equipment is approved for operation in smokeless zones.
- Some models have very hot (>200°C) exposed surfaces.
- Never oversize as low output levels can result in incomplete combustion, tar formation in flues, etc. and shorten system life.
- Always stand appliances on a suitable hearth with a suitable surround, and use an appropriate flue system: these can be expensive, and might cost more than the appliance. Some wood pellet appliances may be used with a balanced flue, a much cheaper arrangement. Existing chimneys designed for open fires are generally not suitable for modern controlled combustion devices without at least having a liner fitted.
- Modern homes can be *too* airtight: it may be necessary to run an outside air supply to the appliance.
- A dry, covered fuel store is required with adequate space – wood is bulky, and often bulk discounts depend on logs or pellets being delivered in sizeable quantities, eg tonne loads.
- Burning wood requires some effort to supply fuel and remove ash. Door glasses and flue ways must be cleaned periodically.
- When not in use for extended periods (eg over the summer), appliances need to be thoroughly emptied of ash, stripped internally, and cleaned out to avoid corrosion problems.
- Flues should be inspected pre- and post-heating season, and swept as necessary.
- If devices are not fitted with automatic ignition, then once lit they will stay lit whether there is a demand for heat or not. Slumbering, ie burning with a low flame, continues to consume fuel and produce some heat, usually in the range 10%–15% of rated output.
- If heat dumping (usually to a single radiator) during boiler slumber periods is undesirable, then a thermal store can be incorporated into the LPHW circuit: this can accumulate heat for later use and also help to meet peak heat demands, thus also addressing another problem – the inclination to oversize the boiler (see third bullet point above).

5.1.2 Influencing factors

Table 1 Influencing factors for biomass

Location	Because of capital costs, human input (the requirement to fill the biomass boiler), and fuel price disparities, biomass systems are not usually installed where gas is available. Space for fuel storage, and to accommodate the heating equipment (which is usually larger than the equivalent gas- or oil-fired device), is required. Biomass appliances are not available for wall-mounting. Logs are more readily available in rural or suburban locations. If bought green or part-seasoned then a large storage space is required, and also a system of stock rotation. Logs are often delivered in quite large commercial vehicles, and loads can cause traffic disruption if left on the public highway. There are areas of the UK without an established wood pellet supply infrastructure, where delivery can be a heavy surcharge to the purchase price.

Table 1 (continued)

Building type	Equipment that slumbers is best suited to high heat loss and high thermal mass buildings. With certain types of construction (eg timber frame), it is not always easy to retrofit flues.
Building occupation	Most off-gas-grid dwellings could accommodate modern biomass installations. Continuously occupied houses with high thermal mass and long heating seasons are particularly well-suited.

5.1.3 Carbon savings

At 75% annual average boiler efficiency:

- Where the alternative is oil-fired central heating, wood displaces 0.33 kg of CO_2 per kWh of delivered heat.
- Where the alternative is coal-fired central heating, wood displaces 0.66 kg of CO_2 per kWh of delivered heat.

5.1.4 Cost-effectiveness

It is difficult to calculate savings with log burning equipment:

- Many households (especially farming families) burn wood grown on the property.
- Logs are typically priced by the 'load' and not on energy content.

Wood pellet is a standard commodity and, reflecting the fact that manufacturing and transporting it uses fossil fuel, its price is usually linked to that of heating oil. Allowing for conversion efficiencies, wood pellet heating should be no more expensive than oil-fired heating, and certainly cheaper than using LPG or electricity. This reckoning does not take capital expenditure into account: a wood pellet boiler installation with fuel store is considerably more expensive than the equivalent oil-fired boiler plus bunded tank.

5.1.5 Local impact

A well-designed wood-burning installation using good-quality dry fuel will usually emit clear fumes, with grey haze occasionally.

Table 2 Impacts of biomass

Noise and vibration	Some people find the fan noise of certain wood pellet stoves intrusive.
Visual impact	Flue installations may be classed as 'permitted development', ie planning permission is not required – although it is wise to check. Planning permission might be needed in conservation areas and national parks, and on listed/heritage buildings.
Other	Buying locally produced wood fuel instead of fossil fuels boosts the local economy.

5.1.6 Complementary technologies

In a well designed system, wood fired heating and solar water heating can be complementary.

5.1.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per typical system: wood pellet central heating for a three-bedroom 1950s house	Energy saved: nil compared with oil fuel. Oil displaced: ~18 000 kWh. CO_2 displaced:* ~4500 kg.
Lifetime energy, carbon and cost savings (25-year useful life)	Energy saved: nil compared with oil fuel. Oil displaced: ~450 000 kWh CO_2 displaced:* ~112.5 tonnes.
Cost-effectiveness – simple payback	N/A – capital expenditure higher. Parity on running costs with oil systems at present. Future trends depend on future [fossil fuel : wood pellet] price ratio.
Typical capital costs (existing building retrofit)	£6000+ installed for 15 kW boiler.
Potential for savings in buildings	Depends on whether there are competing wood pellet suppliers in the locality.
Current state of market development	The (mostly imported) technology is mature but needs further promotion, so that rationalising and designing for – and installing – wood heating systems becomes a standard task for designers/ builders/plumbers/heating engineers.
Typical capital costs (new build)	£6000+ installed for 15 kW boiler.
Typical lifetime	25 years.
Additional benefits	Regional economy benefits. Could be preventing wood waste from being sent to landfill.
Market barriers and risks	Some house types are difficult to retrofit; some dwellings lack space for equipment; some occupants object to tending equipment. Low risk – generally reliable.
Potential for market advancement	Low, unless wood/oil installation price differential decreases. Overcoming negative press from existing poorly performing 'wood heating for its own sake' installations.
Legislative and policy issues	The implementation of the potential Renewable Heat Directive would have an impact on the uptake of biomass systems if it was introduced in the future. Any future updates to Part J of the Building Regulations (Combustion Appliances and Fuel Storage Systems)[3] would also impact on the biomass market.

* This figure does not include any carbon emissions from fuel transport.

5.2 Solar photovoltaic systems

5.2.1 General description of the technology

The energy in sunlight is converted directly into electricity by photovoltaic (PV) cells, which are semiconductor devices. No moving parts are involved. Individual cells only generate low voltages and currents, so they are usually grouped in rectangular 'modules' that comprise a transparent cover, a metal mounting frame and a backplate, thus forming a weatherproof enclosure. Modules are often grouped into arrays. PV cells can also be moulded into solar slates or solar tiles for integration into roofs, or bonded onto glass or metal sheets for incorporation into architectural glazing and fascia systems.

Various types of PV technology use different semiconductor materials and manufacturing techniques. Cheaper variants convert only around 5% of the solar energy into electricity; some leading products achieve 18%. All types can capture energy when the sky is overcast, but maximum output is achieved when the sun is shining perpendicularly onto cells from a clear sky. Because of the wide variation in outputs, PV installations are not usually described in terms of their area but are rated according to their peak power output (kWpeak or kWp), defined using a standard method of measurement. The module areas currently required per kWp output for the different technologies are:

monocrystalline	8 m^2
multicrystalline	10 m^2
amorphous	20 m^2

Depending on UK location, between 900 and 1100 kWh of solar energy falls on each m^2 of unshaded surface annually. In most parts of the UK, PV installations will generate around 800 kWh annually per kWp of installed capacity. A 3 kWp installation should generate the equivalent of a small household's annual electrical consumption (2400 kWh), but this does not allow such an installation to supply the house directly, because of the mismatch in supply and demand:

- Peak power demand in many houses exceeds 10 kW.
- Maximum PV output is in summer, while maximum domestic electricity demand is in mid-winter.

A typical 'grid-connected' installation overcomes this problem by allowing the installation to put power into the domestic mains electricity supply in parallel with the local grid. Thus when the house demands more electricity than the PV can provide, the grid provides the 'top-up'; and when the PV is generating more energy than the house needs, the excess is exported to the grid. In order to connect to the grid, systems must comply with engineering recommendations G83/1 (systems of 16 A per phase or less) or G59 (systems over 16 A per phase). Most domestic installations would fall under G83/1 where the grid operator (known as DNO or Distribution Network Operator) only needs to be notified. Larger systems under G59 require prior permission for connection to be obtained from the DNO.

Some energy suppliers will buy energy electricity exported to the grid. Renewable Obligation Certificates (ROCs) may also be payable and OFGEM can advise on requirements.

The key component in such a system is the inverter, which converts the PV provided direct current (DC) electricity into 240 volts 50 Hz alternating current (AC), and does so in synchronism with the mains. For safety reasons PV inverters must shut down during power cuts.

Meters are also necessary:

- The array output meter measures how much electricity has been generated, so that ROC or 'green' revenue can be earned.

- Where, if appropriate, an export meter measures how much surplus power has been supplied onto the grid from the household, thus allowing additional revenue to be earned.

There are some off-grid PV-powered houses in the UK, but the installations need large and expensive storage batteries.

5.2.2 Influencing factors

Table 3 Influencing factors for solar photovoltaic systems

Location	The building or site should have good access to solar radiation. Rural and suburban sites are likely to have access to more sunlight for longer periods of the day than inner urban locations where other buildings can cast shadows. When any site is surveyed in winter, it should be checked for bare trees that might shade areas when in leaf. Ideally, PV arrays are sited on south-facing roofs pitched at 30° to 45° from horizontal. For flat roofs, angled mounting frame kits are available. Shallow angle mounting reduces energy capture and increases the risk of dirt accumulation. Highest UK solar insolation (solar radiation received at the earth's surface) is in south-west England and South Wales; it is lowest in north-east Scotland.
Building occupation	Most dwellings can benefit from solar PV systems. Households with high power demands that can be justified and are not the result of inefficient equipment and wasteful lifestyles are particularly well-suited: the maximum financial benefit is secured if all the PV power generated is consumed within the home.

5.2.3 Carbon savings

A typical domestic 1.5 kWp installation has an annual yield of around 1200 kWh, offsetting approximately 512 kg per annum of power station CO_2 emissions (standard UK grid generating mix).

5.2.4 Cost-effectiveness

Few solar PV systems manage to pay back the capital expenditure over their operating lives even if building-integrated (possible during construction, re-roofing or when an extension is added), where costs can be reduced by up to 20%.

Currently, PV systems can be financially beneficial to occupants if the installation is heavily subsidised or paid for by a third party. The use of PV to tackle fuel poverty is not recommended as the same capital can usually achieve better results if spent on other energy technologies.

5.2.5 Local impact

Solar PV installations are generally unobtrusive, and the arrays are silent in operation.

Table 4 Impacts for solar photovoltaic systems

Noise and vibration	Usually the only system noise is from the inverter cooling fans, which, if audible at all, should be no louder than computer cooling fans.
Visual impact	Solar PV generally comes under the scope of 'permitted development' so planning permission is not required – although it is wise to check with the local planning department. Planning permission will usually be needed in conservation areas and national parks, and on listed/heritage buildings where the PV surfaces – typically a glossy deep blue – might clash aesthetically. Modules are usually visible, although often not unattractive, and can be integrated within a building's cladding or roof structure, or incorporated within skylight modules. Where having a PV array on a house roof is undesirable, it could be mounted on a garage or shed, or even put at low level with adequate protection.
Other	PV installations can advertise the green credentials of their owners.

5.2.6 Complementary technologies

PV systems complement wind turbines, which generate most power in the winter months – and continue generating at night – and other renewable energy technologies that generate heat, such as solar thermal systems and heat pumps.

5.2.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per kWp	Electricity generated: 800 kWh; CO_2 displaced: 345 kg. If all electricity is consumed within the household, the money saved @ 8.5p/kWh is around £68.
Lifetime energy, carbon and cost savings (20-year useful life) per kWp	Electricity generated: 16 000 kWh; CO_2 displaced: 6933 kg. If all electricity is consumed within the household, the money saved @ 8.5p/kWh is around £1360.
Cost-effectiveness – simple payback	At the moment a system cannot generate sufficient energy to repay the installation cost over its lifetime.
Typical capital costs (existing building retrofit)	£6000 per kWp.
Potential for savings in buildings	Currently poor: PV is only attractive if the capital investment is by others (ie a funding scheme or a landlord).
Current state of market development	PV manufacturing is mature, but the technology is developing rapidly. Further development is needed to reduce price per kWp.
Typical capital costs (new build, building-integrated)	£5000 per kWp.
Typical lifetime	Manufacturers often give a 25 or 30 year guarantee. Output does degrade slightly over time (rate dependent upon technology).
Additional benefits	A better supply/demand match in holiday accommodation: low winter occupancy. New build: collectors built into roof/facade can displace areas of slates/tiles/glass etc.
Market barriers and risks	Currently price is the main barrier, with a low risk as they are generally very reliable.
Potential for market advancement	High – covered in Approved Document L1A 2006 or planning documentation.[4]
Legislative and policy issues	1. Revenue from power generated is lower in the UK than in other countries as any excess energy produced is often sold on to the national grid at a lower rate. 2. If legislation required all new build sales catalogues/house extension or refurbishment quotations to offer PV as an optional extra, and all works had in any case to be configured to allow PV to be retrofitted, this would move the market in favour of PV.

5.3 Solar hot water systems

5.3.1 General description of the technology

Solar collectors (panels) absorb solar radiation and convert it to heat which is transferred to a hot water cylinder by circulating fluid through a series of pipes to pre-heat the water in the cylinder. This pre-heated water is then further heated to useable temperature by an auxiliary system (boiler or electric immersion heater). Solar hot water systems do not usually contribute to the central heating system. There are two standard types of collector: flat plate and evacuated tube.

Flat plate collectors are simple but effective devices, comprising a dark plate within an insulated box with a glass or durable plastic cover. The plate is usually coated with a 'selective' coating to ensure that it has high absorption but low emissivity (heat loss by re-radiation).

Evacuated tube collectors are more sophisticated, with a series of metal strip collectors inside glass vacuum tubes. Their efficiencies are usually higher and they are more effective in cold weather because of their low heat losses, but they do tend to be more expensive than flat plate collectors, and succumb more easily to vandalism.

Both collector types can capture heat whether the sky is overcast or clear. Depending on UK location, 900–1100 kWh of solar energy falls on each m^2 of unshaded UK roof surface annually. The annual energy captured by typical designs is:

- flat plates: 380–450 kWh per m^2 of collector
- evacuated tubes: 500–550 kWh per m^2 of collector.

A typical solar domestic system features 4 m^2 of flat plate or 3 m^2 of evacuated tube, providing 50% to 65% of the energy required annually for water heating.

Most domestic solar systems are known as indirect systems. The pipes connecting the collector to the hot water cylinder connect to a heat exchange coil inside the cylinder. In this way the fluid circulating in the collector never comes into direct contact with the water in the cylinder (which ultimately comes out of the taps) and is therefore able to contain anti-freeze to protect the collector. The coil supplied by the solar system can either be in a dedicated solar cylinder that feeds pre-heated water to an existing domestic hot water cylinder served by a boiler, or it can be the lower coil in a purpose-built twin-coil cylinder where the upper coil is connected to the boiler to provide the 'top-up' when needed.

There are also direct systems that circulate the water contained in an existing domestic hot water cylinder through the collector and back again. As these systems cannot contain anti-freeze, the collector must be designed such that it is not damaged when the water inside it freezes.

Solar systems also require a circulating pump and a temperature control system. These are often powered by mains electricity but some systems use low power DC pumps powered directly from small photovoltaic modules.

All solar thermal systems need a means of storing heat. If a cylinder (as described above) cannot be installed, a device called a thermal store must be fitted: a thermal store holds a mass of solar-heated fluid, and it is the water being heated that flows through a heat transfer coil. Generally, thermal stores are compatible with mains pressure hot water. Accommodating the necessary cylinder or store in small dwellings can prove difficult, however.

Using a solar system to pre-heat the water entering a combination boiler, or any other type of instantaneous water heater, should be avoided unless the water heater is specifically designed to work with a solar system.

5.3.2 Influencing factors

Table 5 Influencing factors for solar hot water systems

Location	The building or site should have good access to solar radiation. Rural and suburban sites are likely to have access to more sunlight for longer periods of the day than inner urban locations where other buildings can cast shadows. When any site is surveyed in winter, it should be checked for bare trees that might shade areas when in leaf. Ideally, collectors are sited on south-facing roofs pitched at 30° to 45° from horizontal. For flat roofs, angled mounting frame kits are available. Some solar system designers offer dual-collector configurations for steep-pitched roofs with ridges aligned north–south. Because of fuel price differentials, solar paybacks are generally shorter in off-gas-grid areas.
Building occupation	Most dwellings can benefit from solar thermal systems. Households with high hot water demand and/or outdoor swimming pools are particularly well-suited.

5.3.3 Carbon savings

A typical domestic-sized installation has an annual yield of 1600–2000 kWh, reducing CO_2 emissions by 400–1000 kg per annum, depending on the fuel/energy displaced and conversion efficiency.

5.3.4 Cost-effectiveness

Solar thermal systems generally have payback times in excess of 10 years but actual figures depend on the system type and orientation, the availability of grants, the fuel/energy displaced and the energy conversion efficiency of the existing hot water supply. Installing solar thermal systems on an existing dwelling can cost up to 30% more than for new build due to the additional infrastructure required to support the system being added to existing hot water systems.

If the occupier has not paid for the installation (eg housing association properties), the payback is not their concern. Savings start immediately, and so this technology can help to relieve fuel poverty.

5.3.5 Local impact

Solar thermal installations are generally unobtrusive and extremely quiet in operation.

Table 6 Impacts for solar hot water systems

Noise and vibration	Usually the only system noise is from the small circulation pump which, if audible at all, should be no louder than a modern central heating pump.
Visual impact	Solar thermal generally comes under the scope of 'permitted development' so planning permission is not required – although it is wise to check with the local planning department. Planning permission will usually be needed in conservation areas and national parks, and on listed/heritage buildings. Collectors are usually visible, although often not unattractive, and can be integrated within a building's cladding or roof structure, or incorporated within skylight modules. Where it is undesirable to have collectors on a house roof, they could be mounted on garage or shed roofs and can even be put at low level.
Other	Solar collectors can advertise the green credentials of their owners.

5.3.6 Complementary technologies

Solar hot water systems can complement all other renewable energy technologies.

5.3.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per typical system	Solar energy captured: 1600–2000 kWh; fuel/energy displaced 2000–2500 kWh. 2250 kWh: CO_2 displaced 400 kg (gas) or 1000 kg (electricity). Gas @ 1.5 p/kWh: savings of around £34 Electricity @ 8.5p/kWh: saving of around £190.
Lifetime energy, carbon and cost savings (30-year useful life)	Fuel/energy displaced: 60 000–75 000 kWh. CO_2 displaced 12 tonnes (gas) or 30 tonnes (electricity). Gas @ 1.5 p/kWh: savings of around £1000 Electricity @ 8.5 p/kWh: savings of around £5700.
Cost-effectiveness – simple payback	8 to 20 years generally quoted: depends on fuel displaced, conversion efficiency, and fossil fuel/energy price escalation.
Typical capital costs (existing building retrofit)	£3000– £7000: depends on supplier.
Potential for savings in buildings	Good.
Current state of market development	The technology is notionally mature, but needs further development so that designing for and installing solar thermal becomes a standard task for all architects/draughters/ builders/ plumbers/heating engineers.
Typical capital costs (new build)	£1000–£4000.
Typical lifetime	30 years.
Additional benefits	In underfloor-heated new build with thermal store: possibility of some solar contribution to space heating in spring/autumn. New build collectors can displace areas of slates/tiles.
Market barriers and risks	Some heating systems make retrofit difficult; some dwellings lack space for equipment; but generally low risk and very reliable.
Potential for market advancement	High – covered in Approved Document L1A 2006 or planning documentation.[4]

5.4 Wind power systems

5.4.1 General description of the technology

The energy in the wind is converted into electricity by a wind turbine. Most domestic-scale wind turbines are horizontal axis devices – that is, miniature versions of wind farm machines. The turbine head comprising the blades and the generator rotates freely on top of the mast to align itself with the wind. In high winds many turbine heads are designed to yaw (turn out of the wind) to prevent overloading. Masts need strong foundations (often large concrete blocks cast in the ground): some masts are free-standing; others use stay wires attached to ground anchors. Usually a buried cable transfers electricity to the house.

There are very few vertical axis turbines on the market, though machines are under development. Vertical axis wind turbines are inherently simpler because they do not have to turn to face the wind; unfortunately – unlike horizontal axis machines – most designs do not self-start.

Building mounted wind turbines have recently appeared on the market but concerns have been expressed about the performance of such machines given the lower windspeeds and increased turbulence in built up areas. One early study[5] has shown that in some large urban environments, taking into account efficiency, lifetime and maintenance, micro-wind turbines may never pay-back their embodied carbon emissions.

Building mounted wind turbines also require caution due to the loads that can be imposed on the building structure and the transmission of vibration into the structure.

As regards energy yield, wind turbine location and siting are crucial determinants:

- Higher average wind speeds are desirable as the energy available is proportional to the cube of the wind speed.
- Obstructions from buildings and trees that reduce wind speeds and cause 'turbulence' should be minimised – to increase output and reduce wear and tear.
- The taller the mast, the better: near the ground, friction effects slow the wind considerably.

Wind turbines are rated by their power output in kW at a given wind speed – but not all wind turbine manufacturers use the same reference speed. Because of the cube law it is crucial to know the facts when comparing different machines. Fortunately, many manufacturers tabulate annual yields at various average wind speeds. For example:

4400 kWh @ V_{ave} 4m/s   8400 kWh @ V_{ave} 5m/s   13 000 kWh @ V_{ave} 6m/s

Generally, investment in a wind turbine should be recouped where there is a minimum average wind speed of 5 m/s; however, while a viable 2.5 kW wind turbine installation should generate at least 4000 kWh pa, which is equivalent to an average household's electricity consumption, it does not follow that a 2.5 kW installation can supply a house with all its electricity because:

- Peak power demand in many houses exceeds 10 kW.
- While maximum output is in winter and therefore coincides with maximum demand, there can be prolonged winter calms, especially when atmospheric pressure is high.

A typical 'grid-connected' wind turbine installation overcomes the problems described above by allowing the wind turbine to put power into the domestic mains electricity supply in parallel with the local grid. Thus when the house demands more electricity than the wind turbine can provide, the grid provides the 'top-up'; and when the wind turbine is generating more energy than the house needs, the excess is exported to the grid. In order to connect to the grid, systems must comply with engineering recommendations G83/1 (systems of 16 A per phase or less) or G59 (systems over 16 A per phase). Most domestic installations would fall under G83/1 where the grid operator (known as DNO or Distribution Network Operator) only needs to be notified. Larger systems under G59 require prior permission for connection to be obtained from the DNO.

Some energy suppliers will buy energy electricity exported to the grid. Renewable Obligation Certificates (ROCs) may also be payable and OFGEM can advise on requirements.

The key component in a grid-connected wind turbine system is the inverter, which converts the variable voltage and frequency three-phase alternating current (AC) electricity provided by the turbine into 240 volts 50 Hz AC, and does so in synchronism with the mains. For safety reasons inverters must shut down during power cuts.

Meters are also necessary:

- The wind turbine output meter measures how much electricity has been generated so that ROC or 'green' revenue can be earned, which at present is not likely to be relevant to the domestic scale.
- Where appropriate, an export meter measures how much surplus power has been supplied onto the grid from the household, thus allowing additional revenue to be earned.

There are some off-grid wind-turbine-powered houses in the UK, but the installations need large and expensive storage batteries.

5.4.2 Influencing factors

Table 7 Influencing factors for wind power systems

Location	The wind turbine should be located optimally for capture of 'clean' wind. Average wind speeds are likely to be higher in rural and outer suburban sites than in inner urban locations. Appropriate wind survey data sets should be used to assess site potential. Ideally, wind turbines are sited as far as possible from buildings, trees or hedges, and where their operating noise will not cause nuisance. The effects of mounting turbines on buildings must be researched prior to installation. There are generally higher average wind speeds in the west of the UK; the British Wind Energy Association database will provide an initial indication of any UK locality's wind energy resource.
Building occupation	Rural dwellings can benefit most easily from wind energy. Consuming the power generated within the home, rather than exporting it, secures the maximum financial benefit.

5.4.3 Carbon savings

A 2.5 kW wind turbine yielding 4000+ kWh a year offsets over 1700 kg power station CO_2 emissions (standard UK grid generating mix).

5.4.4 Cost-effectiveness

Larger wind turbine systems can prove financially beneficial on sites where the resource is good and the installation has been heavily subsidised or paid for by a third party; thus in the right circumstances wind turbines can assist in relieving fuel poverty.

5.4.5 Local impact

Wind turbine installations by their nature tend to be highly visible; there are people who object to the sight and sound (sometimes the perceived sound) of the blades rotating.

Table 8 Impact of wind power systems

Noise and vibration	The certified noise levels of different wind turbines must be compared. Steps must be taken to minimise any potential vibration problems from wind turbine systems.
Visual impact	Wind turbines are seldom classed as 'permitted development', so planning permission is usually required; it might take some negotiation in conservation areas and national parks, and near listed/heritage buildings. Some wind turbines look rather 'industrial'; others less so. If siting a wind turbine within a property's grounds proves difficult, it might be possible to pay for siting it on neighbouring land.
Other	Wind turbines can advertise the green credentials of their owners.

5.4.6 Complementary technologies

Wind turbines complement PV installations, which generate most power in the summer months, and electrically powered heat pumps, which typically deliver four units of heat for each unit of electricity they consume.

5.4.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per kW capacity, V_{ave} = 5.5 m/s	Electricity generated: 2000 kWh; CO_2 displaced: 860 kg. If all electricity is consumed within the household, the money saved @ 8.5p/kWh is around £170.
Lifetime energy, carbon and cost savings (20-year useful life) per kW capacity	Electricity generated: 40 000 kWh; CO_2 displaced: 17 200 kg. If all electricity is consumed within the household, the money saved @ 8.5p/kWh is around £3400.
Cost-effectiveness – simple payback	A well-sited, 50% grant funded 2.5 kW wind turbine could provide a simple payback within a period of about 15 years.
Typical capital costs (free standing wind turbines of 1 to 6 kW)	£3000 per kW capacity, full installation. Generally the larger the machine the lower the cost per kW.
Potential for savings in buildings	Good where there is a good wind resource.
Current state of market development	Wind turbine manufacturing is mature, but the technology is still developing. Demand is growing but is still insufficient for mass production to bring prices down, which is needed to improve domestic market. Designing and installing wind turbine systems needs to become a standard task for civil/electrical contractors.
Typical capital costs (building-mounted)	An installed cost of a 1 kW system for £1700 is typical.
Typical lifetime	Up to 20 years, with occasional maintenance and a mid-life overhaul.
Additional benefits	A better supply/demand match compared to PV. A simpler, cheaper installation is possible where 'raw' electricity is used unsynchronised (no inverter) for water/space heating only.
Market barriers and risks	Price, wind resource and planning are the main barriers; but they are low risk as they are generally very reliable.
Potential for market advancement	High – covered by various planning ordinances etc.
Legislative and policy issues	Revenue from power generated is lower in the UK than in other countries. It would be helpful if wind turbine types were re-classified as permitted development.

5.5 Ground source heat pumps

5.5.1 General description of the technology

Ground source heat pumps (GSHPs) use the same principle as a refrigerator, circulating liquid refrigerant to absorb the energy (heat) from a space. The refrigerant on one side of the circuit (the evaporator) evaporates from a liquid to a vapour and absorbs heat energy in doing so. This is later compressed on the other side of the circuit (the condenser) causing its pressure and temperature to rise and the vapour reverts to a liquid. The hot refrigerant passes through a heat exchanger – in a domestic refrigerator this is attached to the rear – transferring heat to the surrounding air cooling the refrigerant and heating the air. The cycle is continuous.

The basis of the heat pump, therefore, is to take low-grade energy (low-temperature heat from the ground) and upgrade it to a higher, more useful temperature. The only energy it uses is that needed to power the compressor and any circulating pumps. Owing to the refrigerant cycle, far more usable energy is made available than is consumed in the compressor and pumps, making it a very energy- and carbon-efficient system.

In a GSHP the refrigerant absorbs energy from the ground, which is typically at a steady annual temperature of 10–12°C, and releases it at a higher temperature into the space via a heat exchanger. The heat exchange can be to water (most typical) or to air, and it is this hot water or hot air that is the basis of the heating circuit for the dwelling.

The domestic hot water system can also be supplied by the GSHP. In some instances an additional heating source (electric immersion heater) is commonly installed to cater for peak times.

Open-loop GSHP systems using ground water were the most widely used type because the ground water could be extracted and returned using inexpensive wells that required little ground area. But available water is limited, and can foul the evaporator and cause corrosion of the pipework. In addition, there are increasingly stringent environmental regulations on the use of ground water.

Closed loop or ground coupled systems are now the more favoured solution and use a sealed ground heat exchanger (a sealed loop of pipe) buried either horizontally (using a slinky-type coil to maximise the heat extraction from the trench) or vertically (by boring) in the ground. Refrigerant can be circulated directly through this ground heat exchanger (direct expansion systems) but refrigerant leakage and contamination risks make an indirect system using a water/antifreeze solution and heat exchangers the preferred option.

5.5.2 Influencing factors

Table 9 Influencing factors for ground source heat pumps

Location	GSHPs are well-suited to new build applications as their efficiency is improved when supplying low temperature distribution systems such as under-floor heating. Heat pumps have a typical operating temperature limit of 55°C and are not generally suitable for monovalent (see below) operation with traditional wet radiator systems. They can be cost-effective in areas where mains gas is not available. Either a horizontal or vertical ground collector is required; the choice will depend on land area available, local ground conditions and excavation costs.
Building occupation	A GSHP system can be used to provide all the heating load (monovalent system). However, it is worth considering a bivalent system, where the heat pump is used to provide the base heating load, with an auxiliary system covering the additional peak demand. This is because of the relatively high capital cost of the heat pump.

5.5.3 Carbon savings

To maximise the efficiency of a heat pump it is important to have a low heating distribution temperature. For indirect GSHP systems supplying low temperature distribution systems, typical seasonal efficiencies (annual energy delivered by heat pump: total annual energy supplied [for the pumps] to the system) of between 300% and 400% are common, reducing the demand for purchased electricity and associated carbon emissions.

A GSHP with a seasonal efficiency of 350% results in an emission of 0.03 kg carbon for each kWh of useful heat provided, compared to a condensing gas boiler operating at 86% seasonal efficiency, which produces 0.06 kg carbon for each kWh of useful heat provided.

For a small two-bedroom dwelling carbon savings are in the region of 250 kg per annum.

5.5.4 Cost-effectiveness

GSHPs can have a pay-back of between 8 and 15 years; actual figures will depend to a great extent on the type of ground collector, ground conditions, the type of fuel that they displace and economies of scale for the installation (eg blocks of flats).

5.5.5 Local impact

Table 10 Impact of ground source heat pumps

Noise and vibration	Heat pumps can emit constant noise due to the operation of the compressor. Although this is generally low level noise, locating heat pump units in close proximity to bedrooms should be avoided.
Visual impact	The ground collectors will be below ground and hence not seen. The heat pump itself will not cause a visual intrusion; normally it would be installed in a cupboard area.
Other	The components have long life expectancy and high reliability. Life expectancy is 20–25 years, and up to 50 years for the ground coil. There are no boilers, fuel tanks, flues or ventilation requirements and no combustion or explosive gases in the dwelling.

5.5.6 Complementary technologies

As indicated earlier, GSHPs can be installed as a bivalent system using other heating systems.

For domestic hot water, solar-thermal technologies can be used in conjunction with the GSHP.

To be truly carbon neutral there would need to be some electrical generation equivalent to the electricity used to power the pump and circulatory systems.

5.5.7 Technology overview

Technology issue	Technology data
Cost-effectiveness – simple payback	8–15 years.
Capital costs per m^2 of building	£80–£120, but will depend on economies of scale and type of installation. The cost excludes the heat distribution system.
Typical capital costs	£6000; excludes the heat distribution system.
Market barriers and risks	Lack of sufficient numbers of qualified and trained installers.
Legislative and policy issues	Affordable heating requirements in legislation.

5.6 Air source heat pumps

5.6.1 General description of the technology

Air source heat pumps (ASHPs) use the same principles as the GSHP described previously. The basis of the heat pump, therefore, is to take low-grade energy from the surrounding air by means of a fan pulling the outside air over a heat exchanger (evaporator); this energy is then upgraded and the higher temperature refrigerant vapour is released by means of another heat exchanger (condenser).

In ASHPs this heat exchange can be to the air inside the dwelling, and distributed to the different rooms by ducts and supply grilles. Alternatively, the heat exchange can be to water; it is this hot water that is the basis for the dwelling's heating circuit. This heating circuit can be an under-floor heating system or fan-coil units installed in the different rooms, or a combination of the two.

Unlike the GSHP, where the temperature of the ground is relatively stable throughout the year, in an air source heat pump the source air temperature range can be highly variable – not only seasonally but also daily. Also heat pumps operate at their most efficient when the source temperature is as high as possible, but in the UK the mean air temperature for winter is lower than the mean ground temperature. All of these factors have an impact on seasonal efficiency for ASHPs, which is lower compared to GSHP. At low air temperatures the evaporator coil is likely to need defrosting.

5.6.2 Influencing factors

Table 11 Influencing factors for air source heat pumps

Location	ASHPs are not particularly suited to cold winters, where coils may need to be defrosted or an alternative source of heating used in particularly severe conditions. They are best suited to new build applications as they are most efficient when supplying low temperature distribution systems such as under-floor heating. Heat pumps have a typical operating temperature limit of 55°C and are not suitable for use as a monovalent system.
Building occupation	An ASHP system would not be able to provide all the heating load (monovalent system); however, it is worth considering a bivalent system where the heat pump is used to provide the base heating load, with an auxiliary system covering the additional heating demand.

5.6.3 Carbon savings

To maximise the efficiency of a heat pump it is important to have a low heating distribution temperature, and in these circumstances typical seasonal efficiencies are about 250%, which reduces the demand for purchased electricity and associated carbon emissions.

An ASHP with a seasonal efficiency of 250% results in an emission of 0.04 kg carbon for each kWh of useful heat provided, compared to the condensing gas boiler example provided in the GSHP section.

For a small two-bedroom dwelling carbon savings are in the region of 180 kg per annum, depending on the type of auxiliary heating installed.

5.6.4 Cost-effectiveness

This is difficult to evaluate because of the need for auxiliary heating and 'down-time' due to unsuitable source air conditions. However, it is likely to be similar to that of a GSHP.

ASHPs form the largest market share of all the heat pump options, but most of these installations rarely perform the heating duty and are mainly used in their reversible mode to provide cooling.

5.6.5 Local impact

Table 12 Impacts of air source heat pumps

Noise and vibration	Air source heat pumps emit noise from the fan and compressor which can cause a nuisance. They should not be sited in close proximity to bedrooms or neighbouring properties.
Visual impact	Limited – this will be due to the external fan and coil installation.
Other	The internal components have long life expectancy and high reliability.

5.6.6 Complementary technologies

ASHPs can be installed as a bivalent system using other heating systems, and solar thermal technologies can be used in conjunction with ASHPs.

To be truly carbon neutral there would need to be some electrical generation equivalent to the electricity used to power the pump and circulatory systems.

5.6.7 Technology overview

Technology issue	Technology data
Cost-effectiveness – simple payback	8–15 years.
Typical capital costs	£6000; excludes the heat distribution system.
Market barriers and risks	Lack of sufficient numbers of qualified and trained installers.
Legislative and policy issues	Affordable heating requirements in legislation.

5.7 Absorption heat pumps

5.7.1 General description of the technology

Before reading this briefing note please read the previous notes/section on GHSPs

The term 'absorption' in relation to the absorption heat pump refers to the method of compressing the refrigerant, which uses another heat source such as natural gas, propane, solar-heated water, or geothermal-heated water. Because natural gas is the most common heat source for absorption heat pumps, they are also often referred to as gas-fired heat pumps.

There are also absorption coolers available that work on the same principle, but they are not reversible and cannot serve as a heat source. These are also called gas-fired coolers.

Residential absorption heat pumps use an ammonia–water absorption cycle to provide heating. As in a standard heat pump, the refrigerant (in this case ammonia) absorbs the heat from the air or ground and evaporates, and is then upgraded to a more useful heat for the space.

With absorption heat pumps the evaporated ammonia is not increased in pressure by means of a compressor, but is instead absorbed into water. A relatively low-power pump can then pump the solution up to a higher pressure. There is then the need to remove the ammonia from the water; this is achieved by applying a heat source that boils the ammonia out of the water, starting the cycle again.

A key component in the units now on the market is 'generator absorber heat exchanger technology' or GAX, which boosts the efficiency of the unit by recovering the heat that is released when the ammonia is absorbed into the water. Other innovations include high-efficiency vapour separation, variable ammonia flow rates, low-emissions, and variable-capacity combustion of the natural gas.

5.7.2 Influencing factors

Table 13 Influencing factors for absorption heat pumps

Location	Absorption heat pumps can be used in similar situations to other heat pumps applications. However, there are some important differences: - Absorption heat pumps available for domestic applications are only suitable for large residences. - Absorption air heat pumps can operate at temperatures of −20°C and hence can be monovalent.
Building occupation	Similar to conventional air and ground source heat pumps; however, the hot water supplied can be up to 60°C.

5.7.3 Carbon savings

Absorption heat pumps are suitable for low temperature hot water distribution systems. Typical seasonal efficiencies are about 140%.

In gas absorption heat pumps the supplied energy is gas (to heat the ammonia/water solution), with little electrical energy required to drive the pump. Compared to a condensing gas boiler operating at 85% seasonal efficiency, additional carbon savings of 60% are achievable. The exact potential carbon savings for the UK as a whole are difficult to calculate.

5.7.4 Cost-effectiveness

The costs will depend on the type of system – ie ground source, air source, type of heating system. However, the pay back period would be similar to that for the conventional (compressor driven) heat pump.

5.7.5 Local impact

Table 14 Impacts of absorption heat pumps

Noise and vibration	The heat pump can be installed in the open without any additional protection. This also has the advantage of not taking up internal space or transmitting noise to the surroundings.
Visual impact	Limited; it can be installed where appearance is not important.
Other	The internal components have long life expectancy and high reliability.

5.7.6 Complementary technologies

The heat source can be solar heated water.

5.7.7 Technology overview

Technology issue	Technology data
Cost-effectiveness – simple payback	8–15 years.
Typical capital costs	£7000; excludes the heat distribution system.
Market barriers and risks	Lack of sufficient numbers of qualified and trained installers.
Legislative and policy issues	May form part of a solution for affordable heating.

5.8 Small-scale hydroelectric systems

5.8.1 General description of the technology

Although water power was used traditionally to drive many different sorts of machinery directly on-site, nowadays nearly all UK water power installations produce hydroelectricity. This energy can be used flexibly and can be exported for use elsewhere.

Many UK hydroelectricity schemes are located at previously used water power sites, very often where there was a water mill, and where a weir has been retained. Unless the party has existing rights (as would a miller), permission to install equipment might either be refused, or be obtained only after lengthy negotiations with interested authorities such as the Environment Agency. Planning permission will usually be required.

Energy can be extracted from descending water. The amount of power available at a given time is determined by the flow rate measured in m^3/s (or in the case of small schemes litre/s) and the vertical fall or head measured in metres. If no long-term records are available, it will be necessary to quantify the year-round energy generating potential by establishing a prolonged flow measurement regime. For various reasons permission might only be given for a fraction of a river's or stream's total flow to be channelled through a hydropower device.

The water power engineer employs different devices to harness the flow of water, depending on the size of the head. Typical technology choices are:

- For low heads (up to 10 m): high-efficiency versions of traditional water wheels.
- For low to medium heads (up to 50 m): reaction turbines.
- For high heads (over 50 m): impulse turbines.

Mechanical efficiencies range from 70% to over 90%, depending on device type and power rating. When estimating potential power output, generator (and where applicable transmission, ie gearbox) efficiency must be factored in, as must energy dissipated by the governor.

Choosing the machinery and designing the whole hydroelectric installation is very far removed from the sort of 'catalogue engineering' that is often possible with, for example, PV installations. Inevitably, being bespoke and involving as they do civil and mechanical and electrical engineering, and very often environmental consultancy, schemes are expensive – often prohibitively so at lower capacities, unless a scheme's proponents are willing to take on tasks themselves and contract out as little work as possible.

It is not possible to generalise about hydroelectricity scheme paybacks; but although river and stream flow rates vary from season to season and year to year, they usually do so in a way that can be predicted from weather conditions, water table measurements, etc., so paybacks can be calculated on a project by project basis.

A typical hydroelectricity installation will be 'grid-connected', putting power into the building's mains electricity supply in parallel with the local grid. Thus when the building demands more electricity than the hydroelectricity scheme can provide, the grid provides the 'top-up'; and when the site is generating more hydroelectricity energy than the building needs, the excess is exported to the grid.

In order to connect to the grid, systems must comply with engineering recommendations G83/1 (systems of 16 A per phase or less) or G59 (systems over 16 A per phase). Most domestic installations would fall under G83/1 where the grid operator (known as DNO or Distribution Network Operator) only needs to be notified. Larger systems under G59 require prior permission for connection to be obtained from the DNO.

Some energy suppliers will buy energy electricity exported to the grid. Renewable Obligation Certificates (ROCs) may also be payable and OFGEM can advise on requirements.

Most hydroelectric devices directly generate single-phase or three-phase fixed frequency alternating current (AC) power in synchronism with the mains; however, some installations have power conditioning equipment or inverters (see section 5.4 for more information on these). For safety, local hydroelectricity plants are shut down during grid power cuts.

Meters are also necessary:

- The hydroelectricity output meter measures how much electricity has been generated, so that ROC or 'green' revenue can be earned.
- Where appropriate, an export meter measures how much surplus power has been supplied to the grid from the building, thus allowing additional revenue to be earned.

There are off-grid or stand-alone hydroelectricity-supplied buildings in the UK; because the power source is predictable they do not usually need back-up batteries, but might have a standby diesel generator for periods of low water flow, or equipment shut-downs.

5.8.2 Influencing factors

Table 15 Influencing factors for small-scale hydroelectric systems

Location	By its nature, location is the key determinant for hydroelectric power generation: you have to 'go where the water is'. There is generally higher rainfall in the west and north of the UK, and precipitation is higher at higher altitudes. With an existing water power site, local knowledge of its capacity might survive; in many cases this information could be supported by gauging station records. Otherwise, it is advisable to set up a monitoring operation.
Building occupation	Sites with continuously occupied buildings can benefit most from hydroelectric power: consuming the power generated within the building 'round the clock', rather than exporting it, secures the maximum financial benefit.

5.8.3 Carbon savings

Generation at a 60% capacity factor (annual average power output ÷ installed generator capacity) generates around 5300 kWh a year per kW of installed capacity. This offsets around 2300 kg per annum of power station CO_2 emissions (standard UK grid generating mix).

5.8.4 Cost-effectiveness

The above example assumes that the occupier has negotiated a contract with a ROCs broker.

The capacity factor reflects the reduced flow of water in the summer, and highlights the importance of not oversizing the hydroelectric machinery: the higher the rating of the installed equipment, the greater the capital expenditure and the lower the generating efficiency when the device is running at reduced output.

Hydroelectricity systems can prove financially beneficial to building occupiers where the resource is good; in the right circumstances hydroelectric power can assist in relieving fuel poverty – usually indirectly, for example by earning revenue for a community hydroelectricity enterprise.

5.8.5 Local impact

Hydroelectricity installations need not be highly visible, especially where the generating plant is housed in existing buildings.

Table 16 Impacts of hydroelectric systems

Noise and vibration	Given that sluice and weir noise is 'natural', the only noise issue concerns the generator: power house soundproofing may be required. Vibration is not normally an issue except where traditional water wheels are employed.
Visual impact	Planning permission is required for the civil works required for a hydroelectricity scheme; it might take some negotiation in conservation areas and national parks, and near listed/heritage buildings.
Other	Concerns about the impact on the local environment (flora and fauna, including fish and otters) *must* be addressed, as must the general issue of managing flow in watercourses.

5.8.6 Complementary technologies

Hydroelectricity complements electrically powered heat pumps, which typically deliver four units of heat for each unit of electricity they consume – and may indeed use as their ambient thermal energy source the same watercourse as powers the hydroelectricity scheme.

5.8.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per kW installed capacity (60% capacity factor)	Electricity generated: around 5300 kWh; CO_2 displaced: around 2300 kg. If all the electricity is consumed within the building, monetary savings @ 8.5p/kWh are around £450.
Lifetime energy, carbon and cost savings per kW installed capacity (30-year useful life, 60% capacity factor)	Electricity generated: around 159 000 kWh; CO_2 displaced: around 68 000 kg. If all the electricity is consumed within the building, monetary savings @ 8.5p/kWh are around £13 500.
Cost-effectiveness – simple payback N.B. Average value of electricity given as 5p/kWh (on most 100 kW sites the majority of generated power is exported to the grid). Operating costs include rates, insurance, maintenance, spread cost of replacements etc	Example: a 100 kW hydroelectric installation. Capital expenditure: £200 000; operating costs: £30 000 30-year lifetime/60% capacity factor. The lifetime yield is around 4 800 000 kWh. Value of electricity @ 5 p/kWh of around £240 000 and ROC income @ 4.5 p/kWh of around £216 000 results in a simple payback of approximately 15 years.
Typical capital costs	British Hydro Power Association – a complete 100kW installation: - Low head: £115 000–£280 000 - High head: £85 000–£200 000.
Potential for savings in buildings	Excellent at particular locations.
Current state of market development	Hydroelectricity equipment manufacturing is mature and the technology is well-developed. Equipment demand is limited so there is no likelihood of mass production bringing prices down. Designing and installing hydroelectricity systems are likely to remain specialist tasks.
Typical capital costs (turbine plus generator package *only*, not installed)	From a UK supplier – depending on head: - 2.5 kW £5500–£7500 - 15 kW £12 500–£14 000.
Typical lifetime	30 years, with occasional maintenance and a mid-life overhaul.
Additional benefits	A good supply/demand match: usually, more hydroelectric power is available in winter, when demand for electricity is higher. A simpler, cheaper installation is possible where ‘raw’ electricity is used, unsynchronised with the grid, for water/space/process heating.
Market barriers and risks	Finite number and dispersed nature of suitable sites, permit negotiations, and capital expenditure are the main barriers. Low risk once installed as generally very reliable.
Potential for market advancement	Low.
Legislative and policy issues	If the Environment Agency were required to ‘turn the process around’ by identifying sites with hydroelectricity potential and encouraging and assisting site owners to commission feasibility studies, a greater number of projects would be developed.

5.9 Micro combined heat and power systems

5.9.1 General description of the technology

Micro combined heat and power (CHP) is an emerging energy technology that, for use in dwellings, is being presented as a direct replacement for the gas boiler. However, unlike a conventional gas boiler, the system will generate electricity as well as heat for space heating and hot water. Micro CHP installations run on natural gas, but bio-gas systems are a future possibility.

These systems are typically around 1 kWe in size (giving approximately 8 kW_{th}). They are claimed to have a low electrical efficiency at around 15% but a high overall efficiency around 90% when operating in condensing mode.

Aside from the fuel and electricity connections, the main elements of a CHP installation consist of a prime mover, an alternator, a heat recovery system and a control system. There are several types of prime mover used in micro CHP systems but the two most common types serving the domestic sector in the UK are the Stirling engine and the internal combustion engine.

Stirling engines are currently the most prominent micro CHP technology for individual dwellings. These systems are typically around 1 kWe in size giving approximately 5 kW; they are claimed to have a low electrical efficiency at around 15% but a high overall efficiency around 90% when operating in condensing mode. Some Stirling engine system suppliers are also planning to provide the option of configuring the system to work in the event of a power cut, maintaining heating and providing some power. A small number of pioneering applications are currently taking place in the UK.

Internal combustion engine systems tend to be too large and noisy for individual properties and are therefore usually used to supply small groups of dwellings through a network of heating pipes. They are typically around 5 kWe in capacity and tend to have higher electrical efficiencies at around 25%. They also tend to have higher maintenance requirements than Stirling engine systems.

Other types of prime mover in development for micro CHP systems include fuel cells and organic Rankine cycle systems.

5.9.2 Influencing factors

Table 17 Influencing factors for micro combined heat and power systems

Location	Domestic micro CHP installations are usually installed within the kitchen or an adjoining utility room.
Building occupation	Similarly to larger-scale CHP; the number of hours of simultaneous heat and power demand influences the length of the system payback period. However, owing to occupancy patterns, domestic systems are likely to operate for a shorter number of hours (probably around 3000 hours a year) than is the case for larger-scale CHP.

Owing to the erratic electricity demand patterns of dwellings, there will inevitably be some electrical export to the grid. Where this export proportion is high, there is often an adverse effect on the business case because of the low value obtained per unit for exported electricity.

5.9.3 Carbon savings

The carbon savings from micro CHP are, as yet, unproven. The Energy Saving Trust (EST), in conjunction with the British Standards Institution, is developing a procedure (PAS 67)[6] to test the performance of micro CHP systems under laboratory conditions. BRE is developing a methodology that will make use of the laboratory test results to evaluate the energy benefits of micro CHP heating systems in houses. Both the laboratory test procedure and the methodology were issued for industry consultation in January 2006. The Carbon Trust is also undertaking field trials of micro CHP installations and it is planned that the results from the exercise will be available in the near future.

Micro CHP suppliers have, however, made estimates of the savings achievable from their systems. For example, CO_2 savings of 1.5 tonnes per household per annum, equivalent to a 20% reduction in CO_2 emissions, are suggested.

5.9.4 Cost-effectiveness

The cost-effectiveness of micro CHP systems is, as yet, undetermined. However, paybacks of around three to five years have been suggested.

5.9.5 Local impact

Table 18 Impacts of micro combined heat and power systems

Noise and vibration	Noise has been an issue during the development of micro CHP systems. However, this issue may have been overcome and pioneering installations in dwellings are proceeding.
Visual impact	Some domestic micro CHP systems are currently floor-standing. Wall-hung systems are planned for the UK, but the only examples to date are in the Netherlands. Their appearance is very similar to that of a domestic boiler.
Other	Micro CHP systems are installed by trained gas engineers and plumbers and are envisaged as having the same maintenance requirements as a conventional boiler.

5.9.6 Complementary technologies

Unlike conventional CHP systems where separate top-up boilers are invariably used, micro CHP systems in dwellings are direct replacements for the domestic boiler. Some micro CHP systems contain both a prime mover (with heat recovery) and a supplementary burner, while others systems include just the prime mover (with heat recovery system).

Because of the production of both heat and electricity, it is likely that micro CHP is an exclusive technology and incompatible with any other low carbon technologies, except perhaps biomass where the CHP engine uses biomass rather than gas or oil. However, it is still experimental at the individual dwelling scale.

5.9.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per m^2	Estimated at 1.5 tonnes CO_2 per dwelling per year. Estimated at £150 per dwelling per year.
Cost-effectiveness – simple payback	Estimated at around 3–5 years.
Marginal capital cost	Around £500 per kWe (marginal cost).
Potential for savings in buildings	Existing houses with gas boilers could be upgraded.
Current state of market development	New emerging market.
Typical capital costs	£500 above the cost of a conventional boiler, so marginal.
Typical lifetime	Untested, but claimed boiler equivalent.
Additional benefits	Possible operation in power outage.
Market barriers and risks	Low price for exported electricity may extend the payback periods and make this option uneconomic.
Potential for market advancement	1 million replacement boilers per year.
Legislative and policy issues	Could be advanced through the Building Regulations.

5.10 Renewable combined heat and power systems

5.10.1 General description of the technology – complementary to micro CHP information

The term 'renewable combined heat and power' usually refers to the use of biofuels rather than the gas or oil used in more traditional CHP system installations. Such biofuels include biogas (perhaps from landfill), wood and farm waste. At present the only renewable CHP plant operating in the domestic sector in the UK is operating at a community scale. Renewable CHP is an emerging energy technology that is only available at the community scale. Higher levels of insulation and the general trend in the domestic sector of reduced heat demands and increasing electrical demands may make community scale heating schemes less attractive on a purely economic level. However, their CO_2 saving potential and the benefits with regard to addressing fuel poverty may make this technology politically, ethically and environmentally an attractive option for many new and existing housing developments.

5.10.2 Influencing factors

Table 19 Influencing factors for renewable combined heat and power systems

Location	The availability of biofuel supply and the need at present either to link to existing community scale heating networks or to have access to install a new heating network will be considerable limiting factors for the technology.
Building occupation	Owing to the community scale nature of the technology, the occupancy patterns may not be as important. However, it is recommended that where possible buildings with differing occupancy patterns and heat/electrical loads help balance out the demand and ensure maximum use of both heat and power across the community network.

Where the proportion of generated electricity exported to the grid is high, there is often an adverse effect on the business case due to the low price value obtained per unit for exported electricity at present in the UK.

5.10.3 Local impact

Table 20 Impacts of renewable combined heat and power systems

Noise and vibration	Noise associated with any community scale heating system and particularly CHP is an issue, but it can be overcome with the installation of sound insulation.
Visual impact	Most community scale CHP plant is simply housed in a building; however, renewable sources often require significant storage facilities, which should also be considered when how to reduce the visual impact of the installation is investigated.

5.10.4 Complementary technologies

Because of the production of both heat and electricity it is likely that renewable CHP systems are an exclusive technology and incompatible with any other low carbon technologies, except perhaps biomass where the CHP engine uses biomass rather than gas or oil.

5.11 Fuel cells

5.11.1 General description of the technology

The chemical energy in usually gaseous fuels (such as hydrogen, methane [natural gas] and propane [LPG]) can be converted directly into electricity by a fuel cell. As with battery cells, individual fuel cells typically generate low voltages, so they are arranged in a stack which is electrically wired in series. Fuel cells themselves are silent-running electrochemical devices with no moving parts, but a complete generator unit can be quite a complex device containing pumps, fans, control valves, etc. This is because the fuel (unless it is hydrogen) usually has to be reformed into a feedstock that is chemically compatible with the fuel cell. Even with all the auxiliary equipment, fuel cell generators are much quieter than either internal combustion engines or gas turbines.

Fuel cells generate direct current (DC) and are usually connected to an inverter (also known as a power conditioner) that converts this into 230 volts 50 Hz AC single phase or 380 volts 50 Hz three phase, and does so in synchronism with the mains. For safety reasons these inverters must shut down during power cuts.

There are various types of fuel cell technology that use different electrochemical processes. Some operate at nominal ambient temperatures while others run at elevated temperatures and certain types at conditions of extreme heat only, ie up to 700°C.

Fuel cells could be much more efficient than conventional power generating techniques at converting fuel to electricity as their performance limits are not dictated by the laws of thermodynamics or by their materials of construction as are those of boilers, superheaters, steam and gas turbines, etc. Fuel cell conversion efficiencies of more than 80% have already been achieved experimentally, and parasitic power consumption (eg from auxiliary equipment such as fans and pumps) tends to be low.

The balance of the energy consumed is manifested as heat, making fuel cell units potentially excellent CHP devices because:

- Fuel-cell-generated electricity could be much less polluting than power from any 'heat engine'.
- Small-scale fuel cells can be as efficient as large-scale fuel cells, favouring 'distributed generation'.
- Fuel cell heat/power ratios could mirror the demand pattern of modern business premises.

Fuel cells are not yet available as off-the-shelf commercial products. At present, various companies are running field trials of pre-production domestic-scale (typically 1.5 kWe) units powered by natural gas in the EU and US; the Borough of Woking is operating a 300 kW FC CHP unit (www.woking.gov.uk/html/queensaward/W-19.pdf), which has been well publicised.

5.11.2 Influencing factors

Table 21 Influencing factors for fuel cells

Location	The first commercial fuel cell units are likely to be designed to work with natural gas, and therefore suitable for buildings with mains gas connected or available close by.
Building occupation	Candidate buildings for fuel cell installations will have both a minimum continuous electrical demand and a minimum continuous heat demand that can be justified and are not down to inefficient equipment and wasteful practices: this is because: ▪ Fuel cell units will be best suited technically and economically as base load generators. ▪ Consuming power generated within the building (ie rather than exporting it) secures the maximum financial benefit. ▪ Sports centres and larger hotels are good examples of commercial scale buildings. Individual dwellings with significant hot water use and high electrical base loads may be very suitable for the domestic scale implementation of this product.

5.11.3 Carbon savings

Although 80% electrical conversion efficiency has been achieved with laboratory bench devices, the fuel cell units currently on test are only around 30% efficient as electrical generators, which is lower than an average UK grid power station – hence the need to operate fuel cells as CHP units with the waste heat being usefully consumed.

5.11.4 Cost-effectiveness

Fuel cells are likely to first prove cost-effective generating power off-grid as quiet and low-maintenance alternatives to diesel-engined generators. Their quietness means that they are ideal for military use where cost is not the main issue.

5.11.5 Local impact

Fuel cell installations can be either indoor units or unobtrusive containerised outdoor modules, and are quiet in operation. They will be suited to sensitive environments (eg hospitals).

Table 22 Impacts of fuel cells

Noise and vibration	Usually the only system noise is from the various pumps and fans.
Visual impact	Minimal.
Other	In the longer term, widespread investment in fuel cells could result in local urban power grids being mostly supplied by distributed generation.

5.11.6 Complementary technologies

For buildings with justifiable cooling loads, the waste heat from a fuel cell unit could be used to run a heat-driven (eg absorption or desiccant) cooling system.

5.11.7 Technology overview

Technology issue	Technology data
Annual energy, carbon and cost savings per kWp	Performance of commercial models still to be confirmed.
Lifetime energy, carbon and cost savings	Actual operating lives of different technologies still to be confirmed.
Cost-effectiveness – simple payback	Prices of commercial models still to be confirmed.
Typical capital costs (existing building retrofit)	Not yet established.
Potential for savings in buildings	Good, once commercial models come to market.
Current state of market development	Fuel cells are at the pre-commercial stage. Fuel cell technology is being heavily researched because of the potential environmental benefits and commercial rewards.
Typical capital costs (in new build)	Not yet established.
Typical lifetime	Projections are for 20 years, but with intermediate stack replacement.
Additional benefits	DC power generation could result in DC-wired buildings: so much electrical and electronic equipment – including LED lighting – runs on DC power.
Market barriers and risks	Lack of availability and need for more product development are the main barriers. Reliability has not yet been established.
Potential for market advancement	High and multiple uses mean rapid development is likely.
Legislative and policy issues	Development insufficiently advanced.

6 Local authorities and renewable energy technologies

The UK currently obtains around 4% of its energy supply from renewable sources. The government has set a target of 10% of electricity supply to come from renewable energy sources by 2010.

Part of this supply will come from domestic renewable technologies. However, a greater emphasis is being placed on energy providers themselves. The Renewables Obligation (under BERR) places a requirement on electricity companies to increase the percentage of power supplied from renewable sources every year, from 4% currently to 20% by around 2020.

6.1 Home Energy Conservation Act

The Home Energy Conservation Act (HECA) requires every UK local authority with housing responsibilities – 'energy conservation authorities' – to prepare, publish and submit to the secretary of state an energy conservation report identifying practicable and cost-effective measures to significantly improve the energy efficiency of all residential accommodation in their area, and to report on progress made in implementing the measures.

HECA has served to focus the attention of local authorities more closely on the energy efficiency of all residential accommodation, and on developing an integrated approach to their housing and energy efficiency strategies. Improvements achieved through HECA will contribute to meeting the UK's climate change commitments.

6.2 National policy: Planning Policy Statement 22 Renewable Energy

Planning Policy Statement 22 Renewable Energy (PPS 22)[7] sets out the government's national policies for different aspects of land use planning in England. This PPS replaces Planning Policy Guidance Note 22 issued in 1993, the annexes issued in 1994 and the photovoltaics annex issued in 2002.

Positive planning, which facilitates renewable energy developments, can contribute to all four elements of the government's sustainable development strategy:

- Social progress, which recognises the needs of everyone – by contributing to the nation's energy needs, ensuring all homes are adequately and affordably heated; and providing new sources of energy in remote areas.
- Effective protection of the environment – by reductions in emissions of greenhouse gases, the potential for the environment to be affected by climate change is reduced.
- Prudent use of natural resources – by reducing the nation's reliance on ever diminishing supplies of fossil fuels.
- Maintenance of high and stable levels of economic growth and employment – through the creation of jobs directly related to renewable energy developments, but also in the development of new technologies. In rural areas, renewable energy projects have the potential to play an increasingly important role in the diversification of rural economies.

Regional planning bodies and local planning authorities (LPAs) should adhere to the following key principles in their approach to planning for renewable energy:

- Renewable energy developments should be capable of being accommodated throughout England in locations where the technology is viable and environmental, economic, and social impacts can be addressed satisfactorily.
- Regional spatial strategies and local development documents should contain policies designed to promote and encourage, rather than restrict, the development of renewable energy resources. Regional planning bodies and local planning authorities should recognise the full range of renewable energy sources, their differing characteristics and location requirements, and the potential for exploiting them subject to appropriate environmental safeguards.
- At the local level, planning authorities should set out the criteria that will be applied in assessing applications for planning permission for renewable energy projects. Planning policies that rule out or place constraints on the development of all, or specific types of, renewable energy technologies should not be included in regional spatial strategies or local development documents without sufficient reasoned justification. The government may intervene in the plan-making process where it considers that the constraints being proposed by local authorities are too great or have been poorly justified.
- The wider environmental and economic benefits of all proposals for renewable energy projects, whatever their scale, are material considerations that should be given significant weight in determining whether proposals should be granted planning permission.
- Regional planning bodies and local planning authorities should not make assumptions about the technical and commercial feasibility of renewable energy projects (eg identifying generalised locations for development based on mean wind speeds). Technological change can mean that sites currently excluded as locations for particular types of renewable energy development may in future be suitable.
- Small-scale projects can make a limited but valuable contribution to overall outputs of renewable energy and to meeting energy needs both locally and nationally. Planning authorities should not therefore reject planning applications simply because the level of output is small.
- Local planning authorities, regional stakeholders and local strategic partnerships should foster community involvement in renewable energy projects and seek to promote knowledge of and greater acceptance by the public of prospective renewable energy developments that are appropriately located. Developers of renewable energy projects should engage in active consultation and discussion

with local communities at an early stage in the planning process, and before any planning application is formally submitted.

- Development proposals should demonstrate any environmental, economic and social benefits as well as how any environmental and social impacts have been minimised through careful consideration of location, scale, design and other measures.

6.3 Key issues in planning for renewables at the local level

- The introduction of the spatial planning approach within the new planning system provides an important opportunity for integrating renewable energy generation into the wider local planning framework.
- LPAs should prepare criteria-based policies that focus on key local issues, within the framework set out by national planning policy and the Regional Spatial Strategy, or Spatial Development Strategy (SPDs) in London. Policies may relate to standalone schemes and/or the development of integrated renewables within developments.
- SPDs can be useful in illustrating how particular types of technology, or passive solar design principles, can be applied in the particular local context.
- Some LPAs have set specific targets for on-site generation; it may be appropriate for other authorities to do the same, and this should be considered by policy makers.
- LPAs have the scope to demonstrate practical support for renewable energy through their procurement strategies.
- LPAs should encourage community involvement in planning for renewable energy, through consultation exercises during plan-making and also, where possible, by supporting appropriate community-led development proposals.

Source: PPS22 Companion Guide, paragraph 4.6, Communities and Local Government, 2004.[8]

6.4 Government advice on standalone schemes

It is important that the full range of technologies is considered, even though the Regional Spatial Strategy may have identified only one or two of the most likely sources in the short to medium term (ie by 2010).

Development proposals may come forward for other types of schemes, and local policies should also be applicable to them.

Any policy should begin with a statement of general support for renewables. It is usual to then list the issues that will be taken into account in considering specific applications:

- There should be reference to impact on landscape, townscape, natural, historical and cultural features and areas.
- There should be specific reference to the impacts on the amenity of the area (or particular sub-areas within it) in relation to visual intrusion, noise, dust, odour and traffic generation.
- Consideration should be given to the wider environmental, economic and social benefits of renewable energy developments.

Source: PPS22 Companion Guide, paragraph 4.10–4.11, Communities and Local Government, 2004.[8]

6.5 The Merton Rule

The Merton Rule[9] states:

> *The council will encourage the energy efficient design of buildings and their layout and orientation on site. All new non-residential developments above a threshold of 1000 m^2 will be expected to incorporate renewable energy production equipment to provide at least 10% of predicted energy requirements.*

The Merton Rule is already being applied through the North Devon Local Plan, and several local authorities have included the Merton Rule as a fundamental obligation, including Croydon, Oldham, Southampton, Wakefield and many more councils.

A full list of councils that have adopted the Merton Rule can be found at www.themertonrule.org.

6.6 The Milton Keynes Tariff

The Milton Keynes Tariff, commonly known as the Milton Keynes Green Roof Tax, or 'the Tariff', is an initiative based on the council's aim to expand Milton Keynes in a sustainable manner.

The Tariff is based upon a contribution paid by developers to a central fund that is then used to pay for the infrastructure required to support the expanding community of Milton Keynes. The fund is designed to deliver the key infrastructure and community facilities to support Milton Keynes' sustainable growth, defined within the Councils Urban Development Area.

The Tariff will raise up to £310 million by 2016, consisting of payments of £18 500 per dwelling and £260 000 per hectare of employment space, around £67 per square metre. This money goes towards the expected £1.67 billion cost of the sustainable growth of Milton Keynes.

An overview of the aims of the Tariff can be found at: www.miltonkeynespartnership.info/dfiles/DocumentLibrary/MKPTariffBrochure.pdf.

For an in-depth explanation of the Tariff, please visit: www.milton-keynes.gov.uk/local%5Fplan%5Freview/DisplayArticle.asp?ID=50680.

6.7 Woking Borough Council

Woking Borough Council first published a Climate Change Strategy in March 2003, as the town's next step in developing good environmental practice at a local level.

Since then, the UK's first fuel cell CHP system has been opened in Woking Park and progress has been made on a number of the strategy's other key action points. The Council's work has recently been recognised by the government as a Beacon Council.

- Woking Borough Council was granted the Queen's Award for Enterprise 2001 for its approach to sustainability. It is the only local to receive this industry award.
- In 2002, the Council was believed to be the only UK authority to have adopted a comprehensive climate change strategy on a scale likely to meet the Royal Commission on Environmental Pollution targets of 60% reductions of CO_2 equivalent emissions by 2050 and 80% by 2100.
- The Council has installed the UK's first sustainable energy 200 kWe fuel cell.
- The Council set up the first heating, cooling and private wire sustainable energy station in the country.
- Since its energy efficiency and environmental policies were implemented in 1990/91, the Council has achieved a reduction in its own energy consumption and pollutants of almost 49% and a reduction of 77% in CO_2 emissions. Both were achieved by March 2004.
- To tackle fuel poverty, the Council aimed to reduce heating costs of accommodation to a percentage of the state pension and by March 2004 98% of houses could be heated to a normal, standard temperature for 10% of income or less (for sheltered housing) or £10 a week or less (for non-sheltered housing). By March 2004 Woking Borough Council had also helped almost 3700 households in fuel poverty with Energy Conservation grants since 1996/97.

6.8 Kirklees Metropolitan Council

Kirklees Metropolitan Council is one of the leading local authorities in the UK in environmental matters. It has undertaken the largest photovoltaic programme in the UK, with 351 kWp of PV installed on social housing, community buildings and luxury flats.

Photovoltaics are the easiest renewable energy technology to integrate in towns and cities, because they can be installed on roofs and building facades with minimal intrusion and have the highest acceptance by the general public. They are now widely used in Germany and the Netherlands. Starting in 2000, Kirklees Metropolitan Council, based in Huddersfield, has taken part in a major European project to supply electricity from PV systems in city buildings. The EU-funded SunCities Project contributed to the installation of 351 kWp of PV systems on a range of private and public-sector housing and residential homes in Huddersfield. This is the largest domestic PV programme in the UK, and represents about 5% of installed PV capacity. All buildings were either refurbished or newly built to high environmental standards, so households gained the benefits of energy efficiency as well as the more visible PV systems.

A typical household system rated at 1 kWp generates about 800 kWh of electricity per year in the UK, which would give a saving of just over £50 per year if it all replaced imported electricity. The Council has lobbied to get better payment for the export of electricity, and also easier access to ROCs for small generators.

6.9 Croydon Energy Network Solar Water Heating

Croydon Energy Network runs a scheme for households to install solar water heaters at discount prices. The scheme also includes an optional interest-free loan to allow payments to be spread over time.

6.10 Devon County Council

The schemes discussed below were operational until 2006.

Bio-energy capital grants

Bio-energy capital grants are focussed on developing clusters of biomass-powered heating systems in a regional context. Up to 25% capital grants are allowed for certified biomass heating systems.

Solar PV major demonstration programme

Community groups and home owners can apply for funding through the first phase of the £20 million major photovoltaics demonstration programme. The aim is to see PV systems installed on 3000 homes and 140 medium and large non-domestic buildings, with a total of 9 MWp installed capacity.

6.11 The Sun Rise Solar Scheme

The Sun Rise Solar Scheme is a bulk discount scheme that reduces both the cost and time involved in installing solar water heating. Sun Rise provides installed systems from £2400 for one- to two-bedroom flats and from £2900 for three- to four-bedroom houses, inclusive of VAT and a Low Carbon Buildings Programme grant of £400 for domestic installations. A Low Carbon Buildings Programme grant of 50%, or up to £3500 per kWp is also available for solar PV installations. The cost of an installed PV system begins at £4000, including grant and VAT.

6.12 Essex County Council

Essex County Council has published a comprehensive report looking at the renewable technologies that are available for the county. This sets the target of 14% of the county's energy coming from renewable sources by 2010, an interim target that is set out in the regional planning guidance.

For more information see: www.essexcc.gov.uk.

6.13 Fife Council

Fife Council has published two companion Draft Supplementary Planning Guidelines: Wind Energy and Renewable Energy Technologies other than Wind.[10]

Use at microgeneration/domestic scale is supported in principle by Fife Council, with a 10% minimum embedded (on site) generation requirement. Draft Scottish Executive Guidance, SPP 6: Renewable Energy[11] indicates that Scottish ministers are also supportive of this approach.

Planning authorities are directed by the Scottish Executive in NPPG 6[12] to make positive provision for renewable energy developments in the exercise of their land use planning function.

6.14 Surrey Structure Plan 2004

Policy SE2: Renewable Energy and Conservation of the Surrey Structure Plan reads:[13]

> *Development for the generation of energy from renewable sources of wind, sun and biomass as a contribution to the regional target will be encouraged. Small scale proposals to serve individual buildings, or small groups of buildings, are becoming practicable and will be supported. In areas such as the AONBs, landscape considerations may preclude larger schemes, but small scale schemes may be acceptable.*
>
> *Commercial and residential development should be designed in such a way that a minimum of 10% of the energy requirement is provided by renewable resources. The use of combined heat and power or similar technology will be encouraged, and for all developments in excess of 5000 m^2 floorspace should be regarded as the norm.*
>
> *All types of development should incorporate energy efficiency measures in their design, layout and orientation.*

More information from: www.tandridge.gov.uk.

6.15 The Beacon Scheme

The Beacon Scheme rewards innovation in local government. It has several sections in which councils can be rewarded for their performance.

Within the energy section several councils have been awarded Beacon status for their work in delivering renewable targets. The Sustainable Energy Theme status was awarded to Cornwall County Council and partners, High Peak Borough Council, Leicester City Council, London Borough of Lewisham, Nottinghamshire County Council, Shropshire County Council and Woking Borough Council.

Case studies on each of these councils are available from: http://beacons.idea.gov.uk/idk/core/page.do?pageId=5098488.

7 Current and future policy and legislative impacts

Part L of the Building Regulations for England and Wales[14] has been updated regularly to aid compliance with the Energy Performance of Buildings Directive[15] (see section 7.6 for more details). The new regulations came into force in April 2006. These replace the 2002 Approved Documents and split the guidance across four documents. The changes are summarised in Table 23.

Table 23 Regulations for new build and refurbishment from the Building Regulations (2000), Part L Conservation of Fuel and Power, 2006[14]

	New dwellings – Approved Document L1A[4]	Refurbishment (existing dwellings) – Approved Document L1B[16]
Dwellings	Provide a 20% improvement on energy efficiency compared to 2002 regulations. Whole building carbon dioxide emissions target to be achieved or bettered based on notional buildings emissions. Minimum fabric U-values and a requirement to meet minimum air leakage through pressure testing. Provision of energy systems, controls and maintenance information to owners on handover.	A requirement to meet upgrade energy efficiency standards when upgrading fabric and building services. Subject to the renovation providing a simple payback of 15 years or less and being technically feasible.

Table 23 (continued)

	New dwellings – Approved Document L2A[17]	Refurbishment (existing dwellings) – Approved Document L2B[18]
Buildings other than dwellings	Provide a 23% improvement in energy efficiency for naturally ventilated buildings and 28% improvement for air-conditioned buildings when compared to a notional building of same type, size and shape, etc. designed to meet 2002 regulations. Minimum fabric U-values and a requirement to meet minimum air leakage of 10 $m^3/hr/m^2$. Pressure testing is mandatory for buildings over 500 m^2. For smaller buildings, it can be avoided by assuming a high air leakage (15 $m^3/hr/m^2$) in the CO_2 calculation. Appropriate commissioning and the provision of appropriate information including a building log book to allow owners and occupiers to manage energy use efficiently. Metering to allow at least 90% of estimated annual energy use to be attributed to end use (heating, lighting, etc.). This is to include automatic meter reading and data collection in buildings over 1000 m^2.	New work in existing buildings must comply with tighter elemental standards for services, fittings and thermal elements. For buildings over 1000 m^2 where an extension is proposed or where there is an initial provision of, or an increase in the provision of, an existing, fixed service (the principal works), the regulations require additional consequential improvements to be made to the existing building. Consequential improvements could include upgrading HVAC services over 15 years old, inefficient lighting, and building fabric that fails to meet minimum U-values; and increasing low and zero carbon technologies installed. Such improvements are required to be made only if the payback is 15 years or less (7 years for LZC systems) and, in the case of extensions, up to a value of 10% of the proposed principal works. When installing building services, improving the fabric of the building served by the new service is also required, but these measures cannot count towards the cost of consequential works. For extensions greater than 100 m^2 and greater than 25% of the total floor area of the existing building, Approved Document L2A applies.[17]

7.1 Energy White Paper (2003)

The Energy White Paper (2003)[19] states an ambition to reduce projected carbon emissions for 2020 by around 15%, which is expected to come from greater efficiency in the use of energy and a greater dependence on cleaner energy sources supported by capital grants schemes. A longer-term ambition is to reduce emissions by the 60% recommended by the Royal Commission on Environmental Pollution by 2050, which would mean emissions of 'around 65 million tonnes' of carbon a year.

There is also a stated ambition to remove everyone from 'fuel poverty' by 2016–18. Fuel poverty is described as when a household has to spend 10% of its income on energy to adequately heat the home. There has been a reduction to around 3 million households in recent years, helped mainly by a reduction in energy costs. As the price of energy has dramatically increased in recent months – and all projections suggest that this trend is likely to continue – the number of households affected is likely to increase once more.

Fuel poverty is a result of poor-quality housing being occupied by low-income and vulnerable groups. So while increasing benefit payments and falling energy prices moved many families out of fuel poverty as it was defined, it will not have overcome the underlying problem of poor-quality housing that will bring these people back into fuel poverty as energy prices rise once more.

7.2 The Code for Sustainable Homes

The new Code for Sustainable Homes (The Code) sets environmental sustainability performance targets for new homes in England. The Code rates the environmental sustainability of a new home against nine categories of sustainable design including energy; water; waste; materials; surface water run-off; pollution; health and wellbeing; management and ecology. Credits are awarded for good environmental performance against defined standards. Credits are aggregated and weighted to calculate a points score. Points are added together to produce an overall rating on a scale of 1 to 6, where 1 is the lowest and 6 the highest standard. Mandatory minimum standards are set for energy, water use, waste, materials and surface water run-off. Level 6 requires carbon neutrality.

A consultation exercise in 2007 has resulted in the Government's decision to proceed with the implementation of mandatory rating against The Code for all new dwellings. (See The future of The Code for Sustainable Homes – making a rating mandatory: Summary of responses, available from www.communities.gov.uk/publications/planningandbuilding/sustainablehomes).

The Code Technical Guidance (CLG, October 2007) states that "Off-site renewable contributions (to energy use) can only be used (in the calculation supporting carbon neutrality) where these are directly supplied to the dwellings by private wire arrangement". This means that for a new home to be truly carbon neutral, its total energy demand must be supplied by either onsite renewables, or a development-wide renewable source. If energy is supplied from the national grid, even via a renewable source, its contribution to carbon neutrality will not be admissible within The Code.

The Code technical guidance is available from: www.planningportal.gov.uk/uploads/code_for_sustainable_homes_techguide.pdf. The Code is currently being revised and will be available on this website from April 2008.

7.3 Energy Efficiency Action Plan (2004)

The action plan, under DEFRA, sets out how the UK will reduce its energy use across the economy. Focussing on the domestic sector, the main instruments within the plan are:

- An extension of the existing Energy Efficiency Commitment (EEC) scheme to 2011 with a doubling of the funding available (refurbishment).
- Updating the Building Regulations Part L,[14] which was also carried out in order to comply with the EU Energy Performance of Buildings Directive (new build and refurbishment) to require higher-efficiency boiler installations (condensing boilers) during any replacement or new installation.
- Negotiating improvements in appliance efficiency through EU-wide programmes (new build and operational).
- A continuation of the Decent Homes Programme which focuses primarily on insulation and heating systems within social landlord (refurbishment) housing stock.
- Tax relief to landlords wishing to install insulation into their properties (refurbishment) to help bring housing in the private sector to a 'decent' level of thermal comfort.
- Reduced VAT rates for GHSPs (new build and refurbishment).
- Continuation of the Warm Front programme, which addresses fuel poverty (refurbishment).
- Continuation of existing renewable energy grant schemes (new build, refurbishment and operational).

Much of this activity was either already in existence or was required anyway (eg updating Building Regulations) and the majority of the focus understandably is on the existing housing stock.

7.4 Microgeneration strategy

The microgeneration strategy published in April 2006 by the DTI (now BERR) identifies a number of constraints to the take-up of micro-renewable technologies in the UK. These constraints fall into a number of categories. The strategy goes on to make suggestions for how these will be overcome.

Cost constraints

- Researching consumer behaviour to find out what motivates early-adopter purchase decisions.
- Providing clear guidance on ROCs, LECs and REGOs.
- Energy suppliers developing a scheme to reward microgenerators who export excess electricity (if this is not done within 12 months, a scheme will be imposed on them).
- Possibility of including other electricity generation technologies (other than micro CHP) in the EEC framework.

Information constraints

- Develop an accreditation scheme for all micro technologies covering products, installation and codes of practice.
- Consider information campaigns to raise the profile of microgeneration.
- Identify and fill information gaps experienced by planning officers.
- Produce a report for local authorities on the measures that can be taken to improve energy efficiency and microgeneration installations.
- Produce information for the construction industry.

Technical constraints

- Ensure network and market systems are able to cope with growing microgeneration and exporting onto the grid.
- Ensure existing contracts between suppliers and domestic customers do not act as a barrier to installation.
- Ensure wiring regulations do not form an unnecessary barrier to take-up.
- Possible field trial of smart metering and microgeneration to determine effectiveness of combining these two technologies.

Regulatory

Review local plans and take action where these do not fully incorporate Planning Policy Statement (PPS) 22.[6]

Other

- Develop a scheme for installing microgeneration technologies in schools.
- Enhance understanding of potential for microgeneration before deciding on whether a target for microgeneration is required.
- Produce a map of available research and development funding together with guidance on how to apply.
- Develop a route map for each technology.
- Ensure the skills base develops to support levels of increasing demand (especially construction skills eg plumbers and electricians).

7.5 Renewable Energy

The Energy White Paper confirms the current target of 10% of electricity to be supplied from a renewable source by 2010, with an aspiration to reach 20% by 2020. This aspiration caused consternation among renewable energy suppliers, installers and environmental bodies, as this would not integrate with the incremental increases in Renewable Obligations (RO) that utility companies have to purchase. This would leave the industry unclear of future requirements, making investment in renewable energy by utilities more difficult to justify.

The government extended the RO scheme to 2015/16 with corresponding annual increases in renewable generation to reach 15.4% by the end of the period.

The Renewables Innovation Review[20] states that the 10% target will be achieved if current barriers to wind energy are removed. The review states that the wind resource is the only economically viable and scalable technology and that it will be the main focus for the UK reaching its 10% target. According to the review this extension in the RO has removed some barriers to wind energy installation but that institutional barriers remain. There will be a need to upgrade the distribution network in order to allow wind energy to play its part.

The British Wind Energy Association has carried out a number of tests across the UK in locations where wind farms are planned, to assess local attitudes before installation and once operational. All studies show that once the turbines are operating the level of public opposition to them falls.

This drop could be down to media representation, a very active anti-wind energy lobby and a general lack of knowledge on the part of the public that allows the media and lobby groups to create a negative attitude in local populations even before the turbines are installed. Greater awareness of the facts of wind power, the good and the bad, would help improve the chances of future planning permission due to fewer local objections.

Other renewable energy technologies that could play a major part in reducing carbon emissions to help reach the longer term 60% reduction by 2050 include fuel cells and wave/tidal energy. Both are currently at the early stages of development. Serious safety concerns regarding the storage of hydrogen will need to be overcome before fuel cells can be fully utilised. In addition, the generation of hydrogen will have to be from renewable sources if the technology is to be considered a renewable technology.

Much of the renewable policy to date has focussed on the generation of electricity or the localised generation of heat for individual buildings or sites. There are now moves to address community-scale heat production and the provision of renewable heat looks likely to have its own targets set in the near future. Community-scale heating has a number of benefits over individual heating sources including ease of maintenance, the ability of the boilers (or CHP units) to operate at a higher base loads for longer hours than individual heating systems, and reduced running costs (if the costs of all dwelling or building-scale installations is compared to that of a centralised system).

However, its uptake and the maintenance of existing systems is well below that in other European countries with a similar climate. Much of the resistance towards CHP seems to stem from the reputation of a few bad installations in the 1970s and 1980s. Although the apparent problems would not occur in a modern installation, it is very difficult to change market perception in the UK.

7.6 Implementation of elements of EU Directives

While the revisions to the Building Regulations have allowed for the implementation of most of the EU Energy Performance of Buildings Directive, there are a number of areas that are still to be provided for.

The production of energy certificates for display in buildings regularly accessed by the public that are over 1000m^2 and for buildings when they are bought, sold and rented still needs to be developed. The approved calculation methods (SBEM for non-domestic buildings[21] and SAP 2005[22] for domestic properties) do have the ability to produce these energy certificates once it is confirmed how these will look and how the A-G rating system will be calculated.

There is also a need to inspect boilers and air conditioning equipment above a certain size and to provide advice and information. The UK will be providing advice to meet this requirement, but as the Directive requires that such advice will provide the same carbon savings as inspection it is not clear how this will be achieved or demonstrated.

APPENDIX A

Standards and other sources of information

A1 Regulations and Standards applicable across the technologies

- Building Regulations 2000, England and Wales
    - Approved Documents Part L1A, Part L1B, Part L2A, Part L2B
    - Domestic Heating Compliance Guide
    - Low or Zero Carbon Energy Sources: Strategic Guide
    - Approved Document Part J.
- Building (Scotland) Regulations 2004
    - Technical Handbook 2006.
- Building Regulations (Northern Ireland) 2000
- Control of Substances Hazardous to Health Regulations (COSHH) 1994
- Electronic Equipment Regulations (RoHS) 2006 SI 1463
- Pressure Equipment Regulations (PED) 1999
- Water Supply (Water Fittings) Regulations 1999
- BS EN 60335-1:2002 Household & similar electrical appliances – Safety – Part 1
- General requirements BS7671:2001 Requirements for Electrical Installations
- Energy Networks Association Engineering Recommendation G83/1: Recommendations for the connection of small-scale embedded generators (up to 16A per phase) in parallel with public low-voltage distribution networks.

Further information regarding the Microgeneration Certification Scheme is available for download from www.uk-microgeneration.org.uk. The website has full details of the Microgeneration Installation Standards for installers and the Microgeneration Certification Scheme for products.

A2 EU Directives applicable across the technologies

- Energy Performance of Buildings Directive: 2002/91/EC
- Airborne Noise: 86/594/EEC
- Construction Directive: 89/106/EEC
- Electromagnetic compatibility (EMC) Directive: 89/336/EEC
- Energy Labelling Directive: 92/75/EEC
- Energy Using Products Directive (EuP): 2005/32/EEC
- Low voltage (LV) Directive: 73/23/EEC
- Machinery Directive: 98/37/EEC.

A3 Standards for solar thermal systems

- BS 7431:1991 Method for assessing solar water heaters. Elastomeric materials for absorbers, connecting pipes and fittings
- TS 12977-3:2001 Performance characterisation of stores for solar heating systems

- TS 12977-2:2001 Thermal solar systems and components. Custom built systems. Test methods
- TS 12977-1:2001 Thermal solar systems and components. Custom built systems. General requirements
- BS EN 12976-2:2001 Thermal solar systems and components. Factory made systems. Test methods
- BS EN 12976-1:2001 Thermal solar systems and components. Factory made systems. General requirements
- BS EN 12975-2:2001 Thermal solar systems and components. Solar collectors. Test methods
- BS EN 12975-1:2000 Thermal solar systems and components. Solar collectors. General requirements
- BS 7074 Application, selection and installation of expansion vessels and ancillary equipment for sealed water systems
- BS 5449, BS EN 12831 BS EN 12828 Specification of forced circulation hot water central heating systems for domestic premises
- CIBSE Domestic Building Services Panel – design guide for solar water heating.

A4 Standards for solar electric systems

- BRE Digest 438 Photovoltaics: integration into buildings, 2004
- BRE Digest 489 Wind loads on roof-based photovoltaic systems, 2004
- BRE Digest 495 Mechanical installation of roof-mounted photovoltaic systems, 2005
- Understanding building integrated photovoltaics. TM25, CIBSE, 2000.

A5 Standards for heat pump systems

- BS EN 14511:1-4:2004. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors for space heating and cooling.
- BS 7074:1-3:1989. Application, selection and installation of expansion vessels and ancillary equipment for sealed water systems. Code of practice for domestic heating and hot water supply
- BS EN ISO 5198:1999. Centrifugal, mixed flow and axial pumps – Code for hydraulic performance tests – precision class (AMD 10668)
- BS 8207:1985. Code of practice for energy efficiency in buildings (AMD 8151)
- BS 6880-1:1988. Code of practice for low temperature hot water heating systems of output greater than 45kW. Fundamental and design considerations
- BS 6700:2006. Design, installation, testing and maintenance of services supplying water for domestic use within buildings and their curtilages – Specification
- BS EN 378:1-4:2000. Refrigerating systems and heat pumps – Safety and environmental requirements. Basic requirements, definitions, classification and selection criteria
- Ground source heat pumps: a technology review. TN18/99 BSRIA, 1999
- How to design a heating system. Knowledge Series 08, CIBSE 2006.

A6 Standards for wind turbine systems

- BS EN 61400-1:200.5 Wind turbines. Design requirements
- 61400-2 BS EN 61400-2:2006. Wind turbines. Design requirements for small wind turbines

- 61400-11 BS EN 61400-11:2003. Wind turbine generator systems. Acoustic noise measurement techniques
- 61400-12 BS EN 61400-12-1:2006. Wind turbines. Power performance measurements of electricity producing wind turbines.

A7 Standards for biomass systems

- BS 4543-2:1990. Factory made chimneys. Specification for chimneys with stainless steel flue linings for use with solid fuel fired appliances (AMD 8380)
- BS 6461-1:1984. Installation of chimneys and flues for domestic appliances burning solid-fuel (including wood and peat). Code of practice for masonry chimneys and flue pipes
- BS 1846-1:1994. Glossary of terms relating to solid fuel burning equipment. Domestic appliances
- BS 5588-1:1990. Fire precautions in the design, construction and use of buildings. Code of practice for residential buildings.

A8 Associations

- BRE. www.bre.co.uk
- British Photovoltaic Association. www.pv-uk.org.uk
- British Wind Energy Association. www.bwea.com
- Centre for Alternative Technology. www.cat.org.uk
- Combined Heat and Power Association. www.chpa.co.uk
- Heat Pump Association. www.feta.co.uk/hpa
- Home Energy Conservation Association. www.ukheca.org.uk
- Renewable Power Association. www.r-p-a.org.uk
- Solar Trade Association. www.greenenergy.org.uk/sta
- UK Heat Pump Network. www.heatpumpnet.org.uk.

APPENDIX B

Cost information

B1 Typical system costs

System type	Typical system	Typical installed cost (£)*
Flat plate solar thermal	2.5 m^2 or 1 KW equivalent	1750
Evacuated tube solar thermal	2 m^2 or 1 KW equivalent	2000
Photovoltaics	2 kW	10 000
Ground source heat pump	4 kW	7000
Small scale wind turbine	400 W	2000
Pellet boiler	6 kW	6000
Pellet stove	3 kW	4500 per kW

* Based on figures from the Clear Skies and Low Carbon Buildings Programmes.

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16 The Building Regulations 2000. Part L1B: Conservation of Fuel and Power in Existing Dwellings, 2006.

17 The Building Regulations 2000. Part L2A: Conservation of Fuel and Power in New Buildings Other Than Dwellings, 2006.

18 The Building Regulations 2000. Part L2B: Conservation of Fuel and Power in New Buildings Other Than Dwellings, 2006.

19 DTI, February 2003. Energy White Paper: Our Energy Future – Creating a Low Carbon Economy. Download from www.berr.gov.uk/files/file10719.pdf.

20 See www.planningportal.gov.uk/uploads/code_for_sust_homes.pdf.

21 See www.ncm.bre.co.uk/software.jsp.

22 See http://projects.bre.co.uk/sap2005/.

NHBC Foundation publications

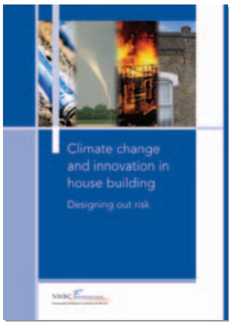
A guide to modern methods of construction

NF1, December 2006

Conserving energy and water, and minimising waste

A review of drivers and impacts on house building

NF2, March 2007



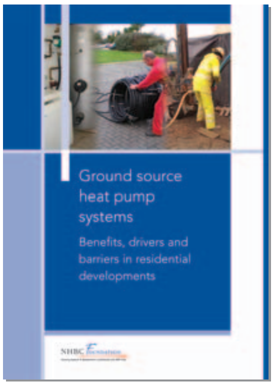
Climate change and innovation in house building

Designing out risk

NF3, August 2007

Risks in domestic basement construction

NF4, October 2007



Ground source heat pump systems

Benefits, drivers and barriers in residential developments

Ground source heat pump systems use low level heat energy created by solar gain in the near surface layers of the earth for space and water heating. This potentially limitless supply of energy appears to be a good route to a sustainable energy supply.

This review has been produced at a time when the take-up of these systems is on the increase. It provides a valuable tool for specifiers, developers and builders looking to incorporate this new technology.

NF5, October 2007

Modern Housing

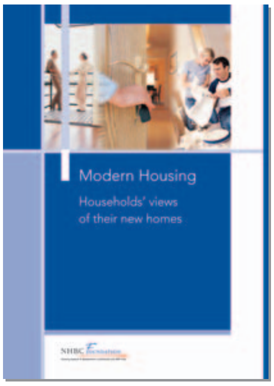
Households' views of their new homes

This review compares Modern Housing (homes built since 1991), older housing stock (pre-1991) and housing built between 2002 and 2004, using data from Communities and Local Government's English House Condition Survey and Survey of English Housing.

The review summarises the results and statistics from these surveys and provides a snapshot of households' views on their homes and neighbourhoods, including suggestions for potential improvements to future housing.

Offering a powerful resource tool the review details information on topics as varied as satisfaction levels, demographics, spatial issues, safety and perceptions of neighbourhoods overall.

NF6, November 2007



NHBC Foundation publications in preparation

- Hydraulic lime mortars
- Site waste management plans

NHBC Foundation
Housing research & development in partnership with BRE Trust
www.nhbcfoundation.org

A review of microgeneration and renewable energy technologies

The use of microgeneration and renewable energy technologies has been highlighted as one key approach in addressing the government's ambitious 2016 zero carbon homes target. With less than a decade within which to develop systems and processes to meet this target, and with strict definitions of zero carbon outlined in the Code for Sustainable Homes, the work needed cannot be underestimated.

This review is, therefore, both timely and pertinent, assessing a variety of the current technologies for their likely capability, impact, payback periods and suitability for use in the domestic sector. In addition it reviews the legislative framework and the mechanisms local authorities are implementing to drive the uptake of these technologies.

NHBC Foundation
Housing research & development in partnership with BRE Trust

The NHBC Foundation has been established by NHBC in partnership with the BRE Trust. It facilitates research and development, technology and knowledge sharing, and the capture of industry best practice. The NHBC Foundation promotes best practice to help builders, developers and the industry as it responds to the country's wider housing needs. The NHBC Foundation carries out practical, high quality research where it is needed most, particularly in areas such as building standards and processes. It also supports house builders in developing strong relationships with their customers.

NF7
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