CE102

New and renewable energy technologies for existing housing

energy saving trust™

Contents

Introduction

Home energy use is responsible for 28 per cent of UK carbon dioxide emissions which contribute to climate change. By following The Energy Saving Trust's best practice standards, new build and refurbished housing will be more energy efficient, reducing these emissions, saving energy, money and the environment.

This guide deals with the integration of new and renewable energy technologies into housing refurbishment schemes. It describes the technologies that are available, as well as how and where they can be used.

These technologies offer alternatives or supplements to conventional domestic fuels and energy systems. Although their capital cost may be relatively high, carbon emissions are much lower than those associated with fossil fuels, and in some cases there are no emissions. The immediate benefit of new and renewable systems is the reduced impact they have on the environment.

In the medium to long term, capital costs are likely to reduce, and along with the anticipated increase in fuel prices and the potential of carbon taxes, the financial viability of many of the technologies will continue to improve. Therefore new and renewable energy technologies will play an increasingly important role in reducing fuel bills; they will also help to reduce the UK's dependence on imported fuels. As a consequence, carbon emissions will be reduced, thereby providing affordable warmth and greater security of supply.

For landlords, there is a potential for increased medium-term asset values, so consideration of new and renewable energy technologies should always be included in landlords' housing asset management strategies. New and renewable energy systems may at first appear expensive, but 'whole life cost' assessments can often demonstrate their real value.

Housing refurbishment schemes provide opportunities to combine the installation of new and renewable energy systems with other improvements. Integrating improvement work in this way not only provides economies of scale, but also permits the adoption of a 'whole house' approach, in which the energy efficiency of the fabric of the house is considered alongside the options for providing heating, hot water, ventilation and electrical power. Even simple single-measure improvements can provide opportunities for new or renewable energy systems; for example, older boilers may be replaced by micro-combined heat and power (micro-CHP) systems or ground source heat pumps, and new hot water systems may incorporate solar pre-heating.

Technologies which are relatively straightforward to integrate such as solar hot water are already being installed at an increasing rate. There is a wide range of support available including guides, case studies and training. Financial grants for feasibility studies and for implementation are available for some technologies. See Further information for more details.

This guide will help landlords and homeowners select the right new and renewable energy systems for their homes. (See Further information for these and other publications referred to in this guide.)

Energy efficiency

When applying new and renewable energy technologies to existing dwellings it is important to reduce the energy demand. Older, not previously improved, dwellings rarely have adequate levels of insulation. Heating systems often have high output and poor efficiency. There will probably be conventional electric lighting (i.e. with tungsten lamps) and older electrical appliances. All of these factors can raise the electric power demand of older dwellings to levels that renewable energy systems may not be able to meet. Improving energy efficiency is therefore a strongly recommended precursor to the installation of renewable energy systems.

Energy efficiency should be improved on a 'whole house' basis wherever possible, including:

- Insulation.
- Reduced thermal bridging.
- Improved air-tightness.
- Controlled ventilation.
- Efficient heating and hot water systems.
- Responsive heating and hot water controls.
- Efficient lighting and appliances.

See Further information for more guidance.

Energy efficiency measures are usually more cost effective and cheaper than new and renewable energy systems. However, in order to identify the most environmentally appropriate improvement specification, a 'whole life' (net present value) analysis should be carried out, taking into account occupants' fuel costs and the social cost of carbon emissions, as well as capital and maintenance costs. Energy efficiency measures and renewable energy technologies should both be considered in these analyses. Such exercises often justify the use of relatively expensive new and renewable energy systems because of the reduction in fuel costs and emissions over the entire life of the dwelling.

Costs and performance

Table 1 (see Appendix A) summarises the relative capital and maintenance costs, as well as performance (in terms of carbon emissions), of seven new and renewable energy technologies. To assist comparison, typical capital, maintenance and running costs of each type of system have been classified on a five-point scale:

- Very high (typical current costs plus more than 25 per cent).
- High (typical current costs plus up to 25 per cent).
- Medium (typical current costs ±5 per cent).
- Low (typical current costs less up to 25 per cent).
- Very low (typical current costs less more than 25 per cent).

The 'typical' value is that of a conventional gas-fired central heating and hot water system with grid-supplied electricity, in an individual dwelling.

Where to use these technologies

Table 2 (see Appendix A) considers the suitability of new and renewable energy technologies to different types of existing housing (high and low density urban housing, distributed suburban housing, and rural housing). While this classification is by no means definitive, it indicates which technologies may usefully be investigated further. Key issues are built form (detached houses, terraces, medium or high-rise blocks, etc) and density. Each of the technology sections that follow include a short summary of the key factors that determine the most appropriate applications.

Combined heat and power

In conventional large-scale electricity generation, more than 65 per cent of the primary energy is lost as waste heat. This accounts for the high cost and high carbon emissions associated with grid-supplied electricity. One way of addressing this problem is to generate electricity locally, and use the waste heat for local heating needs. If an appropriate local heat load exists, such combined heat and power (CHP) systems can be up to 90 per cent efficient, compared with approximately 35 per cent for conventional centralised power generation.

CHP systems have higher capital and maintenance costs than conventional heating using central boiler plant (although the additional capital costs may be offset by financial support from the Energy Saving Trust's Community Energy programme and they can be recovered over the lifetime of the system). The cost of heat is comparable with that of conventional boiler-based communal heating systems. Overall running costs are lower, though, both because of the reduced demand for mains electricity and revenues from the sale of surplus power (depending on the system installed). Carbon emissions are significantly lower provided the heat produced replaces supplies from heat-producing appliances using electricity or fossil fuels.

The most appropriate applications of CHP in existing housing are likely to be on single sites with large numbers of dwellings, such as estates that already have communal heating from central boiler houses. In these cases, when boilers are replaced by CHP plant, the existing heat distribution systems can often be re-used, with little or no modification. It is however necessary to modify on-site electricity distribution systems to use the locally generated electricity.

The key management issues concern the procurement and maintenance of a net metering contract (so that surplus electricity may be sold to the national grid) and arrangements for metering individual dwellings (charging tenants for the use of both heat and power).

CHP systems range in size from a few kilowatts to many megawatts. They can be used to supply groups of dwellings, neighbourhoods or districts. They can run on coal, oil, waste materials, bio fuels or even hydrogen; most, though, run on natural gas. Small-scale CHP units are usually based on internal combustion engines, gas turbines, steam engines or steam turbines. The engine is used as a generator of electric power. The engine cooling system heats water (and exhaust gases may be passed through a heat exchanger) in order to transfer heat to a hot water circulation system, usually supplying radiators or under-floor heating coils. Heat distribution and control systems are similar to those used for conventional heating with central boiler plant. Domestic hot water can be provided via a central hot water storage tank and distribution system, or more commonly by means of local plate heat exchangers that extract heat from the space heating circuit.

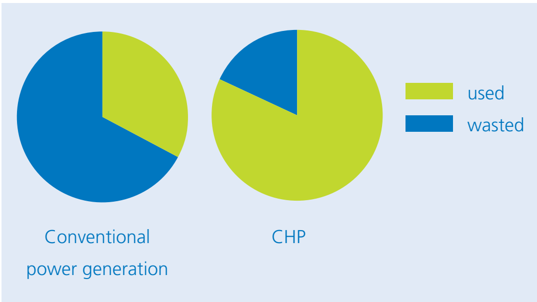

Figure 1
The proportion of primary fuel turned into useful energy
(source: CHPA)

Where to use these technologies

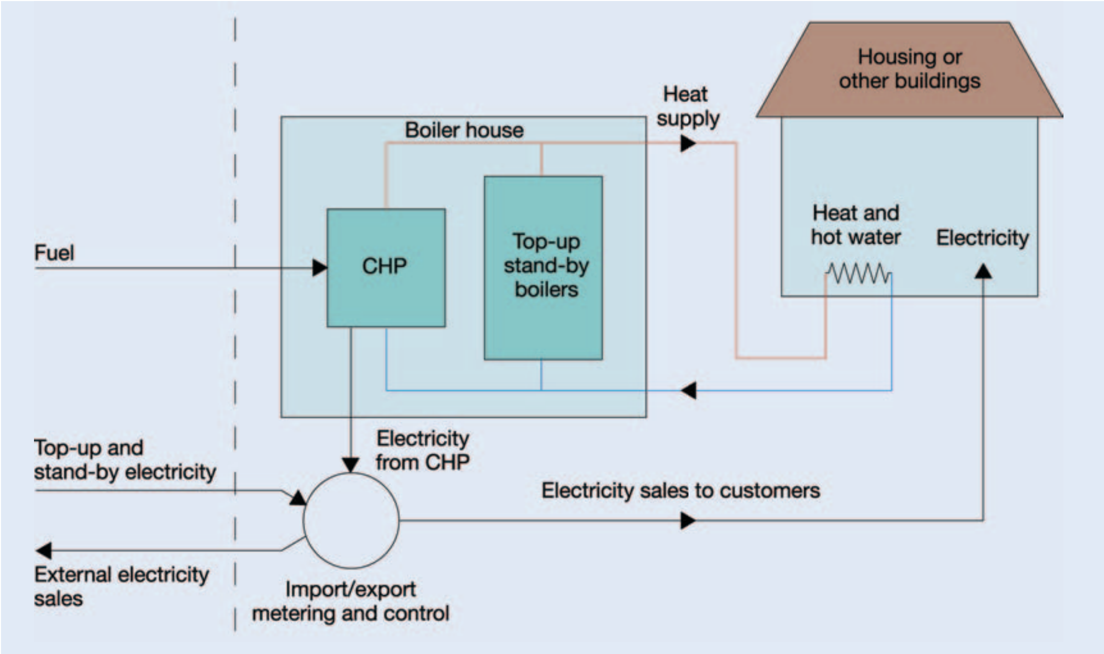

Figure 2
Schematic of a domestic CHP system. In practice, heat and electricity from CHP systems are supplemented by top-up boilers and by connection to the electricity distribution network. This ensures reliability of supply and provides opportunities for electricity sales to other customers.

The key technical challenge in designing a CHP system is to balance the thermal and electrical loads. Systems are usually designed to meet the heat requirement; this often results in a surplus of electric power during the heating season.

If surplus electricity is generated, the basic options are to:

- Sell it directly to customers via a 'private wire' scheme (see below).
- Sell it to customers via the grid and pay use-of-network charges.
- Sell it directly to the grid (which, for gas-fired schemes, will bring the lowest price).

If selling to the grid, the most appropriate solution is 'net metering' where the electricity exported is subtracted from the amount imported, with only the balance being paid for.

Another approach is to size the CHP system to match the base heating load, and use conventional stand-by boilers to meet the peak thermal load. In this case, surplus electricity is not usually a problem but overall carbon emissions are slightly higher because less mains electricity is 'displaced'.

If there is no space heating demand (for example, outside the main heating season), then running the system for water heating and power only may result in a heat surplus. This can be avoided by storing hot water (allowing the system to be run only intermittently to maintain the temperature of the store).

Alternatively, it may be possible to run the CHP system just during the heating season. At other times, hot water is provided by a gas-fired calorifier and electric power is purchased from an external supplier or generated using renewable energy - such as photovoltaics (PV). These arrangements can also make use of net metering contracts.

Where to use these technologies

Figure 3
A typical hydraulic interface unit. The connections are similar to those of a conventional gas boiler except that instead of being connected to a gas main, it is connected to a heat main.

Key facts - CHP

- Capital costs for CHP are approximately £600-£1500 per kWe, plus the cost of the heat distribution network. Total costs (including the distribution network) are usually between £3,000 and £8,000 per dwelling served, with smaller schemes at the upper end of this range.
- For housing developments, a minimum density of 50 dwellings per hectare is recommended. Consideration should also be given to the usefulness of conducting a cost benefit analysis (£/tonne CO_2). See Further information for additional guidance on CHP.

Micro combined heat and power

For individual dwellings or groups of dwellings clustered together, micro-CHP systems are now available. These are predominantly gas-powered and deliver between 1kW and 3kW of electric power (1-3kWe), and between 4kW and 8kW of heat (4-8kWth); one system that incorporates a boiler is claimed to deliver up to 36kWth. They can therefore replace domestic heating boilers for space heating and hot water, whilst offering the additional benefit of electricity generation.

A micro-CHP unit is approximately the same size as a small domestic refrigerator or floor-mounted boiler, and is similar in appearance. It requires a gas supply and a flue. Space heating is delivered via hot water to radiators, and domestic hot water is supplied by a conventional indirect storage cylinder. A micro-CHP unit can be connected into an existing wet heating system, often in place of an existing boiler. Dwellings are thus unlikely to require significant alterations and disruption to the occupants is minimised.

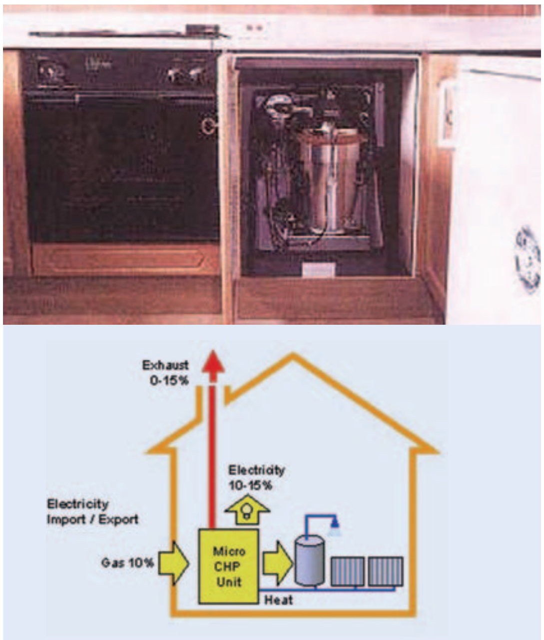

Figure 4
A typical micro-CHP unit
Source: MicroMap, EU Project

The obvious application for micro-CHP in existing housing is in individual dwellings or small groups of dwellings in urban locations where large-scale CHP is not appropriate. Small, well insulated dwellings with low heat loads (up to 6kW) are particularly appropriate, since the system capacity is likely to be closely matched to demand, both in terms of heat and power.

Micro-CHP systems with higher thermal outputs can help with hard-to-treat dwellings (those with solid walls, solid floors and no loft space) where there is a relatively large heat demand and energy efficiency measures are expensive. In this type of dwelling, micro-CHP will produce fewer carbon emissions than a condensing boiler.

Where to use these technologies

Micro-CHP is a relatively new technology and so capital and maintenance costs are high when compared with those of conventional heating systems. National arrangements and standards for net metering contracts are being negotiated with the electricity industry. Some suppliers already have systems in place. Effective from 7th April 2005, the UK Government has introduced a reduced role of VAT (five per cent) for micro-CHP systems. This is designed to help encourage demand for the technology.

Key facts – micro-CHP

- Installed capital costs are of the order of £2,500 for a 1kWe unit, or £3,500 for a 3kWe unit.
- Fuel cost savings (including electricity cost savings), are approximately £150* a year compared with a conventional gas-fired boiler. This gives a payback for the additional costs of approximately five years.

* The cost saving has been estimated by several consultants and by BRE from their work on a range of projects.

Solar water heating

In solar water heating systems, the sun's energy is used to provide domestic hot water. It is particularly appropriate for existing dwellings where heating system improvements are already being undertaken, and a solar collector may be fitted on the roof.

These systems do not generally provide space heating, and can be described as 'solar thermal' systems. Solar water heating systems will be of interest to landlords as they are amongst the most cost-effective renewable energy systems that can be installed on existing dwellings. During the summer months a typical solar hot water system can supply between 80 and 100 per cent of hot water demand. This will be considerably less in winter. The capital cost of installing solar water heating (compared to conventional forms of domestic water heating) is relatively high; however this cost can be recouped through reduced fuel bills.

The sun's energy is absorbed by a roof-mounted solar collector. The two main types of commercially available systems employ one of the following:

- Flat plate collectors.
- Evacuated tube collectors.

The operating principle is the same in both cases: liquid (usually water with anti-freeze) is circulated through the solar collector and heated by the sun; the heated liquid is then passed through a coil in a hot water storage cylinder. The water in the cylinder may then be supplied directly, or raised to a higher temperature (if required) by a boiler or electric immersion heater.

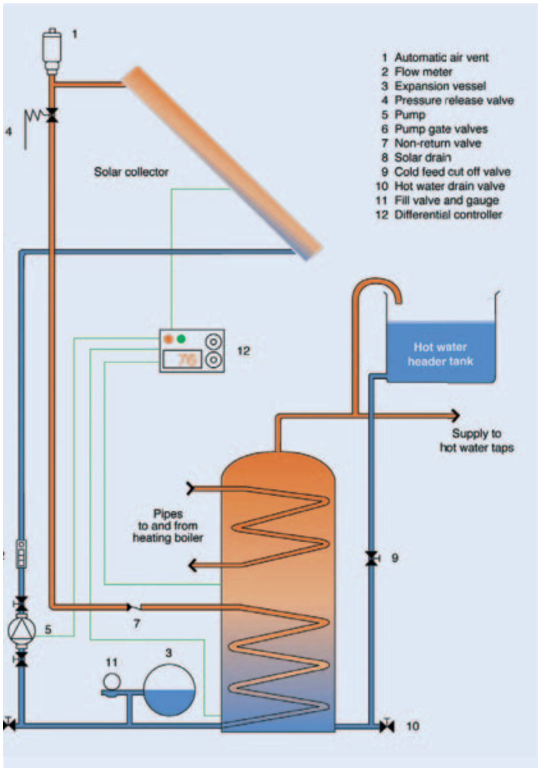

Figure 5
A solar water heating system
courtesy of AES Solar Systems Ltd

Flat plate collectors consist of a flat panel with a heat absorbing surface coating, an insulated back to reduce heat loss and a glass panel on the top that behaves like a 'mini-greenhouse' to help retain the heat in the collector.

Where to use these technologies

Evacuated tube collectors are more sophisticated, but use the same principle. The collector consists of a series of evacuated glass heat tubes grouped together; heat losses are reduced because there is a vacuum inside the tube. They are generally more efficient than flat plate collectors but they have higher capital costs. Evacuated tube collectors may be more appropriate where roof space is limited.

Typically, a solar water heating system will provide most of the hot water required by a dwelling during the summer and a high proportion in the spring and autumn. However, it will only make a minor contribution during the winter. Overall, solar water heating can provide 50-60 per cent of the hot water demand in a dwelling. The figure can vary greatly depending on the occupancy factor, and whether hot water is used during the day (when the sun is shining) or has to be stored until the evening.

The key to success lies in advising the occupants how to make the best use of this technology. Visual displays on controls are one method: a sun symbol which appears when the sun is actually heating the water tells residents that this would be a good time to use hot water, for example in the washing machine.

When considering using solar water heating in existing housing:

- Ensure an adequate area (typically between 2-5m^2) of southerly-oriented (±30º) pitched roof is available (not shaded by chimneys, dormers, etc).
- Provide a larger hot water storage cylinder than would normally be the case with a gas-fired system.
- Check whether planning permission is needed for roof-mounted collectors, especially in conservation areas and other architecturally sensitive locations.

Where dwellings are being re-roofed, or flat roofs are being converted to pitched roofs, consider alternative roof forms (e.g. hipped roofs instead of gable ends) in order to create well-oriented locations on which to mount solar collectors.

Even where it is decided not to include solar water heating, it may be appropriate to install hot water installations that are 'solar ready', which allow solar systems to be added at a later date with minimal disruption.

Key facts – solar water heating

- There are approximately 42,000 domestic solar water heating systems in the UK.
- Capital costs for typical 4m^2 systems on individual dwellings are between £2,000 and £3,000. Communal systems cost less.
- A 1m^2 solar collector will deliver between 400 and 700kWh/yr, and reduce carbon dioxide emissions by between 250 and 1,300kg/yr.
- A typical solar water heating system in the UK (approximately 4m^2) will provide 40-50 percent of a dwelling's domestic hot water requirements, and deliver between 1400 and 2500kWh of useful energy per year. Depending on the fuel being displaced, carbon dioxide emissions can be expected to be reduced by between 400 and 760 kg annually. See Further information for additional guidance on solar water heating.

Photovoltaic electricity

In properly insulated dwellings with an efficient heating system, electricity for lighting and running domestic appliances is likely to represent the largest proportion of overall fuel costs. It will also be the major cause of carbon emissions associated with energy use in the dwelling. Photovoltaic (PV) electricity generation offers the opportunity to reduce these emissions in almost any housing scheme. The only exception may be in high density housing, where there could be problems of over-shading or 'solar access'. PV electricity generation may also be combined with CHP; it supplements the power from the CHP plant, particularly during periods, such as the summer, when the CHP plant may not be operating. PV electricity may be distributed via the same on-site distribution system and surplus power from both sources may be sold to the grid via a single net metering arrangement.

Where to use these technologies

In addition to the potential benefit of contributing to increased mid-term asset values, landlords will note that PV electricity generation can provide an average south-facing house in the UK (with sufficient roof area for modules) with enough power to provide 50-65 per cent of the dwellings electricity requirements. A key advantage of PV (particularly in an urban environment) is its potential to be integrated into the fabric of the building. No extra land space is required and the visual aesthetics of the building need not be altered. Alternatively a feature can be made of the home's PV system – giving a clear indication of 'green' credentials.

PV electricity generation uses light-sensitive, solid-state, semiconductor cells similar to those used in computer chips. These 'solar cells' are grouped together in modules and attached to the outside of a dwelling or integrated into building components such as cladding panels, roof tiles, metal roofing and glazing. PV panels may be mounted on roofs, or on separate structures. When exposed to light (direct or diffuse sunlight) the cells generate DC electric current.

PV modules have conversion efficiencies ranging from approximately three to 18 per cent - the more efficient are usually more expensive though this is not always the case. A PV array (a group of PV modules linked together) with 10 per cent efficient PV modules would generate about 100kWh/m^2 per year on an optimum south-facing roof. Even in cloudy, northern latitudes, PV modules can generate power to meet some or all of the electricity demand of a building. In Oxford, for example, a 4kW PV array built into the roof of a suburban house produces more electricity over the year than is used in the house.

Selecting the right option from the wide range of PV technologies available depends on a variety of factors including peak power capacity, the area available for PV modules and the type of application. Power output from a PV array varies with orientation and tilt, and is significantly reduced by even a small amount of over-shading (e.g. by trees).

Several types of cells are used in PV modules or panels. The most common are silicon, and silicon-based cells. These are available in four main types: monocrystalline (MC), polycrystalline (PC), thin film amorphous silicon (AS) and multilayer amorphous silicon (including double-layer 'tandem junction' and three-layer 'triple-junction').

MC type PV cells are dark blue or dark grey. PC types are usually a lighter blue, but can be produced in a range of colours. Multilayer AS cells are reddish black, some with a purple tinge. Copper indium diselenide (CIS) cells have a glassy black appearance. Specially coloured cells are a little more expensive and usually slightly less efficient than natural coloured cells.

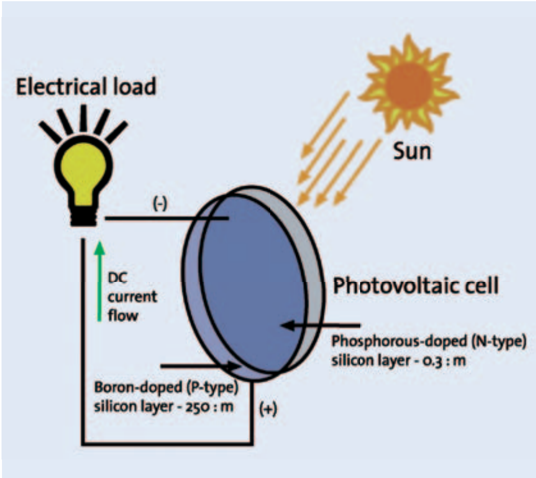

Figure 6
Generating electricity using PV

The most efficient cells are the monocrystalline (MC) types; the next most efficient are polycrystalline (PC). The various forms of amorphous solar cells are the least efficient and least expensive. The relative cost of the different types of cells is not a significant factor. A given application will require a smaller area of the more efficient and expensive types or a larger area of the less efficient and less expensive types.

PV modules are available as laminates (usually on glass substrates) and are connected by metal frames similar to patent glazing. PV modules can be fixed to dwellings via metal roofing systems, as semi-transparent PV glazing, transparent 'tinted' PV glazing, PV façade cladding and PV solar shading. PV-clad roof tiles and slates can be installed with conventional tiles or slates.

Where to use these technologies

Product-related PV systems include PV streetlights, PV security systems, PV-clad shade canopies and electric vehicle parking/charging bays.

Most PV cells generate direct current (DC) electricity, so unless DC appliances are used, an inverter is required to convert the direct current to alternating current (AC).

Figure 7
PV array and solar water heating collectors installed on a house in Cumbria
courtesy of New Progress HA

Figure 8
A typical domestic PV installation

If a net metering contract is used, excess electricity can be sold to an electricity supply company to offset the cost of purchasing electricity (at the same unit rate) during periods of darkness or when there are low levels of natural light. If a net metering contract is not available, it is best to shift electricity use into daylight hours wherever possible.

The capital costs of PV arrays (excluding inverters, grid connections and VAT) are approximately £450/m^2 for MC modules, £375/m^2 for PC modules and £160/m^2 for tandem junction, thin film AS modules. The installed costs of complete PV systems vary from £5,000 to £10,000 per kWp, or from about £400 to £800/m^2 of solar PV modules.

As a general rule of thumb, A PV electricity generation array with optimum orientation and tilt angle delivers (approximately) one of the following:

- In terms of power output, 75-100 Wp/m^2 of array, at a capital cost in the region of £5/Wp or £5,000/kWp.
- Over the course of a year, 100kWh per square metre of array, at a capital cost of approximately £500/m^2.

PV is a flexible and versatile building technology. Panels can be used in roofs, curtain walls and decorative screens, and as direct replacements for conventional materials in the building fabric. PV can be used in glass roofs and in conservatories where it will also provide some solar shading.These products can serve the same structural and weather protection purposes as traditional alternatives, as well as offering the benefit of power generation. PV cladding is probably the only building component that is capable of generating income for a dwelling's occupant by simply sitting there exposed to the light.

Installing PV electricity generation systems in existing dwellings can often be achieved with minimal disruption to residents.

PV tiles should be considered when re-roofing.When this is being done,or flat roofs are being converted to pitched roofs, alternative roof forms can be considered (e.g. hipped roofs instead of gable ends). This can create well oriented pitched surfaces (south ±15º) on which PV may be mounted. Planning permission may be required for roof-mounted arrays in conservation areas or other architecturally sensitive locations.

Where to use these technologies

Key facts – PV

- Solar power has great potential in the UK. In Britain, each square metre of south-facing roof receives 1,000kWh of solar radiation per year. The roofs of many of our homes actually receive more energy from the sun than is needed for space heating and hot water.
- PV electricity generation delivers approximately 100kWh/m^2/yr, at a capital cost of approximately £500/m^2. PVs typically provide 75-100Wp/m^2 at a capital cost of £5/Wp or £5,000/kWp.

Wind power

The wind energy industry is the fastest growing energy industry worldwide; 24,000MW of wind-powered electricity generation capacity had been installed by the end of 2001. A year later, a further 23,000MW had been installed in Europe alone. The UK has 40 per cent of Europe's land-based wind energy potential. It has been estimated that 1MWh of wind-generated electricity reduces carbon dioxide emissions by between 1,200 and 1,600 tonnes a year.

Figure 9
Wind turbine on BowZED House, 2001.
Architect: Bill Dunster.

Wind turbines range in output from 50W to 4.5MW, with even larger machines in development. As the output of conventional wind-powered generators is related to the square of the diameter of the rotor (a 10m diameter rotor will produce four times as much electricity as 5m diameter rotor), there are clear economies of scale. As small wind turbines have a high cost per kilowatt, they are most viable in remote sites. Commercial wind farms use many machines, each usually rated at more than 400kW. See Further information for additional guidance on small-scale wind turbines.

For groups of dwellings or a neighbourhood, it is usually more cost effective to share the cost of a medium or large-scale wind turbine (a 'community wind turbine', or CWT). This can reduce the cost to between £1,000 and £5,000 per house (depending on the number of houses and the size of the turbine). Power from such schemes is not supplied direct to the houses in the community but to the national grid, so no modifications are required to the dwellings themselves. The community's income from the sale of the power offsets the cost of electricity purchased via the grid.

There are many large estates where CWTs might be appropriate, but factors such as local wind regimes, planning permission, and noise levels have to be taken into account. Wind turbines work best on relatively open sites, but modern units on tall towers open up possibilities that would not have been feasible a few years ago.

Figure 10
Wind turbines on a community wind farm
courtesy of Seth Kennedy

Where to use these technologies

Another option is 'off-site windpower'. Building owners, including housing organisations, may invest in wind turbines on wind farms at remote, windy sites. The output of each turbine is dedicated (via a medium- or long-term contract) to a particular user or group of users, for example the residents of a housing estate or of a block of flats. In housing, off-site windpower has the potential to deliver huge reductions in the carbon emissions associated with lighting and appliances.

Key facts – windpower

- One large 600kW wind turbine on a good site (with an annual mean wind speed greater than 6m/s) produces enough electricity to meet the average annual electricity needs of over 300 households.
- Capital costs are about £750 per kW of installed capacity, of which two thirds is the cost of the turbine. Annual operational and maintenance costs are of the order of 0.5 pence per kWh.
- Wind generated electricity costs approximately 2.9 pence per kWh.

Wood fuel boilers

Wood fuel can be derived from waste wood sources or from specially farmed biomass crops such as willow and other plant species. It can be used as an alternative in 'wet' boiler-based heating systems. Fuel costs are dependent on the availability of local supplies.

Provided wood fuels are from a sustainable source, they are usually considered to be 'carbon neutral'. This means that, although carbon dioxide is released when fuel is burned, this should be the same as the carbon dioxide absorbed by the plant while it is growing (and given off when it rots), hence no additional carbon is released into the atmosphere. Some even argue that wood fuels actually produce a net storing of carbon. Pruning trees encourages additional growth, resulting in additional carbon dioxide capture.

Wood fuels come in various forms, but the three main types of wood fuels for domestic heating systems are:

- Wood chips.
- Wood pellets.
- Logs.

Wood that has been processed into chips can be used in a boiler. The main advantage of wood chips is that they are often readily obtainable and relatively cheap. The main disadvantages are the need to store the fuel, the need for an appropriate chimney or flue, and the need for ash removal and disposal. There is also a need for quality assurance, particularly because the water content can be high (and consequently the chips do not always burn as efficiently as drier fuels).

Waste wood can be processed to produce small pellets. The process results in a drier, denser fuel, giving more energy than a comparable amount of chips. Pellets are therefore particularly useful in applications with limited storage space.

There are currently only a few pellet suppliers in the UK, but the market is expected to grow during the next few years. Supplier information can be obtained from www.logpile.co.uk. If wood pellets are transported long distances or imported, the net energy balance (and its effect on carbon emissions reduction) will need to be evaluated.

Figure 11
Wood chips and wood pellets
courtesy of Altechnica

The management of wood-chip or wood-pellet boilers is more complicated than that of gas-fired boilers because of the need to ensure regular deliveries of fuel and to store it on site. It is essential to monitor fuel consumption and order supplies well before they are required. Fuel may be supplied and stored in skips or containers. These can be connected directly to the boiler hoppers, minimising local handling of the fuel. Large volume deliveries can be blown pneumatically into a storage silo connected directly to the boiler hoppers.

Where to use these technologies

Figure 12
A wood pellet stove with a back boiler
courtesy of Centre for Sustainable Energy

Fuel storage and management issues mean that the most obvious applications in existing housing are locations which already have a communal heating system. Existing boilers may be replaced by wood-fuelled boilers but consideration should be given to the delivery and storage of the fuel; the method of transferring the fuel to the boiler; and the removal/disposal of the ash that is produced.

Wood can also be used in individual dwellings, in the form of pellets or logs. A variety of wood-burning stoves are available, many of which can also provide hot water via an indirect hot water storage cylinder. While requiring active management by the occupants, they can (in the case of logs) make use of very inexpensive, locally sourced fuel with minimal net carbon emissions.

Growing wood as a fuel crop is not currently an attractive economic proposition compared to growing wood for other uses; this situation is likely to persist while gas prices remain low. The most likely sources are other activities from which wood fuel is a by-product (e.g. forestry, furniture making), especially in areas where such activities are well established. However, there are companies that will contract to supply and install wood-fuel boilers and provide the fuel.

There are an increasing number of locations in the UK where short-rotation coppiced wood is being grown to provide an energy crop for processing into wood chips. Farmers may be interested in such arrangements because they provide an alternative to food crops at a time of reduced prices and declining subsidies. Even so, these ventures involve risks for both suppliers and customers, due to the need for long-term contracts.

Key facts – wood fuel boilers

- About 13 per cent of the world's primary energy comes from biomass.
- Coppiced willow is one example of a type of biomass fuel that is ideally suited to Northern European climatic conditions.
- One hectare of managed woodland will produce about three tonnes of dried firewood per year; one hectare of short rotation coppice will produce about eight tonnes per year.
- One tonne of wood fuel will produce about 4.5MWh of useful heat; one cubic metre of air-dried broadleaf logs will produce about 1.7MWh. One cubic metre of pine logs will produce about 1.4MWh.
- One cubic metre of solid wood is equivalent to approximately 1.5 cubic metres of stacked logs.
- Wood fuel boilers cost approximately twice as much as gas-fired boilers of equivalent output.
- A wood fuel boiler of 18kW output will require 6kg/hr of fuel (equivalent to 25kW input).

Ground source heat pumps

The ground itself contains useful amounts of energy. There is geothermal energy from geological processes and 'ground energy', which is solar energy that has been absorbed and stored in the ground. Ground source heat pumps (GSHPs) work by transferring heat from the earth to the building by the means of a pump. This useful heat can be used for space heating and hot water. Over 400,000 GSHPs have been installed worldwide.

Where to use these technologies

The most obvious applications to existing housing are for individual houses in rural areas away from gas mains and also for low density urban housing with sufficient available land. Groups of between four and 10 adjacent dwellings, or small blocks containing several flats, might be appropriate. In such cases the capital costs can be shared. GSHPs can also be used to replace base-load boiler plant in communal heating systems.

The technology exploits the fact that the temperature of the earth at moderate depth is slightly higher in winter than the air temperature at the surface (and in summer slightly lower). In the UK, ground temperatures stay fairly constant, between 10º-14ºC, throughout the year. The heat pump uses electricity to extract heat from the ground by circulating a water/anti-freeze mixture through a collector. The collector is either a horizontal pipe laid beneath the ground's surface or a 'U tube' looped inside a vertical borehole of 100-150mm diameter. The most common systems use horizontal collectors approximately 1.5m underground. These are usually more economic than boreholes because the trenches can be made with conventional excavating machinery, they do however require more land area. Vertical collectors are usually in boreholes between 15m and 150m deep.

GSHPs extract heat by cooling the collector water using technology akin to that of a domestic refrigerator (and the system can be reversed to provide cooling). Although heat can be distributed via large radiators, underfloor heating coils are more efficient because they operate at a lower temperature and the floors provide some thermal storage. A GSHP can achieve a coefficient of performance (CoP) of four or more. This means that the system delivers 4kW of heat energy for every 1kW of electricity used to power the pump.

Thus GSHPs can reduce the carbon emissions associated with space heating and cooling. An appropriately configured system can lower the emissions from an all-electric dwelling to a level comparable with (or even potentially lower than) those from a gas-fired condensing boiler. If the electricity to drive the heat pump is derived from a renewable source (e.g. photovoltaic cells or a wind turbine) carbon emissions can be eliminated.

GSHPs for individual dwellings typically cost between £800 and £1,000 per kW capacity. This depends on the cost of the borehole or trench, which is affected by ground conditions. Borehole costs can be reduced if several are drilled in the same area, or if the ground collectors are installed while piling is going on for building substructures (but note that collectors should not be located directly under buildings). Maintenance costs are lower than for conventional gas-fired heating systems, and running costs and emissions are also low. GSHP boreholes have estimated lives of 50 years, and ground loops come with a 25 year warranty

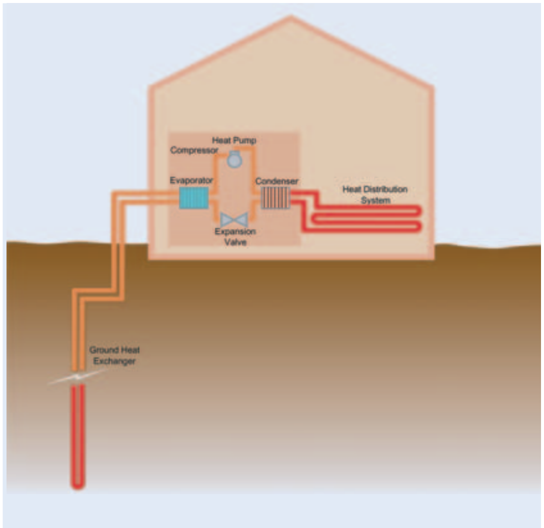

Figure 13
Ground source heat pump schematic

Key facts – GSHP

- GSHPs for individual dwellings typically cost between £800 and £1,000 per kW capacity, depending on the cost of the borehole or ground loop.
- An appropriately configured GSHP system can lower the emissions from an all-electric dwelling to a level comparable with those of a gas-fired condensing boiler system.
- If the electricity to drive the heat pump is derived from a renewable source (e.g. PV cells or a wind turbine), carbon emissions can be eliminated.

Managing new and renewable energy systems

The use of new and renewable energy systems in housing involves the supply of on-site generated heat and/or power (rather than just fuel). In managed housing, these systems are usually managed at 'arms length' by energy services companies (ESCOs), which are set up specifically to manage local energy supplies. They are usually not-for-profit organisations and any financial surplus goes to improve the energy efficiency of the housing they serve or to expand the customer base. In some cases ESCOs are set up by energy supply companies as wholly-owned subsidiaries; in others they are set up by landlords or by the residents themselves. ESCOs owned by supply companies can reduce the technical barriers and costs associated with connecting on-site renewable electricity generation to the grid.

ESCOs use various mechanisms for managing supply:

- Private wire electricity network.
- Co-operative or 'merchant' power supply.
- Grid connected net-metering arrangements.

Private wire networks

Figure 13 is a simple schematic of how a private wire electricity system may operate. The blue lines are the cables 'owned' by the electricity distribution company or ESCO. The red lines indicate energy supplies to the site. All the houses are connected to one on-site electricity distribution node. Ideally, the site has some generating capacity of its own (e.g. wind or PV) and any additional electricity required is purchased from an electricity supply company via the national grid at a bulk purchase rate. Excess electricity generated on-site is sold back via the grid at an agreed rate. The private wire system reduces the overall cost of electricity, and allows for distribution of locally generated renewable energy.

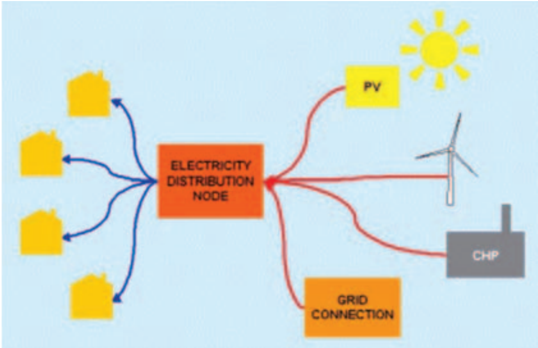

Figure 14
Diagram of a private wire system
courtesy of Rickaby Thompson Associates Ltd

Co-operative or merchant supply

A co-operative may be set up to, for example, participate in a scheme to build a number of wind turbines near the dwellings. The electricity generated is sold to the national grid and the members receive their supplies via the grid. In effect the members of the co-operative claim their energy supply from the wind turbines. This is a good option where it is difficult to develop on-site renewables due to technical or other barriers.

Merchant supply is similar, but the recipient agrees to purchase all the electricity generated from a renewable supply that may be located some distance away (e.g. off-site wind – see above). Merchant supply may be a better option for high density urban developments.

Grid connected and net-metering supplies

This system is appropriate for renewable energy technologies that are integrated with the household electrical system (e.g. PV and micro-CHP).

It involves direct connection to the national grid and the installation of an additional electricity meter that reads how much electricity is exported (i.e. electricity not used directly in the dwelling, but 'sold' via the national grid).

How to develop new and renewable energy systems for managed housing

The approach will be broadly similar regardless of the type of system involved. It should ideally form part of a wider programme of housing improvement, the new and renewable energy systems helping to achieve other objectives such as affordable warmth, good asset management and sustainable development. The use of renewable energy technology should always be combined with improving energy efficiency. The carbon reductions achieved from energy efficiency measures will generally be greater than those from renewables. In addition, it is important to reduce energy demand in the dwellings to a level where renewables can make a significant contribution.

The following step-by-step approach should follow a consideration of energy efficiency measures.

Step 1: Assess the potential

- Consider new and renewable energy technologies when planning refurbishment. Consider whether additional refurbishment (e.g. re-roofing) will facilitate the installation of renewable systems.
- Identify the current and projected energy demand. Evaluate space heating, water heating and electric power requirements (for appliances and lighting). Estimate the contributions that may be made by renewable energy.
- Identify the fuel use and the carbon savings expected from renewable energy technologies.
- Identify the appropriate options - different technologies lend themselves to different types of buildings and sites.
- Consider the use of specialist consultants who can estimate costs, obtain preliminary quotations and help with funding applications.
- Compare the carbon emissions reductions achievable from the various renewable energy technology options, taking into account the type of fuel or energy to be offset.

Step 2: Assess the required investment

- Consider what can be afforded, evaluate residents' benefits and identify the available grant funding, loans and other support mechanisms.

Step 3: Consult with tenants, local residents and contractors

- Tenant approval for the scheme is important as it is required by most grant funding schemes.
- Tenants and residents will need to be informed and educated about the benefits of renewable energy technology.
- Some renewable energy measures may have an impact on local residents.

Step 4: Develop a specification

- Specify the technology and the required performance of the dwellings, in terms of fuel use, fuel costs and carbon emissions.
- Complete a feasibility study including 'whole-life' costing, to establish the net present value (NPV) of the proposal.

Step 5: Apply for funding

- Review and select from the many grant funding schemes designed to promote the development of new and renewable energy.
- Consider seeking non-government grant finance.
- Examine the potential for Renewable Obligation Certificates (ROCs).

Step 6: Implementation

- Apply for planning permission, obtain competitive tenders and implement the scheme.

Appendix A

Cost and suitability tables for renewable energy technologies

Table 1: Capital, maintenance, running costs and performance (in terms of carbon emissions) of new and renewable energy systems, relative to conventional gas-fired boiler heating and hot water systems, and grid-supplied electricity.

	Capital cost	Maintenance cost	Running cost	Carbon emissions	Approximate cost of savings (£/tonne CO_2 saved)
CHP	High	High	Medium	Low	40-80
Micro-CHP	High	Likely to be high	Medium	Low	approx. 600
Solar water heating*	High	Medium	Very low	Very low or zero	130-600
PV electricity	Very high	Low	Very low	Very low or zero	550-1100
Windpower	High	Medium	Low	Very low or zero	195-220
Wood fuel boilers*	High	High	High	Very low	30-230
Ground source heat pumps*	High	Medium to low	Medium	Low	30-350

* Range of cost savings for heating technologies vary according to system installed and fuel replaced – replacing electricity or coal will provide better £/tonne CO_2 saved than replacing gas. All cost savings are based on three-bedroom semi-detached house.

Table 2: New and renewable energy technologies – their suitability in different types of housing.

	Generates heat	Generates power	High-density urban housing	Low-density urban housing	Distributed suburban housing	Rural housing
CHP	✓	✓	Very suitable	Not suitable	Not suitable	Not suitable
Micro-CHP	✓	✓	Not suitable	Sometimes suitable	Very suitable	Very suitable
Solar water heating	✓		Very suitable with communal heating or CHP	Very suitable	Very suitable	Very suitable
PV electricity		✓	Sometimes suitable	Very suitable	Very suitable	Very suitable
Windpower		✓	Not suitable for on-site generation*	Not suitable for on-site generation*	Sometimes suitable	Very suitable
Wood fuel boilers	✓		Generally suitable with communal heating	Sometimes suitable	Sometimes suitable	Very suitable
Ground source heat pumps	✓		Very suitable	Sometimes suitable for groups of dwellings	Very suitable	Very suitable

* As-yet unproven proposals for building-integrated windpower generators may make this a practical option in high- and low-density urban housing,

Further information

Central heating specifications (CHeSS) – Year 2005 (CE51/GIl59)
Community Heating – a guide (CE55)
Domestic Ground Source Heat Pumps: Design and installation of closed-loop systems (CE82/GPG339)
Energy efficient lighting (CE61)
Energy efficient refurbishment of existing housing (CE83/GPG155)
Energy efficient ventilation in housing. A guide for specifies on requirements and options for ventilation (GPG268)
Improving air tightness in existing homes (GPG224)
Innovative Social Housing - Alpine Close, Maidenhead, Berkshire, (CE37)
Installing small wind-powered electricity generating systems (CE72)
Renewable energy in housing - case studies (CE28)
Renewable energy sources for homes in rural environments (CE70)
Renewable energy sources for homes in urban environments (CE69)
Rural biomass Community Heating case study (CE91)
Using whole life costing as a basis for investments in energy efficiency – guidance (CE119)

Other publications

NEP (2002) Pathways to PV, Generating Solar Homes and Nottingham Energy Partnership, Nottingham

Websites for additional information

CHP

Information
www.est.org.uk/communityenergy
www.chpa.org.uk
www.distributedgeneration.gov.uk

Grants
www.est.org.uk/communityenergy

Case Studies
www.est.org.uk/communityenergy

Solar water heating

Information
www.greenenergy.org.uk/sta/
www.practicalhelp.org.uk
www.dti.gov.uk/renewables

Grants
www.clear-skies.org

Case Studies
www.practicalhelp.org.uk/content/case_housing5.htm
www.ecde.co.uk/sunshine

PV electricity generation

Information
www.est.org.uk/housingbuildings
www.pv-uk.co.uk
www.dti.gov.uk/renewables

Case Studies
www.est.org.uk/housingbuildings/casestudies

Windpower

Information
www.bwea.com
www.dti.gov.uk/renewables

Grants
www.clear-skies.org

Wood fuel boilers

Information
www.britishbiogen.co.uk
www.dti.gov.uk/renewables
www.logpile.co.uk

Grants
www.clear-skies.org
www.britishbiogen.co.uk

Case Studies
www.britishbiogen.co.uk/bioeneergy/heating/casestudy.htm
www.dti.gov.uk/renewables

Other websites

INREB Faraday Partnership
www.inreb.org
A DTI-funded project to promote research and technology regarding the integration of new and renewable energy in buildings, based at the Building Research Establishment.

Housing Corporation
www.housingcorp.gov.uk/resources/sustain.htm
The Housing Corporation is the regulator and investment agency for housing associations in England.

Routes to Sustainability
www.routestosustainability.org.uk
Guidance for housing professionals on resources and tools to create more sustainable housing.

Green Street
www.greenstreet.org.uk
Guidance on environmentally friendly refurbishment for existing housing.

Sustainable Homes
www.sustainablehomes.co.uk
A central resource for Housing Associations and Local Authorities, including case studies.

Information on distributed generation
http://www.ofgem.gov.uk/temp/ofgem/cache/cmsattach/306_26march02_fs.pdf
General information and explanatory diagrams on electricity generation via local distributed networks rather than the high voltage transmission network.

Advice and Training
http://cr.net.countryside.gov.uk/
This guide is based on material prepared for the Energy Saving Trust by Rickaby Thompson Associates Ltd, John Willoughby and Altechnica.

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