

# Low and Zero Carbon Technologies in the Scottish Building Standards

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## Summary

This report was commissioned by the Scottish Building Standards Agency to assess the feasibility of a new functional standard, for inclusion within Schedule 5 to Regulation 9 of the Building (Scotland) Regulations 2004, that would require the use of low or zero carbon technologies in large new buildings.

It provides an overview of the low and zero carbon technologies (LZCT), indicating the specific technologies that are potentially available, giving a brief description, an indication of their possible contribution to reducing emissions and a summary of other issues.

It then considers the merits and feasibility of introducing a mandatory functional standard for LZCT into the Scottish Building Regulations and whether the objective of attaining the increase over time in the use of LZCT could be achieved by means other than a mandatory standard. This takes account of the commitments in the Partnership Agreement of the Scottish Executive and the obligations imposed by the Energy Performance of Buildings Directive.

The report recommends that:

- For the foreseeable future, LZCT should not be made mandatory in Scottish Building Regulations.
- To progress the take-up of LZCT, the current review of Section 6 (Energy), which is giving consideration to setting a CO<sub>2</sub> emissions compliance target as a part of a whole energy building approach, should look to set this target at a sufficiently demanding level. If the correct balance is struck, the effect will be one that allows new buildings to be constructed using the traditional conservation of fuel and power approach, but at the same time makes it more attractive for designers to consider adopting LZCT as a part of that approach.
- Consideration should also be given at this stage to the effects of LZCT becoming fully developed and the implications of each technology with regard to the 64 existing mandatory functional standards within the Scottish Building Regulations.

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## 1 Introduction

Section 6 of the of the Building Regulations in Scotland is currently under review. One aspect to be considered as part of this process is how to encourage the uptake of low and zero carbon technologies (LZCT), particularly in large non-domestic new buildings. Traditionally Scottish Building Regulations have been framed by mandatory standards and it is understood that this is currently the preferred option for introducing LZCT, albeit by a functional standard as opposed to the more traditional prescriptive or performance mandatory standards.

This report addresses new buildings and provides an overview of the LZCT, indicating the specific technologies that are potentially available, giving a brief description, an indication of their possible contribution to reducing emissions and a summary of other issues.

It also considers the merits and feasibility of introducing a mandatory functional standard for LZCT into the Regulations and whether the objective of attaining the increase over time in the use of LZCT could be achieved by means other than a mandatory standard.

The report was commissioned by the Scottish Building Standards Agency to provide a platform for policy development, taking account of obligations under the Energy Performance of Buildings Directive and the commitment to the Partnership Agreement of the Scottish Executive.

## 2 Technologies covered in this report

There is a wide variety of technologies and systems that could be considered as being low or zero carbon. This report concentrates on those listed in Table 1, which are the more established technologies with a fair degree of experience in their use. Some other newer technologies, less developed and generally of poorer cost-effectiveness at the present time, are summarised in section 11.

**Table 1 : Important Low and Zero Carbon Technologies**

	<b>Carbon Savings</b>	<b>Cost-Effectiveness</b>	<b>Local Impact</b>	<b>Offset Costs</b>
Solar thermal systems	Low-Medium	Medium	Low-Medium	Low
Photovoltaics	Low	Low	Low	Low-Medium
District Heating	Low-Medium	Medium	Low	Medium
CHP	High	Medium-High	Low-Medium	Low-Medium
Ground source heat pumps	Medium	Medium	Low	Low-Medium
Wind power	Low-Medium	Medium	High	Low
Biomass	High	Medium-High	Medium	Low-Medium

Table 1 gives an indication of the potential benefits of the technologies (based on current on-going work at BRE). The cost-effectiveness assessment is based on applications for buildings with access to conventional energy supplies from the utilities companies ('grid connected'). This will be the case for the vast majority of buildings. For isolated buildings where energy supplies are not available, stand-alone forms of renewable energy are more likely to be financially viable. As prices of energy supplies are likely to change in the future, the relative merits of each technology would need to be studied carefully on a case-by-case basis.

Local impact relates to the implications of the technology other than on carbon emissions, as is discussed in the following sections of the report for each technology. Offset costs relate to the potential to make savings, for example in the provision of other (conventional) heating systems.

Table 2 provides an overview of capital costs, running costs, payback time and CO<sub>2</sub> saving potential (based on information in the Carbon Trust Good Practice Guide 379).

**Table 2 : Costs and CO<sub>2</sub> reduction**

	<b>Capital cost per kW</b>	<b>Running costs</b>	<b>Payback time</b>	<b>Lifetime CO<sub>2</sub> reduction per £</b>
Solar thermal systems	Low-Medium	Low	Low-Medium	High
Photovoltaics	High	Low	High	Medium
District Heating	Medium-High	Low	Medium-High	Medium-High
CHP	Medium	Low-medium	Medium	High
Ground source heat pumps	Medium	Low	Low-Medium	High
Wind power	Medium-High	Low	Low-Medium	High
Biomass	Medium	Low-Medium	Medium	Medium-High

## 3 Solar thermal

### 3.1 General Description of the technology

Energy from the sun can be harnessed in three main ways:

- Passive solar design, which utilises the heat from the sun so that less additional heating is required, thus reducing the overall load;
- Solar thermal, utilising the sun's heat to provide domestic hot water for homes or swimming pools and occasionally for space heating using heated air;
- Solar electric or photovoltaics (PV), which use energy from the sun to create electricity.

Using specially designed mechanical systems, solar thermal systems can generate much more heat for space heating and hot water than passive solar alone.

Solar collectors are at the heart of most solar thermal systems. The collector absorbs the sun's radiated energy and changes it into useful thermal energy. This thermal energy can then be used to provide heated water for residential or commercial use, to provide space heating or cooling, or for many other applications in which fossil fuels might otherwise be used.

There are two basic types of solar heating systems, depending on whether air or a liquid is heated in the solar collector. A liquid-based system heats water or an antifreeze solution in a "hydronic" collector and an air-based system heats air in an "air collector."

Both of these systems collect and absorb solar radiation, then transfer the solar heat directly to the interior space or to a storage system, from which the heat is distributed. If the system cannot provide adequate space heating, an auxiliary or back-up system provides the additional heat. Liquid-based systems are more often used when storage is included.

Systems can be either passive or active in terms of the circulation method. In an active solar water heating system, heated water is moved through the system with the aid of pumps, which increases the system's efficiency but with additional capital cost requirements (for the pump and associated controls). Passive systems rely on natural convection or water pressure to circulate the fluid through the collector to the point of use.

There are several types of solar collectors but the two most common types are:

- Flat-plate collectors
- Evacuated-tube collectors

A typical flat-plate collector is an insulated metal box with a glass or plastic cover (called the glazing) and a dark-coloured absorber plate. Many flat-plate collectors now have selective coatings to increase the temperature and efficiency attained compared to simple matt black absorber plates.

In an evacuated-tube collector, sunlight enters through the outer glass tube and strikes the absorber, where the energy is converted to heat. The heat is transferred to the liquid flowing through the absorber. The collector consists of rows of parallel transparent glass tubes, each of which contains an absorber covered with a selective coating. The absorber typically has fin-tube design (fins increase the absorber surface and the heat-transfer rate), although cylindrical absorbers are also used. When evacuated tubes are manufactured, air is evacuated from the space between the tubes, forming a vacuum. Convective and conductive heat losses are eliminated because there is no air to convect or conduct heat, so evacuated-tube collectors are efficient at higher temperatures and perform well in both direct and diffuse solar radiation.

Solar energy collectors generally come with a 10 year warranty and require little maintenance (largely limited to ensuring that the panels are kept clean). Pollution has little effect on the units as they are maintenance free and rain will help to keep the surface clean.

The use of solar energy collectors to provide domestic hot water and low temperature process heating is a well-established technology where further incremental improvements may be feasible. Although the UK has capability in the manufacturing, installation and servicing of solar water-heating systems, the market in this country is currently small. This is mainly because the cost of systems is high compared with “conventional” alternatives and because public awareness of the technology is generally low.

Solar panels have been used up to now principally for the heating or pre-heating of domestic hot water. However, some systems are emerging which use panels covering large areas, e.g. the whole roof, and the solar energy is used for space heating as well. Experience so far of these larger systems is limited.

### 3.2 Influencing factors

Factor	Preference
Location	The building or site should have good access to solar radiation. Rural and suburban sites are more likely to have access to more sunlight for longer periods of the day than urban locations where other buildings can cast shadows.
Building occupation	A wide range of building types from offices to hotels can use solar thermal systems. Office blocks have good potential because their hot water demand is highest between 9 am and 5 pm. Thus, the match between demand and supply is good and minimises the effect of standing losses from storage vessels.

The best locations for solar thermal systems are for a building with a roof or wall that faces within 90° of south, as long as no other buildings or large trees cause overshadowing. If the roof surface is in shadow for parts of the day, the output of the system decreases.

A consideration is that the roof must also be strong enough to hold the weight of the solar collector, especially if the collector is going to be placed on top of an existing structure.

### 3.3 Technology Overview

Factor	Impact	Comment
Carbon Savings	Low-Medium	Annual output 1,000-2,000 kWh for a system of typical domestic size.
Cost Effectiveness	Medium	Payback times depend on type of system and size of grant if available.
Local Impact	Low-Medium	Solar thermal systems generate no greenhouse gases; are silent and although visible, they could be blended with the building cladding. Planning policy may limit use in conservation areas and on historic buildings.
Offset Costs	Low	
Other Benefits	Low	
Grant Funding	Yes	Available for some sizes of community projects and building types via the Scottish Community and Householder Renewable Initiative.

### 3.4 Carbon Savings

A solar thermal system providing domestic hot water can save over 50% of fossil fuel energy needed to supply hot water demand in a dwelling. A similar percentage should be attainable in many other types of building, depending on solar panel area relative to hot water demand.

### 3.5 Cost Effectiveness

Solar thermal systems generally have payback times in excess of 10 years but actual figures depend on the system type, orientation and use of available grants.

### 3.6 Local Impact

The local impact of these systems includes:

- **Noise & Vibration** – A solar thermal system is completely silent in operation.
- **Visual Impact** – Solar thermal systems are visible, although often not unattractive.

### 3.7 Offset Costs

The inclusion of solar thermal systems does not provide significant opportunities to offset other building costs. The full costs of an alternative means of providing heat is required to meet demand when available solar energy is insufficient (particularly during winter).

### 3.8 Grant Funding

Grant funding is presently available from the Energy Saving Trust via the Scottish Community and Householder Renewable Initiative<sup>1</sup> for households and community installations (i.e. schools, colleges, hospitals and other public buildings).

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<sup>1</sup> Scottish Community and Householder Renewable Initiative (SCHRI) is a programme, funded by the Scottish Executive and managed by Energy Saving Trust (EST), who provide grants and sources of advice for householders and communities on renewable energy. Further information is at [www.est.org.uk/schri/](http://www.est.org.uk/schri/)

## 4 Photovoltaics (PV)

### 4.1 General Description of the Technology

Photovoltaic (PV) systems use cells to convert solar radiation into electricity. The PV cell consists of one or two layers of a semi-conducting material, usually silicon. When light shines on the cell it creates an electric field across the layers, causing electricity to flow. The greater the intensity of the light, the greater the flow of electricity.

There are three basic types of solar cell:

- Monocrystalline: made from thin slices cut from a single crystal of silicon. This has a typical efficiency of 15%.
- Polycrystalline: made from thin slices cut from a block of silicon crystals. This has a typical efficiency of at least 13%.
- Thin Film: made from a very thin layer of semiconductor atoms deposited on a glass or metal base. This has a typical efficiency of 7%.

Photovoltaics are used to generate electricity, either in parallel with mains supplies, connected to the grid via inverters and synchronising gear, or for DC applications with battery back-up.

PV can either be roof mounted or free-standing in modular form, or integrated into the roof or facades of buildings through the use of solar shingles, solar slates, solar glass laminates (where the PV takes the form of semi-transparent glazing) and other solar building design solutions. They require little maintenance, generally limited to ensuring that the panels are kept clean.

The main technical challenge currently facing the substantial worldwide PV industry is the need to reduce costs while maintaining or improving performance. The UK is a relatively small player in the field of PV and is likely to remain so in the short to medium term. The technology is unlikely to make a significant cost-effective contribution to carbon saving in this country over the same timeframe.

## 4.2 Influencing Factors

Factor	Preference
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 urban locations where other buildings can cast shadows.
Building type and occupation	A wide range of building types from offices to hotels to industrial buildings can use PV systems. Office blocks have good PV potential because their electricity demand is significant all year round (including the summer) and because demand is highest between 9 am and 5 pm. Thus, the match between demand and PV supply is good.

The best locations for Photovoltaic systems are for a building with a roof or wall that faces within 90 degrees of south, as long as no other buildings or large trees cause overshadowing. If the roof surface is in shadow for parts of the day, the output of the system decreases. Pollution will have literally no effect on the units as they are maintenance free and the rain will help to keep the surface clean.

Another consideration is that the roof must also be strong enough to hold the weight of the panels, especially if the panel is going to be placed on top of an existing structure.

The availability of photovoltaic output is confined to the daytime, unless separate storage systems are installed, and has seasonal variations (daylight hours change throughout the year).

## 4.3 Planning Considerations

Factor	Impact	Comment
Carbon Savings	Low	PV systems generate a limited amount of energy because of their relatively low efficiency.
Cost Effectiveness	Low	In terms of energy savings the cost-effectiveness is generally poor.
Local Impact	Low	PV systems generate no greenhouse gases; are silent and although visible, they can be blended with the building cladding. Planning policy may limit use in conservation areas and on historic buildings.
Offset Costs	Low-Medium	The cost of the PV wall or roof can be offset against the cost of the building element it replaces.
Grant Funding	Yes	Available for some projects through DTI funded grant programmes, e.g. major PV demonstration programme.

#### 4.4 Carbon Savings

The use of PV displaces some electricity that otherwise will need to be generated by conventional fuels but it is unlikely to supply all the electricity demand of a building. As a rule of thumb, PV installation with monocrystalline silicon panels on a south facing tilted surface provides about 100 kWh/m<sup>2</sup>/year.

In terms of carbon dioxide, 1 kWp of solar cells displaces about 1000 kg of CO<sub>2</sub>.

#### 4.5 Cost Effectiveness

There are some indications that costs and prices of active solar systems are falling which will increase the economic attractiveness of systems. PV technology is not currently competitive with conventional electricity and other renewables. It is currently a high cost technology that requires Government support to make its use more widespread.

There are examples of photovoltaic systems which are used to charge batteries for dedicated applications such as fence electrification, remote telecommunications, information panels and bus shelter lighting, which are more cost-effective than new connections to the grid.

#### 4.6 Local Impact

The local impact of these systems includes:

- **Noise & Vibration** – A PV system is completely silent in operation.
- **Visual Impact** – PV systems are visible, although often not unattractive.
- **Safety** – The PV system should be checked for electrical safety in the same manner as other electrical systems.
- **Other** - Photovoltaic systems are visible and, as such, provide an opportunity to promote the green credentials of their owners.

There is some environmental concern over the lead acid batteries used in some systems for storage purposes.

Heavy metals such as cadmium are used in PV cells and cadmium sulphide is used in PV panels, replacing the more expensive silicone. Cadmium can be difficult to recycle. The production of silicone has an insignificant environmental impact, although some fossil fuels are used in the manufacture of PV cells.

#### 4.7 Offset Costs

The inclusion of Photovoltaic systems provides opportunities to offset other building costs when designed as part of the overall cladding and/or roofing system.

The cost of the system and seasonality precludes supply of the full building electrical load so conventional power supplies are needed to meet the full operating load of the building.

#### **4.8 Other Benefits**

Where installed in schools and universities, PV systems offer teaching and research opportunities.

#### **4.9 Grant Funding**

Government grants are available to help install systems. For domestic properties this is up to 50% of the total cost. More information is available on the website [www.solarpvgrants.co.uk](http://www.solarpvgrants.co.uk).

#### **4.10 Complementary Technologies**

Summers provide more daylight hours than winter. This seasonal variation in the availability of solar energy counters that of wind energy. Wind turbine technology is therefore a useful complementary technology for photovoltaics, providing a spread of energy throughout the year.

To ensure continuous availability of power for non grid-connected installations, battery storage may be required to overcome the variability of daylight.

## 5 District Heating

### 5.1 General Description of the Technology

District heating, also known as community heating, provides heat from a central source to more than one building or dwelling via a network of heat mains. Heat can be supplied to the scheme from boilers fuelled by conventional fuels or renewable sources of energy, or can utilise the heat from combined heat and power (CHP) or industrial waste heat.

Community heating can use a wide variety of fuels which may not be easily applicable to individual domestic heating systems. These include:

- Large scale heating plant (where there is the potential to achieve better efficiency and security of supply through the use of multiple boilers and flexibility in fuel type). Such conventional plant could be fuelled by fossil fuels or biomass.
- Waste heat from power generation.
- Energy from waste or waste heat from industrial processes.
- Geothermal or solar energy.

A distribution network of flow and return pipes transfers the heat from the source to the buildings or dwellings that are connected to the system. Heat exchangers are installed within each building or group of buildings and the energy used can be recorded using heat meters.

District heating schemes vary in size and can consist of individual tower blocks, a university campus, hospital site or an area of a town or city undergoing regeneration. They can also encompass the whole of a city similar to the schemes that serve Southampton, Sheffield, and Nottingham.

Carbon savings attributable to district heating schemes are achieved through the combustion efficiency benefit that the heat source has over the alternative of distributed boilers. Carbon savings can be significant where the heat source includes combined heat and power (CHP) or biomass fired heating plant.

## 5.2 Influencing Factors

Factor	Preference
Location	District heating schemes are best developed where there is a substantial load with a high heat demand density.
Building types	Large public sector buildings, social housing or mixed use developments are suitable core loads

Ideal sites include large buildings or several buildings within close proximity (e.g. city centre and suburban locations) undergoing development or small communities without a gas distribution network where other sources of energy can be utilised (e.g. biomass, biogas, or geothermal energy).

Often district heating is well suited to sites adjacent to large public sector buildings (e.g. hospitals, universities or council offices), or mixed use developments (with round the clock or seasonal demand for energy). Heat networks can be developed by attracting other local customers offering opportunities to develop district cooling, direct electricity supply (with CHP), or for integrating renewable and low carbon technologies.

### 5.3 Technology Overview

Factor	Impact	Comment
Carbon Savings	High	Modern district heating schemes, typically with CHP, deliver significant carbon savings compared with the highest efficiency conventional heat and power supply options. Similarly, carbon savings can be high where schemes are fuelled by biomass.
Cost Effectiveness	Long-term	Capital costs are high because of the required investment in infrastructure (i.e. heating pipework) but well-configured district heating can have a lower whole-life cost than competing technologies. Costs are less for more limited block heating.
Local Impact	Low	The local impact can vary depending on the nature of the scheme but are generally low. Generally schemes are low noise and pollution levels, although in some cases there may be issues of toxicity (e.g. burning municipal waste).
Offset Costs	Medium	District heating removes the need to install combustion plant within individual buildings and frees up space within those buildings.
Grant Funding	Yes	Grant funding is available through the continuation of the Community Energy Programme until March 2008.

### 5.4 Carbon Savings

Modern district heating schemes, typically with CHP or biomass boilers, deliver significant carbon savings compared with the highest efficiency conventional heat and power supply. Particularly for larger city or town centre schemes, savings can become large when the scheme integrates carbon free heat, from municipal waste incineration, industrial waste, or renewable sources. Where gas-fired boilers are still used carbon savings are likely to be modest and arise only when the marginal improvement in combustion efficiency over distributed heat sources exceeds greater distribution losses. When supplied to multiple users, e.g. blocks of flats, heat metering can assist in reducing heat wastage and so maximise the carbon savings.

### 5.5 Cost Effectiveness

Capital costs are high because of the required investment in infrastructure (i.e. heating pipework) but well-designed and located district heating has a lower whole life cost than competing technologies. Financial savings are available through energy savings together with reduced operational and maintenance costs. Payback periods are typically in the range 10 to 20 years, but the infrastructure can continue to deliver savings for several decades beyond this.

## 5.6 Local Impact / Planning Considerations

The local impact of district heating includes:

- **Emissions, Noise & Vibration** – Emissions from district heating are lower than that for distributed systems, but they are released at a single location. This may be from a dedicated building or site, but can be incorporated within some building types (e.g. within a hospital site).
- **Visual Impact** – There is minimal or no visual impact associated with the technology where it can be incorporated within a large site such as a hospital or university. Where the heat source is located within a purpose built structure, there is a requirement for a flue/chimney.
- **Other** – District heating schemes are not highly visible and, as such, do not provide an obvious opportunity to promote the green credentials or image of their owners.

## 5.7 Offset Costs

District heating can reduce the capital costs associated with a development by removing the need to install heating plant within individual buildings. Operating costs, service costs and periodic replacement, can also be affected. It can also release space within each building which would otherwise be required for the location of boilers and associated plant.

## 5.8 Grant Funding

Grant funding is available via the Community Energy scheme until 2008.

## 5.9 Complementary Technologies

District heating can be regarded as an alternative to separate installations which utilise renewable energy technologies to deliver heating. However, where these technologies are used to deliver district heating (e.g. through the use of CHP or biomass boilers to generate heat centrally) or cooling (e.g. through groundwater cooling), the combination of technologies can have a significant impact on potential carbon savings.

## 6 Combined Heat and Power (CHP)

### 6.1 General Description of the Technology

Combined heat and power (CHP) refers to the simultaneous generation of electricity and heat in the form of hot water or steam. CHP is also referred to as 'cogeneration' or 'total energy'. Electricity is generated using an engine or a turbine, with heat being recovered from the exhaust gases and cooling systems. CHP is most appropriate to buildings or sites which have 'round the clock' and a year round demand for heat. Hospitals, hotels and leisure centres with heated swimming pools are the most suitable building types.

CHP operates in parallel with the incoming mains, so that if electricity demand is greater than the output of the plant, then the difference can be made up using traditional supplies. Any excess electricity can, in theory, be sold to other local users or 'exported' (i.e. sold) back to a licensed supplier (although the price for this option is currently low). CHP is normally sized a little above summer base load, and so conventional boilers will be required to meet the peak demand for heat. Excess heat can be dumped, or more efficiently used to serve the needs of other local users via a district heating network.

Carbon emissions associated with CHP are much lower than for conventional electricity generating plant which 'dump' heat that cannot be put to good use. The overall efficiency of CHP plant (including both the electrical and heat output) can be more than 80%, which compares favourably with 35% to 45% achieved at an average power station.

The technology is not new, but packaged units have become more widely available within the UK over the past few decades and units which are small enough to serve a single household are becoming available. Currently there estimated to be more than 1,500 CHP installations in the UK.

CHP has been highly cost-effective in the years following de-regulation of the energy supply market and their uptake has been encouraged by government policy initiatives or grant schemes. However, in recent years the narrowing gap between gas and electricity prices has made the market difficult for CHP. CHP is specifically addressed by one of the task groups set up within the Sustainable Energy Policy Network (SEPN) which seeks to deliver all 130 objectives of the government White Paper.

Almost any fuel can be used for CHP plant, although natural gas and fuel oil are most common, waste and biomass can be used.

CHP is available in a wide range of outputs, serving sites ranging from a single building to meeting the energy needs of a town or district. Micro-CHP is now available with outputs suited to the energy demands of an individual household, although the technology is new to the UK. It is less cost effective than larger scale installations.

Due to its potential economic and environmental benefits, CHP is already a widely used carbon saving technology. The next generation of CHP technologies offers the potential for even better performance, lower costs and lower carbon emissions as a result of improved power efficiency and greater use of

renewable fuels. Developments such as the greater use of biomass fuels could contribute to advanced CHP replacing existing schemes and allow its deployment in new applications.

Stirling engine based micro-CHP schemes may offer a new and potentially promising means of delivering carbon savings in small commercial and other buildings. Although some demonstration schemes have been installed, the technology is basically at the prototype stage and considerable work remains to be done in areas such as performance and operating costs before volume markets can be established.

## 6.2 Influencing Factors

Factor	Preference
Location	Suitable in all geographic locations
Building occupation	<p>More suitable for buildings with a year round demand for heat. Examples include hospitals, hotels, sports or leisure facilities with heated pools and residential accommodation.</p> <p>Also well suited to mixed use developments, where the variety of buildings provides such a demand for heat.</p>

The technology is especially suitable for buildings which have heat demand for a large proportion of the day throughout the year. In order to be cost effective (and to have a major impact on carbon emissions) CHP plant should generally operate for a minimum of 4,000 to 5,000 hours per year. Hospitals are ideal sites for larger CHP installations (several hundred kW) as are some hotels, particularly those with heated pools. Leisure centres with heated pools and residential accommodation (such as student residences, Ministry of Defence accommodation, care homes and apartment blocks) can also be suitable for smaller installations.

### 6.3 Technology Overview

Factor	Impact	Comment
Carbon Savings	High	Carbon reductions can be around 30% when compared to existing conventional boilers and power generation systems.
Cost Effectiveness	Medium-High	Cost effectiveness is dependent on several factors, including the useful heat which can be recovered, the total annual operating hours, maintenance, and the relative price of electricity and oil or gas. Payback periods of 5-10 years are not uncommon.
Local Impact	Low-Medium	CHP installations are relatively unobtrusive – noise and vibration are minimal. Net national emissions are less than conventional solutions.
Offset Costs	Low-Medium	Offset costs depend on the application, energy source replaced and building type. The cost of conventional boilers can be offset.
Grant Funding	Yes	Enhanced capital allowances can apply and the input fuel for some installations is exempt from the climate change levy.  Grants to support the installation of CHP are currently available through the Community Energy programme.

### 6.4 Carbon Savings

CHP can significantly reduce primary energy consumption and can therefore have a major impact on CO<sub>2</sub> emissions associated with the combustion of fossil fuels in conventional power stations and boilers.

Each kW of electrical capacity provided by CHP plant using fossil fuels has the potential to reduce annual carbon emissions by more than one tonne. For plant which is fuelled by waste or biomass the potential is much greater.

### 6.5 Cost Effectiveness

Capital costs for CHP installations are higher than for alternative systems, but this can be recovered over a relatively short period of time (typically 5 to 10 years) for installations where there is a demand for heat and power for 4,500 hours or more each year. Ongoing savings can be substantial because purchased electricity is displaced by power generated using cheaper fossil fuel. The cost effectiveness is sensitive to

the relative price of electricity and fossil fuel which have been subject to frequent variations since de-regulation of the energy supply industries.

The reliability of CHP has been established and installations can have lifetimes of 15 years or more.

## 6.6 Local Impact / Planning Considerations

The local impact of CHP includes:

- **Emissions, Noise & Vibration** – CHP installations generate some noise but this can be significantly reduced by purpose designed acoustic enclosures. Engines will vibrate when they are operational but this is not usually problematic. As with all combustion devices, they do release some carbon dioxide and other emissions, locally, but these are comparable with emissions from conventional boiler plant (perhaps 20% to 50% higher than a boiler system meeting a similar heat demand). These local emissions are more than offset by reduction in emissions at power stations.
- **Visual Impact** – CHP installations are usually contained within boiler houses and plant rooms. Space and flue requirements may be slightly greater than conventional plant, but generally they are unobtrusive.
- **Safety** – There are no specific safety concerns attributable to CHP installations that comply with legislative requirements. The CHP installation must comply with the Electricity Companies Distribution Systems Guidelines G59/1 (Recommendations for connection of Embedded Generation plant to the Electricity Distribution Systems).

## 6.7 Offset Costs

CHP plant can offset the cost of conventional boilers, but there will usually be a need to have standby heat capacity when CHP plant is idle.

## 6.8 Grant Funding

Investment in Good Quality CHP can qualify for Enhanced Capital Allowances, allowing some investors to write off investments in CHP against tax. The fuel used by Good Quality CHP is exempt from the climate change levy (CCL). Good Quality refers to CHP generation that is energy efficient in operation. The CHP Quality Assurance programme determines that quality by providing a practical method for assessing all types and sizes of CHP scheme.

Grant funding is currently available for community heating applications via the Community Energy scheme.

## 6.9 Complementary Technologies

The use of a CHP can reduce the viability of separate installations which utilise low carbon technologies to deliver heating on a large scale, so an option appraisal may be necessary to see which is the best option. However, where low carbon technologies are used to support CHP (e.g. through the use of biomass to fuel CHP, or the utilisation of a district heating scheme to increase the utilisation of heat recovered from CHP), the combination of technologies can have a significant impact on potential carbon savings.

## 7 Ground-source Heat Pumps

### 7.1 General Description of the Technology

Ground-source heat pumps (GSHPs) are used to increase the temperature of a circulating fluid from that of the ground-source (around 10 to 20°C) to a more useful output temperature of around 30 to 50°C. These output temperatures are ideal for low temperature systems, e.g. underfloor heating coils and radiant panels.

The source of heat remains at a relatively constant temperature all year and can be taken from the ground or from water within the ground (groundwater). With the correct design of the “collector”, a loop to gather the available heat by using a refrigerant fluid (or water) in a pipe which is in contact with the ground, the depletion of the heat source is not noticeable and can be considered a truly renewable source of energy.

Ground-source heat pumps require an input of energy, usually electricity, to make use of low grade heat, but they can be energy efficient, producing up to 4 kW of heat output for every kW of electrical input. They can be used in most kinds of building and have both domestic and commercial applications.

There are two basic kinds of collector, horizontal and vertical. The horizontal collector consists of a sealed loop of pipework buried in a trench; the vertical loop is a borehole specifically bored for this purpose and lined with a special grouting mixture to facilitate the heat transfer. The length of the horizontal loop and the depth and number of boreholes are determined by the size of the heat demand.

The use of GSHPs, by reducing primary energy consumption, has the potential to reduce the quantity of CO<sub>2</sub> produced by the combustion of fossil fuels and thus to reduce global warming. A GSHP with an seasonal performance factor of at least 3 will always reduce CO<sub>2</sub> emissions compared with oil-fired boilers, independent of the local electricity generation mix. When used in place of a high efficiency gas fired boiler it will reduce overall emissions of CO<sub>2</sub> providing that mean specific CO<sub>2</sub> emissions from electricity generation do not exceed 0.63 kgCO<sub>2</sub>/kWh.

### 7.2 Influencing Factors

Factor	Preference
Location	Locations with: <ul style="list-style-type: none"> <li>- land available which is suitable for excavation for a horizontal loop, or</li> <li>- suitable geology for vertical loop(s)</li> </ul>
Building occupation	More suitable in high levels of occupancy

GSHPs are suitable in most locations as final output depends on the size of the loop and the heat pump itself rather than on location.

The availability of ground-source heat is not confined to certain times of the day or year but some locations exhibit more seasonal behaviours than others according to local geology.

Ground source heat pumps are most efficient when they operate continuously and so are most suitable for buildings which are in constant use such as housing developments, hotels and hospitals.

In the UK at present, around 250 ground-source heat schemes are being installed annually.

### 7.3 Technology Overview

Factor	Impact	Comment
Carbon Savings	Medium	Power input : typically 1 to 12 kWe. Annual output depends on the load profile and the proportion of DHW supplied from the GSHP system.
Cost Effectiveness	Medium	The fact that installations are dependent on local circumstances and that the UK heat pump market is currently developing quite rapidly make it difficult to estimate what the additional capital cost of a GSHP system might be over a conventional system.
Local Impact	Low	Heat pump installations are unobtrusive and noise and pollution free.
Offset Costs	Low-Medium	Depending on application, energy source replaced and building type.
Grant Funding	Yes	Available for households and community projects via the Scottish Community and Householder Renewable Initiative.

### 7.4 Carbon Savings

The use of GSHPs, by reducing primary energy consumption, has the potential to reduce the quantity of CO<sub>2</sub> produced by the combustion of fossil fuels and thus to reduce global warming.

For the current UK mix of fuels which are used to generate electricity, a GSHP with an seasonal performance factor of at least 3 will reduce CO<sub>2</sub> emissions compared with gas and oil-fired boilers.

### 7.5 Cost Effectiveness

The reliability of heat pump components is good, with expected lifetimes of 10 to 15 years. The expected lifetime for polyethylene or polybutylene ground coils is much longer, with warranties being offered for up to 50 years.

Capital costs are higher than for alternative systems, mainly because of the costs associated with the ground coil. In the UK there are currently too few installations to benefit from economies of scale so costs are higher than in other countries where the technology is well established. However, for an electrically driven GSHP typical energy costs are between 50 to 70% less than for electric resistance heating and the technology can be cost effective where gas and oil fired systems are not possible.

## 7.6 Local Impact / Planning Considerations

The local impact of GSHPs includes:

- **Emissions, Noise & Vibration** – Heat pump installations are pollution free and noise levels are generally low. There are no local emissions and, although there will be carbon dioxide emissions associated with their electricity use, these are less than conventional gas or oil boilers.
- **Visual Impact** – Heat pump installations are unobtrusive. The technology used in ground-source heat heating systems has very low visual impact and most of the infrastructure can be hidden beneath the ground. When using a horizontal loop, the surface is simply returned to its previous use.
- **Safety** – Many of the safety considerations appropriate to any refrigeration or air conditioning system apply to the use of heat pumps since the working fluid is often a controlled substance that needs to be handled by trained personnel. There is no cause for concern as once the system is commissioned an accidental release of refrigerant is unlikely.
- **Other** - Heat pumps are not highly visible and, as such, do not provide an obvious opportunity to promote the green credentials or image of their owners.

## 7.7 Offset Costs

Heat pumps are an alternative to the installation of other systems to provide the heat demand of a building. For commercial applications where heating and cooling are provided, the additional cost of the ground coil can be substantially offset by the elimination of other plant and a reduction in the space needed for plant room. For small commercial and domestic applications, the use of the technology is currently more cost-effective where mains gas is not available, where its use potentially offsets the costs of oil tanks or coal storage.

## 7.8 Grant Funding

Grant funding is presently available from the Energy Saving Trust via the Scottish Community and Householder Renewable Initiative for households and community installations (i.e. schools, colleges, hospitals and other public buildings).

## 7.9 Complementary Technologies

Heat pumps are more efficient when supplying heat continuously so the most cost-effective size is not designed to supply 100% of the load. Peak loads are supplemented by additional heaters or heating systems. When the intended final use of some of the heat is for hot water, a suitable complementary technology is the use of solar thermal collectors.

All electricity-generating technologies based on renewable sources are also complementary as they can produce the energy required to drive the heat pump, enhancing the carbon savings.

## 8 Wind Power

### 8.1 General Description of the Technology

Wind power is used to generate electricity, either in parallel with mains supplies, connected to the grid via inverters and synchronising gear or for DC applications with battery back-up. In order to generate worthwhile quantities of electricity, average wind speeds of more than 5 m/s are typically required.

There are two basic kinds of turbine, horizontal axis and vertical axis. There are variations within these broad classifications. Horizontal axis turbines are generally more efficient and most commercial models are of this type. These comprise a central hub with (usually three) evenly spaced blades, that rotate at a fixed rate, regardless of wind speed. Minimum wind speeds of 3.5 to 5 m/s are required to allow turbines to cut in and turbines include automatic braking devices which operate when wind speeds exceed a safe limit such as 20 to 25 m/s.

The power output of wind turbines depends on two factors: the swept area of the rotor and the wind speed. The relationship between power output and swept area is approximately linear, but power output increases more rapidly than a linear relation with the wind speed.

The best locations for wind turbines are away from obstructions which affect air flow, including any features of buildings which may have an affect on airflow. Ideal geographical locations include near hill tops, narrow valleys and the coast. Roof mounted ducted wind turbines are available which can be incorporated into roofs of a high-rise buildings. They have the advantage of capturing the high wind speeds of typically more than 6 m/s available on rooftops of urban buildings.

Wind characteristics are specific to each location and evaluations of the feasibility of wind power at any particular site will require details of historic meteorological data. This is available, free of charge, from various sources (see section 8.3).

The use of turbines to convert the power of the wind into electricity represents a growing market and is a developed technology with significant carbon saving potential in the UK and elsewhere. The key barriers affecting wind deployment in the UK are non-technical, i.e. public acceptability and the securing of planning permission for individual schemes. Although none of the world's major wind turbine manufacturers are UK companies, the wind power skills base in this country currently includes both developers and component manufacturers.

## 8.2 Influencing Factors

Factor	Preference
Location	Rural or exposed locations
Building occupation	Suitable for all patterns of occupancy

Turbines are suitable in all locations although higher outputs will be achieved in rural or exposed locations. In contrast, outputs tend to be lower in sheltered locations, or where air flow is altered by obstructions such as buildings.

The availability of wind power is not confined to certain times of the day or year but some locations exhibit seasonal behaviours (coastal areas have particular sea breeze patterns) and are able to contribute to energy demand all year around.

## 8.3 Technology Overview / Planning Considerations

The Scottish National Planning Policy Guideline NPPG6 (Renewable Energy Developments) provides statements of Scottish Executive policy on nationally important land use and other planning matters.

Factor	Impact	Comment
Carbon Savings	Low-High	Annual outputs depend on systems and local factors and cover a wide range of values.
Cost Effectiveness	Medium	Typical payback periods of 10-20 years.
Local Impact	High	Wind turbines are highly visible
Offset Costs	Low	None
Other Benefits	Medium	Wind turbines offer teaching and research opportunities. Some local communities welcome them as tourist attractions.
Grant Funding	Yes	Available for single micro turbines and medium sized turbines for community projects.

## 8.4 Carbon Savings

A turbine located on or close to a building would typically have peak outputs of up to 10 to 20 kW, generating 10,000 to 40,000 kWh per annum. This is equivalent to approximately 5% to 20% of the electricity consumption of a typical 4,000 m<sup>2</sup> open plan office.

Medium-sized turbines (>100 kW) can be installed on the grounds of many buildings, but these will usually require independent foundations, towers, etc.

## 8.5 Cost Effectiveness

Wind turbines are widely recognised to be one of the most financially viable of the renewable energy technologies. Further, Scotland has one of the windiest climates in Europe and is ideally placed to exploit wind energy.

For small scale, building integrated applications, simple payback periods of approximately 20 years can be achieved. For larger installations the economics become more attractive.

## 8.6 Local Impact / Planning Considerations

The local impact of wind turbines includes:

- **Noise & Vibration** – Careful positioning of turbines and good design of rotors normally ensures that noise from turbines is not normally significant. Noise levels are generally low and are often masked by wind-generated noise. The vibration impact of turbines fitted to building is largely unknown and would require detailed evaluation during the development of any designs.
- **Visual Impact** – Wind turbines are highly visible, although often not unattractive. Building integrated turbines, with outputs of 10 to 20 kWe are typically around 7 m in diameter. Consideration may need to be given to reflections from moving turbines and shadow flicker but this effect depends on prevailing wind direction and turbine design. Because wind speed increases with height, turbines are installed at the tops of buildings or on separate towers. For building integrated applications these are usually 10 to 20 m above ground level.
- **Safety** – Many of the safety considerations appropriate to large turbines (e.g. proximity to power lines, loss of blade) are easier to address for smaller scale of building integrated rotors.
- **Other** - Wind turbines are highly visible and, as such, provide an opportunity to promote the green credentials and enhance the image of companies who use them.

## 8.7 Offset Costs

The inclusion of wind turbines does not provide significant opportunities to offset other building costs. The intermittent nature of the wind cannot guarantee supply and so conventional power supplies are needed to meet the full operating load of the building. There are examples of wind turbines which are used to charge batteries for dedicated applications such as automatic intruder detection systems, fence electrification and remote telecommunications.

Where wind turbines are integrated within a building as an alternative to a free-standing installation, the civil engineering infrastructure costs can be offset.

## 8.8 Other Benefits

Where installed in schools and universities, turbines offer teaching and research opportunities. Some local communities have found them to become a tourist attraction.

### **8.9 Grant Funding**

Grant funding is presently available from the Energy Saving Trust via the Scottish Community and Householder Renewable Initiative for households and community installations (i.e. schools, colleges, hospitals and other public buildings).

### **8.10 Complementary Technologies**

Winters are usually windier than summer. This seasonal variation in the availability of wind energy counters that of solar energy. Photovoltaic technology is therefore a useful complementary technology for wind power, providing a spread of energy throughout the year.

To ensure continuous availability of power for non grid-connected installations, battery storage is required to overcome the intermittent availability of wind power.

## 9 Biomass

### 9.1 General Description of the Technology

Energy from biomass is produced by burning organic matter. Biomass products such as trees, crops or animal dung are harvested and processed to create bio-energy in the form of electricity, heat, steam and solid fuels. Biomass is also referred to as 'bioenergy' or 'biofuel'.

Biomass is carbon-based so when used as fuel it also generates carbon emissions. However, the carbon that is released during combustion is equivalent to the amount that was absorbed during growth and so the technology is largely carbon-neutral. Unlike fossil fuels, biomass can be replaced relatively quickly.

Wood burning is an ancient technology, but recent advances in technology have led to major improvements in combustion efficiency and more energy can now be recovered from fuel. Also, modern processes such as gasification and pyrolysis allow high calorific fuels to be produced which have more widespread applications (although this is presently mainly relevant for large scale applications ranging from 5 to 40 MWe as there are still uncertainties surrounding efficiencies for smaller applications).

The main types of biomass are:

- **Wood biomass** – this includes forest products, short rotation coppice (SRC), i.e fast growing, regenerative woody species such as willow, hazel and poplar, miscanthus (elephant grass) and other wood waste such as pallets and construction and demolition wastes. The moisture content of woody biomass affects the energy content of the fuel and many products require pre-drying before they can be used.
- **Vegetable oil crops** – cellulose and vegetable oil crops such as palm oil or rapeseed can be processed to create liquid fuel. This can be used as vehicle fuel and to power engines including generating plant.
- **Animal residues** - cattle, chicken and pig waste can be converted to bio-energy by conversion to methane gas.

The potential for biomass in the UK is good, although a reliable and reasonably local supply of fuel from forestry, farming or industrial sources is required. The government is committed to biomass because it is a low carbon energy source and because of its potential to boost rural economies.

Biomass fuel can be combusted to provide heat in fully automated boilers that are readily available from a large number of manufacturers around the world. Although the development of the market for biomass heat in the UK offers significant scope for carbon savings at modest cost, the high cost of biomass boilers compared with fossil fuel units of equivalent size and the lack of fuel supply infrastructure represent major barriers to take-up. Addressing these barriers will depend on a volume market for biomass becoming established.

## 9.2 Influencing Factors

Factor	Preference
Location	<p>Locations with access to suppliers of biomass (i.e. within a maximum radius of 100 miles), delivery routes and with sufficient space for storage.</p> <p>Biogas generation is more suited to sites with good access to manure or food wastes.</p> <p>Some biomass, especially wood, is not generally suitable in smoke control areas.</p>
Building occupation	The technology is appropriate to all building types

## 9.3 Technology Overview

Factor	Impact	Comment
Carbon Savings	High	Biomass installations can deliver all of the heating requirements for a building or a development using a carbon neutral fuel source.
Cost Effectiveness	Medium-High	Generally competitive, and highly cost-effective in rural areas or where there is no mains gas supply
Local Impact	Medium	There may be adverse transport impacts associated with fuel deliveries and requirements for flues in some cases. However, the growth of managed biomass fuel supply chains can support biodiversity.
Offset Costs	Low-Medium	The plant costs attributable to fossil fuel alternatives to biomass fired plant can be offset.
Grant Funding	Yes	Available for households and community projects via the Scottish Community and Householder Renewable Initiative.

## 9.4 Carbon Savings

The use of biomass to meet energy needs can have a significant impact on carbon emissions attributable to a building or development. The carbon savings are at their greatest when the buildings are located next to a biomass supply. Biomass boilers can meet the year-round demand for heat. Where biomass is used to fuel generating plant this can be further enhanced.

## 9.5 Cost Effectiveness

Capital costs are higher than conventional systems and costs vary significantly from site to site, depending on fuel type, heating infrastructure and the cost of a boiler plant. However, the technology is currently competitive when compared with oil-fired or electrical heating and in some cases with gas-fired heating.

Biomass can be particularly cost-effective in replacement situations where the existing infrastructure removes the cost for providing new boiler houses and fuel stores. Often it can be appropriate where users produce their own fuel or are able to obtain it at zero cost (i.e. if diverted from waste streams).

## 9.6 Local Impact / Planning Considerations

Due to the public's unfamiliarity of the technology a consultation process with the local community, suppliers and end users, prior to the design stage is recommended for community and large scale projects.

Other local impact includes:

- **Emissions, Noise & Vibration** – There may be noise and vibrations associated with producing and subsequent transport (via road or rail) of wood fuels, but not with the installation itself. There may be problems associated with emissions e.g. for domestic appliances, wood can only be burnt within exempted appliances under the Clean Air Act if they are located within a Smoke Control Area.
- **Visual Impact** – The visual impact of biomass plant is generally similar to that for conventional plant, although there may be special requirements for flues for some fuel types (e.g. wood). Storage of fuel stock is a much more significant visual impact issue.
- **Operation & Safety** – There are no particular health and safety concerns associated with the technology. Guidelines for the operation of biomass systems, as for other solid fuel appliances exist. These are especially concerned with fuel storage and handling, as well as operating stoves and boilers. Further information is available from Clear Skies, including applicable European Directives and labelling under the “Manufacturers/ Product Criteria” area of their web site ([www.clear-skies.org](http://www.clear-skies.org)), and British BioGen ([www.britishbiogen.co.uk](http://www.britishbiogen.co.uk)) for Good Practice Guidelines for producing, handling and storing biomass fuel.
- **Biodiversity** – In the areas where they are grown, biomass can support an increase in wildlife species, particularly birds and insects.

## 9.7 Offset Costs

The capital cost for biomass boilers can be quite high, but biomass boilers can remove the need for fossil fuelled boilers.

Biomass fired plant has a higher space requirement than most other alternatives because of the requirement for fuel storage and an automated fuel feed system for most biomass boilers.

Plans exist for the introduction of a renewable heat obligation scheme similar to the Renewable Obligation for electricity at present. Certificates under the Renewable Heat scheme will credit heat produced from biomass and further enhance its economic viability.

## **9.8 Grant Funding**

Grant funding is presently available from the Energy Saving Trust via the Scottish Community and Householder Renewable Initiative for households and community installations (i.e. schools, colleges, hospitals and other public buildings).

The Bioenergy Capital Grants Scheme supports the early deployment of proven biomass-fired heat and power generation projects and more than £4.2 million support funding is available for biomass-fired heat and small combined heat and power (CHP) projects under the Scheme. It also supports the development of fuel production and distribution networks.

## **9.9 Complementary Technologies**

Where storage is available, biomass is available regardless of weather conditions and so it works well with intermittent forms of renewable energy, particularly solar thermal energy.

As with other types of boiler or thermal plant, biomass can be used to provide heating around a local neighbourhood or group of buildings and to fuel combined heat and power (CHP) plant.

## 10 Combinations of Technologies

Of the technologies covered in this report, some are complementary (e.g. wind power and photovoltaics could both be installed at a site, each contributing to electricity supply under different conditions); whereas others can be mutually exclusive (e.g. it is unlikely that ground source heat pumps will be installed at a site which already has a heat source such as biomass).

Table 3 indicates those technologies which can be effectively installed as a combination (identified by '√'), together with those technologies which are unlikely to be complementary and therefore would not generally be installed together (identified by '×').

**Table 3 : Combinations of technologies**

	Solar thermal	Photovoltaics	District heating	Combined heat and power	Ground source heat pumps	Wind power	Biomass
Solar thermal		√			√	√	
Photovoltaics						√	
District heating				√	×		√
Combined heat and power					×		√
Ground source heat pumps							×
Wind power							
Biomass							

√ technologies which are generally complementary

× technologies which can be mutually exclusive

## 11 Secondary Low and Zero Carbon Technologies

This section gives brief descriptions of other LZC technologies which are less well developed and therefore, at the present time, are expensive relative to their carbon savings when compared to the technologies considered in sections 3 to 9.

### 11.1 Fuel Cells

Fuel cells can operate using non-carbon fuels. In industrial and commercial markets, they could represent an attractive potential option for use in premium power, back-up power and CHP applications. Such deployment would help UK companies to achieve environmental performance targets and could contribute significantly to sustainable energy use. As with other potential fuel cell applications, there is a need to reduce capital costs and for more information on performance under typical commercial conditions. The interest and investment in this technology has increased rapidly over the last ten years.

### 11.2 Absorption Cooling

The cooling of buildings is a growing market that, due to reliance on electrical systems, could be a significant source of carbon dioxide emissions in the future. Although more environmentally friendly cooling systems based on gas and other alternatives are being introduced, barriers to their take-up exist in the UK, such as a lack of sales, service and support infrastructure. Moreover, there is no UK manufacturing capability that could meet growing demand for alternative systems of this kind.

Absorption cooling is a technology that uses heat to produce a cooling effect instead of using electricity. It is applicable mainly to commercial and industrial buildings and there are a number absorption chillers in the UK. Most of these are relatively small, gas fired, air-conditioning units but some plants are larger-scale. Absorption cooling is unlikely to replace conventional refrigeration systems on a substantial scale but in certain conditions it presents opportunities for environmental and economic benefits.

### 11.3 Waste to Energy

Two main technologies are applicable to schemes that combust municipal solid waste and capture the heat produced. Firstly, grate combustion systems, which are well established and cost competitive in the UK and overseas; and secondly, fluidised bed combustion systems, which are not commercially proven in the UK but are used elsewhere. Advanced options, such as gasification and pyrolysis, are under development. Overall, waste to energy has valuable greenhouse gas saving potential, with precise performance depending on the carbon content of the waste combusted. Although waste to energy plant are likely to have a growing role in the UK, they are expensive to build. Public perceptions and planning permission difficulties are significant barriers.

## 11.4 Ground Source Cooling

The cooling demand for some buildings can be met by circulating ground water. The fluctuations in ground temperature decrease with depth and, at only a few meters below the surface, the temperature of the ground remains fairly constant, well below summer outside air temperatures.

The ground water circuit can be either an open loop or a closed loop system.

In an **open loop** system, a heat exchanger separates the ground water circuit from the cooling circuit within the building. Water is extracted from the ground, passed through a heat exchanger, then either returned to the ground or discharged to a river or sewer. This may affect the local water table and permission to abstract water is required.

**Closed loop** systems comprise a continuous loop of pipework which is buried in the ground below the water table. The water which is circulated through the ground is also used by the cooling distribution system within the building. The ground loops can be vertical (up to depths of 100 m) or horizontal (typically 2 m below ground).

The cool water can be used to provide cooled ventilation air directly or it can be circulated through ceiling panels or coils providing a chilled ceiling system (although condensation needs to be considered within buildings where cold surfaces are exposed to warm humid air).

A detailed ground survey will usually be required to determine the suitability on any particular site.

## 11.5 Low-Head Hydro

The technology required to harness low-head hydro power for electricity production is highly developed, efficient and well understood, with a number of schemes and technology suppliers operating in the UK. As a result of the relatively high cost of exploitation together with the environmental and regulatory issues associated with hydro development the UK market is relatively restricted, with opportunities for further cost-effective deployment being limited.

## 11.6 Geothermal

The natural heat within the earth can be harnessed as a carbon saving energy source by the exploitation of aquifers, naturally occurring deposits of hot water in deep porous rocks underground. The technology to do this is mature and well understood. However, UK aquifer resources are low in temperature and their location is not well matched with areas of high heat demand. Hot Dry Rock technology which is the extraction of heat through the injection of water into dry rock formations could represent a further means of capturing geothermal energy. However it faces many technical barriers and is unlikely to be competitive in the UK in the short to medium term.

## 11.7 Biomass for Local Electricity Generation

Solid fuels derived from plant materials can be utilised by a range of technologies for the production of baseload electricity. The use of standard combustion/steam cycle plant for this purpose is already commonplace in well-wooded parts of the world, such as Scandinavia and North America. However, because of their low conversion efficiency, the small biomass power stations that would be appropriate to

fuel supply conditions and transport infrastructure in the UK would produce high cost electricity. Advanced conversion plants offer the prospect of much higher conversion efficiencies and therefore lower cost power, but are not yet fully commercialised.

### **11.8 Solar Thermal Electric**

Solar thermal electric systems work by focusing and absorbing solar radiation and using the captured energy to generate electricity via steam turbines. The need for high and reliable levels of direct sunlight means that this technology is unlikely to make any contribution to carbon saving in the UK in the short, medium or long term. Moreover, solar thermal electric has yet to achieve or maintain unassisted commercial deployment anywhere in the world. This slow progress towards the market means that there will only be limited opportunities for the UK to benefit from advances elsewhere in the world in the short term.

## 12 Possible new functional standard in the Scottish Building Regulations

### 12.1 The drafting of a functional standard

If a specific requirement for the use of low and zero carbon technology were to be incorporated into the Scottish Building Regulations, it could be implemented by a functional standard such as:

**In order to comply with standard [6.1] every building must be designed and constructed in such a way that a proportion of the fuel and power used for heating, cooling, lighting or hot water supply is derived from a decentralised zero carbon production technology, or a low carbon production technology.**

#### Limitation

This standard does not apply to:

- a) Small buildings (less than 1000 m<sup>2</sup> floor area);
- b) Buildings which do not use fuel or power for controlling the temperature of the internal environment.

There follows in 12.2 to 12.4, below, some observations on the implications of such a requirement and its relationship with both the Partnership Agreement and the Energy Performance of Buildings Directive.

### 12.2 Issues associated with a functional standard

It is commendable that consideration is being given to a mandatory approach to introducing LZCT into Scottish Building Regulations. There are however some associated issues that need some careful consideration before embarking upon such a measure. The difficulty with an approach based on a mandatory requirement is that the cost of installing LZCT are still relatively expensive compared to insulating the building envelope. The current design standard which includes the type of fuel, envelope U-values, air permeability and performance of building services focus on existing technologies which are well established. Many LZCT's are still in their infancy or are still developing in relation to the established design standards. To make LZCT mandatory will likely increase building capital costs by a significant proportion. The CO<sub>2</sub> saved by LZCT will always be balanced relative to cost, together with other environmental and social factors.

The primary LZCT that could be installed are:

- 1) Solar thermal systems
- 2) Photovoltaics (PV)
- 3) District Heating
- 4) Combined Heat and Power (CHP)
- 5) Ground-source Heat Pumps
- 6) Wind Power
- 7) Biomass

and as a secondary list:

- 8) Fuel Cells – Commercial
- 9) Absorption Cooling
- 10) Waste to Energy
- 11) Ground Source Cooling
- 12) Low-Head Hydro
- 13) Geothermal
- 14) Biomass for local electricity generation
- 15) Solar thermal electric

The items on the secondary list are at a disadvantage as they are more expensive and are less developed, therefore suffering poor paybacks. If the primary list were to become mandatory, those on the secondary list would be less attractive and that could significantly impede their further development.

Available grants via Energy Efficient Commitment funding from utility companies, together with Carbon Trust and Energy Saving Trust funding would have to be reviewed and adjusted if LZCT became mandatory. The ability of current manufacturers would have to be investigated to ensure that LZCT could be produced in large numbers. Manufacturers are unlikely to cope with the immediate increased demand for their products therefore there is a need for a gradual take-up in LZCT with existing grant incentives. Only a small proportion of installers are qualified at present to install LZCT. If they were to be made mandatory the quality of installation may wane as some installers would not be trained in their installation. A gradual take up of LZCT would create a sensible way forward, enabling more installers and building standards officers to become trained and qualified. In the case of the former, this enables them to certify their installations and in the case of the latter, to verify such installations, all done via a managed market transformation.

There are also significant associated costs and technical issues with some LZCT, for example owing to the need for backup boilers in the case of CHP & solar systems, that would require careful consideration in each case.

Given that future reviews of Section 6 will specify increasingly lower targets for CO<sub>2</sub> emissions, it is likely that renewable energy sources will take an increasingly important role as a means of achieving lower emissions. There are technical limitations to the improvement of conventional heating systems, for example; and increasing the thermal insulation of building envelopes beyond current levels will become

increasingly expensive and subject to diminishing returns. The consequence of the latter point is that, as the overall standards become more demanding, the attractiveness of renewable energy sources relative to conventional measures should gradually increase, without specific mandatory requirements to adopt renewables.

### 12.3 Partnership Agreement

The Partnership Agreement of the Scottish Executive<sup>2</sup> contains commitments to encourage the take up of renewable energy sources, particularly in regard to electricity generation but also more generally. Relevant extracts are:

(Page 7) We will work towards our target for 40% of Scottish electricity generation to be from renewable sources by 2020 as part of our commitment to addressing climate change.

(Page 9) We will work towards our target for 40% of Scottish electricity generation to be from renewable energy sources by 2020. We will support the development of wave, tidal and solar energy and support the development of technologies to promote the greater use of fuel from wood and other energy crops. We will press the UK Government and electricity companies to strengthen the electricity grid. We will encourage participation in renewable energy projects by communities and local authorities.

(Page 40) We will strengthen building standards to ensure that energy conservation levels improve to high and effective levels and consult on ways to ensure that new homes and public buildings increasingly incorporate solar power or other renewable energy sources.

(Page 47) We will build on our participation at the Earth Summit held in Johannesburg by working with the UK Government, where appropriate, to meet our commitments to tackle climate change, and promote renewable energy and other aspects of sustainability.

(Page 48) We will take measures to reduce energy use, including the increased use of solar power and the introduction of energy conservation measures, throughout the public sector.

The framing of building regulations needs to take account of these commitments, particularly the one made on page 40, which has been assigned to the Scottish Building Standards Agency (SBSA). From the SBSA Corporate Plan, 'Target 3b' identifies that this commitment is to be met by May 2007.

### 12.4 Energy Performance of Buildings Directive

The EPBD in Article 5 specifies:

For new buildings with a total useful floor area over 1000 m<sup>2</sup>, Member States shall ensure that the technical, environmental and economic feasibility of alternative systems such as:

- decentralised energy supply systems based on renewable energy,
- combined heat and power,

<sup>2</sup> <http://www.scotland.gov.uk/library5/government/pfbs.pdf>

- district or block heating or cooling, if available,
  - heat pumps, under certain conditions,
- is considered and is taken into account before construction starts.

Paragraph 12 in the 'Recital' to the Directive gives the following guidance:

Buildings will have an impact on long-term energy consumption and new buildings should therefore meet minimum energy performance requirements tailored to the local climate. Best practice should in this respect be geared to the optimum use of factors relevant to enhancing energy performance. As the application of alternative energy supply systems is generally not explored to its full potential, the technical, environmental and economic feasibility of alternative energy supply systems should be considered; this can be carried out once, by the Member State, through a study which produces a list of energy conservation measures, for average local market conditions, meeting cost-effectiveness criteria. Before construction starts, specific studies may be requested if the measure, or measures, are deemed feasible.

Article 5 of the EPBD is to be implemented by 4 January 2006.

### 13 Implications of LZCT for the existing guidance

In the Building (Scotland) Regulations 2004, Regulation 9 and Schedule 5 set out the requirements for building construction in the form of 64 mandatory functional standards. SBSA have published Handbooks, one for domestic construction and one for non-domestic, that provide practical guidance to complying with the regulations.

In Schedule 5 the standards are given in these six sections:

Section 1	Structure
Section 2	Fire
Section 3	Environment
Section 4	Safety
Section 5	Noise
Section 6	Energy

As LZCT becomes developed it would be appropriate to consider the implications of the technologies, and whether or not the existing guidance should be extended to embrace issues arising from the use of LZCT in buildings.

Appendix A to this report provides an initial appraisal, indicating the functional standards for which the guidance could beneficially be reviewed.

The issues are amplified in Appendix B for the primary LZCT listed in 12.2.

## 14 Conclusions and recommendations

It could be said that the Scottish Building Standards Agency by commissioning this report have fulfilled the second paragraph of Article 5 of the EPBD, particularly when it is read in conjunction with paragraph 12 of the 'Recital', which refers to a study which is carried out once by Member States, for average local market conditions. Clearly from 12.2 above, the disadvantages to setting a functional standard outweigh the advantages. To cease work on this subject, however, at the outcome of this report would certainly not meet the objective of the Partnership Agreement and consequently the following is recommended:

- For the foreseeable future, LZCT should not be made mandatory in Scottish Building Regulations.
- To progress the take-up of LZCT, the current review of Section 6, which is giving consideration to setting a CO<sub>2</sub> emissions compliance target as a part of a whole building approach, should look to set this target at a sufficiently demanding level. If the correct balance is struck, the effect will be one that allows new buildings to be constructed using the traditional conservation of fuel and power approach, but at the same time makes it more attractive for designers to consider adopting LZCT as a part of that approach.
- Consideration should also be given at this stage to the effects of LZCT becoming fully developed and the implications of each technology with regard to the 64 existing mandatory functional standards within Scottish Building Regulations.

## Appendix A – LZCT and the functional standards

The table below provides an overview of where LZCT impacts on the functional standards of the Scottish Building Regulations.

- √ identifies technologies which potentially have an effect on current guidance
- ~ identifies technologies which potentially have minor effect on current guidance
- Blank identifies technologies which have no effect on current guidance

Standard	Solar thermal systems	Photovoltaics	District Heating	CHP	Ground source heat pumps	Wind power	Biomass	Fuel cells	Building cooling	Waste to energy	Ground source cooling	Low-head hydro	Geothermal	Biomass for Electricity	Solar Thermal Electric
	Primary LZCT							Secondary LZCT							
<b>Structure</b>															
1.1	√	√	~	~	√	√	~	~	~	~	~	√	~	~	√
1.2															
<b>Fire</b>															
2.1			√	√	~		√	√	√	√			~	√	
2.2			~	~	~		~	~	~	~			~	~	
2.3	~	~	~	~		~	~	~	~	~				~	~
2.4															
2.5															
2.6							√							√	
2.7	~	~													
2.8															
2.9															
2.10															
2.11															
2.12															
2.13															
2.14															
2.15															

Standard	Solar thermal systems	Photovoltaics	District Heating	CHP	Ground source heat pumps	Wind power	Biomass	Fuel cells	Building cooling	Waste to energy	Ground source cooling	Low-head hydro	Geothermal	Biomass for Electricity	Solar Thermal Electric
<b>Environment</b>															
3.1			√	√			√	√	√					√	
3.2															
3.3												√			
3.4															
3.5															
3.6															
3.7															
3.8															
3.9															
3.10															
3.11															
3.12															
3.13															
3.14															
3.15															
3.16															
3.17			√	√			√		√	√				√	
3.18			√	√			√		√	√				√	
3.19			√	√			√		√	√				√	
3.20			√	√			√		√	√				√	
3.21			√	√			√		√	√				√	
3.22			√	√			√		√	√				√	
3.23															
3.24															
3.25															
3.26															
<b>Safety</b>															
4.1															
4.2															
4.3															
4.4															
4.5	~	√	~	√	√	√	~	√	~	~	~	√	~	√	√
4.6															
4.7															
4.8															

Standard	Solar thermal systems	Photovoltaics	District Heating	CHP	Ground source heat pumps	Wind power	Biomass	Fuel cells	Building cooling	Waste to energy	Ground source cooling	Low-head hydro	Geothermal	Biomass for Electricity	Solar Thermal Electric
4.9			✓	✓	~		✓	✓	✓	✓			✓	✓	
4.10															
4.11															
4.12															
<b>Noise</b>															
5.1				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
<b>Energy</b>															
6.1															
6.2															
6.3			✓	✓	✓		✓			✓			✓	~	
6.4			✓	✓	✓		✓		✓	✓	✓		✓	~	
6.5															
6.6									✓		✓				
6.7	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
6.8	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

## Appendix B – Issues for LZCT in the Building Standards

	Section	LZCT	Standard	Comment on effect of LZCT on standards
1	Structure	Solar thermal systems	1.1	The roof must be strong enough to hold the weight of the solar collector.
		Photovoltaics	1.1	The roof must be strong enough to hold the weight of the solar panel.
		District Heating	1.1	The same consideration as a conventional gas boiler room.
		Combined Heat and Power	1.1	The same consideration as a conventional gas boiler room.
		Ground-source Heat Pumps	1.1	When excavating the ground the impact on the stability of building has to be considered
		Wind Power	1.1	The roof or gable end of a building must be strong enough to hold the weight of a wind turbine unit.
		Biomass	1.1	The same consideration as a conventional boiler room. The boiler room could only be located on the ground floor with sufficient storage space for biomass fuel.
2	Fire	Solar thermal systems	2.7	External exposure to fire for roof cladding and roof coverings have to be considered.
		Photovoltaics	2.7	External exposure to fire for roof cladding and roof coverings have to be considered..
		District Heating	2.1	The same consideration as a conventional gas boiler room.
		Combined Heat and Power	2.1	The same consideration as a conventional gas boiler room.
		Ground-source Heat Pumps		No effect.
		Wind Power		No effect.
		Biomass	2.6	Storing of biomass fuel must be taken into account. The storage installation must be designed to inhibit fire from spreading beyond its boundary.

	<b>Section</b>	<b>LZCT</b>	<b>Standard</b>	<b>Comment on effect of LZCT on standards</b>
3	Environment	Solar thermal systems		No effect.
		Photovoltaics		No effect.
		District Heating	3.1, 3.17 to 3.22	The same consideration as a conventional gas boiler room.
		Combined Heat and Power	3.1, 3.17 to 3.22	The same consideration as a conventional gas boiler room.
		Ground-source Heat Pumps		No effect.
		Wind Power		No effect.
		Biomass	3.1, 3.17 to 3.22	The same consideration as a conventional gas boiler room.
4	Safety	Solar thermal systems		No effect.
		Photovoltaics	4.5	The electrical cabling and switch gear has to be safely designed and installed to the appropriate electrical standard.
		District Heating	4.9	No effect - to the same standard as a conventional boiler system.
		Combined Heat and Power	4.5, 4.9	The electrical cabling and switch gear has to be safely designed and installed to the appropriate electrical standard. In addition it has to conform to G59/1 connecting to the Regional Electricity Companies Distribution System.
		Ground-source Heat Pumps	4.5	The electrical cabling and switch gear has to be safely designed and installed to the appropriate electrical standard.
		Wind Power	4.5	The electrical cabling and switch gear has to be safely designed and installed to the appropriate electrical standard
		Biomass	4.5, 4.9	No effect - to the same standard as a conventional boiler system.

	<b>Section</b>	<b>LZCT</b>	<b>Standard</b>	<b>Comment on effect of LZCT on standards</b>
5	Noise	Solar thermal systems		No effect.
		Photovoltaics		No effect.
		District Heating	5.1	No effect - to the same standard of acoustic separation as a conventional boiler room.
		Combined Heat and Power	5.1	Installations generate some noise but this can be reduced by acoustic enclosures. The building plant room must be designed to take care of any excess noise generated.
		Ground-source Heat Pumps	5.1	No effect - to the same standard of acoustic separation as a conventional boiler room.
		Wind Power	5.1	The vibration impact of turbines fitted to buildings is largely unknown and would require detailed evaluation during the development of any building design.
		Biomass	5.1	No effect - to the same standard of acoustic separation as a conventional boiler room.

	<b>Section</b>	<b>LZCT</b>	<b>Standard</b>	<b>Comment on effect of LZCT on standards</b>
6	Energy	Solar thermal systems	6.7, 6.8	The solar system has to be commissioned. Information on the operation and maintenance of the system must be provided.
		Photovoltaics	6.7 & 6.8	The PV system has to be commissioned. Information on the operation and maintenance of the system must be provided.
		District Heating	6.3, 6.4, 6.7, 6.8	The same consideration as a conventional gas boiler room. The heating services must be designed and commissioned to achieve optimum energy efficiency. All space heating pipes, ducts and vessels must be thermally insulated. Information on the operation and maintenance of the system must be provided.
		Combined Heat and Power	6.3, 6.4, 6.7, 6.8	The same consideration as a conventional gas boiler room. The heating services must be designed and commissioned to achieve optimum energy efficiency. All space heating pipes, ducts and vessels must be thermally insulated. Information on the operation and maintenance of the system must be provided.
		Ground-source Heat Pumps	6.7, 6.8	The heat pump has to be commissioned. Information on the operation and maintenance of the system services must be provided.
		Wind Power	6.7, 6.8	The turbine has to be commissioned. Information on the operation and maintenance of the system must be provided.
		Biomass	6.3, 6.4, 6.7, 6.8	The same consideration as a conventional gas boiler room. The heating services must be designed and commissioned to achieve optimum energy efficiency. All space heating pipes, ducts and vessels must be thermally insulated. Information on the operation and maintenance of the system must be provided.