Office of the
Deputy Prime Minister
Creating sustainable communities

Low or Zero Carbon Energy Sources: Strategic Guide

May 2006
1st Edition

Office of the Deputy Prime Minister
Creating sustainable communities

The Building Regulations 2000

LOW OR ZERO CARBON ENERGY SOURCES: STRATEGIC GUIDE

First edition May 2006

Published by NBS for the Office of the Deputy Prime Minister.
NBS is part of RIBA Enterprises Ltd.

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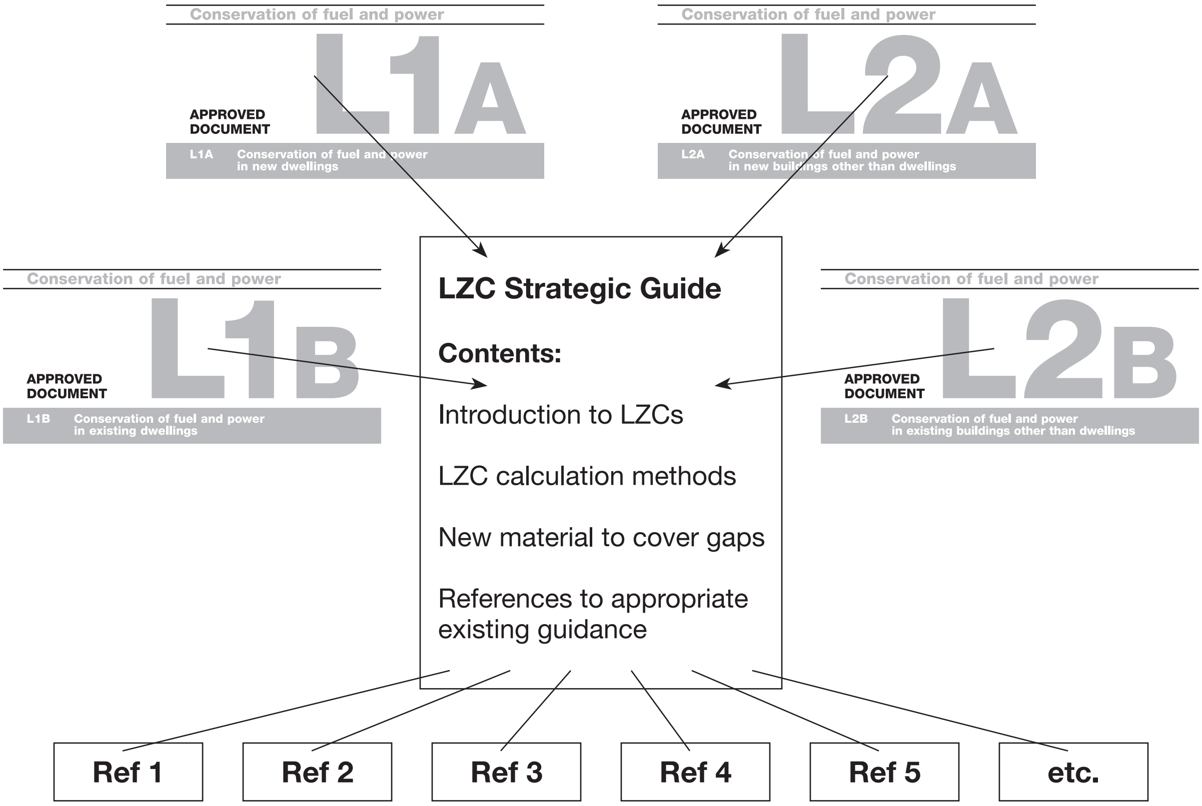
Stock code 57644
ISBN-10 1 85946 224 3
ISBN-13 978 1 85946 224 9

Contents

1. Introduction

Low and zero carbon (LZC) energy sources are increasingly being installed in buildings, e.g. small-scale and micro-CHP units, photovoltaic panels and building-mounted wind generators. This Strategic Guide is intended to support the inclusion of LZC energy sources in Part L and Approved Documents ADL1A, ADL1B, ADL2A and ADL2B of the Building Regulations. The desire to exploit LZC energy sources is driving the rapid development of many technologies, and this first LZC guide represents an understanding of these technologies at this time. Future revisions and additions to the guide will be required to capture new developments and enhanced understanding of currently available technologies.



This guide should provide sufficient information to enable the reader to decide if a particular LZC energy source is appropriate for the building under consideration and to estimate the potential for carbon dioxide emissions reduction.

The contents of the guide comprise:

a. An introduction to LZC energy sources, focusing on building-integrated/building-attached applications.

b. A set of calculation methods to enable the carbon dioxide emissions reduction potential of individual LZC energy sources to be calculated in domestic and non-domestic building applications. These or similar methods are also incorporated into the standard calculation methods, SAP and SBEM, and other calculation models.

c. Outline guidance on key issues for certain LZC energy sources where this is lacking in current literature.

d. References to recommended performance standards and guidance information.

LZC energy sources are best applied to a building where conventional energy efficiency measures have already been included. LZC sources will normally be most cost-effective when they are used to satisfy an energy demand already minimised through efficient design and use of energy conservation measures. For information and guidance on how to reduce demand through energy efficiency measures, reference should be made to numerous publications by CIBSE, BSRIA, the Carbon Trust, EST, ODPM, BRE and similar organisations.

The calculation methods presented in this guide are simplified manual procedures which will provide an estimate of the reduction in carbon emissions resulting from the application of an LZC technology. They should be helpful where no other manual method exists or as an alternative to more sophisticated techniques when the input data required by these techniques are unavailable. These calculation methods may differ from those used in comprehensive energy-modelling programmes and those approved by Government for Building Regulations purposes. For calculations aimed at showing compliance with Building Regulations, the Government-approved methods must be used.

The carbon dioxide emissions factors for gas and grid-supplied and displaced electricity used in this document are those adopted by the ODPM and included in the draft Approved Documents. The factor for grid-supplied electricity is the average for the current annual generation of electricity. Other organisations use different carbon dioxide emissions factors for electricity displaced from the grid by renewable sources, based on power stations that generate electricity from fuels with higher emissions such as coal. It is important to recognise that these emissions factors are used to give an indication of the carbon dioxide savings and to allow comparison of savings from different LZC sources on an equivalent basis. They do not necessarily provide an estimate of actual savings.

2. Absorption cooling

2.1 Introduction

Absorption cooling is a technology that uses heat instead of electricity to produce a cooling effect. It is applicable mainly to commercial and industrial buildings and there are many 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 mass basis, but in certain conditions it presents opportunities for reaping environmental and economic benefits. Some favourable factors which reduce running costs and carbon emissions include the existence of a CHP plant that operates below maximum capacity, available waste heat, or a low-cost source of fuel (such as landfill gas).

In most cases, absorption cooling is chosen as a less environmentally damaging alternative to other technologies, by making use of heat that would otherwise be wasted. When coupled with a CHP plant, absorption cooling becomes particularly attractive as it introduces an additional consumption of heat and thus improves the utilisation and viability of the CHP plant, particularly in summer. Moreover, since the only moving parts are small internal pumps, the operation of an absorption chiller creates much less noise and vibration than conventional cooling technologies.

Absorption cooling is based on the same physical principles as most refrigerating systems with the difference that a chemical absorber and generator, plus a pump, replace the compressor. The technology relies on pairs of chemicals that have strong affinity to dissolve in one another and enable the heat absorption and then rejection process. There are two basic types of absorption chiller using well-proven pairs of chemicals:

a. Lithium bromide/water systems.

b. Ammonia/water systems.

Lithium bromide/water systems are widely available as packaged units of cooling capacity ranging between 100kW and several thousands of kW. A technical limitation is the temperature of the chilled water, which for practical purposes can be reduced down to no lower than about 5ºC.

Ammonia/water systems are available in small (30–100kW), medium (100–1000kW) and large (>1000kW) sizes, appropriate, for example, to offices of 1000m^2, 6000m^2 and >15,000m^2. With these systems there is no limitation on cooling temperatures, and achieving as low as –60ºC is possible.

Like all cooling systems, absorption cooling effectively takes heat from one place and rejects it elsewhere (to the atmosphere). The efficiency of this process is defined by the Coefficient of Performance (CoP), which is the produced cooling effect divided by the energy input to the system (in kW). The CoP can range between 0.7 for standard plants and 4 for more complex and efficient ones. Plants operating at even lower CoPs can be beneficial as they can make use of low-grade waste heat and reduce the overall carbon dioxide emissions from a building.

The environmental impact of an absorption chiller can be compared with a conventional refrigeration plant using the Total Equivalent Warming Impact (TEWI) value, which is an index developed by the British Refrigeration Association.

2.2 Performance calculation method

For the purpose of calculating the potential of absorption cooling to contribute towards lowering the carbon dioxide emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
Q_{ctot}	kWh	Total space cooling demand	
A	%	Percentage of total cooling demand met by absorption cooling plant	
Q_c	kWh	Annual cooling demand to be met by the absorption chiller(s), which may be all or some fraction of the total space cooling demand	$Q_{ctot} \times A$
CoP_{abs}	None	Seasonal CoP of the absorption chiller(s)	
Q_h	kWh	Resulting heat input requirement of the absorption chiller(s)	Q_c/CoP_{abs}
Cf_h	$kgCO_2/kWh$	Carbon dioxide burden of the heat supply to the absorption chiller(s)	(see below)
C_{abs}	kg	Resulting carbon dioxide emissions due to the operation of the absorption chiller(s)	$Q_h \times Cf_h$
CoP_e	None	Seasonal CoP of the conventional electric chiller(s) that would have been employed instead of the absorption chiller(s)	
Q_e	kWh	Resulting electricity input requirement of the conventional chillers	Q_c/CoP_e
Cf_g	$kgCO_2/kWh$	Carbon dioxide factor for natural gas	0.194
Cf_e	$kgCO_2/kWh$	Carbon dioxide factor for grid-supplied electricity	0.422
Cf_{de}	$kgCO_2/kWh$	Carbon dioxide factor for grid-displaced electricity	0.568
C_{con}	kg	Resulting carbon dioxide emissions owing to the operation of the conventional chiller(s)	$Q_e \times Cf_e$

The carbon dioxide emissions saving that results from absorption chiller(s) can be derived as follows:

$$C_s = C_{con} - C_{abs}$$

Gas-fired absorption cooling

For direct fired absorption cooling, the carbon burden of the heat supply is dependent upon the efficiency of combustion. Hence, if the burner is equivalent to a grade A appliance with a seasonal efficiency of 86% the carbon dioxide burden will be:

$$Cf_h = 0.194/0.86 = 0.226 kgCO_2/kWh$$

CHP heat supply

For absorption chillers employing heat from a CHP system, the carbon burden of the heat is equal to the carbon dioxide burden of the fuel supply less the carbon dioxide value of the electricity generated. Assuming that 10 units of fuel generate 3 units of electricity and 6 units of heat and 1 unit is wasted (i.e. 90% overall efficiency), then if the fuel is gas the carbon dioxide burden of the heat can be calculated as follows:

$Cf_g = (0.6 \times Cf_h) + (0.3 \times Cf_{de})$, **so** $0.194 = (0.6 \times Cf_h) + (0.3 \times 0.568)$, **and** $Cf_h = 0.04 kgCO_2/kWh$

Waste heat supply

For absorption chillers employing waste heat that would otherwise be rejected (e.g. from an industrial process), the carbon burden of the heat can be deemed to be zero and hence the carbon dioxide emissions saving (C_s) is equivalent to the carbon dioxide burden of the conventional chiller(s) (C_{con}).

2.3 Additional guidance

Key areas that need to be considered with regard to an absorption cooling plant are design, installation, commissioning and maintenance. Comprehensive information on these is available in:

a. Good Practice Guide (GPG) 256. An introduction to absorption cooling. Action Energy, 2001.

The issues covered include:

Design

a. Benefits – designing to optimise the usage of available excess or waste heat.

b. Appropriate and inappropriate uses – types of plant, chemicals, cycles, system choice criteria.

c. Sizing – peak cooling demand, source of waste heat, auxiliary cooling capacity.

d. Heat rejection – quantities and temperature.

Installation and maintenance

e. Packaged and special design systems.

f. Overheating and overcooling.

g. Heat rejection.

h. Heat exchanger fouling.

i. Spares, services, servicing intervals; when expert help is needed; handling and disposal of refrigerants.

3. Biomass

3.1 Introduction

Biomass is an alternative solid fuel to the conventional fossil fuels and has an impact on carbon emissions that is close to neutral. Various types of biomass fuel are in use, the most common being the woody biomass, which includes forest residues such as tree thinnings, and energy crops such as willow short rotation coppice. Biomass is converted into a manageable form that can be directly fed to the heat or power generation plant, thus replacing fossil fuel. As a result, applications can range from large-scale heating boilers to individual house room heaters to combined heat and power generation (CHP). For building applications, the fuel usually takes the form of wood chips, logs and pellets. Wood pellets are essentially compacted high-density wood with low moisture content, thus having a higher calorific value per unit volume or weight. Supply and storage of the biomass fuel should be carefully considered especially for larger plants.

The typical applications are:

a. Biomass boilers replacing standard gas- or oil-fired boilers for space heating and hot water (for individual buildings or district heating systems).

b. Standalone room heaters for space heating.

c. Stoves with back boilers, supplying domestic hot water.

d. Biomass CHP for heat and electricity generation – for additional information about this application, refer to the domestic CHP section of this document.

Appliances can achieve efficiencies of more that 80%. Sizes start at 3–5kW capacity for room heaters and go up to hundreds of kW or MW for industrial-scale plants and community energy schemes. Many of the applications are sized to meet a specific base load, with additional top-up and back-up provided by gas boilers.

Although biomass is a widespread technology in many European and North American countries, in the UK the market is not yet well developed. However, applications of small-scale boilers and individual room heaters are increasing. These devices can run on logs, wood chip or pellets, with the latter designed for either manual or automatic feed. An integrated hot water storage tank or an accumulator can enable the supply of heat to be decoupled from the actual combustion of the fuel.

The capital cost of automated biomass heating systems is significantly greater than that of conventional ones, mainly because of the more complicated feeding mechanisms and the currently smaller market for biomass appliances. A typical 10kW automated domestic biomass stove would cost between £1,500 and £2,000, and the fuel prices are around £60–65 per tonne of woodchip (25% moisture content) and £160–200 per tonne of delivered wood pellets.

Biomass CHP plants are suitable for larger scale projects and appear viable at capacities above 0.5MW. Sizing needs to reflect the proportion of heat demand planned to be met by the CHP.

Some of the standards specifically applicable to biomass boilers and heaters are listed below:

a. BS EN 12809:2001. Residential independent boilers fired by solid fuel. Nominal heat output up to 50kW. Requirements and test methods.

b. BS EN 12815:2001. Residential cookers fired by solid fuel. Requirements and test methods.

c. BS EN 13229:2001. Inset appliances including open fires fired by solid fuels. Requirements and test methods.

d. Pr EN 14785. Residential space heating appliances fired by wood pellets. Requirements and test methods.

e. PD 6434:1969. Recommendations for the design and testing of smoke reducing solid fuel burning domestic appliances.

f. BS EN 13240:2001. Room heaters fired by solid fuel. Requirements and test methods.

g. BS 4543:1990. Factory-made insulated chimneys.

h. BS EN 303-5:1999. Heating boilers. Heating boilers with forced draught burners. Heating boilers for solid fuels, hand and automatically fired, nominal heat output of up to 300kW. Terminology, requirements, testing and marking.

3.2 Performance calculation method

A way of calculating the potential of a biomass heating plant to contribute towards lowering the carbon dioxide emissions of a building is shown in the following table.

Rows marked * require values to be obtained for the particular biomass fuel and the comparison case (gas, oil, waste heat etc).

Symbol	Units	Description	Value
Proposed Biomass Plant			
Q_{htot}	kWh	Annual demand for heating and hot water provision	
B	%	Percentage of heating demand met by biomass plant, which may be 100% for dwellings or less for non-domestic or community heating applications	
Q_{bio}	kWh	Annual heating supplied by biomass plant	$Q_{htot} \times B$
E_{bio}*	%	Seasonal efficiency of boiler plant calculated in accordance with CIBSE Applications Manual 3: Condensing boilers	
Q_{bfuel}*	kWh	Calorific content of fuel input to the biomass heating plant	Q_{bio} / E_{bio}
Cf_{bfuel}*	$kgCO_2/kWh$	Carbon dioxide burden of the biomass fuel supply	
C_{bio}	kg	Resulting carbon dioxide emissions due to the operation of the biomass plant	$Q_{bfuel} \times Cf_{bfuel}$
Comparison Case			
E_{com}*	%	Seasonal efficiency of comparison heating plant as calculated in accordance with the Non-domestic Heating, Cooling and Ventilation Compliance Guide	
Q_{com}*	kWh	Fuel input to the comparison heating plant to provide equivalent output to the biomass heating plant	Q_{bio} / E_{com}
Cf_{com}*	$kgCO_2/kWh$	Carbon dioxide factor for fuel supply to the comparison heating plant	
C_{com}	kg	Resulting carbon dioxide emissions due to the operation of the comparison heating plant	$Q_{com} \times Cf_{com}$
C_s	kg	CO_2 saving from the proposed biomass heating plant	$C_{com} - C_{bio}$

3.3 Additional guidance

Design

The main benefit of biomass technology is the significantly reduced level of carbon emissions owing to the fuel carrying zero (or very close to zero) carbon burden. Over their lifecycle, biomass fuels sourced and processed from sustainable sources within 25 miles of the biomass plant can be regarded as carbon neutral and hence the fuel carries no carbon burden. Many biomass fuels transported for greater distances can also be regarded as carbon neutral because the alternative destination of the fuel is often land-fill where it would decompose to generate methane, which is significantly more potent as a greenhouse gas than CO_2.

Key planning and design issues regarding biomass boilers include:

Building space and organisation to accommodate and operate the plant

Biomass boilers for individual dwellings (15–50kW) are floor standing and no larger than a standard kitchen unit (600 × 600 × 900). Larger boilers for non-domestic or community energy applications will require plant room space similar to their gas or oil counterparts. Arrangements for flues will be more onerous than those for gas or oil boilers and access will be required for ash removal. Sufficient fuel storage is required to cover the time between two deliveries and, if relevant, for seasoning logs on site. The quantity of fuel in a single delivery will depend upon the size of the boiler and the cost and reliability of fuel supply. The fuel type also needs to be considered as logs and wood chip take up more space than pellets for the same heat output. Outside access to the plant room and storage is important for handling the delivered fuel, which should be appropriate to its means of transportation.

Biomass boilers have to run for some time before they achieve the desired output temperature and hence some form of heat storage is desirable to provide instant heating and hot water. Storage also allows the boiler to operate at a higher efficiency as lower temperatures over a longer burning time is a better and more sustainable regime. Additional space may be required for a hot water storage tank, which for a standard house could be up to 1,000 litres.

Sizing the biomass plant

As a replacement for domestic gas or oil boilers, biomass boilers will need to meet the total heating and hot water demand of the dwelling, and therefore their capacity should match that of the existing boiler. For new buildings, the heat output should be calculated as for an equivalent gas- or oil-fired boiler.

For non-domestic buildings, relying solely on biomass entails some risk because of the possible unreliability of the fuel supply and need for short periods of down time for maintenance. As biomass boilers are significantly more expensive than gas or oil boilers, it is both safer and cheaper to size the biomass boiler to meet a base load, and to provide additional top-up/back-up gas or oil boilers. The capacity of the biomass boiler can be estimated from historic energy demand in an existing building installation and will need to be calculated for a new building. For preliminary calculations, 50% of the annual heat demand can be used as a guide.

The choice of fuel will be influenced by the desired combustion efficiency of the boiler as well as by the fuel supply chain. It is important to identify a reliable long-term fuel source and have alternative suppliers. The price and quality of the fuel depends on the quantities ordered, and considerable benefits are associated with bulk purchases. For cost and embodied carbon reasons, deliveries from local sources (less than 25 miles away) are recommended.

Room heaters are smaller capacity, typically off-the-shelf products suitable mainly for residential buildings. They require a flue or chimney outlet and a constant supply of fresh air through a permanent opening. Most woody fuels are suitable for burning, and manufacturers' recommendations should be given in the system specification. Fuel storage will depend on the heater capacity and the proportion of the heating demand met. Room heaters need a drain to the chimney in order to release condensation.

Additional design issues that need to be addressed for biomass plants include:

a. Ventilation – biomass-combusting appliances in principle require significant combustion air and can create a visible plume or smoke discharge in some conditions.

b. Noise – again for ventilation reasons, larger fans are installed on biomass boilers, which may result in increased noise levels. The fuel supply mechanism will also cause noise intermittently whenever the boiler is on.

c. Safety – handling and feeding fuel into the burner should be undertaken with care. Automatic fuel feeding systems must be designed to avoid fire spreading back to the fuel store. The risk of incomplete combustion is addressed by a number of in-built mechanisms in most boilers, but it is worth asking the boiler supplier to confirm how a particular boiler addresses this risk.

Further information on system type and size selection and comparing different products is available from:

a. The official guide to approved solid fuel products and services 2003/2004. HETAS Ltd.

b. The British BioGen code of practice for biofuel pellet burning roomheaters <15kW. British Biogen, 2001.

c. Product criteria for automatically fed woodpellet stoves. Clear Skies, 2003.

d. Product criteria for wood fuel boilers. Clear Skies, 2003.

e. The National Energy Foundation (http://www.net.org.uk/greenenergy/index.htm).

Biomass installations are subject to the Building Regulations, Approved Document J: Combustion appliances and fuel storage systems.

Installation, commissioning and maintenance

Currently, there is a wide range of biomass systems on the market with specific characteristics and requirements. Installation should be carried out by a suitably qualified HETAS installer. Modern systems are increasingly automated and, once installed, require little interference by the user. Initial tuning of the various sensors, fans and other features should be performed by a trained installer, after which annual maintenance checks are recommended, including pressure and leakage tests.

Specific safety measures and procedures should be in place. For instance, should the electricity supply fail the pump will stop and in the absence of a natural thermosyphon the boiler could overheat. In this situation, the boiler controls should shut off the fuel supply and shut down the boiler. Locating the boiler on the ground to provide a thermosyphon and provision of a safety pressure valve are also recommended. New models now allow the system to be fully pumped and sealed from the atmosphere.

User guidance

Manual fuel feeding should be handled with care and back burning avoided by maintaining an adequate clearance between the fuel store and the burner.

New biomass boilers can have a high level of mechanical sophistication, with automatic fuel feed, self-adjustment of sensors and performance self-test. They are simpler to operate and only the main performance parameters can be directly controlled without the need for a qualified professional.

Setting the boiler temperature is among the key user responsibilities. Biomass boilers run more efficiently and last longer with high combustion and return temperatures. Similarly, the speed of the circulation pump and thermostatic bypass must be set correctly and this requires awareness of the demand levels.

For larger and more complex systems, access to a qualified engineer either on site or on rapid call-out will be required.

4. CHP (Micro-CHP)

4.1 Introduction

Some of the first designs of small combined heat and power (CHP) systems are now becoming available for individual houses, group residential units and small non-domestic premises. CHP at the large commercial size is now fairly common in premises which have a simultaneous demand for heating and electricity for long periods, such as hospitals, recreational centres and hotels. Compared with using centrally generated electricity supplied via the grid, CHP can offer a more efficient and economic method of supplying energy demand, if installed and operated appropriately, owing to the utilisation of heat which is normally rejected to the atmosphere from central generating stations, and by reducing network distribution losses due to local generation and use.

CHP for small buildings is now available as a result of the development of small gas- (or oil-) fired engines, linked to electric generators, with heat available for use in the building. Whilst some systems have several years of running experience and demonstrated savings, others, particularly at the smallest level, have as yet unproven performance.

Most systems replace (or run in parallel with) a domestic sized boiler and will be linked directly into the building electricity distribution system. Heat generated will be used for space and water heating, and additional heat storage may be used to lengthen use periods, to assist in warm-up and to improve overall energy efficiency. For overall good energy efficiency, as with all CHP, usage must be heat demand led. Thus, a sophisticated control system is required and users should be made aware of efficient operating practices.

There are currently two types of mechanical engines available:

a. Internal combustion engines.

b. Stirling engines.

Internal combustion engine systems normally supply an electrical output of upwards of 5kW, with a heat output of upwards of 10kW. They are normally suitable for groups of flats, grouped residential buildings such as nursing homes, and some small commercial premises, depending on the heat demand. The units will normally be located in a dedicated boiler house and will need to run for more than 10 hours a day to be economic.

Stirling engine systems use a ‘heat engine’ as the motive force for the generator, and these units are available with an electricity output of around 1kW upwards. With a power to heat ratio of between 6:1 and 3:1, these systems are most suitable for larger new houses, older houses with high heat demand and some small commercial premises. Stirling engine systems cannot be modulated rapidly and take several minutes to start up and close down. Thus, they cannot be used in quite the same way as traditional domestic boilers, which are normally sized for maximum start-up loads and cycle on/off to maintain required temperatures. Stirling engine systems are used differently and their control strategy is designed to deliver the same heating performance, whilst maximising the length of time for which the generator produces electricity and thus maximising the carbon emission savings. Peak heat demand can be supplied by an integral or separate heat-only source or by using a water-based heat storage system, thus allowing the CHP to run more or less continuously for long periods and providing for the steady-state heat demand.

Other CHP systems under development and commercialisation include fuel cells and ‘Organic Rankine Cycle’ engines. Fuel cells chemically convert hydrogen into electricity and heat. Hydrogen can be made from fossil fuels, normally natural gas, or may be available in the future from other renewable sources. Fuel cells are still at the development and testing stage, and it is not known how they will operate in the domestic and small commercial situation. The Organic Rankine Cycle is similar to the cycle of a conventional steam turbine, except for the fluid that drives the turbine, which is a high molecular mass organic fluid.

Micro-CHP systems offer the potential to reduce carbon emissions, but their operation and interaction with the buildings in which they operate is very complex. Understanding of the energy performance and carbon savings benefits is developing and, on the basis of best available information and operating data to date, these devices are unlikely to be appropriate for modern flats and houses with small heat loss. More experience and performance-in-use data are needed to identify the most appropriate locations and operating regimes.

The electricity output from small systems, at around 1kW, is still likely to be more than the background demand in an occupied house for much of the time, and thus the surplus should be exported to the grid via an import/export meter.

Calculations of overall system efficiencies are complicated as they must consider the heat output together with the effects of the displaced electricity from central generation via the grid. The calculation methodology is given below. Micro-CHP calculations are included in the revised SAP methodology.

A new Publicly Available Specification (PAS) for laboratory testing micro-CHP packages intended for use in dwellings is being prepared. The PAS describes a procedure to measure heating and electrical performance under a range of standardised operating conditions. When this is available, the results of testing will be fed into the calculation methods.

As micro-CHP systems operate within the context of the building, the equipment, installation and testing must all comply with the relevant standards. These include:

a. 90/396/EC. Gas Appliance Directive.

b. 98/37/EC. Machinery Directive.

c. 89/336/EC, 92/31/EC, 98/13/EC. EMC Directive.

d. 73/23EC, 93/68/EC. Low Voltage Directive.

e. BS 5546:2000. Specification for installation of hot water supplies for domestic purposes, using gas-fired appliances of rated input not exceeding 70kW.

f. BS 5440 1:2000. Installation and maintenance of flues and ventilation for gas appliances of rated input not exceeding 70kW net (1st, 2nd and 3rd family gases). Specification for installation and maintenance of flues.

g. BS 5440 2:2000. Installation and maintenance of flues and ventilation for gas appliances of rated input not exceeding 70kW net (1st, 2nd and 3rd family gases). Specification for installation and maintenance of ventilation for gas appliances.

h. BS 6891:1998. Specification for installation of low pressure gas pipework of up to 28mm (R1) in domestic premises (2nd family gas).

i. BS 5449:1990. Specification for forced circulation hot water central heating systems for domestic premises.

j. BS 7593:1992. Code of practice for treatment of water in domestic hot water central heating systems.

k. BS 6798:2000. Specification for installation of gas-fired boilers of rated input not exceeding 70kW net.

l. BS 7671:2001. Requirements for electrical installations. IEE Wiring Regulations. Sixteenth edition, plus Guidance Note 7 to the Wiring Regulations.

m. Gas Safety (Installation and Use) Regulations, 1998 (as amended).

n. Health and Safety Document 635 (Electricity at Work Regulations, 1989).

o. G83/1. Connection of small scale generators. Electricity Association, 2003.

p. Electrical Safety, Quality and Continuity Regulations, 2003.

4.2 Performance calculation method

For the purpose of calculating the potential of a micro-CHP system to contribute towards lowering the carbon dioxide emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
Q_{htot}	kWh	Annual heating demand for space heating and hot water	
M	%	Percentage of heating demand met by micro-CHP	
Q_h	kWh	Annual heating supplied by micro-CHP	$Q_{htot} \times M$
R_q	kW	Rated heat output of micro-CHP (maximum)	
h	hours	Full hours run (equivalent)	Q_h/R_q
R_e	kW	Rated net electricity output of micro-CHP (maximum)	
Q_e	kWh	Net electricity generated	$R_e \times h$
Cf_e	$kgCO_2/kWh$	Carbon dioxide factor for grid-displaced electricity	0.568
C_e	kg	Carbon dioxide saved owing to electricity from micro-CHP	$Q_e \times Cf_e$
R_f	kW	Rated fuel consumption of micro-CHP	
Q_{fchp}	kWh	Annual fuel consumption of micro-CHP	$R_f \times h$
Cf_{fchp}	$kgCO_2/kWh$	Carbon dioxide factor for fuel supply to micro-CHP	Gas = 0.194
C_{chp}	kg	Resulting carbon dioxide emissions due to fuel consumed by micro-CHP	$Q_{fchp} \times Cf_{fchp}$
E_{con}	%	Seasonal efficiency of conventional boiler	86% for grade A gas boiler
Q_{con}	kWh	Annual fuel consumption of conventional boiler	Q_h/E_{con}
Cf_{fcon}	$kgCO_2/kWh$	Carbon dioxide factor for fuel supply to conventional boiler	Gas = 0.194
C_{con}	kg	Resulting carbon dioxide emissions due to gas for conventional boiler	$Q_{con} \times Cf_{fcon}$

Performance calculations are made on an annual basis, with the assumption that the CHP system use is heat led. The performance of the micro-CHP is based on the hours run. This is calculated by dividing the annual heat demand of the building (space heating, water heating, process heating) which will be supplied by the CHP system by the rated maximum heat output of the CHP machine itself, excluding any heat-only element contained in the installation. This calculation must, therefore, take into account any other heating system that will help to supply peak heat demand in order to give the actual heat supplied by the CHP installation (accounted for above by the factor ‘M’).

The carbon dioxide emissions saving resulting from a micro-CHP system can be derived as follows:

$$C_s = C_{con} - C_{chp} + C_e$$

4.3 Additional guidance

No generic design, installation, commissioning, maintenance or user guidance is available at present. Refer to manufacturers’ literature.

5. Ground cooling

5.1 Introduction

Ground cooling uses the relatively constant ground temperature to provide summertime cooling through ground heat exchangers. These heat exchangers could either be air-to-ground or water-to-ground (aquifer):

a. Ground-coupled air cooling – the outside air is drawn through an underground system by a ventilation plant. Heat transfer from the ground results in cooler air in the summer. The technique is suitable for new mechanically ventilated buildings with appropriate ground conditions. The main benefits are reduced peak demand for cooling, which helps to reduce the size and cost of the HVAC system. Favourable factors include ground temperatures of less than 12°C and softer ground medium. Pipes are typically placed at 5m depth and sufficient land area should be available for the output requirements. The recommended distance between pipes is 1m.

b. Ground water cooling – this technique exploits the nearly constant temperature of underground water, access to which is through wells or purpose-built reservoirs. Low temperature water is pumped up to the surface to a heat exchanger through which ventilation air passes. Alternatively, the ground water can be passed through coils fitted in walls or ceilings, but condensation risks should be considered. Only certain sites have appropriate ground water conditions, and therefore this method has limited application.

The ground-coupled air cooling systems can either provide fully independent room air cooling or be supplementary to other mechanical ventilation. Capital costs are relatively high and application is most viable for commercial buildings. Various levels of cooling are possible:

a. Comfort cooling with relatively low-rated air flow. The ground-coupled system provides displacement ventilation. The supply temperature should always be below that of the room.

b. Room cooling aims to remove the internal heat gains via the ventilation system. Usually, larger air flow rates are required. It is generally unlikely that such a system alone will meet constant levels of high heat gains.

c. Auxiliary cooling is used to supplement an existing cooling system.

5.2 Performance calculation method

For the purpose of calculating the potential of ground cooling to contribute towards lowering the carbon dioxide emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
Q_{ctot}	kWh	Total space cooling demand	
A	%	Percentage of total cooling demand met by ground cooling system	
Q_c	kWh	Annual cooling demand to be met by the ground cooling system	$Q_{ctot} \times A$
K_s	kWh/m^2 of ground coupled area	Seasonal plant output per functional unit	
S	m^2	Ground-coupled area to meet entire required percentage of cooling demand	Q_c/K_s
K_c	kW/m^2	Capacity per functional unit installed	
P_{gc}	kW	Total capacity of ground cooling system to meet specified cooling demand	$S \times K_s$
T	h	Ground cooling system annual run time to meet specified cooling demand	Q_c/P_{gc}
K_p	kW	Air or water circulation pump rating	

Q_{gc}	kWh	Resulting power input requirement of the ground cooling system	$T \times K_p$
Cf_{gc}	$kgCO_2/kWh$	Carbon dioxide burden of the power supply to the ground cooling system	Electricity = 0.422
C_{gc}	kg	Resulting carbon dioxide emissions due to the operation of the ground cooling system	$Q_{gc} \times Cf_{gc}$
CoP_e	none	Seasonal CoP of the conventional electric cooling systems (which would have been employed instead of the ground source one)	
Q_e	kWh	Resulting electricity input requirement of the conventional cooling system	Q_c/CoP_e
Cf_e	$kgCO_2/kWh$	Carbon dioxide factor for electricity supply	0.422
C_{con}	kg	Resulting carbon dioxide emissions due to the operation of the conventional cooling systems	$Q_e \times C_e$

The carbon dioxide emissions saving resulting from a ground cooling system can be derived as follows:

$$C_s = C_{con} - C_{gc}$$

Ground cooling systems are suitable for non-residential building applications and are sized to meet all (100%) or part of the building's cooling demand. Economically viable installations provide at least 50% of the cooling demand. As a result, the level of carbon emissions reduction follows from the decision on the size of ground cooling system. Thus, it is not relevant to set a specific carbon target.

5.3 Additional guidance

More information on ground source heat pump technology can be found in the following publications:

a. Design tools for low energy cooling: technology selection and early design guidance. Denice Jaunzens (ed.). BRE ECBCS, 2001.

b. New ways of cooling – information for building designers. GIR085. EEBP programme, 2001.

Key areas covered:

a. Overview – benefits; ambient conditions; technology principles; system components.

b. Appropriate and inappropriate applications – types of plant; system choice criteria.

c. Sizing – peak demand; materials; system configuration.

d. Cooling effect – temperature transfer and storage.

e. Site selection; trenches and ducts.

f. Lifespan and operation.

g. Air circulation.

For further guidance, refer to manufacturers' specifications and installation instructions.

6. Ground Source Heat Pumps (GSHP)

6.1 Introduction

Ground source heat pump (GSHP) technology is already widely used in North America and several European countries, with over 500,000 units installed worldwide. Diverse applications include space heating, water heating, heat recovery, space cooling and dehumidification in both the residential and commercial building sectors.

The technology makes use of the energy stored in the Earth's crust, which comes comes mainly from solar radiation. Essentially, heat pumps take up heat at a certain temperature and release it at a higher temperature. This is achieved by means of ground collectors (coils), in which a heat exchange fluid circulates and transfers heat via a heat exchanger to the heat pump. The cycle is driven by the temperature difference between the ground and the circulating fluid.

A system that would supply 50% of the space and water heating demand of a typical house would need 80–100m of ground coils, and for commercial buildings this can reach thousands of metres. Different space configurations of piping are possible depending on the available land, soil conditions and excavation costs:

a. Horizontal collectors require a relatively large area of land free from hard rock. They are most appropriate for small installations, and particularly for new build. The pipes are buried in trenches 1–2m deep. Spatial optimisation is possible by laying pipes in group loop configurations, but minimum distances should be maintained in order to allow for good thermal exchange.

b. Vertical collectors are used where land is limited and are suitable for most soil and rock types. Vertical borehole heat exchangers could also be of various configurations (single, double, U-shaped, etc.) with typical diameters of 0.1–0.2m and between 15m and 180m deep. Minimum spacing between adjacent boreholes of 5–15m should be maintained to prevent thermal interference.

c. Parallel and series connection can be used where there is more than one horizontal loop or borehole.

Almost all heat pumps in operation are based on the vapour compression cycle, which combines efficiency, safety and reasonable cost. However, high-capacity compressors are required, which reduces the overall benefit of the system. The effectiveness of heat pumps is measured by the ratio of the heating capacity to the power input, referred to as the Coefficient of Performance (CoP), and only calculated ratios of more than 1.0 should be considered.

The heat exchanger is a very important component, and small temperature differences can have a critical effect on the efficiency of the systems. Larger exchangers provide greater heat transfer but entail higher cost, and therefore sizing should be based on economic optimisation. Heat pumps are also reversible and alongside heating can provide space cooling in the warm season. Water-to-refrigerant exchangers are most common, where the type of refrigerant influences the design and efficiency of the system.

Technology-specific standards that heat pump systems must comply with include:

a. BS EN 255-4:1997. Air conditioners, liquid chilling packages and heat pumps with electrically driven compressors. Heating mode. Requirements for space heating and sanitary hot water units.

b. BS EN 378:2000. Specification for refrigerating systems and heat pumps. Safety and environmental requirements.

c. BS EN 60335-2-40:2000, IEC 60335-2-40:2000. Specification for safety of household and similar electrical appliances. Particular requirements for electrical heat pumps, air conditioners and dehumidifiers.

d. ISO Standard 13256:1998. Water-source heat pumps: Testing and rating for performance – Parts 1&2.

6.2 Performance calculation method

For the purpose of calculating the potential of ground source cooling to contribute towards lowering the carbon dioxide emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
Q_{htot}	kWh	Annual heating demand for heating and hot water provision	
G	%	Percentage of heating demand met by ground source heat pump which may be 100% for electrically heated dwellings or less for non-domestic or community heating applications	
Q_{gshp}	kWh	Annual heating supplied by heat pump	$Q_{htot} \times G$
CoP_{gshp}	None	CoP of the ground source heat pump	
Q_h	kWh	Resulting electrical energy consumption of the heat pump	Q_{gshp}/CoP_{gshp}
Q_p	kWh	Electrical energy consumption of circulating pump for ground source loop	130kWh per year for typical single family house
Cf_h	$kgCO_2/kWh$	Carbon dioxide burden of the power supply to the heat pump	Grid-supplied electricity = 0.422
C_{gshp}	kg	Resulting carbon dioxide emissions due to the operation of the heat pump	$(Q_p + Q_h) \times C_h$
E_{con}	%	Seasonal efficiency of conventional heating plant (boiler)	Electric =100%, A rated gas = 86%
Q_{con}	kWh	Fuel input to the conventional heating plant to provide equivalent output to the ground source heat pump	Q_{gshp}/E_{con}
Cf_{con}	$kgCO_2/kWh$	Carbon dioxide factor for fuel supply to the conventional heating plant	Grid-supplied electricity = 0.422 Natural gas = 0.194
C_{con}	kg	Resulting carbon dioxide emissions due to the operation of the conventional heating plant	$Q_{con} \times Cf_{con}$

The carbon dioxide emissions saving resulting from ground source heat pumps can be derived as follows:

$$C_s = C_{con} - C_{gshp}$$

The heat pump compressor is typically driven by electric power and therefore the carbon burden of its operation is that of the electrical input, $Cf_h = 0.422kgCO_2/kWh$. Fossil fuel compressors are available and have a higher efficiency in primary energy terms. In this case, the carbon factor for the fossil fuel used should be employed. For gas, $Cf_h = 0.194kgCO_2/kWh$.

Ground source heat pumps for residential applications are feasible if they replace electric heating and hot water, and in this case meeting 100% of the demand is recommended. For non-residential buildings, the GSHP system can be sized to meet either the full heating and hot water demand (100%) or part of it. Economically viable installations provide at least 50% of the heating and hot water demand for the building.

6.3 Additional guidance

More information on ground source heat pumps technology can be found in the following publications:

a. Ground source heat pumps – a technology review. BSRIA Technical Note TN 18/99, 1999.

b. Closed loop ground-coupled heat pumps. IEA Heat Pump Centre Informative Fact Sheet 2, 2002.

c. Heat pumps for buildings: Key points. Roger Hitchin, BRE, November 2003.

d. Product criteria for ground source heat pumps. Clear Skies, 2003.

Key areas covered:

a. Overview – benefits; ambient conditions; technology principles; system components.

b. Appropriate and inappropriate applications – types of plant; chemicals; cycles; system choice criteria.

c. Sizing – peak demand; materials; system configuration.

d. Heat output – temperature transfer and storage.

e. Site selection; trenches and boreholes.

f. Lifespan and operation.

g. Heat transfer and storage.

7. Photovoltaics (PVs)

7.1 Introduction

Photovoltaic modules convert sunlight directly into DC electricity and can be integrated into buildings. Photovoltaics (PVs) are distinct from other renewable energy technologies since they have no moving parts to be maintained and are silent. PV systems can be incorporated into buildings in various ways: on sloped roofs and flat roofs, in façades, atria and shading devices. Modules can be mounted using frames or they can be fully incorporated into the actual building fabric; for example, PV roof tiles are now available which can be fitted in place of standard tiles.

Currently, a PV system will cost between £4.5k and £10k per kWp, and frequently part of this cost can be offset owing to the displacement of a conventional cladding material. Costs have fallen significantly since the first systems were installed (1980s) and are predicted to fall further still.

Deployment in the UK has started with several building-integrated field trial schemes and a major demonstration programme.

While single crystal silicon remains the most efficient flat plate technology (15–16% conversion efficiency), it also has the least potential for cost reduction. PV cells made from multicrystalline silicon have become popular as they are less expensive to produce, although they have a slightly lower efficiency.

Thin film modules are constructed by depositing extremely thin layers of photosensitive materials on a low-cost backing such as glass, stainless steel or plastic. As much less semiconductor material is required than for crystalline silicon cells, material costs are potentially much lower. Efficiencies are much lower, around 4–5%, although this can be boosted to 8–10% by depositing two or three layers of thin film material. Thin film production also requires less handling as the films are produced as large, complete modules and not as individual cells that have to be mounted in frames and wired together. Hence, there is the potential for significant cost reductions with volume production.

In future, materials such as dye-sensitised polymers may offer very-low-cost PV materials, but the efficiency of these materials needs to be improved from their present low levels (1–2%).

Since PVs generate DC output, an inverter and other equipment is needed to deliver the power to a building or the grid in an acceptable AC form. The cost of the inverter and these 'Balance Of System' (BOS) components can approach 50% of the total cost of a PV system. Hence, simplification and cost reductions in these components over the coming years will also be necessary to make PV systems affordable.

PV systems must all comply with the following standards:

a. BS 7671:2001. Requirements for Electrical Installations, IEE Wiring Regulations, 16th edition, 2001.

b. BS IEC 61215:1995. Crystalline silicon terrestrial photovoltaic (PV) modules. Design qualification and type approval.

c. BS IEC 61646:1997. Thin-film terrestrial photovoltaic (PV) modules. Design qualification and type approval.

d. Engineering Recommendation G83/1. Connection of small scale generators. Electricity Association, 2003.

e. Engineering Recommendation G59/1. Electricity Association, 2000.

7.2 Performance calculation method

For the purpose of calculating the potential of solar PV systems to contribute towards lowering the carbon emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
C_{tot}	kg	Total carbon dioxide emissions regulated by Part L	
$C_s\%$	%	Percentage carbon dioxide emissions saving target	As set out in the brief
C_s	kg	Carbon dioxide emissions saving target	$C_{tot} \times C_s\%$
I_{max}	kWh/m²/year	Maximum annual irradiation at the specific location	
K_E	%	Module conversion efficiency	
K_P	%	Positioning factor based on system's tilt and orientation	
K_I	%	Inverter efficiency	
K_L	%	System losses	
K_D		Packing density	
U	kWh/m²	Output per functional unit installed	$I_{max} \times K_E \times K_P \times K_I \times K_L \times K_D$
R	kWpeak/m²	Module rated output	0.11
Cf_{de}	$kgCO_2$/kWh	Carbon dioxide factor for grid-displaced electricity	0.568
Q_e	kWh	Annual electricity output to meet carbon dioxide target	C_s/Cf_e
A	m²	Area of the PV system required (constrained to available area)	Q_e/U
P	kWpeak	PV system rated output	$R \times A$

Solar PV systems are not directly related to any specific building fabric element or service. They therefore allow for reasonable flexibility in their sizing, subject to certain constraints, the most important being available surface area (roof or façade). Thus, the carbon dioxide emissions saving target can be determined first and the PV system developed to meet it. A range of carbon dioxide reduction levels (e.g. 10%, 20%, etc.) can be applied in the calculation in order to arrive at a satisfactory result for area size, generating capacity or total output of the PV system. This is practicable as most systems are grid connected and their entire output is either utilised on site or exported to the grid.

7.3 Additional guidance

More information on solar photovoltaic technology can be found in the following publications:

a. Photovoltaics in buildings: safety and the CDM Regulations. DTI, February 2000.

b. Photovoltaics in buildings: a design guide DTI. Max Fordham and Partners/Fielden Clegg Architects, March 1999.

c. Photovoltaics in buildings: guide to the installation of PV systems. DTI, 2002.

d. Solar electricity: a layman's guide to the generation of electricity by the direct conversion of solar energy. FC Treble, 1999.

e. Photovoltaics in buildings: testing, commissioning and monitoring guide. DTI, 1998.

f. Pathways to PV: generating solar homes project. The Housing Corporation, NEP, PVUK, 2003.

g. Planning Policy Guidance Note 22: Renewable energy – annex on photovoltaics.

h. Planning Policy Guidance Note 15: Planning and the historic environment.

i. Engineering Recommendation G83/1. Connection of small scale generators. Electricity Association, 2003.

j. Engineering Recommendation G59/1. Electricity Association, 2000.

8. Solar hot water

8.1 Introduction

Solar thermal and, especially, active Solar Domestic Hot Water (SDHW) heating is a well-established renewable energy system in many countries outside the UK. It can be one of the most cost-effective renewable energy systems available.

It is appropriate for both residential and non-residential applications. For a single typical house, for instance, a suitable water heating system would occupy 2.5–4m^2 of roof space. The cost would be £1,500–£5,000 for a flat plate system that will provide around 50% of the typical hot water demand, and up to £5,000 for an evacuated tube system that will provide around 60%.

Solar hot water can be applied cost-effectively in a number of non-domestic building types, such as hospitals, nursing homes and leisure facilities, which have high demands for domestic hot water. SDHW systems are not so cost-effective in commercial buildings, where the demand for hot water is lower.

Technical and market research has been undertaken in the UK, the main conclusions being that most systems are technically proven and will provide a significant contribution to hot water demand if correctly installed. Installer training and accreditation schemes supported by the DTI have helped allay fears of poor quality installations, and this is on-going.

Solar thermal systems in the UK normally operate with a back-up source of heat, such as gas or electricity. The solar system pre-heats the incoming cold water, which is topped up by the back-up heat source when there is insufficient solar energy to reach the chosen target temperature.

Solar collectors are best mounted at an incline with a southerly orientation, although orientations between south-east and south-west are acceptable. With increased collector area, orientations between east and west are also acceptable. Collectors can also be mounted on south-facing vertical walls or horizontally, so that a large proportion of the building stock is suitable for solar thermal systems.

There are four main types of solar collector that can be used in SDHW systems. These are:

a. Evacuated tubes.
b. Glazed selective surfaced flat plate.
c. Glazed non-selective surfaced flat plate.
d. Unglazed plastic collectors (mostly used for swimming pool heating).

There are several design features of systems that can affect performance, including drainback or antifreeze systems, twin coil or preheat cylinder, and control systems.

The following standards are available for SDHW systems and components:

a. BS 6785:1986. Code of practice for solar heating systems for swimming pools.

b. BS 6757:1986. Methods of test for thermal performance of solar collectors.

c. EN 12975-1:2005. Thermal solar systems and components – Solar collectors – Part 1: General requirements.

d. EN 12975-2:2001. Thermal solar systems and components – Solar collectors – Part 2: Test methods.

e. EN 12976-1:2000. Thermal solar systems and components – Factory made systems – Part 1: General requirements.

f. EN 12976-2:2000. Thermal solar systems and components – Factory made systems – Part 2: Test methods.

g. ENV 12977-1:2001. Thermal solar systems and components – Custom built systems – Part 1: General requirements.

h. ENV 12977-2:2001. Thermal solar systems and components – Custom built systems – Part 2: Test methods.

i. ENV 12977-3:2001. Thermal solar systems and components – Custom built systems – Part 3: Performance characterisation of stores for solar heating systems.

8.2 Performance calculation method

For the purpose of calculating the potential of solar hot water systems to contribute towards lowering the carbon emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
Q_{hwtot}	kWh	Annual hot water demand	
I_{av}	kWh/m^2 per year	Average annual irradiation at the specific location	
K_E	%	SDHW system conversion efficiency	See EN 12975 for collector
K_P	%	Positioning factor based on system's tilt and orientation	
K_u	%	Utilisation factor	
U	kWh/m^2	Output per functional unit installed	$I_{max} \times K_E \times K_P \times K_u$
M	%	Percentage of hot water demand met by SDHW system	Maximum 50% (less if collector area constrained)
Q_{hw}	kWh	Annual hot water supplied by SDHW system	$Q_{hwtot} \times M$
A	m^2	Net area of the SDHW collector to meet desired target M%	Q_{hw}/U
Q_{pump}	kWh	Energy input for circulating water in the SDHW system (circulating pump)	
$Q_{control}$	kWh	Energy loss without thermostatic control	75kWh per year from DTI side-by-side testing
Cf_e	$kgCO_2/kWh$	Carbon dioxide factor for used electricity	Grid-supplied electricity = 0.422 PV electricity = 0.0
C_{shw}	kg	Resulting carbon dioxide emissions due to the operation of the SDHW system	$(Q_{pump} - Q_{control}) \times Cf_e$
Cf_{con}	$kgCO_2/kWh$	Carbon dioxide factor for fuel supply to a conventional boiler	Natural gas = 0.194 Grid-supplied electricity = 0.422
C_{be}	%	Conventional boiler efficiency during intermittent operation	
C_{con}	kg	Resulting carbon dioxide emissions due to the operation of a conventional boiler for an equivalent output of the SDHW system	$Q_{hw} \times Cf_{con}/C_{be}$

The carbon dioxide emissions saving resulting from a solar hot water system can be derived as follows:

$$C_s = C_{con} - C_{shw}$$

Increasingly, the circulation pump carbon dioxide burden is being reduced to zero as PV panels are installed in parallel with an SDHW system to power, or offset, their electricity demand. However, these benefits can be fully realised only in combination with differential thermostatic control from the collector to the storage.

Solar hot water systems are most economically designed to meet only a proportion of the hot water demand for the building. As solar irradiation is greatest in the summer when demand is lowest, it is not possible to meet the entire annual demand by increasing the size of the system. For both residential and non-residential buildings, a maximum of 50% of the DHW may be recommended.

8.3 Additional guidance

Design guidance

For solar DHW system design guidance, refer to the following publications:

a. Planning and installing solar thermal systems – a guide for installers, architects and engineers. German Solar Energy Society, 2005.

b. Solar thermal heating – design guide. CIBSE Domestic Heating Group, 2006.

Installation, commissioning and maintenance issues

For guidance on installation and commissioning of SDHW systems, refer to the following publications:

a. Solar thermal systems – successful planning and construction. Dr. Felix A. Peuser, Karl-Heinz Remmers and Martin Schnauss, 2002.

b. Solar water heating – a guide for installers. BRE/EST Energy Efficiency Best Practice, 2005.

User guidance

General user guidance on SDHW systems is available in the following publications:

a. Heating water by the sun: a layman's guide to the use of flat plate solar collectors for domestic water heating and for heating swimming pools. Solar Energy Society, 2001.

b. Tapping the sun – a guide to solar water heating. Chris Laughton, 2004.

9. Wind energy technology

9.1 Introduction

Wind power is the most successful and fastest spreading renewable energy technology in the UK with a number of individual and group installations of varying size, capacity and location. Traditionally, turbines are installed in non-urban areas with a strong trend for large offshore wind farms. In parallel with the design and development of ever-bigger machines, which are deemed to be more efficient and cost-effective, it is being increasingly recognised that smaller devices installed at the point of use, i.e. urban settings, can play an important role in reducing carbon emissions if they become mainstream.

At present there is a wide range of available off-the-shelf wind products, many manufactured in the UK and EU with proven good performance and durability. The dominant type is horizontal axis wind turbines (HAWT), which are typically ground mounted. Vertical axis wind turbines (VAWT) have limited market presence and there is a trade-off between lower efficiency and potentially higher resistance to extreme conditions. Capacity ranges from 500W to more than 1.5MW, but, for practical purposes and in built-up areas in particular, machines of more than 1kW and below 500kW are likely to be considered.

Wind technology is also currently one of the most cost-effective renewable energy technologies, which is attributable to the large scale of installations reducing the unit output cost. Individual building or community wind projects, although smaller, have the advantage of feeding electricity directly into the building's electricity circuit, thus sparing costly distribution network development and avoiding distribution losses. The downside is the still high capital cost per kW installed for smaller turbines, plus location constraints, such as visual intrusion and noise. The wind regime in urban areas is also a concern owing to higher wind turbulence which reduces the potential electricity output.

In most cases, wind turbines are connected to the electricity grid and all generated energy is used regardless of the building demand fluctuations. The output largely depends on the wind speed and the correlation between the two is a cube function. This means that in short periods of above-average wind speeds the generation increases exponentially. As a result, it is difficult to make precise calculations of the annual output of a turbine, but average figures can provide useful guidance to designers and architects. In reasonably windy areas (average wind speed of 6m/s) the expected output from 1kW installed is about 2500kWh annually.

The cost per kW installed varies considerably by manufacturer and size of machine with an indicative bracket of £2,500–£5,000. With a lifespan of more than 20 years, wind turbines can save money if design and planning are carried out in a robust way.

Building-integrated wind turbines are starting to be a reality in the UK, but potential projects may face difficulties with obtaining planning permission. There are a few examples now of permitted development rights for certain rooftop turbines in some local councils. A number of horizontal axis devices specifically designed for building integration are now available commercially, having design and reliability parameters relevant to the urban context. Building-mounted vertical axis devices are under development.

At present, turbines installed near buildings, as well as community installations for groups of buildings, should be regarded as the larger wind energy source related to buildings, when they contribute to the carbon emissions from these premises using 'private wire' networks. However, the contribution of several building-integrated turbines in a development is likely to become significant in the next few years.

Some of the standards specifically applicable to wind technology are listed below. Other standard building regulation and planning requirements also apply, particularly with regard to visual impact, noise, and health and safety:

a. BS EN 61400-2:1996, IEC 61400-2:1996. Wind turbine generator systems.

b. BS EN 61400-21:2002. Wind turbine generator systems. Measurement and assessment of power quality characteristics of grid connected wind turbines.

c. Engineering Recommendation G83. Connection of small scale generators. Electricity Association, 2003.

9.2 Performance calculation method

For the purpose of calculating the potential of wind energy systems to contribute towards lowering the carbon emissions of a building in order for it to meet the compliance requirements of Part L of the Building Regulations, the factors to be considered are:

Symbol	Units	Description	Value
C_{tot}	kg	Total carbon dioxide emissions regulated by Part L	
C_s %	%	Percentage carbon dioxide emissions saving target	As set out in the brief
C_s	kg	Carbon dioxide emissions saving target	$C_{tot} \times C_s$ %
R	kWh/kW	Rated turbine unitary output for typical wind speed	
K_I	%	Inverter efficiency	
U	kWh/kW	Unitary output	$R \times K_I$
Cf_e	$kgCO_2/kWh$	Carbon factor for grid-displaced electricity	0.568
Q_e	kWh	Annual electricity output to meet carbon dioxide target	C_s/Cf_e
C_T	kW	Capacity of turbine to meet carbon dioxide target	Q_e/U

Wind turbines are not directly related to any specific building fabric element or service. They therefore allow for reasonable flexibility in their sizing subject to certain constraints, the most important being location (visual impact). Thus, the carbon dioxide emissions saving target can be determined first and the turbine capacity worked out around it. A range of carbon reduction levels (e.g. 10%, 20%, etc.) can be applied in the calculation in order to arrive at a satisfactory result for generation capacity or total output. This is practicable as most systems are becoming grid connected and either their entire output is utilised on site or the surplus exported to the grid.

It is important to point out that the performance of a wind turbine depends largely on the available wind resource in terms of wind speed and occurrence. Variations in the output and the corresponding carbon savings are considerable owing to the exponential character of electricity generation with the increase/decrease of wind speed. The calculation method presented uses assumed average parameters for wind speed and corresponding output per unit of generation capacity. In reality, the wind regime at any particular location may differ significantly from the national average. Site monitoring to determine local wind conditions can avoid potentially significant design calculation errors.

9.3 Additional guidance

Design and selection issues

An overview of different types, sizes and applications of wind turbines can be found in the following publications:

a. Wind energy technologies for use in the built environment. Blanch, M. Wind Engineering, vol.26, No3, pp 125–143, 2000.

b. Product criteria for wind turbines. Clear Skies, 2003.

Further information on the technology, existing installations, products and suppliers can be found at:

a. British Wind Energy Association (BWEA), www.bwea.com. The BWEA has a section dedicated to small scale wind turbines, www.bwea.com/small.

b. National Energy Foundation (NEF), www.nef.org.uk, www.greenenergy.org.uk.

Installation, commissioning and maintenance

Installing a wind turbine requires planning permission. The main considerations that are taken into account by the planning authorities are the visual impact and health and safety issues, such as noise and vibration. Wind turbines are not likely to be permitted on protected area sites, such as SSSI, and in urban conservation areas. Noise and vibration are related to the operation of the turbines, and their proximity to buildings requires an assessment of the impact on residents' comfort.

Wind turbines are highly engineered products which require specialist installation, commissioning and maintenance. It is the supplier who carries out these tasks in order to ensure proper functioning and connection of the machines and to issue a warranty. This applies to all sizes of turbines.

Specific installation guidance is typically available from manufacturers for each product. For turbines of up to 15–20kW capacity, standard delivery, assembly and erection procedures are listed and apply. For ground-mounted turbines in this range, foundation parameters, minimum installation working area and minimum distances to buildings and structures are specified.

Larger turbines require specific installation procedures. Access to the site is important for delivering larger components by special vehicles. Assembly sequence and necessary equipment should be worked out in advance and supplied by the installer.

Installing a wind turbine also involves connection to the electricity grid. Permission from the local electricity supplier is necessary as well as an up-front agreement for power purchase.

Full installation can take as little as a single day for smaller devices. Larger capacity installations may require considerably more time (weeks).

Maintenance of horizontal axis wind turbines is usually on an annual basis and requires lowering of the generator to the ground. This is performed by a qualified professional. Health and safety requirements must be observed. For larger machines, maintenance is typically carried out on the tower itself by an expert. Vertical axis turbines entail less maintenance effort as the generator is located at the foot of the turbine tower. Specialist service, however, is required.

User guidance

Once installed and connected to the grid there is very little the user needs to worry about regarding a wind turbine. The manufacturers' user manuals should describe actions in extreme conditions, such as severe weather or accidental structural damage to the machine.

Most turbines operate continuously throughout the year, and generation and supply of electricity is fully automatic. Users have access to the metering devices showing output and export levels, for which guidance is available from the turbine installers. Apart from this, users are not required to deal with any other equipment setting and tuning.

Health and safety recommendations should be followed, particularly when performing maintenance and if accidental breakdowns occur.

Published by NBS, part of RIBA Enterprises Ltd, and available from:

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London EC2P 2EA

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ISBN-10 1 85946 224 3
ISBN-13 978 1 85946 224 9

Stock code 57644

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ISBN 1-859462-24-3
9 781859 462249