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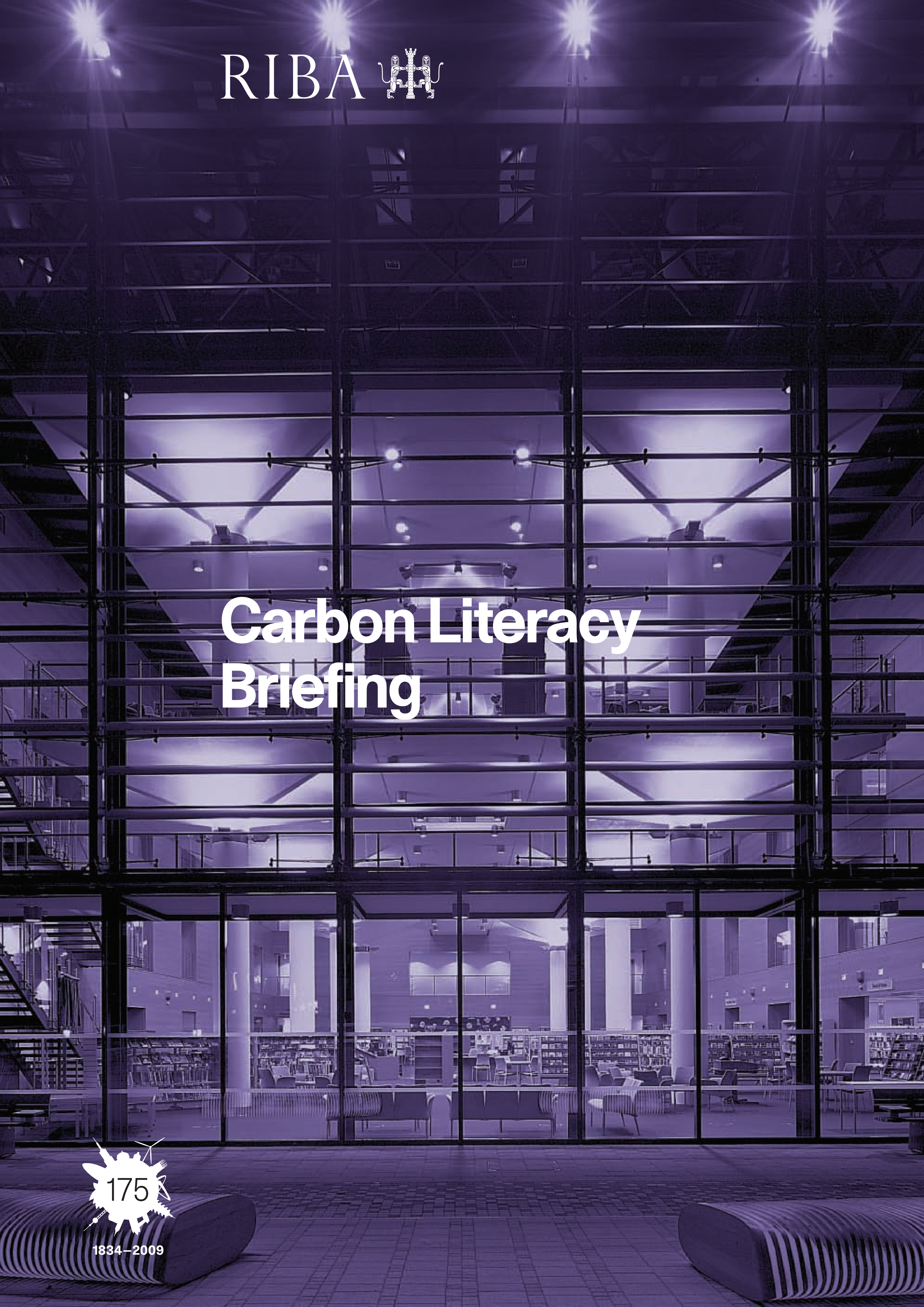

Carbon Literacy Briefing

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1834–2009

Cover image Jubilee Library, Brighton. The library is designed by Bennetts Associates to take advantage of the natural energy provided by the south coast setting – specifically sunshine and wind. The sun's energy is gathered through the south facing front glazed wall in winter, with built-in solar shading and automatically opening vents to reduce solar gain and glare in summer. Heat generated by people and equipment in the building is also harnessed and re-used. Energy use has been minimised, and instead of air conditioning, natural ventilation refreshes the atmosphere inside and cools the building. Wind towers on the roof use the breeze to draw excess heat from the floors below.

Photo Peter Cook/VIEW/ Bennetts Associates

About this Document

This is one of six components of Climate Change Tools, a package of guidance developed by the RIBA to encourage architects to engage with the issue of climate change and to deliver low-carbon new buildings and low-carbon refurbishment of existing buildings.

This *Carbon Literacy Briefing* explores the carbon dioxide emissions associated with energy use in buildings; the other elements of this package of guidance are:

- A *Climate Change Briefing*, setting the scene about climate change, its causes and its impacts
- *Principles of Low Carbon Design and Refurbishment*
- *Low Carbon Standards and Assessment Methods*
- *Low Carbon Design Tools*
- *Skills for Low Carbon Buildings*

Each guide summarises its subject and provides links to other sources of more detailed information.

You can explore all of the RIBA Climate Change Tools at www.architecture.com/climatechange

In 2003, carbon dioxide emissions associated with energy use in the UK were approximately 560 million tonnes. Almost half of this came from energy use in buildings.

Energy use in housing accounts for slightly more than half of the emissions associated with energy use in all buildings, amounting to 27% of the UK total.

This document focuses on carbon literacy related to buildings, but you need to take into consideration the carbon impacts of transport and construction and other processes and products, as well as wider environmental impacts such as water efficiency, waste minimisation and sustainable drainage systems.

Introduction

In the 1960s, the famous American engineer Richard Buckminster Fuller used to ask his audiences of engineers the question: 'How much does your building weigh?' His interest was in efficient designs that used less material but, of course, nobody could ever answer his question.

In the 1980s, in the wake of the 1981 OPEC oil embargo, another famous American engineer, Fred Dubin, asked his audience of architects and engineers: 'How will your building perform if it has to run on half as much energy as you expect it to need?' Again, few could provide an answer.

The twenty-first century equivalent of Buckminster Fuller's question is: 'How much carbon dioxide does your building emit?'

When British architects are asked this question, they rarely know the answer, so they seem unlikely to know the answer to the contemporary equivalent of Dubin's question either. Even when architects do know how much carbon dioxide their buildings are expected to make, they rarely seem to know whether the answer is good or bad – perhaps because they are unaware of benchmarks against which to assess their buildings. Or to put it another way: if you don't measure it you can't manage it.

This guide is an attempt to address this problem, by explaining the relationship between buildings and carbon dioxide emissions, and by summarising some of the existing benchmarks for building energy use and associated emissions.

Carbon Dioxide Emissions in Context

Information about carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions associated with energy use in buildings needs to be set in the broader context of climate change and why reducing emissions is important.

Climate change brought about by man-made emissions of greenhouse gases has been identified as the greatest challenge facing human society at the beginning of the twenty-first century.

Action to address climate change falls into two categories: mitigation policies are designed to reduce greenhouse gas emissions to slow down or stop climate change; adaptation policies are designed to adjust society to cope with climate changes that are already happening or are likely consequences of current GHG emissions.

The *Climate Change Briefing* that forms part of the RIBA Climate Change Tools explains the mechanisms of climate change, summarises UK emissions and explains the challenge that climate change presents to our society.

Overall, each person in the UK is responsible for around 10 tonnes of greenhouse gas emissions per year.

One approach to reducing emissions is known as 'contraction and convergence'[1]. This involves emissions from industrialised nations reducing (contracting) and emissions from all nations converging to an overall target consistent with stabilising greenhouse gas concentrations in the atmosphere. Over time, emissions would contract and converge to an equal share per person. To achieve this equitable distribution, each of us in the UK would need to reduce our average annual carbon dioxide emissions from 10 tonnes to two tonnes.

To provide some context a little closer to home, it is interesting to consider some of the carbon dioxide emissions associated with a typical UK family of four:

- Energy use in the home (for heating, hot water, cooking, lighting and the use of appliances) results in carbon dioxide emissions of approximately six tonnes of per year[2]
- Fuel used in an average family car, driven an average number of miles, will produce approximately four tonnes of carbon dioxide per year (and a second car will account for between two and four more tonnes)
- Travel by air to a family holiday at a Mediterranean resort will give rise to approximately four tonnes of carbon dioxide emissions
- Food on the family table (including cultivation, harvesting, processing, packaging, storage and distribution) will account for approximately seven tonnes of carbon dioxide per year.

1 Contraction and Convergence is the science-based, global climate-policy framework, proposed to the United Nations since 1990 by the Global Commons Institute. See www.gci.org.uk It is supported by many climate change scientists and policy makers, including the Royal Commission on Environmental Pollution. See www.rcep.org.uk/energy.htm

The UK Government's Energy White Papers in 2003 and 2007 established an 'aspirational' target for reducing carbon dioxide emissions:

'to put ourselves on the path to cut the UK's carbon dioxide emissions by some 60% by about 2050, with real progress by 2020.'

This has become known as the 'carbon 60' (or C60) target.

Some climate change scientists now suggest that deeper cuts in GHG emissions will be required before 2050.

Energy Basics

Energy is measured in joules (J). This is a very small unit: 4,200 J are needed to raise the temperature of 1 kilogramme of water by 1 degree Celsius.

Temperature is a measure of the energy content of a body or substance. It is measured in degrees Celsius (°C) or degrees Kelvin (K), which are essentially the same. Heat always flows from a hotter body or substance to a cooler one.

Power is the rate of transfer of energy, or the rate of heat flow, and is measured in Watts (W). 1 Watt is 1 joule per second. 1 kilowatt (kW) is 1,000 Watts. Here are typical power ratings for some energy using and energy producing devices:

Compact fluorescent lamp	20 W
Electric room heater	1 to 3 kW
Car engine	100 kW
Community-scale wind turbine	1 MW
Coal-fired power station	1 to 5 GW

The main units are multiples of Watts:

1 kW = 1,000 W (103)
1 MW = 1,000,000 W (106)
1 GW = 1,000,000,000 W (109)

Heat Loss

A typical house has a heat loss of 10 kW; an energy efficient house might have a heat loss of 3 kW.

If heat losses are measured when there is a 20°C difference in temperature between inside and outside, then the specific heat loss of the energy efficient house is given by:

3000 W/20°C = 150 W/°C

The **kilowatt-hour** (kWh) is a way of expressing the amount of energy the house requires; this is the unit used on fuel bills (and 1 kWh is equal to 3.6 MJ).

Useful Energy

This is the amount of energy that is needed to keep a building warm. The useful energy needed to keep the energy efficient house warm (at 20°C) will be:

3 kW x 24 hr = 72 kWh per day

Delivered Energy

Building systems are rarely 100% efficient. So the amount of energy that needs to be delivered to the building will generally need to be greater than the useful energy required.

If the house is electrically heated, by a 100% efficient heater, then the delivered energy required is:

3 kW x 24 hr = 72 kWh per day of electricity

However, if the house has an 80% efficient gas boiler, then the delivered energy required is:

(3 kW x 24 hr)/0.8 = 90 kWh per day of gas

The lower the efficiency of the heating system, the more delivered energy is required to supply the useful energy requirement.

Energy Efficiency and Carbon Dioxide Emissions Factors

For the purpose of comparing buildings, **energy efficiency** is usually expressed as the annual delivered energy requirement per unit of floorspace, measured in kWh/m^2/yr. It is often helpful to divide this into two components – electricity, and energy from fossil fuels.

Fossil fuels such as gas are hydrocarbons, which require oxygen when they burn, e.g.

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

methane + oxygen -> carbon dioxide + water vapour

From the chemical equation above, it is possible to calculate the amount of carbon dioxide produced for each unit of fuel that is burnt. This is the **carbon dioxide emission factor**, which is usually expressed in kilogrammes of carbon dioxide per kilowatt-hour of fuel that is burnt ($kgCO_2$/kWh).

The carbon dioxide emission factor for mains electricity takes into account all the emissions associated with generating electricity from various fuels including coal, oil, nuclear energy and renewables.

Emission Rates

Another comparative measure of the energy or environmental performance of buildings is the **Building Emission Rate** (BER – for non-domestic buildings) or the **Dwelling Emission Rate** (DER – for dwellings) measured in $kgCO_2/m^2$/yr. These are the measures used in the Building Regulations Part L and the Code for Sustainable Homes, where they are compared with a Target Emission Rate (TER) also measured in $kgCO_2/m^2$/yr.

2 This is a typical figure for an unimproved 1930s semi-detached house with a newer, moderately efficient central heating system – but the range of emissions, across different types of houses, is from less than two to more than twenty tonnes per year

Existing Buildings and New Build

The data in Figures 1 to 5 relate to the existing building stock, which now consists of approximately two million non-domestic premises and approximately 25 million dwellings.

The average rate of replacement of the non-domestic building stock is approximately 1% per year, but there is much variation between sectors, and significant growth.

The average rate of replacement of the domestic building stock is approximately 0.5% per year, and there is significant growth (the number of dwellings has risen from 18 million in 1976 and is expected to reach 27 million by 2020 – a 50% increase in 44 years).

Currently the carbon dioxide emissions associated with energy use in new buildings largely cancel out the reductions obtained by improvement of existing buildings. If overall reductions in carbon dioxide emissions are to be made, either the rate of improvement or the rate of replacement of existing buildings must increase, or both.

Carbon Dioxide Emissions from UK Buildings

Figure 1 shows UK delivered energy in 2000, broken down by broad economic sectors. Delivered energy is the energy delivered by the fuel industries to their customers, and the total across all sectors was 6,695 petajoules (PJ). It is clear that many of the sectors on the chart will have involved some level of energy use in buildings.

Figure 2 shows energy delivered to UK buildings in 2000, broken into three sectors: domestic, commercial and public buildings and industrial buildings. At 3,122 PJ the total energy delivered to buildings was approximately 47% of the overall total from Figure 1, so buildings used nearly half of the energy delivered in the UK.

Note that the UK's 25 million domestic buildings used 63% of the energy delivered to buildings, whilst the two million industrial, commercial and public buildings accounted for the remaining 37%.

The next three charts focus on the non-domestic building stock.

Figure 3 shows energy delivered to UK non-domestic buildings in 2000. Note that offices (including government offices), retail premises, and hotels and catering accounted for over half of the total of 880 PJ. These sectors are the ones in which buildings are most likely to be mechanically ventilated or air conditioned.

Figure 4 shows carbon dioxide emissions associated with energy use in non-domestic buildings, broken down by fuel type, in 2000. Nearly two-thirds of the emissions (61%) were associated with the use of electricity, most of which was used for lighting, mechanical ventilation, air conditioning and equipment such as computers.

Figure 5 shows UK carbon dioxide emissions associated with energy use in non-domestic buildings in 2000, broken down by energy end-use. Note that heating accounted for nearly half (41%) of carbon dioxide emissions and lighting accounted for almost one quarter (23%). Cooling and ventilation contributed a relatively modest 5%, but this figure is growing, and there is a danger of sustained growth if more buildings are air conditioned as an adaptation to a warming climate.

Figure 1

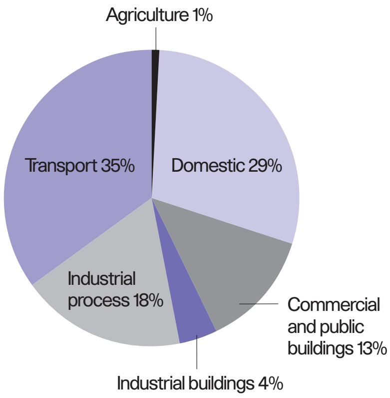


Figure 2

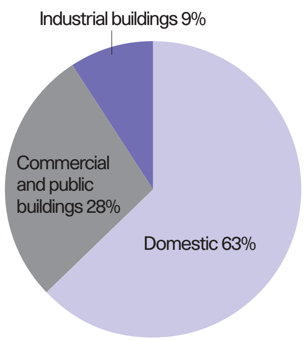


Figure 3

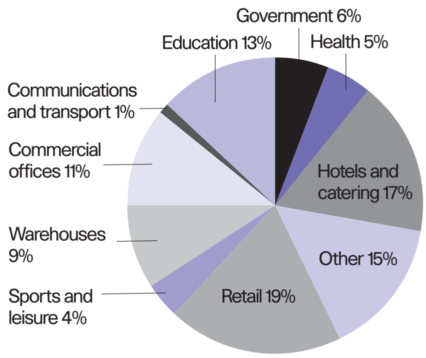


Figure 4

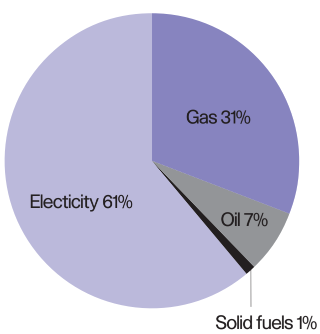


Figure 5

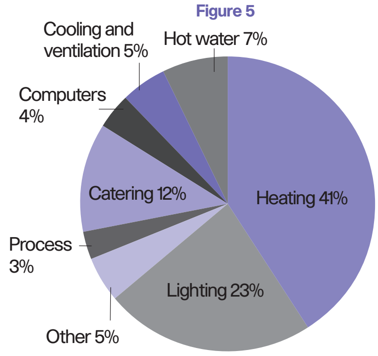


Figure 1 UK delivered energy in 2000
Figure 2 Energy delivered to UK buildings in 2000
Figure 3 Delivered energy in UK non-domestic buildings in 2000, broken down by sectors
Figure 4 UK carbon dioxide emissions associated with energy use in non-domestic buildings in 2000, broken down by fuel type
Figure 5 UK carbon dioxide emissions associated with energy use in non-domestic buildings, in 2000, broken down by energy end-use

(Source: CIBSE Guide F)

Carbon Dioxide Emissions Factors

One of the reasons electricity accounts for such a high proportion of carbon dioxide emissions associated with energy use in buildings is that more emissions arise from using one unit of energy in the form of electricity than, for example, one unit in the form of natural gas. This is because the process of generating electricity is relatively inefficient, and emissions are calculated from 'primary energy' – that is the fuel burnt in the power station (oil, coal, gas, etc).

The relative emissions of different types of energy are expressed in terms of a carbon dioxide emissions factor. Electricity has a high 'carbon dioxide emissions factor' compared with other fuels. Even with a proportion of nuclear generation, and an increasing contribution from renewable sources such as wind-power, the emissions factor for grid electricity is more than twice that for mains gas.

Table 1 sets out carbon dioxide emissions factors for various fuels, and their ratio with the emissions factor for mains gas. (Note that these emissions factors do not account for emissions of other greenhouse gases.)

Although in terms of factors, renewable energy sources (e.g. solar water heating, wind-power, local photovoltaic electricity) have no emissions associated with them, the use of wood fuel does involve a relatively small level of emissions. This is because, whilst the carbon dioxide emitted when wood is burnt is almost exactly matched by the carbon dioxide absorbed by the tree as it grows, the factor takes account of emissions associated with the use of fuel in felling (e.g. chainsaws) and transport.

Other biofuels, for example biodiesel derived from maize, have much higher emissions associated with cultivation, harvesting, processing and distribution.

Other renewable energy sources do have a carbon impact in terms of the materials used, production processes and transport and distribution. However, the protocol for calculating emissions factors does not include these. You can find out more about the emissions associated with products – known as embodied carbon or embodied energy – in *The Green Guide to Specification* www.bre.co.uk/greenguide or in the *Green Building Handbook* www.ribabookshops.com.

When designing a low-carbon building, it is always better to incorporate building services that use fuels with low emissions factors – or better still, use energy from a local renewable source.

Fuel	Carbon dioxide emissions factor (kg CO_2/kWh)	Emissions factor relative to mains gas
Mains gas	0.194	1.00
LPG	0.234	1.20
Oil	0.265	1.40
Solid fuel	0.291	1.50
Grid electricity*	0.422	2.20
Renewable energy	0.000	0.00
Wood	0.025	0.13

Table 1 Carbon dioxide emissions factors for some common fuels (source: SAP 2005)

*The published emissions factors for electricity are based on the Government's forward projections of the 'dash for gas' in the electricity generation industry, to 2010. These projections have not been borne out, and the current emissions factor for grid electricity is thought to be approximately 0.55 kgCO_2/kWh, which is 2.84 times that for mains gas

Energy Use and Emissions Benchmarks for Buildings

To establish energy efficiency and carbon dioxide emissions standards, we need 'benchmarks', or indicators of the levels of energy use and emissions that might be considered typical, and those associated with good practice in low-carbon design and refurbishment.

Domestic Buildings

The sections below set out carbon dioxide emissions for three typical new-build dwellings:

- A two-bedroom flat (60 m^2)
- A three-bedroom semi-detached house (83 m^2)
- A three-bedroom, three-storey town house (98 m^2).

For each property type, a table presents the estimated emissions when the house is designed and specified to meet the current Building Regulations[3], and the Code for Sustainable Homes Levels 3, 4, 5 and 6. Each table incorporates a chart showing the relative level of carbon dioxide emissions for each specification.

About the Tables

The first column identifies the five specifications; the second column shows the Dwelling Carbon Dioxide Emissions Rate (DER) in $kgCO_2/m^2/year$; and the third column shows the carbon dioxide emissions predicted by SAP, in tonnes/year. These figures only include emissions associated with energy use for heating, hot water and lighting; the emissions associated with cooking and the use of domestic appliances are not included. The fourth column of each table shows the total carbon dioxide emissions, in tonnes/year, including those associated with heating, hot water, cooking, lighting and the use of appliances[4].

Code for Sustainable Homes

The Code for Sustainable homes sets broad environmental performance standards, including energy efficiency, for new housing. It establishes six levels of performance and is aligned with planned changes to Building Regulations in the period to 2016.

Code for Sustainable Homes Level 3 must be achieved by all publicly-funded new housing, and this is expected to be the standard required by the Building Regulations from 2010, for all new housing. Code for Sustainable Homes Level 4 is expected to be the standard required by the Building Regulations from 2013, and the Government's aspiration is that all new housing should achieve Code for Sustainable Homes Level 6 by 2016.

If the dwellings are specified to meet Level 5 of the Code for Sustainable Homes ('zero carbon' for heating, hot water and lighting) the appropriate figures in the second and third columns of the tables become zero. If the dwellings are specified to meet Level 6 of the Code for Sustainable Homes ('net zero carbon' for all uses) the appropriate figures in the fourth columns of the tables become zero; in these cases the use of grid electricity for cooking and appliances must be offset by electricity generated on-site from renewable sources, and supplied to the grid.

More information about the Code for Sustainable Homes can be found in *Low Carbon Standards and Assessment Methods*, part of the RIBA Climate Change Tools package.

3 The house conforms to the guidance in the Approved Document to Part L1A of the Building Regulations (2006); the Dwelling Carbon Dioxide Emissions Rate (DER) is equal to the Target Carbon Dioxide Emissions Rate (TER)

Figure 6 This example relates to a two-bedroom flat, mid-floor, mid-block with a floor area of 60m²

2 bed flat	Dwelling emissions rate ($kgCO_2/m^2/yr$)	SAP carbon dioxide emissions (tonnes/yr)	Total carbon dioxide emissions (tonnes/yr)
Building Regulations Part L1A (2006)	19.30	1.17	2.02
Code for Sustainable Homes Level 3	14.48	0.88	1.73
Code for Sustainable Homes Level 4	10.81	0.66	1.51
Code for Sustainable Homes Level 5	0	0	0.85
Code for Sustainable Homes Level 6	0	0	0

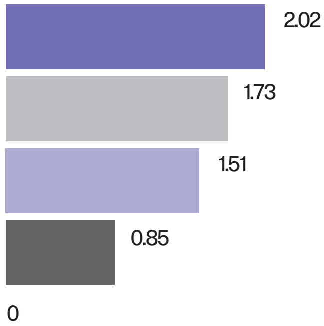


Figure 7 This example relates to a two-storey, three-bedroom, semi-detached house with a floor area of 83m²

3 bed house	Dwelling emissions rate ($kgCO_2/m^2/yr$)	SAP carbon dioxide emissions (tonnes/yr)	Total carbon dioxide emissions (tonnes/yr)
Building Regulations Part L1A (2006)	22.85	1.80	2.96
Code for Sustainable Homes Level 3	17.14	1.35	2.51
Code for Sustainable Homes Level 4	12.80	1.01	2.17
Code for Sustainable Homes Level 5	0	0	1.16
Code for Sustainable Homes Level 6	0	0	0

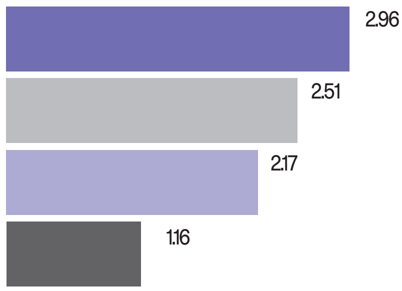
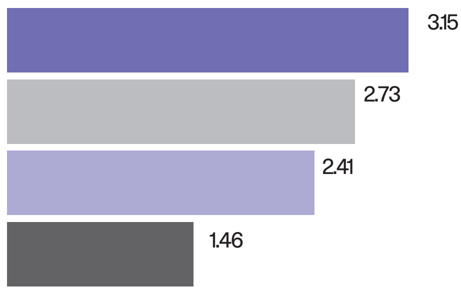


Figure 8 This example relates to three-storey, three-bedroom, mid-terraced townhouse with a floor area of 98m²

3 bed town house	Dwelling emissions rate ($kgCO_2/m^2/yr$)	SAP carbon dioxide emissions (tonnes/yr)	Total carbon dioxide emissions (tonnes/yr)
Building Regulations Part L1A (2006)	18.80	1.69	3.15
Code for Sustainable Homes Level 3	14.10	1.27	2.73
Code for Sustainable Homes Level 4	10.53	0.95	2.41
Code for Sustainable Homes Level 5	0	0	1.46
Code for Sustainable Homes Level 6	0	0	0



4 All data in figures 6 to 8 have been calculated by Rickaby Thompson Associates Ltd, using BREDEM-12 based NHER Plan Assessor (SAP 2005) software, under standard occupancy. Dwelling designs were made available for analysis courtesy of Bellway Homes, BMH Construction and Careys

Non-Domestic Buildings

The non-domestic building stock is far less homogenous than the domestic stock – there are far more building types.

Energy use in non-domestic buildings and the associated carbon dioxide emissions are dependent on five key factors:

- Building form
- Building fabric
- Building services
- Activity accommodated
- Management of the building.

Even amongst buildings of a common type such as 'offices' there are many different combinations of these factors: some offices are in purpose-built blocks, but many are in converted terraced houses or attached to industrial buildings; some offices have central plant HVAC systems, but many have domestic-scale heating systems and rely on natural ventilation. Similar observations may be made about retail buildings, industrial buildings, educational buildings and healthcare buildings.

Because of this diversity, it is very difficult to establish benchmarks for building performance. A widely-used UK source of this information is CIBSE Guide F *Energy Efficiency in Buildings*[5], Part C of which presents energy benchmarks for many different types of non-domestic buildings. These benchmarks have been derived from a wide variety of sources with a focus on measured (not predicted) energy use in existing buildings.

The CIBSE benchmarks relate to buildings without renewable energy systems, and are not particularly challenging. Other benchmarks and best practice standards may be found in some of the Carbon Trust's publications[6] , and a new set of benchmarks is currently being developed for Energy Performance Certificates (EPCs) and Display Energy Certificates (DECs). The Passive House standard (which may be applied to non-domestic buildings) sets a more challenging performance target of 15kWh/m^2/yr for space heating demand and 120kWh/m^2/yr for primary energy use. See the guide to *Low Carbon Standards and Assessment Methods* that forms part of the RIBA Climate Change Tools for further information.

Figures 9 to 16 illustrate the CIBSE benchmarks for energy use and the associated carbon dioxide emissions for four types of existing buildings: offices, retail buildings, industrial buildings and schools. In each case, 'typical' and 'good practice' benchmarks are given[7]. For the reasons explained above the spread of performance of existing buildings is very much wider than indicated by the benchmarks – the performance of many buildings is worse than 'typical', and in some cases performance is better than 'good practice'.

Where existing buildings are to be refurbished, it is appropriate to adopt energy standards equivalent to the appropriate good practice benchmark, or better.

When new buildings are being designed it is appropriate to adopt energy standards at least equivalent to 'good practice', and moving towards low- or zero-carbon standards.

5 CIBSE *Energy Efficiency in Buildings* Guide F, Chartered Institute of Building Services Engineers, London, 2004

6 See www.carbontrust.co.uk/publications

Offices

Figures 9 and 10 illustrate the CIBSE benchmarks for office buildings. Four types of buildings are considered:

- Naturally ventilated, cellular offices
- Naturally ventilated, open-plan offices
- 'Standard' air conditioned offices
- 'Prestige' air conditioned offices (e.g. corporate headquarters).

The charts illustrate the significant energy-use and emissions penalty associated with air-conditioning and increased services, where there is much more intensive use of electricity than in naturally ventilated buildings. This is why low-carbon designs should avoid air conditioning wherever possible, or limit air conditioning to small areas (e.g. computer suites) where it may be unavoidable.

Figure 9

Offices energy use (kWh/m²/yr)

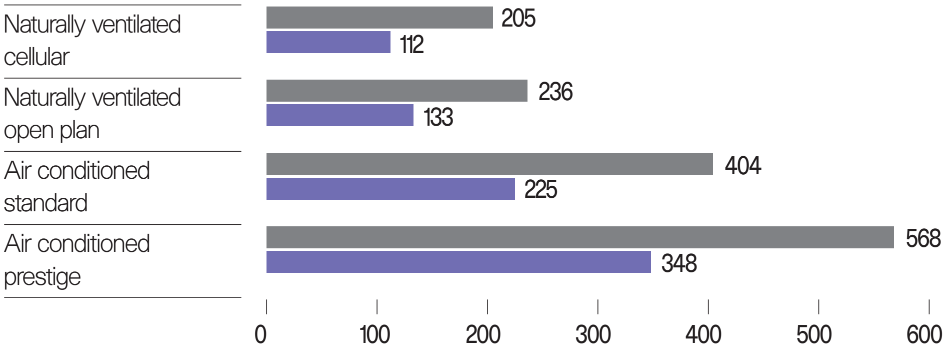


Figure 10

Offices total carbon dioxide emissions (kg/m²/yr)

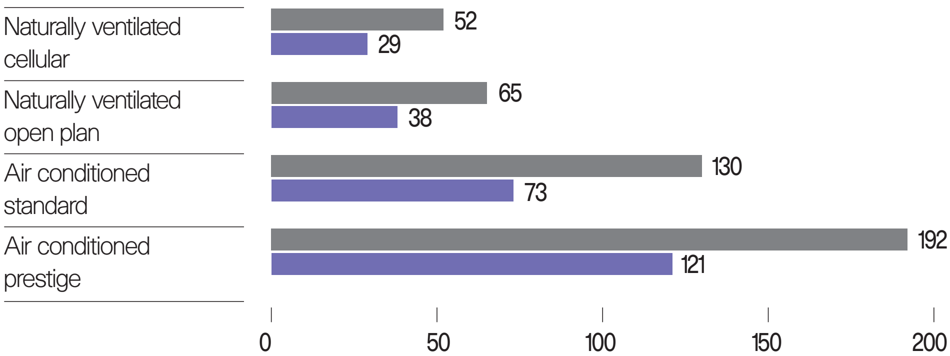


Figure 9 Energy benchmarks for office buildings (Source: CIBSE Guide F)
Figure 10 Carbon dioxide emissions benchmarks for office buildings (Source: CIBSE Guide F)

Typical practice
Good practice

System	Delivered energy (KWh/m²/yr)							
	Natural ventilation cellular		Natural ventilation open plan standard		Air conditioned prestige		Air conditioned	
	Good practice	Typical	Good practice	Typical	Good practice	Typical	Good practice	Typical
Gas/oil heating and hot water	79	151	79	151	97	178	107	201
Catering gas	0	0	0	0	0	0	7	9
Cooling	0	0	1	2	14	31	21	41
Fans, pumps and controls	2	6	4	8	30	60	36	67
Humidification	0	0	0	0	8	18	12	23
Lighting	14	23	22	38	27	54	29	60
Office equipment	12	18	20	27	23	31	23	32
Catering electricity	2	3	3	5	5	6	13	15
Other electricity	3	4	4	5	7	8	13	15
Computer room	0	0	0	0	14	18	87	105
Total gas or oil	79	151	79	151	97	178	114	210
Total electricity	33	54	54	85	128	226	234	358

Table 2 Detailed energy performance benchmarks for four types of typical and good

7 In 2007, a review for CIBSE and CLG concluded that these benchmarks are inconsistent, out of date and overdue for review. A new set of stringent statutory benchmarks for use on Display Energy Certificates for public buildings is now being finalised. The development of voluntary benchmarks for different building sectors is also being encouraged. All of these new benchmarks are intended to have consistent technical underpinnings related to agreed allowances for buildings' needs, rather than historical statistics

Retail Buildings

Figures 11 and 12 illustrate the CIBSE benchmarks for retail buildings, the stock of which is very diverse. The figures demonstrate the significant increase in energy use and the associated emissions with depth of plan (e.g. in department stores), because of the increased use of artificial lighting and mechanical ventilation, and with refrigeration (e.g. in food stores). Supermarkets are typically deep-plan buildings that combine high levels of artificial lighting with mechanical ventilation and refrigeration.

Figure 11 Energy use benchmarks for retail buildings (Source: CIBSE Guide F)

Figure 12 Carbon dioxide emissions benchmarks for retail buildings (Source: CIBSE Guide F)

Figure 11

Retail energy use (kWh/m²/yr)

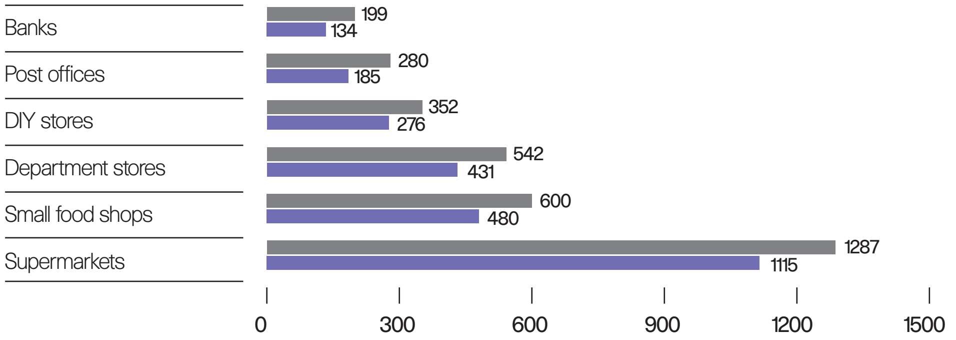
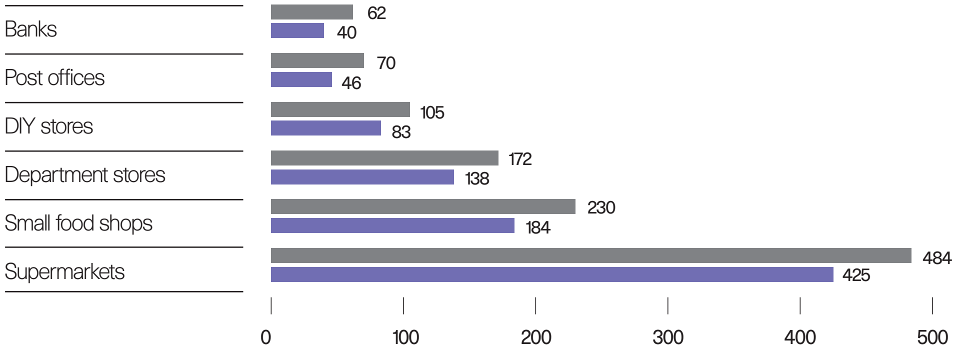


Figure 12

Retail carbon dioxide emissions (kg/m²/yr)



Industrial Buildings

Figures 13 and 14 illustrate the CIBSE benchmarks for industrial buildings (excluding process energy). The stock of these buildings is also diverse, ranging from small unheated workshops to very large chilled warehouses. The figures for storage buildings hide the wide variation between unheated warehouses (which may only be intermittently lit) and chilled warehouses that are continuously cooled.

Figure 13 Energy use benchmarks for industrial buildings (Source: CIBSE Guide F)

Figure 14 Carbon dioxide emissions benchmarks for industrial buildings (Source: CIBSE Guide F)

Figure 13

Industrial buildings energy use (kWh/m²/yr)

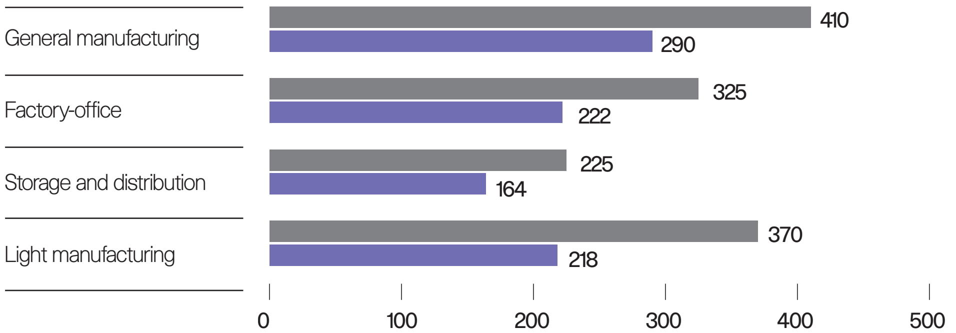
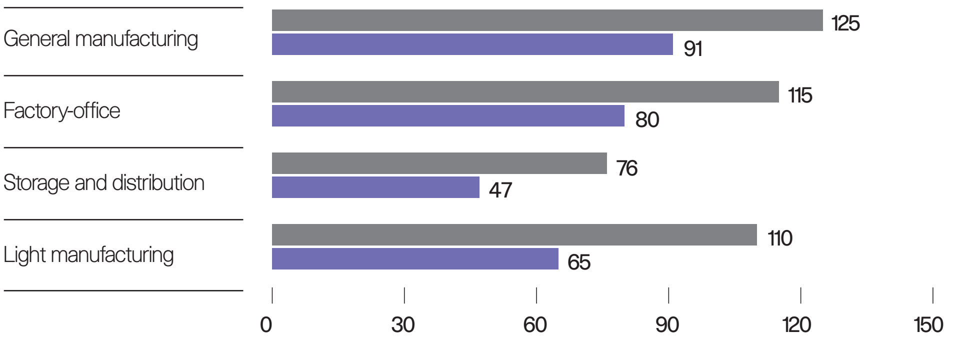


Figure 14

Industrial buildings carbon dioxide emissions (kg/m²/yr)



Typical practice

Good practice

Figure 15

Schools energy use (kWh/m²/yr)

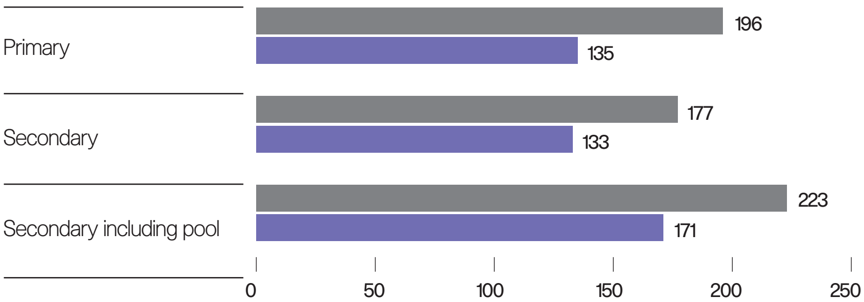


Figure 16

Schools carbon dioxide emissions (kg/m²/yr)

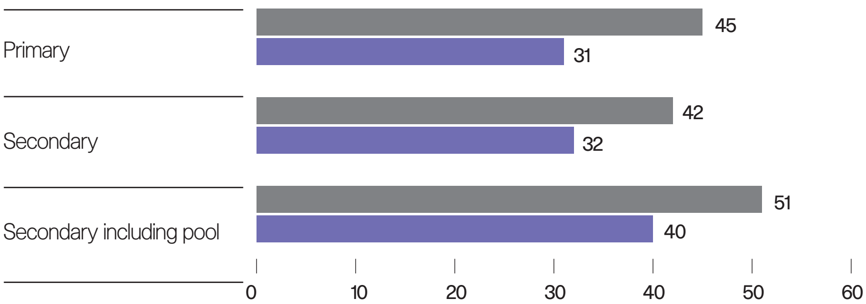


Figure 15 Energy use benchmarks for schools (Source: CIBSE Guide F)

Figure 16 Carbon dioxide emissions benchmarks for schools (Source: CIBSE Guide F)

Typical practice

Good practice

Schools

Figures 15 and 16 illustrate the CIBSE benchmarks for primary and secondary schools (with and without swimming pools). These figures are for existing schools, in which energy use is notoriously variable because of unpredictable, intermittent occupancy patterns (including long unused periods) and variations in built form, daylighting and ventilation.

Recent monitoring and evaluation of energy use in new 'low energy' schools has suggested that this subject is not as well understood as had been supposed; electricity use is increasing because of extended hours of use, the growing number of computers, electronic whiteboards, server rooms, security equipment, etc. Schools are also being provided with more building services than they have had in the past, in order to meet more exacting environmental standards.

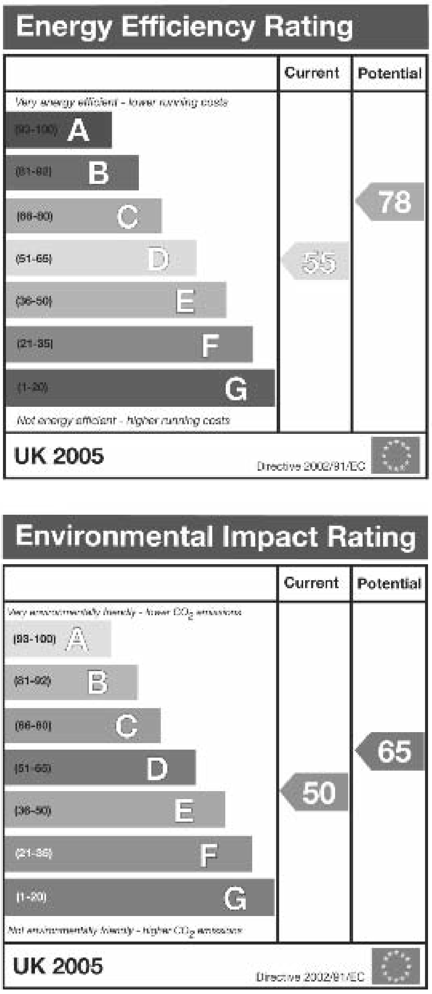
Using the Benchmarks

CIBSE Guide F includes many more benchmarks based on measured energy use in existing buildings in most sectors, broken down both by building or activity type and by energy end-use (e.g. heating, hot water, ventilation, cooling, lighting and small power). It is recommended that architects refer to these benchmarks whenever they are not familiar with the energy performance of a building on which they are working.

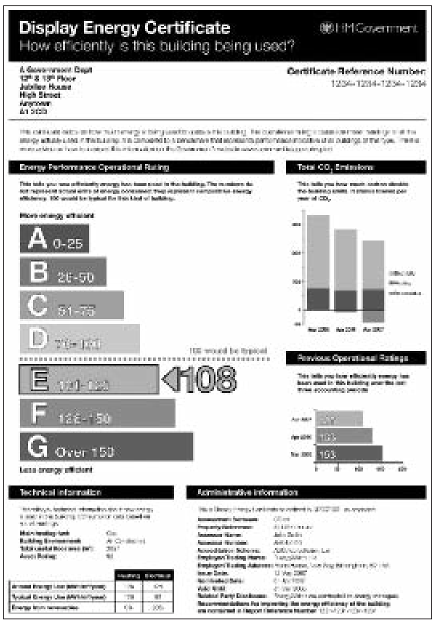
Low-carbon refurbishments should deliver buildings with performance better than the 'good practice' benchmark.

Low-carbon designs for new buildings should deliver performance significantly better than the 'good practice' benchmarks.

In both cases the use of renewable energy systems will further reduce carbon dioxide emissions towards the low- and zero-carbon standards that are reviewed in the guide to *Low Carbon Standards and Assessment Methods*.



Energy efficiency and environmental impact ratings on a domestic EPC



A sample Display Energy Certificate showing operational rating

Energy Performance Certificates and Display Energy Certificates

Energy Performance Certificates (EPCs) are required when a new building is first occupied, and whenever its occupancy changes – that is, when it is sold or when there is a new tenancy.

Display Energy Certificates (DECs) are required for some publicly accessible buildings.

For **dwellings**, EPCs report the SAP energy ratings and Environmental Impact Ratings (EIRs, based on the SAP carbon dioxide emissions) on a banded A–G scale:

A 92–100
B 81–91
C 69–80
D 55–68
E 39–54
F 21–38
G 1–20

Band A represents excellent performance (i.e. low fuel costs and low emissions) and band G represents very poor performance (i.e. high fuel costs and high emissions).

For **non-domestic buildings**, EPCs report 'Asset Ratings' and/or 'Operational Ratings'; they are intended to send market signals about the relative performance of comparable buildings.

The Asset Rating of a new building is the ratio of the predicted carbon dioxide emissions from the building (the Building Emission Rate, BER) to a Standard Emission Rate (SER). The BER is calculated by approved software (e.g. an implementation of the Simplified Building Energy Model, SBEM).

The SER is the Reference Emission Rate (RER) multiplied by 0.765, and the RER is calculated for a reference building of the same size and shape as the actual building, specified to meet the 2002 Building Regulations, with gas-fired heating and hot water services, and in which each space is heated and cooled to fixed set-points (irrespective of whether the equivalent spaces in the actual building are heated or cooled or not). A gas-heated building that is just compliant with the 2006 Building Regulations will have an Asset Rating of 100. A better performing building (i.e. one with lower carbon dioxide emissions) will have a lower Asset Rating. EPCs present Asset Ratings on a banded A–G scale, where A represents excellent performance and G represents very poor performance:

A 0–25
B 25–50
C 51–75
D 76–100
E 101–125
F 126–150
G Over 150

In addition, an A+ rating is assigned to buildings with less than net zero carbon dioxide emissions, i.e. buildings that export more locally generated renewable energy than they take from the grid.

EPCs also report the minimum standard of performance required by the Building Regulations (the Target Emission Rate, TER) and the performance of a 'typical' building that would comply with the 1995 Building Regulations.

The Operational Rating of a building is determined some time after the building has been occupied, from measured energy use data according to an assessment and reporting methodology developed by CIBSE. It is shown on a Display Energy Certificate.

More detailed information about energy ratings and emission rates can be found in the RIBA Climate Change guide on *Low Carbon Standards and Assessment Methods*.

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