WHAT COLOUR is YOUR BUILDING?

Measuring and reducing the energy and carbon footprint of buildings

David H. Clark

30 minute summary

www.whatcolourisyourbuilding.com

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This book … challenges all those involved in the built environment – policy makers, planners, designers, builders, managers and occupants – to focus on the issues that make a difference. This book is an accessible, practical guide to reducing energy consumption and CO_2 emissions, providing a fresh approach but grounded in commercially available technologies.

Extract from Foreword by Sir David King

UK Foreign Secretary's Special Representative for Climate Change, Chair of Future Cities Catapult

Debunking myths and providing a simple step by step guide to measuring and minimising real energy use, this is essential reading.

Paul King, CEO of UK Green Building Council

An indispensable read for anyone who is serious about tackling carbon emissions.

Richard Francis, Chair of BCSC Low Carbon Working Group

A very good and timely read.

Pooran Desai, OBE, co-founder BioRegional and International Director, One Planet Communities

Compulsory reading for all built environment students.

Miles Keeping, Partner of Deloitte Real Estate and Chairman of IPF Sustainability Interest Group

Essential reading for all sustainable construction and property practitioners.

Steven Borncamp, co-Director of Construction21: International and Founding President of Romania GBC

Remarkable common sense.

Andrew McNaughton, CEO Balfour Beatty plc and Vice President of the Institution of Civil Engineers

Guidance and data is clearly presented and in a straightforward way free from jargon.

Professor John Connaughton, University of Reading, School of Construction Management and Engineering

Lucid and comprehensive.

Rab Bennetts, OBE, Director, Bennetts Associates

David's call to action rings true.

S. Richard Fedrizzi, Chairman of World Green Building Council and President & CEO of USGBC

For further details refer to Testimonials page on the book's website.

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Key messages

The book aims to put the whole carbon footprint of office buildings into perspective and to identify practical opportunities to reduce energy consumption and CO_2e emissions.

Actual energy performance is far more important than good intentions (design ratings) but is not visible in most office buildings or board rooms. We need:

- Mandatory, publically disclosed ratings based on actual energy consumption.
- Separate benchmarks for landlords and tenants.
- Benchmarks that take into account intensity of occupation, not just floor area.

It is easy to save energy in buildings – the most obvious method is to turn stuff off (or down) when it is not needed. Building design doesn't need a radical overhaul – just a healthy dose of common sense and the application of good design principles:

- Architects need to rethink façade design to increase useful daylight and thermal comfort, and reduce heat losses in winter and solar gains in summer.
- Engineers need to design for low annual energy consumption and not just to meet peak loads which only occur on a handful of days each year.
- Facility managers need to better understand how they can run their buildings more efficiently.
- Controls need to be kept simple and easy for users to understand.

Renewable energy systems in buildings can only practically contribute between 5 and 10% of CO_2e reduction and at costs typically exceeding £70 per tCO_2e. We need:

- To use renewables in buildings only when they make sense.
- To avoid liquid biofuel CHP and wind turbines on buildings.
- To change planning rules to prevent inappropriate use of renewables to tick boxes.
- Simple mechanisms to allow building owners and occupants to invest in more cost effective large scale off-site renewable energy generation.

Embodied carbon provides a reasonable proxy for material resource efficiency, but more research is required to obtain better data for materials, products and buildings:

- It is typically less than 20% of the whole life operating carbon in office buildings.
- Designers and purchasers can help to drive reductions by using purchasing power to favour lower carbon products with robust certification.

The location of an office building has a surprisingly large impact on the whole carbon footprint and shouldn't be ignored. Planners, building owners and employers need to encourage people to use greener modes of transport.

1. Energy and carbon in buildings

Chapter 1 introduces global issues with energy and climate change, examines the contribution that buildings make and establishes why $kgCO_2e$ is adopted as the unit of measurement for the carbon footprint in the book.

Global energy consumption is a function of three factors: the number of consumers (people), their demand for services (expectations) and the efficiency with which the services are provided (efficiency). A pseudo equation for this, which applies at building, city and global scales, is:

$$\text{Energy consumption} = \frac{\text{no. of people} \times \text{expectations}}{\text{efficiency}}$$

The global population is predicted to increase by 25% over the next two decades, from 6.9 billion in 2010 to 8.6 billion in 2035. More people means more energy consumption. At the same time, people's incomes in developing countries are rising, leading to further demands for energy as their expectations for a high energy lifestyle increase.

The factor currently relied on by governments to reduce consumption is energy efficiency. However, history suggests, somewhat counter-intuitively, that as we improve energy efficiency, rather than reducing energy consumption it often goes up. For example, as cars became more efficient we could afford to drive further, and efficient gas central heating allows all rooms to be heated to higher temperatures for longer periods rather than using a single gas fire to heat one or two rooms.

Global energy consumption is currently predicted to increase by 30% between 2010 and 2035, with fossil fuels providing 75% of the energy supply. This rising demand will create competition, leading to higher energy prices and security of supply issues because fossil fuels are not an unlimited resource. Many countries are seeking to limit their reliance on imported fossil fuels, and their exposure to energy cost increases, by both reducing energy consumption and investing in alternative energy sources, including renewables.

When fuel is converted into energy to power buildings, industry and transportation it releases greenhouse gases (GHG). The amount of GHG emitted depends on the type of fuel used.

$$\text{GHG emissions} = \text{energy} \times \text{carbon content of fuel}$$

The radiative forcing of the climate system, which causes global warming, is dominated by increasing atmospheric concentrations of greenhouse gases, primarily due to carbon dioxide (CO_2) from human activities. There is currently broad scientific and political consensus that global warming since 1750 (the start of the Industrial Revolution) must be kept below 2 °C to avert dangerous climate change. This requires greenhouse gas concentrations in the atmosphere to be limited to 450 parts per million (ppm). In 1750, they stood at 280 ppm and in 2010 had risen to 390 ppm.

People using buildings use energy, constructing and refurbishing buildings requires energy, and commuting to and from buildings consumes energy. Nearly all of this energy comes from the combustion of fossil fuels. Buildings are responsible for 30% of the global greenhouse gas emissions and 40% of global energy consumption. Over the next 20 years, energy consumption in buildings globally is predicted to double. Limiting this increase will therefore be essential if any international climate change strategy is to be successful.

The purpose of the book is to quantify the energy consumption and whole carbon footprint of buildings, primarily offices, and to provide practical guidance on how to reduce these. The footprint, as shown in Figure 1.3, comprises:

- **operating** – the electricity, gas and other fuels used in a building for heating, cooling, ventilation, lighting, hot water, computers, servers and other equipment
- **embodied** – the energy consumed in manufacturing, delivering and installing the materials used to build, refurbish and fit-out a building, and their disposal at end of life
- **transport** – the energy used to get people to and from a building.

The footprint is quantified using kilograms of carbon dioxide equivalent ($kgCO_2e$) which allows different forms of energy consumption – electrical, heat, embodied and motive (transport) – to be compared using a single metric. In the United Kingdom and many other countries, it also provides a reasonable proxy to measure how efficiently energy is being used.

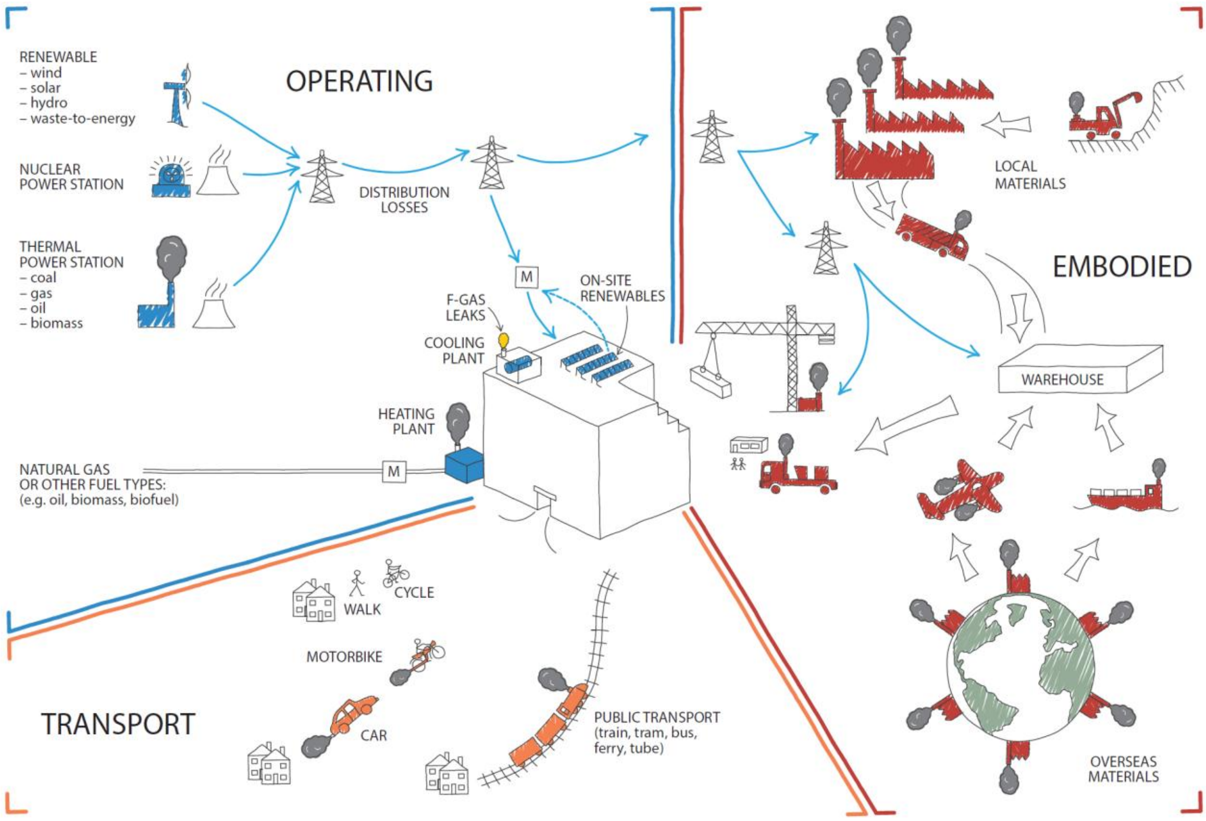


Fig 1.3 **GHG emissions associated with the construction and occupancy of buildings**

2. How much energy do buildings actually use?

Chapter 2 evaluates the actual (not design) energy performance of office buildings and proposes that benchmarks should be based on occupied area and occupancy, with separate ratings for landlords and tenants.

The primary unit for benchmarking energy/carbon performance of offices adopted in the book is:

$$kgCO_2e/m^2 = \frac{\text{energy consumption} \times CO_2e\text{ emission factor}}{\text{Gross Internal Area}}$$

Energy consumption is the metered annual energy consumption in the whole building (kWh), CO_2e emission factors convert kWh to $kgCO_2e$ (electricity = 0.6, natural gas = 0.2) and Gross Internal Area (GIA) is the total floor area inside the building in m^2.

The lowest annual electrical energy consumption possible in 2013 in a fully occupied office (refer to Figure 2.1) is around 50 kWh/m^2 or 30 $kgCO_2e/m^2$ of GIA. It is not zero carbon, even with on-site renewables.

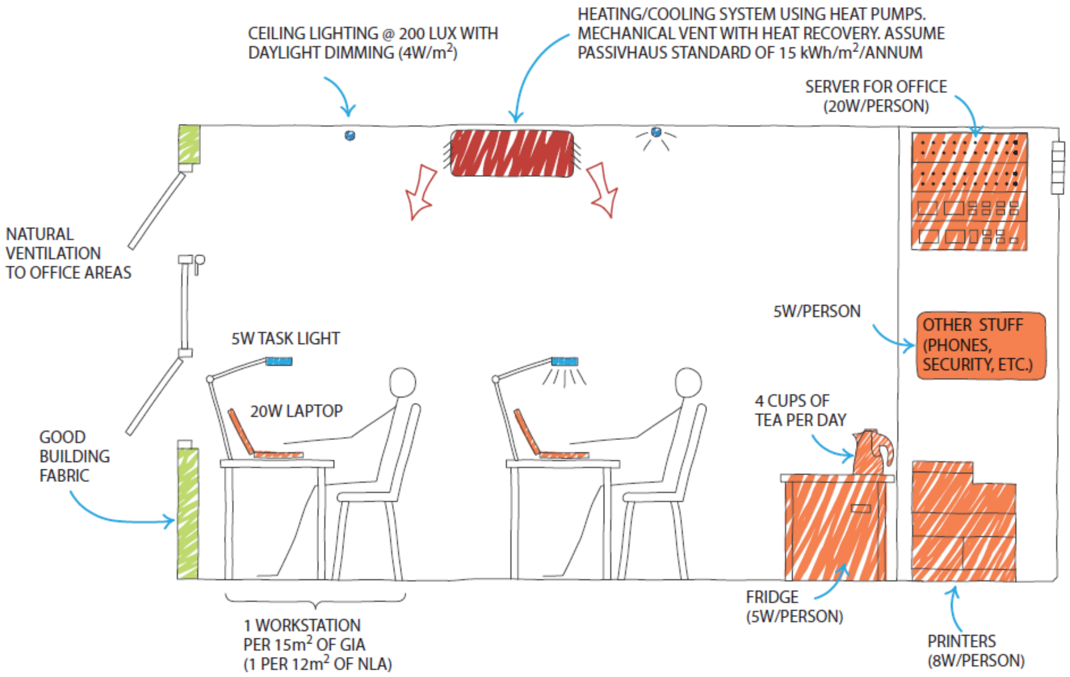


Fig 2.1 The lowest energy possible in an occupied office in 2013?

The very best performing green offices have an energy performance of between 30 and 40 $kgCO_2e/m^2$. They are typically owner occupied, two to four storeys tall, have openable windows and are located away from city centres. The majority of air conditioned commercial offices in the UK, which are possibly also more intensively occupied than the exemplar green buildings, rarely have an energy performance less than 100 $kgCO_2e/m^2$ of GIA and some exceed 200 $kgCO_2e/m^2$.

In the book an operating carbon benchmark for UK office buildings of **100 kgCO_2/m^2 of GIA** is proposed, with separate benchmarks for the landlord of 50 kgCO_2e/m^2 and for tenants of 750 kgCO_2e/person. Appendix D provides more detail on this.

The primary purpose of an energy benchmark or rating is to make energy visible and to draw a line in the sand so that building owners, facility managers and occupants can put the energy consumption of their building into perspective – and then be motivated to take steps to reduce it. While this may sound simple, it is also apparent that without legislation there is currently little incentive for landlords and occupants to voluntarily report and display the annual energy performance of commercial buildings. To trot out the old cliché: if you don't measure it, you can't manage it.

To get anywhere near zero carbon buildings in the future will require new technologies, lower carbon energy sources and, possibly the hardest nut to crack, changing the expectations and behaviour of the people designing, constructing, selling, managing and occupying buildings. While a step change in performance may be a while in coming, there are lots of opportunities to make significant reductions in energy use in most new and existing buildings today without too much difficulty.

The starting point is to have a clear understanding of the actual performance, and how and where the energy is being used. Chapter 6 outlines ten steps to reducing energy consumption. Chapter 7 discusses how much on-site renewables can realistically contribute to reducing the carbon footprint of commercial buildings.

THE PERFORMANCE GAP – EPC V REALITY

There is no correlation between Energy Performance Certificates (EPC) ratings and actual energy consumption in commercial buildings with the difference being up to a factor of 5.

This is because EPCs are a comparison of regulated energy features (the building fabric's thermal properties and the energy efficiency of some building services) with those of a reference building. They do not, and were never intended to, predict the energy consumption of the building, although this is not widely appreciated.

While EPCs undoubtedly have a role to play in improving the fabric of buildings and the energy efficiency of services, their limitations need to be understood if they are to usefully inform design decisions in new and refurbished buildings. They are not the key tool to benchmark and drive actual reductions in the energy consumption and CO_2e emissions of real buildings.

3. Embodied carbon

Chapter 3 delves into the dark art of calculating embodied carbon, provides typical values that can be used for quick estimates and compares this with operating carbon over a 60-year lifespan.

The embodied energy of a building is the primary energy required to make, deliver, assemble and dispose of all the materials used in its construction, refurbishment and demolition. Embodied carbon is the $kgCO_2e$ released due to the embodied energy plus any process emissions, such as CO_2 released by the chemical reaction when cement is produced. It is often annotated as ECO_2.

To illustrate the basic principles of embodied carbon (and energy), consider a concrete block. Figure 3.1 shows where the key energy inputs and process emissions occur when using this product in a building.

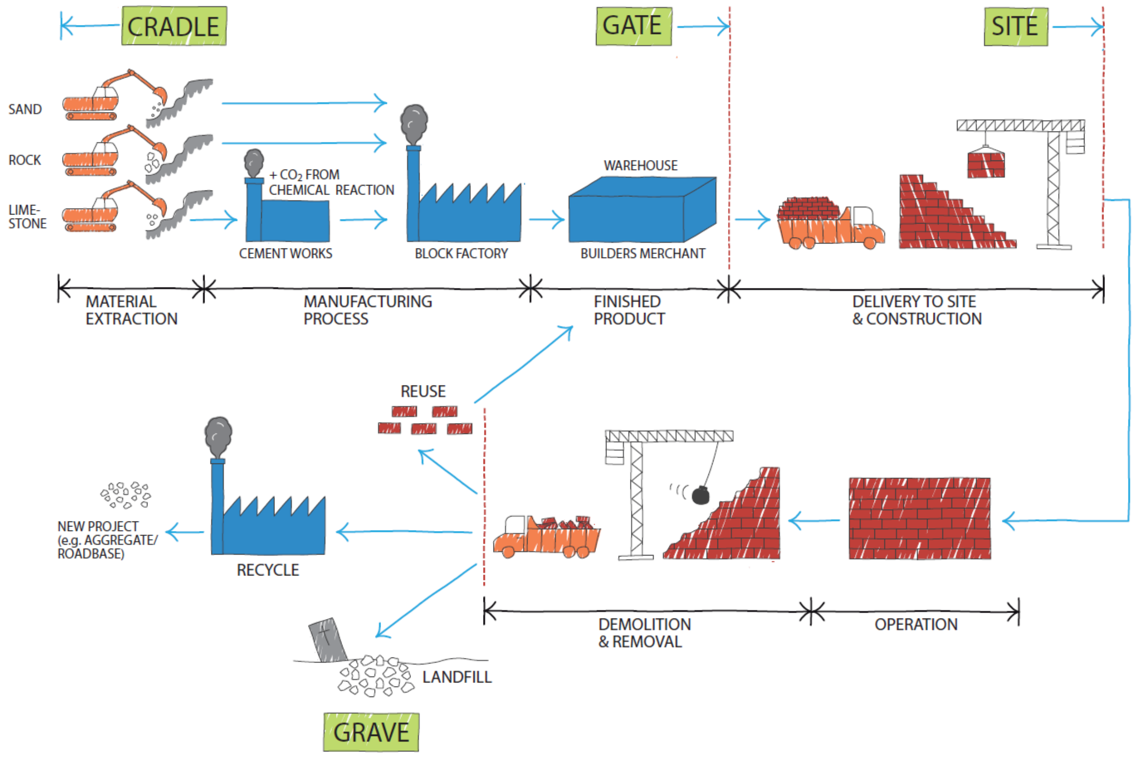


Fig 3.1 The embodied carbon stages in the life of a concrete block

This also shows the typical boundaries used in embodied carbon calculations. The whole life embodied carbon of a building is a function of the initial embodied carbon, the life expectancy of the materials and equipment, the frequency of refurbishment and fit-out, how long the building lasts before it is pulled down and what happens to all the materials at the end of their life in the building.

Different assumptions lead to significant differences in results. In particular, the end-of-life assumptions, such as what happens to timber, can be highly contentious and must be clearly stated when calculating the whole life embodied carbon of a building.

The most important aspect of calculating the embodied carbon, irrespective of the methodology used, is to obtain the breakdown by materials or elements for a particular building. This can then be used to identify and target the biggest opportunities to reduce embodied carbon. The split for the construction of a new office building might look something like Figure 3.4. While the breakdown between different buildings is highly variable, the structure usually accounts for over half of the initial embodied carbon.

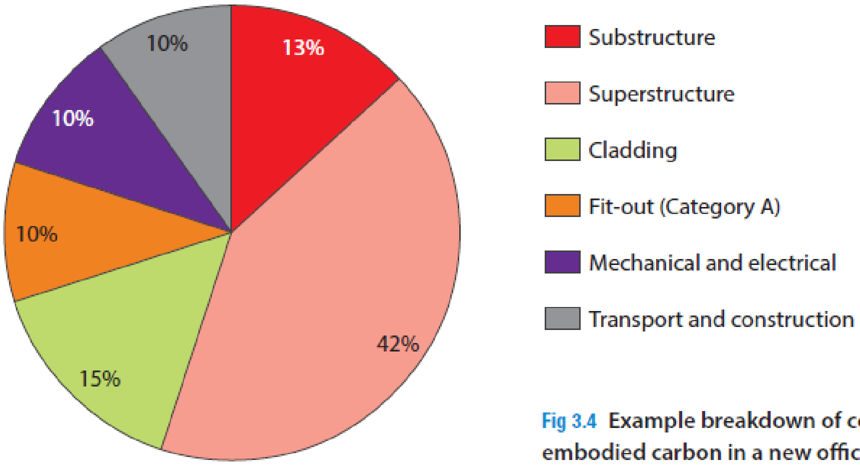


Fig 3.4 Example breakdown of construction embodied carbon in a new office building

The embodied carbon for new construction of office buildings is typically between **500 and 900 $kgCO_2e/m^2$ of GIA**. This is equivalent to 5 to 10 years of the CO_2e emissions due to the energy consumption of typical UK office buildings – refer to Appendix E for further details.

Embodied carbon is clearly important, but it is not as significant as energy consumption. It does, however, represent the first CO_2 emissions associated with a building and, once released, cannot be taken back (with operating carbon there is always the opportunity to make reductions over the life of the building).

Agreeing how to measure whole life embodied carbon is still problematic, but reducing it through resource efficiency (good design and material specification) is relatively straightforward. The embodied carbon due to fit-out is not well understood, but could account for up to half of the whole life embodied carbon and this warrants further research.

Undertaking a detailed assessment of embodied carbon is often expensive, but rules of thumb are just as useful in the early stages of design when key decisions are being made. Due to the wide range of data and assumptions for different structural materials, embodied carbon assessment is not a reliable tool for deciding the primary structural form (e.g. steel v concrete).

Chapter 8 provides guidance on how to reduce embodied carbon in buildings.

4. Transport carbon

Chapter 4 discusses how location influences the way that people choose to travel to a building, and compares commuting CO_2e emissions for a typical city centre building with out-of-town locations.

The operating and embodied carbon due to the design, construction and operation of office buildings was discussed in Chapters 2 and 3. However, transport is rarely given much emphasis when considering the whole energy and carbon footprint of buildings. In 2011, emissions due to transport accounted for 20 to 25% of the UK's total CO_2e emissions.

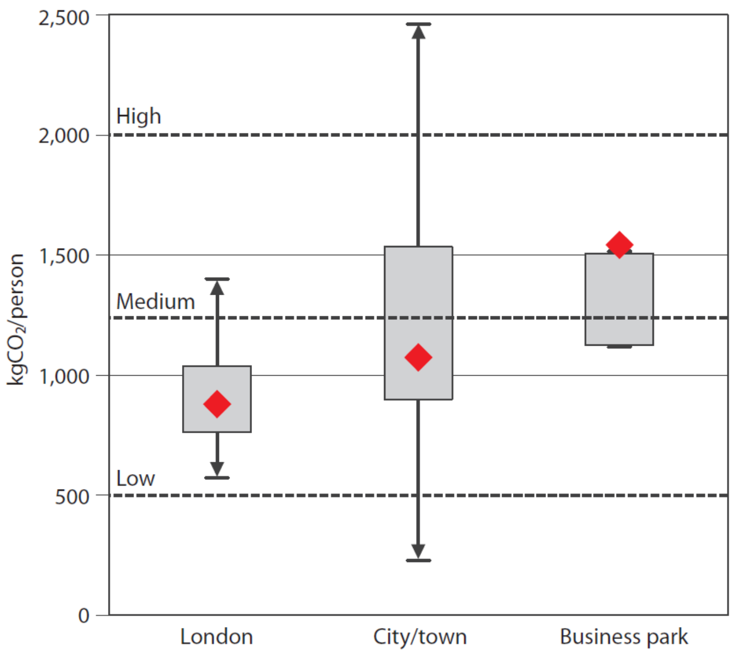
Car travel dominates the transport emissions and distance travelled in the UK. The decision on whether or not to drive to work is influenced by a number of factors including:

- distance from home to workplace
- proximity of the building to a frequent and reliable public transport system
- journey travel times
- cost of travel
- availability and cost of car parking
- parking controls or congestion charge zones
- facilities for cyclists
- type of business undertaken – is the work primarily office-based or is travelling to other buildings necessary?
- travel plans and incentives to use alternatives to cars.

Every office building is unique, due to its location and the people working in it. To accurately determine the travel distances and modes to and from a building, and therefore the CO_2e emissions, is difficult without undertaking a travel survey of every building occupant. Figure 4.3 summarises the results of 19 commuting travel surveys for individual offices together with the findings of an analysis of the 2002 census data in the UK. The building locations are categorised under three generic location types:

- London – anywhere within Zones 1, 2 and 3 of the London public transport system
- city/town – which includes outer suburbs of London
- business park – located on the edge of towns or cities.

The studies for London offices and business parks give reasonably consistent results: the former has abundant public transport and limited parking, the latter has the opposite. The survey values for city/town vary by a factor of 10, which reflects the diversity of office types and locations. The lowest value (241 $kgCO_2$/person) is a university office in which 80% of occupants either cycle or walk.



The grey blocks show the survey results falling within the upper and lower quartiles.
The vertical lines show the full range of results.
The diamonds show the results of the 2002 census data analysis. (Source: Wyatt, P.)

Fig 4.3 **Summary of commuting survey results and 2002 census analysis by location type**

The review of the limited data available for travel associated with office buildings in the UK suggests that annual transport CO_2e emissions for commuting typically fall within a range between **750 and 1,500 kgCO_2e/person**. Transport carbon can consequently be higher than operating carbon in some office buildings. The distance that people travel to work (and their mode of transport) is a major variable and difficult to predict at the planning and design stages. Transport Assessment data could potentially be used to estimate this when actual occupant survey data is not available. A simple methodology is described in Appendix F.

While transport carbon can be difficult to predict or quantify, particularly when planning new buildings, one thing is clear, the importance of a building's location should not be understated or ignored when considering its carbon footprint and credentials – but it usually is. Chapter 9 provides guidance on how landlords and tenants can reduce CO_2e emissions due to commuting to and from office buildings.

5. Whole carbon footprint

Chapter 5 combines the operating, embodied and transport CO_2e emissions into a whole carbon footprint, with indicative benchmarks. A simple benchmarking tool can be downloaded from www.wholecarbonfootprint.com.

In the introduction to the book the whole carbon footprint (which is also a proxy for energy resource consumption) was defined as the greenhouse gas emissions associated with operating, embodied and transport energy. In Chapters 2, 3 and 4, the typical CO_2e emissions for each of these in office buildings was discussed. The final step is to combine them into a simple single metric that can be used to consider the whole energy and carbon footprint during the planning and design stages of projects and the operation of existing buildings.

The CO_2e emissions for operating, embodied and transport are in different formats and so the following assumptions were made to combine them into a single, comparable metric:

- The footprint will be based on 1 year of carbon emissions (with 2,600 hours of use).
- The unit will be $kgCO_2e/m^2$ of GIA with an assumed base occupancy of 1 per 15 m^2.
- The annualised embodied carbon will be equal to the total calculated CO_2e emissions over 60 years divided by 60.
- The effect of decarbonisation will be excluded as it is difficult to predict this with any degree of certainty (and it will affect all three components to some degree anyway).

For each carbon component, three benchmark scenarios are considered: high, typical and low. The values are taken from the previous chapters and summarised in Table 5.2.

	$kgCO_2e/m^2$ of GIA/year				
	Operating	Embodied (initial)	Embodied (refurbishment/ fit-out)	Transport	**Total**
Low	50	8	5	33	**96**
Typical	100	12	8	83	**203**
High	150	18	11	133	**312**

Table 5.2 **Whole carbon footprint benchmarks for UK offices (excluding Category B fit-out)**

Figure 5.1 shows the breakdown of carbon in an office building with the typical operating, embodied and transport benchmarks. While every building will have its own unique footprint and breakdown, this diagram is useful in indicating the importance of the building location and commuting habits of the occupants on the overall carbon footprint.

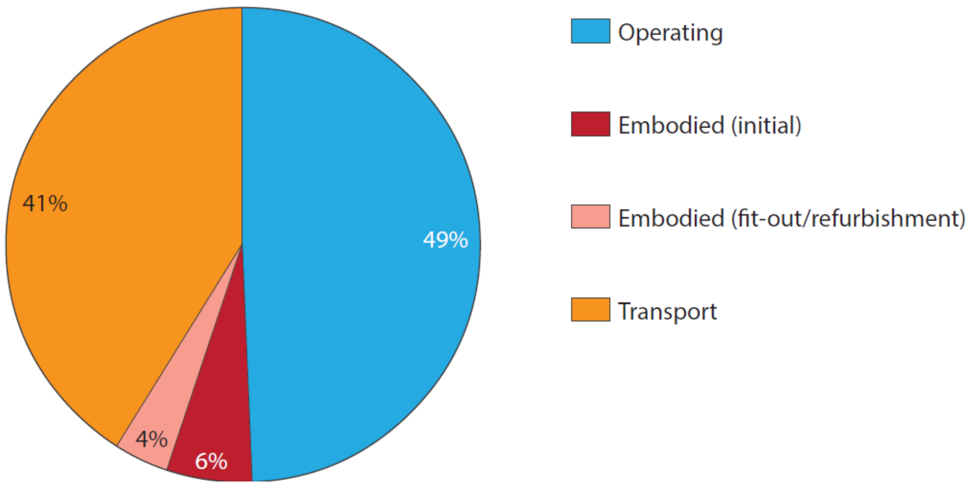


Fig 5.1 Carbon footprint breakdown of an office building in the UK using typical benchmarks for each category (excluding Category B fit-out)

Appendix G describes a potential methodology for a simple whole carbon rating using the data and principles set out in the book. A basic tool using the methodology can be downloaded from www.wholecarbonfootprint.com. The rating score calculation is:

$$\text{Score} = \frac{\text{total footprint } (kgCO_2e/m^2) \times 100}{\text{adjusted benchmark } (kgCO_2e/m^2)}$$

The primary inputs required to benchmark a building are:

- floor area
- annual energy consumption
- embodied carbon over a 60-year period
- travel emissions per person per year
- occupancy density*
- hours of use*
- CO_2e emission factors for electricity and heating source*
- frequency of fit-out and refurbishment.

The benchmark is adjusted to suit variables marked with an asterisk (*) and default values for low, typical and high embodied and transport emissions can be used if actual values for a building are not known.

An indicative whole carbon benchmark of around **200 $kgCO_2e/m^2$ of GIA per annum** is suggested as typical for a UK office building based on a 60-year assessment period. However, it is rather pointless to establish a benchmark if it doesn't then stimulate any further action. Now that the whole carbon footprint has been, somewhat crudely, defined, the next step is to do something to reduce it.

6. Ten steps to reducing energy consumption

Chapter 6 outlines ten steps to low energy consumption, including addressing our expectations of buildings, how they are managed and maintained, and the design/selection of building fabric, heating, cooling, ventilation, lighting and equipment.

The ten steps to reducing energy consumption set out in this chapter can be applied to the design of new buildings and the refurbishment and operation of existing buildings. The first issues are to identify the extent of consumption and where and when it is being used (step 1) and to challenge standard design assumptions related to lighting and comfort (step 2).

Steps 3 to 10 are summarised in Figure 6.2, which also shows the components assessed in building regulations (regulated energy). The building fabric (step 3), does not consume energy directly, but does influence consumption due to ventilation (step 4), heating and cooling (step 5) and lighting (step 6). The equipment plugged in by the occupants (step 7) and miscellaneous other services, such as domestic hot water and lifts (step 8), complete the energy-consuming items in the building.

The building may work brilliantly on paper, but if the systems are not set up correctly, handed over with clear instructions and then carefully maintained (step 9), then they will not work efficiently. Finally, the influence of people must be considered. Empty buildings do not use much energy. It is the people in buildings that lead to energy use, so it is important to engage with the occupants and make it easy for them to save energy (step 10).

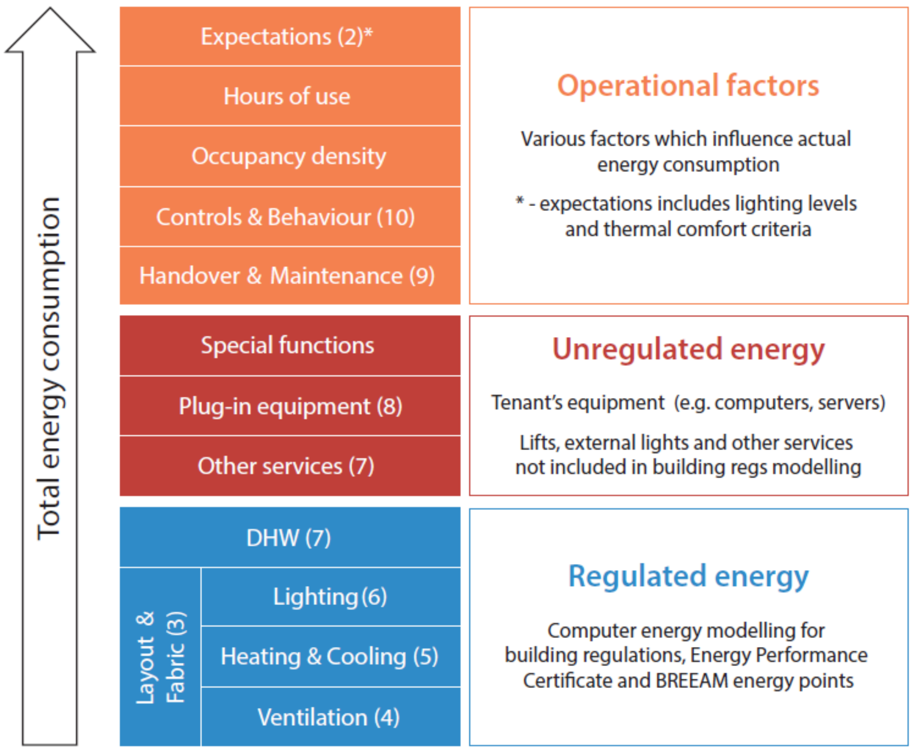


Fig 6.2 **Typical energy consumption components – regulated, unregulated and operating**

In order to deliver low energy buildings it is essential to recognise the difference between energy efficiency and efficient design. To illustrate this issue, consider two identical meeting rooms – one with three light fittings and the other with six. Both rooms have the same type of fittings and so are treated as having the same energy efficiency by Part L Building Regulations and EPC ratings – but the room with six fittings will have twice the annual energy consumption.

Designing for low energy is a function of both quality (efficiency) and quantity (total power installed and hours of operation). This is one reason (of many) for the performance gap between design energy ratings and metered energy consumption.

Table 6.8 summarises the key actions described in Chapter 6 to reduce energy consumption in the design and operation of buildings. There is unfortunately not space in this summary document to provide more detail on the ten steps – you'll have to buy or borrow the book for these. Further detail is provided in Appendix H which can be downloaded for free.

Every building is unique – a combination of location, layout, façade, systems and occupants – and consequently there is no one-size-fits-all approach to reducing energy consumption. Different buildings will require different solutions within the ten steps.

Issue		Key points
1	Understand how energy is being used	Compare the performance against benchmarks, focus on operational energy not design ratings, identify the big energy uses and users and target these. Establish a metering and energy management plan. If you can't monitor it, you can't manage it.
2	Challenge design criteria	Consider whether alternative lighting and thermal comfort criteria can be adopted – task lighting approach and wider temperature bands.
3	Building fabric	Achieve an appropriate balance between daylight, views, heat loss and solar gain – is a fully glazed building the best solution? Provide good air tightness.
4	Ventilation	Can the windows be opened and a natural/mixed mode strategy be adopted? Mechanical systems should be designed to minimise fan power and running hours.
5	Heating and cooling	Design systems for efficient year-round operation and not just to meet peak demand. Zoning and controls are critical.
6	Lighting	Provide the right amount of light only where and when it's needed. Develop a lighting strategy using daylight, efficient fittings and controls.
7	Equipment	Purchase energy efficient servers, computers, monitors and appliances. Implement power management strategies and turn stuff off at night.
8	Other services	Saving water saves energy. Use efficient lifts and reduce unnecessary lift movement. Consider power factor correction.
9	Commissioning, handover and maintenance	Implement a commissioning plan and use the Soft Landings Framework. Incentivise the project team beyond handover. Proactive maintenance saves energy.
10	People	Engage with occupants and make it easy for them to save energy. Establish green teams and provide simple user guides.

Table 6.8 **Summary of the ten steps to reducing energy consumption**

Keep it simple, size it right,
do it well, follow it through,
tune it up, capture the feedback and
continuously improve.

7. Renewable energy

Chapter 7 assesses the contribution that renewable energy systems can realistically make to reduce CO_2e emissions in individual buildings and asks 'Is it possible to make an urban building zero carbon using on-site renewables?'

Renewable systems can generate the two forms of energy used in buildings:

- heat – a low grade energy that is usually generated at the point of use, either in buildings or in district heating networks
- electricity – a high grade energy that can be generated anywhere and distributed via national grid infrastructure.

Since heat is difficult to move around (district heating systems are rare in many countries) and demand for heat is seasonal (higher in winter, lower in summer) then any surplus heat generated by renewable heat systems in individual buildings is usually wasted. The heating systems evaluated in this chapter are solar thermal, heat pumps, biomass boilers and combined heat and power (CHP), both natural gas and biofuel.

In comparison, any surplus electricity generated on site can usually be exported into the national grid and so doesn't go to waste. Renewable electricity systems can therefore be sized to suit available space and budget whereas renewable heating is usually sized to suit the building's heat demand. The electrical systems evaluated are photovoltaics, wind turbines and CHP.

This chapter provides an overview of the different renewable energy systems, including rules of thumb for the sizing and evaluation of each in two 10,000m^2 ten storey buildings – Building X (an office) and Hotel Y. The maximum CO_2 savings that each system can realistically make from a technical perspective (i.e. ignoring financial viability) are shown in Figure A.

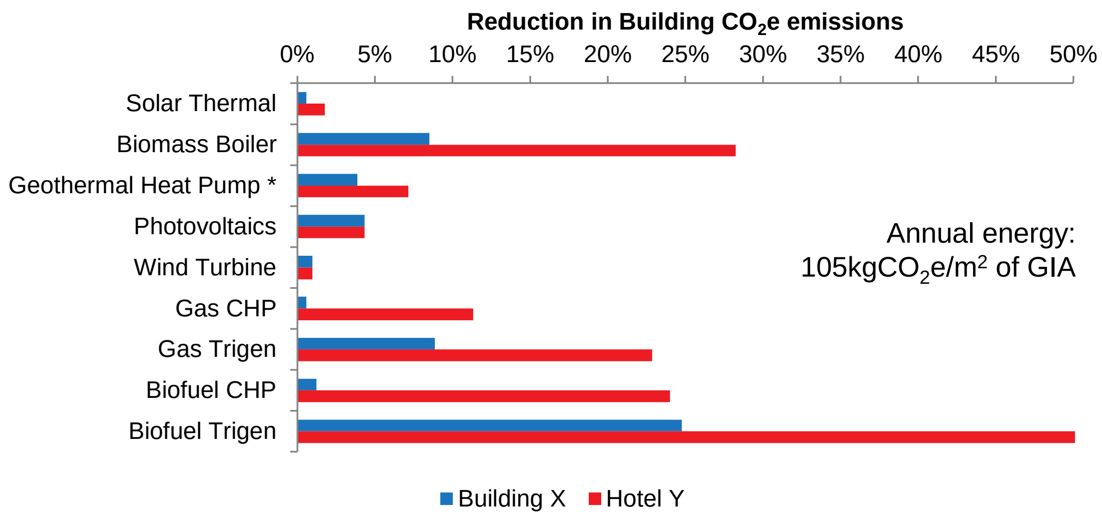


Fig A **Summary of maximum CO_2e reductions due to renewable energy systems in Building X and Hotel Y** (adapted from Table 7.20 in Chapter 7).

It is not possible to install all of the systems in the same building and add up the maximum savings because they either occupy the same space (e.g. PV and solar thermal panels) or they are meeting the same demand for heat (e.g. biomass boilers and gas CHP). The maximum possible CO_2e reduction due to on-site renewable systems in these buildings is 30% in Building X and 60% in Hotel Y. The bulk of this theoretical reduction would be due to the use of biofuel trigeneration. Hotel Y could also potentially achieve a 33% reduction using a combination of biomass boilers and photovoltaics.

If the use of biofuel or biomass is not possible, due to various constraints including access for delivery, noise from delivery trucks, storage constraints, air quality emission standards and/or high fuel costs, then the maximum possible savings reduce to 14% in Building X and 28% in Hotel Y. It is important to note that these estimated savings are based on installing the largest possible renewable energy systems in the buildings. The systems are likely to be smaller in practice (and the CO_2e savings consequently lower) when capital costs, energy demand, export tariffs, maintenance costs, integration with HVAC systems and available floor/roof space are considered in more detail.

ZERO CARBON USING PHOTOVOLTAICS?

To make the 10 storey Building X 'zero carbon' using photovoltaics alone would require 1,750 MWh of electricity to be generated to offset the total building emissions (gas and electricity) of 105 kgCO_2e/m^2. The required area of monocrystalline PV panels at 10° tilt is 15,000 m^2 which equates to 1.5 m^2 of panel area for every 1 m^2 of floor. Figure 7.14 shows the area of roof needed (24,500 m^2). The capital cost of the 2.3 MWe system (excluding the roof) would be around £2.3 million (£230/m^2 of GIA).

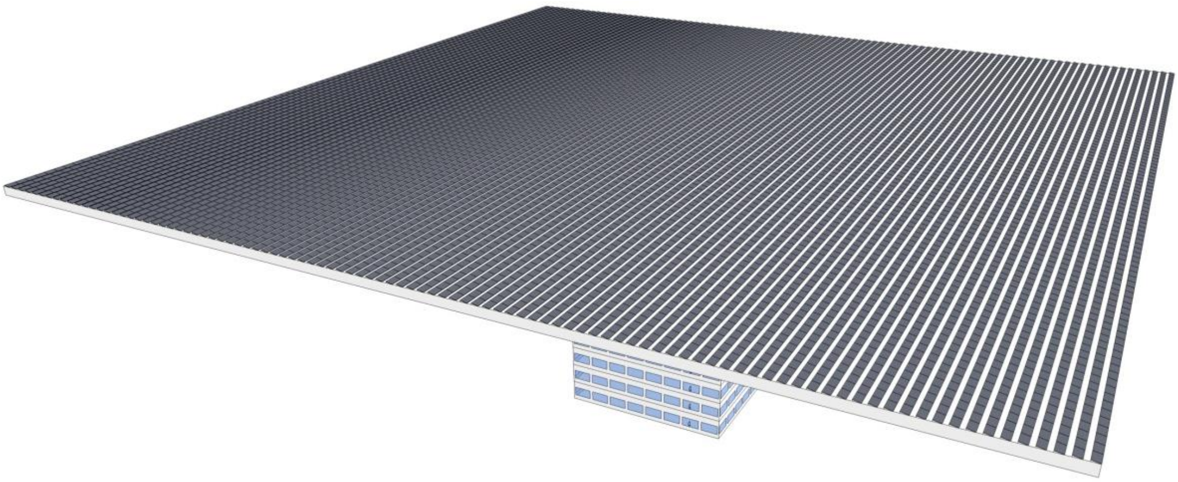


Fig 7.14 **Area of PV panels to make Building X zero carbon**

The cost of carbon (£ per tCO_2e) for each system was calculated using the net present cost of the capital and energy costs / savings (ignoring government incentives) divided by the CO_2e savings over a 15-year period. In 2014, the European Union Emissions Trading Scheme (EU ETS) put the cost of carbon at less than £10 per tonne. The only system with a carbon cost less than £10 per tonne is gas CHP – and that is not a renewable. Most systems cost over £100 per tonne.

The purpose of this chapter is to put into perspective the maximum contribution that renewable and low carbon energy systems can make to reducing CO_2e emissions in typical non-domestic buildings. Some of the savings are disappointingly small – but it is important to have a realistic understanding of costs and benefits so that money can be invested in solutions that deliver the maximum CO_2e savings.

On-site renewables should be selected based on the technical and commercial viability on a particular site – and not according to some arbitrary planning requirement. Government incentives are usually required to make many renewable systems financially viable compared to fossil fuel alternatives. This is because the latter are also often subsidised by governments and have the benefit of almost a century of market development.

Making it easy for building owners and developers to invest in off-site systems, and have the renewable energy attributed directly to them (and ensuring that the renewable energy benefit is not sold twice), would encourage investment in more cost effective renewable solutions.

A green building is not an energy guzzler with a few visible solar panels, wind turbines or biofuel deliveries. Adding renewable energy systems should be the icing on the cake of an efficient building, and not lipstick on a gorilla.

SHOULD LIQUID BIOFUEL BE USED IN BUILDINGS OR IN TRANSPORT?

Transport accounts for 20 to 25% of the UK's CO_2 emissions, primarily through the consumption of fossil fuels – petrol and diesel. Liquid biofuels are a finite resource – there is a limited amount of land available for their production. Second generation biofuels, such as recycled cooking oil, have an even more limited supply. Should this limited resource be used in buildings or in transport? The answer is obvious – use it in vehicles. Liquid biofuel CHP in commercial offices is a vanity exercise to score points in rating tools and tick arbitrary local planning requirements – it is a waste of resources and money.

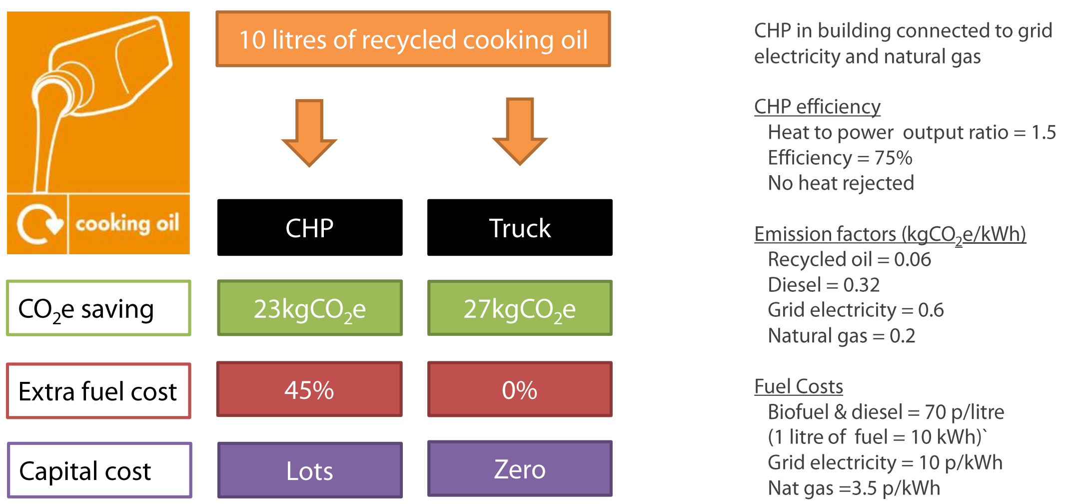


Fig B **Comparison of CO_2 and costs between using biofuel in CHP and vehicles**

8. Lower carbon materials

Chapter 8 describes a pragmatic approach to reducing the embodied carbon of buildings and fit-outs, providing guidance on how to specify low-carbon materials and products and how to reduce CO_2e emissions associated with construction activities.

This chapter looks at methods of reducing the embodied carbon by focusing on the components and materials that have the biggest impact. At the top of the list is concrete, which typically accounts for between 30 and 50% of the initial construction embodied carbon; however, fit-out components, which may at first glance appear minor, can also have a significant impact over the life of the building if they are replaced regularly.

Figure 8.1 shows an embodied carbon breakdown for a new 21-storey steel framed office building with three basement levels over a 60-year period. It assumes that the façade and central building services are replaced after 30 years and that a fit-out takes place every 15 years (including carpets, ceilings, partitioning and tenant services). The purpose is to illustrate the principle that embodied carbon must be considered over the lifetime of the building and not just during the initial construction. The lifespan of components should not be ignored.

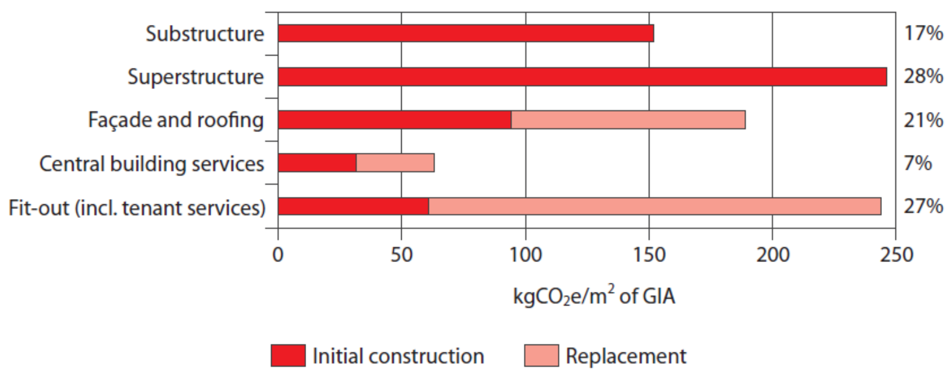


Fig 8.1 Indicative embodied carbon over 60 years for a 21-storey steel framed office building with three basement levels

This chapter provides detailed guidance on reducing the embodied carbon of the following products and activities, which typically account for over 70% of the embodied carbon in buildings: concrete, steel, timber, masonry, windows and curtain walling, carpets, plasterboard, furniture, external paving and construction process / waste.

The process of reducing embodied carbon can be summarised as follows:

- Design for low carbon by considering the type of materials, their efficient use and their expected life.
- Choose low carbon versions of the materials.
- Minimise wastage on site and design for deconstruction (reuse/recycling at end of life).

One of the best ways in which designers and contractors can reduce embodied carbon is to challenge the supply chain to deliver lower carbon products. While the building industry can be notoriously conservative and slow to innovate, the power of purchasers to influence a market should not be underestimated. Reliable and transparent product labelling, such as Environmental Product Declarations (EPDs), will be essential to facilitate this.

Measuring and reducing the embodied carbon of buildings is still an emerging field and further research is required. Data is patchy, has a wide range of uncertainty (+/-30% is as good as it gets) and is usually only available for generic materials rather than products from specific suppliers. Until EPDs are widely available it will be difficult to compare the embodied carbon of one supplier's product with that of another. In the interim, common sense has to be applied instead.

The specific steps to reduce embodied carbon will depend on the building design, the materials used and how they are assembled. In all cases there will be opportunities to make savings. Targeting the biggest components will deliver the majority of the benefits. On a typical office building project, by adding all these savings together, embodied carbon reductions of up to 20% should be achievable with little or no additional capital cost. These measures can be identified in the early design stages of projects using simple assessments (similar to developing a preliminary cost plan).

The debate surrounding steel versus concrete structural frames is an unwelcome distraction; both types have similar overall embodied carbon footprints and both will continue to be used in buildings for economic and technical reasons.

REDUCING CONCRETE ECO_2

The primary material to focus on is concrete, which is found in all office buildings. It is probably the only material where the project team can directly control the ingredients used in the product and, by doing so, reduce an office building's initial embodied carbon by between 5 and 10%.

The most commonly used cement is Portland cement, which accounts for around 95% of the embodied carbon of a typical C28/35 grade structural concrete mix. The simplest way to reduce the embodied carbon of concrete is to reduce the amount of Portland cement required in a mix by:

- avoiding over specification of strength
- using cement replacements
- use of admixtures.

Further detail on how to do this is given in the book.

9. Green travel

Chapter 9 discusses how building owners and tenants can encourage the use of greener modes of transport for commuting and business travel.

Chapter 4 showed that the CO_2e emissions due to people commuting between home and work can be greater than the CO_2 emissions due to the energy consumption of their office building. How people choose to get to work is primarily determined by the time, cost and convenience of their transport options. The location of a building, including its proximity to cheap car parking and a reliable public transport network, will have more influence than the number of cycle racks provided in the basement.

Figure 9.1 shows how people travelled to work in the UK in 2009. Cars account for two-thirds of all commuting trips, and for 85% of these trips the car had only one occupant. The data is reasonably consistent across the UK, except in London where car use drops to 37% and public transport increases to 48%. For business trips, the use of cars increases to 78% in the UK.

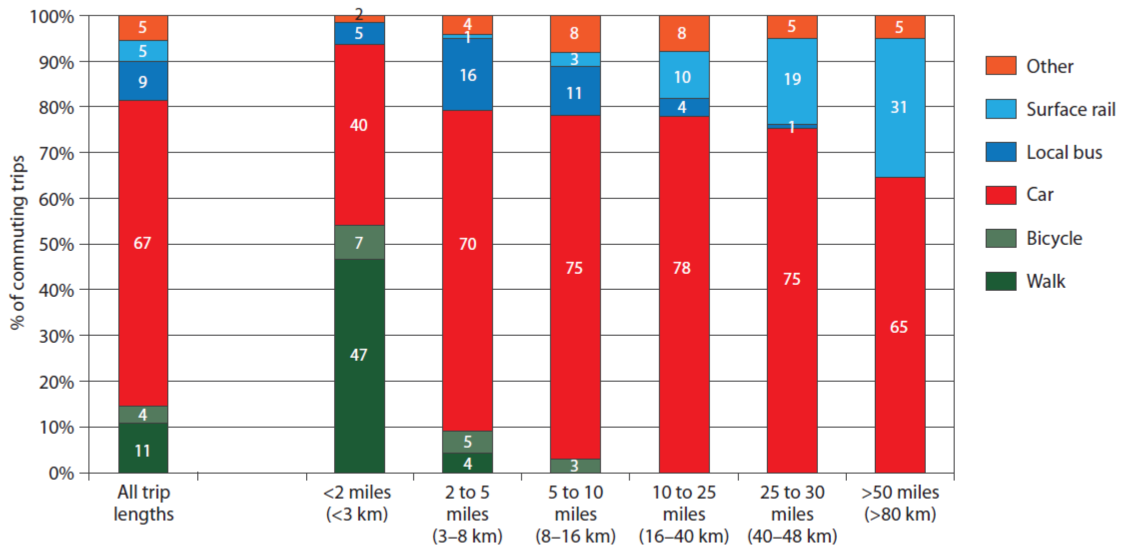


Fig 9.1 Mode of travel for commuting trips in the UK for different trip lengths (source: DfT, 2011)

This chapter provides examples of initiatives to encourage walking, cycling, using public transport, using more efficient vehicles & car sharing and telecommuting. Many of the initiatives are relatively simple, and have other benefits including improving health and well-being (no one gets fit sitting in a car), reducing congestion and accidents, and saving money.

10. Making the business case

Chapter 10 outlines the potential ingredients to incorporate into a business case for investment in low-carbon buildings and refurbishments, including cost of occupancy and occupants, financial incentives and building value.

To radically improve energy efficiency and reduce its carbon footprint, the property industry needs to make changes which will require investment in both capital and people. In making a business case for such investment it is necessary to demonstrate to the decision makers in an organisation a compelling financial return, preferably with low risk and worthwhile additional benefits, such as enhanced corporate reputation.

In many organisations it may be difficult to recognise and account for revenue savings arising from capital expenditure in energy reduction. An additional challenge in commercial offices is the question of who gets the energy cost savings, landlord or tenant, which will depend on the leasing arrangements.

This chapter does not describe how to prepare a business case. Instead, the aim is to summarise some of the main drivers for, and barriers to, greener and lower carbon office buildings that might be incorporated into a business plan presented to decision makers. Table 10.1 (overleaf) summarises the different categories discussed.

Which ones apply will depend on who is preparing the business case and who the decision makers are – refer to Figure 10.3.

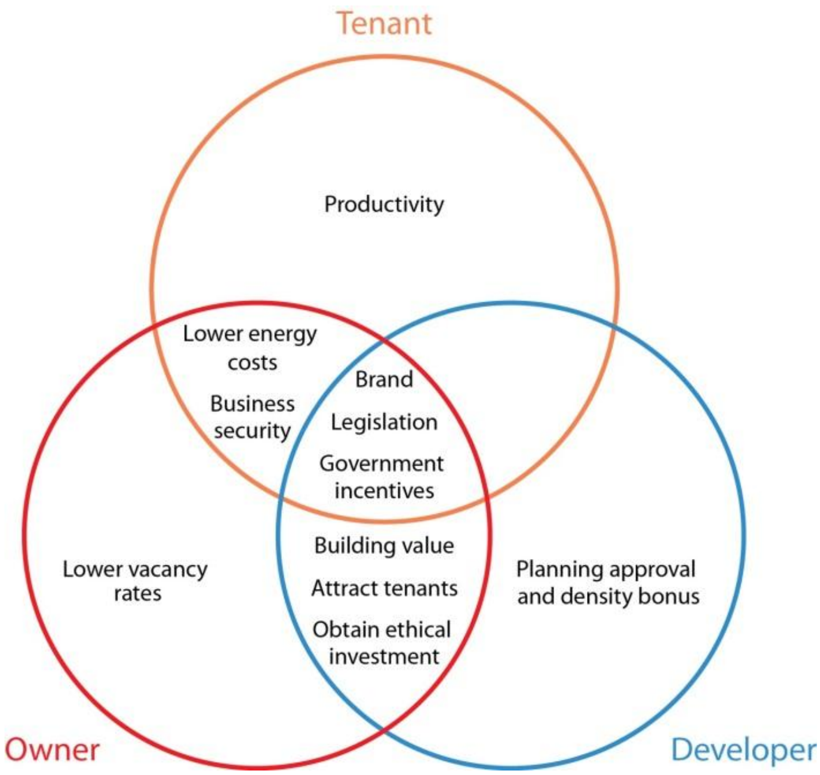


Fig 10.3 Summary of business case issues for tenants, developers and building owners

	Category	Comments
1	Legislation	More stringent building regulations, the requirement to obtain minimum energy ratings for sale/lease of office buildings and mandatory reporting of energy performance will influence the value of existing buildings as well as the cost of new buildings and refurbishments.
2	Government incentives	Financial benefits can include direct payments (e.g. grants, feed-in tariffs), low interest green loans, enhanced capital tax allowances, reduced business rates and property tax relief. Faster planning approvals and density bonuses can also provide financial incentives to build greener.
3	Cost of occupancy	Rising energy costs and carbon taxes will increase the cost of occupying a building. A 25% reduction in energy consumption in a typical 10,000 m^2 air conditioned office building can deliver savings of £7/m^2. Assuming that energy costs increase by 5% per annum this is £0.9 million over 10 years.
4	Cost of occupants	People are by far the largest annual cost in an office building, and also have a significant influence on energy consumption. A green office building in London, which contributes to improving the occupant's productivity by 1%, can deliver annual cost savings of £40/m^2 (more than the total cost of energy). This equates to £4.8 million over 10 years in a 10,000 m^2 building with 750 people.
5	Brand	A trusted brand has value, although this is difficult to quantify. Brand is important to developers, designers, contractors, landlords and employers (tenants).
6	Tenant requirements	Most large corporate and government tenants have set sustainability and energy targets for the properties they build, purchase or lease. Whether they enforce these when making decisions on property is open to debate.
7	Building value	The amount, if any, of increased financial value in sustainable buildings (the 'green premium') is not yet proven. However, there appears to be broad agreement in the UK property industry that poorly performing buildings will have lower value (a 'brown discount') compared to those built to more stringent energy standards.
8	Business security	Will the building be adaptable to a changing climate and does it rely on cheap energy to be affordable to occupy?
9	Ethical investment	This is still a relatively minor driver in the property industry – but is its time coming?

Table 10.1 Summary of issues to consider in a business case for a low carbon building

A business case could be a detailed cost benefit analysis of a lighting upgrade made by the facility manager in a building, or it could be a strategic business case regarding the long-term composition of an international property portfolio. Whatever the project, it should be possible to make a compelling business case for investing in energy and carbon reduction in buildings – it is just a case of putting the right ingredients together.

Further Information

Appendices

The appendices to the book are published in electronic (pdf) format and can be downloaded for free from www.whatcolourisyourbuilding.com. They provide calculations, background information and further detail on the topics covered in the ten chapters of the book.

Part 1: What Colour

- A Energy, CO_2 and climate change
- B CO_2e emission factors
- C Energy consumption data
- D Operating energy rating methodology
- E Embodied carbon data
- F Transport carbon data
- G Whole carbon footprint benchmarking

Part 2: Changing Colour

- H Reducing operating carbon
- I Renewable energy data
- J Materials data
- K Travel planning
- L Financial incentives
- M Building X and Hotel Y

Information Papers & Benchmarking Tool

Over 30 information papers are referenced in the book and appendices. They contain technical details, additional data and/or research on specific topics and can be downloaded from the website www.wholecarbonfootprint.com. A simple whole carbon benchmarking tool can also be downloaded from the website. It combines operating, embodied and transport carbon into a single metric. Various default values for embodied and transport carbon are provided if these are not known for a specific building to place operating CO_2 emissions in context.

About the author

David Clark has over 20 years' experience designing buildings in the UK and Australia, is chartered in both structural and building services engineering, and has specialised in sustainability since 2002. He was the principal author of the first Green Star rating tool in Australia and has worked on numerous award-winning green buildings. David is a Partner with Cundall Johnston & Partners and, in addition to working on building designs, leads their corporate sustainability and R&D activities. His twitter address is @David_H_Clark.

About Cundall

Cundall Johnston & Partners LLP ("Cundall") is a multi-disciplinary engineering design practice with offices in the UK, Europe, MENA, Asia and Australia. They have a strong reputation for the sustainable design and analysis of buildings which is recognised through numerous awards. Cundall was the first consultancy to be endorsed as a One Planet Company by BioRegional. For further details on their services, projects and office locations refer to www.cundall.com.