Sustainable Building Design

Sustainable Building Design: Principles and Practice

Edited by

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Foreword by Dave King: Architect and Founder of Shed-KM

Whilst this book will be of obvious interest to designers, it will also help those in other disciplines to understand how buildings can be made to lessen their environmental impact and yet provide high-quality, valuable space.

Sustainability has to be at the heart of 21st century design – but is informed by, and will, in turn, inform, other associated technical, conservation, aesthetic and financial considerations. Bringing these building blocks of any incipient scheme to the notice of designers and students is sometimes difficult, but nevertheless rewarding when achieved. This book by David Shiers and Miles Keeping provides not only an extremely comprehensive catalogue of useful references and methods, but also illuminating sections tracing the progress of projects from early design onwards through the realisation process. Here, architectural and engineering solutions are analysed from first sketches to provide evidence of the underlying science against the more elusive, but necessary quotient of inspirational design.

This process, part practical, part intellectual (as evident in Arup's strong research base) never loses the thread of the necessity to take environmental impact, in both resourcing and construction, absolutely seriously from generative thoughts through to completion.

As a textbook, this volume excels – using case studies as exemplars, brings the design process into focus by providing a tantalising insight into how a factual knowledge base can be utilised to provide a backbone to the excitement of actual design.

The research and the many digital learning links used here are arranged within a constructed academic framework and so will be of great help to students of the built environment as an easy-to-access source of information. Perhaps more importantly, many of the ideas and projects presented here will, for the property professionals of today and tomorrow, provide inspiration. This book is to be recommended to students and practitioners alike.

Acknowledgements

As well as to all of the team members who were involved in the many projects referred to here, thanks are due to:

At Arup: Ann Marie Aguilar, Michael Beaven, Mick Brundle, David Pearce, Mark Fisher and Malcolm Smith.
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1

Introduction

Miles Keeping[1], David Shiers[2], Ann-Marie Aguilar[3] and Michael Beavan[3]

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> *The term 'Total Architecture' implies that all relevant design decisions have been considered together and have been integrated into a whole by a well organised team empowered to fix priorities. This is an ideal which can never - or only very rarely - be fully realised in practice, but which is well worth striving for, for artistic wholeness or excellence depends on it, and for our own sake we need the stimulation produced by excellence.*
>
> Ove Arup, 1970, http://publications.arup.com/publications/o/ove_arups_key_speech.

Achieving excellence in design and construction is, arguably, an even greater challenge today than when Ove Arup first began practice as an engineer and architect in the 1920s.

Now, as then, each project design and construction team must tackle what is a unique combination of variables, particular to an individual building or piece of infrastructure. Site-specific technical and aesthetic considerations, the functional needs of the eventual users, financial and contractual constraints, macro-economic conditions, Building Codes and legal requirements (all of which are subject to constant change), mean that every new project is, in effect, a *prototype*.

But as awareness has grown of the potentially devastating effects of contamination, atmospheric emissions and the finite nature of many natural resources, now, at this point in the 21st century, designers and project managers must also help to achieve the international community's wider goals of reducing negative environmental impacts arising from human activity. The increasing interconnectedness of societal systems around the world means the design and management of buildings and infrastructure must respond not only to local and national ecological issues but also to global environmental concerns.

It could be said that the principles of sustainability have long been at the heart of the best architecture and engineering projects. Even before the term 'green' was applied to buildings, many designers tried hard to strike a responsible balance between the natural and the built environments and to meet the needs of the present, whilst leaving a

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positive legacy for future generations. However, today there is an expectation that *all* property professionals put sustainability at the heart of their projects and indeed, there is legislation in many parts of the world to ensure that this is the case. But how is the environmental impact of property to be minimised whilst at the same time ensuring that buildings also meet the high aesthetic, practical and financial expectations of stakeholders?

In order that Built Environment students and practitioners can better understand how to meet today's sustainability objectives, this book sets out to explain some of the techniques used by leading architects and engineers.

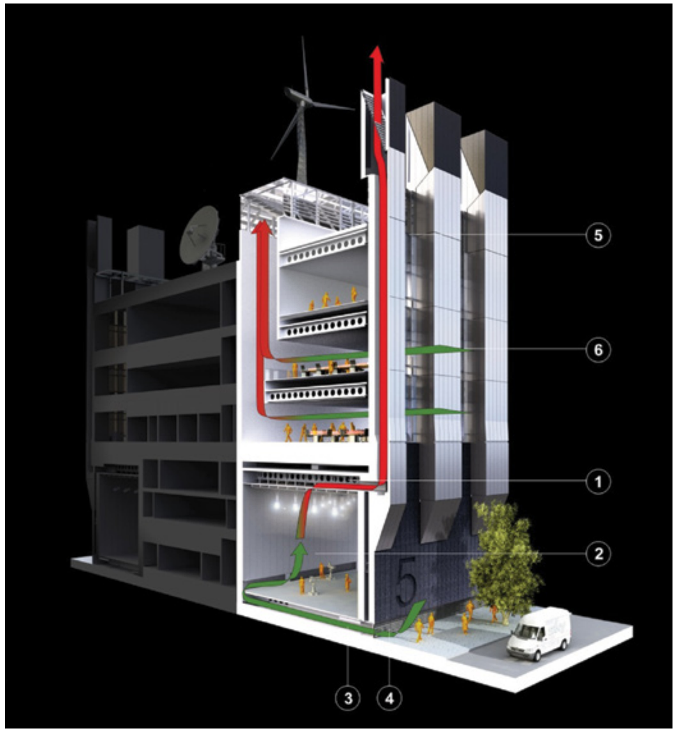
Sustainable or 'green' building can be defined as 'design and construction which seeks to minimise negative environmental impacts in an integrated and holistic way over the whole life-cycle of the project'. Green projects will commonly have the following features:

- Maximised opportunities to re-use existing buildings, structures and materials through recycling, refurbishment, conversion, adaptation and extension.
- Utilised and/or enhanced existing public transport networks to reduce dependency on fossil-fuel-powered vehicles as part of a carefully planned transport strategy.
- Minimal negative site impact through sensitivity to site ecology, flora and fauna.
- Minimal consumption of energy from non-renewable sources both during construction and post-occupancy through the use of energy-efficient lighting, heating, 'natural' ventilation and cooling systems and by careful orientation and façade treatments.
- The use of materials which have the lowest possible environmental impact and which have been responsibly sourced as part of a carefully planned maintenance, repair, reuse and replacement strategy.
- Responsible water management both in use, through 'grey water' capture and in disposal, through Sustainable Urban Drainage Systems (SUDS).
- Carefully planned waste management strategies during both construction and after occupation.
- Minimal use of harmful chemicals in the construction and post-occupancy management of the project through careful specification of construction material preservation treatments, cleaning fluids, paints and solvents as well as substances which may harm human health, wildlife and insects.
- High standards of air quality and natural lighting to ensure healthy indoor environments for living and working.
- Respectful, transparent and inclusive engagement with local community and stakeholder groups and a positive contribution to the public realm.

Environmental Assessment

Low environmental impact projects would also normally have an independently certified 'green badge' which measures and verifies good practice. Licensed assessors evaluate energy efficiency, levels of carbon emissions, transport impacts, the use of low impact materials etc. against a set of metrics derived from Life Cycle Assessment (LCA) data by leading environmental researchers, architects and engineers within organisations such as the Building Research Establishment (BRE) and the US Green Building

1. Waste heat from the studio lights rises through the studio ventilation chimneys
2. As waste heat rises, a small negative pressure is set up in the studios
3. This pressure drop overcomes the resistance of the sound attenuators, drawing in fresh cool air from the exterior
4. Exterior intake grilles
5. When external conditions are in appropriate for natural ventilation, mechanical ventilation and cooling of the studio spaces can be implemented using the same chimneys.
6. Office natural ventilation chimney follows similar principles



Principles of 'Natural Ventilation' as illustrated at the Sky TV studio, London, UK. *Source:* Image courtesy of Arup Associates; http://www.arupassociates.com/en/case-studies/sky-studios/.

Council (USGBC). Assessment programmes including *BREEAM* (the Building Research Establishment Environmental Assessment Method), *LEED* (Leadership in Energy Efficient Design) in United States and *Green Star* in Australia are now widely used with some 538,200 BREEAM certified developments globally and almost 2,230,600 buildings registered for assessment since its launch in United Kingdom in 1990 (BRE, 2016).

Commonly used green design and assessment tools:

- BREEAM: http://www.breeam.com/
- LEED: http://www.usgbc.org/leed
- Green Star: http://www.gbca.org.au/green-star/green-star-overview
- Passivhaus: http://www.passivhaus.org.uk/
- The Home Quality Mark: http://www.homequalitymark.com/
- SKA: http://www.rics.org/uk/knowledge/ska-rating-/
- The Green Guide to Specification: http://www.brebookshop.com/documents/sample_pages_br501.pdf & https://www.bre.co.uk/greenguide/podpage.jsp?id=2126

Other sources of guidance for practitioners and clients include:

- Blue Angel Ecolabelling: http://www.ecolabelindex.com/ecolabel/blue-angel
- Managing Agents Sustainability Toolkit: http://www.betterbuildingspartnership.co.uk/sites/default/files/media/attachment/bbp-managing-agents-sustainability-toolkit.pdf

The use of environmental scoring systems has become a popular way of marketing the 'green credentials' of the buildings and master plans of property owners, occupiers and other stakeholders. Such badging is seen increasingly as an indicator of, and is synonymous with, high-quality design and a progressive, responsible approach to social and environmental concerns.

Users of these tools should be aware that although their methodology strives to be objective and robust, as with any scoring system, marking criteria, parameters, performance standards, the reliability of the underpinning data used and the level of importance attributed to particular issues are subject to debate. For example, when scoring the 'greenness' of a building project, is *resource use* (say, of water) more or less important than *waste management* issues?

No environmental design tool will be without its critics, but as long as methodologies are transparent, the ways of measuring green performance will remain useful and, at the very least, will encourage designers, engineers and constructors to move in the right direction.

Typical BREEAM Categories against which the environmental performance of a project are assessed:

Management	*Health and Wellbeing*
Project brief and design Life cycle cost and service life planning Responsible construction practices Commissioning and handover Aftercare	Visual comfort Indoor air quality Safe containment in laboratories Thermal comfort Acoustic performance Safety and security
Energy	Transport
Reduction of energy use and carbon emissions Energy monitoring External lighting Low carbon design Energy-efficient cold storage Energy-efficient transportation systems Energy-efficient laboratory systems Energy-efficient equipment Drying space	Public transport accessibility Proximity to amenities Cyclist facilities Maximum car parking capacity Travel plan
Water	Materials
Water consumption Water monitoring Water-leak detection Water-efficient equipment	Life cycle impacts Hard landscaping and boundary protection Responsible sourcing of materials Insulation Designing for durability and resilience Material efficiency

Waste	Land use and ecology
Construction waste management Recycled aggregates Operational waste Speculative floor and ceiling finishes Adaptation to climate change Functional adaptability	Site selection Ecological value of site and protection of ecological features Minimising impact on existing site ecology Enhancing site ecology Long-term impact on biodiversity
Pollution	
Impact of refrigerants NO_x emissions Surface water run-off Reduction of night-time light pollution Reduction of noise pollution	

Source: BRE Global, BREEAM UK New Construction non-domestic buildings technical manual 2014 Reference: SD5076 – Issue: 4.0

EPCs and DECs

From 2005 onwards, the requirement for an Energy Performance Certificate (EPC) indicating the energy efficiency of the fabric and the building services of most individual commercial and residential properties was rolled out in United Kingdom. Following the introduction of EPCs, certificates showing the energy use and efficiency of the *operational* performance of many types of commercial property also became a requirement in the form of a Display Energy Certificate (DEC) (Figure 1.1).

Taking the form of an ‘ecolabel’ similar to that found on white goods, these ratings are a legal requirement for most buildings and part of a 2002 EU Directive programme to reduce energy use in buildings (EU Directive 2002/91/EC; http://www.energysavingtrust.org.uk/home-energy-efficiency/energy-performance-certificates; https://www.gov.uk/buy-sell-your-home/energy-performance-certificates).

As with any designed system, actual performance in its operation is not always that which the designers had anticipated. In the case of buildings, we very often see a significant performance gap between design intent and operations. This is because of the innocent misunderstanding that designers have of how the building will be operated once it is occupied. In other words, design tools and metrics inadequately account for building occupiers’ behaviour.

When new buildings are commissioned, regulations dictate that they need to be certified as having achieved a certain level of energy efficiency. In United Kingdom, for example, EPCs are mandatorily required for the construction, sale and letting of buildings and are meant to demonstrate the building’s energy performance. But the problem with EPCs is that they assess only the theoretical performance of the building and its design intent, but do not measure the energy actually consumed in the building once it is occupied. Consequently, buildings which appear to be energy efficient very often are not.

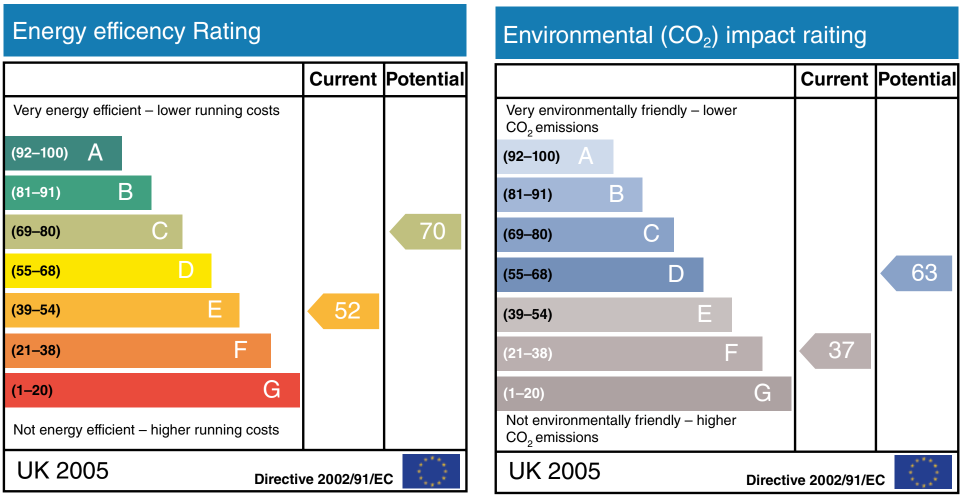


Figure 1.1 Typical Energy Certificates. *Source:* https://en.wikipedia.org/wiki/Energy_Performance_Certificate used under CC BY SA-3.0 https://en.wikipedia.org/wiki/Wikipedia:Text_of_Creative_Commons_Attribution-ShareAlike_3.0_Unported_License

Evidence of this performance gap has been provided by the Better Buildings Partnership and JLL (JLL, 2012) which found that because there is such a variation in occupiers' energy demands (which can depend upon factors such as energy loadings of fitted-out space, intensity of energy use and occupiers' operating hours), pre-occupation building energy assessments have no correlation to actual energy consumption. In this study of over 100 commercial buildings in London, it was discovered that buildings with the lowest energy asset rating (G) performed better in terms of energy intensity than buildings with the best energy asset rating (A). Equally, a building with a high-energy asset rating (B) performed worse than most buildings with lower energy asset ratings (C to G) (http://www.jll.co.uk/united-kingdom/en-gb/Research/JLL_BBP_tale_of_two_buildings.pdf).

The problem is designers are driven by the use of design tools and metrics which do not account for occupier behaviours. Until such time as designers are required and able more accurately to determine the realistic performance of a building with occupiers in it, we shall not be able to design buildings with suitable levels of energy efficiency and will therefore continue to produce poorly performing buildings (some of which might even win awards for their energy-efficient design!) and lock-in carbon inefficiency for future generations to deal with.

If designers are to improve their practice in this area, they will need to invest more time and thought in undertaking suitable post-occupancy evaluations (POE) and analysing the results so as to inform future design decision-making.

Materials and Components

The life-cycle impacts of construction materials are measured in a design tool known as the *Green Guide to Specification*. In *Green Guide*, the environmental performance of materials is rated using an A+ to E scale so that specifiers can see at a glance which material or component option (Element Type) provides the lowest negative environmental impact (http://www.brebookshop.com/documents/sample_pages_br501.pdf).

Life Cycle Assessment (LCA)

LCA is a method of evaluating the environmental impacts of construction materials and components over their full life cycle, from the 'cradle to the grave'. This means taking into account all the impacts associated with the production and use of the material from the first time there is a human intervention (normally the extraction and transport of the raw materials) until the last (the fate of the materials in the waste stream).

Undertaking LCA is a detailed and complex process involving many measures of the environmental impacts associated with the manufacture, transport, maintenance, repair, replacement and disposal of materials over a building's lifetime (normally taken as 60 years).

LCA involves calculating an extensive range of impacts including:

- The mass in tonnes of all the materials used in manufacture (including packaging)
- Production and transport energy (measured in terms of mega joules of fossil fuel depletion and kg of climate changing CO_2)
- Emissions from manufacturing, energy use, transport and disposal (e.g. CO_2, methane, nitrogen oxides and sulphur dioxide)
- Water extraction (measured in m^3)
- Ozone depletion (measured relative to the equivalent amount of ozone-depleting CFCs)
- Human toxicity (using the EU toxicity model *USES-LCA* which describes the effects of toxic substances on the environment using a common reference unit related to the substance dichlorobenzene – a toxin and acknowledged carcinogen, see https://en.wikipedia.org/wiki/1,4-Dichlorobenzene)
- Waste disposal (in terms of tonnes of solid waste produced)

These data are normally obtained via environmental databases (sometimes held by national governments), trade associations and the manufacturers themselves.
See: Ecoinvent, http://www.ecoinvent.org/database/database.html

Environmental Legislation

In many jurisdictions of the world, the regulation of the environmental performance of buildings has developed most quickly since the 1980s. In those early days of performance regulation, the focus was usually upon the health and safety of building occupiers and builders. As our understanding of sustainability risks has developed, we now better appreciate how buildings are responsible for significant amounts of resource depletion, contributing to climate change and leading to other environmental degradation and so regulation has encompassed these issues.

At a supranational level, the European Union (EU) has taken significant steps in developing our understanding of the impact which buildings have on our environmental capacity. Given the highly developed nature of EU member states, it is not surprising that its building sector is one of its most resource-consuming economic sectors. The EU suggests that over their whole life cycle (i.e. from the extraction of materials, through the manufacturing of construction products and the construction process itself, to building use and maintenance) buildings in the EU account for approximately:

- 1/2 of extracted materials
- 1/2 of energy consumption
- 1/3 of water consumption
- 1/3 of waste generated

These issues form the basis of environmental regulation of buildings in most jurisdictions because national and municipal governments and other policy-forming bodies are cognisant that they will need to deal with resource efficiency across buildings' life cycles, particularly relating to energy, water and waste, and that such regulation will only increase in importance (http://ec.europa.eu/environment/eussd/buildings.htm).

During the design and construction phases of building procurement, design professionals will need to consider each aspect of locally applicable regulation in the following areas:

- Operational performance
  - Targets and standards for reducing energy and water use and waste generation (e.g. Minimum Energy Efficiency Standards)
  - Building regulations relating to thermal and water efficiency (e.g. Part L of the Building Regulations)
  - Taxes applicable to the occupation and ownership of buildings (e.g. Climate Change Levy)
  - Requirements to monitor and improve building performance (e.g. Energy Savings Opportunity Scheme)
  - Incentives to improve building performance (e.g. Feed-In Tariffs)
- Building Assessment
  - Providing evidence of attainment of a specific level of green building assessment (e.g. BREEAM or LEED), for example, to secure planning permission
  - Certification of certain aspects of building performance (e.g. an EPC)
- Waste
  - Duty of care regulations relating to the transportation, storage and recycling of waste, especially waste classed as 'hazardous' (e.g. Waste Transfer Notices)
- Materials
  - Requirements to declare the environmental characteristics of individual products (e.g. Environmental Product Declarations)
  - Requirements to demonstrate the responsible sourcing of materials (e.g. certification against Programme for the Endorsement of Forest Certification (PEFC) or the Forest Stewardship Council (FSC) criteria).

Since the end of the 20th century, the focus of much regulation has understandably been on seeking to tackle climate change and the security of energy supplies, both through adaptation and mitigation. There is no doubt that regulation in the area of climate change mitigation will increase in terms of the demands placed upon building owners and developers and thus their professional advisers. In this regard, designers of buildings must ensure that they are able to forecast likely regulatory change relating to operational carbon emissions as well as embodied carbon within buildings. A key aspect of this will relate to how building designs and refurbishment plans avoid locking-in carbon inefficiency by specifying carbon-inefficient materials and systems which do not enable a flexible approach to reuse and recycling.

Corporate Social Responsibility – CSR/ESG

As regulators have increasingly turned their attention to sustainability-related matters and climate change in particular, we have witnessed many building owners and developers becoming more attuned to the need to demonstrate an approach to good corporate citizenship which goes beyond regulatory compliance. Corporate Social Responsibility (CSR) grew out of philanthropic motivations of business people and in the latter part of the 20th century as business and social interests became more closely aligned; we saw stakeholder expectations for a more strategic approach. In the 21st century, many real estate owners and developers have formalised their approach to CSR and integrated it more firmly within their day-to-day operations as Environmental, Social and Governance (ESG) activities.

Building designers need to understand their clients' ESG motivations which will have significant implications for the work they do in designing and delivering new buildings and overseeing the refurbishment of the existing building stock. We can divide these motivations or drivers into three categories:

- *Internal drivers* Many organisations acknowledge that if they can demonstrate meaningful attendance to ESG issues, they will thereby demonstrate an appropriate approach to risk management in their operations and delivery of their product – buildings. This has obvious appeal to their shareholders and other stakeholders, such as lenders, joint venture partners and insurers, and arises because their buildings should be characterised by being less costly, less likely to be in breach of regulations, have greater market appeal and suffer reduced obsolescence rates.

  Another motivation for businesses to promote ESG factors within their organisations relates to human resources factors, in the belief that having recognisably good ESG policies and procedures will be attractive in the recruitment and retention of employees, particularly millennials.
- *Market drivers* Owners and developers of commercial properties clearly appreciate that in order to maximise returns they need to provide buildings which will appeal greatly to target occupiers and purchasers. We have witnessed very significant growth in demand for buildings which demonstrate high levels of environmental performance and in themselves enable occupiers to display their own preferences for strong corporate ESG performance.
- *Regulatory drivers* As discussed earlier, regulatory change relating to building design and performance has grown significantly in recent years and is likely to do so further as resources become scarcer and climate change worsens. The importance of this as a historic driver of improved ESG performance by building owners and developers should be obvious. What is less clear, perhaps, is how the evolving regulatory context

will lead to changes in the ESG-related demands of building designers' clients – it is likely that an even greater focus on carbon efficiency as well as transparency in environmental assessments and reporting will exercise the minds of building designers in future.

Those real estate organisations which can ably demonstrate that they have a high-quality approach to ESG issues internally, tend to be those which set the bar when it comes to the quality of their products and the standards which their project partners, including building designers, have to meet in order to help their clients produce market-leading buildings. Examples in this regard are provided in British Land's Sustainability Brief and Hermes Investment Management's Responsible Property Investment Report 2015 (http://www.britishland.com/sustainability/governance-and-policies/policies; https://www.hermes-investment.com/wp-content/uploads/2015/10/Hermes-Real-Estate-Responsibilitiy-in-practice.pdf).

To suggest that all building owners and developers have sufficiently strong approaches to ESG would be a woeful underestimate of the current situation, however. So, whilst designers need to understand their clients' motivations in this regard, they will also need to ensure that they provide sufficient leadership in this area in order that their clients' interests and sustainability are both best served. In this respect, they should first be sure that their own approaches to ESG are fit for purpose but in trying to help their clients improve ESG approaches, they might be well advised to examine the approaches of some market-leading building owners and developers such as those discussed herein.

'Green Value'

Understanding how to produce buildings with lower environmental impact is necessary and of course vital to the work of today's and future design teams. The science relating to buildings' effects upon the Earth's systems and thus the need for lower impact and more environmentally efficient buildings is well documented. We are increasingly seeing efforts to reduce the environmental impact of buildings being scientifically based on the need, for example, to meet specific carbon emission targets which should contribute to a sustainable future.

It is essential to also recognise that many buildings are financial assets – they represent investments to owners who, particularly in the non-domestic property world, often do not occupy the buildings themselves. Rather, the buildings are assets which produce income and are tradable commodities. In this context, it is important to understand the motivations of such owners and particularly to appreciate how financial markets have responded to the changing need for green buildings.

Real estate developers and owners seek to maximise the value of their assets and understand that value is influenced by a variety of factors. These factors have traditionally included location, quality of design and construction, obsolescence rates, lease terms, operating expenses, liquidity and the quality of tenants. Appreciating how to balance the relative merits of these when determining the value of a building has long been part of the art of valuation.

But as sustainability-related issues have increasingly become important because of regulatory change and thus a greater number of green buildings have come to the market, valuers have had to understand how these traditional market factors can be seen differently and that new factors must also be taken into consideration. Furthermore, they need to appreciate how greener buildings have increased in demand amongst particular groups of investors and developers, as well as occupiers, namely those who are interested in top quality or 'prime' buildings.

Figure 1.2 usefully summarises determinants of value of green buildings as they relate to the different stakeholders.

There have been a number of studies which purport to demonstrate that, in essence, the greener the building, the higher the value and it can be tempting to accept this as a modern maxim. Of course, the truth is rather more nuanced than this and, indeed, some studies, although few, have even tried to demonstrate that the opposite can be

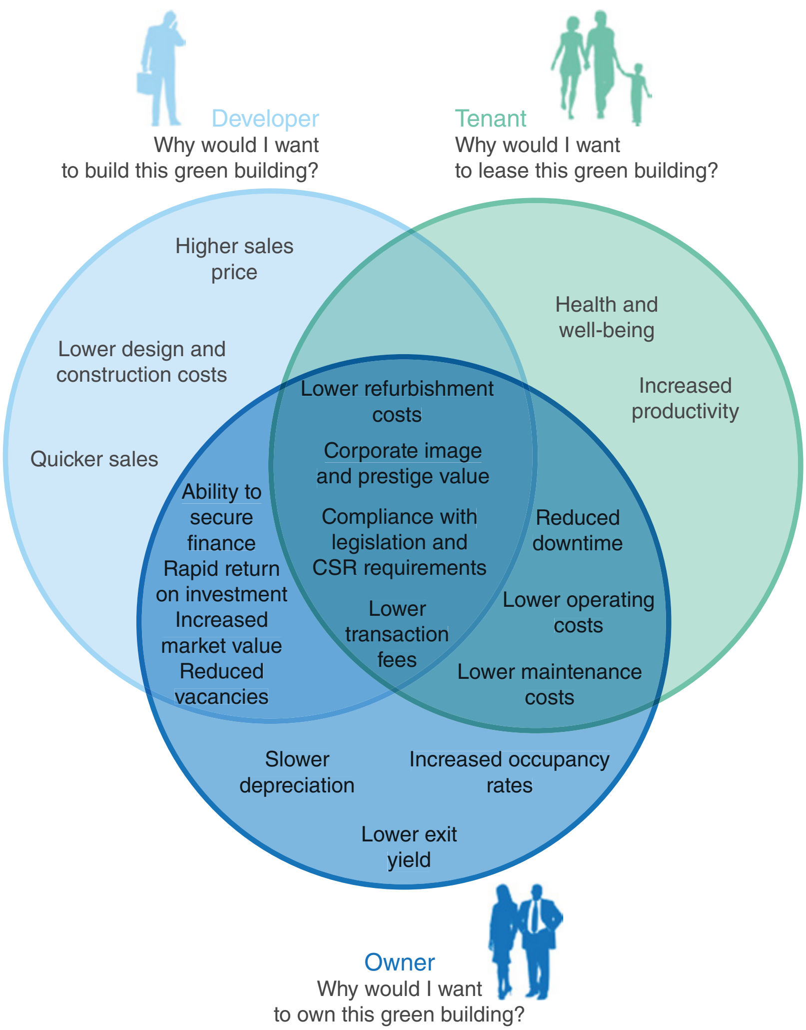


Figure 1.2 WGBC (2013) The Business Case for Green Buildings. *Source:* http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf

the case. But working through the evidence, both empirical and anecdotal, tells us quite a compelling story that buildings which are more valuable than their otherwise comparable peers tend to be greener buildings. In other words, better quality and certainly 'prime' buildings are nearly always green buildings. This is very valuable knowledge for landlords and developers who commission new buildings and refurbishments and are eager for their buildings to be let out or sold more quickly and have slower rates of obsolescence, quicker rates of rental growth and higher occupancy rates.

Study of the green value phenomenon began in the early 2000s. The following provide a useful analysis of the key issues:

- Eichholtz, P., Kok, N., Quigley, J.M. (2010) "Sustainability and the dynamics of green building: New evidence of the financial performance of green office buildings in the USA". Research Report. RICS Research.
- Fuerst, F. & McAllister, P. (2011) "The impact of energy performance certificates on the rental and capital values of commercial property assets". Energy Policy. Vol 39 No 10, pp.6608–6614.
- Newell, G., McFarlane, J. & Kok, N. (2011) "Building Better Returns. A Study of the Financial Performance of Green Office Buildings in Australia." University of Western Sydney; Australia and University of Maastricht, Netherlands.
- Pivo, G. & Fischer, J. D. (2010) "Income, value and returns in socially responsible office properties". Journal of Real Estate Research. Vol 32 No 3, pp. 243–270.
- Sayce, S., Sundberg, A. & Clements, B. (2010) "Is Sustainability Reflected in Commercial Property Prices: an analysis of the evidence base". Kingston University; London.
- World Green Building Council (2013) "Business Case for Green Buildings: A Review of the Costs and Benefits for Developers, Investors and Occupants". WGBC. (http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf accessed 02-09-2016).

The Design Process

This book makes extensive use of case study examples provided by a number of leading designers including Arup Associates. By studying the work of influential and innovative architectural and engineering firms and the forward-thinking clients and construction companies with whom they work, it is hoped that students and practitioners can better understand how today's built environment challenges can be met.

From the founding of the firm, Arup have strived to be as socially and environmentally responsible as possible in all their actions (they have been actively engaged with humanitarian and charitable causes for almost 70 years) whilst at the same time often leading the way in the innovative architectural and engineering solutions which they have devised.

The firm was founded in London in 1946, as Ove N. Arup Consulting Engineers; a practice where professionals of diverse disciplines could work together to produce projects of greater quality than was achievable by their working in isolation. In 1963, Ove Arup, together with the architect Philip Dowson, formed Arup Associates; a unique, multi-disciplinary design studio which combined all disciplines in a single team with a common method and philosophy.

Arup's *Unified Design* Principles*:*

- Unified design delivers a holistic architecture driven by a sustainable agenda.
- Designs must achieve whole life sustainability which reaches beyond obvious notions of 'energy saving' to maintain culture and tradition through a re-prioritisation of the importance of human experience, the senses and memory.
- Whole life sustainability places people first. It enhances the cultural value systems found within different locations rather than creating modernist models that expect people, cities and places around the world to behave in identical ways.
- Design must evolve from the user's perspective at a human scale both for the individual and the community.
- Unified design is a radical, pan-disciplinary, collaborative approach that focuses on people-oriented design from the outset, through the unified vision of architects, engineers, artists, sculptors, social scientists and others. The design process should maximise the potential of collective creativity.
- Design solutions are generated from fundamental research and experiential goals.
- Optimum solutions are found through exploratory parallel studies.
- There are no standardised solutions for any site, context or use.
- There is no pre-determined visual style; each project finds its own unique expression.
- Each project aims to discover rich and subtle environments which respond to all the senses.

(Arup Associates, 2008)

Whilst each construction project may be, in effect, unique, the underlying principles of the design process vary little. The same fundamental steps are followed for any project whether it is large-scale infrastructure or small-scale product design: *analysis, conceptualisation, synthesis, verification (testing), resource planning* and *execution.*

In simple terms, the requirements of the brief are established and the main constraints and challenges of the project identified (*analysis*); technical and logistical solutions are developed addressing the problems to be solved (*conceptualisation*) which embody the values and philosophy of the project team and stakeholders (*synthesis*); prototypes, models or other representations are created in order to test the solution and to refine the design (*verification*); the materials and resources needed to deliver the design are organised and the project is built and handed over (*resource planning and execution*).

It is important to remember, however, that the handing over and occupancy of a project are not the end point in any design process. One of the key principles of the sustainable agenda is to assess 'whole-life' impacts, performance and costs. *Life Cycle Assessment* or *Life Cycle Analysis* (LCA) and *Quality Assurance* protocols now ensure that the performance of all buildings and products should be monitored throughout their entire life cycle and must be continually reviewed and improved.

For many architects and engineers, the design process is not linear. Rather, it is often thought of as being circular because problems are rarely either solved or indeed fully

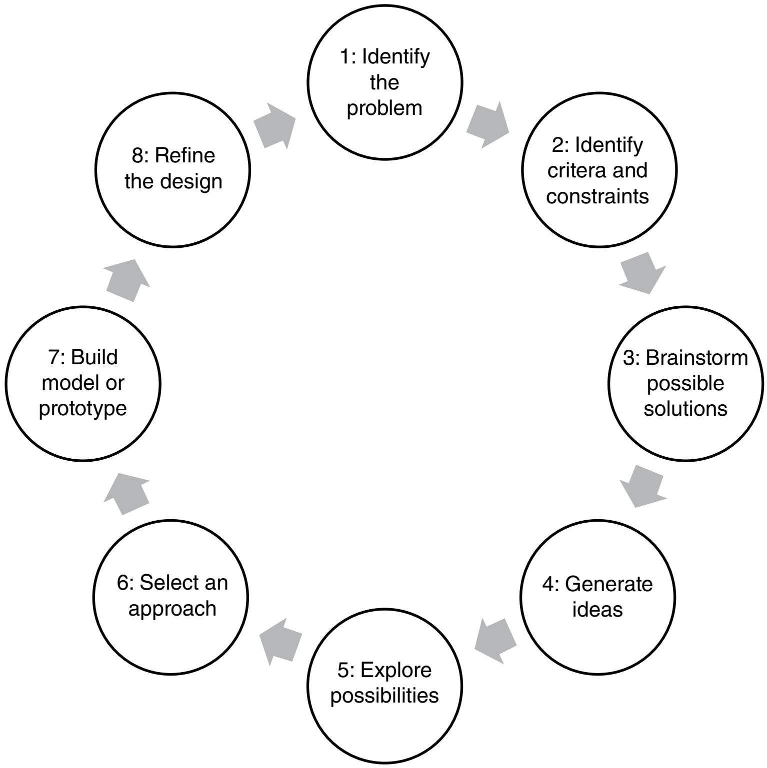


Figure 1.3 The Basic NASA Engineering Design Process. *Source:* NASA, https://www.nasa.gov/pdf/630754main_NASAsBESTActivityGuide6-8.pdf

understood first time, but require several rounds of analysis and problem solving during the development of a project.

An explanation of a classic Design Process can be seen in these 'work stage steps', first developed by NASA to solve design problems in the space programme (Figure 1.3):

1) Identify the Problem e.g. how do we design the…which will…?
2) Identify Criteria and Constraints i.e. specify design requirements (criteria) and list the limits on the design due to available resources and the environment (constraints).
3) Brainstorm Possible Solutions - sketch, model, describe and explain ideas as the team discusses ways to solve the problem. Graphics and descriptors should be quick and brief.
4) Generate Ideas – develop two or three ideas more thoroughly by creating more detailed descriptors e.g. 3-D drawings or models which are accurate and where parts and measurements are clearly labelled.
5) Explore Possibilities – the developed ideas should be shared and discussed among the team. Pros and cons of each idea are recorded on or next to the descriptors and drawings.
6) Select an approach work in teams to decide which of the proposals best solves the problem and write a statement to explain why the team chose that solution. This should contain reference to the criteria and constraints set out at Stage 2.

7) Build a Model or Prototype - construct a scale or full-size model based on the drawings.
8) Refine and Improve the Design - examine and evaluate the prototype against the criteria and constraints at Stage 2. Enlist or present to others to review the solution and help to identify the changes which need to be made (Figure 1.3).

(NASA, 2016) https://www.youtube.com/watch?v=c0wh4GxoL28&list=PLiuUQ9asub3TqAiPRqhOjudMTPeMzwPtL&index=6

However, it is perhaps more helpful to visualise the design process as an upward *spiral*, where the idea, building or product is in an ongoing state of evolution and improvement in response to identifying and then solving technical, aesthetic, financial and procurement-related problems at an ever-more detailed level.

The idea of a constantly improving 'Quality Spiral' was developed by an Engineer, Joseph Juran, in the 1950s. His experience as a practitioner had enabled him to see how a more systematic, yet dynamic approach to design might make consistent, repeatable and reliable outcomes more likely rather than using more intuitive approaches to problem-solving and those where solutions would often become fixed at an early stage (https://www.youtube.com/watch?v=OEN48Vz7KRA; https://www.youtube.com/watch?v=umkh4pUnAhg; https://www.google.co.uk/?ion=1&espv=2#q=joseph%20juran%20quality%20spiral).

Problem solving in building is an inter-disciplinary, collaborative process. *Source:* Image courtesy of Arup Associates.

Every Arup project is a response to a specific client and particular site and viewed as a new opportunity with no pre-defined style. Instead, always working from the inside out, through multiple parallel studies, the practice seeks to find an optimum solution which responds to the external environment but which is never driven by image alone. Every project results from a level of client collaboration and research and there are no standard solutions.

Arup have developed tools to help their designers identify and analyse the key requirements of clients and building occupiers. By using surveys, workshops, interviews and

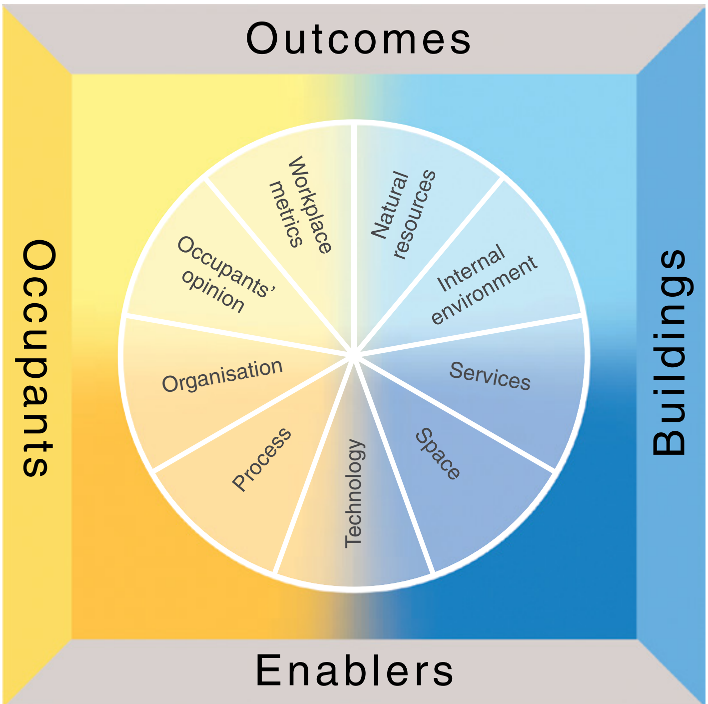


Figure 1.4 The Integrated Workplace Performance Tool. *Source:* http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1

other data analysis tools, the needs and priorities of the building users, their productivity issues and relationships with social and physical environments can be identified and addressed in the design of buildings.

For example, the *Integrated Workplace Performance Tool* (IWP) was developed by Arup in 2004 specifically to consider client workplace and productivity issues (Figure 1.4).

The nine sectors shown here can affect the performance of the building and are spilt into 'soft' aspects (left side), physical aspects (right side), those which can be assessed (outcomes) and those which can be both assessed and changed (enablers).

IWP is used as a structuring tool to gather a clear understanding of the client requirements and to develop guidelines for the design of effective and flexible facilities that support the productivity and well-being of their occupants, while also reflecting the organisation's culture. The IWP methodology is valuable not only in structuring the data collection process and analysing the information gathered, but also in communicating ideas within the final document issued to the organisation's teams.

The tool was derived from Professor David Canter's work to support architects in developing design briefs for various types of project. It is conducted by asking a small sample of people across an organisation, in a structured way, to indicate their understanding and experience of the various departments and sections that make up the whole organisation (exploring the atmosphere and style of those departments and sections in ways that relate to the social and physical arrangements that enable them to be effective). This process reveals the adjacencies and relationships within the organisation and indicates the significance of the spatial relationships that characterise the organisation at various levels of detail.

The first phase is to develop a design framework for the workplace and to give the brief a development context and focus. The second phase captures and analyses the responses of the occupiers before, in the third phase, Arup Associates (partnered with Arup's organisational behaviour consulting team) develop the final brief.

The IWP framework allows the workplace to be considered as individual aspects in context or in a holistic manner. Such evaluations provide deeper analysis and understanding of the psychological and social representations individuals hold regarding their environment, and enable this to be translated into recommendations for that environment's design. An iterative workshop is normally carried out to develop the design and layout of the environment from the users' perspective, normally a half-day focus group workshop held with a small, yet representative sample of users meeting with representatives of Arup Associates.

See Case Examples at:

Ibid. http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1

The *Socio-Technical Systems* (STS) approach illustrated below was developed by Professor Chris Clegg in 2008 in association with Arup Associates for use in schools and offices projects (Figure 1.5). This tool utilises workshops and focus groups in order to develop the design and layout from the client's perspective, based on six characteristics of the built environment.

The STS model uses a structured approach to elicit the users' personal views, needs, and perspectives on six fundamental characteristics of the built environment (people, processes, technology, vision and goals, culture and the building itself), to effectively and reliably inform the design. Workshops provide a means of piloting the approach and also serve to highlight where additional focus may be required for ensuring that all important and relevant information continues to be drawn out and considered in the design.

These exercises are intended to deliver general schematic representations of the overall psychophysical structure of the organisation, as perceived by individual respondents and various sub-groups of respondents. These schematic representations appear similar to the 'bubble diagrams' that feed directly into many architectural briefs, but unlike those hypothetical frameworks for selecting building form and environmental characteristics, these were derived directly from those who have day-to-day experience of the organisation. As tools to support the design process, these diagrams prove valuable to the design team and to the client in understanding perceptions of the business and its functionality, and consequently, the spatial relationships within the architecture that directly respond to these business and functional needs.

It is important that clients feel positive about this type of collaboration as sensitivities and dynamics between directors and executives, front line and support staff from different parts of an organisation can be challenging. Using an inclusive, but strictly academic approach, Arup have learned that the designer's mediating role in social and organisational mapping exercises between these different worlds is critical (Figure 1.5).

In 2011, Arup introduced the Sustainable Project Appraisal Routine programme (SPeAR); a tool which appraises projects based on key themes such as transport, biodiversity, culture, employment and skills (Figure 1.6).

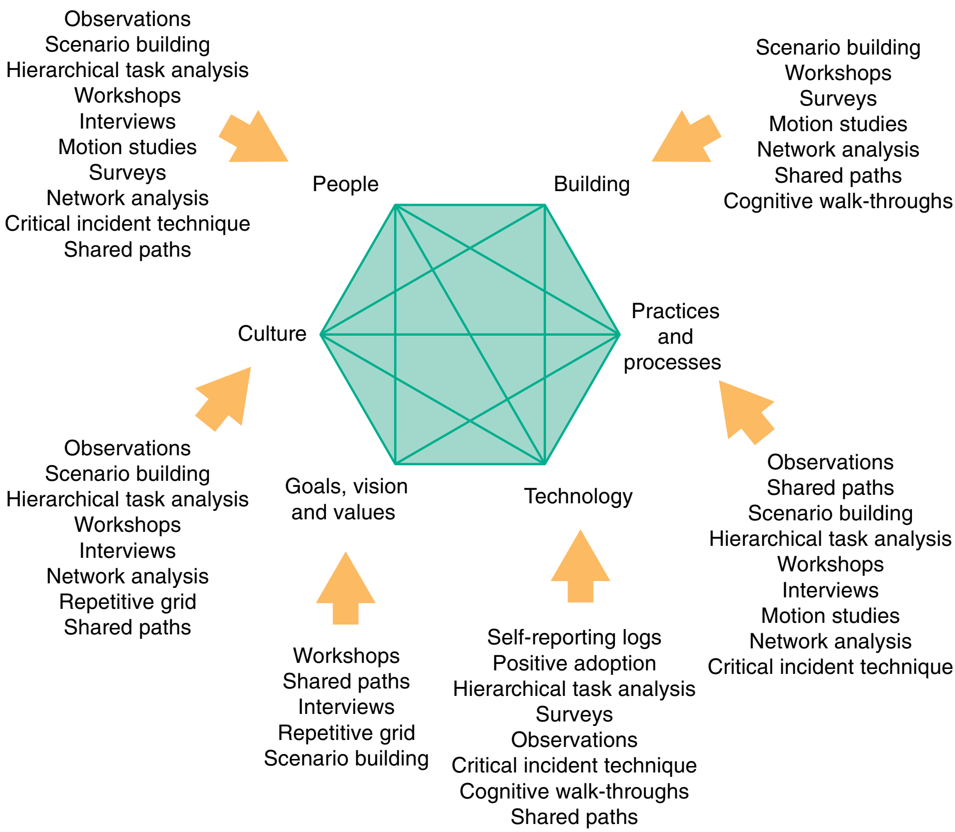


Figure 1.5 The Socio-Technical Systems (STS) design tool; developed by Prof. Chris Clegg and Arup in 2008. STS and the other tools used by Arup, identify the most relevant design decisions so that they can inform the overall solution. *Source:* Ibid. http://publications.arup.com/publications/t/the_arup_journal/2010/the_arup_journal_2010_issue_1. Also see: https://www.google.co.uk/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=Arup+integrated+workplace+performance+tool

Results are presented graphically on the SPeAR® diagram – a traffic light system indicates performance in each area. The software also generates a tabulated summary of the input data so the process is robust and auditable (http://www.arup.com/Projects/SPeAR.aspx; http://www.arupassociates.com/en/exploration/unified-design-research-unit-people-centred-design/).

The tool covers all kinds of projects including design and delivery of new infrastructure, master plans and individual buildings. It helps to monitor and evaluate project performance and support informed decision-making throughout a project. Early on it might be used to carry out a baseline appraisal, gap analysis or identify key performance indicators. During the design stage it can be used to compare and assess the pros and cons of various design options, identify key risk areas, guide decision-making and stakeholder participation, and assess the implications of design changes. It can also be used to undertake evaluation upon project completion, and during operation, which can inform organisational learning and approaches to future projects (Figure 1.6).

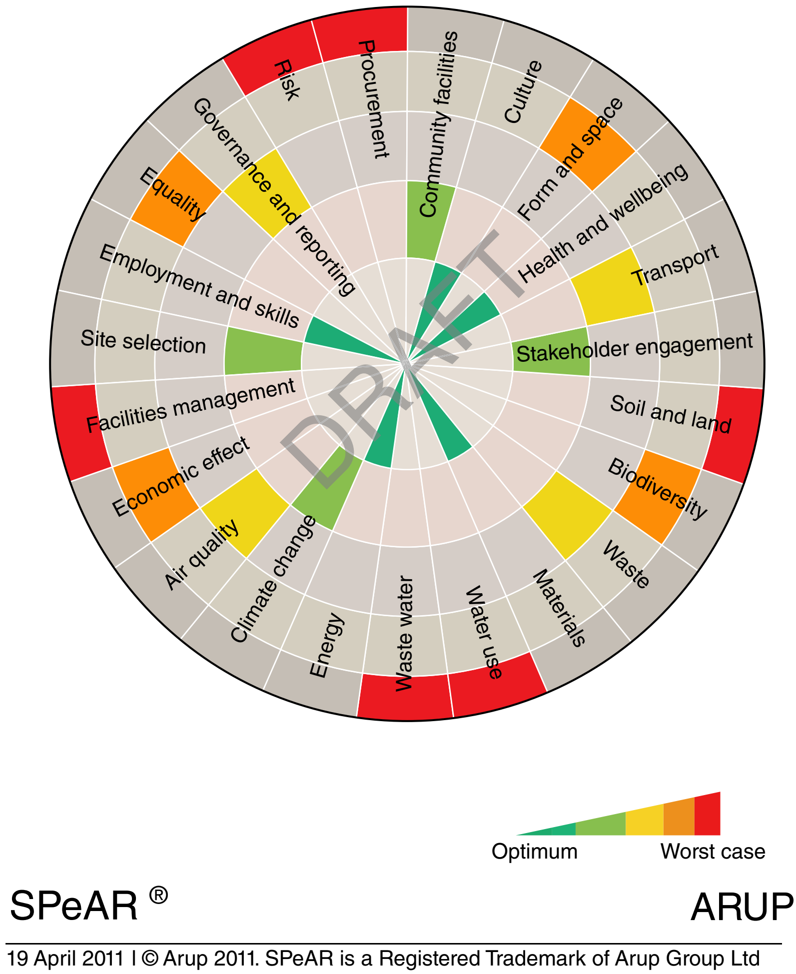


Figure 1.6 The Arup SPeAR tool. See demonstration at: http://www.oasys-software.com/spearapp/app/flash.html

All of the tools described above show the workplace as a system of inter-related elements and provides a comprehensive framework of factors to be considered when designing a new building. It is the integration of the solutions arrived at for each of the problems identified which can lead to a unified design or, in the words of Ove Arup, *Total Architecture.*

The Arup projects described in this book are evidence of both a dedication to quality and to *Total Architecture* whereby all relevant disciplines and design decisions are integrated into a unified whole. This approach has evolved over time from the firm's initial focus on structural design in projects such as the Sydney Opera House, through to the work of Arup engineer Peter Rice on the Centre Pompidou in Paris and the recent engineering and architectural works at the Beijing and London Olympics.

The holistic and inclusive approach of the Arup practice today can be attributed in part to its unconventional ownership structure. It is managed 'in trust' on behalf of its entire staff who are in effect, partners in a collective enterprise, dedicated to the pursuit of Ove Arup's stated goal of excellence.

Cost and programme considerations are critical factors in the development of Total Architecture. Rarely seen as an obstacle to achieving original and innovative design by Arup, construction cost targets have played an important part in the design process and have helped to create integrated, sustainable solutions which meet the needs of clients, users and the community. Buildings and infrastructure which are delivered over-budget or late are often the result of less than rigorous analysis, design or procurement planning. They may also have been wasteful in their construction and are therefore less sustainable.

> *The skill of an Architect and the excellence of an architectural solution are measured by the ratio between what is obtained, and what is expended.*
>
> Ove Arup, Speech to the Architectural Association of Ireland, 1954
> *Source:* http://elastemgzn.com/mysteries-of-the-mall/

Also see:

Arup Associates; *Making Green Pay*, http://publications.arup.com/publications/a/a2_magazine/a2_magazine_issue_2

In the 21st century, what is *expended* can be taken to include not only financial cost but also the natural resources and human commitment invested in projects and the negative impacts on habitats and ecosystems. What is *obtained* from a building must also be measured in more than monetary value; there must be net-gain socially, environmentally and architecturally.

In this context, however, it is of vital importance that we recognise the need to deliver buildings which are consistent with an environmentally sustainable future and specifically those which help to mitigate climate change. As per the discussion in Chapter 4, scientific consensus on climate change has been achieved and the buildings sector needs to play a leading role in reducing global temperature rises.

Many countries have set targets for carbon emissions reduction (e.g. the UK Climate Change Act 2008 has set United Kingdom a legally binding target of an 80% CO_2 emissions reduction by 2050) and will need to regulate and encourage their citizens, businesses and other organisations to play their part in meeting such commitments. In December 2015, 196 countries signed the Paris Agreement at the United Nations Climate Change Conference, COP 21. The Agreement sets a goal of limiting global warming to less than 2 °C compared to pre-industrial levels and to attempt to limit the temperature increase to 1.5 °C. In order to achieve the 1.5 °C goal, global emissions will have to achieve a rate of zero before 2050. These estimates of necessary emission levels are based on scientific estimates and these need to translate into decision-making at the national and sub-national levels, including within the decisions and actions that businesses make.

Historically, whilst recognising the significant role that buildings play in contributing to climate change, building owners and developers have set somewhat arbitrary targets for energy and emission reductions. Very often these targets have been based on estimates of reductions which can be made most easily (the 'low-hanging fruit' analogy) rather than on a systematic approach to helping to meet scientifically agreed targets such as the 1.5 °C goal suggested by COP 21. This needs to change if a sustainable future is to be achieved and building designers will have to understand the role that science-based targets will play as the basis for setting long-term goals for greenhouse gas emission reductions. Science-based targets have been defined as:

> *Targets adopted by companies to reduce GHG* [greenhouse gas] *emissions are considered 'science-based' if they are in line with the level of decarbonisation required to keep global temperature increase below 2°C compared to pre-industrial temperatures, as described in the Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). [Applies to the 4th or 5th AR of IPCC as well as modeling of the IEA.]* http://sciencebasedtargets.org/

Land Securities has developed science-based targets which, it considers, will bring emission intensity from its properties – including its tenants – into line with an 80% reduction by 2050 (http://www.landsecurities.com/websitefiles/Sustainability_Report_Online_2016.pdf).

In the absence of anything like the sort of regulation needed to meet objectives such as that of COP 21 and in the context of a growing population and economic growth, it will be increasingly important for all to consider how best such targets can be met through voluntary action before potentially harsh corrective regulation needs to be implemented. It will certainly be in businesses' best interests to undertake early action and perhaps in the buildings sector particularly, given its significant contribution to carbon emissions and the longevity of its product.

Also see:

http://www.arup.com/homepage_cities_climate_change
http://publications.arup.com/publications/c/cities_alive
http://publications.arup.com/publications/a/a2_magazine/a2_magazine_issue_16
www.arup.com/~/media/Publications/Files/Publications/A/Arup_in_cities_v3.ashx

Whilst this book stresses the importance of a unified approach to design, the text is divided into six principal chapters; each addressing an important aspect of sustainable architecture and engineering:

- Master Planning
- Transport
- Energy
- The Building Envelope
- Environmental Services
- Materials

Each section may be read on its own or as part of a narrative which attempts to provide an overview of the sustainable design process.

Throughout the text, photographs, architectural and engineering drawings and diagrams, case examples as well as other data and information are often provided via web links. Whilst the main text sets out to explain the principles of property-related sustainability, it is intended that this book should also act as a portal to other sources where detailed information and further links can be accessed.

Bibliography

Arup, O. (1954) *Key Speech to the Architectural Association of Ireland*. The Irish Architect and Contractor.

Arup, O. (1970) *Key Speech to Arup Partners*, Winchester. Arup Publications (https://www.arup.com/-/media/Arup/Files/Publications/O/Ove-Arups-Key-Speech.pdf

Arup Associates (2008) *Unified Design*, John Wiley & Sons, London, pp. 20–21. http://eu.wiley.com/WileyCDA/WileyTitle/productCd-0470723319.html (accessed 14 June 2017).

Arup Associates; *Making Green Pay*, http://publications.arup.com/publications/a/a2_magazine/a2_magazine_issue_2 (accessed 14 June 2017).

BRE (2016) *Statistics on numbers of BREEAM Registered projects*, http://www.breeam.com/ (accessed February 2016)

BREEAM (2014) *UK New Construction Non-Domestic Buildings Technical Manual 2014*, Reference: SD5076 – Issue: 4.0. IHS and BRE Press.

Eichholtz, P., Kok, N. and Quigley, J.M. (2010) *Sustainability and the Dynamics of Green Building: New Evidence of the Financial Performance of Green Office Buildings in the USA*. Research Report, RICS Research.

European Union Directive 2002/91/EC

European Union Directive 2002/91/EC

Fuerst, F. and McAllister, P. (2011) The impact of energy performance certificates on the rental and capital values of commercial property assets. *Energy Policy.*, 39 (10), 6608–6614.

http://eandt.theiet.org/magazine/2016/06/ove-arup-exhibition.cfm?origin=EtOtherStories (accessed 14 June 2017).

http://www.oasys-software.com/spearapp/app/flash.html (accessed 14 June 2017).

https://en.wikipedia.org/wiki/Energy_Performance_Certificate (accessed 14 June 2017).

https://www.google.co.uk/webhp?sourceid=chrome-instant&ion=1&espv=2&ie=UTF-8#q=Arup+integrated+workplace+performance+tool (accessed 14 June 2017).

https://www.nasa.gov/pdf/630754main_NASAsBESTActivityGuide6-8.pdf (accessed 14 June 2017).

Newell, G., McFarlane, J. and Kok, N. (2011) *Building Better Returns. A Study of the Financial Performance of Green Office Buildings in Australia*, University of Western Sydney; Australia and University of Maastricht, Netherlands.

Ove Arup http://www.engineering-timelines.com/who/arup_O/arupOve13.asp (accessed 14 June 2017).

Pivo, G. and Fischer, J.D. (2010) Income, value and returns in socially responsible office properties. *Journal of Real Estate Research.*, 32 (3), 243–270.

Sayce, S., Sundberg, A. and Clements, B. (2010) *Is Sustainability Reflected in Commercial Property Prices: An Analysis of the Evidence Base*, Kingston University, London.

WGBC (2013) "The Business Case for Green Buildings": http://www.worldgbc.org/files/1513/6608/0674/Business_Case_For_Green_Building_Report_WEB_2013-04-11.pdf (accessed 14 June 2017).

2

Master Planning

Miles Keeping[1], David Shiers[2] and Malcolm Smith[3]

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Master planning is the generation of an overall development concept which incorporates the present and future use of land and buildings in a particular location. A master plan can be required for almost any scheme, ranging in scale from entire cities and 'New Towns' to development zones, business parks, city blocks or even a single site.

Master planning is needed for projects where:

- *regeneration* or *urban growth* is required
- *new settlements* are proposed
- there are multiple developers or landowners who require a coordinated, integrated development strategy
- a future major event is to take place which can be a catalyst for regeneration (such as the 2012 London Olympics)
- there is a need to protect assets such as *Conservation Areas*, *National Parks*, *Environmentally Sensitive* sites or *Areas of Outstanding Natural Beauty*
- there are complex issues between developers or landowners
- neighbourhood development has to be carefully managed for economic, social, conservation or community infrastructure reasons

An *understanding of place* is critical in the development of a successful master plan if it is to create a clear, consistent and sustainable framework for development and one which can respond to future changes in use requirements and the local environment.

See PAN 83; Planning Advice Note on Master Planning:

http://www.scotland.gov.uk/Publications/2008/11/10114526/2

Master plans can be devised by Urban Designers, Town and Transport Planners and Architects; usually in collaboration with a developer and in consultation with Local, Regional or National government, local businesses, community groups and other stakeholders.

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

The key stages in the development of a master plan normally include:

- Inception – establishing a clear brief of what is required, based on the needs and expectations of the stakeholders (the eventual users and the fundraisers of the project).
- Feasibility – following the appointment of a multi-disciplinary team to ensure that the requirements of the stakeholders are achievable, financially, practically and within the anticipated time frame.
- Design – based on thorough appraisal of the physical, social, environmental and economic constraints and opportunities of the site and through consultation with Local Planning Authorities, communities and business organisations. Detailed proposals are developed which can deliver the necessary architectural, transport, amenity and utility requirements of the project:
  – The physical aspects and constraints of the site including the topography, orientation, geographical and features or barriers such as rivers, rail and road networks and existing buildings must be taken into account in the initial phases of the design alongside any legal or planning restrictions.
  – Existing and possible proposed routes giving access to and from the development area are often the first master-planning issues to be addressed. Whether the context is urban or rural, pedestrian and road traffic access and circulation is of critical importance. It is the location of these routes which will provide the framework for development. In many schemes, it is along the principal routes to, from and across the site that the most significant buildings or features of the scheme are located. In some projects, the most important access roads are also given special visual importance by the creation of significant vistas and architectural or landscaping features.

In the typical master plan shown on the website below, the existing physical features of the site have informed the master planning of the scheme. Adopting formal, rectilinear road patterns on those parts of the site near existing city blocks (top left), the proposed road layout changes to respond to the curve of river and the existing main road at the bottom of the plan and to give a softer, more 'organic' edge to the river frontage, park, and landscaped lake. Ibid. http://www.scotland.gov.uk/Publications/2008/11/10114526/2.

The route leading to the footbridge across the river has been given special significance by making it tree-lined and running it across the entire site to link the town, the new development, the riverside path, river view and an existing park. The main access road to the scheme is at the bottom of the plan, designed to take the visitor directly to the main public realm features of this project – the ornamental lake, parkland and stream.

- In parallel with the development of an access and circulation strategy, 'zoning' and architectural design issues are normally addressed. Building use types (i.e. residential, commercial, industrial, etc.) are strategically located within the scheme and such issues as building heights, densities, massing and architectural style and types of materials are considered.

Regeneration – Master Planning in the Existing City

An example of how areas within an existing city are zoned for specific uses can be seen in the spatial master plan developed by the City of Bath as it sought to develop its Western Riverside area – a site with significant architectural heritage and conservation challenges and constraints (http://www.bathnes.gov.uk/sites/default/files/sitedocuments/Planning-and-Building-Control/Planning-Policy/SPDs/BWRSPD-Part2SpatialMasterplanPlan2-1to2-4.pdf).

On the plan 2.3, page 21, in the City of Bath, Western Riverside Area Summary Masterplan, the relationship between key pedestrian routes (shown by red dots), the three main vehicle access points (red circle/white arrow) public realm leisure/cultural activity areas (blue dotted circles), architectural landmarks (white star on purple background), proposed uses on the site (residential, retail/offices/leisure mixed use and the new offices for Wessex Water) are shown on this zoning diagram. Note how the proposed landmarks and public realm areas are located on the access and transit points and along the 'prime' river frontage in order to draw people to the site.

Property developers are always keen to get the most out of the land and buildings they own and measure this in terms of financial return. In order to maximise this, they will seek to ensure that any emerging local planning policy is favourable to development potential they may perceive and work with local planning authorities to try to achieve as successful a planning approval as possible. Within that context, developers will seek to derive as much utility from their sites as possible whilst recognising that providing a mixture of property uses and high-quality public realm is often likely to improve overall performance of a development scheme. It is for this reason that leading developers have policies which seek to provide for the amenity of residents and local workforces, a good example being British Land's "Places People Prefer" approach (http://www.britishland.com/; https://www.youtube.com/watch?v=CbgGVLrcdqs):

High-quality schemes such as British Land's Regents Place and Paddington Basin provide excellent examples of a mix of office, retail and leisure uses on urban sites.

On the City Core master plan for the Curzon Street neighbourhood of the City of Birmingham (http://bigcityplan.birmingham.gov.uk/wp-content/uploads/2010/08/Big-City-Plan-Part-2.pdf – pages 36 & 37):

> the designers propose new public realm open spaces for theatre and exhibitions etc. at the edges of the site (see plan at locations 7, 9, 10, 15–17) and improved public squares to provide retail and restaurants within the existing city blocks at the heart of the scheme (at 1, 4, 5, 11–13). Both devices are intended to attract visitors and to generate vibrant and commercially viable neighbourhoods.

Primary and local walking routes (shown in green and black dotted lines) are also identified on this plan, showing main access ways to and across the site as well as linking important transport hubs (Metro stops and rail stations). Identifying principle walking routes is important in identifying potential retail use along thoroughfares with good footfall and well-known retailers and restaurateurs can also be used as a magnet to draw people to parts of a scheme which might otherwise remain peripheral. The existing city blocks are shown in white and whilst others have been earmarked for regeneration (orange) or new development (pale blue). Improvements to some of the surrounding roads including making them less of a barrier to pedestrian access are shown in red.

Throughout the master plan, architectural massing, height, style and materials of proposed buildings as well as the design of public squares and thoroughfares, landscaping and street furniture are shown using CGI and visualisations

http://www.birmingham.gov.uk/cs/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-Disposition&blobkey=id&blobtable=MungoBlobs&blobwhere=1223546561368&ssbinary=true&blobheadervalue1=attachment%3B+filename%3D766661Curzon_HS2_Masterplan_Part_2.pdf

http://bigcityplan.birmingham.gov.uk/wp-content/uploads/2010/08/Big-City-Plan-Part-1.pdf

https://www.birminghambeheard.org.uk/development/birmingham-curzon-hs2-masterplan-for-growth/supporting_documents/Curzon%20HS2%20Masterplan%20Part%201.pdf.

New urban development schemes where pedestrians can move easily and comfortably between shops, restaurants, public amenities and (sometimes) residential districts along appropriately scaled streets, represent a relatively new approach to contemporary master planning. Whilst many traditional towns and historic city centres still retain their network of pedestrian friendly streets and public squares, an accessible, vibrant public realm provision has often not been a feature of large-scale master-planning development or regeneration over the last 80 years.

Throughout the 20th century, in particular in United Kingdom during the 1950s and the 1960s, many town and city centres were blighted by new large-scale commercial developments comprising huge, monolithic shopping centres, office blocks and multi-story car parks and by an approach to town planning which prioritised motor vehicles over pedestrians and speculative development over communities and small businesses. Existing urban blocks and streets were swept away to accommodate featureless, wind-swept expanses of wide, fast roads, flyovers and roundabouts and many of the problems associated with a desolate public realm (which can be seen in parts of cities like Birmingham) are still being addressed by city master planners today.

The origin of many of the problems epitomised by the worst of 1950s and 1960s master planning, lies in some of the 'Modernist' ideas developed in the early 20th century and widely adopted internationally after 1945.

The socially motivated pioneers of Modernism hoped that cities based on rationally planned grids of modular blocks utilising Industrial Age building techniques and materials, would deliver a utopian society with improved standard of living for all (http://architizer.com/blog/modernist-utopian-architecture/).

Believing that the political and economic structures of the 19th century had 'failed' (the carnage of the First World War being used as undeniable proof of this) and that the lavishly decorated, stylistic excesses of the past were socially divisive, many Modernists thought that the brave new world of the machine age, clean, honest and uncorrupted, held the key to a new, more democratic and happier life for all.

With its strict grid planning and extensive use of new building materials and technologies, Le Corbusier's 1925 scheme for Paris envisaged traditional streets and the historic city centre being largely demolished and replaced by modern 60-storey steel and concrete towers with metal-framed windows and glass curtain walling, each served by wide roads set in a vast, open landscape. These ideas were further developed and published in his book 'The Radiant City' in 1935 and were to become particularly influential in post-1945 master planning and development (http://www.archdaily.com/411878/ad-classics-ville-radieuse-le-corbusier).

As war-damaged buildings and poorer quality neighbourhoods were swept away in United Kingdom after the Second World War, so too was the historic urban grain of many towns and cities. The new large-scale, high-rise housing and office developments of the 1950s and the 1960s were often built on the sites of demolished small-scale, low-rise buildings, whilst traditional high streets were replaced by shopping malls adjoining multi-storey car parks served by wide dual carriageways, underpasses and elevated ring-road systems.

After cars became affordable for the average family in the 1950s and the 1960s and freight began to be carried by lorry rather than by an ageing railway system, road networks and car parking came to be the dominant considerations when master planning both existing and new towns and cities.

In the Radiant City, the separation of road and pedestrian circulation can be clearly seen in the architects' impressions. Pedestrian 'streets in the sky', exposed to the elements, are set in a vast, unrelieved concrete landscape of infinite perspective.

The photograph of the construction of Croydon Flyover in the 1960s below, shows how new road systems of dual carriageways and gyratories often cut through low-rise buildings and historic streets and neighbourhoods:

https://www.paimages.co.uk/image-details/2.13191762 (Press Association Archive)

See also: https://www.theguardian.com/cities/2015/may/27/the-magic-of-croydon-is-londons-punchline-having-the-last-laugh

Photographs of low-rise, compact Croydon in the 1930s: http://www.disused-stations.org.uk/c/central_croydon/

In the 1950s Britain, even when new road systems were planned only as part of a town's future development, temporary road systems and the threat of demolition could blight entire neighbourhoods for years (http://www.cbrd.co.uk/articles/croydon-ring-road/history.shtml).

Where urban regeneration or extension is required, there is inevitably a balance to be struck between renewing what may be impoverished, damaged or of poor quality and retaining those positive features of existing neighbourhoods which can provide social amenity and continuity.

Urban Renewal in History

There are many historical examples of large-scale urban renewal being planned and in some instances implemented, in the aftermath of natural disaster or in response to rapid social or political drivers. In Wren's plans for London after the Great Fire of 1666, Maia's re-planning of Lisbon after the earthquake of 1755 and in Haussmann's redesign of the centre of Paris in 1852, master plans were designed around grids of avenues and carefully arranged axes, vistas, squares, piazzas, public monuments and parks but also required parts of existing street networks to be demolished as regulations on sanitation (and even on the design of building frontages) were introduced.

See Wren's plan for London following the Great Fire at: http://www.londonancestor.com/maps/map-wren.htm
Wren's plan for London as visualised by the artist Paul Draper: http://www.draperdrawings.com

Also see:

http://londontopia.net/culture/art/great-london-art-sir-christopher-wrens-full-vision-fire-ravaged-london/
https://www.insightguides.com/inspire-me/blog/wrens-plans-for-a-new-london
https://en.wikipedia.org/wiki/Christopher_Wren

A plan of Haussmann's work in Paris (1853–1870) showing the boulevards and streets built by Napoleon III and Haussmann during the Second Empire can be seen at:

https://commons.wikimedia.org/w/index.php?curid=15714684
http://www.arthistoryarchive.com/arthistory/architecture/Haussmanns-Architectural-Paris.html
https://en.wikipedia.org/wiki/Rue_de_Rivoli#/media/File:Paris_as_seen_and_described_by_famous_writers_(1900)_(14804499333).jpg
https://commons.wikimedia.org/w/index.php?curid=455220

They also built the Bois de Boulogne, Bois de Vincennes, Parc des Buttes-Chaumont, Parc Montsouris and many smaller parks and squares, but in doing so, cut through some of the pre-existing fabric of medieval Paris. See the photo of The Rue St. Nicolas du Charonnet, one of the narrow medieval streets near the Pantheon on the Left Bank before its demolition and redevelopment (https://commons.wikimedia.org/w/index.php?curid=30709098).

The plan by Manuel da Maia and others (da Maia (1667–1768), Eugénio dos Santos (1711–1760) and Carlos Mardel (1696–1763)) for rebuilding the Lower Town of Lisbon after the earthquake of 1755 can be seen at the website below. Note the gridded street plan and its contrast with the more organic patterns of the original city shown on the right of the plan in pink.

https://commons.wikimedia.org/w/index.php?curid=19182281
https://en.wikipedia.org/wiki/Manuel_da_Maia

The approach of architect planners like Wren, Haussmann and their Renaissance predecessors, was based on the principles of Classicism. Their vision for the city was for centrally planned, organised urban spaces which would provide visual delight and a longed-for sense of order, in contrast to the often chaotic, squalid conditions found in tightly packed, unregulated cities.

See *The Ideal City* c 1480 by Fra Carnevale (https://en.wikipedia.org/wiki/Fra_Carnevale#/media/File:Fra_Carnevale_-_The_Ideal_City_-_Walters_37677.jpg).

In these ambitious city plans, the massing and height of the urban blocks and buildings was restricted by the materials and technologies of the time and so, unlike their 20th century counterparts, visual and experiential impact was limited. Similarly, transportation in the 17th, 18th and 19th centuries was by riverboat, carriage or cart rather than by car and so street networks, whilst important arteries for trade and communication did not dominate pedestrian use. The new tree-lined avenues and boulevards of Paris and Lisbon were primarily intended to be enjoyed by their citizens.

Remodelling existing towns and cities can still be achieved without resorting to wholesale clearances and the austere architecture of the Modernist approach. It has been to these earlier, classically inspired examples that contemporary master planning has looked in recent years for direction.

By the end of the 1960s, many aspects of city planning (in particular high-rise mass housing) had acquired a negative image. There was an obvious public dislike of large-scale unadorned, Modernist design and a concern that it was a contributing factor in increasing social problems, vandalism and criminality.

See the example of the Sheffield Park Hill estate, 1960s at:

http://www.dezeen.com/2014/09/10/brutalist-buildings-park-hill-jack-lynn-ivor-smith/
http://www.theguardian.com/artanddesign/the-camera-eye/2014/mar/05/park-hill-sheffield-utopian-estate-left-to-die

The collapse of a high-rise block of flats in east London in 1968 in which three people died and a 1974 corruption case involving some 23 Local Authorities responsible for the planning, building and management of large-scale public housing and urban renewal schemes, further damaged the credibility of the Modernist project and led to alternatives being explored (http://news.bbc.co.uk/onthisday/hi/dates/stories/march/15/newsid_4223000/4223045.stm; http://news.bbc.co.uk/onthisday/hi/dates/stories/may/16/newsid_2514000/2514277.stm).

In the mid-1970s, a 'post-Modernist' approach to planning and architecture emerged which acknowledged the importance of individualism, variety and diversity. Many of the so-called 'rules of Modernism' (i.e. simple, clear, rational planning which was derived directly from the required function, was free of decoration and usually built 'on grid' from modern materials with a strong horizontal and vertical emphasis) were challenged by the possibilities of mixing historical styles and materials to respond to the special requirements of the location, architectural context and the building users. In housing schemes in particular, planning and design which met the needs of specific user groups, were developed through smaller scale projects by Housing Cooperatives and Associations as well as by many Local Authorities.

A good example of this alternative approach in the 1970s can be seen in the St Marks Road, London, Local Authority Housing scheme by Jeremy Dixon built 1975–1979. An early 'post-modern' response to the mass housing which had gone before, these small-scale, terraced houses set within an existing street, were constructed from traditional materials and provided a stark contrast to the1960s' modular, high-rise, concrete and steel-framed flats (http://www.c20society.org.uk/botm/st-marks-road-housing-london/).

In the 1970s, Winchester Council housing scheme shown on the website below, bungalows and maisonettes are grouped around a green space:

http://www.winchester.gov.uk/housing/

However, the social problems and poor conditions associated with poorly designed, badly managed Modernist housing schemes of the 1950s and the 1960s remain in some areas (http://www.dailymail.co.uk/news/article-2316072/Poignant-pictures-decaying-crime-ridden-housing-estate-fallen-ruin-remaining-residents-await-bulldozers.html).

Whilst in housing schemes, alternatives to Modernism were widely developed throughout the 1980s, a new approach to larger scale, commercial city planning and development took longer to appear. In 1988, the Broadgate development in London finally broke the mould and demonstrated the merits of providing accessible, vibrant public space and amenity as opposed to creating only that space which can be sold, let or used for essential access and circulation. In this large, mixed-use scheme, master planned by Arup and the developer, Rosehaugh Stanhope, an early decision was taken to make the internal public spaces traffic-free. Vehicle access and circulation were to be below ground, leaving the central arena space and new streets and squares, quiet and safe for public events, street cafes and shopping. The layout of this scheme was generated largely by the patterns of movement to-and-from the nearby railway terminus of Liverpool Street station and by the intersections with the existing pattern of city blocks. The development has continued to evolve over time and remains a commercially successful, viable urban space.

http://www.arupassociates.com/en/projects/broadgate-circle/
http://www.broadgate.co.uk/Content/PDF/BroadgateArchitectureLeaflet.pdf
http://www.arupassociates.com/en/projects/broadgate-development/
http://static.london.gov.uk/mayor/strategies/noise/docs/urbandes/01broadgate.pdf.

Broadgate Circle, London, UK. *Source:* Image courtesy of Arup Associates.

A 'New Urbanism'

Throughout the 1990s, the master planners of some new residential projects sought to return to the model of the traditional street where smaller scale housing developments would be reintegrated with neighbourhood shops, workplaces, schools, parks and other civil amenities and linked by networks of footpaths and streets where cars were not dominant

http://www.botsfor.no/publikasjoner/Litteratur/New%20Urbanism/About%20New%20Urbanism%20by%20Robert%20Steuteville.pdf
http://www.tandfonline.com/doi/abs/10.1080/10511482.2000.9521387#.VcnER3FViko
https://en.wikipedia.org/wiki/New_Urbanism

This New Urbanism had much in common with the Garden City movement that sought to deliver good quality homes which acknowledged the continuing importance of craftsmanship and were made from traditional materials (http://www.sacred-texts.com/utopia/gcot/index.htm).

Socially beneficial amenities and tree-lined thoroughfares were intended as markers of civic identity whilst at the same time, physical well-being was enhanced by a renewed relationship with the natural environment through the use of town centre green space and landscaping. Through thoughtful, sensitive design, New Urbanism sought to re-introduce a sense of community which had, it was said, been largely lost in the Modernist era.

The 'New Urbanism' regeneration of Stockholm's Sankt Eriksomradet quarter involved both new-build and restoration of older buildings and can be seen at the website below. Between 1995 and 1998, a total of 770 new homes was completed.

https://sv.wikipedia.org/wiki/S:t_Eriksområdet

At the 1990s development at Jakriborg, near Malmo, Sweden, the use of pre-industrial revolution, traditional materials, small architectural scale and a 'village' design approach taken have been compared to the 'new town' of Poundbury, United Kingdom (https://en.wikipedia.org/wiki/Jakriborg; http://www.a10.eu/magazine/issues/1/housing_jakriborg.html; http://bettercities.net/article/20-poundbury-winning-converts-20839).

Significantly, as New Urbanism stressed the importance of a more responsible attitude to the natural environment, it also helped set the scene for the emergence of sustainability as an important part of many city planning schemes from the 1990s onwards.

One of the first UK schemes which embraced the principles of both New Urbanism and sustainability was the BedZED project in London in 2002. This scheme was made up of high-density, mixed-use, low environmental impact rectilinear urban blocks comprising 82 homes and 2500 m^2 of live-work space (http://www.zedfactory.com/zed/?q=www.zedfactory.com/zedlife; http://www.bioregional.com/wp-content/uploads/2015/05/BedZED_toolkit_part_2.pdf).

If designers like Arup can be said to have reminded property professionals of the importance of a high-quality *local* public realm in schemes such as Broadgate by adding architectural, social and financial value to the city, then the environmental movement of the 1990s can claim to have encouraged developers, architects and planners to consider the *global* public realm by placing a value on the world's natural resources and ecosystems.

The emergence of a sustainable urbanism stressed the importance of neighbourhood and community involvement certainly, but it also sought to reduce ecological footprints through better care of flora and fauna, encourage more compact city areas which mitigated urban sprawl and transport impacts, minimise pollution, emissions and waste, use water more efficiently and deliver energy from renewable sources.

Good examples of this can be seen at the low environment impact Candlestick Point project, San Francisco, completed in 2007 (http://www.sfocii.org/ftp/uploadedfiles/Projects/HPS-Phase1-OpenSpace-Streetscape-Masterplan.pdf; http://www.usgbc.org/projects/shipyardcandlestick-point?view=overview).

In the redevelopment of the area of North Manchester (NOMA) near Victoria station begun in 2009, the master planners at Arup were acutely aware of how 'place making' can shape the future of a location. With the Co-operative Group's new NOMA HQ building at its heart, the regeneration initiative for this part of the city delivers redefined urban working and living environments that will attract local and international investment, transforming the future of the city centre (http://www.noma-manchester.com/media/1171/noma-interactive-developments_2014.pdf; https://www.youtube.com/watch?v=J_Krk2zb88I).

The NOMA redevelopment project, Manchester, UK. *Source:* Image courtesy of Arup Associates.

As urban environments become increasingly complex, issues such as changes to household size and local demographics, land scarcity, air quality and noise pollution, require innovative solutions derived from a *whole systems* understanding of the built environment.

There are now many fine examples of lower environmental impact projects all over the world and comprehensive guidance to help master planners and communities deal better with even the most challenging regeneration projects.

The American LEED-ND programme sets out a list of desirable environmental features which should be present in a master plan and provides guidance on how these might be achieved. This includes advice on *Neighbourhood Patterns* for *Connected and Open Communities* through providing:

- Walkable Streets
- Compact Development
- Mixed-Use Neighbourhood Centres
- Mixed-Income Diverse Communities
- Reduced Parking Footprint
- Transit Facilities and Transportation Demand Management
- Access to Civic and Public Spaces
- Access to Recreation Facilities
- Community Outreach and Involvement
- Local Food Production
- Tree-Lined and Shaded Streets
- Neighbourhood Schools

From: http://www.usgbc.org/redirect.php?DocumentID=6407; showing checklists and *environmental credit* spread sheet.

Also see the resources below which explain the LEED-ND Neighbourhood Pattern and Design criteria for measuring 'sustainable' neighbourhoods:

https://www.nrdc.org/cities/smartgrowth/files/citizens_guide_LEED-ND.pdf
https://escholarship.org/uc/item/49f234rd#page-6

In addition to the LEED-ND programme, the LUDA regeneration process sets out a project analysis and sustainable decision-making model for the regeneration of Large Urban Distressed Areas (LUDA) which ensures that all the stakeholders are involved in a joint learning process:

- Diagnosis
- Visioning
- Programming
- Implementing
- Monitoring

See 'LUDA: Improving quality of life in Large Urban Distressed Areas' project – Research funded by the European Commission, EVK4-CT2002-00081 which has been developed to identify what activities should underpin the decision-making in the sustainable urban regeneration and what methods and techniques can be used to do this.

http://www.luda-project.net/compendium/pdf/hbe4_annex.pdf
http://www.luda-project.net/compendium/handbookE5.htm

Both the LEED-ND programme and the LUDA protocols provide useful guidance on and insight into, the contemporary approach to master planning in the city. Whilst LUDA is primarily an appraisal checklist tool for regeneration projects, many of the principles set out are equally applicable to wholly new build schemes or projects which are a mix of refurbishment, alteration, extension and new build.

Other UK regeneration projects can be seen at:

http://www.urbansplash.co.uk/residential/park-hill
http://www.bbc.co.uk/news/magazine-37088796

https://www.youtube.com/watch?v=Q84yo3wwWJo
https://www.youtube.com/watch?v=MBGHOEH2v_c
https://www.youtube.com/watch?v=qNR-_syoCdA&feature=youtu.be
http://www.urbansplash.co.uk/residential/new-islington
http://www.urbansplash.co.uk/gallery/new-islington

New Settlements and Large-Scale Urban Growth

Many of the earliest known *centrally planned* new settlements and cities of the ancient world (as opposed to communities which grew 'organically' over time) were built to establish a colonial presence in often hostile environments. The grid plan of classical Greek cities such as Miletus (around 5th century BC) was laid out to be easily defendable and to move goods and troops into, across or through the new city in the most efficient way possible. They were however, not merely military trading posts but had at their heart, civic, religious and cultural public spaces (http://www.goddess-athena.org/Museum/Temples/Miletus/Miletus_map.html).

At the Greek colonial city of Paestum in Italy in the 6th century BC, public space was considered of such importance that the *Agora* (meaning the Town Square – from the Greek 'to talk') covered some 4 ha. Allocating sizeable areas of towns and cities such as Paestum, Priene and Roman Timgad as public amenity was in sharp contrast to earlier Greek cities such as Mycenae (c1500 BC) where the plan of the city consisted of groups of buildings which were clustered around the palace of the king (Wallace-Hadrill, 2015).

http://www.bbc.co.uk/programmes/b067922h
http://historum.com/ancient-history/83155-ptsd-ancient-times-new-evidence-11.html
http://www.ancient-wisdom.com/greecemycenae.htm

Although not 'centrally planned', the rulers of ancient Rome dedicated much valuable city centre real estate to public use as Roman engineers took the provision of infrastructure to new levels of sophistication. With many public fountains and large-scale baths kept in operation by eleven aqueducts for a population in 300 AD of over one million, Rome before its fall in 400 AD was arguably the world's first *megacity* (http://rkgregory.cmswiki.wikispaces.net/Ancient+Rome; https://www.youtube.com/watch?v=MqMXIRwQniA; http://scanlabprojects.co.uk/projects/bbcrome; https://vimeo.com/157700425?from=outro-embed).

It is perhaps the provision of these two features, *public space* and large scale engineered *infrastructure*, which can be said to define the city as we know it. By contrast, earlier settlements such as Mycenae, Jericho and Catalhoyuk in 7500 BC appear to us to be more a collection of buildings arranged in an ad-hoc manner (http://www.sci-news.com/archaeology/science-catalhoyuk-map-mural-volcanic-eruption-01681.html; http://www.catalhoyuk.com/).

Large-scale, planned urban growth and new settlements were (and often continue to be) prompted by rapid population increase, political, social and economic change (e.g. the extensions of Edinburgh in the 1800s, Barcelona in the mid-19th century and Tel Aviv in the 1920s) as well as by lucrative development opportunities (e.g. the development of the Georgian city of Bath, United Kingdom, from the 1760s onwards; http://www.18thc-cities.paris-sorbonne.fr/index-3.php?lang=fr).

In Bath, new town houses built by Architect John Wood and others, arranged around a Classically inspired Grand Circus, elegant City Squares and a Royal Crescent, offered affluent would-be purchasers, a home in an 18th century arcadia (https://en.wikipedia.org/wiki/Royal_Crescent).

In the development of Edinburgh in the 18th century, a new circus, squares, park gardens and streets 'on grid' contrast markedly with the informal layouts of the older parts of the city (https://en.wikipedia.org/wiki/New_Town,_Edinburgh; http://www.bbc.co.uk/history/british/civil_war_revolution/scotland_edinburgh_01.shtml).

Cerda's plans for the enlargement of Barcelona in the 1860s (today's *Eixample* area of the city), took the art of master planning to a new level of socially conscious design. Five hundred and fifty residential city blocks were built around carefully sunlight-orientated central gardens to help improve the health of residents and facilitate social engagement (see Cerda's General Theory of Urbanisation, 1867 and Busquets, Joan (2005) *Barcelona, the urban evolution of a compact city*, ISBN 88-8447-204-0, Harvard University, p. 122; https://commons.wikimedia.org/wiki/File:PlaCerda1859b.jpg).

(From Ildefons Cerdà i Sunyer, Museu d'Historia de la Ciutat, Barcelona)

In contrast to such a progressive approach to city living, the unregulated development in many of Britain's towns and cities in the 19th century continued to lead to overcrowded, unhealthy and crime-ridden environments, often with very poor water supply and sanitation.

Records show that in the 1840s, in the largely rural Home County of Surrey, the average life expectancy was 45, whereas it was 37 in London and in the industrial port city of Liverpool, 26. At the time of death, the average age of manual labourers and those in domestic service was 15.

The statistics from the Registrar General in 1841 also show that in densely populated parts of the East End of London such as Bermondsey, Shoreditch and Whitechapel, mortality rates could be twice those of middle-class Londoners (see Chadwick's '*Report on an Enquiry into the Sanitary Condition of the Labouring Population of Great Britain*', *1842*).

http://www.victorianweb.org/history/chad1.html

Poor sanitation and overcrowding had also meant that between 1830 and 1850, epidemics of typhus, influenza and cholera swept through English cities killing tens of thousands and led to the first Public Health laws in 1848. Concerned religious groups such as the Wesleyan Methodists (founding the Salvation Army in the East End of London in 1865) and the work of 'social cartographers' such as Charles Booth who, between 1886 and 1903, produced a map of London where each street was coloured to show social class and deprivation, further raised awareness of the dire state of many cities and their inhabitants (see Booth's 'Inquiry into Life and Labour in London' and http://booth.lse.ac.uk/static/a/4.html). The conditions in which the poorest in society were continuing to live, combined with a fear of political unrest, therefore, remained a major cause of public concern and led to the emergence of a New Liberalism towards the end of the 19th century (https://en.wikipedia.org/wiki/The_Salvation_Army; http://journals.cambridge.org/action/displayAbstract?fromPage=online&aid=3326652; http://www.victorianweb.org/science/health/health10.html).

In an attempt to counteract the more negative effects of the laissez-faire political and economic culture of the 19th century, the social reforms of the New Liberalism which occurred at the end of the 1900s and in the early years of the 20th century were founded on the principle of 'collectiveness'. New Acts which passed through Parliament included welfare support for the poorest in society, a National Insurance scheme (for health care and unemployment benefits), a Factory Act to improve health and safety in the workplace, a revised and extended Public Health Act and free school education. The Housing and Town Planning Act of 1909 set out regulations to prevent further building of back-to-back terraced housing and required Local Authorities to introduce town planning procedures and ensure that all homes were built to a good standard of functional and spatial amenity. It was against this political backdrop that an urban planning model emerged whereby working people could lead happier, healthier lives (https://openlibrary.org/books/OL23305443M/Housing_town_planning_etc._act_1909).

A number of 19th-century philanthropic industrialists had built 'model villages' for their workers; many founded on the Quaker principles of temperance and social justice. Good quality new homes were often built utilising traditional 'arts and crafts' designs, styles and materials and the schemes also provided access to nature, parks and leisure amenities for their workers. The mill owner, Titus Salt, built Saltaire near Bradford in 1851, the industrialists George and Richard Cadbury created Bourneville near Birmingham between 1893 and 1900 and Joseph Rowntree built New Earswick in Yorkshire (1902–1904).

http://whc.unesco.org/en/list/1028
http://news.bbc.co.uk/1/hi/uk/3056286.stm
http://www.bbc.co.uk/northyorkshire/content/articles/2005/10/06/nwe_earswick_places_feature.shtml

William Lever set up Port Sunlight in Cheshire between 1899 and 1914 seeking to 'socialise and Christianise business relations and get back to that close family brotherhood that existed in the good old days of hand labour'. In exercising this benign paternalism, Lever continued to invest the profits from his business into the village '…to provide for you everything that makes life pleasant – nice houses, comfortable homes, and healthy recreation' (http://www.theunbrokenthread.com/blog/2015/05/09/lady-lever-art-gallery/; http://bournvillevillage.com/old-bournville/cadbury-how-it-put-bournville-on-the-map-literally/; http://www.libraryofbirmingham.com/article/bournville-village-trust-catalogue).

Ebenezer Howard's Garden City movement further developed the philanthropist's idea of building new manufacturing and living centres outside the traditional city, so that entire communities could live and work in healthier, happier environments nearer the countryside (http://www.sacred-texts.com/utopia/gcot/index.htm).

In the section showing the 1902 edition of 'Garden Cities of Tomorrow' at the website below, Ebenezer Howard's plans for urban expansion occurring through 'off-shoots'; self-sufficient communities planned on a concentric layout of boulevards, parks and open spaces, can be seen. The Garden City is intended to be a 'satellite' of a central city of no more than 50,000 people, all linked together by a modern road and rail network. Also see the earlier 1898 diagrams No. 3 & No. 7.

https://en.wikipedia.org/wiki/Ebenezer_Howard

First at Letchworth, 34 miles north-west from London (1904), and at Hampstead Garden Suburb (commenced 1906), then later at Welwyn, Hertfordshire (from 1920), the ideas of the Garden City movement started to be used in commercially funded housing projects. Howard and the architects and Town Planners, Unwin and Parker, designed and developed affordable, low-density housing projects, with leafy roads, green spaces and, in the case of 'new towns' such as Letchworth and Welwyn, extensive 'green belt' areas surrounding them. The layouts, however, often did not utilise Howard's strict geometric plan forms, opting instead for less formal, more 'organic' patterns of roads, amenities and public spaces (Purdom, C.B. (1925), The Building of Satellite Towns).

For more on Welwyn: http://cashewnut.me.uk/WGCbooks/web-WGC-books-1925-1.php
For Letchworth: https://en.wikipedia.org/wiki/Letchworth
For Hampstead Garden Suburb: http://www.hgstrust.org/the-suburb/history-of-the-suburb.shtml

The ideas of the Garden City movement were also being adopted in other countries. In United States, at Forest Hills Gardens in the Queens district of New York in 1904 and later, in 1929 in Radburn, New Jersey, elements of Howard's vision were being adopted in the planning of new, leafy town suburbs and 'Neighbourhood Units', concepts which would go on to influence many future residential developments in North America (http://www.queensnewyork.com/forest/about.html; http://repository.upenn.edu/cplan_papers/31/).

The early years of the 20th century also saw the emergence of Town Planning and Urban Design as professions in their own right. The campaigning Town and Country Planning Association was set up in 1899, pre-dating the founding of the professional body, the Royal Town Planning Institute in 1914. The first recognised academic course was started at the University of Liverpool in 1909 and at Harvard in 1924.

Using many of the ideas of the Garden City, a Scottish biologist, sociologist and town planner, Patrick Geddes, adopted a location-sensitive, small-scale approach to master planning in north Tel Aviv in 1927. Built to enlarge the historical city of Jaffa, the new town of Tel Aviv was commissioned by the British Government at that time, as Palestine was part of the British Mandate in the Middle East.

The scheme consisted of shaded avenues and a free-flowing street pattern; orientated east-west to catch the sea breezes. In Geddes's master plan, public parks, squares, civic amenities and around 40 residential blocks with small, inner gardens at their centre were arranged around a network of streets and pathways where roads and traffic were relegated in the planning hierarchy in favour of the pedestrian (http://0-www.tandfonline.com.alpha2.latrobe.edu.au/doi/abs/10.1080/02665439508725829; https://en.wikipedia.org/wiki/Geddes_Plan_for_Tel_Aviv).

The approach taken to Town Planning and the design of new homes after the First World War, appears to have been driven by both utopian ideals and practical considerations. Many of the objectives of the Garden City Movement, that is good quality homes, gardens, public amenity and access to green space providing the right conditions for a happy family life, continued to be pursued, but were also now subject to the constraints of urgent demand and economics as the country tackled a shortage of decent homes for returning troops and their families (http://www.locallocalhistory.co.uk/municipal-housing/heroes/).

Schemes such as the Becontree Estate near Dagenham in Essex (where 25,000 homes were built between 1921 and 1935) and other large-scale projects in and around London, show that many of the ideals of the Garden City Movement were subject to compromise in the wider interests of speed and economy (Whitehead, J. (1995) The Growth of Muswell Hill; https://www.lbbd.gov.uk/wp-content/uploads/2014/09/Infosheet16-Becontree-Estate.pdf).

However, the challenge of re-housing large numbers of residents of the increasingly decaying towns and cities of the 19th century as well as catering for population growth and new factories for modern, production-line type manufacturing processes, led many Town Planners and politicians in the 1920s and the1930s to look to the ideas of *Modernism* rather than the Garden City model to provide solutions.

In a strange irony, Modernist architects and planners shared many objectives with the champions of the Garden City Movement. Both sought to provide high-quality family living environments, good public space, decent amenities and to integrate arts and crafts in daily life. There was, in short, a common desire to reshape and improve towns and cities for the greater good, but the design principles which Modernism adopted to achieve these ends, could hardly have been more different from their predecessors (https://municipaldreams.wordpress.com/2013/11/05/stevenage-new-town-building-for-the-new-way-of-life/; http://www.skyscrapercity.com/showthread.php?t=342217&page=2; http://www.liverpoolcityregion.uk/key-projects-in-halton.html; https://commons.wikimedia.org/w/index.php?title=File%3ANew_Town_COI.ogv).

New cities were also built to establish centres for civic administration (e.g. Melbourne, Chandigarh and Brasilia).

http://www.slideshare.net/MrudhulaKoshy/urban-planning-in-chandigarh-a-reflection
http://archiveofaffinities.tumblr.com/post/5032022816/le-corbusier-west-front-of-the-secretariat
http://www.fastcodesign.com/1671306/bras-lia-and-chandigarh-symbols-of-modernist-hope-and-failure

Following United Kingdom's post-Second World War re-building programme, the construction of the New Towns of the 1950s and the 1960s and the subsequent accusations of failed 'social engineering' by master planners and architects, there has been an understandable nervousness about building entire stand-alone communities in rural areas. Although most residential development since the 1970s tended to extend existing conurbations in an incremental manner, what were in effect 'New Towns' were built at Milton Keynes (begun in 1970), at South Woodham Ferrers, Essex (from 1972) and at Poundbury, Dorset (from 1994) (http://www.bdonline.co.uk/milton-keynes-the-making-of-a-suburban-dream/3092485.article; http://www.rudi.net/files/34C883261E9D499EA3241201F5A612E7.pdf).

South Woodham Ferrers in Essex was built on the principles set out in the highly influential *Essex Design Guide* in which the County Council provided guidance on such master-planning issues as providing traffic-free public spaces, ensuring urban 'privacy by design' for residents and architectural forms, landscaping and materials which responded to and respected the local *vernacular*. There was an emphasis on providing winding street patterns which provided intimate neighbourhoods with green courtyards, lanes and pathways to serve small-scale, richly landscaped, informally laid out new housing. The guide set out principles which were widely adopted in housing master plans of the 1970s, some of which can still be seen in schemes today (http://www.placeservices.co.uk/media/56456/essex-design-guide_1973-all.pdf; https://www.essex.

gov.uk/Environment%20Planning/Planning/Transport-planning/Infomation-for-developers/Documents/19715_essexdesignguide.pdf).

In Leon Krier's 1994 master plan for Poundbury, a small civic centre was surrounded by informally laid out networks of streets and mixed-use development (http://duchyofcornwall.org/assets/images/documents/Poundbury%20Factsheet%202015.pdf; http://www.bdonline.co.uk/leon-krier%E2%80%99s-secret-code-for-poundbury-revisited/3126807.article).

In recent years, 'New Towns' or even large-scale 'urban extensions' often do not get further than the concept stage. Requiring a huge front-end investment in terms of money, time and expertise, proposed new settlements are subject to Local Authority and Regional Development Control constraints, infrastructure and transport demands, local and national political debate as well as requiring extensive consultation with stakeholders which may include residents, businesses, nature conservancy and architectural conservation groups.

However, successive UK governments have recognised the shortage of housing in the country; in particular, of affordable properties. In also acknowledging the importance of sustainability, the Government stated its intention to support the building of up to 10 new Eco-towns in 2007. A short list of 15 schemes was drawn up in 2008 which was further reduced to 4 in 2009. As of 2015, after cuts in government budgets and a review of the sustainability standards being required of developers, Bicester Eco-town in Oxfordshire (North West Bicester) is the only one of the schemes to have begun construction to the original green standards (https://en.wikipedia.org/wiki/New_towns_in_the_United_Kingdom; https://en.wikipedia.org/wiki/Eco-towns).

Bicester Eco-town

The current plan for Bicester comprises 6000 new homes plus business premises, schools, health and community centres, nurseries, a community farm, allotments, an orchard, a country park and a nature reserve; all of which are set in green space equivalent to 40% of the gross development area. The new town will have a town square and much of the energy supply to the largely low-carbon buildings will be provided from renewable sources (http://nwbicester.co.uk/wp-content/uploads/2014/06/13016_Masterplan_Vision_290514_email.pdf; https://en.wikipedia.org/wiki/North_West_Bicester; http://nwbicester.co.uk/2014/01/construction-begins-on-the-uks-first-eco-town/; http://www.bioregional.com/our-work/).

Taking many of the ideas of the Garden City, the Essex Design Guide and from urban planning pioneers such as Geddes, the Bicester scheme places great emphasis on green space utilising the existing natural landscape and water features as a setting for new tree-lined boulevards and informal street patterns which link low-carbon neighbourhoods, businesses and public amenities (https://www.youtube.com/watch?v=-_IpG7Ntjlg#t=52; http://nwbicester.co.uk/masterplan/masterplan-proposals/draft-masterplan/).

At Bicester, the existing hedgerows, woodlands, streams, bridleways and footpaths are to be retained to form the framework for new green corridors which also contain new reed beds, ponds and areas for wild flowers. The routes and connectors within the development include traffic-free cycle routes and pedestrian-friendly pathways which will be used to provide access to new green space and activity areas (http://nwbicester.

co.uk/masterplan/masterplan-proposals/draft-masterplan/green-spaces-and-landscaping/; http://nwbicester.co.uk/wp-content/uploads/2014/08/Masterplan_Vision_and_Objectives.pdf).

Built on the edge of the Bicester conurbation, the new Ecotown has been master planned to act as a transition between the higher density urban environment of the existing town and the open farmland in the north. Consequently, higher housing densities (shown in darker yellow) can be seen in the southern development area, becoming lower density as the scheme reaches the more rural areas to the north and north-west.

Higher density housing is located alongside more intense land uses in the south-east corner of the site. Densities then become lower as the scheme follows the existing Bure Stream as it runs north-west from the south-east corner of the site towards the rural landscape beyond the new town.

The contrast between the envisaged high-density 'high street' development proposed for the south of the town and the treatment of the 'rural edge' can be seen in sketch design proposals in the master plan.

The master plan also sets out detailed design principles for a range of town planning issues such as biodiversity, play areas, living and working, social amenities, transport, employment, energy, water use, recycling and an environmental strategy for the design of individual homes. See page 105 of master plan at website:

http://nwbicester.co.uk/wp-content/uploads/2014/08/Masterplan_Vision_and_Objectives.pdf

Preston Beach, Western Australia

At Preston Beach, south of Perth, the master planners at Arup were faced with the challenge of developing a New Town scheme close to an environmentally sensitive area which had historically been subject to unregulated development and use as poor quality agricultural and grazing land.

The 900 ha site, approximately 80 miles south of the growing city of Perth, needed to provide housing for up to 10,000 people on around 4500 tenant lots. One of the ways in which the master planners were able to resolve the tension between the need for development and the desired restoration and subsequent protection of the natural environment of the site, was to fashion bushfire-resistant ecological buffers into a series of 'xeriscape' parks (landscaping which requires no supplementary irrigation), resulting in a net gain of ecological habitats.

The site lies off the Old Coast Road next to the Yalgorup National Park which includes the protected hyper-saline aquatic ecosystems and dunes which lie next to the Indian Ocean in this part of Western Australia.

The surrounding area is a complex environmental system of forests, lakes and wetlands and a precious habitat for a range of wildlife, in particular many types of water birds. These sites also contain thrombolites; rock-like formations which resemble limestone boulders made from microorganisms, individually too small for the human eye to see. The Park is one of the very few places on earth where it is possible to see these living structures.

Preston Beach Development site near the Yalgorup National Park. *Source:* Image courtesy of Arup Associates.

See Thrombolites at Lake Clifton, Yalgorup National Park:

https://en.wikipedia.org/wiki/Lake_Clifton,_Western_Australia
http://www.westernaustralia-travellersguide.com/thrombolites.html

From the outset of the project, all master-planning decisions were subject to the principles of Arup's *Integrated Urbanism*, that is:

- To protect Human Health, manage the Natural Environment, promote Economic Vitality and Individual Prosperity, ensure responsible Energy production, develop Urban–Rural Linkages through better Mobility and Access and facilitate good Governance and Civic Engagement.
- Develop responsible Water and Flood management systems.
- Achieve Sustainable Land uses through a balance of agricultural, industrial, residential and commercial uses.

Master planning the Preston Beach project was undertaken in three key stages:

1) The *Visioning Process*: establishing the high-level performance requirements of the project. This was carried out in workshops with the client (Preston Beach Developments JV Pty Ltd.), the design team including the structural and services engineers, and Local Authority Planners. This phase of the project also included 'risk' workshops where key areas were identified and evaluated and where risk avoidance and minimisation strategies were outlined.

2) *Setting the Parameters* of the development: a document-based and research-based exercise – that is ***evidence based,*** which looked at effects of, and on, the scheme of demographics, transport, Environmental Impacts, infrastructure requirements and so on.
3) *Exploring the design options* and their implications. For example, if the design was to go to the higher end of environmental performance, what would it mean in terms of costs, time, resourcing and so on and what other aspects of the project would this affect, for example procurement? This phase required a design team of around 20 for about three months.

One of the aims of the project was to achieve the right balance among the density of the development (and hence its profitability), its functional requirements and its architectural and environmental value. High residential densities were achieved, but contained within designated areas separated by sports fields and pathways down to the sea which, in turn, acted as retreat zones in the event of bushfires.

By acknowledging the developers' financial imperatives whilst at the same time seeking to respond to the technical demands of the site and maintain the public realm and open space standards of the original vision, the design team was able to give the scheme a uniqueness to the project which otherwise might have been missed. The design solutions achieved at Preston Beach demonstrate the importance of 'designing for the place' and of remaining open to the idea that a problem could become an opportunity.

Arup prepared a comprehensive water and wastewater strategy as part of the integrated master plan; the implementation of water sensitive urban design was central to restoring and enhancing the sensitive ecosystem in the area, whilst complementing natural drainage patterns and integrating storm-water management into the landscape. The water strategy was developed to provide a high level of flood protection to the area and ensure a sustainable supply of water which significantly reduces water demand. The strategy incorporates measures such as wastewater recycling which helps maximise the synergy between managing the supply of water with other benefits to ecology and landscape (Alchon, 2003).

At Wanzhuang eco-city in China, the client brief was to develop a sustainable master plan to accommodate the growth of an eco-city within a landscape formed of sporadic small-scale settlements, orchards and farmland.

As agricultural land disappears in China following rapid urbanisation and desertification, Wanzhuang provides a unique opportunity to explore eco-city development and, with water management an increasingly important issue, uses a focus on agriculture as a starting point.

Located halfway between Beijing and the port city of Tianjin, the 80 km^2 site has been selected by the Chinese Government for development into a city that will accommodate approximately 400,000 people by 2025.

Preserving, utilising and enhancing the local knowledge and farming skills of Wanzhuang's residents are vital. The rural landscape promotes close contact with nature, a proven source of well-being.

Arup assembled a multi-disciplinary design team to prepare the detailed master plan and sustainability design guidelines. A best practice, evidence-based sustainability appraisal process was used to integrate the urban design, landscape, agricultural, economic development, cultural, sustainable resettlement, transport, logistics, energy, water, waste and resources, environmental, and commercial framework strategies.

The rural landscape of the Wanzhuang eco-city development promotes close contact with nature.
Source: Image courtesy of Arup Associates.

Wanzhuang eco-city. *Source:* Image courtesy of Arup Associates.

The emerging concept of the proposal is a cluster of villages around a shared town centre, connected to the Beijing-Tianjin corridor. The compact, mixed-use development proposed around the existing villages allows for the conservation of important productive land and agricultural heritage, the existing urban fabrics of the villages and other elements of the existing natural landscape.

The successful development of Wanzhuang eco-city will help to explore a new way to solve China's urban-rural gap and to achieve harmonious urbanisation.

Analysing the site and its economic, environmental and social context, the strategy Arup developed looked to preserve and protect the natural features of the site's landscape, including its existing settlements and local industries, whilst allowing for sensitive low-impact growth in the form of 'expanded villages'.

Wanzhuang eco-city, China. Client: SIIC China. *Source:* Image courtesy of Arup Associates.

The following is from a piece by Katie Scott in *Wired* magazine:

'Peter Head of Arup and author of a Future Cities report foresees a possibility that in the future, we may live in 'a network of decentralised mixed-use settlements, or clusters connected by high speed public transport and broadband communications' and this, he argues, is 'a more sustainable and resilient solution' than simply building towards the skies.

The Wanzhuang eco-city proposal was created for an area that suffers from 'huge water shortages', writes Head. 'Arup's urban designers proposed an integrated urban agriculture and food system which replaces extensive wheat and corn cropping with labour-intensive vegetable and fruit cropping.

In doing so, the strategy delivers 100 percent food security for fresh fruit and vegetables for the new community and significantly reduces water consumption, as well as doubling farming income and increasing the number of jobs related to agriculture in the area by 50 percent.

But in United Kingdom, Head recognises that we simply do not have the space to create new settlements and therefore must 'retrofit' our cities. He writes: 'In low density suburbs, like those common in the US, retrofitting could start with putting very high density mixed-used interventions into new public transport node points, thereby creating a new vibrancy and services without dramatically changing the landscape of the suburb itself.'

'The streetscape can then be refashioned by introducing walking and cycle routes, renewable energy capture, and car clubs to reduce car use, all of which would serve to deliver a significant reduction in CO2 emissions.' He adds that these may lead to some areas being abandoned and returned to greenfield sites suitable for agriculture.

However, Head admits that this proposal is not just based around a new form of urban architecture, but would require a complete shift in public attitudes – everything from how we live and how we travel to our awareness of our carbon consumption. In fact, Head suggests penalties for those who over-consume; but also, to counter this, legislation to ensure that everyone can access renewable energy even if it is relatively more expensive compared to fossil fuels.

But financing remains an issue. In China, there are many new cities under construction and new ideas about sustainability are therefore welcome; but will people in United Kingdom consider, for example, accepting responsibility for their own energy consumption? Or that they should move into smaller settlements after years of megacity living'.

For full article see:

http://www.wired.co.uk/news/archive/2011-07/01/arup-model-cities

The Business Park

Since the 1980s, the *Business Park* in United Kingdom has evolved from the *Industrial Estate*. What were often planned to be no more than featureless service roads lined with utilitarian warehouses and cheap office buildings began to have good quality buildings, rich landscapes and water features providing natural habitats for flora and fauna and communal amenities including cafes, wine bars, crèches and gyms for the occupiers of the site.

Schemes such as the 140 ha Stockley Park (first master-planned by Arup in the mid-1980s) had the objectives of providing both good architecture and a strong public realm provision. The developer, Stuart Lipton, commissioned different firms of leading architects including Arup, Norman Foster, Geoffrey Darke, Troughton McAslan and Ian Ritchie to provide the buildings. A later, more detailed master plan by DEGW included an arena complex as the social heart of the scheme which opened in 1989 and contained shops, restaurants, a wine bar and sports facilities (http://www.arup.com/projects/stockley%20park; http://www.bdonline.co.uk/taking-stock-at-stockley-park/3129506.article; http://www.stockleypark.co.uk/occupiers/landscaping).

Possible Discussion Points – the big master-planning issues going forward:

- Managing existing, still growing super-cities is problematic in terms of air quality and poverty – particularly in Asia, India and South America.
- Master-planning regeneration projects in post-industrial countries such as United Kingdom, United States is an ongoing need.
- New settlements are planned in response to the need for economic growth in developing countries, for example China. Is the eco-city the future?

Bibliography

Alchon, S. (2003) *A Pest in the Land: New World Epidemics in a Global Perspective*, University of New Mexico Press, p. 21. ISBN 0-8263-2871-7.

Howard, E. (1965) Lewis Mumford (Introduction), in *Garden Cities of To-Morrow (1898 & 1902)*, 1st edn (ed. F.J. Osborn), Faber https://archive.org/details/gardencitiestom00howagoog,.

Ove Arup (2014). *Future Cities*, http://www.arup.com/design_book/future_cities & http://publications.arup.com/publications/f/future_cities_uk_capabilities_for_urban_innovation (accessed 14 June 2014).

Scottish Government (2008) *PAN 83; Planning Advice Note on Master Planning*: http://www.scotland.gov.uk/Publications/2008/11/10114526/2 (accessed 14 June 2014).

Wren's plan for London as visualised by the artist Paul Draper: http://www.draperdrawings.com (accessed 14 June 2014).

file:///C:/Users//715539Big_City_Plan_Part_2.pdf, pp. 36–37.

http://www.birmingham.gov.uk/cs/Satellite?blobcol=urldata&blobheader=application%2Fpdf&blobheadername1=Content-Disposition&blobkey=id&blobtable=MungoBlobs&blobwhere=1223546561368&ssbinary=true&blobheadervalue1=attachment%3B+filename%3D766661Curzon_HS2_Masterplan_Part_2.pdf (accessed 14 June 2014).

https://www.paimages.co.uk/image-details/2.13191762 (accessed 14 June 2014) (Press Association Archive).

http://www.listingsresource.cbre.eu/propertymediafiles/242377_Brochure_1.pdf (accessed 14 June 2014).

3

Transport

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The environmental impact of transport is highly significant. In the United Kingdom for example, 23% of greenhouse gas emissions (117.9 $MtCO_2e$ in 2014) was attributed to transport, the second largest sector after energy supply from the burning of fossil fuels; gas, coal and oil (31%). Over 98% of this is emitted directly as CO_2, rather than other greenhouse gas species (DECC, 2016). Across Europe, overall greenhouse gas emissions decreased 15% between 1990 and 2007, whilst emissions from transport increased by 36% (DG-CLIMA, 2016). Declines since 2008 are largely attributable to the global recession. Despite some optimism that this might have started a permanent downward trend (e.g. discussions about having reached 'peak car' (POST, 2013)), there are signs that emissions from this sector are on the increase again (DECC, 2016; Figure 3.1).

Emissions from transport are primarily caused by the combustion of fossil fuels to provide energy for generating motion, either directly, as with internal combustion engines (ICEs) in road vehicles or jet engines, or indirectly in power stations to generate electricity for plug-in vehicles or electric trains. It is not just emissions of greenhouse gases that are of concern. Transport emits a wide range of 'conventional' air pollutants (including nitrogen oxides (NOx), particulate matter (PM), Sulphur dioxide (SO_2), volatile organic compounds (VOCs) and carbon monoxide (CO)). These pose a wide range of health risks, both in urban areas where transport sources are concentrated and emission levels become very high, or outside urban areas where they contribute to levels of regional pollution (especially particulate matter and ozone (O_3)).

In the United Kingdom, over 96% of over 700 declared Air Quality Management Areas are related to transport (and predominantly road transport) (Defra, 2016). Whilst air pollution has historically been associated with respiratory problems, increasingly it has become linked to cardiovascular problems (e.g. heart attacks) as efforts to clean up more visible pollutants like soot and smoke have resulted in a greater number of very fine particles that are so small that they can pass through the lung wall into the blood stream. Currently, the annual estimate for deaths related to air pollution in United Kingdom is around 50,000 (Holder, 2014, Environmental Audit Committee, 2010), and around 600,000 across Europe (WHO, 2015). This is compared to between 1713 and

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

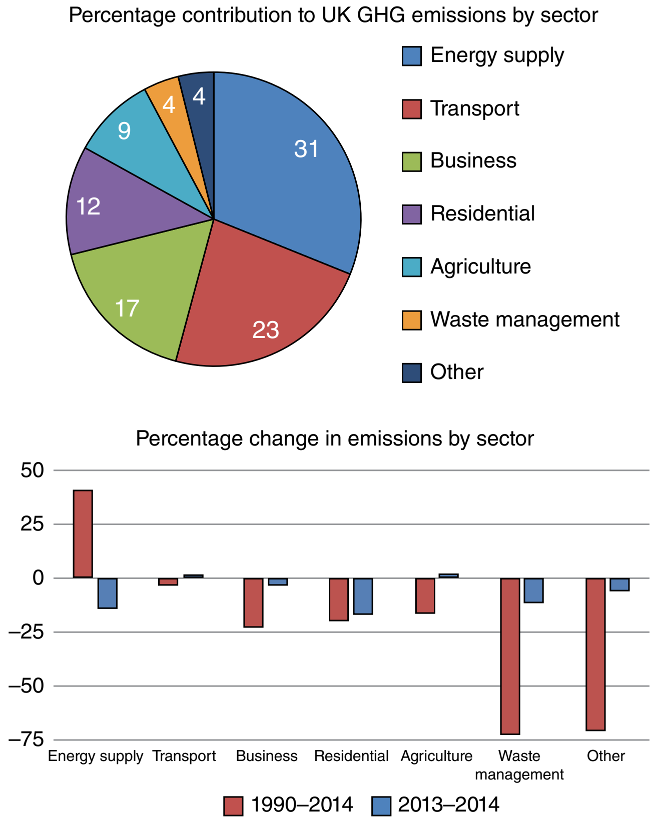


Figure 3.1 Greenhouse gas emissions in United Kingdom. *Source:* Government of Japan; http://www.mlit.go.jp/kokusai/MEET/data_en.html.

3450 deaths annually between 2000 and 2013 from road traffic accidents (RTAs). Transport-related air pollution in United Kingdom is estimated to reduce also the *average* life span by seven to eight months, though this is very unevenly distributed and some sections of the society are likely to be exposed to greater amounts and lose more (Barnes and Chatterton, 2017; Chatterton et al., 2016).

Emissions and RTAs are not, however, the only health and environmental risks from transport. Noise is perhaps the next greatest concern, with recent indication that 55% of those living in urban areas in the EU-27, almost 67 million people, endure daily road noise levels defined as excessive (EEA, 2009). It is estimated that noise from rail and road transport is linked to 50,000 fatal heart attacks every year and 200,000 cases of cardiovascular disease in the EU (Transport and Environment, 2008). These health effects are caused by the body's stress reaction to persistent noise leading to increased hormone levels of adrenaline and cortisol leading to increased risks of hypertension, stroke, heart failure, and immune problems (Mead, 2007; Figure 3.2).

Transport can also have crucial social as well as physical health impacts (though these often intersect with each other). Transport corridors can significantly impact on the quality of public space, both in urban and rural areas. This can have impacts on both

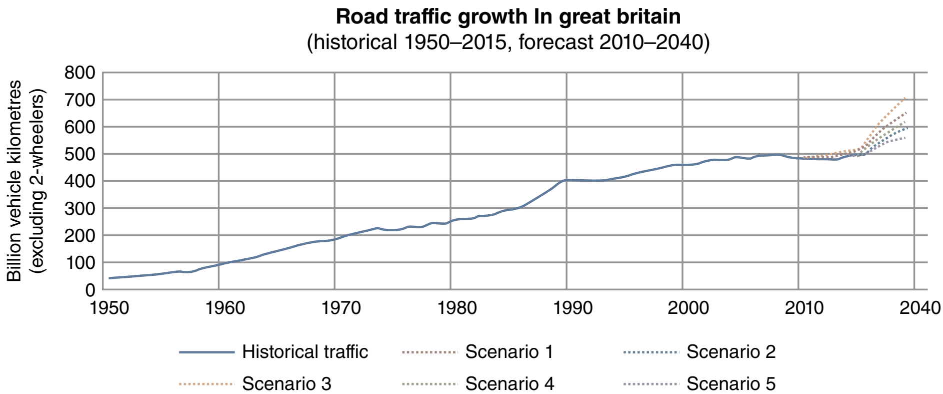


Figure 3.2 Growth of road traffic in United Kingdom.

the general well-being of local residents, and their physical health, through marring their mood to take physical activity. In his seminal book, Livable Streets,[1] Donald Appleyard (1981) presented evidence from San Francisco on the extent to which the amount of traffic on residential streets leads to the breakdown (or failure to establish) of social relations, affecting people's entire sense of place.

See a video on this work by Streetfilms:

https://vimeo.com/16399180

This work was revisited in Bristol, United Kingdom, in 2009 and the findings were found to be just as valid (Hart and Parkhurst, 2011).

Whilst the impacts described earlier have been outlined mainly in terms of road transport, this is because it hurts significantly far more people due to its pervasive nature. Many of the same effects are just as applicable to other forms of transport such as rail, aviation and shipping (Figure 3.3).

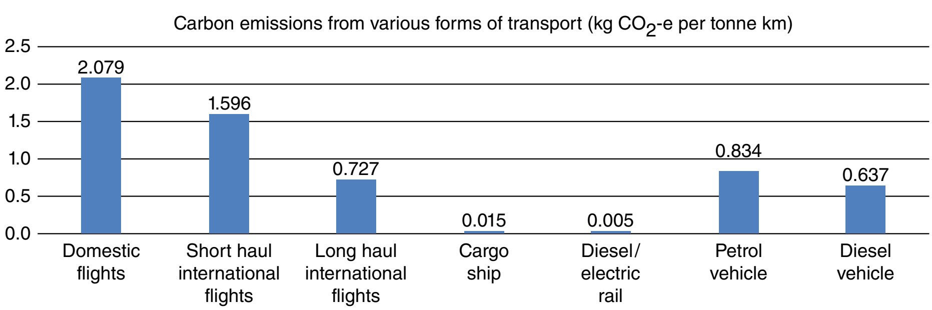


Figure 3.3 Conversion factors used to estimate carbon emissions from various forms of transport, including air freight (2011). *Source:* http://archive.defra.gov.uk/environment/business/reporting/pdf/110707-guidelines-ghg-conversion-factors.pdf.

1 https://books.google.co.uk/books?id=pfreUQKD_4QC&redir_esc=y

Alternative Fuelled Vehicles

As discussed earlier, the impacts of most concern regarding transport are normally those associated with fossil fuel use (e.g. air pollution, carbon emissions and to some extent noise). There can often be conflicts between the management of air pollution and greenhouse gas emissions from transport (Defra, 2010, Tiwary et al., 2014), with methods to reduce one type of emission sometimes leading to greater emissions of the other (unless the option is to reduce transport activity levels overall). Despite evidence that predictions of transport growth appear to have been unreliable for some time, forecasts for road traffic growth, in United Kingdom at least, are for significant expansion, and therefore much effort is being put into trying to address these problems through technical means rather than through demand management (which at best is seen only as a way of slowing this growth) (Figure 3.4).

One of the main ways for addressing these issues is through the replacement, fully or partly, of fossil fuels with 'alternative fuels'. These might consist of fuels which are cleaner in terms of air pollution (e.g. liquid petroleum gas (LPG), or compressed natural gas (CNG) instead of petrol or diesel), fuels which, theoretically, might have a lower climate impact over their lifecycle (e.g. bio-diesel, bio-ethanol or bio-gas as replacements for conventional diesel, petrol and CNG), or fuels that emit no pollutants at point-of-use (e.g. electricity – though this may lead to emissions overall depending on how it is generated).

The infrastructure necessary for fuelling the 35 million vehicles registered for use on the roads in United Kingdom has developed over more than a century. Along with the fact that the average life of a vehicle is over 10 years and thus fleet turnover is very slow (though not as slow as with building stock) this means that efforts to decarbonise the vehicle fleet entirely (Committee on Climate Change Fourth Carbon Budget) will happen quite slowly.

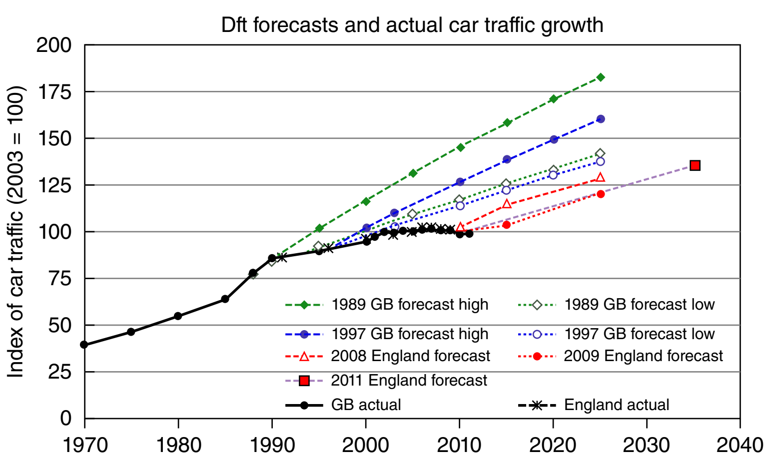


Figure 3.4 UK Government Department of Transport car traffic growth forecast. *Source:* DfT & Goodwin 2012.

Alternative Fuels

The term 'alternative fuel' is generally used to describe any means of powering transport that is not conventional petrol or diesel. This generally covers gas, biofuels and electricity. It is worth noting, however, that diesel has been considered to be a low carbon alternative to petrol and has been pushed heavily in United Kingdom for over a decade. This started in the early 2000s with the Blair government's changes to Vehicle Excise Duty to make it based on CO_2 emissions, which favoured diesel vehicles. Between 1994 and 2012 the percentage of diesel cars in the UK fleet increased from 7.4% to 32.7%.

Despite concerns raised early on about potential air pollution impacts due to the higher emissions of nitrogen oxides and particulate matter from diesels compared to petrol vehicles, these were largely ignored and have led in part to the widespread exceeding of the European air quality values that we experience today.

Various forms of gas are the next most common alternative fuels, predominantly CNG and LPG. These are generally used on converted spark ignition petrol engines, although CNG which is most common on larger vehicles can be used on converted diesel engines either by introducing a spark ignition system or running a bio-fuel system using diesel as an ignition source.

The term bio-fuels covers a range of fuels, primarily bio-ethanol, bio-diesel and bio-gas, that replace petrol, diesel and natural gas respectively. These can be used as a 100% replacement, but due to variability in fuel quality and issues with engine design, these are most commonly used as a blend with conventional fuels. Current road fuel standards (since 2013) in United Kingdom allow for up to 10% of petrol sold at the pump to contain bio-ethanol, though this must be labelled 'E10' and a lower mix of 5% ethanol sold alongside it for vehicles which have compatibility problems with high levels of bio-fuel.

Bio-fuels are being increasingly used in trains,[2] shipping[3] and aviation[4] although levels of uptake are still very low. Significant carbon savings were initially anticipated from bio-fuels due to the theory that they would be 'carbon neutral' because of the CO_2 released on combustion having been recently absorbed from the atmosphere by the plants it was made from. However, emissions associated with the manufacturing process, delivery of fuels and the conversion of land to grow fuel crops mean that a complex life-cycle assessment needs to be undertaken to ensure they are actually more sustainable than conventional fuels (and in many cases it is not clear that they are). Similarly, with conventional air pollutants, they do not always provide a clear-cut improvement on conventional fuels. Bio-fuels can be divided into first- and second-generation bio-fuels. First-generation bio-fuels are made from sugars and vegetable oils in arable crops grown for the purpose. Second-generation bio-fuels, which tend to be more sustainable, can be made from woody crops, agricultural residues and waste.

Electricity has a long history as a transport fuel. It has been used to power trains, buses and trams through overhead wires or third rails since the 19th century. Also,

2 http://www.berkeleybiodiesel.org/usage-of-biodiesel-fuel-a.html
3 http://biofuelstp.eu/shipping-biofuels.html
4 http://aviationbenefits.org/environmental-efficiency/sustainable-fuels/passenger-biofuel-flights/

many trains that we might consider to be diesel powered are actually diesel-electric trains used as diesel engine to turn a generator to send power to an electric motor (similar to some hybrid vehicles – see below). Electric cars were also quite common in the late 19th and early 20th Centuries until decreasing costs of petrol production pushed them out of the market. Electric vehicles (EVs) come in two main categories, pure EVs, which operate on a battery which needs to be charged from an external source, and hybrids, which operate on a combination of an electric motor and a conventional (usually petrol or diesel) ICE.

There are a wide variety of ways in which hybrid vehicles can operate. Primarily these are using the ICE as the main source of power and the electric motor to increase torque, using the electric to drive the vehicle and an ICE to generate electricity for it, and thirdly, switching between using the ICE and electric motor to drive the transmission depending on both driving conditions (e.g. urban or motorway) and available battery charge. There are also Plug-In Hybrids which can charge from the mains allowing them to operate mainly as a pure EV. Whilst EVs are of great benefit to air pollution (being largely zero-emission at point-of-use) their carbon benefits are very dependent on two key factors. Firstly, for plug-in vehicles, how the electricity used to charge them is generated[5] as emissions varies hugely in respect of coal-fired Power Station's gas generation and renewables. Secondly, the more complex manufacturing required for electric motors and batteries. Recent studies have suggested that in United States, battery electric cars generate *half* the CO_2 emissions of the average comparable petrol car. Better – but still some way off 'zero-emissions'.

Currently, the UK government is aspiring that every new vehicle sold be electric by 2040. However, even with a recent surge in purchases, in 2014/2015 sales still only reached 1% of all vehicle sales for the first time. It is not just the desirability of EVs that might affect the levels of uptake, however; there are concerns about both the quantities of lithium required for batteries and about the amount of electricity necessary to power them.

Ultimately, it is hard to see how current predictions for transport growth can be achieved sustainably, and demand management will need to play a much greater role in transport policy, through changes to land-use policies, re-thinking how we currently engage with transport intensive activities (including going to work) and replacing travel with virtual mobility that is through the use of Internet conferencing and so on.

https://en.wikipedia.org/wiki/Carbon-neutral_fuel
https://en.wikipedia.org/wiki/Electric_vehicle

The 1990s saw a significant change in Europe in approaches to reducing air pollution. Previously, 'pollution control' measures were used to focus efforts on reducing the amount of emissions that came out of individual chimneys (both industrial and domestic). Due to the increasing success of this approach in controlling problems associated with these point sources, and because of the increasing pollution problems caused by growth in road transport, a new approach to 'Air Quality Management' was introduced. This came about in United Kingdom through Part IV of the 1995 Environment Act and across Europe through the 1996 European Air Quality Framework Directive (96/62/EC)

5 http://shrinkthatfootprint.com/electric-cars-green

and related Daughter Directives (now replaced by the 2008 Air Quality Directive (2008/50/EC)). This change consisted of supplementing existing emission controls, with a set of health-based targets for the concentration of pollutants in ambient air (see Longhurst et al., 2009 for a full discussion). Moving to a system based on ambient concentrations of pollutants had two main drivers. First, it allowed the management of problems arising from 'diffuse' sources of pollution such as traffic, where large numbers of low-emitting sources lead to a significant cumulative problem. Secondly, it more directly links air pollution problems to health risks, meaning that high levels of pollution within built-up areas with poor dispersion and high numbers of people exposed, are considered a more important problem than similar levels of emissions, for example, on a motorway passing through a sparsely populated area. But, as highlighted above, this puts it at odds with the management of greenhouse gas emissions, where location of emissions is irrelevant.

The UK legislation, and the national air quality strategies that followed from it, established a two-tier framework for action. At a national level, responsibility for air pollution resides with the Department for Environment, Farming and Rural Affairs (Defra). Two main criticisms have been targeted at national policy. Firstly, there is little evidence of 'joined-up government' and although Defra have responsibility for assessing and improving air quality, there has been poor integration with other relevant departments (such as Department for Transport, Department for Health and Department for Communities and Local Government (planning)). Arguably, it is these departments that have much greater scope for implementing policies and interventions to improve air quality. Secondly, national policy has relied almost entirely on improvements to engine emissions through European policy on 'Euro emission standards.' These regulations have not been as successful as anticipated at reducing vehicle emissions under real world driving conditions (as opposed to laboratory tests c.f. the Volkswagen 'emissions scandal'[6]). This problem is worst in diesel vehicles, which, as described earlier, enjoy high incentives in United Kingdom. In the absence of a real push to reduce road transport from the government over the last two decades, this has largely led to a flat lining in pollution after initial significant gains were made in the early 1990s through the introduction of three-way catalytic convertors under the 'Euro 1' standards.[7] It is national government that is tasked with reporting on air pollution to the European Commission and complying with air quality 'Limit Values' under the various EU Directives.

At a local level in the United Kingdom, action on assessing and improving air quality is undertaken under the 'Local Air Quality Management' process established by the 1995 Environment Act. The specific requirements of the Act are elaborated in Technical and Policy Guidance for local authorities, and the task of environmental health officers at the level of District or Unitary authority. As with national government, this means that air quality policy ends up poorly integrated with transport policy generally, resulting in considerable knowledge about the extent and nature of air pollution problems, but little in the way of successful action (see Olowoporoku *et al.*, 2009). This lack of integration is further compounded by air quality being given little political attention and receiving little in the way of resources from national government to match responsibilities. Also,

6 http://www.its.leeds.ac.uk/about/news/implications-of-the-vw-scandal/
7 https://www.theaa.com/motoring_advice/fuels-and-environment/euro-emissions-standards.html

although there is a legal requirement to undertake regular reviews of air quality, there has been no clear legal need for LAs to actually achieve AQ targets (although the 2011 Localism Act has now, controversially, enabled EU fines for non-compliance to be passed down to local authorities).

In the Brazilian city of Curitiba, the benefits of an integrated low environmental impact transport system and thoughtful urban growth policies can be clearly seen. Dedicated rapid transit bus lanes and tram services provide an efficient transport system which is used by 80% of travellers in the city

http://www.bbc.co.uk/schools/gcsebitesize/geography/sustainability/sustainable_living_rev4.shtml
https://www.youtube.com/watch?v=r4sumpEqnlY
https://en.wikipedia.org/wiki/Rede_Integrada_de_Transporte
http://www.reimaginerpe.org/node/344

Although new transport infrastructure is sometimes seen as a 'necessary evil' which results in significant negative environmental and community impacts, public transport is necessary to provide social and economic sustainability and growth. The challenge, as always, is to minimise harmful effects whilst providing 'enabling infrastructure' which will bring the desired economic and social benefits (Figure 3.5).

For example, in the construction of the new Road and Rail transport route through the Kösching forest, near Ingolstadt, Germany, a potentially large environmental impact was reduced through the use of a Road-Rail Parallel Layout. This approach was also adopted in the 1984 Paris-Lyon high-speed rail route project which achieved a 14% parallel layout with the highway. In 2002, the Cologne-Frankfurt high-speed rail link

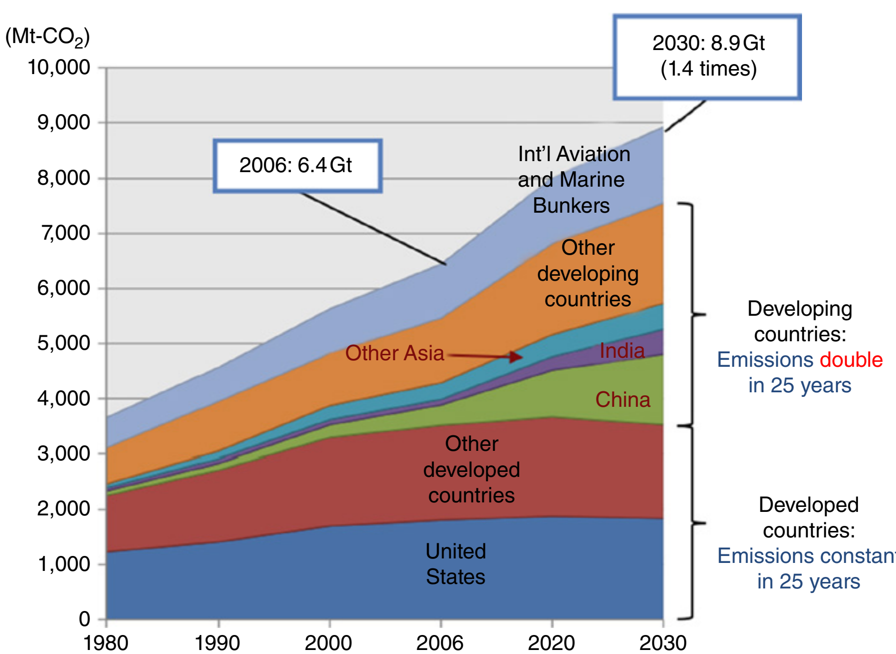


Figure 3.5 Trends in transport CO_2 emissions: 1980–2030.

delivered a 70% parallel development, drastically reducing the scheme's environmental footprint (https://en.wikipedia.org/wiki/Environmental_impact_of_transport; https://en.wikipedia.org/wiki/K%C3%B6ln%E2%80%93Frankfurt_high-speed_rail_line).

The development of CTRL Stratford/Stratford International in London and at Ebbsfleet International, Kent are both projects which demonstrate the transformative power of transport hubs when used as enabling infrastructure.

The High Speed 1 rail link project and the design of the Stratford and Ebbsfleet stations was devised within the wider context of the Master Planning proposals for East London and the North Kent area of southern England. In 1991, then Secretary of State for the Environment, Michael Heseltine, identified the East Thames area as being in urgent need of large scale regeneration and had called for the creation of a 'linear city' of 575,000 new homes (http://www.building.co.uk/news/the-wasteland/1020280.article).

Subsequent initiatives by both central and local governments failed to generate the necessary funding for the large-scale regeneration of East London or the transport links originally envisaged until the proposals for a High Speed rail link to the Channel Tunnel. Even at that time, when still in its very early stages of development, the new route was seen mainly as a means of improving transport links to the Channel Tunnel. However, Arup saw the regeneration potential of a new train track and stations in East London and its possible role in the Thames Gateway project. Arup developed the concept of a commuter rail capability interspersed with international trains, involving the regeneration of three areas: Ebbsfleet in north Kent, Stratford in East London and St Pancras in central London. The introduction of wider private sector interests and the Government contribution of political support essentially shaped the project's feasibility. The new transport hub of Stratford was later to be key to the successful bid for the London 2012 Olympic Games.

Commencing in 1996, work on the track, the tunnel, the stations and some of the associated regeneration workwas already well advanced when the Olympic Committee came to United Kingdom in 2005 to review the London bid.

The weakness of the bid had always been seen as the perceived poor transport links between East London and the centre of the city, but when the International Olympic Committee came to visit in February 2005, they were driven in Land Rovers through the almost completed tunnel from Stratford to central London (http://www.futurevents.com/projects/london2012.html).

The event showed how near East London was to the city centre and how fast the future transport link would be between St Pancras and Stratford. The 4.7 mile/7.5 km journey took about half an hour by Land Rover but would take just 7 min on the specially purchased Japanese bullet trains to be known as the 'Javelin Shuttle'. The drive through the tunnel would prove to be a memorable event and the IOC was, it seems, won over; London was awarded the Games in July 2005. Subsequently, the transport planning for the London 2012 Olympics was deemed to have been a success (http://www.theguardian.com/uk/2005/feb/17/transport.Olympics2012).

Arup worked together with fellow shareholders Bechtel, Halcrow and Systra to set up Rail Link Engineering (RLE) in 1994 to design and project manage the 109 km high-speed railway.

Arup's involvement with High Speed 1 dates back to 1989, when it developed an alternative route for a link between London and the Channel Tunnel to that proposed by British Rail. The 'Arup Alignment' – approaching London from the east via Stratford – embraced the need for the link to connect with the Europe-wide high-speed rail network and help to regenerate areas of north Kent and east London.

The railways we are putting in now will last for centuries to come, so we need to get them right. http://video.arup.com/?v=1_ym5hvs7z Rail and Arup, presented by Colin Stewart. *Source:* Image courtesy of Arup Associates.

High Speed 1:

- Involvement of over 1600 Arup staff.
- Required tunnelling beneath 2600 properties, 67 bridges, 12 km of surface railway, 600 pipelines and 4 London Underground stations.
- Rejuvenated the *Grade 1* listed St Pancras station
- Crossed the River Medway on the longest-span, high-speed rail viaduct in Europe.
- Soil from the excavations was used to help the link to sit unobtrusively low in the landscape.
- Created 250 ha of new native woodland around the line.
- Completed on time and within budget.
- Helped to bring in over £10 billion of regeneration investment to create new development in Stratford, King's Cross/St Pancras and Ebbsfleet.

Ebbsfleet International

- Created 420 ha of urban regeneration
- Led to the building of 10,000 new homes/5.5 m sq. ft. of commercial space
- GBP £300 million infrastructure project

Stratford International

- Created 132 ha of urban regeneration
- Acted as a catalyst for 3,200,000 m^2 of mixed-use development
- GBP £1.4 billion infrastructure project
- 4.5k new homes and 45k jobs predicted over 20 years.

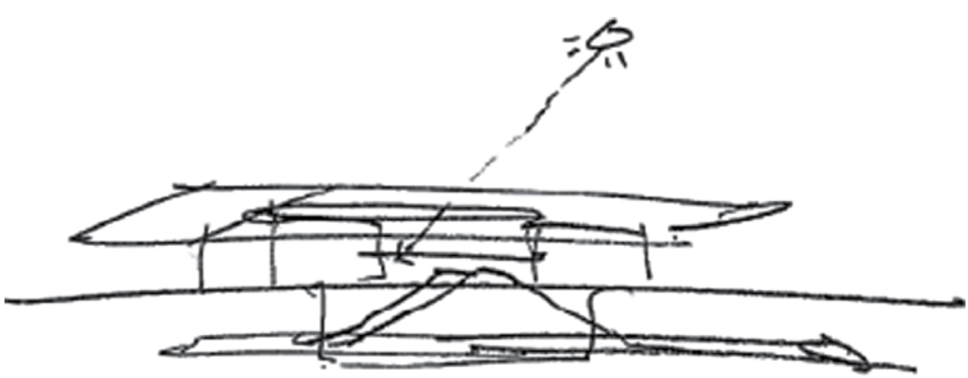
The principal challenges:

- Designing two stations whilst working within a political context and managing the systemic challenges of *collaboration* in large-scale infrastructure projects.
- The revitalisation and regeneration of an urban area through improved infrastructure.
- Making transport more sustainable including enhancing accessibility to the existing transport system and improving links to two major new transport hubs.
- The High Speed 1 project was to involve not only many technical challenges, but also changes in ownership and investor interests throughout the development process. The costs of the project were to come under particular scrutiny and required the designers to ensure that their proposals met often very exacting cost targets.

The station projects were undertaken using a form of contract which meant that the consortium was required to complete the work within a fixed budget. Under the terms of such contracts, the financial risk of overruns and/or additional costs are normally borne by the consortium contractors.

Although Arup had already prepared costed detailed design proposals for Stratford and Ebbsfleet, once the project was given the final go-ahead, very challenging new financial constraints were introduced by the project management team. If the project was to retain its design-led approach, the design team would have to incorporate a new, higher level of design discipline. At one stage in the project, the cost of the original Arup design proposals had to be reduced by some 20% of their original budget. This stricter approach to project costs led to greater functionality being achieved and elements of the building simultaneously acting in different ways in order to create better value.

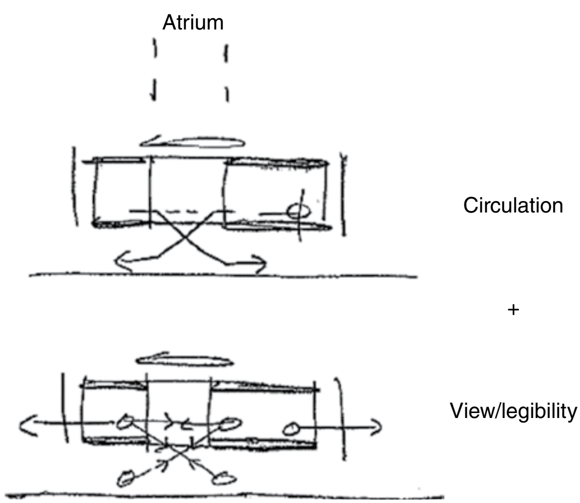
The layouts for both Ebbsfleet and Stratford were designed around an atrium where light floods in and spaces can be naturally ventilated, reducing energy capital and running costs and allowing smoke out in the event of a fire. These atria also provide orientation and legibility as the stations are not then relying on signage to direct people; passengers are naturally drawn to the train by the 'intuitive wayfinding' of the phototropic emphasis of the light pools. All of these features are achieved primarily by the architecture of the scheme, thus minimising reliance on expensive artificial lighting, signage and environmental control systems.



Sketch section through Stratford station: atrium light pools. *Source:* Image courtesy of Arup Associates.

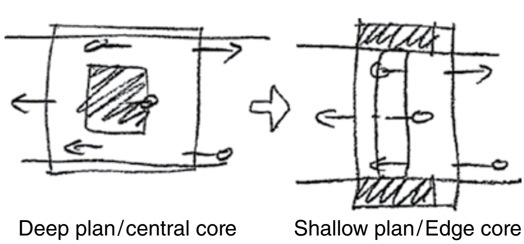
The project also illustrates the importance of architects fully understanding the technical challenges and cost implications of their ideas. Being able to justify designs as cost effective enables the architect to control the quality of the project and to retain the trust and confidence of contractors and clients, thus ensuring that the approach remains 'design led'. This is particularly important in the case of transport engineering projects where the specialist nature of the technical elements often takes the project down the *Design and Build* pathway.

As part of the 'value engineering' process, the two stations; Stratford and Ebbsfleet, were designed as a pair to give greater economy of scale. Whilst having dissimilar demand profiles, the stations share similar peak passenger flows and key functionality common denominators. They were therefore conceived as 'twin' stations based on a prototypical design, maximising efficiencies in design development and procurement. Architecturally, each station is composed of horizontal and vertical planes wrapped around a central atrium, which draws light and passengers down to platform level.



Sketch sections: circulation & legibility. *Source:* Image courtesy of Arup Associates.

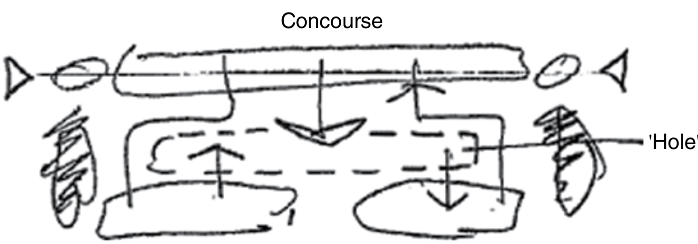
In the design of stations, there are two basic typologies, the first being to have trackside core concourses and the second, to position the core concourse above the tracks.



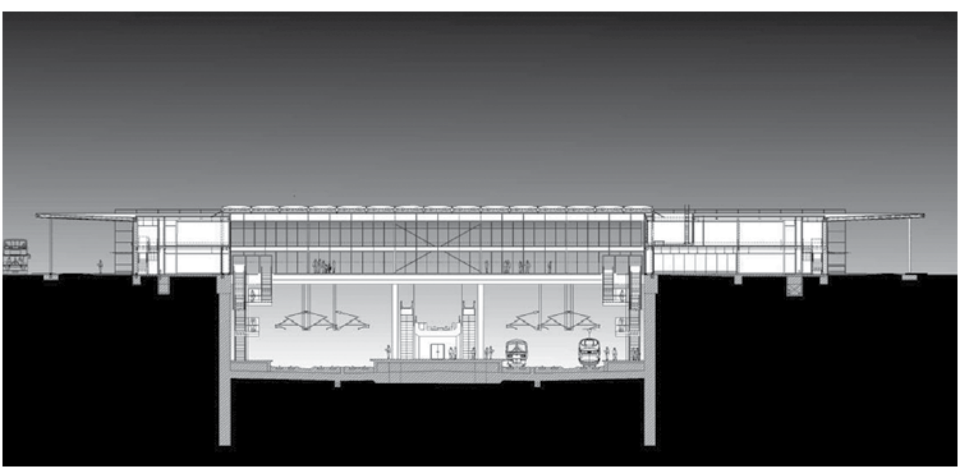
Sketch plans of station typologies: bridge (central) core/concourse *versus* trackside (edge) core/concourse. *Source:* Image courtesy of Arup Associates.

In the case of Stratford, it was felt that as a regeneration project, the concourse should be located on a bridge above the tracks, as this better linked the community together. However, this 'bridge solution' carried a cost premium of around £5 m. Fortunately, not all aspects of value engineering are about arriving at the cheapest solution but rather as Ove Arup himself said, obtaining *best value*; '…the ratio between what is obtained, and what is expended'. The argument that the new station at Stratford had an important role to play as a community thoroughfare, linking the two sides of the railway, was therefore to eventually win the day and the bridge solution was adopted, facilitating easier pedestrian flows into the heart of Stratford town centre.

The tunnel boring machines dumped spoil to form the landscaping for the new development of the Westfield shopping centre and the Olympic Park. This meant no massive transportation of spoil away from site which would have been a huge transport environmental impact. Instead, the spoil became regeneration enabling works.

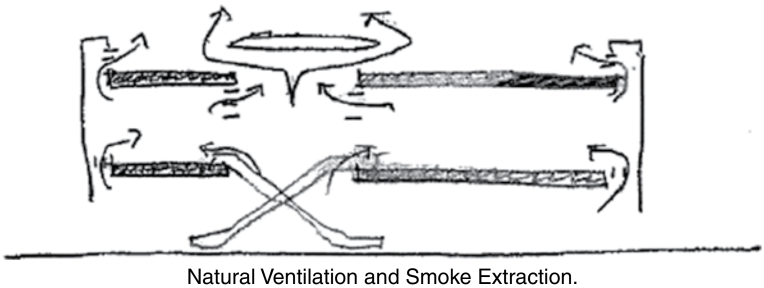


Sketch plan: circulation pattern. *Source:* Image courtesy of Arup Associates.



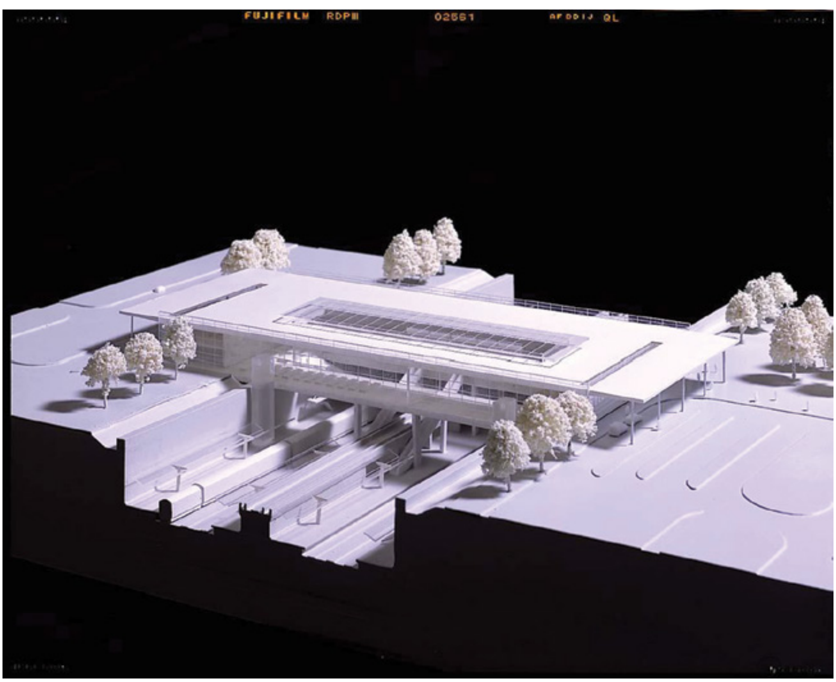
Section through Stratford station. The station was conceived as a bridge structure connecting the two sides of the box and uniting the two halves of the growing community, continuing as a pedestrian spine into the heart of Stratford town centre and the Lea Valley beyond. *Source:* Image courtesy of Arup Associates.

A lot of High Speed 1 is underground in London; so a large, open zone was needed for emergency evacuation and in order to provide for the removal of smoke in the event of a fire and general fumes on a day-to-day basis.



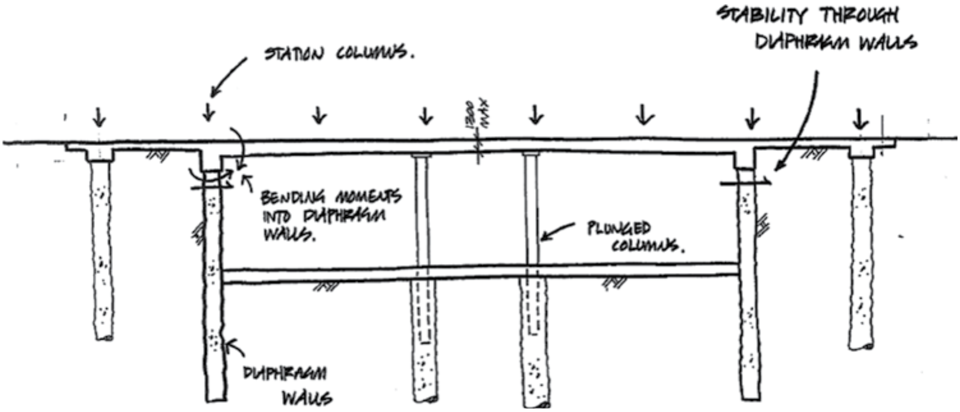
Sketch section: natural ventilation and smoke extraction. *Source:* Image courtesy of Arup Associates.

Stratford International sits centrally over a deep concrete box structure connecting the tunnel sections at either end. The box is 1 km long, 26 m deep and up to 55 m wide with access provided down to platform level via escalators.

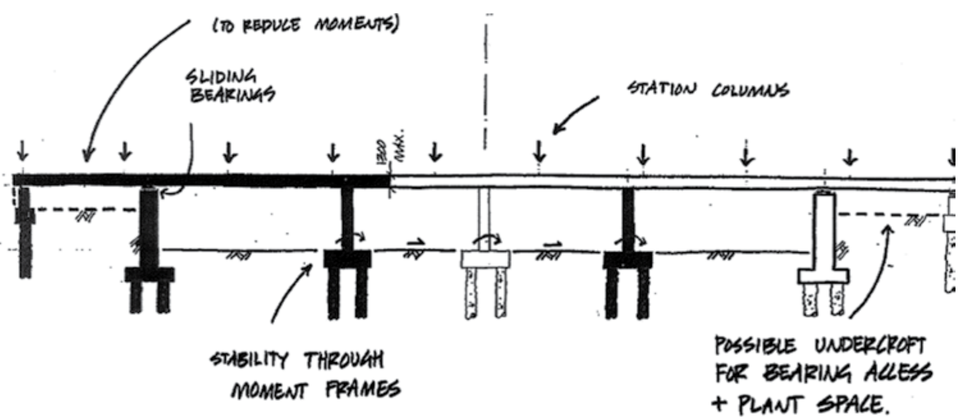


Model of Stratford station. *Source:* Image courtesy of Arup Associates.

The track layouts were a 'given' (as designed by *Systra* and the rail companies) but were different at Stratford from those at Ebbsfleet, resulting in different-sized



Ebbsfleet: concourse slab support. *Source:* Image courtesy of Arup Associates.



Stratford: top-down structural sequence. *Source:* Image courtesy of Arup Associates.

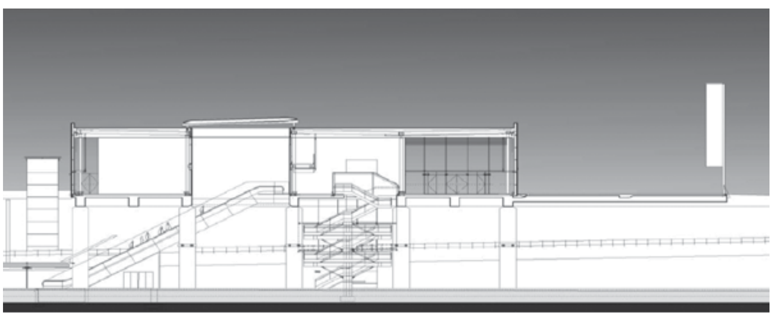
platforms, structural spans and column grids and so on. Arup, therefore, had to design a structural system which could be adapted to both stations.

At Ebbsfleet, the atrium provides visual connectivity unifying the different stages of the journey and enhancing the ability to navigate intuitively around the station. Glazed walls offer spectacular views over the track level and trains rushing through at high speed.

Primary points of circulation and decision-making are emphasised by natural daylight.

Ebbsfleet International sits over a rail cutting with escalator access provided down to platforms within a central atrium.

One of the project's main objectives was to stimulate the regeneration of the Thames Gateway region including a planned mixed development of light commercial, office and residential around Ebbsfleet station. The new station comprises both high-speed domestic commuter and high-speed international services with interchange to fast-track buses, taxis and up to 9000 car parking spaces providing an extensive park-and-ride facility.



Sections through Ebbsfleet station.

High-quality, durable materials have been used to provide a calm and legible visual environment as a neutral backdrop to the dynamic of people and train movements.

Glass, steel and natural stone are used to define the horizontal and vertical planes of the enclosure.

A low-energy environmental control strategy has been adopted for both stations. Protected from the weather by an inflated ETFE roof, the atrium divides the station into shallow floor plates which can be naturally ventilated.

Natural ventilation devices are integrated into the fabric of the building with the external glazed walls extending up beyond the flat roof to form a ventilated parapet. With no requirement for mechanical ventilation, the overall building envelope was reduced in height by 2 m.

As catalysts for regeneration, the stations had to create a strong presence within the surrounding areas. The stations have large expanses of glass to maximise visual permeability by day and announce themselves as illuminated boxes as seen at night. Simple geometric forms have been adopted for the enclosures so as to make the stations clearly legible from a distance. A strong horizontal plane roof extends to either end to form welcoming porte-cochere entrances.

Ebbsfleet station and its new park-and-ride provision.

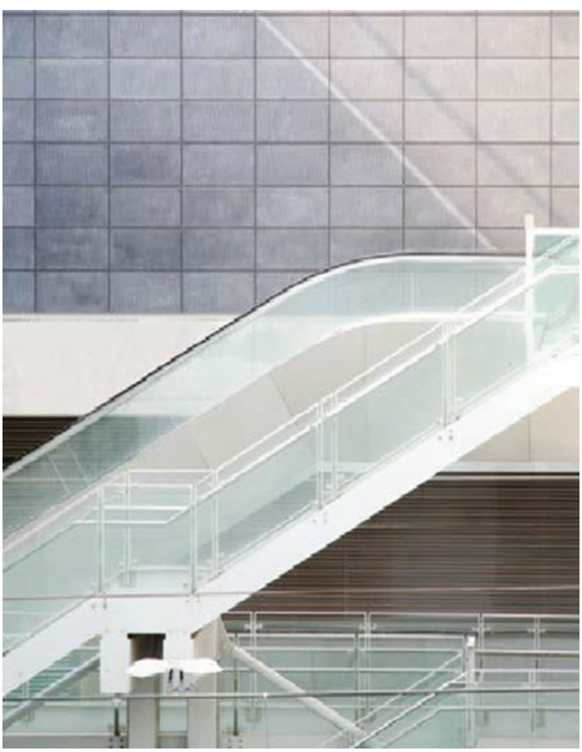
Designs are flexible and intended to be able to absorb future increases in passengers. Predictive programme software is used to estimate future space requirements taking into account local population growth, increased demand from expanding businesses and so on and Arup, Halcrow, Raillink all had input into the design of these modelling tools.

Such software can provide estimates as far forward as 2026. In the next 15 years, passenger demand is expected to grow 20%.

At present, both stations are primarily meeting local demand, as there is not much international traffic. However, Crossrail is coming and so may increase the population of these areas and, therefore, the demand for international transport.

HS1 has received many awards as a major project in a range of categories including engineering, construction, architecture, environment, safety, transport, property, planning and retail, including the following:

Ebbsfleet station entrance.



Inside Ebbsfleet station. *Source:* Image courtesy of Arup Associates.

Concourse at Ebbsfleet. *Source:* Image courtesy of Arup Associates.

- 2007 British Construction Industry Awards Highly Commended Major Project
- 2008 National Transport Awards – Outstanding Project of the Year
- 2008 Sustainable Communities Awards – highly commended in the sustainable development category
- 2008 Institute of Civil Engineering Brassey Award for Ebbsfleet International – Structural Project Category

Bibliography

AA (2017) *Helping cut carbon and reduce greenhouse gas emissions from transport*, The Automobile Association 22nd May 2017 http://www.theaa.com/motoring_advice/news/biofuels.html (accessed 12th June 2017).

Appleyard, D., Gerson, M. S., and Lintell, M. (1981). *Livable Streets, Protected Neighborhoods*. University of California Press. https://books.google.co.uk/books?id=pfreUQKD_4QC&redir_esc=y (accessed 12 June 2017).

ATAG (2017) *Passenger Biofuel Flights, Air Transport Action Group*. http://aviationbenefits.org/environmental-efficiency/sustainable-fuels/passenger-biofuel-flights/ (accessed 12th June 2017).

Barnes, J. and Chatterton, T. (2017) An environmental justice analysis of exposure to traffic-related pollutants in England and Wales. *WIT Transactions on Ecology and the Environment*, 210 (12), 431–442. ISSN 1743-3541. Available from: http://eprints.uwe.ac.uk/28882 (accessed 16 June 2017).

Berkley Biodiesel (2017) *Usage of Bio-diesel Fuel* http://www.berkeleybiodiesel.org/usage-of-biodiesel-fuel-a.html (accessed 12th June 2017).

Brook Lyndhurst (2015) *Uptake of Ultra Low Emission Vehicles in the UK: A Rapid Evidence Assessment for the Department for Transport*, August 2015 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/464763/uptake-of-ulev-uk.pdf (accessed 12th June 2017).

CCC (2013) *The Fourth Carbon Budget Review – part 2: the cost effective path to the 2050 target*, UK Committee on Climate Change 11th December 2013, https://www.theccc.org.uk/publication/fourth-carbon-budget-review/ (accessed 12th June 2017).

Chatterton, T. and Barnes, J. (2016) A social and spatial analysis of emissions from private vehicle use in Great Britain. *WIT Transactions on Ecology and the Environment*, 207, 99–110. ISSN 1743-3541. Available from: http://eprints.uwe.ac.uk/28883 (accessed 16 June 2017).

Chatterton, T.J., Anable, J., Barnes, J. and Yeboah, G. (2016b) Mapping household direct energy consumption in the United Kingdom to provide a new perspective on energy justice. *Energy Research & Social Science*, 18, 71–87. doi: 10.1016/j.erss.2016.04.013

Chatterton, T., Longhurst, J., Leksmono, N. *et al.* (2007) Ten years of local air quality management experience in the UK: an analysis of the process. *Clean Air and Environmental Quality*, 41 (4), 26–31. ISSN 1444–2841 Available from: http://eprints.uwe.ac.uk/8109 (accessed 16 June 2017).

Chatterton, T.J. *et al.* (2016a) Mapping household direct energy consumption in the United Kingdom to provide a new perspective on energy justice. *Energy Research & Social Science*, 18, 71–87. doi: 10.1016/j.erss.2016.04.013

Clark, A.(2005) *Decision makers go underground to ride the route of new rail link*. Guardian Newspaper article, Thursday 17 February 2005.

DECC (2016) *2014 UK Greenhouse Gas Emissions*, Final Figures, Statistical Release, UK Department of Energy and Climate Change, February 2016 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/496942/2014_Final_Emissions_Statistics_Release.pdf (accessed 8 June 2017)

Defra (2010) *Air Pollution: Action in a Changing Climate*, Department of Environment, Food and Rural Affairs, March 2010 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69340/pb13378-air-pollution.pdf (accessed 12th June 2017).

Defra (2016) *Summary Air Quality Management Area Data*, Department for Environment, Food and Rural Affairs. https://uk-air.defra.gov.uk/aqma/summary (accessed 12 June 2017).

DfT (2013) *Vehicle Licensing Statistics: 2012*, Department for Transport Statistical Release, 11th April 2013 https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/198753/vls-2012.pdf (accessed 12th June 2017).

DG Clima (2016) & EC (2017) *A European Strategy for low-emission mobility*, European Commission http://ec.europa.eu/clima/policies/transport/index_en.htm (accessed 12 June 2017).

EAC (2010) *Environmental Audit Committee Air Quality Fifth Report of Session 2009–10 Volume I*, HC 229-I, House of Commons, 22nd March 2010 http://www.publications.parliament.uk/pa/cm200910/cmselect/cmenvaud/229/229i.pdf (accessed 12th June 2017).

EEA (2009) *Turn Down the Noise - Softening the Impact of Excess Transport Noise*, European Environment Agency, 25th May 2009 http://www.eea.europa.eu/articles/turn-down-the-noise-2013-67-million-europeans-endure-high-transport-noise-exposure (accessed 12 June 2017).

ETIP (2017) *Use of Biofuels in Shipping, European Technology and Innovation Platform: Bioenergy*. http://biofuelstp.eu/shipping-biofuels.html (accessed 12th June 2017).

Goodwin (2012) *'Peak Car' Where did the idea come from? And Where is it going?*, Presentation for Centre for Transport and Society Winter Conference 2012 http://www2.uwe.ac.uk/faculties/FET/Research/cts/projects/reports/WC2012_goodwin_peak_car.pdf (accessed 12th June 2017).

Hart, J. and Parkhurst, G. (2011) Driven to excess: impacts of motor vehicles on the quality of life of residents of three streets in Bristol UK. *World Transport Policy & Practice*, 17 (2), 12–30. ISSN 1352–7614 Available from: http://eprints.uwe.ac.uk/15513 (accessed 16 June 2017).

Holder in Air Quality News (2014) *UK nitrogen dioxide mortality figures due next year 5th December 2014* http://www.airqualitynews.com/2014/12/05/uk-nitrogen-dioxide-mortality-figures-due-next-year/ (accessed 12 June 2017).

http://ec.europa.eu/environment/air/quality/legislation/existing_leg.htm (accessed 16 June 2017).

http://ec.europa.eu/environment/air/transport/road.htm (accessed 16 June 2017).

http://laqm.defra.gov.uk/supporting-guidance.html (accessed 16 June 2017).

http://www.airqualitynews.com/2014/06/23/passing-on-eu-fines-to-councils-unfair/ (accessed 16 June 2017).

http://www.arup.com/_assets/_download/download228.pdf (accessed 16 June 2017).

http://www.arup.com/_assets/_download/download234.pdf (accessed 16 June 2017).

http://www.legislation.gov.uk/ukpga/1995/25/part/IV (accessed 16 June 2017).

http://www.railwaysarchive.co.uk/documents/HS2_RouteEngineeringStudyAppendices_2010.pdf (accessed 16 June 2017).

https://www.gov.uk/government/publications/the-air-quality-strategy-for-england-scotland-wales-and-northern-ireland-volume-1 (accessed 16 June 2017).

Hunt, T. (2015) *Is There Enough Lithium to Maintain the Growth of the Lithium-Ion Battery Market?*, Greentech Media http://www.greentechmedia.com/articles/read/Is-There-Enough-Lithium-to-Maintain-the-Growth-of-the-Lithium-Ion-Battery-M (accessed 12th June 2017).

Longhurst, J.W.S., Irwin, J.G., Chatterton, T.J., Hayes, E.T., Leksmono, N.S. and Symons, J.K., 2009. The development of effects-based air quality management regimes. *Atmospheric Environment*, 43(1), pp.64-78. 10.1016/j.atmosenv.2008.09.050 (accessed 16 June 2017).

Mead (2007) *Noise Pollution: 'The Sound behind Heart Effects' published in Environmental Health Perspectives*, 115 (11), A536–537.

MLIT (2008) *World's CO2 Emissions in 2006, Ministry of Land, Infrastructure, Transport and Tourism*, Japan http://www.mlit.go.jp/kokusai/MEET/data_en.html (accessed 12th June 2017).

Olowoporoku, D., Hayes, E., Longhurst, J., and Parkhurst, G. (2009) *Managing local traffic-related air pollution in England presentation*. http://www.polisnetwork.eu/uploads/Modules/PublicDocuments/managing_local_traffic-related_air_pollution_in_england.pdf and Paper: https://www.researchgate.net/profile/Enda_Hayes/publication/265990201_Managing_local_traffic-related_air_pollution_in_England/links/54ae762d0cf2213c5fe4f175.pdf (accessed 16 June 2017).

POST (2013) *Peak car use in Britain, Parliamentary Office of Science and Technology (POST) briefing document for the Commons Transport Select Committee*, November 2013. http://www.parliament.uk/documents/commons-committees/transport/POST-briefing-on-peak-car.pdf (accessed 12 June 2017).

Shrink That Footprint (2013) *The 'electric cars aren't green' myth debunked* http://shrinkthatfootprint.com/electric-cars-green (accessed 12th June 2017).

T&E (2008) *Can you hear us? Why it is finally time for the EU to tackle the problem of noise from road and rail traffic*, European Federation for Transport and Environment 08/1 http://www.transportenvironment.org/sites/te/files/media/2008-02_traffic_noise_can_you_hear_us.pdf (accessed 12 June 2017).

Tiwary, A., Chatterton, T. and Namdeo, A. (2014a) Co-managing carbon and air quality: pros and cons of local sustainability initiatives. *Journal of Environmental Planning and Management*, 57 (8), 1266–1283. doi: 10.1080/09640568.2013.802677

Tiwary, A., Chatterton, T. and Namdeo, A. (2014b) Co-managing carbon and air quality: pros and cons of local sustainability initiatives. *Journal of Environmental Planning and Management*, 57 (8), 1266–1283. doi: 10.1080/09640568.2013.802677

WHO Regional Office for Europe, OECD (2015). *Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth*. Copenhagen: WHO Regional Office for Europe. http://www.euro.who.int/__data/assets/pdf_file/0004/276772/Economic-cost-health-impact-air-pollution-en.pdf?ua=1 (Accessed 12 June 2017)

4

Energy

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In most countries, advances in manufacturing, technology, heating and cooling systems in buildings and transport, continue to drive an increasing demand for energy which is still largely met by the burning of fossil fuels (coal, oil and natural gas). Although the development of alternative, 'renewable' sources of energy such as solar, wind and water, now make a significant contribution to energy production in many parts of the world, serious concerns remain about the emissions of carbon dioxide, other gases and pollutants which result from the use of fossil fuels.

The Emission Database for Global Atmospheric Research Emission Database shows that emissions of CO_2 were 33.4 billion tonnes in 2011, 48% more than those of 20 years ago (EC, 2011). The Inter-governmental Panel on Climate Change (IPCC) has estimated that over the past century, the global level of CO_2 in the atmosphere has increased by more than 39%, from 280 ppm during the pre-industrial era to the record high level of 400 ppm in May 2013 (IPCC, 2007).

http://www.sciencedirect.com/science/article/pii/S1364032114005450
https://www.youtube.com/watch?v=eiBiB4DaYOM
http://www.EnergyPLAN.eu
https://www.youtube.com/watch?v=MxJz6NSz8eg

Concerns about greenhouse gases and other atmospheric pollutants and their possible link to climate change, have resulted in much energy policy and practice in United Kingdom, determined by national and EU environmental legislation. This legislation has not only resulted in conventional energy sources becoming more efficient and less polluting, but has also driven the increasing demand for renewable energy sources.

The EU's climate and energy policy sets the following targets for 2020:

- A 20% reduction in EU greenhouse gas emissions from 1990 levels.

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

- Raising the share of EU energy consumption produced from renewable resources to 20%.
- A 20% improvement in the EU's energy efficiency.

In United Kingdom, the Climate Change Act (2008) sets legally binding greenhouse gas emission reduction targets of at least 80% by 2050 (with an interim target of 26% by 2020) against a 1990 baseline, which are to be achieved through action taken in United Kingdom and abroad.

The National Planning Policy Framework (NPPF) was published in March 2012. It is intended to replace various existing Planning Policy guidance documents so as to make the planning system less complex and more accessible. Key sections from the NPPF include Paragraph 95, which states that: 'To support the move to a low carbon future, local planning authorities should …when setting any local requirement for a building's sustainability, do so in a way consistent with the Government's zero carbon buildings policy and adopt nationally described standards'.

From Arup Guidance note 2015. See Appendices for the full document.

Renewable Energy Options

Technologies which generate electricity or heat from natural resources such as Solar Rays, Wind, Water, Biomass, Ground Source, Anaerobic and Hydropower, are considered 'renewable' because, unlike coal, oil and natural gas, they are not *finite*. Combined Heat and Power systems are not, strictly speaking, renewable, as they often rely on a fossil fuel source. They are, however, a more efficient and less polluting way to generate electricity and energy for buildings (https://www.carbontrust.com/media/7379/ctv010-renewable_energy_sources.pdf).

Photovoltaic Panels

Photovoltaic (PV) panel technology harnesses energy through the sun's rays and is currently one of the most efficient forms of renewable electricity generation.

PV arrays can sit in the landscape or on or within the building envelope as building integrated photovoltaic (BIPV) panels. Both arrangements actively convert solar energy into electricity that can be used in commercial or residential buildings. The PV cells are arranged into modules, then into arrays and then finally placed on the land or onto buildings (https://www.carbontrust.com/media/81357/ctg038-a-place-in-the-sun-photovoltaic-electricity-generation.pdf; www.samlexsolar.com).

BIPVs are most commonly fitted to the roof of buildings and then connected to the national grid. However, in both commercial and residential buildings, they can be integrated into skylights, facades, windows, curtain walls and, in thin form, into roof tiles and shingles, although shading from surrounding buildings or trees can have an adverse effect on the efficiency of the system (http://inhabitat.com/solar-panel-roof-tiles/).

There are four principal types of PV cells:

1) Monocrystalline PV (mono-si)
2) Polycrystalline PV (poly-si)

3) Thick-film PV
4) Thin-film PV

(Elsadig, 2005: 69)

The most common PV cells on the market are made out of two silicon semi-conductors. When the photons from the sunlight hit the semi-conductors, they excite the electrons making them jump from the boron-doped *p*-type silicon conductor to the phosphorous-doped *n*-type silicon conductor (Jariwala and Jariwala, 2014: 39). This flow of electrons creates an electric field across the layers, which is then used to power the building. 'Doping' the silicon semi-conductors is important because it makes the conversion to electricity more efficient by increasing the energy of the outer shell electrons (Shepard and Shepard, 2014; www.gosunsolutions.com).

Once installed, PVs are environmentally 'clean'. Sunlight is free and the cells produce no carbon, emissions or noise pollution. The cells are made of silicon, which at present is an abundant material (Jariwala and Jariwala, 2014).

PV cells' embodied impact is relatively small and has rapidly decreased in recent years through research and development. Raugei and Frankl (2009) looked at the life cycle energy (LCE) consumption of PV systems and its environmental impact. They found that poly-si rooftop cells in the 1990s had an LCE of 167 g (CO_2)/kWh whereas in 2008 they had only an LCE of 37 g (Co^2)/kWh, a fourfold improvement.

Manufacturing costs have been reduced through innovation in the production of the silicon crystals used. Previously, crystals were made in the form of an ingot and then cut into thin wafers. This was very expensive. Now, silicon crystals are grown into a ribbon shape and do not need cutting or strict temperature control (Shepard and Shepard, 2014: 431).

Energy used during transportation has also decreased in the past few years, as manufacturing has started within United Kingdom by companies such as Sharp Solar and Sunsolar Energy. Furthermore, Sunsolar Energy has stated that all the parts needed to make the product will be locally sourced (www.greenwisebusiness.co.uk, 2012).

This, however, may be an optimistic outlook when taking a more global viewpoint, as there are still significant amounts of imported PV cells manufactured in countries that have lower green taxes. For example, many EU countries continue to import panels manufactured in China (http://www.iea.org.uk, 2014).

As with the embodied impact of PV cells, the unit cost of the panels has also been reducing. Jariwala and Jariwala (2014) found that manufacturing prices decreased by 50% in 2011 alone. A 4 kWp system (16 solar panels) that used to cost £15,000 in 2011 is now available from £5400 plus 5% VAT. However, initial costs of buying and installing solar panels remain relatively high. Typically, a 4 kWp residential system in south west England will produce around 4.000 kWh per year. This will provide a year one return of around £1000, a return of just over 20% (www.comparemysolar.co.uk, 2014).

Hammond *et al.* (2011) found through life-cycle assessment that systems are unlikely to pay back their investment over a life span of 25 years, but that they would recover their embodied impact in just 4.5 years. However, it is likely that because there has, for example, been progression in research and manufacturing since 2011, the payback time for the embodied impact will be shorter. In addition, this study was completed when there were no government feed-in-tariffs.

The maintenance of solar panels is easy and requires relatively little work since there are no moving parts (Shepard and Shepard, 2014: 427). This makes the monetary payback quicker as the service charge, once installed, is small.

Government feed-in-tariffs did mean that home owners could get economically rewarded for installing PVs. For example, in a residential property that has a system size of 4 kWp, the feed-in-tariffs could save homeowners approximately £750 a year (http://www.energysavingtrust.org.uk).

However, such incentives can be withdrawn as a result of changing government policy and the state of the national economy.

The clearest practical constraint for using BIVPs within United Kingdom is the amount of sunlight a year received and its intermittent nature. Although solar panels can produce energy under cloud cover, peak performance is with maximum sunlight intensity hitting the cells. Shepard and Shepard (2014) found that the mean annual solar power received was about three times more in countries like Egypt than in Great Britain; 300 rather than 100 W/m^2. It was also found that the distribution of solar radiation is much 'flatter' annually in Egypt, whereas in England, solar radiation is the highest in June when demand for energy is the lowest.

The Heron Tower in London has an area of 3200 m^2 and 855 modules on the façade of the building. This is estimated to have a power output of 34 kWp (Solar Technology Centre, 2014). However, another tower has been given planning permission to be constructed on the South side of the building. This means that it will shade the PV modules and significantly reduce the power output. This clearly highlights the practical constraints that could occur with PV's.

Although some PV arrays can suffer low social acceptability through poor aesthetics and high capital costs (Raugei and Frankl, 2009: 294), this is slowly changing, as it becomes more fashionable to be seen to be 'going green'. In particular, companies are putting more investment into renewables to ensure their business is viewed as being ethically and environmentally responsible. This can be seen at Marks & Spencer's Donnington Park distribution centre where they have started to install 24,272 solar PV panels in order to further enhance their sustainability credentials (www.greenwisebusiness.co.uk, 2014).

BIVPs have a high cost compared to conventional energy sources. To be competitive with the normal route of generating electricity through burning fossil fuels, the cost of generating electricity needs to be £0.07 per kWh (Shepard and Shepard, 2014: 434). In order to be the product of choice, solar panel technology needs to become cheaper so that there is not such a big lag time from installation until their economic value is realised, at present, many years later (www.gosunsolutions.com, 2014). Increased efficiency and increased ability to integrate PV's into new and old buildings are happening at a rapid pace, with new thin-film photovoltaics being designed that reduce manufacturing costs (www.gosunsolutions.com).

Some 'solar slates' for houses have also been designed in order for PVs to be more aesthetically pleasing and less obtrusive, but at present, cost significantly more than the normal roof BIVPs (http://www.energysavingtrust.org.uk, 2014).

However, such innovation could mean that PV will become increasingly easy to embed into the buildings of the future.

Carbon costs of transportation can be significant depending on the location of production, the sources of raw materials and the main markets for the product. For example, a 190 W solar panel weighing 22 kg can create 57 kg of CO_2 if it is transported by air or 7 kg if transported by ship.

The total cost for a 1 MW solar farm is just under £50,000 and payback takes around 7–10 years at 12% interest, not taking into account the purchase of the land (Mandal, 2014). The carbon cost of disposing of the PV is still unknown, as it is such a new technology and few have reached the end of their life span (Shah et al., 1999). The UK government reduced the feed-in-tariffs in 2012 to 10 p/kWh for schemes greater than 250 kWh and this subsidy has since dropped to 6.38 p/kWh (Ofgem e-serve, 2014).

Combined Heat and Power (CHP)

As can be seen from the diagram and video clip below, heat is the waste product created by the movement of the electricity generating process (http://www.theade.co.uk/what-is-combined-heat-and-power_15.html).

Combined heat and power is a system that produces heat and electricity at the same time. This can be done on a large scale with co-generation power plants or for smaller projects with micro-CHP's in commercial and residential buildings. CHP's are made from four elements (IEA, 2011):

1) Prime mover
2) Electricity generator
3) Heat recovery system
4) Control system

www.energysolutionscenter.org

There are many different types of CHP's normally depending on what 'prime mover' is used. Prime movers can be a reciprocating engine, a heat recovery steam generator, steam turbine, gas turbine or a micro-turbine (www.centreforenergy.com).

The three main micro-CHP's are Stirling engine, internal combustion and fuel cells. Fuel cells are new to the UK market and are not yet used commercially (Shepard and Shepard, 2014: 89–90). Micro-CHP's in residential buildings look like a typical boiler (www.energysavingtrust.org.uk; https://en.wikipedia.org/wiki/Stirling_engine).

Different CHP's produce a different output ratio of heat and electricity. Micro-CHP's on average currently produce a lot more heat than electricity at a ratio of about 6:1 for domestic appliances. In a residential building, micro-CHP systems tend to be Stirling engines powering CHP boilers because they are compact and less noisy (www.thegreenage.co.uk, 2014).

Fossil fuels power a prime mover which is attached to an electrical generator. This electrical generator produces the electricity that goes to the building or is sold back to the national grid. Heat produced from the prime mover is caught and used to heat the air and water in buildings (www.centreforenergy.com, 2014).

Fuel cells work differently because electricity and heat are produced and used from a chemical reaction. Hydrogen is the fuel and is placed into a cell stack that contains an anode, cathode and electrolyte layer. The hydrogen then reacts with oxygen producing the electricity and the heat (www.fuelcellenergy.com, 2014).

There are four different types of fuel cells: molten carbonate fuel cells, solid oxide fuel cells, phosphoric acid fuel cells and polymer electrolyte fuel cells. The big advantage of CHP's powered by fuel cells is that the ratio of heat to electricity is 1:1, which is much more commercially beneficial (IEA, 2011).

Burning fossil fuels normally charge CHP's, but they are more efficient and are low carbon compared to obtaining electricity from the national grid and cut a building's carbon footprint by up to 40% (www.thegreenage.co.uk, 2014).

Installation and maintenance are easy for most micro-CHP's as they are the same as a standard conventional boiler and usually mean that the service charge on the building will not increase dramatically. A typical residential micro-CHP has to be charged only every 10,000 h (www.energ-group.com, 2014).

CHP's work well because occupiers tend to want heat at the same time that they want electricity. In a residential building for example, building users want hot water in the mornings and the evenings, therefore, electricity will also be produced at 'peak demand' periods (www.thegreenage.co.uk, 2014).

Due to the government's targets of reducing CO_2 emissions by up to 80% by 2050, if CHP's are installed in buildings, owners can benefit from government subsidies through their feed-in-tariffs (www.energysavingtrust.org.uk, 2014).

At present, a Stirling engine micro-CHP for a residential building costs around £7400, rising to £8000 for an LPG unit, not including installation costs (www.thegreenage.co.uk, 2014).

The economic payback time for micro-CHPs is relatively good. According to the Energy Saving Trust's (2014) 'cashback calculator' shows the amount an average residential home owner can be expected to save annually by installing a micro-CHP boiler. Data produced by the UK government in 2013 on what figure to use for the annual generation of kWh per year for a UK domestic household has been used (www.gov.uk, 2013; http://tools.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Cashback-Calculator; http://www.energysavingtrust.org.uk/scotland/tools-calculators/cashback-calculator).

The cashback calculator found that by installing a micro-CHP in a residential building, the landlord could save approximately £784 a year excluding any maintenance costs. After 10 years £7844 could be saved, thus recovering the cost of buying the micro-CHP.

A current limitation of CHP's is that they are not hugely flexible in the ratio of heat to electricity that they can produce. Current micro-CHP's on the market for domestic use can produce 1 kWh of electricity when the boiler is working at its maximum capacity. Putting this into perspective, a kettle needs 3 kWh of electricity to boil 1 l of water (www.thegreenage.co.uk, 2014).

In addition, in the summer when no heating is required, the CHP will not be producing any electricity. However, larger CHP's produce more heat and, therefore, more electricity, thus making CHP's more viable for larger commercial buildings (Chwieduk, 2003: 213).

Some companies selling CHP's claim that they have an efficiency rate of between 80 and 90% and decrease energy consumption by around 15–45% (Smith et al., 2013). However, the word 'efficiency' must be deconstructed; 80–90% is the *total efficiency,* not the heat or electricity efficiency. With CHP's, increasing the heat production decreases electricity production (MacKay, 2009: 149) and so, the future development of CHP's perhaps needs to focus on making the ratio of heat and electricity production the same, as electricity is more valuable than heat.

Studies show that CHP can reduce energy costs in many different types of commercial building and that the costs of installing CHP plants can have a payback period in the range of 7–9 years (Ibid. & Maidment and Tozer, 2002).

The costs of the systems vary as they are building specific and, because this is a new technology, there is little reliable research to show if the efficiency of CHP remains the same throughout its lifetime, or indeed, how long these systems last. CHP has practical constraints, requiring planning permission for plants less than 50M (LGA, 2014), needing more space than the non-renewable equivalent system and can be noisy.

Also, as the demand for power in buildings tends to spike at different times of the day and seasonally, unnecessary heat can be generated. However, with careful management, excess heat can be used by connecting other buildings to the system. CHP's also require grid connection in order to get the 4.1 p/kWh UK Government generation tariff (Ofgem, 2014). The amount it receives quarterly is calculated by the tariff level multiplied by the heat generated. Recently, the UK Government withdrew its Levy Exception Certificates which reduced tax rates on buildings with CHP (LGA, 2014 & CHPA, 2013).

The global CHP market is currently increasing at a fast rate with an expectation that it will grow 20.2% up to 2019. This is because the government is funding many leading companies and experts in order to create new technologies (www.digitaljournal.com).

Development is focusing on fuel cell technology because of its ability to produce a higher ratio of electricity to heat. They are the products which utilise a chemical reaction which is more sustainable than current CHP technology. Larger systems such as internal combustion engines, can be fuelled by fuel cells rather than by fossil fuels and therefore significantly reduce the carbon emissions released into the atmosphere (Neef, 2008: 265–272).

If CHP's can be fuelled by fuel cells or biomass rather than fossil fuels and manufacturing costs can be decreased, then CHP's can become an excellent way for buildings to significantly decrease their carbon footprint and embodied impact.

Ground Source

Ground source heating or cooling works by transferring heat to or from the ground via a heat pump in the building and a loop of water and/or antifreeze-filled pipework buried in the ground. The captured heat is then used for water or space heating within the property

https://www.youtube.com/watch?v=KE3SvNRmwcQ
https://www.youtube.com/watch?v=jzXt55ZGsNw
http://energy.gov/energysaver/articles/geothermal-heat-pumps
http://www.energysavingtrust.org.uk/domestic/ground-source-heat-pumps
http://www.gshp.org.uk/documents/CE82-DomesticGroundSourceHeatPumps.pdf
https://en.wikipedia.org/wiki/Geothermal_heat_pump).

The feasibility of these systems for particular buildings will depend on the building itself, ground conditions, plot size and accessibility for digging trenches or boreholes.

A well-insulated, thermally efficient building is essential if the system is to function correctly and whilst the payback period of these systems has been found to be cost effective when replacing electricity or coal as the prime heating source, they are less economical for buildings using mains gas.

Because of the lower water temperatures required, ground source systems are also more commonly used with underfloor heating systems or warm air heating rather than with radiators (EST, 2016).

Biomass Boilers

Biomass is organic matter which comes from plants and trees and is most commonly burnt in compressed block, wood chip or pellet form as a fuel source in boilers to provide heat to residential, institutional and commercial properties or to district heating plants such as this proposed installation in Northamptonshire, United Kingdom

http://www.theade.co.uk/nexterra-consortium-reaches-financial-close-on-biomass-gasification-plant-in-northamptonshire_3044.html
https://en.wikipedia.org/wiki/Biomass
https://www.youtube.com/watch?v=JZak3wa8gZQ
https://www.youtube.com/watch?v=ZNVx_ndDE8U
http://www.carbontrust.com/media/31667/ctg012_biomass_heating.pdf
http://www.carbontrust.com/resources/guides/renewable-energy-technologies/biomass-heating-tools-and-guidance/
https://www.gov.uk/government/publications/woodfuel-guidance
http://www.ucsusa.org/clean_energy/our-energy-choices/renewable-energy/how-biomass-energy-works.html#.VebXvCVViko
http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/BEC_TECHNICAL/BEST%20PRACTICE/36491_FOR_BIOMASS_1.PDF
http://www.energysavingtrust.org.uk/domestic/biomass
http://www.theade.co.uk/medialibrary/2014/10/14/f8e891d8/Llanwddyn%20Biomass%20Case%20Study.pdf
http://www.thegreenage.co.uk/tech/biomass-boilers-versus-conventional-gas-boilers/.

Whilst the initial cost of a biomass boiler is more than that of conventional gas or oil-fired boilers, the running costs per kWh can be lower compared to non-renewable sources (Berkovic-Subic et al., 2014). A study by Chau et al. (2009) found that biomass boilers for the commercial production of food in greenhouses were seven times more expensive for a 5 MW plant than the equivalent natural gas boilers. However, the same study also concluded that a biomass boiler saved 3000 tonnes of CO_2 compared to a natural gas boiler.

On average, a wood chip burner has around 70% efficiency whilst a pellet burner has an efficiency of around 80% for both residential and commercial (Hebensteit et al., 2014). According to Hebensteit et al. (2014) the payback time for a wood chip burner is up to 12 years, depending on the flue gas temperature.

Irresponsible, uncontrolled harvesting of timber can cause deforestation leading to soil erosion, loss of biodiversity and eutrophication (http://toxics.usgs.gov/definitions/eutrophication.html; http://study.com/academy/lesson/what-is-eutrophication-definition-causes-effects.html).

Consequently, all large-scale commercial UK biomass boilers have to run using sustainably sourced (FSC accredited) wood, using a variety of wood types (Ofgem, 2014). The UK Government's Department of Energy and Climate Change (DECC) has provided a 10 p/kWh subsidy for the generation of heat from biomass boilers although this policy is of course subject to change (DECC, 2013). The financial cost of this requirement to use only sustainably sourced timber does seem to mean that only larger boilers for commercial buildings are commercially viable. Smaller boilers (in the 1 MW range) often co-fire biomass and natural gas to give a better rate of return (Saidur et al., 2011). In United Kingdom, biomass is still perceived by some as an evolving technology requiring a substantial upfront investment with an uncertain future financial payback profile.

Wind Turbines

Wind turbines use natural wind movement to generate electricity and first started generating commercial electricity in United Kingdom in 2008 when the technology provided around 1% of the total electricity generation of the country. Generally, the larger the blades on the turbine, the greater the electricity generated and therefore also determining the height of the turbine itself (Lu et al., 2002; https://www.youtube.com/watch?v=qSWm_nprfqE; http://energy.gov/eere/wind/inside-wind-turbine-0; http://www.ifpaenergyconference.com/Wind-Energy.html).

Wind turbines need to be in a position where there are constant and relatively high wind speeds. Their location in United Kingdom has been controversial in terms of noise creation, visual pollution and a claimed adverse effect on residential house prices (Devine-Wright, 2004; Sims *et al.*, 2010).

Because of opposition from the public and local planning authority, many commercial buildings do not have wind turbines.

The 2 MW wind turbine stands 85 m tall with a blade diameter of 71 m and can power up to 1500 homes (Enercon, 2014).

Large-scale wind turbines are defined as greater than 1000 kW (or 1 MW). The 1000 kW and 2000 kW turbines both have a payback of under 5 years, whereas the 3000 kW has a payback of 10 years. This is because the project cost of the turbines increases by £2 million and because the tariff rate drops from 11.86 to 3.23 p/kWh from 1000 and 2000 to 3000 kW respectively (Renewables First, 2014).

Wave and Hydropower

Although not widely used in United Kingdom (producing only 1.8% of UK electricity and 18% of renewable energy), hydropower produces more than 70% of renewable energy worldwide and more than 16% of all electricity generated internationally. The main sources of hydropower are dams, rivers and tides.

Whilst providing an excellent source of emission-free, renewable energy, hydropower from dams has been associated with a number of negative environmental impacts resulting in the building of huge reservoirs necessary including ecosystem damage and loss of land, forced relocation of communities, flooding caused by poor construction or natural disaster and methane emissions from decaying plant material lost underwater (https://en.wikipedia.org/wiki/Hydroelectricity; https://en.wikipedia.org/wiki/Tidal_power).

Anaerobic Digestion

As with hydropower, anaerobic digestion processes whereby gas produced by the breakdown of biodegradable waste materials including food, sewage solids, paper and grass cuttings, is then burnt to produce energy, is not a major source of energy in United Kingdom. However, there are over 300 plants in the country at present with plans to develop over 450 new sites in the future (http://www.nnfcc.co.uk/bioenergy/ad-deployment-report, 2016; https://en.wikipedia.org/wiki/Anaerobic_digestion; http://www.biogas-info.co.uk/resources/biogas-map/).

Conclusion

Although renewable technologies help to reduce CO_2 emissions, to date no studies have been able to determine the full carbon footprint (including sourcing materials, production, transportation and disposal) of the renewable technologies discussed here. It can be concluded, however, that wind turbine technology has the quickest payback time (of around 4 years) but obviously depends on a constant supply of wind and can also be harder to gain planning permission for. CHP works well in commercial buildings and can reduce both financial and environmental costs. Whilst they are efficient sources of energy, biomass boilers don't work as well on a commercial scale as they rely on large deliveries of sustainable (and therefore expensive) wood or other certified products. PV has been a huge success in United Kingdom despite the reduction in tariffs. It generates an income for the customer and has a relatively quick payback time. Current installations are, however, so new that they may be outdated and relatively inefficient within 10 years as newer renewable energy technologies rapidly evolve.

Bibliography

Aso, R. and Cheung, W. (2014) Towards greener horizontal-axis wind turbines: analysis of carbon emissions, energy costs at the early design stage. *Journal of Cleaner Production*, **87**, 263–274.

Bateman, L. (2012) http://www.greenwisebusiness.co.uk/news/midlandsbased-solar-firm-to-build-10m-uk-pv-manufacturing-plant-3403.aspx#.VEqYO4vF8rg (accessed 24 October 2014)

Bateman, L. (2014) http://www.greenwisebusiness.co.uk/news/61mw-solar-array-to-power-mands-castle-donington-warehouse-4491.aspx#.VEqZZ4vF8rg (accessed 24 October 2014)

Berkovic-Subic, M., Rauch, M., Dovic, D. and Andrasay, M. (2014) Primary energy consumption of the dwelling with solar hot water system and biomass boiler. *Energy Conversion and Management*, **87**, 1151–1161.

Biomass Boiler FAQs (2014) *Tundra Biomass Boilers*. www.tundrabiomassboilers.co.uk/biomass-boiler-faqs/index.html (accessed 24 October 2014)

Biomass Energy Centre (2014) *Forestry Commission: Frequently Asked Questions.* http://www.biomassenergycentre.org.uk/pls/portal/docs/PAGE/PRACTICAL/INSTALLING%20BIOMASS%20SYSTEMS/BEC%20FAQ%20V1%20JUNE%2009.PDF (accessed 24 October 2014)

Booth, P. and Stagnaro, C. (2014) http://www.iea.org.uk/blog/the-folly-of-europe%E2%80%99s-decarbonisation-plan (accessed 23 October 2014).

Boukhanouf, R. (2011) Small combined heat and power (CHP) systems for commercial buildings and institutions, in *Small and Micro Combined Heat and Power (CHP) Systems* (ed. R. Beith), Woodhead Publishing, pp. 365–394.

British Hydropower Association (2014) *Hydropower - Protecting the Environment - Supporting Rural Communities. (Online)* http://www.british-hydro.org/ (accessed 10 March 2014)

Brundtland Commission (1987) *The World Commission on Environment and Development's Report Our Common Future*, Oxford University Press, Oxford.

Centre for Energy (2014) http://www.centreforenergy.com/AboutEnergy/ (accessed 23 October 2014).

Chau, J., Sowlati, T., Sokhansanj, S. *et al.* (2009) Techno-economic analysis of wood biomass boilers for the greenhouse industry. *Applied Energy*, **86** (3), 364–371.

Cherrington, R., Goodship, V., Longfield, A. and Kirwan, K. (2013) The feed in tariff in the UK: A case study focus on domestic photovoltaic systems. *Renewable Energy*, **50**, 421–426.

CHPA (2013) *LEC Scheme Ends for CHP Generators.* http://www.chpa.co.uk/lec-scheme-ends-for-chp-generators_1325.html (accessed 25 October 2014)

Chwieduk, D. (2003) Towards sustainable-energy buildings. *Applied Energy*, **76**, 211–217.

Compare My Solar (2014) http://www.comparemysolar.co.uk/ (accessed 25 October 2014).

DECC (2013) *Non-Domestic Renewable Heat Incentive.* https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/265854/Non-Domestic_Renewable_Heat_Incentive_-_Improving_Support_Increasing_Uptake_-_PUBLISHED.pdf (accessed: 24 October 2014)

Department of Energy and Climate Change (n.d.) *Digest of UK Energy Statistics.*

Devine-Wright, P. (2004) Beyond NIMBYism: towards an integrated framework for understanding public perceptions of wind energy. *Wind Energy*, **8** (2), 125–139.

Digital Journal (2014) http://www.digitaljournal.com/pr/2207959 (accessed 20 October 2014).

Eco-tricity (2014) *Eco-Tricity Rolls out the Worlds Frist Wind Powered Car Charger.* http://inhabitat.com/ecotricity-rolls-out-the-worlds-first-wind-powered-car-charger/ (accessed 24 October 2014)

Elsadig, A. (2005) *Energy Efficiency in Commercial Buildings*, http://www.esru.strath.ac.uk/Documents/MSc_2004/elsadig.pdf (accessed 24 October 2014).

Ener-g (2014) http://www.energ-group.com/combined-heat-and-power/micro-cogeneration/ (accessed 23 October 2014).

Enercon (2014) *E70 Tried and Tested Technology.* http://www.enercon.de/en-en/61.htm (accessed 24 October 2014)

Energy Savings Trust (2014) http://www.energysavingtrust.org.uk/Generating-energy/Getting-money-back/Cashback-Calculator (accessed 22 October 2014).

Energy Savings Trust (2016) site http://www.energysavingtrust.org.uk (accessed April 2016).

Energy Solutions Centre (2014) http://www.energysolutionscenter.org/gas_solutions/micro_chp_mchp.aspx (accessed 22 October 2014).

European Commission (2011), Emission database for global atmospheric research EDGAR, European Commission: http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2011 (accessed 14 June 2017)

Feed in Tariffs (2014) *Carbon Trust.* http://www.carbontrust.com/resources/faqs/technology-and-energy-saving/feed-in-tariffs (accessed 25 October 2014)

Fthenakis, C.K. (2008) Emissions from photovoltaic life cycles. *Environmental Science and Technology*, **42** (6), 2168–2174.

Go Sun Solutions (2014) http://gosunsolutions.com/education.php (accessed 22 October 2014).

Gov UK (2013) https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/295244/Revisions_to_DECC_domestic_energy_bill_estimates.pdf (accessed 22 October 2014).

Gov UK (2014) https://www.gov.uk/government/policies/reducing-the-uk-s-greenhouse-gas-emissions-by-80-by-2050 (accessed 24 October 2014)

Hammond, G. *et al* (2011) Whole systems appraisal of a UK building integrated photovoltaic (BIVP) system. *Energy, Environmental and Economic Evaluations*, **40** (2012), 219–230.

Hebensteit, B., Schnetzinger, R., Ohnmacht, R. *et al.* (2014) Techno-economic study of a heat pump enhanced flue gas heat recovery for biomass boilers. *Journal of Biomass and Bioenergy*, **71**, 12–20.

IEA (2011) *Technology Roadmap: Energy-Efficient Buildings Heating and Cooling*, International Energy Agency, France.

IPCC (2007a), IPCC fourth assessment report: climate change 2007 (AR4) from IPCC website: http://ipcc.ch/publications_and_data/publications_and_data_reports.shtml/ (accessed 14 June 2017).

IPCC (2007b) *IPCC (200&) IPCC Fourth Assessment Report: Climate Change 2007 (AR4) from IPCC* http://ipcc.ch/publications_and_data/publications_and_data_reports.shtml/ (accessed 14 June 2017).

Jariwala, A. and Jariwala, S. (2014) An overview of electricity generation sources, in *Green Power: Perspectives on Sustainable Electricity Generation* (eds J.N. de Figueiredo and M.F. Guillén), CRC Press.

Jui-Sheng, C. and Wan-Ting, T. (2011) Failure analysis and risk management of a collapsed large turbine tower. *Engineering Failure Analysis*, **18** (1), 295–313.

Kerstin, O. and Pacca, S. (2013) Life cycle assessment of an onshore wind farm located at the north-eastern coast of Brazil. *Renewable Energy*, **53**, 60–70.

Knowles, J. (2011) Overview of small and micro combined heat and power (CHP) systems, in *Small and Micro Combined Heat and Power (CHP) Systems: Advanced Design, Performance, Materials and Applications* (ed. R. Beith), Woodhead Publishing, pp. 3–16.

Leung, D., Caramarra, M. and Maroto-Valer, M. (2014) An overview of current status of carbon dioxide capture and storage technologies. *Renewable and Sustainable Energy Reviews*, **39**, 426–443. http://dx.doi.org/10.1016/j.rser.2014.07.093.

LGA (2014) *Combined Heat and Power.* http://www.local.gov.uk/climate-change/-/journal_content/56/10180/3510573/ARTICLE#issues (accessed 25 October 2014)

Lu, L., Yang, H. and Burnett, J. (2002) Investigation on wind power potential on Hong Kong islands- an analysis of wind power and wind turbine characteristics. *Renewable Energy*, **27** (1), 1–12.

MacKay, D. (2009) *Sustainable Energy Without the Hot Air*, UIT Cambridge Ltd, Cambridge.

Maidment, G. and Tozer, R. (2002) Combined Cooling heat and power in supermarkets. *Applied Thermal Engineering*, **22** (6), 653–665.

Mandal, A. (2014) *Design & Estimation of 1 MW Utility Scale Solar V Power Pant: Technical and Financial.* http://www.academia.edu/5449881/Design_and_Estimation_of_1MW_utility_Scale_Solar_PV_Power_Plant_Technical_and_Financial_UPDATED_ (accessed 14 June 2017).

Naimaster, E. and Sleiti, A. (2013) Potential of SOFC CHP systems for energy-efficient commercial buildings. *Energy and Buildings*, **61**, 153–160.

Neef, H.J. (2008) Hydrogen and fuel cell research for future markets, in *Sustainable Energy Production and Consumption: Benefits, Strategies and Environmental Costing* (eds F. Barbir and S. Ulgiati), Springer, Netherlands, pp. 265–272.

Ofgem (2014a) *Tariffs that Apply for Non-Domestic RHI for Great Britain*. https://www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi/tariffs-apply-non-domestic-rhi-great-britain (accessed 25 October 2014)

Ofgem (2014b) *Non-Domestic Renewable Heat Incentive (RHI).* https://www.ofgem.gov.uk/environmental-programmes/non-domestic-renewable-heat-incentive-rhi (accessed 24 October 2014)

Ofgem e-serve (2014) *Feed-in Tariff Payment Rate Table for Photovoltaic Eligible Installations for FIT.* https://www.ofgem.gov.uk/ofgem-publications/89096/fitpaymentratetableforpublication1october2014pvtariffs.pdf (accessed 25 October 2014).

Paish, O. (2002) Small hydro-power: technology and current status. *Renewable and Sustainable Energy Reviews*, **6** (6), 537–556.

Palmer, D. (2009) *Frequently Asked Questions*. Retrieved from Biomass Energy Centre: www.biomassenergycentre.org.uk (accessed 14 June 2017).

Pearson, P. and Watson, J. (2010) *Parliamentary Group for Energy Studies*, UK Energy Policy 1980–2010, pp. 1–44.

Perry, S., Klemes, J. and Bulatov, I. (2008) Integrating waste and renewable energy to reduce the carbon footprint of locally integrated energy sectors. *Energy*, **33** (10), 1489–1497.

Polhill, R. (n.d.) *Heron Tower.* http://www.herontower.com/pdf/factsheet.pdf (accessed 14 June 2017).

Popovski, K. and Vasilevska, S. (2008) Sustainability and economic feasibility of combinations of renewable energy sources (RES) and fossil fuels for production of heat and electricity, in *Sustainable Energy Production and Consumption: Benefits, Strategies and Environmental Costing* (eds F. Barbir and S. Ulgiati), Springer, Netherlands, pp. 159–170.

Raugei, M. and Frankl, P. (2009) Life cycle impacts and costs of photovoltaic systems: current state of the art and future outlooks. *Energy*, **34** (3), 392–399. WESC 2006. 6th World Energy System Conference. http://www.sciencedirect.com/science/article/pii/S0360544209000061 (accessed 14 June 2017).

Renewables First (2014) *Investing in Wind and Hydropower Projects.* http://www.renewablesfirst.co.uk/investing-in-projects/ (accessed 25 October 2014)

Saidur, R., Abdelaziz, E., Demirbas, A. *et al.* (2011) A Review on biomass as a fuel for boilers. *Renewable and Sustainable Energy Reviews*, **15** (5), 2262–2289.

Samlexsolar (2014) http://www.samlexsolar.com/learning-center/solar-cell-module-array.aspx (accessed 23 October 2014).

Shah, A., Torres, P., Scharner, R. *et al.* (1999) Photovoltaic Technology: The Case for Thin-Film Solar Cells. *Science*, **285** (5428), 692–698.

Shepard, W. and Shepard, D. (2014) *Energy Studies*, 3rd edn, London, Imperial College Press.

Sims, S. *et al.* (2010) Modelling the impact of wind farms on house prices in the UK. *International Journal of Strategic Property Management*, **12** (4), 251–269.

Smith, A., Mago, P. and Fumo, N. (2013) Benefits of thermal energy storage option combined with CHP system for different commercial building types. *Sustainable Energy Technologies and Assessments*, **1**, 3–12.

Solar Technology Centre (2014) http://www.solartechnologycentre.co.uk/Products/Solar%20Modules%20Datasheets/Scheuten/STC_Brochure_BIPV.pdf (accessed 22 October 2014).

The Carbon Trust (2011a) *A Place in the Sun*, https://www.carbontrust.com/media/81357/ctg038-a-place-in-the-sun-photovoltaic-electricity-generation.pdf (accessed 14 June 2017).

The Carbon Trust (2011b). *Heating, Ventilation and Air Conditioing*, https://www.carbontrust.com/resources/guides/energy-efficiency/heating-ventilation-and-air-conditioning-hvac/ (accessed 14 June 2017).

The Carbon Trust (2011c). *Taking the Heat*, https://www.carbontrust.com/media/81385/ctg061-taking-the-heat-biomass-heating-low-carbon-buildings.pdf (accessed 14 June 2017).

The Green Age (2014) http://www.thegreenage.co.uk/chp-boilers-a-comprehensive-buyers-guide/ (accessed 19 October 2014).

United Nations General Assembly (1987) *Report of the World Commission on Environment and Development: Our Common Future*, United Nations, New York.

5

The Building Envelope

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The building envelope includes any part of the building which separates the external and internal environments, also the ground floor, outer walls, roof, windows and doors.

Enclosing and fitting-out a building provide shelter from rain, wind, snow and extremes of hot and cold, offering comfort and security for occupiers and users. Whilst many human settlements are still built using available local materials such as timber, mud brick, straw and stone, most modern buildings use industrially produced construction materials and advanced technologies to provide a high level of moisture-and-sound resistance, structural stability, thermal comfort and energy efficiency.

Some historic examples of the use of stone and timber can be seen at the websites below including Neolithic stone buildings at Skara Brae on Orkney, Scotland and a reconstruction of a Neolithic fortified village showing a palisade wall and stilt houses at the Pfahlbau Museum Unteruhldingen, Germany.

http://jmir3.no.sapo.pt/Ebook2/History.of.Building_Britannica.Parte_1de%202.pdf
https://en.wikipedia.org/wiki/History_of_construction)

In the United Kingdom, materials such as locally produced thatch for roofs, timber framing and 'wattle and daub' walls and traditional Cob walling (earth, water and straw) are still to be found in many older properties, particularly in rural areas (https://en.wikipedia.org/wiki/Wattle_and_daub; https://en.wikipedia.org/wiki/Cob_(material); https://www.youtube.com/watch?v=2E03Z8Jn2vw).

In many countries, an expansion in trade and economic growth drove demand for new residential, commercial, industrial and institutional buildings from the Middle Ages onwards. In response, technological developments, an improved understanding of the science of materials, building standards and construction technologies consequently became more sophisticated. During the 19th century in the United Kingdom, this process was accelerated by the industrial revolution, the migration of people to towns and cities and an expanding population. As a result, construction on a

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

commensurately industrial scale took place using factory-made materials produced by increasingly advanced manufacturing techniques.

The design drawing for a typical house from 1898 on page 1 of the UWE website below, shows a timber-roof structure of rafters and purlins supporting clay tiles or slates, enclosing a normally uninsulated roof space. The outer walls were solid 225 mm thick brick, internal partitions were a single brick thick and the timber-ground floors were suspended above bare earth in the main rooms, but with a solid concrete floor in the kitchen and scullery areas. The foundations for the main walls and the 'sleeper walls' supporting the raised timber-ground floors are brick, standing on concrete supports or 'footings'.

http://fet.uwe.ac.uk/conweb/house_ages/elements/print.htm

The diagrams above also explain the evolution of methods used to support the imposed loads (occupiers, furniture and equipment, snow and lateral wind loads) on buildings and of the self-weight of the construction materials used. The function of any foundation system is to safely transmit structural loads to the ground, so that the building remains stable and safe. The diagrams show how main external and internal (load bearing) walls of the house are supported by concrete foundations in the form of strip, raft and pile foundations.

As residential, commercial and institutional buildings become larger, the depth, mass and complexity of the foundation system used often increase and can represent a large proportion of the money and time expended

http://www.buildingregs4plans.co.uk/foundation_floor_wall_3d_detail.php
https://www.youtube.com/watch?v=J9MzxAzP1pY
http://www.designingbuildings.co.uk/wiki/Pad_foundation
http://civilconstructiontips.blogspot.co.uk/2011/06/pad-foundations.html
https://en.wikipedia.org/wiki/Deep_foundation
https://www.youtube.com/watch?v=PqcPHsiBFQc
http://environment.uwe.ac.uk/geocal/foundations/Fountype.htm
https://www.youtube.com/watch?v=vc4_5M1rhFg.

A typical 1930s house (shown below) would also have had solid brick outer walls (later with cavities for better damp resistance and thermal performance) and would also often be rendered or 'pebble-dashed'. The internal partitions were of brick, concrete block or timber stud and the roof was made from timber rafters, roof trusses or frames supporting a clay tile or slate roof covering. The dimensions are shown in feet and inches:

http://www.constructionphotography.com/Details.aspx?ID=24290&TypeID=1

However, from the 1920s onwards, cavity walls increasingly became the external wall construction of choice for architects and builders and after 1945, virtually all new houses used this form of outer wall. Most were formed of two brick 'skins' or 'leaves' (or an outer brick and inner concrete block work skin) each approximately 110 mm/100 mm wide with a 50 mm cavity between them. The two leaves were tied together by metal wall ties to ensure structural stability with the idea of filling the cavity with insulation adopted later as the Building Regulations progressively demanded higher standards of thermal efficiency.

Note that even in pre-Industrial Revolution designs for external walls, a Damp Proof Course (DPC) was commonly inserted in the lower part of the wall to prevent moisture being drawn up from the ground into the wall by capillary action, leading to dampness inside the building. Modern DPCs are normally made from a heavy-duty PVC-based material, but in the past were made from bitumen impregnated felt, slate or other available impervious materials.

To see how the construction techniques developed, look at the diagrams on The Evolution of Building Elements website at:

http://fet.uwe.ac.uk/conweb/house_ages/elements/print.htm

For more cavity wall insulation information, see:

http://aeenergysolutions.com/services/cavity-wall-insulation/

Pitched Roofs

Until the 1950s, domestic pitched roofs in United Kingdom were mainly constructed from cut rafters which were supported by arrangements of struts, ties and purlins (to prevent mid-span 'sag'). Traditionally, the joints between the different hand-cut timber pieces were formed by splices or Mortice and Tenon joints, held in place by wooden pegs, but by the end of the 19th century, the timbers were often cut by machine and jointed using metal nails, screws and bolts. Small section timber battens were then fixed to the top of the rafters on to which tiles or slates were nailed or 'hung'. Prior to the 1920s, the use of roofing felt under the slates or tiles to provide an additional rain barrier would not have been a 'given' and the use of insulation within the roof space toowas not the requirement it is today.

Typical forms of traditional timber-roof construction can be seen at:

http://fet.uwe.ac.uk/conweb/house_ages/elements/print.htm

Modern timber roofs are most commonly of the Trussed Rafter type. These lightweight, computer designed structures are manufactured off site and then delivered by lorry where they can be erected quickly and without the need for skilled labour. They cannot, however, be easily altered to accommodate additional storage space or extra attic rooms (https://www.youtube.com/watch?v=n0CrtpuWL4w).

Flat Roofs

Although rarely, if ever, truly 'flat', anything less than 10^0 of slope or 'pitch' is considered flat and most have a slight gradient or 'fall' to ensure that rain water runs to a suitable gulley or gutter. These roofs have provided a popular, adaptable and relatively inexpensive roofing solution, particularly since the building boom of the post WW2 period. Modern flat roofs are constructed from a wide range of materials and can achieve good thermal and weather-proofing performance (http://www.arsystems.co.uk/epdm-flat-roofing/roof-types/).

In typical domestic flat roof construction, the roof deck is normally supported by timber-roof joists and a plywood decking, the weather-proof top surface can be made from PVC-based products or from metal, asphalt or bitumen impregnated sheet materials

https://www.youtube.com/watch?v=WZ6Ng6YI9OA
https://www.youtube.com/watch?v=TpqgM-jxVAU
https://en.wikipedia.org/wiki/Flat_roof.

In larger, non-domestic buildings, the structure of flat roofs is normally steel, concrete or a composite construction using both materials, normally with flagstone, asphalt and stone chippings or proprietary products as a top surface.

In both domestic and commercial flat roof construction, stone chippings protect the water-proof asphalt or bitumen from the harmful effects of the suns' UV, damage from maintenance workers and the additional surface area provided by the stone chippings can speed up the process of rainwater evaporation.

Steel decking can also be used as a roofing system for pitched roofs and unlike slates or tiles, can achieve very shallow slopes without compromising the weather-proofing characteristics or being prone to lifting in high winds

https://www.nexus.globalquakemodel.org/gem-building-taxonomy/overview/glossary/composite-steel-deck-and-concrete-slab--rme3
http://www.corrugatedsteelsheet.com/roofing-sheets/galvanized-corrugated-roofing-sheets.html
http://www.corrugatedsteelsheet.com/roofing-sheets/corrugated_sandwich_panel.html
https://6dprojects.wordpress.com/2011/08/17/roofs-construction-and-roof-covering/
http://www.greenspec.co.uk/building-design/concrete-flat-roof-insulation/
http://insulation.com.au/tools/commercial-product-selector/
http://roofhugger.com/docs/InsulatedAssemblies.pdf.

As stated, most flat roofs have, in the past, required rain water to be drained away to a gulley by means of a slight slope or 'fall', normally around a 1:40 gradient. This is to prevent 'standing water' which increases the risk of ingress and which can, over time, damage roofing materials.

http://www.buildingregs4plans.co.uk/guidance_flat_roof_drainage.php
http://webarchive.nationalarchives.gov.uk/20151113141044/
http://www.planningportal.gov.uk/uploads/br/br_pdf_adh_2002.pdf
https://www.planningportal.co.uk/info/200130/common_projects/47/roof/4

However, the recent introduction of 'green roofs' has meant the adoption of new design principles. Green roofs use Sedum or other plants, bedded in an appropriate soil substrate to provide a living top surface to the roof which, offering an environment for insects and flowers, also insulates the building and safely holds and collects rain water for irrigation rather than having to dispose of what has become in United Kingdom, a valuable commodity (http://www.superhomes.org.uk/resources/sedum-roof-covering/; http://www.greenroofs.com/archives/energy_editor.htm).

Although looking after such roofs is more akin to landscape gardening than to building maintenance, as long as the waterproof materials beneath the living medium are carefully selected and detailed, these roofs can make a valuable environmental and visual contribution (https://en.wikipedia.org/wiki/Flat_roof; https://www.youtube.com/watch?v=wyNviteSOzY).

Ground Floor Construction

As with roofs, ground floors normally consist of a structure, insulation, a moisture resistant barrier and top surface. Ground floors can be made using flagstones, solid *in situ* concrete, suspended timber, precast concrete beam and block and finished with a wide range of hard and soft floor finishes. The floor structure is designed to carry the loads from people, furniture, equipment or even vehicles which will be imposed on the floor, whilst the top surface or 'floor finish' must have the appropriate resilience, durability, visual, acoustic, fire resistance and cleanability characteristics for the uses which will be carried out on it. The damp proofing of ground floors which are in contact with the ground, is achieved through the use of a heavy-duty PVC Damp Proof Membrane (DPM) which, overlapped with the DPC in the lower part of the outside walls, forms an impenetrable barrier to moisture rising up into the building.

For diagrams of basic types of floor construction

http://fet.uwe.ac.uk/conweb/house_ages/elements/section3.htm
https://www.youtube.com/watch?v=I4haJf6ZiHo
https://www.youtube.com/watch?v=j5NBk2BwG0c).

Videos on upper floor construction (not part of the envelope) (https://www.youtube.com/watch?v=zin8GtugLH4; https://www.youtube.com/watch?v=YEcayBTEOt0).

Framed Construction

In high-rise office buildings, the use of a Steel Frame on which external wall cladding panels of stone, concrete or lightweight steel and glass could be attached, evolved during the last part of the 19th century and first part of the 20th century, achieving widespread use in United States during the 1950s.

See notes below on the history of high-rise building and the example of the Woolworth Building, NYC, under construction in 1908 and as completed, photographed in 1913 – a steel frame supporting terracotta and concrete cladding panels, reaching a height of 240 m or 790 feet (https://en.wikipedia.org/wiki/Louis_Sullivan#Sullivan_and_the_steel_high-rise; https://en.wikipedia.org/wiki/Woolworth_Building).

In the Seagram building of 1958, identical elevations were wrapped around a rectilinear plan, serviced by overhead mechanised air conditioning ducts. However, in 1958, insulation in the walls of buildings of this type was often minimal; energy was cheap and the technology was available to deliver round-the-clock controlled heating and ventilation

http://www.archdaily.com/59412/seagram-building-mies-van-der-rohe
https://en.wikipedia.org/wiki/Seagram_Building
https://en.wikiarquitectura.com/index.php/Seagram_Building.

In the detail drawing shown on the website below, the curtain walling detail shows the concrete fire proofing around a steel column, the glazed curtain wall sections and the top of the air supply grilles in the floor:

http://www.greatbuildings.com/buildings/seagram_building.html

However, the mechanised, technologically dependent approach seen in many air conditioned Modernist commercial buildings until the 1990s, changed as designers sought to use some of the design features seen in buildings of the past to achieve cooling and ventilation and reduce heat from the sun's rays.

In this modern office building in Brazil shown on the website below, the design strategy uses passive means to cool the building.

> The screened façade on the sides blocks the rising and setting sun, while a patch of green roof and overhangs help mitigate midday sun exposure. Patios and overhangs at the front of the building scoop up the sea breezes through operable windows.
>
> Modules set within the side of the façade indent on each floor to allow office occupants to enjoy a small patio and green space complete with trees. The front and back also have outdoor space providing views of the sea and forested hillside respectively. The building is topped off with a solar electric array to help offset power consumption.
>
> (Michler, A. Inhabitat, 2011) http://inhabitat.com/winning-office-tower-design-marries-looks-with-efficiency/

Contemporary timber-framed 'green' homes in United States can be seen on the website below showing how the inside of these buildings is kept dry and well ventilated and thermal comfort is maintained.

http://www.greenbuildingadvisor.com/
http://www.greenbuildingadvisor.com/green-basics

Also see *Passivhaus* design principles, standards and construction techniques at:

https://en.wikipedia.org/wiki/Passive_house
https://www.youtube.com/watch?v=GCA7YA_X6Lc
https://www.youtube.com/watch?v=NgDRKSQp2RI.

Modern walling materials must also have good visual characteristics, be durable, easy to maintain and be fire-resistant and in doing so, comply with the aesthetic and functional performance standards set down in development control and building code regulations.

The walls of buildings use a vast range of materials to achieve exacting standards including brick, concrete block, stone, insulated timber-framed construction, steel, aluminium and glass:

Metal cladding and roofing systems: http://www.steelconstruction.info/Building_envelopes.

Rainscreen sytems: http://www.kmearchitectural.com/technical/rainscreen/.

Building Envelope Design Case Example: Ropemaker Place, London 2009.

Ropemaker Place is a 21 storey office building located on the northern boundary of the City of London and the London Borough of Islington.

The original brief was for the replacement of an existing building which, coincidentally, had been engineered by Arup in the 1980s. The designs for a replacement building had already obtained Planning Permission, but following a change of site ownership in 2006, Arup Associates, the integrated architectural and engineering studio within Arup, were commissioned to re-design the existing proposals and to deliver a finished building within 3 years.

The client and building owners, British Land, also wanted a sustainable building which would reduce both operational costs and environmental impact as well as have a wide range of flexible and adaptable floor plates with high specifications to meet the needs of a variety of future tenants.

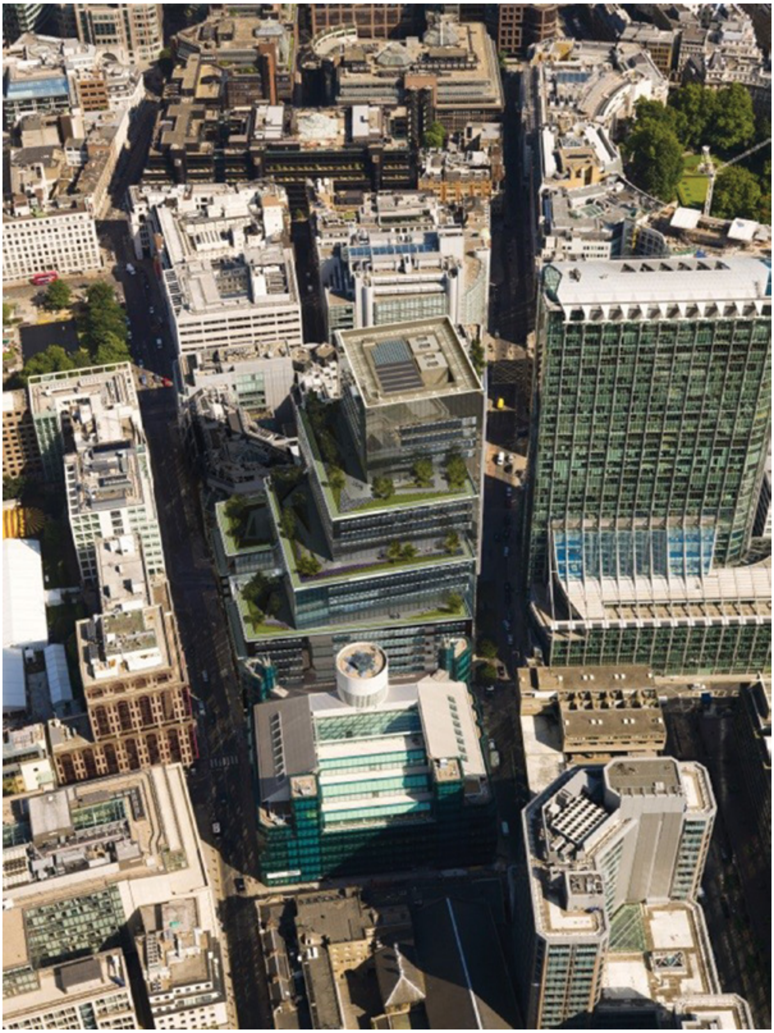
The scheme was completed in 2009. On day one, the contractual rent was £24.05 million per annum, rising to £27.5 million per annum on minimum uplifts at first reviews. On 30 September 2012, Ropemaker Place was valued at £455 million. When it was sold in 2013, British Land received net proceeds of £461 million in cash from the sale after costs, 1.4% above the September 2012 book value (British Land, 2013).

See article and videos at: http://www.architectsjournal.co.uk/ropemaker-place-london-by-arup-associates/8604601.article, http://www.arupassociates.com/cn/news/ropemaker/.

- The building is a 21-storey, 83,710 m^2 development providing 52,000 m^2 net of office space, 1297 m^2 of tenant space, 1410 m^2 of retail facilities at ground level and over 1850 m^2 of roof garden terraces.
- The site is approximately 0.5 ha and is close to three London Underground stations and the Barbican Centre with its range of cultural and leisure amenities.
- The building cost £145 mn. Construction began in 2006 and was handed over in May 2009. Cost per sq.m. was approximately £1750.

Ropemaker Place, London. *Source:* Image courtesy of Arup Associates.

- First office building in London to be pre-certified for the US Green Council's LEED 'Platinum' Core & Shell rating.
- Energy efficiency 32.7% better than *Building Regulations Part L2A: 2006* requirements.
- Building carbon emission rating (BER) of 24.6 $kgCO_2/m^2$ annually
- Air leakage rate of 5 $m^3/h/m^2$ of façade at a pressure of 50 Pa.
- Rated BREEAM (Building Research Establishment Environmental Assessment Method) 'Excellent' with a score of 72.7%.
- Building designed and constructed by only two organisations: Arup Associates as Architect, Structural and Building Services designer (supported with specialist consultancy from Arup and Townshend Landscape Architects) and *MACE* as Project Manager, Construction Manager and Cost Consultant (with in-house Quantity Surveyors, *Sense*).
- Designed to be suitable for multi-tenancy with a variety of floor sizes including two large designated trading floors at the first and second floor levels.
- The servicing strategy allows for market leading servicing provision with security of supply and resilience.
- The developer client, British Land, wanted the building to be finished by early summer 2009, the site having been acquired by them in 2006. They felt sure that the central London commercial property market would, by the second half of 2009, be in recovery and that the building would, therefore, achieve good rental values, if let at that time. British Land also felt that building during an economic recession, whilst not without risk, was a good time to take advantage of lower construction costs
- Although the scheme which Arup inherited had obtained planning permission, early consultation with Islington Council suggested concerns about the massing of the original design and the way in which it might impact upon views along Chiswell Street on the northern edge of the site.
- Because of the client's wish for a fast completion, both Arup Associates and the client team were mindful of the need to avoid anything controversial in terms of massing. There were potential problems of views from the South Bank of the Thames being affected by a new building, as it could interfere with the background setting of the dome and peristyle of St Paul's Cathedral. These studies ultimately determined the maximum height of the building.
- British Land wanted Ropemaker Place to be a 'green' building which was flexible enough to be sub-divided to provide a good tenant mix for easier letting in what was still likely to be a tricky office market.
- Whilst time was an issue, construction cost was also a critical consideration for British Land. Their fiduciary responsibilities meant that they had to take all reasonable steps to ensure that the capital costs of the project did not jeopardise longer-term profitability for stakeholders.
- The project had to overcome the difficulties of the existing foundations. The existing building on the site had a single storey basement with foundations which included a reinforced concrete raft foundation and mass concrete fill from the earlier 1980s building. This overlaid reinforced concrete pad foundations from an even earlier 1950s building over part of the site together with 6.0 m thick perimeter existing buttress walls. The need for deeper basements to accommodate extensive services and plant thereby releasing the roof terraces for landscaped terraces, meant that excavation for new basements had to start before the main design of the building was



Ropemaker Place – the urban context. *Source:* Image courtesy of Arup Associates.

settled. A basement design and construction strategy had to be developed whereby a supplementary Planning Permission for the basement was agreed before the main planning permission for the building, allowing work to start.

With time and money being of such critical importance to the success of Ropemaker, the development of a strong sense of trust among client (British Land), architect/engineer (Arup) and contractor (MACE) was vital. Lack of confidence in fellow key stakeholders can lead to nervousness and over-scrutiny of decision-making processes resulting in delays and additional costs.

Arup Associates had successfully delivered important projects for British Land in the recent past (such as the nearby Plantation Place) and so a strong relationship already existed.

Plantation Place, City of London. Completed in 2004. *Source:* Image courtesy of Arup Associates.

The contractors, MACE, were given ultimate responsibility for the delivery of all construction and building cost matters and so single points of decision-making were established in both Arup and MACE to deal with design, cost and programme issues. Communications were, therefore, simpler and as a result, a fast-track design and build programme was possible.

Ropemaker Place is a large building, required to sit among a variety of scales with more modestly sized buildings to the north along Chiswell Street, forming part of an existing, relatively small-scale city street.

The overall architectural form was derived from several programme requirements, and from responding to the local urban realm, rights-of-light and daylighting requirements. The building was conceived as six large, interlocking cubic volumes, ascending as a series of useable garden terraces, reflecting the larger City scale towards City Point Tower and Moorgate, while respecting the smaller scale of the Islington borders.

Ropemaker Place as seen looking West along Chiswell Street. *Source:* Image courtesy of Arup Associates.

Designating the terraces as useable green roofs consigned all services plant to the basement levels and a roof plant enclosure above the top floor.

Although the site was not within any designated view corridors relative to St Paul's Cathedral, the overall building height was determined by verified view studies, particularly from the Thames South Bank. These showed that if it exceeded 110.00 m above Ordnance Datum, the top of the building would be visible between the western towers of St Paul's – controversial for both planning and heritage groups. This could have added significant, unacceptable risk to the programme, so the height was limited to this level (Figure 5.1).

The planning authority also required that the massing along the northern site boundary of Chiswell Street be held at six storeys, with an agreed two-story setback at the upper levels of approximately 3 m from the street frontage, a condition already implemented in the recently completed block nearby at 10 Chiswell Street (not Arup designed). The planning authority's requirement was to maintain the overall townscape massing on both sides of Chiswell Street, particularly in views along the street. Initial discussions revealed sensitivities regarding the previous consent on the site, where the mass of the tower element at the north-east corner did tend to be visible from these viewpoints (Figures 5.2–5.5).

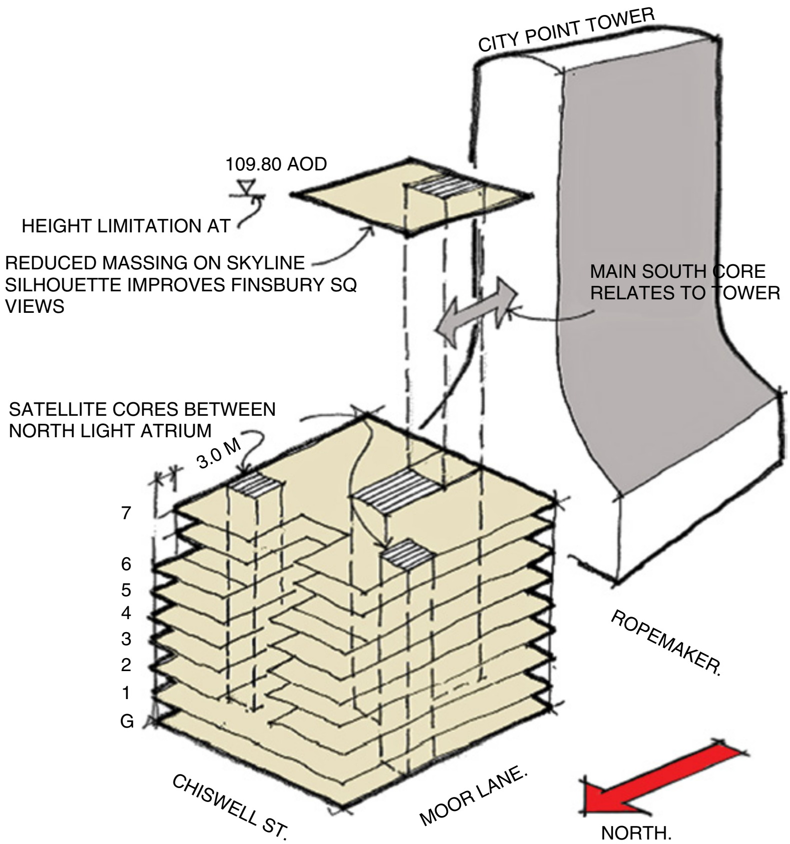


Figure 5.1 Building anatomy.

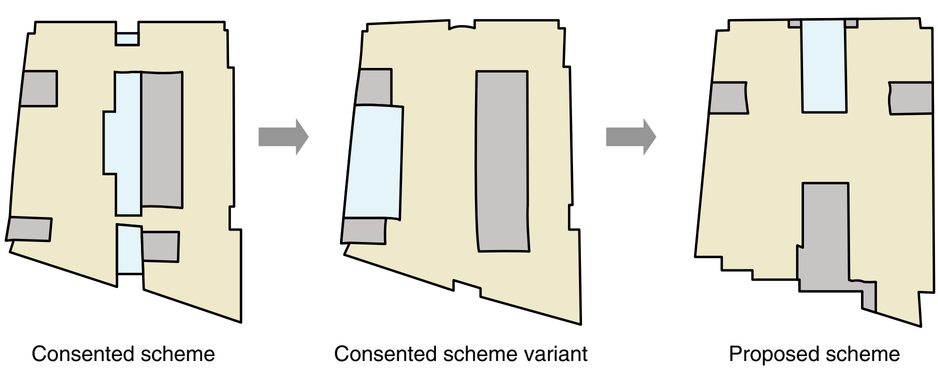


Figure 5.2 Consented scheme massing study and plans.

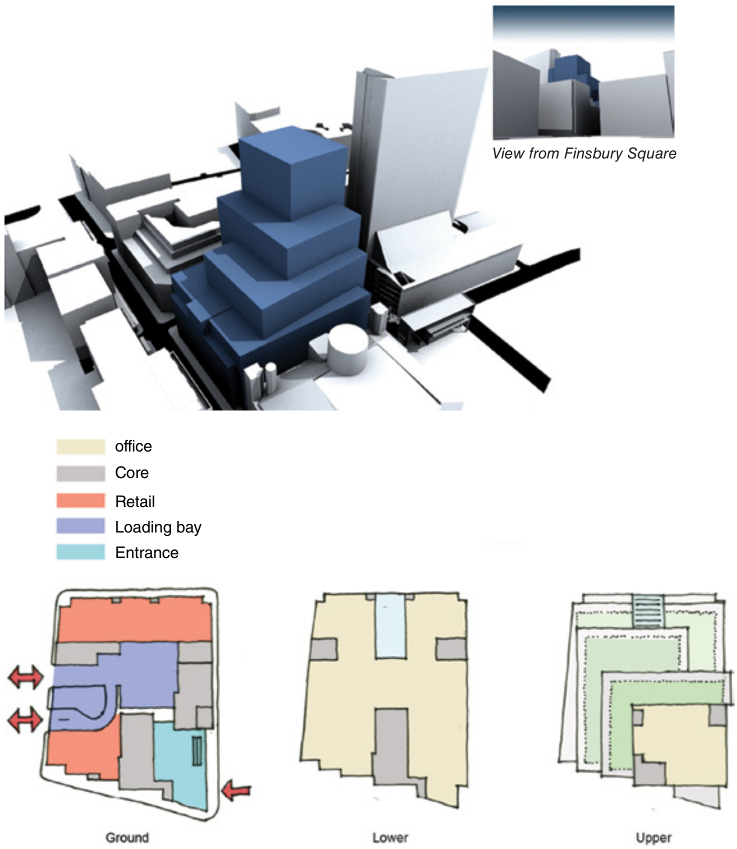


Figure 5.3 Proposed scheme massing study and plans.

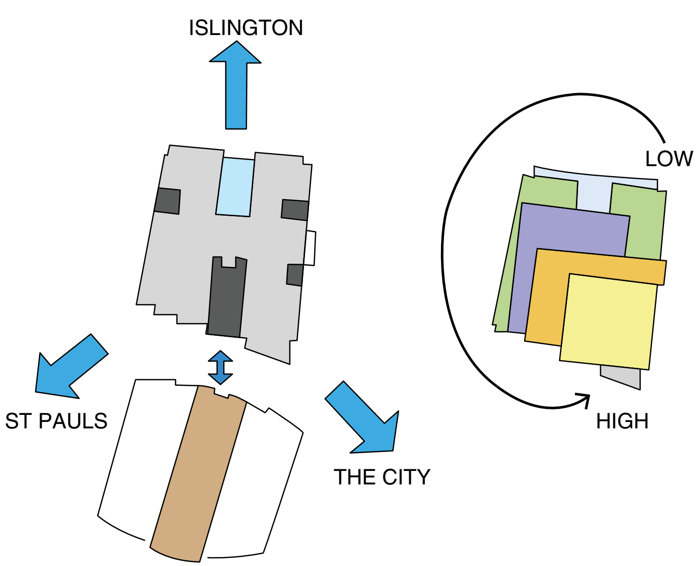


Figure 5.4 Proposed building aspect and massing.

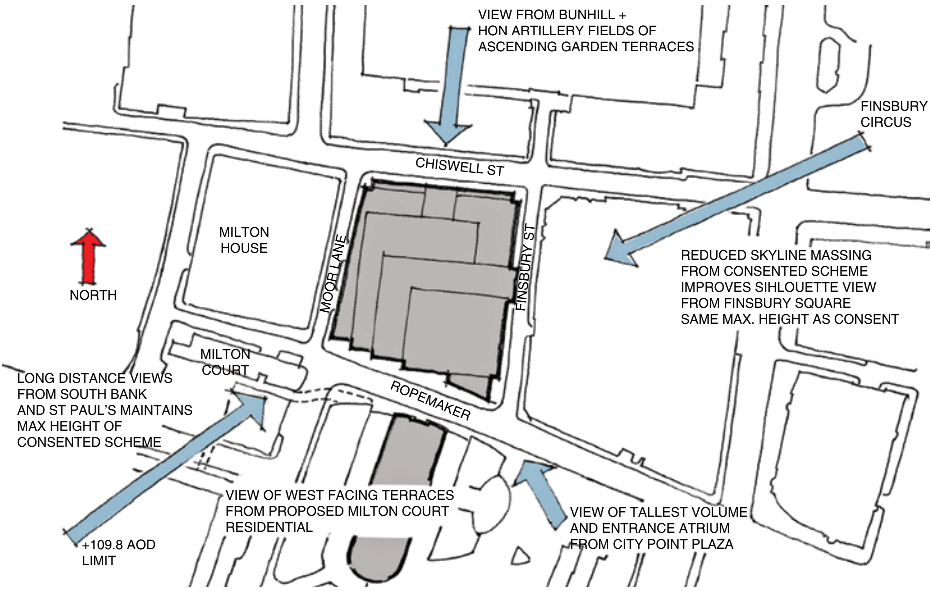
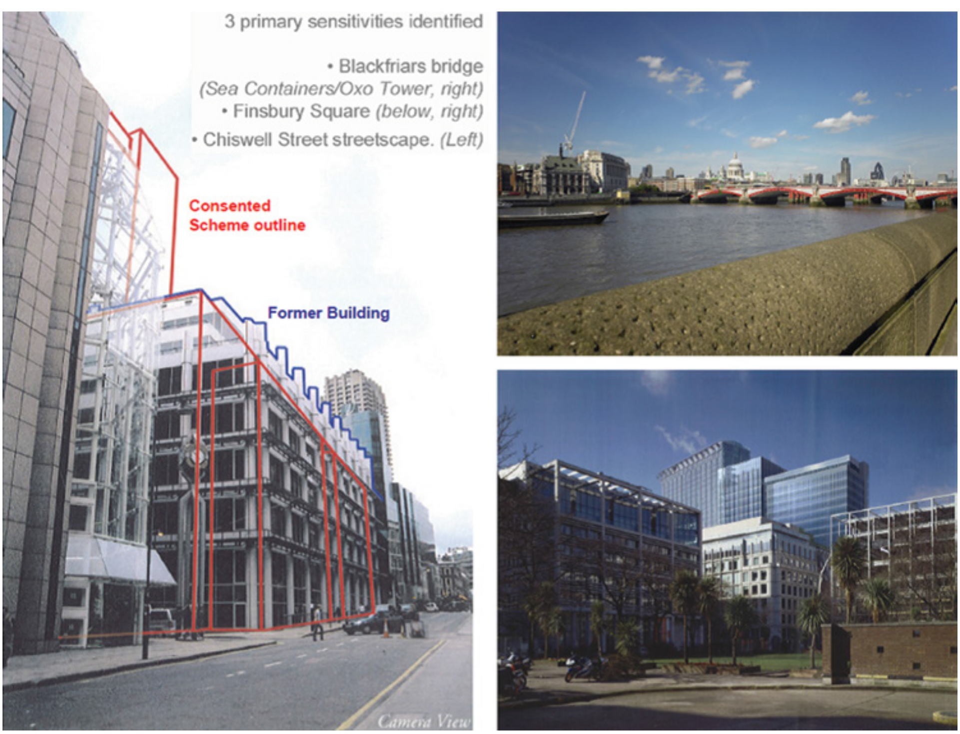


Figure 5.5 Strategic views of Ropemaker place.



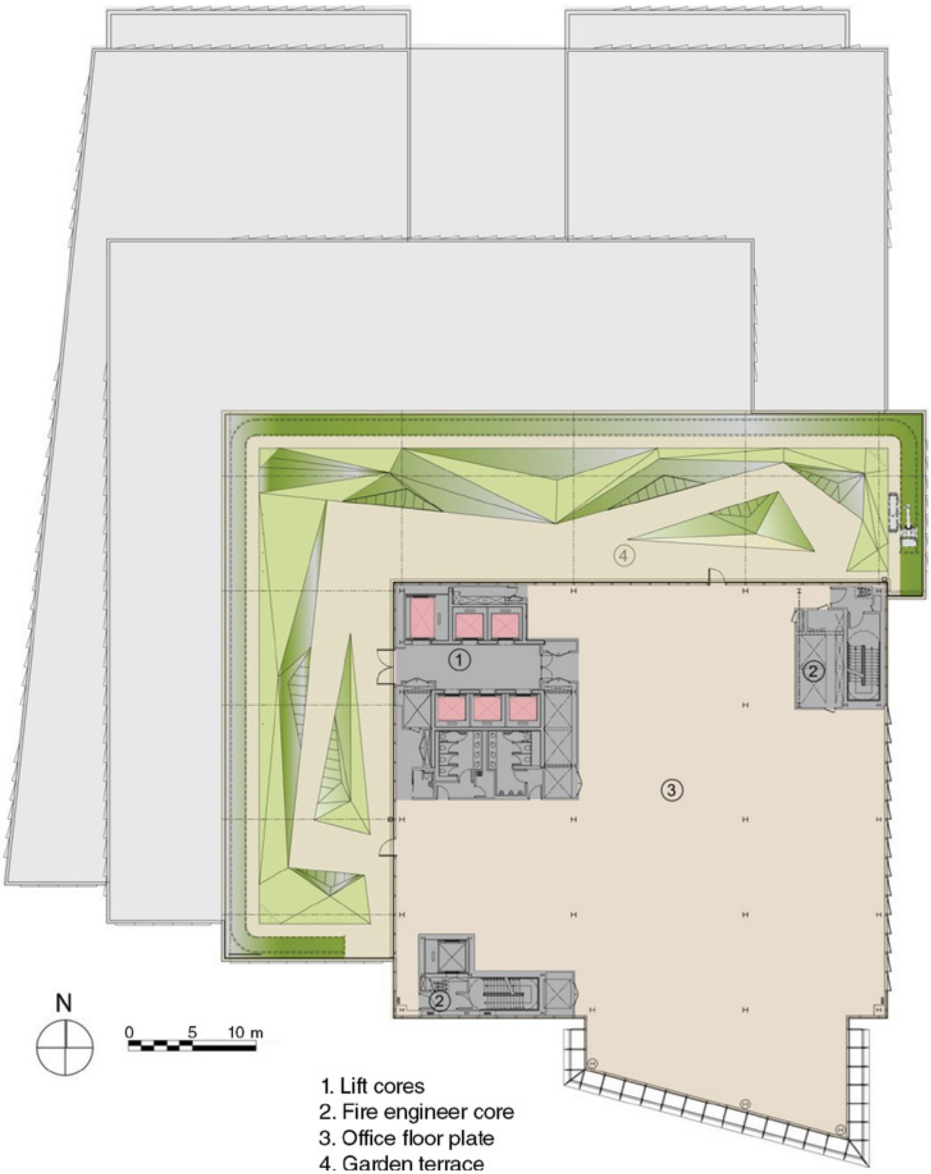
Consented scheme views.

Ropemaker Place was to be seen not as an *object* building but rather as one which would be glimpsed from the surrounding streets and a 'good neighbour' to its setting.

Ropemaker Place seen looking South along Finsbury Street.

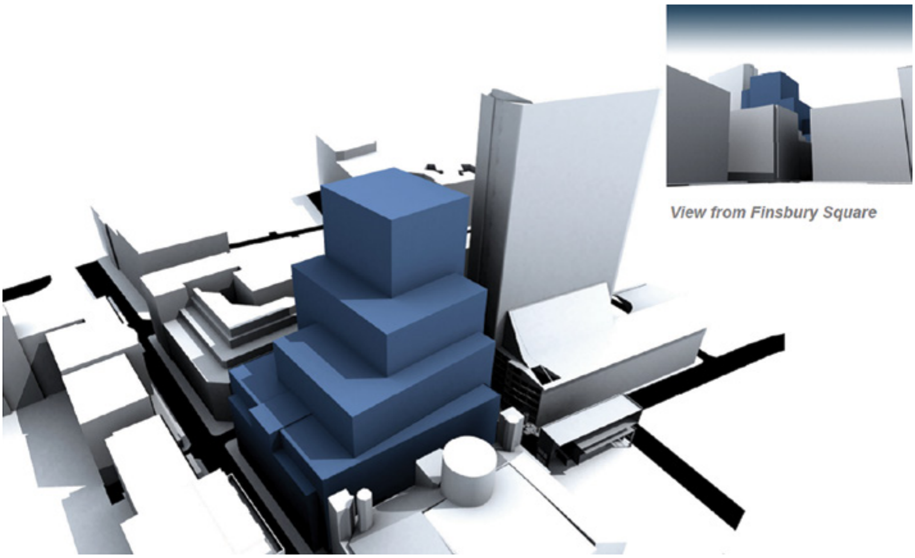
Ground Floor and Upper Level Plans

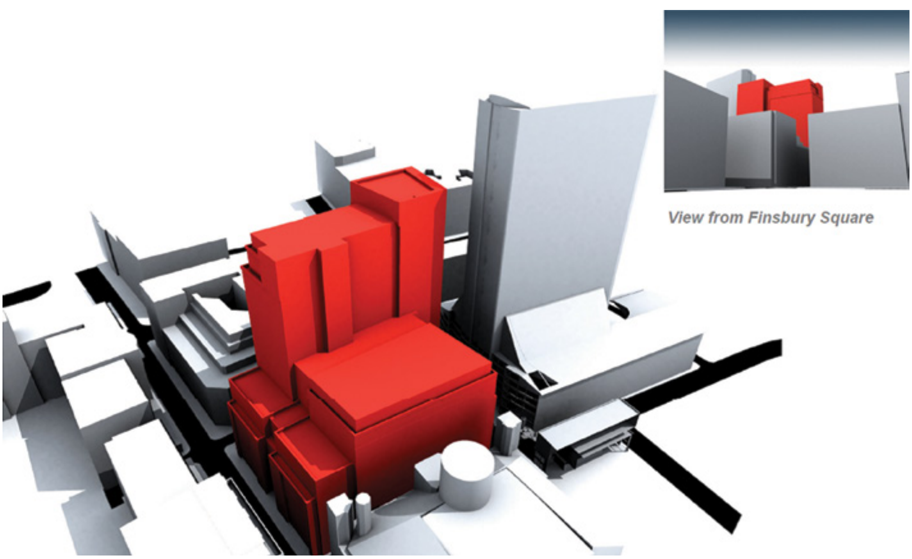
1. Entrance to ropermaker place
2. Reception
3. Lift cores
4. Escalator hall



1. Lift cores
2. Fire engineer core
3. Office floor plate
4. Garden terrace

Consented scheme massing study.





Proposed scheme massing study.

The use of the 'green' roof terraces within the scheme draws upon the Arup Associates tradition of creating high-quality outdoor spaces in the City and of supporting biodiversity whenever possible. The provision of such terraces on this project pre-dated the current requirements in the London Plan. These 'green lungs', still rare in City architecture, are an example of Arup's interest in the greening of buildings and associated social, environmental and biological advantages (Figures 5.6 and 5.7).

The roof terraces at Ropemaker Place are more challenging than, for example, a sedum roof, as these need regular maintenance and good management and irrigation

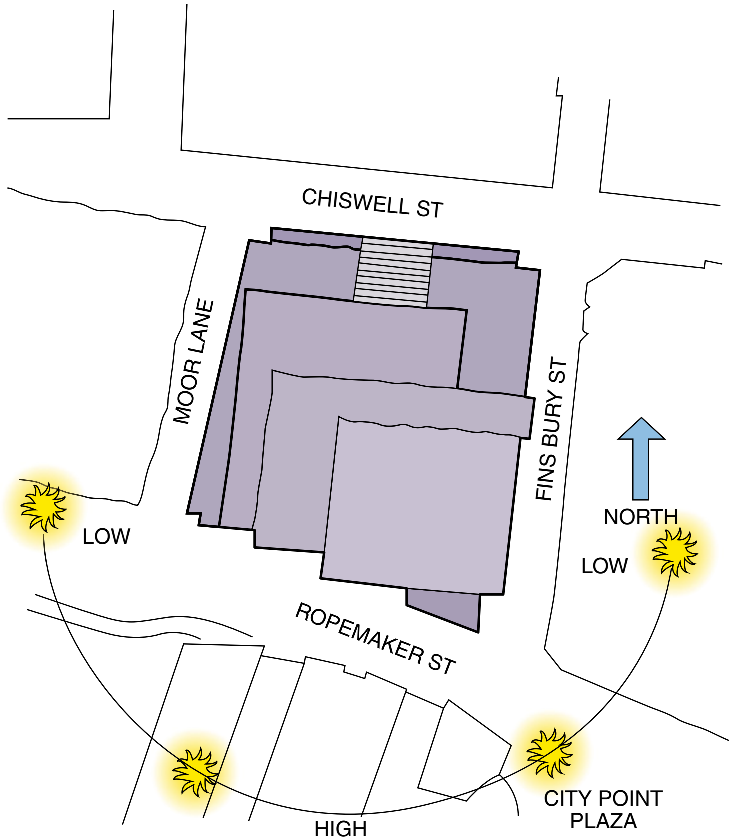


Figure 5.6 Ropemaker site orientation.

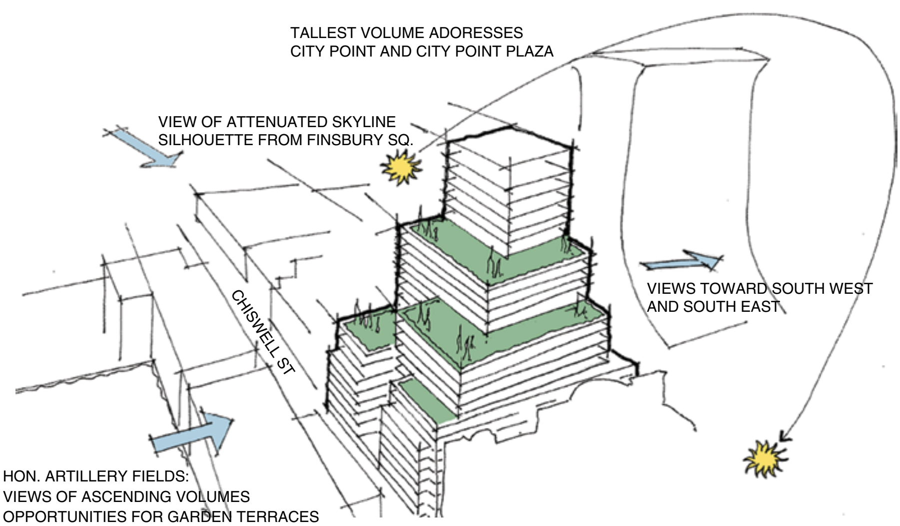


Figure 5.7 Sketch: green roof terraces and gardens.

during dry spells. Well-designed drainage is essential, and extreme care must be taken in the detailed design and construction to avoid the risk of leaks. If substantial planting and mounding are to be incorporated, there are also structural considerations.

Green roofs serve important purposes, including absorbing rainwater, providing insulation, creating a habitat for wildlife, helping to lower urban air temperatures and combating the heat island effect. Arup Associates designed substantial roof gardens for the Wiggins Teape offices at Basingstoke (Gateway 1) in the 1970s. These were tiered terraces accessed from the office floors and mainly for occupier use, though they were also useful in supporting bird and insect life due to their diversity of planting. Similarly, the earlier Plantation Place building in the City of London was designed to incorporate on its roof terraces a series of gardens for amenity.

The office floors were planned on a 1.5 m grid which, coordinated with the base structural column geometry of 9.0 m × 13.5 m, gives large spans and deep, clear office plans. Floor-to-floor heights are generally 3.95 m, providing 2.75 m floor-to-ceiling accommodation with a typical raised floor zone of 150 mm.

Levels 1 and 2 were designed as dealer floors with enhanced floor-to-floor heights of 4.2 and 4.5 m, respectively; providing 3.0 m floor-to-ceiling and a 450 mm raised floor. The integrated structural services zone incorporating cellular beams is 1050 mm deep. Levels 1–16 can be sub-divided to a maximum of four separate tenancies (Figure 5.8).

Arup's lead engineer on the new project, Rob Pugh, had worked on the 1980s building and so understood the original structural design and specifications.

The team concluded that if they simply drilled through existing basement floor slab to incorporate new piled foundations; they would lose the basement area and therefore have to put services plant on the roof, meaning a waste of light-filled, valuable space on the upper storeys of the building. Also, not using roof areas for air handling plant meant that roofs could be used as external garden terraces for occupier amenity and enhanced biodiversity.

The 6-m thick existing concrete buttress retaining walls were known to have supported loads up to 12 storeys since the 1980s. As the original design information was available and core samples confirmed their structural stability, advantage was taken of the walls' re-use as perimeter foundations of the new building as well as their retaining wall capabilities. In total 20% of the footprint of the building is supported on existing foundations, enhancing the sustainable design credentials by working *with* the constraints, not against them.

Structural Design Strategy

The structural design played a major role in enhancing the project's success through strategic decisions to bring buildability to the heart of the design, enabling the brief, the architecture and the sustainability objectives to be delivered within the required time scale.

This involved establishing three principal phases of work, providing appropriate, efficient and economic responses to each, and ensuring an overlap between planning, design and construction.

When the client purchased the site in April 2006 with planning consent for the previous developer design, the existing building had been demolished and an extensive combination of previous 1950s and overlaid 1980s concrete foundations were left in place. This influenced the previous developer decision to limit to a single basement, leaving

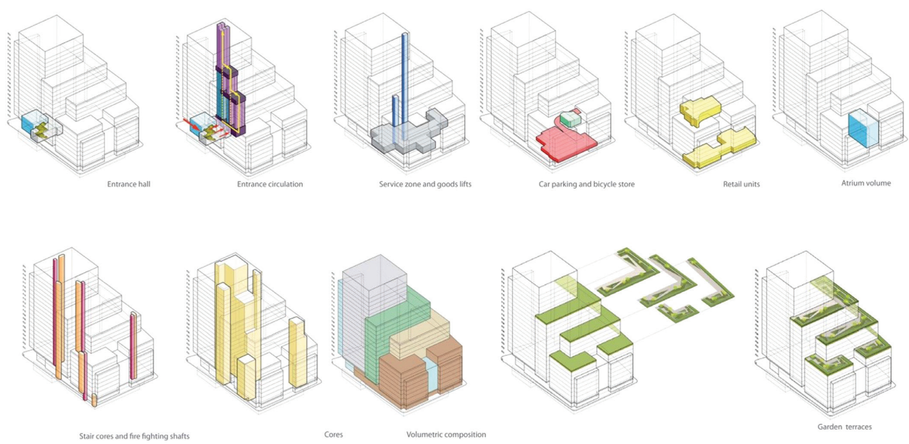


Figure 5.8 Ropemaker's ascending landscaped garden terraces that cover most of the available roof, provide a balance between public amenity for the building's occupants and a biodiverse habitat for insects and birds.

North-south section.

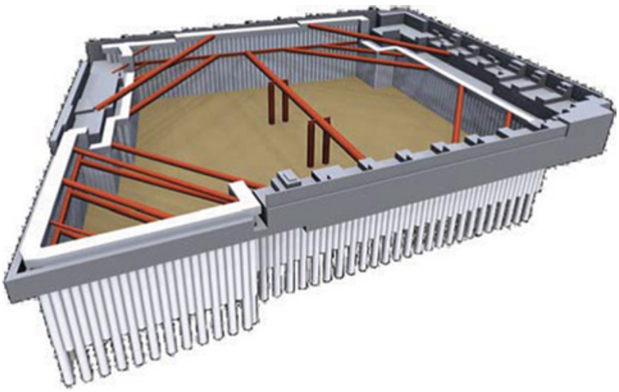
no option but to use the entire roof for plant. The new proposal, with its ascending garden terraces, required most plant areas to be relocated to a much deeper basement, with the remainder out of view above the ultimate storey.

The project needed to overcome the difficulties of the existing foundations, as excavation of the major new basement had to start before the new design was fully known or the new planning consent could be gained. A basement design and overall construction strategy was therefore devised whereby a supplementary permission for the basement could be found within the existing consent, allowing significant enabling works to begin. This, in turn, allowed time for the new planning approval process, and the design and award of sequential substructure and superstructure works packages to maintain the required construction time scale.

The key to unlocking this in practical terms was the way the new building and stepped massing, integrated with structural framing, was overlaid to accommodate the site constraints. The most substantial existing perimeter foundations were re-used, with excavation for the new basement only within the clearer central zone. The new building's geometry, stepping and loading were balanced between new and existing foundations by adapting the grid to suit a predominant orthogonal central zone, with adjustable tapers at the edges. This unique harmony of architecture, formed from its urban setting as well as its physical constraints and structural response, exemplifies Arup Associates' integrated approach to design.

The design strategy comprised the following key structural stages:

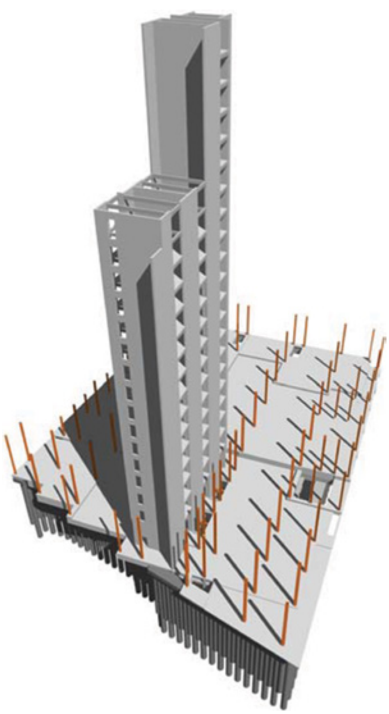
1) *Enabling works:* Demolition of existing substructure within retained perimeter buttresses, installation of secant pile retaining walls and temporary propping works, and bulk excavation as advanced works for proposed new basement substructure.



Enabling works, to give time for a new building planning application.

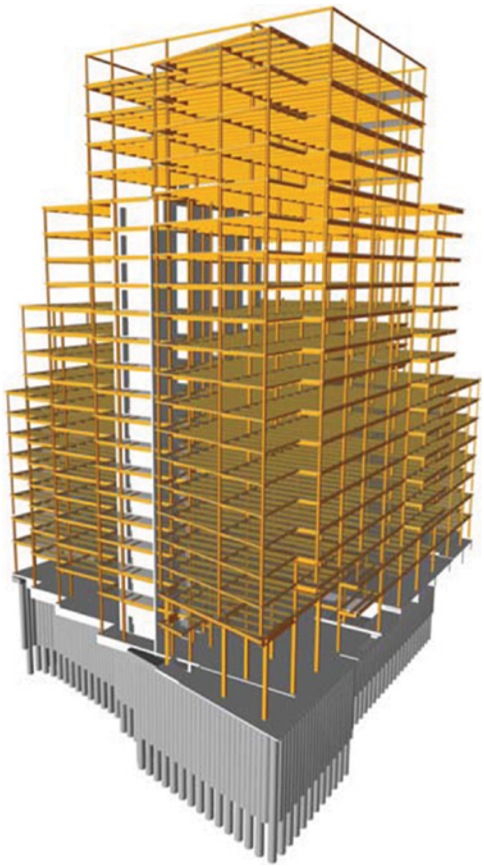
2) *Concrete substructure:* Construction of a reinforced concrete raft foundation and basement framing up to ground floor to complete a substructure 'box'.

   As the superstructure stability is provided by reinforced concrete walls at the primary core, this work was also included as an independent slip-form operation in advance of the steelwork.



Concrete substructure.

3) *Steel superstructure:* Construction of multi-storey steel framing, metal decking and normal weight concrete slabs to form the superstructure floor plates.



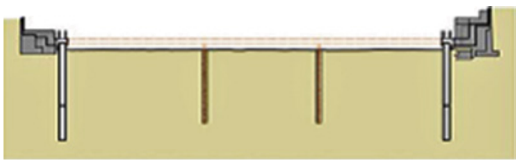
Steel superstructure, for fast construction of critical path façades and following trades.

Enabling works steps

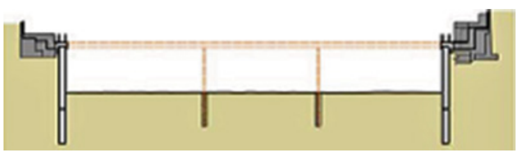
(a) First stage demolition/pile probing through existing reinforced concrete raft, inside the line of existing perimeter buttress retaining walls, to form trench for new secant wall.

(b) Secant pile wall installation, with access at existing basement reinforced concrete raft.

(c) Second stage demolition/clearance to central area of existing reinforced concrete raft.

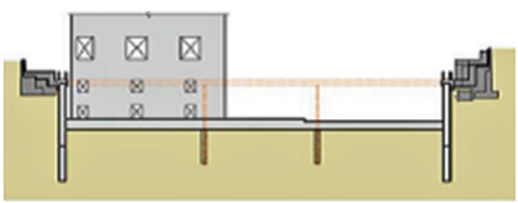


(d) Secant pile trim, capping beam, and temporary propping installation (supported on temporary piles at centre).

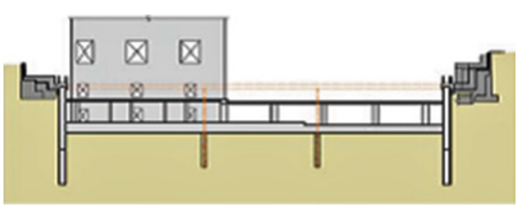


(e) Bulk excavation to new lower basement formation level.

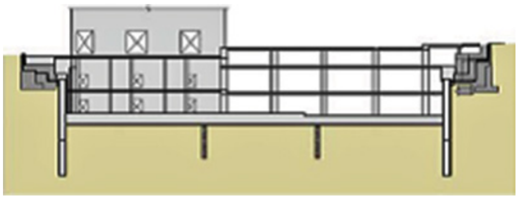
Substructure and core steps



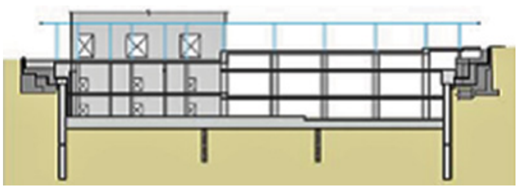
(f) Lower basement reinforced concrete raft and slip-form core commencement.



(g) Middle basement slab, beneath propping level, and removal of props from above.



(h) Completion of upper basement and ground floor slab construction, plus ongoing core construction.



(i) Steel superstructure commencement, accessed by mobile craneage directly off ground floor slab.

Superstructure supported by new lower basement raft, and by existing upper basement buttresses at the perimeter.

Enabling Works

The site was an open, former single-storey basement, with existing foundations that included a reinforced concrete raft foundation and mass concrete fill from the 1980s, overlaying 1950s reinforced concrete pad foundations over part of the site, together with 6 m thick perimeter buttress retaining walls. These buttresses were known to have supported loads of a building up to 12 storeys since the 1980s.

Original design information was available and sample cores were drilled on site to prove the founding on London Clay. Since these buttresses would have presented a significant difficulty to remove, advantage was taken of their re-use as perimeter foundations for the new building, as well as their retaining wall capabilities, to limit the extent of demolition and required new retaining wall construction. In total, 20% of the footprint of the new building is supported on existing foundations, enhancing the sustainable design credentials.

Significant existing raft slab demolition and deeper excavation work were still required.

The mass of the existing foundations was exploited for use as perimeter buttress retaining walls, within which the central area foundations could be demolished and new deep excavation formed within a temporary works-supported secant pile wall.

This was deliberately positioned off grid, so that forming the basement 'hole' was effectively 'off-line' of the as-yet-unknown final building design.

This work was let as a separate enabling works package, which commenced within 6 months of the client's site purchase.

Substructure Design

The substructure was committed to a bottom-up construction, as a site start had to be made and the piled foundation design that would have permitted top-down could not yet be defined.

A raft foundation at the central lower level was thus the most pragmatic choice to form a compatible system with the re-used existing perimeter upper level buttresses, as well as with the bottom-up construction sequence.

The design was optimised by calibrating normal software analysis and structural design techniques with more sophisticated soil/structure modelling, to more definitively assess and confirm the adequacy of overall and differential settlement characteristics. This enabled economies in raft thickness and excavation depth. The technique has since been applied to other Arup projects.

Site view to the south, showing the slip-form platform prepared for launch from the lower basement raft slab, between propped secant pile and existing buttress retaining walls.

The remainder of the basement substructure was in reinforced concrete, due to the short lead-in required and robust means of permanently supporting the retaining walls. As the superstructure needed to be in more lightweight steel-framed construction to satisfy the maximum foundation capacities of both the retained existing perimeter foundations and the new raft, it was practical to separate the substructure as a discrete concrete works package. This offered a longer lead-in for the following steel superstructure package. Concrete works started on the first anniversary of the client's site purchase.

The sequence of enabling works and substructure construction was thus dovetailed to transfer basement stability from the temporary propping to permanent slab support systems

View from the south-east corner of slip-form core construction progressed to level 15 of 21, with the first four-storey bay of steelwork commenced.

Stability Core Design

The overlap between sub and superstructure works was further enhanced by including the main slip-formed concrete stability core within the substructure package and launching it directly off the raft foundation slab.

The core essentially comprised the three connected cells of low-, mid- and high-rise lifts, stopping off at levels 8, 15 and 21, respectively. Services risers were kept outside the core walls to maintain cell simplicity and avoid complex penetrations. The risers were instead within their own 'ring' of column supports, which, in turn, avoided long-span floor beam reactions on the core walls, and the subsequent need for heavy connection plates cast into the core walls, further simplifying and speeding core construction.

Lobby slabs were cast *in situ* on permanent metal deck formwork as the core progressed, with spliced coupler joints to subsequently connect stiff 'arms' to bypass the services zone and maintain diaphragm integrity with the main floor plate. The concrete substructure and core to level 21 were completed 18 months after site purchase.

Steel Superstructure Design

Various studies were made to evaluate the preferred planning grid for the office floor plate. Essentially, all were based on steel frame with composite lightweight concrete metal decks, as opposed to concrete frame alternatives, in the interests of lightweight construction to remain within the viable capacity of the combined raft and re-used existing perimeter foundations. Long spans, 15 m and above, were generally ruled out due to the corresponding high column loads. Long spans were also not appropriate to the stepped building massing and floor plate arrangement, as they would have generated significant additional transfer structure.

The orthogonal building geometry and core anatomy were thus developed with a base, repetitive, 9 m × 13.5 m structural grid of cellular steel beams, offering deep clear floor plates, set back at grid lines to mitigate transfer structure, with a variable perimeter grid to adjust the otherwise simple orthogonal plan to suit the trapezoidal site footprint and foundation constraints.

The cellular beams do not occupy the full depth of the structure/services zone, but have a reduced depth to allow fan coil condensate drains to run in a 300 mm clear zone beneath, while ductwork runs through the beams. This option also allows the tenants the alternative of fitting a chilled ceiling.

Secondary beam spacing selected was 3 m. The merits of 4.5 m spacing were studied to further reduce steel piece count and potentially enhance programme, but this was found to increase steel weight, overall building weight, performed less well dynamically, and the nominal programme advantage for steel erection did not, in principle, follow through to speed up the following cladding to improve the end date.

A study of footfall vibration effects showed the advantage of using normal weight concrete over lightweight, and so the former was adopted, to also make use of preferred site placing and finishing characteristics.

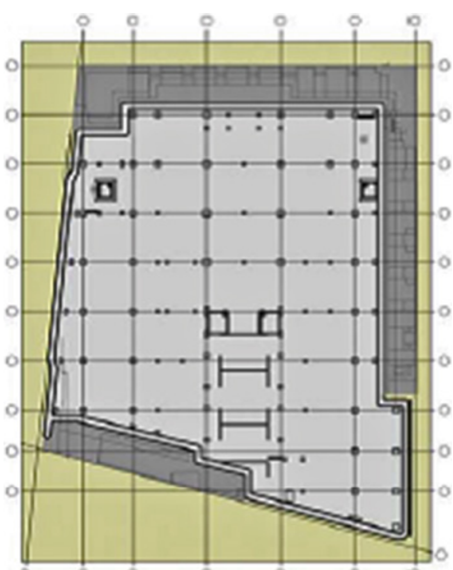
The steel frame is fully fire engineered, with fire assessment first mitigating the required fire resistance periods and thickness of any protection required, and then fire analysis defining where protection was not required. Generally, fire protection is provided to all beams that connect directly to columns, but all other secondary beams are left unprotected. Where fire protection was required, it was provided as an off-site applied intumescent coating to minimise site activity. The result saved not only the material cost of coatings, but also time and handling logistics.

Due to the eccentricity on plan of the primary concrete stability core at the south of the site, additional stability bracing was added at the secondary stair cores towards the north of the site to mitigate dynamic lateral torsional effects.

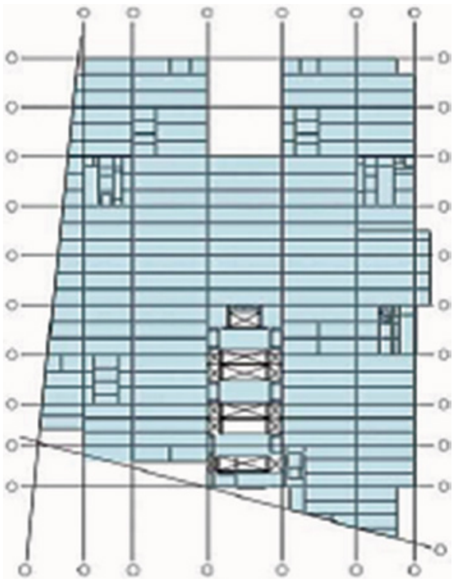
Collaboration with the construction manager and steel contractor enabled all construction logistics, temporary loadings, crane openings, and tolerance allowances to be directly incorporated into the design documentation, which was delivered in a sequence to suit the procurement and construction. Steel frame 3-D model transfer, and general fabrication drawings approval were also directly managed, with the fabricator's modellers working alongside in the design office.

Steel frame nearing completion, and façade commenced.

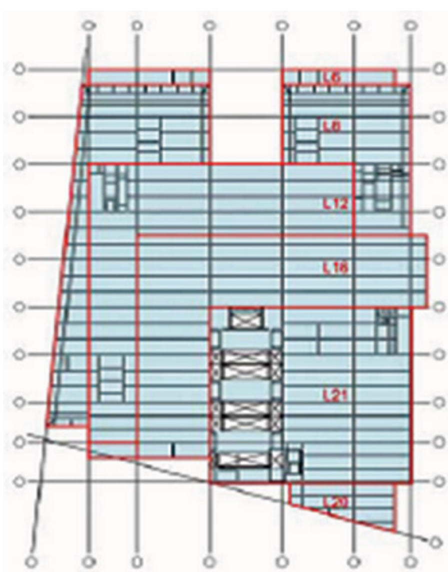
Structural grid layouts.



(a) Substructure: to adjust the otherwise simple plan to suit the trapezoidal site footprint, avoid obstructions and re-use existing perimeter foundations.



(b) Typical superstructure floors: large open floor plates, though moderated spans to balance loading between new raft and existing buttress foundations.



(c) Roof terraces: structure set back at grid lines to mitigate transfer structure.

The Façade Design

For reasons of economy, operational efficiency and sustainability, a high level of thermal performance was required on the cladding. So it was decided to develop a glazing system which would have both high levels of solar control and insulation. Primarily, this meant that the window glazing was limited to around 50% of the total façade area; this was helped by the main cores being arranged on plan so they engaged with the cladding. Furthermore, the position of the building suggested that if the windows were orientated away from the solar path, there would be advantages in reducing the cooling energy load. It was also important to the architects that the design would exploit the natural crystalline and kinetic visual properties of glass as its colours and reflective hues respond to the ever-changing qualities of natural light.

The glazing system and, in particular, the unique design of the solid glazed sections was refined in association with the artist, Antoni Malinowski, who assisted in the choice of the subtle nuances of colour. Sample glazing panels were manufactured and placed on the roof of Arup Associates studio in Fitzroy Square, London, and observed and photographed over many weeks in a range of light and weather conditions. Once the optical and colour choices of these panels were established, full-size two-storey mock-ups were built by the Trade Contractor, Schneider, adjacent to their assembly factory in Wrocław, Poland, for visual and technical assessment, as part of the procurement process.

The site orientation determined that the façades should face directly towards the north, south, east and west aspects orthogonally. The combination of the interlocking cubic massing and setbacks with the immediate architectural context creates an animated composition of light and shade from the changing sun path, varying with weather and the seasons.

A double-skinned façade, as at Plantation Place, was rejected. Budgets were limited and the necessarily deep galleries required for maintenance outside the office interior – preferred by the London market – reduced the net area substantially compared with a single-skin façade. Natural ventilation, which may have made a double-skin sensible at upper levels, was ruled out on grounds of cost and noise.

The façade design exemplifies the integration of architectural treatment with environmental performance. A bespoke system of unitised, 1.5 m wide modular cladding, designed as a series of storey-height insulated cassettes with projecting and tilting vision panels where required, provided a combination which reduced the average annual energy consumption for cooling by up to 27% compared to a flat façade.

The cladding system was installed from the individual floors using sophisticated mechanical manipulators and without expensive and time-consuming tower cranes.

Projecting Windows

Ropemaker's façade design was key to its environmental strategy. The windows to the east and west project from the flat façade and tilt in the vertical axis away from the sun towards the north to reduce incident solar radiation, helping to reduce peak cooling loads and energy consumption. Similarly, the south-facing windows are rotated around a horizontal axis, leaning forward. The rotation allows for an element of self-shading, similar to what can be achieved by louvres and projections. A secondary effect is the reduction of solar transmission of the glazing due to the increase in the solar angle of incidence. The effect of the window geometry varies with orientation and conditions, but annual energy consumption for cooling is reduced in all cases (Figure 5.9).

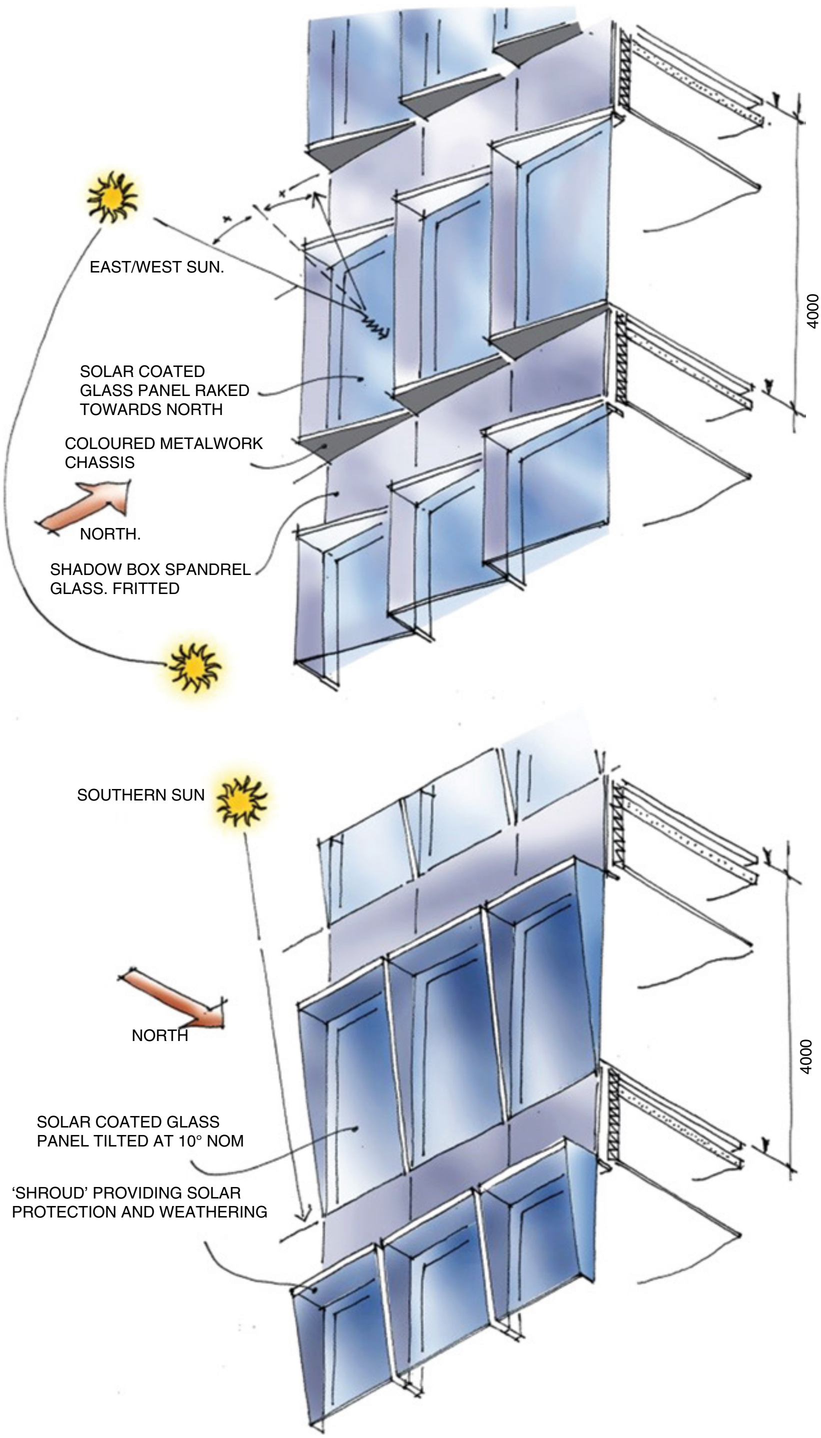
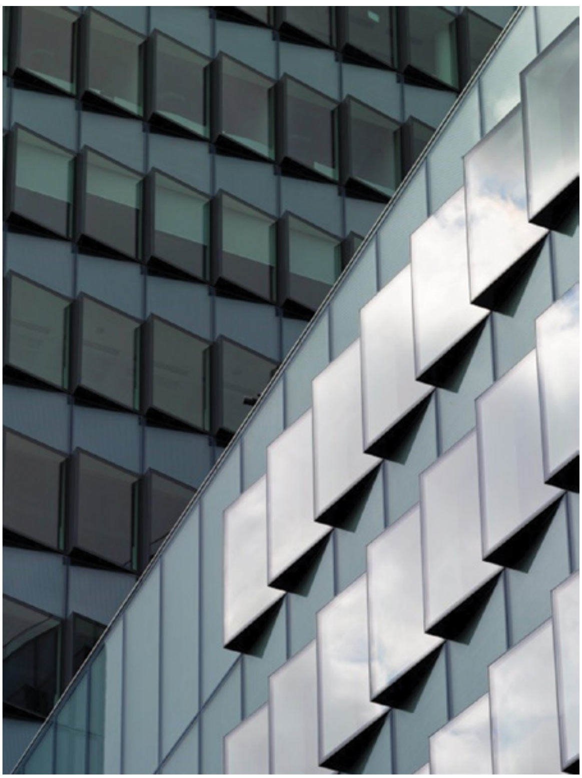


Figure 5.9 Sketch designs for tilting windows.

These projecting windows are arranged in serrated compositional blocks that, with the large areas of optical spandrel glass, create additional surface animation and modelling. The building was designed to minimise space heating demand and infiltration losses through the external fabric so that energy use for space heating was reduced; this was achieved through good insulation and airtightness in the building envelope. The use of a double pressure gasket line reduces the air leakage rate to $5\,m^3/h/m^2$ of façade at a pressure of 50 Pa, bettering the UK *Building Regulations Part L* requirement of $10\,m^3/h/m^2$.



Projecting windows; tilted on the vertical axis.

Internally, the cill height of the projecting windows was fixed at 500 mm from finished floor level. This provides within the window module a usable surface that invites occupiers to use as an occasional seat and increases the area of insulated spandrel. The cill was finished with a lacquered timber panel as standard; this can be enhanced if required.

Above the main entrance loggia on the south-east corner, a projecting volume, triangular in plan, was provided with a series of external horizontal glass sunshade louvres over 20 storeys in height to attenuate solar transmission. This change to the cladding programme was for architectural and environmental reasons; the windows here are exposed fully to the southern sun with no shading from surrounding buildings, and the change of cladding grain gives the projecting volume additional emphasis on the Ropemaker Street/Finsbury Street corner above the entrance.

Main entrance south-east corner showing tilting windows.

Spandrel Panels

The insulated glass spandrels that cover over 50% of the building's envelope were constructed as shadow box cassettes, incorporating a special optical glass with back panels, coloured to correspond to the cubic volumes of the massing. The layering of colour based on five different indigo tones into the interlocking cubes further enhances this changing canvas. For each block, a single colour based on the NCS *Natural Colour System*® 3 became the base colour to the opaque spandrel panel viewed through the glass prism.

The spandrels were designed to express depth, light penetration and reflectivity in areas of the façade where visual 'depth' when viewed from the exterior was desirable, but vision through the glass from the interior was not required. The 'shadow box' usually comprises a double-glazed clear glass unit with a coloured opaque insulated panel some distance behind the glass surface, with pressure equalisation to the exterior through a series of slot vents in the carrier frame.

The glass units are frameless and bonded back to the supporting carrier frames by structural silicone, masked by a coloured 'frit' band 40 mm wide and selected to align as closely as possible to the background tone when viewed through the layers of glass. This

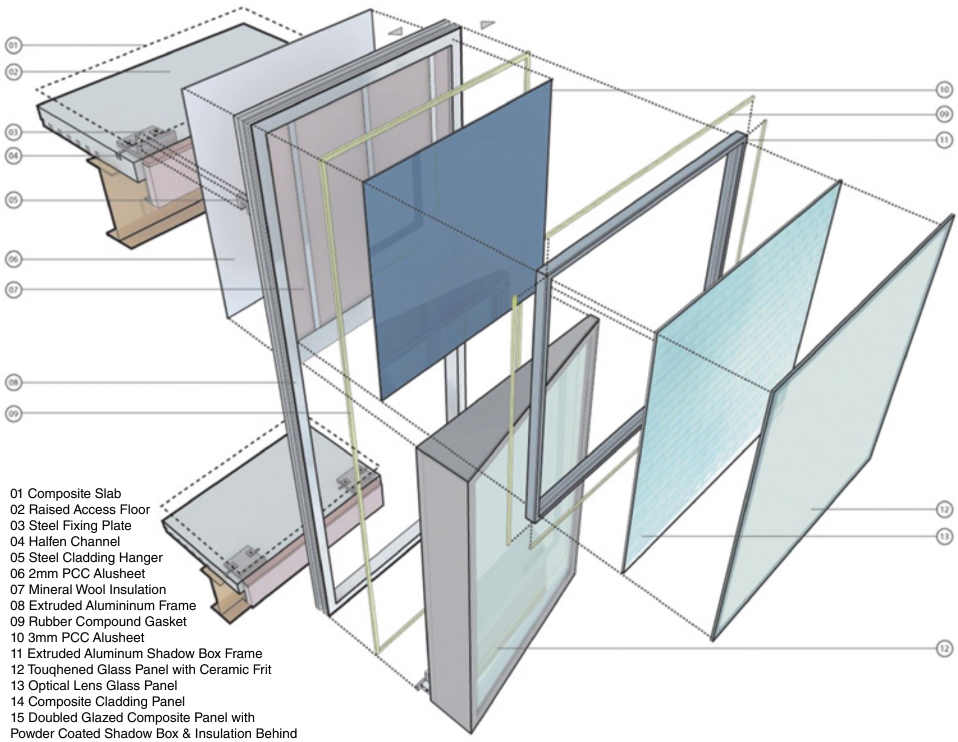


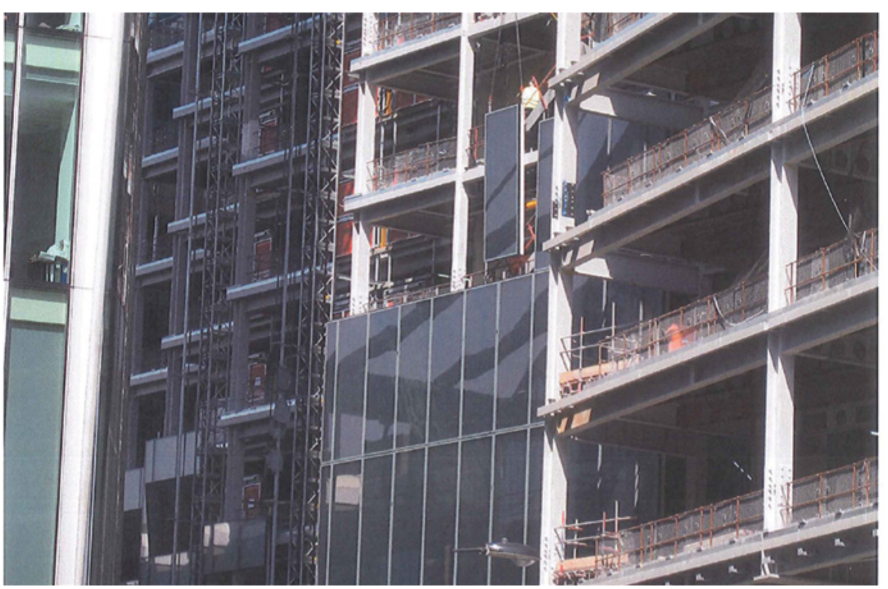
Figure 5.10 Window assembly drawing.

'kit of parts' was completed by identically designed opening panels for smoke venting (invisibly incorporated into the system), co-ordinated air grilles, high-level plant enclosure screens and glass balustrades (Figure 5.10).

The overall visual effect is created by the combined properties of the lens and cladding glass unit and their relationship to the base colour. The optics of the glass dilute the colour in the encapsulated panel, producing a softer effect analogous to the addition of varnishes to base colour in *Old Master* paintings. Overlaid on this are sky and context reflections from the immediate surroundings.

On overcast days or in shadow, cloud reflections, the context, and lower light levels create a more muted effect. Direct sun illuminates the spandrel interior and excites the background colour. This to some extent, is obscured by light reflections from the lens glass. Viewing angles acute to the spandrel surface, such as when seeing the building along a street or at high level from the ground, tend to increase reflections and much reduce the percentage of the diffused base tone. Conversely, viewing angles more perpendicular to the spandrel surface decrease reflections and increase the percentage of the diffused base tone. The optical properties and refined detail of the glass facades, together with the interlocking cubic massing, produce an ever-changing appearance, depending on the weather patterns and ambient light of the City sky.

Main entrance.



The façade panels being hoisted into place.

Energy conservation and the adoption of viable renewable energy technologies feature heavily in the building, although the team was keen to avoid 'Greenwash'. The strategy throughout was to keep solutions simple by making the building as passive as possible.

The Construction Managers, MACE, used WRAP's NetWaste tool, which showed the new building included 24% recycled content and 86% of materials from the site clearance were reused. 30% of new steelwork was manufactured from scrap and the existing buttress foundations on the site perimeter from the previous building were reused, adding up to 20% of the site footprint.

During construction, a Site Waste Management Plan was also in place. Construction waste was segregated into 12 different waste streams, managed and monitored, resulting in more than 75% of construction waste being diverted from landfill. Regular audits were carried out to ensure that every effort was being made to maximise the recycling of waste generated on site. To enable waste recycling during operation, dedicated recycling storage space was provided inside the building.

Wherever possible, *Green Guide* 'A' rating and responsibly sourced materials were supplied during construction. Concrete floors and roof achieved A+ Green Guide rating and frame, foundation, floors, roofs and timber finishes were responsibly sourced. Design measures to reduce waste included the Technik flooring solution that reduced waste by over 50% compared to traditional screed and prefabricated toilet construction reduced waste on site significantly. All timber used on site was sourced from sustainably managed sources.

During construction, water and energy used on site as well as energy associated to transport on site were monitored and there was Construction Environment Plan to ensure that best practice guidance was followed in respect of reducing the risk of pollution to air from dust generation. Advice was disseminated to site operatives via 'toolbox talks', advising on eight air pollution control measures including dust sheets, damping down and covering skips.

A petrol interceptor was included in the arrangements for the basement car park to provide onsite treatment for areas at risk from water course pollution. The strategy for water management included provision for storage and dealing with storm water run-off whilst conserving water through the design of plumbing systems.

A 90 m^3 rainwater harvesting tank allows attenuation of 80% of the run-off from hard roof areas and 30% of the run-off from green roof areas; the green roof attenuating up to 70% of the rainwater that falls on it. WCs have a 4.5 l flush, urinals have IR proximity controls, and auto-shut off taps are installed. Harvested rain water has been used to flush water closets in addition to waste cooling tower blow-down water. Water to showers is limited to between 9 and 12 l/min and faucets are low flow or aerated.

Ropemaker's Building Emission Rate (BER) is 24.6 $kgCO_2/m^2$ annually, approximately half that of a standard air-conditioned, 2008 Part L-compliant office, and is 32.7% better than Part L2A 2006. A combination of biomass boilers, foundation-stored heat harnessed by a heat pump, 75 m^2 of solar hot water heating panels and 75 m^2 of solar photovoltaics have been used, which provided onsite renewables (required by the Local Authority Planners) at 12–15% of the building energy demand. All exterior lighting was designed in accordance with the guidance in the Institution of Lighting Engineers (ILE) Guidance note.

The energy reduction strategy focused on an airtight, thermally efficient envelope, heat demand being minimised by recovering heat where it was not required and using it in other areas. Free cooling was maximised and the building has achieved an air leakage rate of 5 m^3 of air per hour per m^2 of façade at a pressure of 50 Pa.

The site location provides excellent transportation links and convenience to occupiers, as the site is triangulated by three London Underground Stations and is near the Barbican Centre with its extensive cultural opportunities. Liverpool Street Station and Broadgate are to the east of the site, with the City and its institutions beyond.

The development provides a very limited number of car parking spaces (only 23) and 54 motorcycle parking spaces. Ropemaker exceeds BREEAM requirements by providing 270 secure and well-lit cycle storage spaces, plus 15 showers with changing rooms and 235 lockers.

Ropemaker's usable green roof terraces enhance the ecological value of the site by providing 1850 m^2 of new green roof area and over 30 species of plant life including trees, shrubs and seasonal herbaceous planting, both suitable for biodiversity and occupier amenity.

Ropemaker is BREEAM 'Excellent' rated (score 72.7%). It satisfies the entire heating and hot water demand through the use of passive design and renewable energy systems and an array of other sustainable technical features. The building also became the first office building in London to achieve LEED Platinum, core and shell pre-certification. The building has an Energy Performance Certificate (EPC) 'B' rating (score of 46).

The base building heating/cooling systems are designed to allow independent occupant thermal control in all separate rooms/areas within the building. The metering strategy allows for the monitoring of different energy demands throughout the building and sub-metering is provided for each office floor.

Water meters have a pulsed output with a BMS connection to facilitate the remote monitoring of water consumption. The building incorporates a system capable of detecting major water leaks both within the building and between the building and the site boundary.

Product Design: The Wave-Form Ceiling at Ropemaker

The design of bespoke façades components, furniture, and fittings in Arup Associates' buildings has always been a natural aspect of the practice's multidisciplinary approach. Many items are specified in the normal course of a project, but situations can arise where a particular idea cannot be resolved with available materials and components, so there is an imperative to invent from first principles. An obvious example of this is the façade cladding system at Ropemaker, whilst another is the waveform ceiling and lighting system developed for the main entrance and atrium ceilings in collaboration with Zumtobel Lighting, SAS international and Stortford Interiors. It is a refinement of similar ceilings designed with Zumtobel in previous British Land projects in the City.

The purpose was to create an indirect/direct lighting source, with an acoustic performance, giving the 10.5 m tall corner entrance foyer spatial impact and visual focus in the views from City Point Plaza and Ropemaker Street. A series of illuminated vaulted waves seem to flow into the interior, its volume perceptually expanded by the up-lit waveform surfaces.

This curvaceous profile provides a visual tour de force as well as a practical solution to the lighting and acoustic requirements. The ceiling comprises curved, preformed, white polyester powder coat, micro-perforated steel sheeting with a white tissue interlayer and an acoustic blanket, together with a clear acrylic 'basket' diffuser to contain the individually addressable linear fluorescent luminaires. The basket diffuser is a bespoke linear extrusion designed using Zumtobel's patented waveguide technology, which refracts a proportion of the light flux onto the ceiling and the remainder into the interior volume (Figure 5.11).

The relationship between the diffused refracting light source and the reflective surfaces, together with the profile, was determined through extensive mock-ups that iteratively refined the design. Other crucial features – concealed fixing details, panel accessibility, and material finish – were also determined at this stage.

The ceiling system had to form both the main internal ceiling surface and also the external canopy surface, so as to give visual continuity between the interior and exterior systems. In practice, as both ceilings need to be fully accessible, the internal system uses a hook-on system for support, and the external system a more robust and secure suspension method.

This involves a concealed but accessible cam lock and fixed hinge to support the panels and allow access to services in the void area above.

The individual ceiling cassettes were based on a 1500 mm module (1475 mm actual), designed both to exactly fit a standard linear fluorescent luminaire and for ease of construction and replacement.

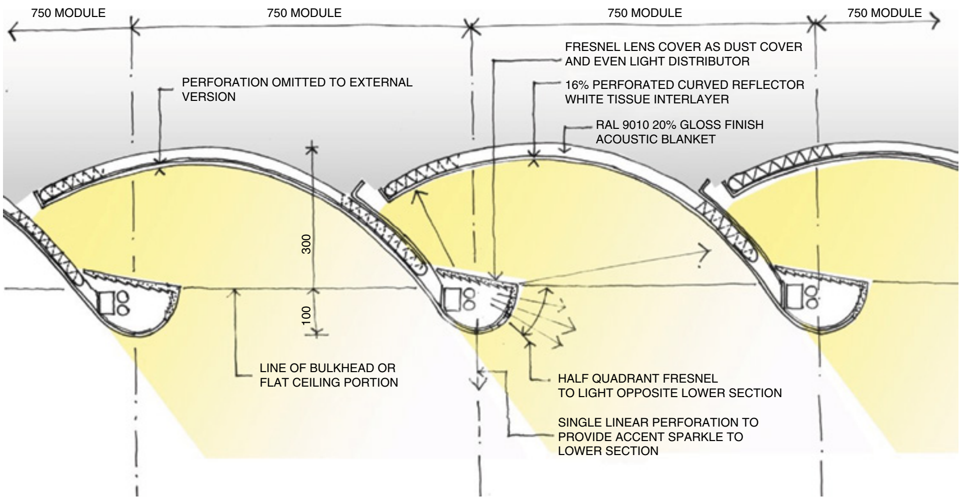
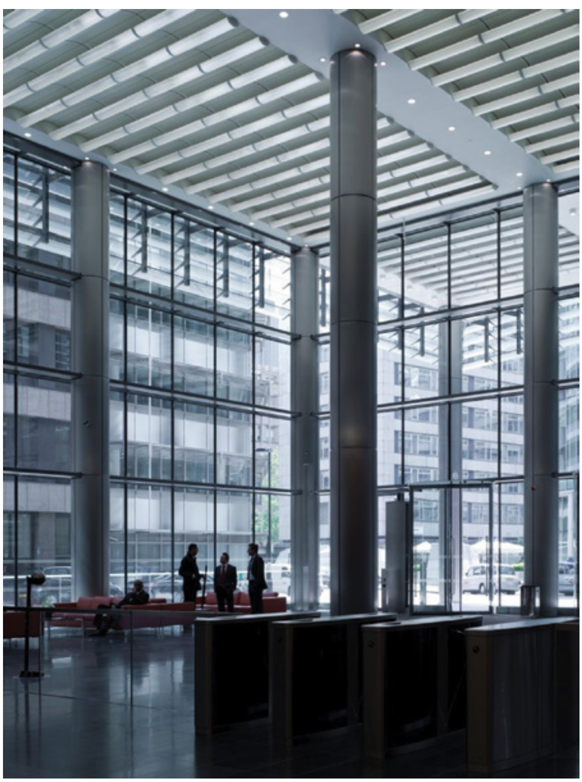
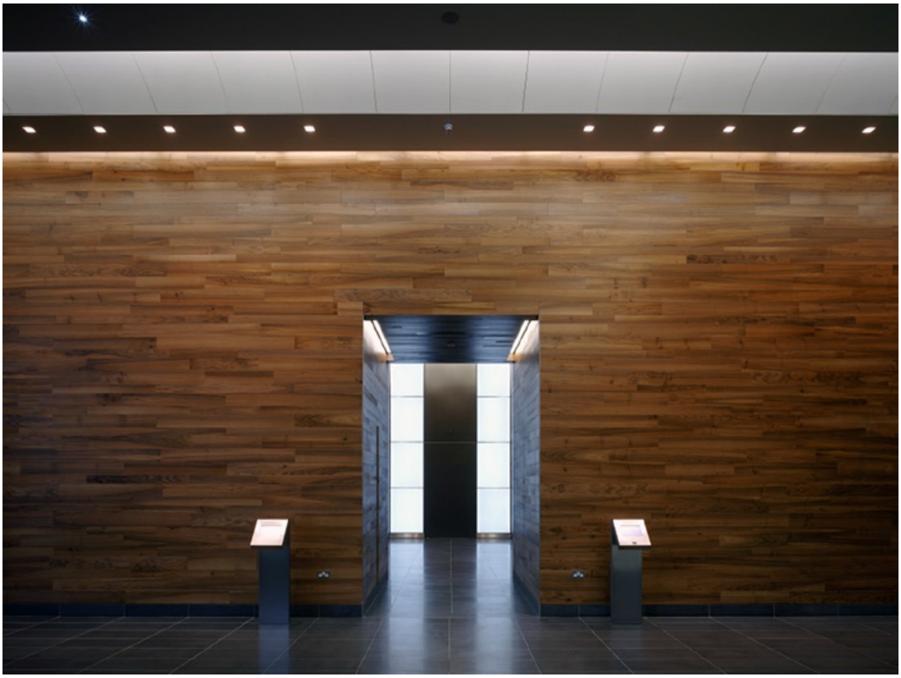


Figure 5.11 Wave-form ceiling design drawing.

The entrance foyer, through its spacious volume, finishes, and lighting design, appears now as the main focus to the local urban context and provides a transformed backdrop to the street promenade and activities centred on City Point Plaza.



The main entrance Foyer.



Entrance Foyer wall.

Completion

Completion of the entire building was achieved three years after the initial site purchase and within the original budget. This achievement justifies the client's preference for an integrated design and construction team approach and reflects well on the collaborative and 'can-do' spirit of all those involved.

Ropemaker Place was the only UK office building to have been shortlisted for an Award in the 'offices' category at the World Architecture Festival, held in Barcelona in 2010.

Bibliography

NB Sections of the text above first appeared in the Arup Journal (2010/2)

Anderson, D. *et al.* (2006) The *Technik* floor system. *The Arup Journal*, **41** (2), 34–35.

British Land (2013) Press Release, March 2013. Accessed on 21.11.13

Brundle, M. *et al.* (2005) Plantation place development, City of London. *The Arup Journal*, **40** (2), 34–43.

Building Regulations (2006) *Part L: Conservation of fuel and power*, Building Regulations.

Dowson, P. (1977) Offices. *The Arup Journal*, **12** (4), 2–23.

http://www.london.gov.uk/thelondonplan/ (accessed 14 June 2017).

http://www.ncscolour.co.uk/ (accessed 14 June 2017).

http://www.thegreenguide.co.uk/ (accessed 14 June 2017).

6

Environmental Services

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Environmental or *Building Services* systems and equipment must deliver comfort and amenity to the users of property through carefully designed heating, cooling, ventilation, good air quality, lighting, power, telecoms, IT, security systems, water supply and drainage.

Building services are an important part of building design and can account for 30% of the capital cost and 50% of the running costs of a typical UK office building (BSRIA, 2012). Moreover, building services should never be seen simply as mechanical and electrical kit which can be 'bolted-on' to a building, but must ever be seen as integral to a successful, economic design strategy, to be carefully considered at the outset of the design process.

The Building Services Research and Information Association (BSRIA) has published an excellent series of guides which explain the principles of mechanical and electrical building engineering and can be referred to when reading this chapter.

https://www.bsria.co.uk/about/
https://bsria.files.wordpress.com/2015/02/bsria-blue-book-20151.pdf
https://www.designingbuildings.co.uk/wiki/Rules_of_Thumb_-_Guidelines_for_building_services

The design of Building Services and choice of appropriate systems is determined by a range of factors including:

- Planned-for capital and running costs.
- Specific use of the building for example general purpose office space, laboratory, commercial kitchen and restaurant, sports use, auditoria and so on.
- Location of the building that is if in an urban centre, there may be pollution and noise issues.
- Available plant space within the planned-for building including access for maintenance and replacement. For example, in a simply serviced office building (radiators and opening windows plus some mechanical systems for some internal rooms) the

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

space required would be 6–10% of the total floor area. In a highly serviced building, 15–30% of the floor space would be needed for services (Ibid.).
- Noise and acoustic considerations for example within a lecture theatre or concert hall.
- Level of energy use for reasons of carbon reduction targets.
- Level of control required, that is close, immediate control via a full air conditioning as opposed to natural ventilation systems which respond more slowly to changes outside and inside the building.
- Level of comfort required.

Source: BSRIA

Predicting the conditions under which building occupiers will be *comfortable* in terms of temperature, ventilation rates, air movement and humidity levels and so on can be a complex and demanding challenge as an individual's perceptions and preferences can vary widely according to gender, metabolic rate, geographical location, the tasks performed, the clothes worn and the temperature of the surrounding surfaces in a specific situation.

Most guidance states that if, according to occupier surveys and/or the use of a predicted mean vote (PMV) system, at least 80% of the building occupiers are comfortable, then an acceptable standard has been achieved

http://www.designingbuildings.co.uk/wiki/Thermal_comfort_in_buildings
http://www.designingbuildings.co.uk/wiki/Predicted_mean_vote
http://auworkshop.autodesk.com/library/building-science/human-thermal-comfort
https://en.wikipedia.org/wiki/Thermal_comfort.

The ideal level of thermal comfort for most people doing normal office-type activities is normally predicted to be around 22 °C, ±2°. For activities involving physical effort, the bottom of the temperature range drops to 16°. However, it has been found that in basic, non-air-conditioned buildings, people will adapt to seasonal changes in temperature and that the acceptable internal temperature can be as low as 18 degrees in the winter and as high as 28° in the summer. Similarly, humidity levels are often between 40% and 60% in highly serviced buildings, but may be as wide ranging as 30–70% in basic buildings at different times of the year (www.cbe.berkeley.edu/comforttool).

The ways in which individuals perceive 'comfort' in naturally ventilated buildings, has become a field of study in its own right. It has raised a number of issues including the need for the occupiers to be less 'passive' compared with the way they might have behaved in older, fully air-conditioned buildings where temperature and ventilation could be changed by simply altering the settings on a control panel (http://escholarship.org/uc/item/2pn696vv#page-1).

Building occupiers experiencing discomfort as a result of temperature, humidity or air quality will not only be distracted from their activities, but may also develop stress-related conditions, physical or psychological problems which will result in lower levels of productivity and higher rates of absenteeism. Building occupier comfort is now the topic of much research and of very great interest to both building owners and businesses

http://www.hse.gov.uk/temperature/thermal/managers.htm
http://www.eci.ox.ac.uk/research/energy/downloads/40house/background_doc_c.pdf
http://www.sciencedirect.com/science/article/pii/S0378778812003027

http://ibe.sagepub.com/content/20/5/511.short
http://www.emeraldinsight.com/doi/abs/10.1108/14725960310807944.

As discussed in Chapter 5, energy use in buildings has become one of the most important issues in building design.

To help designers deliver lower energy buildings, BSRIA have set out five basic energy efficiency strategies, relevant to most building types:

- During warm weather, solar heat gain (the sun's rays heating up the internal spaces of buildings) should be minimised through the use of external shading or tinted glass and the careful consideration of the orientation of building's facades. Each elevation of a modern 'green' building may vary considerably in its design configuration, amount and type of glazing and the type of materials used.
- In winter, solar gain and heat gains from the building's equipment, lighting and so on can be used to heat the building.
- Natural ventilation should be used wherever practical constraints allow. Deep floor plans (over, say, 15 m) and high levels of internal partitioning can interfere with the efficient flow of air by natural convection. Where sufficient cooling cannot be achieved by natural ventilation, mechanical fans moving ducted air around the building can provide a 'mixed mode' system which requires less energy than full air-conditioning.
- Where the functional requirements of the building allow, the use of the outside air to provide cooling is preferable to the use of refrigeration plant; this is known as 'free cooling'.
- Where possible, the amount of daylight entering the building should be maximised to reduce dependency on artificial lighting.

https://www.iea.org/publications/freepublications/publication/buildings_roadmap.pdf

In United Kingdom, the most simple heating systems consist of a boiler (normally fuelled by gas, diesel or oil), distribution pipework through which the hot water from the boiler is pumped around the system and the source of the heat output into the building, the 'emitters' (most commonly in the form of radiators). There are different types of boilers including condensing and dual fuel (which can use a combination of gas and oil) and, as discussed in Chapter 5, biomass boilers.

Panel radiators (usually made from steel and including a thermostatic control valve) are still a popular choice to provide a simple heating solution to homes and those commercial properties where opening windows can provide ventilation or where mechanical ventilation is installed.

Although the term 'radiator' implies that heat is transmitted via radiation, in fact, a large proportion of the heat is distributed by *convection*.

Convector heaters, like radiators, use pumped hot water, but rather than circulating in a steel panel, the hot water passes through a finned hot water pipe.

Underfloor heating has become more common in recent years, having proven to be an efficient and unobtrusive system in kitchens, bathrooms and certain types of public space including foyers and shopping centres. Most underfloor heating systems use either hot water pipes or embedded electrical elements within the floor structure. They are not a popular choice in office buildings as the underfloor zone is often required to provide data and power supplies to work stations and may also mean the use of raised floors.

In large spaces such as warehouses, sports halls and factories, high-level radiant heating is often used, leaving the floor space unobstructed and the heating units less likely to be damaged by the activities carried out within the space. These emitters directly warm the occupants by radiation without having to heat up the surrounding air which would be cooled by air entering the space through large doorways.

These units can be gas-fired radiant tube or warm air heaters, use hot water panels or strips or can be electric-powered quartz.

See high-level hot water radiant strip heating in factories, high-level warm air heaters with flues and so on at: http://www.powrmatic.co.uk/products/heating/browse/

The natural ventilation of buildings is the preferred option if practically possible, as it is the easiest to maintain (no mechanical moving parts) and does not incur financial or environmental costs through energy use. Natural ventilation can be achieved by the use of simple opening windows in a single sided or cross ventilation arrangement or can use 'stack ventilation' which works by using the natural effects of temperature differences within spaces.

See diagrams at:

http://www.bioregional.com/wp-content/uploads/2016/04/The-BedZED-Story.pdf (page 6)
https://www.bsria.co.uk/download/product/?file=MAikRpUb1Ng%3D (page 7)

These diagrams explain the use of stack and wind ventilators (sometimes fan assisted) which can bring ducted fresh air or remove stale air to or from any part of the building.

High-level *Chilled Beams* are also commonly used in green buildings and utilise pumped cold water to cool ceiling level warm air, causing it to fall back into the space below due to its negative buoyancy.

However, some internal spaces, because of their design, location or use, require additional, mechanically assisted heating, cooling and ventilation.

In many factories, underground car parks, kitchens and in the internal toilets and bathrooms of commercial buildings, mechanically assisted air changes are necessary if ventilation requirements under the Building Regulations are to be met.

As well as providing ventilation, mechanically ducted air is also used to supply filtered heated or cooled air to internal spaces within buildings. These systems can range in complexity from simple warm air units mounted on walls or on ceilings to complex installations of air handling equipment, often found on the roofs of larger buildings.

Fan coil units require only fresh air and a hot/chilled water supply can be used to meet the heating and cooling needs of individual spaces. They are a flexible alternative to large air handling systems (https://en.wikipedia.org/wiki/Fan_coil_unit).

Full air conditioning is used where the demands of the geographical location (i.e. extreme climatic conditions), the site (noisy and/or polluted city centres), or the building's size, height or use mean that the internal conditions must be wholly controlled. Air conditioning means that the building (or parts of it) is treated as a 'sealed box' where the incoming air is filtered, humidified and cooled/heated and where stale air is extracted to be cleaned and reused or released back to the outside

https://www.youtube.com/watch?v=t0sjFKPdvIc
https://en.wikipedia.org/wiki/Variable_air_volume
https://www.youtube.com/watch?v=YCogTVa3XOw.

There are several generic types of air-conditioning system, many of which involve complex technologies, large plant rooms in basements or on roofs plus high capital and running costs. However, these systems offer immediate control of internal environmental conditions, either by the use of individual space sensors or by allowing individual control of temperature, humidity and ventilation rates.

Whilst domestic heating systems may be controlled by simple thermostats and control panel settings, the complex environmental systems in modern commercial buildings require sensors to monitor internal conditions and data handling software.

Building Management Systems (BMS) are networked digital control systems usually having at least one operator terminal. Graphic displays linked to room sensors show the temperature, humidity, occupancy levels and ventilation rates of individual spaces as well as energy consumption data. Such terminals can be located at remote locations such as a company HQ if desired (https://en.wikipedia.org/wiki/Building_management_system; https://www.youtube.com/watch?v=rCjoCoclwoc).

In recent years, digital software has been developed to incorporate BMS into *Integrated Building Management Systems*. These tools not only control the building's environmental systems, but can also be used to record a range of security, maintenance, fire precaution status and even procurement data, to inform building owners and to prompt Facilities Managers on the need for action (https://www.youtube.com/watch?v=−9_n3gy7Fc0).

For information on thermal insulation materials and technologies including argon gas and vacuum systems and so on, see:

https://en.wikipedia.org/wiki/Insulation_(list_of_insulation_material)
https://en.wikipedia.org/wiki/Vacuum_insulated_panel
https://en.wikipedia.org/wiki/Insulated_glazing
http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

For information on low-energy lighting and design, see:

http://www.lowenergydesigns.com/
http://www.arup.com/projects/kings_cross_station#!lb:/projects/kings_cross_station/kings_cross

For information on Retrofitting and upgrading the environmental systems of existing buildings including historic properties, see:

http://transact.westminster.gov.uk/docstores/publications_store/Retrofitting_Historic_Buildings_for_Sustainability_January_2013.pdf
http://www.ukgbc.org/resources/key-topics/new-build-and-retrofit/retrofit-domestic-buildings

For information on user behaviour and managing change (e.g. full AC vs natural ventilation systems), see:

http://energy.gov/sites/prod/files/2014/06/f16/change_performance.pdf
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/60536/behaviour-change-and-energy-use.pdf
http://danlockton.co.uk/research/Making_the_user_more_efficient_Preprint_hyperlinked.pdf

For information about the techniques and materials used in United Kingdom's first BREEAM Outstanding office building at 1 Angel Square, Manchester, see:

https://en.wikipedia.org/wiki/One_Angel_Square

https://www.youtube.com/watch?v=_Lm87EzgG-0
http://www.coop.co.uk/corporate/aboutus/one-angel-square/
https://en.wikipedia.org/wiki/N.O.M.A.,_Manchester

Sustainable Drainage Systems (SUDS)

Rather than using the traditional combined or dual drainage systems whereby rainwater from roofs, roads and hard standings and wastes from WCs, baths and basins, are drained by main sewer to treatment plants to be cleaned and returned to rivers or the sea, SUDS either captures water for irrigation or allows it to seep back into the ground via permeable materials built into the landscape

https://en.wikipedia.org/wiki/Sustainable_drainage_system
http://www.susdrain.org/case-studies/case_studies/surgery_kington_herefordshire.html
http://www.fangornlandscapes.co.uk/suds.html.

To see an existing housing scheme with a new SUDS, go to https://connect.innovateuk.org/web/sustainable-drainage-systems-suds/article-view/-/blogs/5486115.

For diagrams of typical *Combined*, *Dual* and other common drainage layouts and systems, see:

http://www.draindomain.com/system%20layout.html

Environmental Services Case Examples

Citi Data Centre, Frankfurt, Germany; *Sky* TV Studio, London, United Kingdom.

Citi Data Centre, Frankfurt, Germany: *a low-carbon, LEED Platinum solution to the problem of high-energy use.*

The Information and Communications Technology industry produces around 2% of all global emissions (Gartner, 2008). Data storage centres are normally huge sheds full of heat generating servers, but by rethinking conventional approaches, the designers of the Citigroup Data Centre created a high-tech workplace, surrounded by large open spaces and gardens.

Built at Am Martinszehnten, 10 km from Frankfurt city centre, the original brief was not for a sustainable building. Citigroup's initial requirement was for a robust, efficient, well-engineered property, the received wisdom at the time being that it simply wasn't possible to make energy-hungry data centres low carbon. However, the client was committed to the principles of *Corporate Responsibility* demanding carbon reduction targets. In order to help the client to achieve this, Arup Associates led on the idea of making the project low environmental impact and to take on the challenge of designing and delivering the world's first LEED Platinum data centre.

By using advanced energy systems and forward-looking IT strategies, this data centre takes up only 30% of the power normally needed to provide cooling in such facilities, using only 'recovered' energy to provide space heating to the loading facility and the 1500 m^2 of offices. Water cooling is a major consumer of energy in data centres, and so by installing a *reverse osmosis* system, it was possible to recover some 90% of all waste water, saving some 35 million litres of water each year.

The data center is surrounded by lush, open spaces, giving staff a place to relax. *Source:* Image courtesy of Arup Associates.

Putting sustainability at the heart of the project, the team also brought the building within the budget and within the required tight delivery programme.

- Floor Area: 230,000-square-foot/21,270 m^2 of data centre and office accommodation.
- Budget: 170 mn Euro.
- Due to the demanding programme, the scheme was designed to be delivered in two phases. The agreed phasing path provided 50,000 ft^2 of gross data area plus all the ancillary space for Phase I and the scheme was delivered in February 2008. For Phase II, a further 50,000 ft^2 of gross data area remained as an empty shell, without floors, ceilings and so on but with fire detection and sprinklers installed for fire safety until completion in 2010.

Whilst reducing the power loads of a data centre building was, perhaps, the main challenge for the design team, both the client and the consultants were also committed to achieving the best *overall* 'green score' against LEED criteria.

In terms of power consumption for building services and carbon emissions, a typical data centre of this size would be expected to use around 400 MWh/year and produce around 46,000 tonnes of CO_2/year. Arup and Citigroup set themselves targets of a 70% reduction in power consumption and 25% reduction in carbon dioxide emissions; highly demanding, but they deemed them as achievable targets within pre-existing cost and programme constraints.

The original budget had been for a non-green building, so, projected construction costs were closely monitored throughout the design process. Arup kept to the same level of fees even though this new approach required more work. Fortunately, as an integrated design practice, architecture, building services and structural design were developed in a holistic way in order to achieve the requisite value engineering.

For the design team to achieve their green objectives for such a building, they were required to re-evaluate and re-design many of the technical systems commonly used in most data centres, including the design of the cooling towers, the static, lead acid batteries normally used and the computer room air conditioning (CRAC) plant.

At the same time, Citigroup's IT engineers had to review and, in some instances, rethink the ways in which data centres were fitted out and operated. This would include considering the extensive use of new, energy-efficient, virtualised technology built into special modular cabinets to reduce heat gain within the building and the amount of cable space needed. This questioning of established practices would lead to a reduction in cable use by some 250,000 km.

Although both the designers and the client were aware that all innovations carry a degree of risk, the reliability of the energy supply and the operational efficiency of the data centre remained paramount in all technical decisions taken. A Diesel Rotary Uninterruptable Power Supply (DRUPS) providing the necessary energy supply backup system would hence be a pre-requisite, as would be the use of cooling towers in order to keep the servers at the required temperature.

The overall mass and large areas of facades which enclose the modern data centre can have significant visual impacts and both the designers and the local planning authority were keen to find ways to mitigate them.

The building utilises both natural ventilation and air conditioning systems and is, therefore, a 'mixed mode'. In data centres, air-conditioning equipment and cooling towers are a necessary requirement for which there are, to date, no practical alternatives.

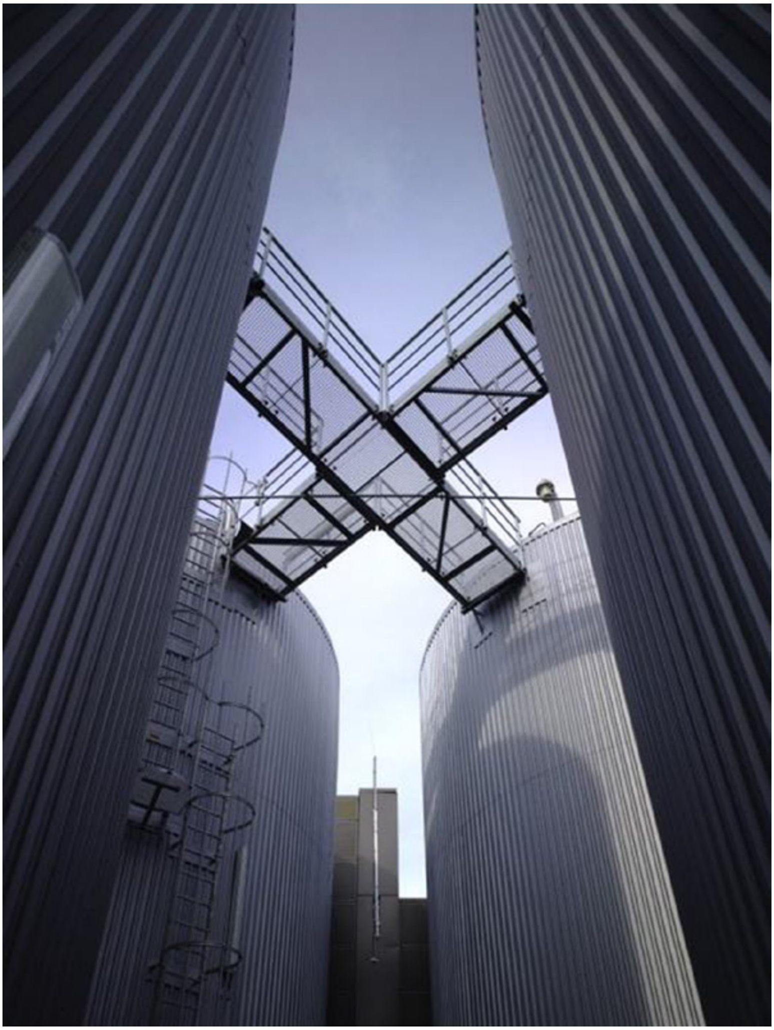
The design of most conventional cooling towers requires high levels of water consumption. On this project, Arup's engineers utilised a *reverse osmosis* system; this uses less water, does not rely on salt and water softeners to be added to the water supply and does not need the same amount of the chemicals required to combat legionella.

Used primarily to obtain drinking water from sea water, *reverse osmosis* is a water purification process which, if used aptly, can not only reduce water consumption but also assist in heat recovery. In its cooling processes, the Frankfurt data centre estimates using 50 million litres of water per annum *less* than a conventional equivalent building.

Whilst the design team led the efforts to improve the building and plant performance of conventional data centres, the client had also to review the ways in which the building was to be used.

The Real Estate team from Citigroup was signed up to the idea of a lower energy building from an early stage, but to identify opportunities for in-use energy savings, Arup were also required to engage with the Facilities and IT Teams to better understand their operational objectives. As with all construction projects, effective solutions require a thorough understanding of the problems to be solved and are developed through the recognition of and respect for the culture and priorities of the other stakeholders.

Most data centres operate using *all* the servers *all* of the time. In this project, the designers and the IT Operations team reviewed this practice and instead opted for fewer servers working at a greater capacity with the remainder kept on 'standby' mode. Similarly, as the Operations and IT teams became inspired by the green aims of the project, data handling systems were reviewed leading to the installation of more energy-efficient computer systems.



Cooling towers. *Source:* Image courtesy of Arup Associates.

For example, the design and configuration of the standard CRAC equipment was enhanced and simplified so as to better use the principles of natural ventilation, thereby reducing consumption from 9.3 to 3.3 kW per unit (Figure 6.1).

Conventional data centres use batteries to store energy in case of sudden power loss in order to keep operations ticking until backup generators operate. Here, rather than use batteries, a flywheel feeds energy back to start up the generators. In buildings of this type, batteries use approximately 5% of the building's energy, but, as this system needs only around 0.5%, there is a significant saving in energy.

In the 1500 m^2 office space, the accommodation is naturally ventilated, utilising a chilled ceiling. Heating in the offices and in the loading areas is provided by heat recovered from the data centre.

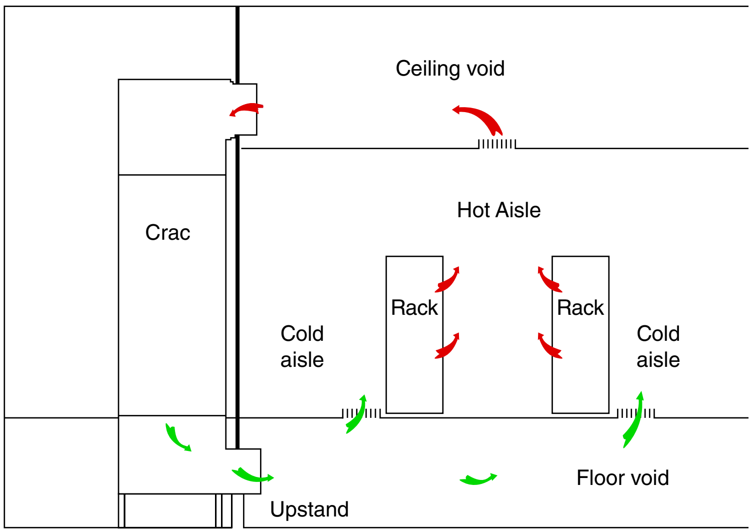


Figure 6.1 Computer room air conditioning (CRAC) arrangement.

Arup and the Operations team initiated many other measures like these, driving down energy consumption within the building to 30% of that used by a traditional data centre and improving the power utilisation efficiency (PUE) factor from a norm of 2 down to 1.2.

Overall, the building saves 11,750 tonnes of carbon a year which is the equivalent of 500 people's total carbon footprint. If all the world's data centres did this, enough power would be saved to power a country the size of Belgium

http://www.arupassociates.com/en/case-studies/citi-data-centre/
http://thoughts.arup.com/post/details/292/bring-data-centres-in-from-the-cold
http://inhabitat.com/citi-data-center-leeds-germany-to-a-green-future/
http://www.arup.com/news/2013_09_september/19_september_data_centre_obtains_the_first_leed_gold_certification_in_spain
http://publications.arup.com/publications/u/ukmea_sustainability_report
http://www.building.co.uk/arups-low-energy-citi-data-centre/3130455.article
http://www.e-architect.co.uk/frankfurt/frankfurt-data-centre
https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/542558/Consumption_emissions_May16_Final.pdf
https://www.theguardian.com/environment/2015/sep/25/server-data-centre-emissions-air-travel-web-google-facebook-greenhouse-gas).

Not only does the Frankfurt centre reduce carbon, costs, emissions and the technical plant areas, it achieves improved statistical reliability due to the reduced plant items needed.

The scheme's short programme time meant that very high levels of prefabrication and regularity in the structural grid used were required in order to reduce the number of different structural elements needed.

The potential visual impacts of the scheme were addressed in part by providing green roofs to the two-storey offices, the main data centre and the loading area, the planting from which then covers a 55 m long, 12 m high 'green wall'. Deciduous trees, hedges and wire mesh fences covered by creepers, further soften the visual impact of the building, whilst the main mass of the buildings is set back from site boundaries and buffered by gardens.

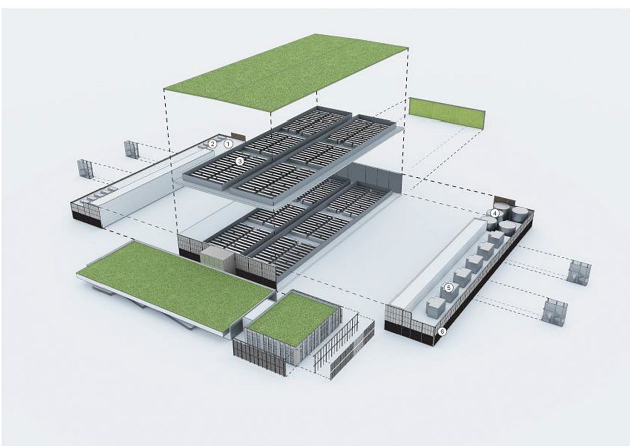
The data centre's 'green wall'. *Source:* Image courtesy of Arup Associates.

In Germany, many consumer materials are produced in the context of a low-waste, low-environmental impact, high recycling-rate culture. Building Codes and Regulations too are part of a responsible approach to the quality and assembly of materials, and standards are high and hard to meet. However, the contractors and legislators knew relatively little of the LEED requirements in terms of material procurement or construction. In order to adhere to the LEED materials *Chain of Custody* and procurement/disposal tracking needs, the construction and procurement teams needed to adopt different practices and the requirement for LEED procurement protocols was written into the building contract. In the final construction, all materials met the LEED low-VOC, recycled content (27%) and local sourcing targets (40%+). 100% of all construction waste was diverted from landfill.

The project's construction company has subsequently added this newly developed green procurement expertise to its Environmental Declaration and skill sets.

Also see:

http://www.arupassociates.com/en/case-studies/citi-data-centre/
http://www.arup.com/projects/citigroup_citi_data_centre



Section showing server floors and green roofs. *Source:* Image courtesy of Arup Associates; http://www.arupassociates.com/en/case-studies/citi-data-centre/.

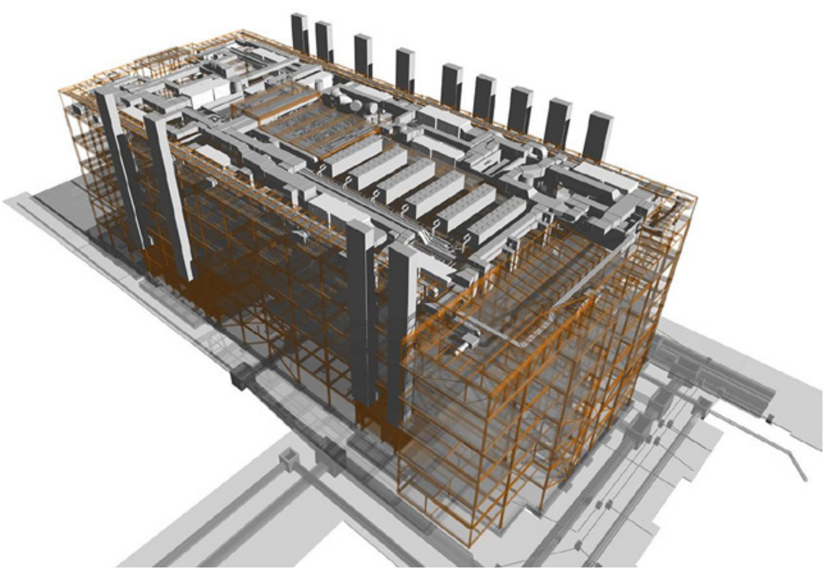
Sky* TV Studio, London, United Kingdom*; environmental engineering in the world's first low-energy TV studio.

- Desk space for 1300 staff.
- Eight recording studios; subsequently two additional 'open studio' areas.
- 700-server data centre.
- 23,000 m^2 of floor space and an approximate building footprint of 100 m × 50 m.
- Achieved an energy consumption reduction target of 67% less than a conventional equivalent building.
- Completed in 2011.

Sky Studios houses recording, post-production and transmission facilities for Sky's broadcast and sports news departments, including eight state-of-the-art, naturally ventilated studios, naturally ventilated offices and free-cooled data rooms.

Sky TV's brief for a genuinely sustainable, flexible HQ challenged Arup Associates to radically minimise energy use throughout, and maintain a clear focus on the human experience of the building. Post-production and technical spaces are positioned centrally, with office space wrapping around the perimeter of the building to allow access to natural daylight and fresh air, as well as views outdoors and across floors.

The building atrium allows visual communication between all levels, providing employees with a sense of scale and location. A cantilevered zone above the entrance contains a series of people-centered spaces, including green rooms, breakout zones, a cafe and meeting rooms.



BIM image: sky studios. http://www.arupassociates.com/cn/case-studies/sky-studios/

Initially, the main challenge for the design team was to ensure that energy consumption levels within the building would be significantly less than in a conventional TV studio and broadcasting facility. The normal cooling load for such buildings is in the region of 500 w/m^2 but studio and office lighting are also heavy users of energy.

Compared with a traditional equivalent building, the designers wished to deliver a reduction in energy consumption of around 60%, giving an EPC Rating of 'A', a 20% reduction in CO_2 and to derive at least 20% of energy from on-site renewables, as required by the client.

At the same time, there were operational issues for the occupiers and the Facilities Management team which needed to be addressed as part of the briefing process. Many studio staff were more used to the more *passive* approach to environmental services found in fully air conditioned environments; where heating and cooling control was an instantaneous process triggered by the click of a switch or by a remote BMS.

In naturally ventilated buildings, however, the process is more 'interactive', resulting in slower environmental control response time. The design team, therefore, spent many hours developing a clearer understanding of the technical demands of TV operations and also explaining the nature of a green project to stakeholders including TV presenters and the client's building operations team. This process involved 3 Arup staff for, on average, 12 h per week for 8 months.

One understandable source of concern for the client's Facilities and Operations team was the absolute need for reliability of the energy supply and the other basic functions of the building. As a broadcaster, Sky TV is a 24-h, 7 days per week international operation, meaning that their buildings must be dependable and able to deliver continually useable studio and office environments.

There were also a number of other challenging technical and space planning issues to be resolved. For example, for cooling purposes, TV studio equipment rooms would ideally be located on the outside of the building. However, office environments in sustainable buildings need good levels of day lighting, and so, ways had to be found to get the benefits of 'free cooling' to in-board equipment rooms.

Although the majority of the BSkyB Board and its own engineers were very supportive of the sustainability agenda, some were naturally concerned about the 'green' approach and the perceived increased risk of additional time and expense. As part of the project development and management process, the design team had to set aside adequate time and resources for the briefing, explanation and negotiation with stakeholders in order for the project to be a success.

This process would include discussions with the contractors. each of whom would have their own sustainability targets and requirements, including the managing contractor. The managing contractor was to take responsibility for many aspects of the detailed design and they too were to take a careful look at the cost and time implications of some of the technologies being put forward.

During the demolition of the previous building on the site, 90% of the demolition material was recycled and waste targets for the construction of the new studio were also set high at 97% of construction waste being diverted from landfill. 98% of all timber used during construction was to be FSC certified.

The design of the studios was 'process driven'. In the same way that the design of a concert hall for classical music might start with a careful analysis of the key space planning and technical requirements of an auditorium, an understanding of the function of a TV studio was derived from thorough research supported by client briefings and workshops. The resulting design ideas flowing from that process were then adapted to fit the site.

The BSkyB board was looking for 20% of the energy needs of the building to be generated by on-site renewables. A scoping exercise was carried out examining the practical and economic feasibility of utilising some of the most commonly used forms of renewable energy in United Kingdom:

- Photovoltaic (PV)
- Ground source heat
- Wind
- Biomass
- Combined heat and power (CHP)

If none of these systems had been suitable, Arup Associates planned to use grid supplied energy from a renewable source such as off-shore wind. 'Special Uses' such as TV studio processes are normally ignored in the consumption calculation when looking at Part L Building Regulation compliance models and renewable calculations. However, BSkyB chose to include these to calculate a more realistic energy consumption and use this as the basis of their renewables provision.

Given the requirements of the building type and the constraints of the location, an approach based solely on PV and wind was ruled out on the grounds of practical feasibility and costs. The study also concluded that the installation of a Ground Source Heat system would have delayed the site clearance programme and that the cost-benefit ratio predictions were inconclusive.

The study showed that a biomass fuelled Combined Cooling Heating and Power plant offered the best solution for the project. It would provide sufficient renewable energy to reduce the carbon emissions by the required 20%, enough energy annually to power the equivalent of 3000 homes, and heat 600 homes. Transport impacts too, were an important part of the feasibility study as the raw materials for such a system would have to be delivered to site. However, as the building is located on an edge-of-town site to the west of London with good road links for sourcing materials, the projected environment impacts were within an acceptable range. Arup had been carrying out ongoing research into renewable systems prior to this project and so were confident in suggesting an Austrian-made advanced woodchip system for this building.

At the same time as renewable *supply* was being researched, the designers were also looking at ways to reduce energy *consumption* in the building. The challenge for the design team was to design natural ventilation to the high loads created by traditional studio lighting, which was achieved and proven in the commissioning of the studios.

Once the building was occupied, energy reduction strategies were further helped by the introduction of new light-emitting diode (LED) technologies in studio lighting. Alongside recent advances in camera technology enabling images to be recorded at lower light levels, this change has meant reduced energy use and less heat from the lighting systems.

In a sector which is technology-based such as broadcasting, change is often rapid and far reaching. Flexibility and future proofing, therefore, underpinned many aspects of the design of Sky Studios (http://downloads.bbc.co.uk/outreach/BBC_LEL_Guidelines.pdf).

The giant natural ventilation chimneys of the recording studios are revealed on the exterior of Sky Studios leading some to regard the building as an example of a new 'power station architecture' for the 21st century.

The building is divided horizontally into three zones: 'make', 'shape' and 'share'. Lower floors contain the giant studios within which television content is made. Middle floors contain the data centers, production facilities and editing suites within which the content is 'shaped'. The upper floor contains the transmission platforms from which the television signal is 'shared'.

Studios require very close control of external noise. Natural ventilation would appear to run counter to this objective, as noise is normally brought in along with the fresh air. In this building however, the system is driven by the waste heat given off by the studio lights. Hot air from the lights would usually need to be cooled mechanically, but here the air rises out through giant ventilation chimneys visible on the exterior of the building, drawing in cool, fresh, external air below the studios through a series of sound attenuators. Where external conditions are inappropriate for natural ventilation, mechanical ventilation and cooling of the studio spaces can be implemented.

Chiller Units

The design and specification of the chiller units to be located on the roof was identified as being of particular importance in the special context of this building. The client's engineering team proposed using bespoke manufactured chillers from one of their regular suppliers which incorporated Turbocore compressors using magnetic bearings to reduce maintenance requirements and increase reliability as well as provide higher part and full load operating efficiencies. At the time of design, these were still a comparatively new technology, but showed the client's commitment to test out and apply new thinking to the design process.

Equipment Room 'Free Cooling'

The large number of data equipment racks that are provided to support the media facility normally use significant amounts of cooling energy. To reduce the amount of mechanical cooling required, the design team developed a strategy to use outside air cooling. Large low-energy supply fans are located on the roof of the building providing filtered air via large builders work shafts. This air is mixed with the room air via local room units providing savings on mechanical system cooling. Waste heat is rejected using similar low-energy exhaust fans located on the roof.

'No Gas' Supply

At the request of the client engineering team, the building is not provided with a gas supply. The initial brief indicated that providing year-round cooling for the building would be required with minimal heating. The design team determined that a minimal heat source would still be required after accounting for free cooling and heat recovery systems. Water-to-water heat pumps assist in providing chilled water for cooling of technical spaces. The waste heat from these is used to provide heating for fresh air systems and façade heat losses.

Domestic hot water for showers and so on is provided using waste heat from the combined heat, cooling and power plant.

Mixed Mode Ventilation

The general workspace office areas of the building are located at the perimeter to allow natural ventilation to be used when external ambient conditions allow. High- and low-level openings are provided within the façade to allow occupants to control personal environmental conditions as required. In the deeper plan office space, a central shaft links each floor allowing additional natural daylight combined with automatically controlled louvres which provide 'stack' driven ventilation.

When external ambient conditions are too cold or too hot for natural ventilation, the openings are automatically locked, closed by the BMS. The building air handling plant then takes over providing minimum fresh air ventilation in the winter and enhanced ventilation in the summer. Air is introduced into the space through floor mounted up-flow diffusers, using the generous floor void space which is already provided to cater for the extensive technology cabling systems. Up-flow ventilation allows air to be supplied close to room temperature for both cooling and heating requirements. High floor-to-ceiling heights allow heat to be removed at high level from the space at a higher than normal temperature in the summer. This approach requires less summer cooling compared to ceiling mounted systems which use much lower supply air temperatures.

Post-production and technical spaces are positioned centrally, with office space wrapping around the perimeter of the building to allow access to natural daylight and fresh air and vistas outdoors and across floors. While a BMS optimises the cooling and ventilation of the building, windows can be individually controlled by occupants during a natural ventilation period.

The building atrium allows a visual communication between all levels of the buildings, providing employees with a sense of scale and location, while a cantilevered zone above the entrance contains a series of people-centred spaces, including green rooms, breakout zones, a cafe, and meeting rooms.

There are eight state-of-the-art naturally ventilated studios, naturally ventilated offices for 1300 people, and free-cooled data rooms for more than 700 computer servers.

The client needed the building to be operational for the start of the 2011/2012 Premier League Football Season which led to a challenging construction programme.

A steel frame was chosen to enable rapid erection of the primary frame, with the design being released ahead of following trades to overcome fabrication lead-in time. One of the significant challenges of incorporating studio facilities into a building is how to span the building above over the large studio spaces. The choice of long-span cellular beams, which could span clearly over the studios and provide column-free office space above, avoided the need for costly transfer structures above the studios. The building services can be integrated within the beam depths enabling the floor-to-floor heights to be minimised. This strategy produced a saving of 2 m on the overall building height, equivalent to £0.5 mn off the cladding budget.

The building is also used as a satellite transmission facility, imposing strict sway and rotation limits on the building structure. Steel bracing is provided within the façade to maximise its lever-arm from the centre of mass of the building and hence its efficiency. To minimise the impact on the aesthetic of the façade, this bracing is hidden in stair cores and behind the studio chimneys as they rise up the building.

As part of the need to reduce cooling loads in the building, a high-performance façade system was developed. The design, therefore, had to include areas of solar shading and provide high levels of natural lighting. So, the façade designs are different on each elevation, depending on orientation and exposure. The façade of the building also incorporates motorised, top-hung opening windows as part of natural vent system. Extensive testing was required to be sure that these systems were both quiet and dependable.

Once the design of the façade system was finalised, carefully drafted, detailed performance standards then proved to be effective in delivering this element of the building as originally conceived.

Since completion, the design brief of providing a flexible facility has allowed a continual change in the way the building is used. A second 'on-floor open studio' has since been added and further catering facilities included within the Atrium space. 'Future Proofing' for BSkyB's business, indeed for all clients, remains a vital factor in the Arup design process.

Bibliography

BSRIA (2012) *Illustrated Guide to Building Services*, https://www.bsria.co.uk/download/product/?file=izGNVziWFHU%3D

Beaven, M. and Vincent, J. (2004) Ch. 6 *Engineering Intelligence Through Nature*, in *Intelligent Buildings – Design, Management and Operation*, Second edn (ed. D. Clements-Croome), Thomas Telford.

Gartner (2008) *Thought piece on Disruptive Digital Technologies*, http://www.gartner.com/newsroom/id/681107 (accessed 2014).

http://www.archdaily.com/382951/harlequin-1-arup-associates/ (accessed 14 June 2017).

http://www.architecturetoday.co.uk/?p=12885 (accessed 14 June 2017).

http://www.arupassociates.com/en/case-studies/sky-studios/ (accessed 14 June 2017).

http://www.worldbuildingsdirectory.com/project.cfm?id=2939 (accessed 14 June 2017).

http://www.e-architect.co.uk/london/harlequin_1_bskyb.htm (accessed 14 June 2017).

http://www.bioregional.com/wp-content/uploads/2016/04/The-BedZED-Story.pdf (accessed 14 June 2017) (page 6).

https://www.bsria.co.uk/download/product/?file=MAikRpUb1Ng%3D (accessed 14 June 2017) (page 7).

https://en.wikipedia.org/wiki/Insulation_(list_of_insulation_material) (accessed 14 June 2017).

https://en.wikipedia.org/wiki/N.O.M.A.,_Manchester (accessed 14 June 2017).

7

Materials

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In the United Kingdom, the construction materials sector consumes around 400 million tonnes of raw materials every year, meaning it is the country's largest user of natural resources (UKGBC, 2016).

Choosing building components which, in their manufacture and use, consume fewer resources and are less polluting can, therefore, help to reduce the nation's carbon footprint and enhance the overall environmental credentials of the building. Construction materials consume natural resources including minerals, fossil fuels for energy production, timber, oil-based products and water have major transport impacts and add to the waste burden as they are replaced and their production processes may release chemicals into the atmosphere including nitrogen oxide and sulphur dioxide.

Although it is generally accepted that the operational impacts of buildings still outweigh the embodied impacts arising from materials production and construction, as the operational performance of property steadily improves, this ratio will come down, thus making the selection of environmentally responsible materials ever more important (CPA, 2012).

http://www.c-a-b.org.uk/wp-content/uploads/Guide_understanding_the_embodied_impacts_of_construction_products.pdf
http://www.ukgbc.org/resources/additional/key-statistics-construction-industry-and-carbon-emissions

To assess the environmental impact of a construction material, the embodied CO_2 and resources used and the waste and emissions created are measured at each stage of the product's manufacture, use and disposal. This 'cradle-to-grave' analysis is known as life cycle assessment (LCA) and requires the collection and interpretation of often complex and extensive quantitative data collected by environmental consultancies, trade associations, manufacturers and national governments (Figure 7.1).

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

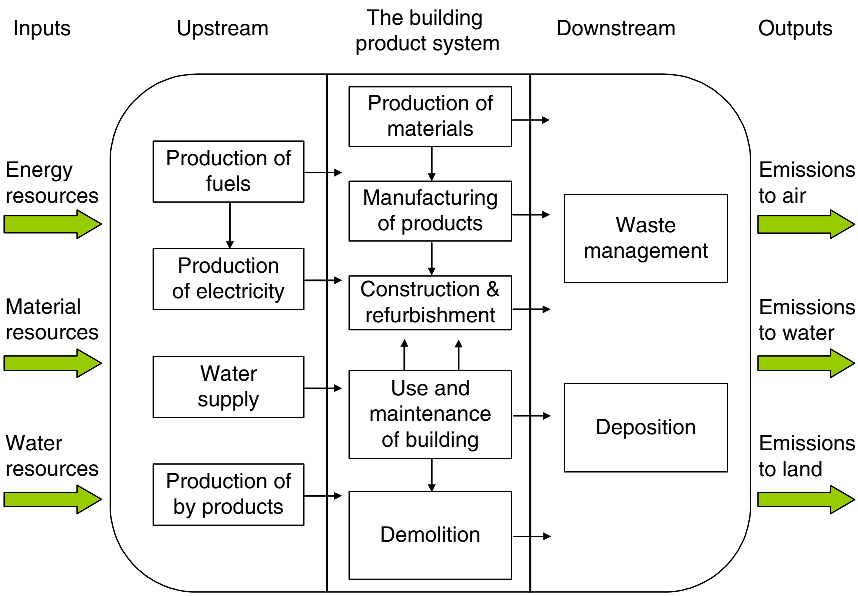


Figure 7.1 The life-cycle system of a building and its interventions with the physical environment.
Source: The Green Guide to Specification, 2009.

In a simplified example, for the production of clay roof tiles, an LCA would require the measured energy and resources use data for the following stages of the product's life cycle:

Winning of the raw materials and their manufacture

- the extraction of the clay from the ground and its transportation to the factory
- the extraction and distribution of natural gas for the kiln
- the mining and transport of fuels for the generation of electricity for use in the factory
- the production and transport of raw materials for the packaging
- the manufacture and transport of packaging materials for the tiles
- the manufacture of the tiles including the energy used and the emissions created
- the transport of the tiles to the building site

The product in use

- the extraction and production of the materials for fixing the tiles to the roof
- the on-site labour impacts of hanging of the tiles
- the maintenance of the tiles, including cleaning, repairing and replacing

Removal/demolition and disposal

- the on-site removal of the tiles at the end of their useful life
- the fate of the materials in the waste stream

(Ibid.)

The Green Guide to Specification is one of the industry's most widely used sources of information in providing designers, architects and property managers with information on how to make the best environmental choice when selecting materials. Part of both *BREEAM* and the *Code for Sustainable Homes*, *Green Guide* uses LCA data measured against the 13 impact categories of BRE's Environmental Profiles Methodology to assess the environmental performance of materials, then presents the complex quantitative results in an easy-to-use A*–E rating system where A* is the best choice and E the worst.

The environmental impact categories used and the issues they represent:

Environmental impact category	**Environmental issue measured**
Climate Change	Global Warming or Greenhouse Gases
Water extraction	Mains, surface and groundwater consumption
Mineral resource depletion	Metal ores, minerals and aggregates
Stratospheric ozone depletion	Gases that destroy the ozone layer
Human toxicity	Pollutants that are toxic to humans
Ecotoxicity to water	Pollutants that are toxic to the ecosystem
Nuclear waste	Spent fuel, high- and intermediate-level radioactive waste
Ecotoxicity to land	Pollutants that are toxic to the ecosystem
Waste disposal	Material sent to landfill or incineration
Fossil Fuel Depletion	Coal, Oil or Gas consumption
Eutrophication	Water pollutants that promote algal blooms
Photochemical Ozone Creation	Air pollutants that cause respiratory problems
Acidification	Gases that cause Acid Rain etc.

The studies undertaken in developing the *Green Guide* also revealed which elements within buildings have the potential to have the greatest environmental impact over a notional 60-year life of the average building (including the maintenance and replacement of elements). These elements, therefore, demand particular attention when making a specification choice.

http://www.brebookshop.com/documents/sample_pages_br501.pdf

As can be seen in *Green Guide*, the external walls together with some materials used to provide road and path surfacing in heavily trafficked outside areas, appear to have the greatest environmental impacts. Many external walls comprise high-mass materials, whereas road and path surfacing must often be maintained and replaced at frequent intervals, hence their greater impacts.

Although internal floor finishes such as carpets were not measured in the Green guide of 2009, the pie chart below from the 2002 third edition shows that surprisingly, given their relatively low mass, these had the greatest environmental impact, again due to the large quantities used in the United Kingdom and the number of times they were replaced in the building's life cycle (Figure 7.2).

A wool/nylon mix carpet with foam backing/underlay was chosen as typical for commercial buildings in 2002. Because carpets are replaced frequently (perhaps as many as

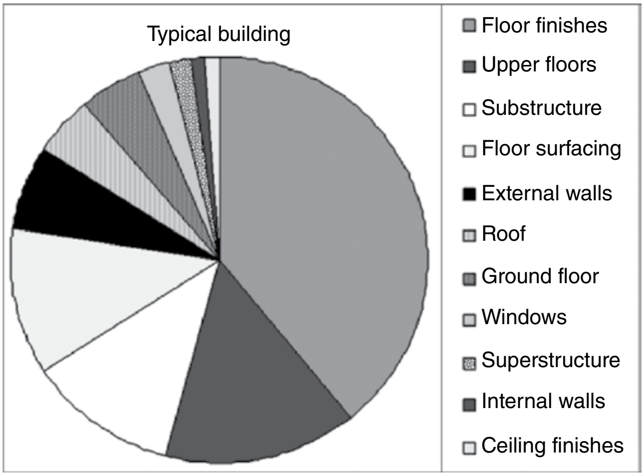


Figure 7.2 The environmental contribution of building elements. *Source:* From Green Guide, 2002.

12 times over a 60-year period), the environmental impacts associated with this element could be very significant – around 40% of the total building impacts. However, changing the specification to a carpet with recycled rubber crumb or natural fibre underlay, could reduce by up to two-thirds the overall impact of the floor finishes.

Upper floor structure (forming most of the floor within an office building), had the next largest impact, accounting for around 15% of the total building impacts. Floor surfacing (based on a typical office raised access floor 150 mm high), was the third largest impact. Raised access floors provide modern offices with considerable flexibility, but at 12% of the total, their environmental impact was significant.

Substructure (foundations etc.) had a similarly large impact. The specification of substructure is dependent on the ground conditions and the mass of the structure above. The design of substructure may offer designers possibilities of reducing impact.

External walls made a significant contribution to the impacts of the typical building (around 7% of the total). Walls and windows together accounted for 10% of the total embodied impact.

The impacts of the roof and ground floors were of similar magnitude, both around 5% of the building total. The impacts of both roof and ground floor will increase or decrease depending on the number of storeys in the building, the greatest impact being for single-storey buildings.

As with substructure, the design of ground floors (that is floors in contact with the ground such as basements) is largely governed by the ground conditions and the choice of substructure. Therefore, it was not possible to offer guidance on this.

Of the major design elements, windows had the lowest impact (only 3% of the building total). For a building with higher glazing ratios, the impact of windows will increase as the impact of the external walls reduces.

Superstructure (the structure supporting the floors above ground) has a smaller impact than the other major elements. This conclusion is based on a mix of steel and concrete framed buildings. In fact, the choice of structure makes very little difference to the overall impacts of the building because both account for around 2% of the total.

The smallest impacts (around 1% each for our typical building) are derived from the internal walls (based on a standard open plan office) and the ceiling finishes (based on a combination of suspended ceiling and plastered soffit options).

For the latest information on the impacts of materials, responsible sourcing of materials and BREEAM Chain of Custody verification and standards, see:

https://www.bre.co.uk/greenguide/podpage.jsp?id=2126 and Green Guide on-line at https://www.bre.co.uk/greenguide/calculator/page.jsp?id=2071
http://www.breeam.com/BREEAMUK2014SchemeDocument/content/09_material/mat03.htm
http://www.ukgbc.org/sites/default/files/BREEAM%20Uncovered%20-%20Responsible%20Sourcing%20-%20Summary.pdf
https://www.bre.co.uk/page.jsp?id=3424

For information on designing for future removal, disposal and replacement, see:
http://www.asbp.org.uk/uploads/documents/resources/Reducing-Material-Demand-in-Construction[2].pdf

For information on disposal and waste stream issues, see:

https://www.wbdg.org/resources/cwmgmt.php
http://www.sustainablebuild.co.uk/reducingmanagingwaste.html
http://ec.europa.eu/environment/waste/construction_demolition.htm
http://ec.europa.eu/environment/waste/studies/cdw/Improving%20management%20of%20CDW%20-%20Workshop%20-%20Background%20paper.pdf

For information on initiatives to promote manufacturer product labelling in the EU, see:

http://ec.europa.eu/growth/tools-databases/newsroom/cf/itemdetail.cfm?item_id=8664
http://www.ihs.nl/fileadmin/ASSETS/ihs/Marketing/prospective_students_pages/ECO_and_MFUI/GREEN_LABELS_Final_report_edited1.pdf
http://www.ecolabelindex.com/ecolabels/?st=region=europe

Hazardous and Deleterious Materials

If found in existing buildings, materials which are deemed *hazardous* (e.g. Asbestos) or *deleterious* (degrading) must be carefully managed and/or disposed of by taking expert advice and following the appropriate technical guidance notes for example:

https://www.designingbuildings.co.uk/wiki/Deleterious_materials_in_construction
https://www.rics.org/uk/shop/Investigating-Hazardous-Deleterious-Building-9898.aspx
http://www.hse.gov.uk/comah/sragtech/techmeassegregat.htm
http://www.hse.gov.uk/waste/hazardouswaste.htm

The use of construction materials which can be harmful to human health such as some chemical treatments, adhesives, solvents and so on are governed by the COSHH Regulations.

http://www.hse.gov.uk/coshh/basics.htm

Materials Case Example: Druk White Lotus School, Ladakh: *the humility of the learning process*

> The idea of having a modern school which lays equal emphasis on the importance of preserving the valuable aspects of a traditional culture is very encouraging.
> I have always believed in giving equal importance to both modern scientific knowledge and traditional Buddhist culture.
>
> *His Holiness the Dalai Lama*

Located at an altitude of 3,500 m and accessible only for 6 months of the year, Leh Valley in Ladakh, northern India, is bordered by Tibet and Pakistan. Arup have been working with a trust charity since 1997 to design and create a school for local children and a place of cultural learning and communication for the whole region.

The Lea Valley, Ladakh, India.

See:

http://www.arupassociates.com/en/case-studies/druk-white-lotus-school/
http://www.arup.com/projects/druk_white_lotus_school/druk_white_lotus_school_film
http://www.arupassociates.com/en/exploration/local-stone-druk-white-lotus-school/
http://www.designshare.com/index.php/case-studies/druk-white-lotus-school/
http://www.arupassociates.com/en/projects/

Conceived as a model for sustainable development in the Ladakh region, the school is designed to cater for 750 pupils from nursery age to 18 years old.

Perched in the Indian Himalayas, the school must also withstand extreme temperatures and earthquakes. Arup's design for the school combines sustainable local materials and traditional construction techniques with leading-edge environmental design.

A team of architects and engineers from Arup and Arup Associates is responsible for the master plan, concept and detailed designs of each phase of construction. The first phase, the nursery and infant courtyard, opened in September 2001, to be followed by the junior school in 2005. The final phase, the senior secondary school, was completed in 2013.

The project is the brainchild of His Holiness Gyalwang Drukpa and is executed by Drukpa Trust, a UK-registered charity. To support the school, each year, Arup gives an engineer or architect from the design team unpaid leave to work on site. They act as ambassadors for the Trust and help the local construction team.

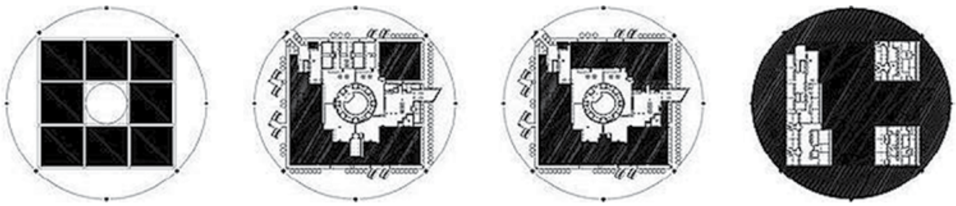
The school's buildings are flexible and provide an excellent learning environment. All this is achieved using local sustainable materials and building techniques.

The location also has many advantages. At an altitude of 3500 m, the school is ideally placed to use solar energy.

In October 2008, the first phase of the Druk White Lotus School 42 kWp photovoltaic system was completed, providing reliable power to the whole site. It uses an initial installation of 9 kWp of PV panels, which also act as external shading devices for three of the school buildings. The PV installation was 60% funded by Arup Associates, who used this project to offset their carbon footprint for 2007. Previously, electricity was available only intermittently from the local grid or by operating the school's diesel generator. The system includes batteries to provide electricity in hours of darkness, which can also be charged from local mains electricity or the site generator.

The school provides a quality teaching environment, previously unavailable in Ladakh, and will respond to the specific cultural needs of the people. The project has received a number of World Architecture Awards: Best Green Building, Best Education Building and Best Asian Building in 2002.

See video at: http://www.arup.com/projects/druk_white_lotus_school/facts#!lb:/projects/druk_white_lotus_school/druk_white_lotus_school_film



The school is designed around the circular 'mandala' form – an ancient Indian symbol of wholeness and ultimate symbol for the organisation.

Construction photograph and model of the Pema Karpo library. *Source:* Image courtesy of Arup Associates.

Aftermath of a mudslide in 2010.

The finished timber structure.

The completed Pema Karpo Library.

Many of the challenges of the project were as a result of its remote location and extreme environment. It would have proved very difficult to source many of the materials required to build the school. Even though the design would utilise local materials as far as possible, some would simply not be available for a building of this type and size. For example, steel and large timber sections had to be imported from Kashmir and double-glazing units needed to be made by importing single-glazing and assembling the units on-site so as reduce travel distances for the supply of materials.

The energy supply to the site was by means of electricity and was available only intermittently from the local grid or by operating the school's diesel generator. With such an erratic source of energy, even the use of power tools would be affected. This would have to factored into the design of the building to ensure that assembly of the components would be possible under such conditions.

A thorough understanding of traditional building morphologies, local materials and assembly techniques required extensive study prior to undertaking the design of the proposed school . Arup worked closely with the local craftsmen to better understand how materials were used and detailed, as many of the local craftsmen were unused to referring to architectural drawings.

The extreme nature of the mountain desert location meant that the design team would have to face the challenges of seasonal day-to-night temperature ranges of between +35 to −30 °C. Torrential rain and mudslides were common and the building would have to comply with Indian seismic codes to prevent damage from earthquakes.

In order to fulfil its primary function, the school would have to provide a safe and secure environment, conducive to learning, with comfort being paramount to the happiness and well-being of the children and the teachers.

One of the first phases of the design process involved studying local, traditional building types, including the monasteries in the region. The layout of the buildings was found to often utilise the traditional nine-square grid of the mandala surrounded by a series of concentric circles.

Traditional techniques of warming and cooling, utilising thermal mass and cross-ventilation were researched, then incorporated, but supplemented with a number of appropriate modern technologies to create excellent day-lit, naturally ventilated spaces, passively heated by the sun. It was also a requirement that the design required minimal maintenance and running costs, while providing accommodation to modern standards.

The school buildings consist of a series of classrooms and staff offices grouped in two parallel buildings, planned around an open courtyard, which provides play areas and additional secure outdoor teaching spaces.

The buildings, appositely separated to avoid overshadowing, take maximum advantage of the unique solar potential of the high altitude location by using glazed, south-facing facades to gather the sun's energy and high thermal inertia walls to store the gained heat.

On winter mornings the daytime teaching areas are quickly heated up by means of combining optimal 30° south-east orientation with fully glazed solar facades.

In the summer, operable windows and roof lights allow cross-ventilation for cooling and fresh air.

All classrooms are entered from the courtyard via a lobby, which provides a thermal buffer. Each classroom has a quiet warm corner, with a small stove on a concrete floor that is used only on days of extreme cold weather. Timber floors elsewhere and white-painted mud rendered walls are provided for maximum teaching flexibility in clear, uncluttered spaces.

During the construction planning phase, the site manager was of particular importance in liaising with the craftsmen who built the school and Arup used mock-ups to develop assembly details so that a two-way dialogue would be possible.

Whilst the location of the project presented many challenges, it was found also to offer some opportunities which the designers turned to their advantage. At an altitude of 3500 m, the school is ideally placed to use solar energy. The system chosen includes batteries to provide electricity in hours of darkness, which can be charged also from local mains electricity or the site generator.

Water is a limited resource and so, solar power was used to pump ground water to a tank on the northern boundary of the site. The water distribution network then supplied the school, reusing some water for irrigation of planted areas to supplement the low rainfall of the area.

Solid granite blocks used for the outer wall came from stone found on or adjacent to the site. Inner walls were made from local mud brick, forming cavity walls for significantly improved insulation and high durability. The roof is of a traditional Ladakh mud and timber construction, including poplar and willow from local monastery plantation.

By supporting the heavy roof on a structure that is independent of the walls, Arup's design team made sure that the school was built to the Indian seismic code.

Durability, flexibility and earthquake soundness are central aspects that govern structural design in this highly seismic zone. Ladakh is classified in seismic zone IV, the second highest category of the Indian Building Code. Although there have been no major earthquakes in the area in recent times, Ladakh has frequent tremors. The disasters caused by the Gujarat (2001) and the Pakistan (2005) earthquakes showed the lack of well-engineered earthquake-resistant buildings in India and Pakistan and the devastation that can result, so that a strong seismic strategy was developed for the Druk White Lotus School. The building structures use timber frames to resist the seismic loads and ensure life safety in the event of an earthquake. Traditional Ladakhi buildings are not engineered for seismic design, but with the application of some simple structural principles and details, a huge improvement in earthquake safety can be achieved. One of the aims of the project is to act as an educational tool in the appropriate application of seismic design to traditional construction techniques. Thus, all structural solutions such as steel plates for the beam-column connection and cross bracing cables are exposed, revealing the simple yet effective solutions adopted.

All buildings have cavity walls on three sides. Granite blocks set in mud mortar are used for the outer leaf, while traditional mud-brick masonry is used for the inner leaf. This gives increased thermal performance and durability compared to the locally rendered mud-brick walls. The Ladakhi-style heavy mud and straw roof is used and is supported by a timber structure that is independent of the walls. Steel connections and cross bracings provide earthquake stability. Despite the complexity of the structural analysis, the design has been translated into simple solutions that have been easily understood by the local craftsmen, and construction made within the constraints given by local materials and techniques (http://www.arupassociates.com/en/news/druk-white-lotus-school-mud-slide-defenses/).

Bibliography

Anderson, A. and Shiers, D. (2002) *The Green Guide to Specification*, Third edn, Wiley-Blackwell.

Anderson, A., Shiers, D. and Steele, K. (2009) *The Green Guide to Specification*, Fouth edn, Wiley-Blackwell. http://eu.wiley.com/WileyCDA/WileyTitle/productCd-1405119616.html (accessed 14 June 2017).

Anderson, J., Thornback, J., Construction Products Association (2012) pp. 53, Report in pdf form available at http://www.c-a-b.org.uk/wp-content/uploads/Guide_understanding_the_embodied_impacts_of_construction_products.pdf (accessed 14 June 2017).

Carter, B. (ed.) (2006) *Building Culture: Druk White Lotus School: A Sustainable Model for Education + Design*, School of Architecture and Planning, University of Buffalo, State University of New York in Buffalo, New York.

http://www.dwls.org/ (accessed 14 June 2017).

http://www.dwls.org/sustainability.html (accessed 14 June 2017).

Intelligent Buildings International (2009) piece: http://www.academia.edu/2506608/Druk_White_Lotus_School_Ladakh_India (accessed 14 June 2017).

The Construction Products Association (2012), *A Guide to Understanding the Embodied Impacts of Construction Products*. http://www.c-a-b.org.uk/wp-content/uploads/

Guide_understanding_the_embodied_impacts_of_construction_products.pdf (accessed 14 June 2017).
UK Green Building Council (UKGBC) (2016) *Key Statistics and Carbon Emissions data sheet*, available at: http://www.ukgbc.org/resources/additional/key-statistics-construction-industry-and-carbon-emissions (accessed 14 June 2017).

Conclusions

This book does not claim to provide the reader with the definitive guide to achieving integrated, sustainable development; nor can it explain how to design and build with zero negative environmental impacts. However, a number of common principles run through the projects presented here which, if applied, may at least be helpful in delivering a lower carbon-built environment where the potential negative effects of schemes can be *minimised*.

After studying the projects described in this book, the editors have reached three important conclusions about designing excellent buildings which are also sustainable:

- Although identifying and analysing the objectives and constraints of a project in detail can involve much time-consuming research and consultation, these efforts ensure that integrated, achievable solutions are delivered which address the functional, economic, aesthetic, social and environmental needs of users and the wider community.
- All relevant design decisions should be considered together by a collaborative team consisting of like-minded specialists as 'only the intimate integration…of disciplines will produce the desired result.'
- Designers and engineers should see themselves first and foremost as facilitators, helping to achieve the aspirations of stakeholders and the society. It is perhaps in the humility of the enabler that the spirit of Sir Ove Arup most clearly endures.

Appendix A

The Arup Story

From *Engineering Timelines*:

http://www.engineering-timelines.com/timelines.asp
http://www.engineering-timelines.com/who/arup_O/arupOve.asp
http://www.engineering-timelines.com/who/arup_O/arupOve12.asp
https://prezi.com/k9ab2jlvjfuc/copy-of-copy-of-contemporary-engineering-at-the-edge/

Early career of Ove Arup

1922–1923	Working for Christiani & Nielsen, Hamburg office
1923	Moves to London office of Cristiani & Nielsen as chief designer
1932–1933	**Labworth Café**: Architect: Ove Arup

Labworth Cafe, Essex, UK Architect: Image courtesy of Arup Associates

1933	**Gorilla House, London Zoo**. Architect: Berthold Lubetkin, Tecton
1934–1938	Director and chief designer at J.L. Kier & Co

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

1934–1935	**Highpoint I.** Architect: Berthold Lubetkin, Tecton

Highpoint I, London, UK Architect: Image courtesy of Berthold Lubetkin, Tecton, Engineering timelines

Penguin Pool, London Zoo, UK Architect: Berthold Lubetkin, Tecton Photo: Image courtesy of Jane Joyce, Engineering timelines

1935	**Working-class residential flats**. competition win
1937	**Finsbury Housing Projects**
1937–1938	**Highpoint II**. Architect: Berthold Lubetkin, Tecton

Arup & Arup Ltd

1938	Sets up Arup & Arup Ltd with Arne Arup, his cousin
1938	**Finsbury Health Centre**. Architect: Berthold Lubetkin, Tecton
1943–1944	**Mulberry Harbour pierhead fendering** with Ronald Jenkins
1944	**Arcon prefabricated housing.** Steel frame design
1945–1951	**Brynmawr Rubber Factory**. Architect: Architect's co-partnership
1946	April 1st, Arup & Arup Ltd dissolved

Ove N. Arup consulting engineers

1946	April 1st–6th, Ove N. Arup Consulting Engineers established
1946	**Bus Station and Office, Dublin**. Architect: Michael Scott

Ove Arup & partners

1949	Ove Arup & Partners established. Partners: Ove Arup, Ronald Jenkins, Geoffrey Wood, Andrew Young
1949–1954	**Hunstanton Secondary Modern School**. Architect: Alison and Peter Smithson
1951	**Festival of Britain footbridge**
1951	**Aero Research factory, Duxford**
1951–1956	**Bank of England Printing Works**. Architect: Easton & Robertson
1953	Ove Aup awarded CBE
1955	Ove Arup & Partners West Africa, and Ove Arup & Partners South Africa established
1956	**Hallfield Primary School**. Architect: Drake & Lasdun
1956–1962	**Coventry Cathedral**. Architect: Sir Basil Spence

(Photo: The Editors)

Coventry Cathedral
A vast but thin-skinned concrete roof structure supported by slender, tapering concrete columns whose bases are audaciously detailed where they meet the cathedral floor (http://www.claisse.info/structures.htm)

1957 — **TUC Congress Memorial Building**. Architect: David du R. Aberdeen

1957–1973 — **Sydney Opera House**. Architect: Jørn Utzon

(Photo: Julian Evans)

The Sydney Opera House
A performing arts centre which stages 1500 productions each year, attended by 1.2 million people. It is also a UNESCO World Heritage site visited by over 7 million people annually.

Though certainly not without its dramas, the history of the project illustrates what can be achieved by the successful collaboration of Architect and Engineer (http://www.engineering-timelines.com/who/arup_O/arupOve8.asp)

1959 — Ove Arup & Partners Rhodesia established

1959–1960 — **St James' Place, London**. Architect: Sir Denys Lasdun

1960 — Ove Arup & Partners Scotland established

1960–1964 — **Royal College of Physicians**. Architect: Sir Denys Lasdun

Royal College of Physicians, London
Architect: Sir Denys Lasdun
Photo: Image courtesy of Arup Associates

1960–1964 — **St Catherine's College, Oxford**. Architect: Arne Jacobson

1961–1963 **Kingsgate footbridge**

1961–1963 **Smithfield Poultry Market**. Architect: T.P. Bennet & Son

1962 **Falmer House, University of Sussex**. Architect: Sir Basil Spence

1963 Arup Associates established as an architectural practice

1963 Ove Arup & Partners Ireland, and Ove Arup & Partners Sierra Leone established

1964 Ove Arup & Partners Australia established

1965 Ove Arup & Partners Nigeria, and Ove Arup & Partners Ghana established, West Africa dissolved

1965–1970 **Snape Maltings Concert Hall**. Architect: Arup

1966 Ove Arup awarded RIBA Gold Medal for Architecture

1966 Ove Arup & Partners Zambia, and Ove Arup & Partners Malaysia established

1966	UK partnership reformed as Ove Arup & Partners Consulting Engineers and Arup Associates
1966	Ove Arup awarded IStructE Maitland Medal
1967–1972	**York Minster** central tower underpinning

York Minster Central Tower Underpinning, York, UK
(Photo: Image courtesy of Arup Associates)

1968	Ove Arup & Partners Jamaica established
1969	Philip Dowson appointed partner
1970	Ove Arup knighted for services to architecture and engineering
1970	Ove Arup Partnership becomes parent firm to Ove Arup & Partners and Arup Associates
1970	Ove Arup & Partners Singapore established
1971–1977	**Centre Georges Pompidou**, Paris. Architects: Rogers & Piano

The work of Arup engineers such as Peter Rice who worked on the Pompidou Centre, embodies many of the values of the Arup philosophy. Not solely concerned with achieving functionality in the structure, he regarded an engaging, legible and comprehensible structural system as key to making a connection with the people who would use this very public building.

Comprehensibility would mean *accessibility*. For Rice, evidence of the involvement of the creative individual in the structural design of a building was important, as this gave the building a personality which a more mechanistic approach to structure would not. (Image courtesy of Engineering timelines)

1973	Ove Arup awarded IStructE Gold Medal
1977	Ove Aup Partnership reconstituted, trust ownership established
1978–1985	**Lloyds of London HQ.** Architect: Richard Rogers Partnership
1979–1986	**Hong Kong & Shanghai Bank HQ.** Architect: Foster and Partners
1980	Arup Acoustics established
1981	Broadgate development, London

Broadgate, London

1982

No. 1 Finsbury Avenue, Broadgate
Note the use of solar shading

1985–1991

Gateway 2, Offices and Business Park

Gateway 2 – Wiggins Teape Building, Basingstoke, UK
An innovative, naturally ventilated building in a landscaped business park environment

Stansted Airport, Main Terminal.
Architect: Foster and Partners

Stansted Airport Main Terminal, UK
Architect: Foster and Partners Photo: Image courtesy of Arup Associates

1986

Ove Arup elected Honorary Royal Academician

1988	February 5th Ove Arup dies
1989	The Ove Arup Foundation established

Later notable Arup projects

1990–1994	**Kansai International Airport terminal building**, Osaka Bay, Japan. Architect: Renzo Piano Building Workshop
1992	Ove Arup Partnership becomes a company owned in trust for the benefit of employees
1996–2000	**Øresund Bridge** linking Sweden and Denmark
1997–2004	**30 St Mary Axe (Swiss Re)**. Architect: Foster and Partners
1998–2002	**Millennium Bridge, London**. Architect: Foster and Partners
1999	Ove Arup Partnership becomes a limited company
1999–2001	**National Museum of Australia, Canberra**. Architect: Howard Raggatt, ARM
1999–2007	**Terminal 4, JFK Airport, New York.** Architect: Skidmore, Owings & Merrill
2000	The name 'Arup' adopted for the whole group
2002	The Etihad Stadium, Manchester

The Etihad Stadium, Manchester

2004/2005	Plantation Place, London

2012 Kings Cross Station, London

Kings Cross Station, London

A £400 mn development and restoration project in central London

See video on lighting design: http://www.arup.com/projects/kings_cross_station#!lb:/projects/kings_cross_station/kings_cross

Appendix B

Arup Guidance Note on GLA Requirements for Renewables

Gives the following guidance for determining planning applications: 'Local planning authorities should expect new development to:

- comply with adopted Local Plan policies on local requirements for decentralised energy supply unless it can be demonstrated by the applicant, having regard to the type of development involved and its design, that this is not feasible or viable; and
- take account of landform, layout, building orientation, massing and landscaping to minimise energy consumption'.

Finally, paragraph 97 states: 'To help increase the use and supply of renewable and low carbon energy, local planning authorities should recognise the responsibility of all communities to contribute to energy generation from renewable or low carbon sources. They should: …identify opportunities where development can draw its energy supply from decentralised, renewable or low carbon energy supply systems and for co-locating potential heat customers and suppliers'.

In London, the **Greater London Authority – Mayor of London Sustainable Design and Construction Supplementary Planning Guidance (2014) and London Plan** *(italics = best practice)* states that the overall carbon dioxide emissions from a development should be minimised through the implementation of the energy hierarchy lean > clean > green set out in London Plan policy 5.2. and that Developments should be designed to meet the following Regulated carbon dioxide standards, in line with London Plan policy 5.2.

Non-domestic buildings

Year	Improvements beyond 2010 Building Regulations
1st October 2013–2016	40%
2016–2019	As per the Building Regulation requirements
2019–2031	Zero carbon

This policy also states that 'To avoid complexity and extra costs for developers, the Mayor will adopt a flat carbon dioxide improvement target beyond **Part L 2013 of 35%** to both residential and non-residential development' and that:

'Where a planning application includes **refurbishment or retrofitting** works for a major development, applicants should submit energy strategies which follow the energy

Sustainable Building Design: Principles and Practice, First Edition. Edited by Miles Keeping and David Shiers.

hierarchy and demonstrate appropriate reductions in carbon dioxide emissions. Whilst the targets in policy 5.2 apply to major developments, it is acknowledged that for many schemes involving existing buildings, it will be a challenge to meet these targets, except perhaps where a development can connect to a low or zero carbon energy source.

- *Developments should contribute to ensuring resilient energy infrastructure and a reliable energy supply, including from local low and zero carbon sources.*
- *Developers are encouraged to include innovative low and zero carbon technologies to minimise carbon dioxide emissions within developments and keep up to date with rapidly improving technologies.*
- Development applications are to be accompanied by an energy demand assessment.
- The design of developments should prioritise passive measures.
- *Developers should aim to achieve Part L 2013 Building Regulations requirements through design and energy efficiency alone, as far as is practical.*
- Where borough heat maps have identified district heating opportunities, boroughs should prepare more detailed Energy Master Plans (EMPs) to establish the extent of market competitive district heating networks.
- Developers should assess the potential for their development to:
  - connect to an existing district heating or cooling network;
  - expand an existing district heating or cooling network, and connect to it; or
  - establish a site wide network, and enable the connection.
- Where opportunities arise, developers generating energy or waste heat should maximise long term carbon dioxide savings by feeding the decentralised energy network with low or zero carbon hot, and where required, cold water.

- 2.5 Renewable energy
  - Boroughs and neighbourhoods should identify opportunities for the installation of renewable energy technologies in their boroughs and neighbourhoods.
  - Major developments should incorporate renewable energy technologies to minimise overall carbon dioxide emissions, where feasible.
- 2.5 Carbon Offset
  - Boroughs should establish a carbon off-set fund and identify suitable projects to be funded.
  - Where developments do not achieve the Mayor's carbon dioxide reduction targets set out in London Plan policy 5.2, the developer should make a contribution to the local borough's carbon dioxide off-setting fund.
- 2.5 Retrofitting
  - Boroughs should set out policies to encourage the retrofitting of carbon dioxide and water saving measures in their borough.
  - Where works to existing developments are proposed, developers should retrofit carbon dioxide and water saving measures.
- 2.5 Monitor Energy Use
  - *Developers are encouraged to incorporate monitoring equipment and systems where appropriate to enable occupiers to monitor and reduce their energy use.*
- 2.5 Supporting resilient energy supply
  - *Developers are encouraged to incorporate equipment that would enable their schemes to participate in demand side response opportunities.'*

In the **City of London**, the CS15 Sustainable Development and Climate Change guidance sets out policies:

- To enable City businesses and residents to make sustainable choices in their daily activities creating a more sustainable City, adapted to the changing climate.
- Requiring all redevelopment proposals to demonstrate the highest feasible and viable sustainability standards in the design, construction, operation and 'end of life' phases of development.
- Whereby proposals for major development should aim to achieve a BREEAM rating of 'excellent' or 'outstanding'.
- Requiring development to minimise carbon emissions and contribute to a City-wide reduction in emissions.
  - adopting energy-efficiency measures;
  - enabling the use of decentralised energy, including the safeguarded Citigen CHP network, CHP-ready designs in areas where CCHP networks are not yet available, and localised renewable energy technologies;
  - adopting offsetting measures to achieve the Government's zero carbon targets for buildings.
- Avoiding demolition through the re-use of existing buildings or their main structures, and minimizing the disruption to businesses and residents.

- Under DM15.1 Sustainability requirements:
  - Sustainability Statements must be submitted with all planning applications in order to ensure that sustainability is integrated into designs for all development. For major development (including new development and refurbishment) the Sustainability Statement should include as a minimum:
    - BREEAM or Code for Sustainable Homes pre-assessment;
    - an energy statement in line with London Plan requirements;
    - demonstration of climate change resilience measures.
  - BREEAM, Code for Sustainable Homes and/or Housing Quality Mark assessments should demonstrate sustainability in aspects which are of particular significance in the City's high density urban environment. Developers should aim to achieve the maximum possible credits to address the City's priorities.
  - Innovative sustainability solutions will be encouraged to ensure that the City's buildings remain at the forefront of sustainable building design. Details should be included in the Sustainability Statement.
  - Planning conditions will be used to ensure that Local Plan assessment targets are met.
- DM15.2 Energy and CO_2 emission assessments:
  - Development design must take account of location, building orientation, internal layouts and landscaping to reduce likely energy consumption.
  - For all major developments, energy assessments must be submitted with the application.
- DM15.3 Low and zero carbon technologies:
  - For development with a peak heat demand of 100 kW or more, developers should investigate the feasibility and viability of connecting to existing decentralised energy networks. This should include investigation of the potential for extensions

of existing heating and cooling networks to serve the development and development of new networks where networks are not available. Connection routes should be designed into the development where feasible and connection infrastructure should be incorporated wherever it is viable.
  - Where connection to offsite decentralised energy networks is not feasible, installation of on-site CCHP and the potential to create new localised decentralised energy infrastructure through the export of excess heat must be considered.
  - Where connection is not feasible or viable, all development with a peak heat demand of 100 kW or more should be designed to enable connection to potential future decentralised energy networks.
  - Other low and zero carbon technologies must be evaluated. Non-combustion-based technologies should be prioritised in order to avoid adverse impacts on air quality.
- DM15.4 Offsetting of carbon emissions:
  - All feasible and viable on-site or near-site options for carbon emission reduction must be applied before consideration of offsetting. Any remaining carbon emissions calculated for the lifetime of the building that cannot be mitigated onsite, will need to be offset using 'allowable solutions'.
  - Where carbon targets cannot be met on-site, the City Corporation will require carbon abatement elsewhere or a financial contribution, negotiated through an S106 planning obligation to be made to an approved carbon offsetting scheme.
  - Offsetting may also be applied to other resources including water resources and rainwater run-off to meet sustainability targets off-site where on-site compliance is not feasible.

The clear message from these policy initiatives is that in the foreseeable future, building energy requirements must be met from sources which are not wholly reliant on a fossil-fuelled national Grid but should utilise energy derived from renewable sources to include, if possible, a proportion which is generated locally.

Background; Policies and Legislation

EUROPEAN UNION: EU Climate Change Package

- The EU's climate and energy policy sets the following targets for 2020:
  - A 20% reduction in EU greenhouse gas emissions from 1990 levels;
  - Raising the share of EU energy consumption produced from renewable resources to 20%;
  - A 20% improvement in the EU's energy efficiency.

NATIONAL: Climate Change Act 2008

- The Climate Change Act sets legally binding greenhouse gas emission reduction targets of at least 80% by 2050 (with an interim target of 26% by 2020) against a 1990 baseline, which are to be achieved through action taken in the UK and abroad.

NATIONAL: The National Planning Policy Framework (NPPF)

- The National Planning Policy Framework (NPPF) was published in March 2012. It is intended to replace various existing Planning Policy guidance documents so as to make the planning system less complex and more accessible. Key sections from the NPPF are:

- Paragraph 95, which states that: 'To support the move to a low carbon future, local planning authorities should …when setting any local requirement for a building's sustainability, do so in a way consistent with the Government's zero carbon buildings policy and adopt nationally described standards'.

Appendix C

Arup Team Members

The Arup teams working on the projects described in this book included the following people:

Michael Beaven is a Director of Arup Associates in London and leads environmental and building services engineering in Arup Associates. He was lead environmental and building services director for Ropemaker Place.
Mick Brundle was a Director of Arup Associates in London. He was architectural director for Ropemaker Place.
David Pearce is an environmental services engineer and was part of the BskyB Studio team.
Ann Marie Aguilar joined Arup Associates in 2006 as a Sustainability Design Specialist. Her focus at Arup Associates is on improving human experience in the built environment and the opportunities to instill 'Wellness in the Workplace'.
Paul Dickenson is an Associate Director of Arup Associates in London and a design manager in the practice. He was Arup Associates project manager for Ropemaker Place.
Robert Pugh is an Associate Director of Arup Associates in London and leads structural engineering in Arup Associates. He was lead structural director for Ropemaker Place.
Malcolm Smith is a Director and Global Leader of Master Planning and Urban Design at Arup. He has recently been made an Arup Fellow.
Francesca Galeazzi is a Sustainability Specialist based in Shanghai as a design-team member at Arup Associates, an international, multi-disciplinary organization devoted to pioneering innovative, sustainable design. She was instrumental in the development of the Druk White Lotus School in Ladakh, India.
Mark Fisher is an architect at Arup Associates.

Other team members:

Andrew Allsop, Gert Andresen, Simon Anson, Jake Armitage, Jenny Austin, Chris Bryant, Alan Burge, Gary Burnap, Melissa Burton, Jonathan Chew, Kenny Chong, Carl Collins, Peter Connell, Sarah Crabtree, Sho Das-Munshi, Philip De Neumann, James Devine, Tarun Devlia, Philip Dixon, Rory Donald, John Edgar, Mike Edwards, Shu-Lei Fan, Geoff Farnham, Martin Finch, Pietro Franconiero, Holly Galbraith, Andrew Gardiner, Marjan Gholamalipour, Sarah Glover, Maureen Godbold, Wendy Grant, Tony Greenstock, Andy Harrison, Neil Hitchen, Tony Hoban, Tom Honeyman,

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Architects Colour Consultant for façades: Antoni Malinowski.

Index

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