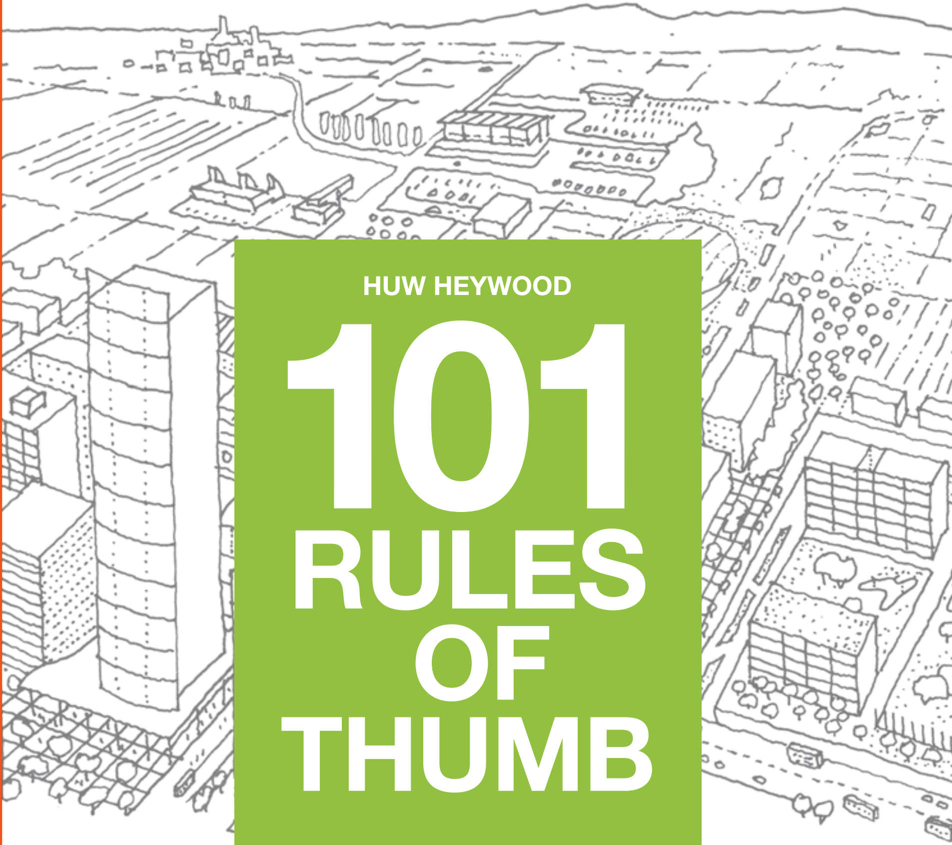
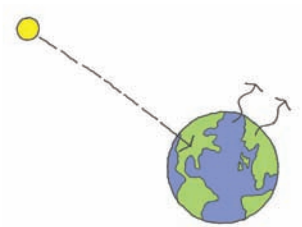


HUW HEYWOOD

101 RULES OF THUMB

For Sustainable Buildings and Cities



RIBA Publishing

101 RULES OF THUMB

For Sustainable Buildings and Cities

Following the success of its enormously popular predecessor (*101 Rules of Thumb for Low Energy Architecture*) the next title in this pithy series now focuses our attention on the bigger picture in sustainability: the overarching design of our buildings and cities.

With ever-increasing pressure on the planet's ecosystems, resulting from population growth, urbanisation and climate change, people across the world are becoming more aware of the need for the cities they live and work in to be sustainable. Yet the issue of how to be sustainable – and what sustainability actually means – can seem a confusing and complex one.

Fortunately, here is a book to shed light on this complex area. Providing both definition and guidance, these 101 rules illustrate an approach to sustainability that relates to the processes which are commonly adopted for the design, construction and operation of buildings and cities. Universally applicable no matter where you are in the world, the rules serve as an ideal starting point for students as well as an aide-memoire for more experienced readers and practitioners.

All illustrations by Huw Heywood assisted by James Scrace

101 RULES OF THUMB

For Sustainable Buildings and Cities

I wish to thank all the professional and academic reviewers of the manuscript, whose views and comments have helped to keep the focus of the book sharp. They include: Sofie Pelsmakers, Lynne Sullivan, Roddy Langmuir, Brian Edwards and James Warne, all of whom gave their highly respected professional expertise so willingly. I am grateful to Dr Bill Davies and Dr Nick Koor for their specialist input, and to RIBA Publishing for their continuing support of the series. A special thanks goes to James Scrace for applying his visual, technical and organisational skills in the making of the book. Once again I am indebted to Betty for her patience and support.

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HUW HEYWOOD

101 RULES OF THUMB

For Sustainable Buildings and Cities

CONTENTS

PREFACE

The first book in the 101 Rules of Thumb series concentrated on how to design low-energy-use buildings, which is just one subject within the much bigger picture of sustainable design. This second title focuses on that big picture.

As a species, we spend 90% of our time in buildings – and, since the year 2000, more of us now live in cities than in rural conditions. Entire new cities are emerging in the developing world, and mega-cities are forming as existing urban centres merge – all of which puts an increased pressure on the planet's ecosystems. As a result, people across the world are becoming more aware of the need to design, construct and manage a sustainable building stock.

Despite this, a lack of clear guidance for sustainable architecture and cites is regularly cited as a specific knowledge gap in industry and in education. In order to understand how to make buildings and cities sustainable, an interested person would have to digest a vast body of literature on a very wide range of subjects spanning the arts, science and technology, the social sciences and humanities – a daunting task for an author, let alone for most busy project leaders, professionals and design students.

The aim of these rules, therefore, is to draw on and interpret the essential themes of the key literature, representing them in one all-encompassing volume that enables readers to know where to start, what to focus on and what works.

INTRODUCTION, AND WHAT THE RULES OF THUMB ARE FOR

Since its birth 4.5 billion years ago, our planet has survived much more than we humans have thrown at it (and removed from it) in the last mere 200,000 years. Geologically speaking, we now live in the Holocene epoch – an era that began around 11,700 years ago, and which has witnessed both the development of civilisations and the dawn of cities. The emerging message is that it is not the fragility of the planet but rather the risk we pose to ourselves, our vulnerability resulting from our own actions in the environment, which results in the need for sustainable thought and action. Sustainability is a large, complex topic, but at its heart is the simple truth that everything we humans need to survive and thrive is provided by the natural world, meaning that we must find a productive balance with nature if we are to endure. In a sense, this book is about the global concerns of ecosystem destruction, species loss, climate change, food and energy supply, pollution and waste which dominate sustainability literature, but it does not dwell on the negative: the rules of thumb seek to provide a positive framework for good decisions.

The multidimensional nature of sustainability represents both its attraction and its difficulty. Phrases that we have become used to, and which are often used interchangeably, include ‘ecological’, ‘green’, ‘environmental’, ‘eco-friendly’ and ‘bioclimatic design’, and we often hear buildings and cities described as ‘environmentally sustainable’. But a building or a city could be designed with strong environmental/ecological credentials (eg, achieving low energy use, incorporating sustainable resources, addressing human comfort) but still be unsustainable because it is rejected by society, generates waste and pollution, is too complex to operate or too costly to run. To design sustainable built environments we need to be constantly and holistically mindful of the people we are designing for (now and into the future), of the places in which we are designing and of the nature of our planet. In this way, those with a passion to create beautiful and enduring buildings and spaces will be the ones who find innovative and lasting solutions for the way we live with our planet. The rules of thumb are for those who wish to take seriously their ethical responsibility to commission, design, operate and inhabit our current and future buildings and cities sustainably.

This book is structured in five chapters illustrated with diagrams, as was the first book in the series. Chapters 1 to 4 set out the rules of thumb and Chapter 5 shows how those rules might be applied strategically, and does so within the context of an important emerging idea: that we should not simply be seeking to do less harm but rather pursuing positive outcomes for the environment, for ecosystems and for people. The illustrated rules of thumb in Chapters 1 to 5 are, if you like, the book; a picture is, after all, worth a thousand words. Then, a narrative bibliography explains the book, providing the background research and references to key texts, as well as ideas for further sources of information and this author’s commentary.

As sustainability is an ever-evolving, trans-disciplinary subject encompassing a hugely diverse range of ideas and topics, the reader will find in the following chapters reference to the chemistry and ecology of building materials, the study of soundscape, the habits of owls, biomimetics, social justice and equity, the earth sciences, human physiology (how humans work), building physics (how buildings work), urban climatology, hydrology, health, the processes of design and urban agriculture, to name just a few.

Nonetheless, the subjects that sit under the umberella of sustainability are all connected, and this is reflected in the attempt to show, via cross-referencing at the end of each rule, where particulatly strong links exist. It is hoped that the reader finds this a useful device because, in the true spirit of sustainable thinking, it emerges that in fact a powerful connection exists between each and every one of the rules of thumb presented in the following pages.

CHAPTER 1
THE PRINCIPLES OF SUSTAINABILITY

- The nature of sustainability
- The welfare of future generations
- Creating sustainable environments
- Climate change

1. THERE'S ONLY ONE PLANET EARTH

There is only one earth, and its ability to support an ever-increasing human population is limited. Based on today's rate of consumption, we need one and a half earths to provide all our resources and to absorb our waste and CO_2. We are treating the planet like an overdrawn bank account. At this rate, by 2050 we would need the support of three earths, which we do not have. There is an ethical duty to design the built environment to operate within the planet's means, and to a minimum ecological footprint.

Links with all other Rules

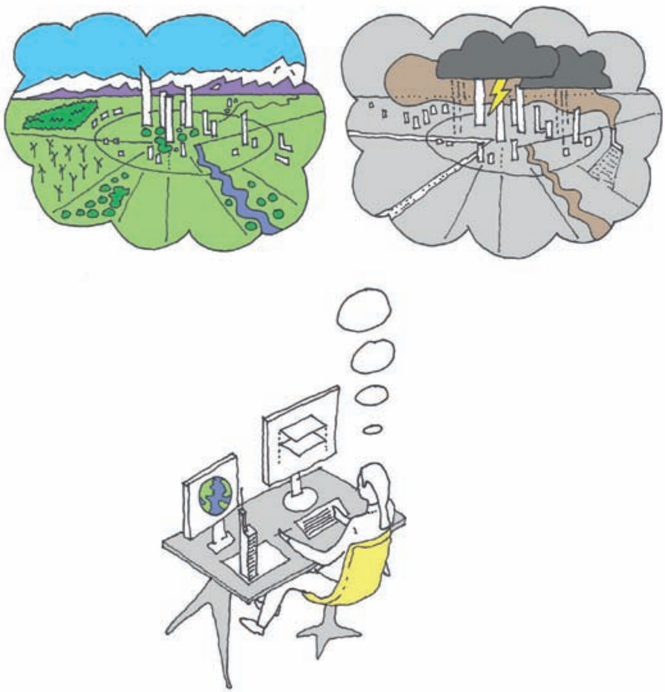
RULE 1

2. SUSTAINABILITY MEANS THINKING ABOUT TOMORROW TODAY

Our decisions and actions as designers today will have an impact on the planet for future generations. The designer's goal is the improved long-term quality of both human life and of supporting ecosystems. Make all decisions with future generations in mind.

Links with rules 1, 12, 15, 19, 20, 22, 37, 45, 54, 69, 76

RULE 2

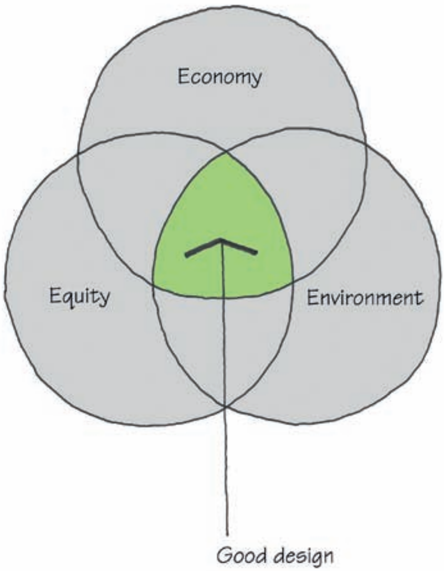


3. ECONOMY, EQUITY, ENVIRONMENT: THE THREE PILLARS OF SUSTAINABILITY

These three pillars of sustainability are known as the ‘three Es’. All of society benefits from buildings that are affordable to procure and functional to operate, now and into the future. Society must need and want development for it to be inclusive, it must have cultural and historical relevance and it must be joyful and useful to all. And because good design is enduring, it always seeks to protect and enhance the environment and its ecosystems.

Links with rules 1, 5, 7, 8, 45, 75, 83, 94

RULE 3



4. SUSTAINABLE DESIGN IS A METHOD, NOT A STYLE

Buildings and cities will only be sustainable if we set out intentionally to make them so, and this requires an interdisciplinary understanding of the economic, social, environmental and technical issues to be applied from the outset. Once a building has been designed, it is too late to make it sustainable: bolt-on features and gadgets that contribute little or nothing of environmental value are known as ‘eco-bling’, and they are often merely boastful. Set out to make buildings sustainable, or else they will not be.

Links with rules 1, 5, 6, 45, 89, 95

RULE 4

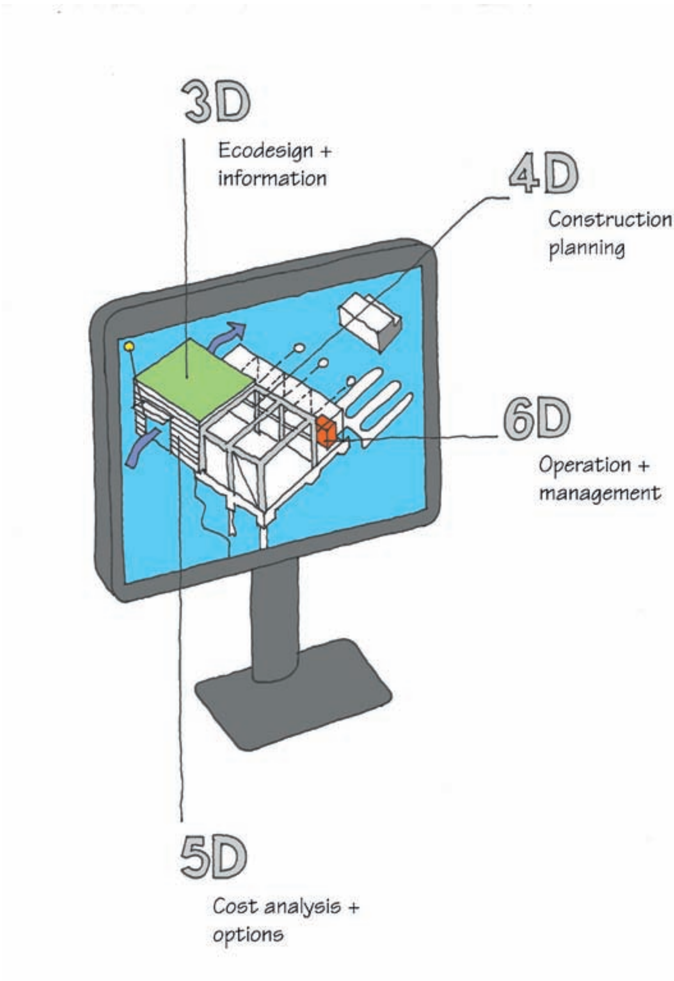
Sustainability or eco-bling?

5. SUSTAINABLE DESIGN IS 6-DIMENSIONAL

A sustainable building is holistic, conceived with its whole life in mind. The effectiveness of its environmental design qualities, as well as its environmental impacts, can be examined during the design stages. This is possible because traditional 2D drawings have become intelligent 3D virtual models, in which time is the 4th dimension and the lifetime cost of our decisions is the 5th. In a 6D model, the as-built project information would become available to the owner in order to enable sustainable operation of the building. Innovate with the available tools, to create sustainable environments – design in six dimensions.

Links with rules 1, 3, 4, 6, 15, 23, 26, 33–37, 38, 42, 45, 69, 75

RULE 5


3D
Ecodesign + information
4D
Construction planning
6D
Operation + management
5D
Cost analysis + options

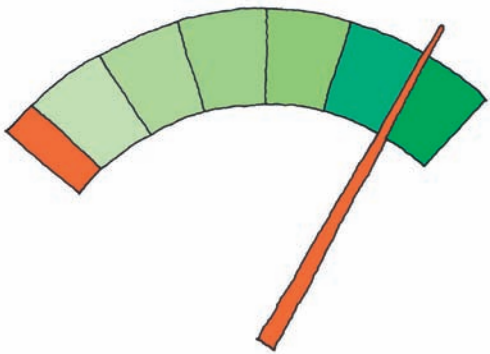
6. HOW ‘GREEN’ IS YOUR BUILDING?

‘Green’ means sustainable, but there are many shades of green. A ‘light-green’ building will target a few of these rules of thumb. A ‘deep-green’ building will successfully adopt most of them. Aim for the deepest green possible. A deep-green building will:

- Have a highly energy-efficient envelope
- Be a net producer of energy and a zero-carbon emitter
- Optimise use of resources and embodied energy
- Minimise water use and waste
- Be healthy and non-polluting
- Be long lasting, adaptable and easy to dismantle

Links with rules 1, 4, 5, 10, 11, 12, 19, 23, 26, 33–37, 38, 42, 45, 72, 73, 74

RULE 6

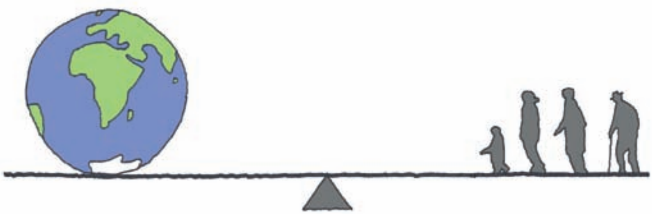


7. WHAT ON EARTH IS THE ENVIRONMENT?

The ancient Greeks did not have the word 'environment'. The word as we use it today is relatively new: coined during the Industrial Revolution, its meaning is linked to humankind's influence on the planet. To design with environmental sensitivity, we must first know what the environment is: it consists of all elements of the physical and biological world and the interrelationships between them.

Links with rules 1, 3, 8, 45

RULE 7



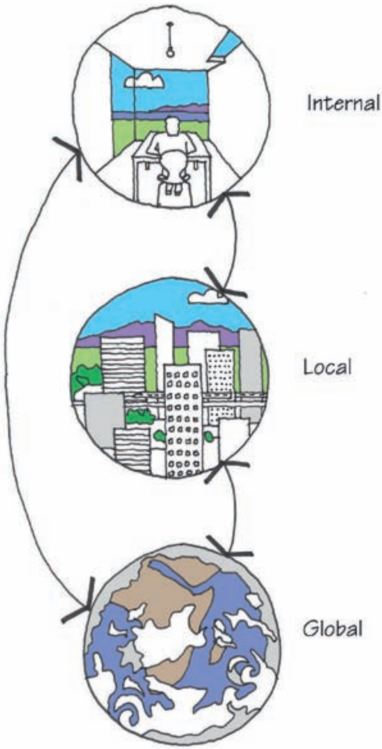
Air, water, land,
natural resources,
flora, fauna, humans

8. THERE ARE DIFFERENT SCALES OF ENVIRONMENT

The environment in which we live constitutes not only our immediate surroundings; it is important to remember that it exists simultaneously at a global, local and a building-interior scale. Designers and occupiers of buildings and cities operate in each of the scales of the environment at all times.

Links with rules 1, 3, 7, 9, 45

RULE 8

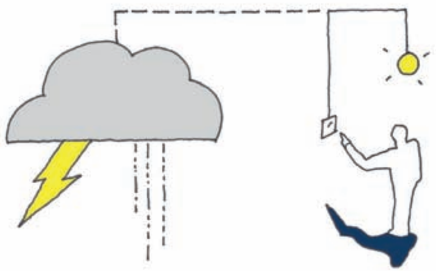


9. WHAT YOU DO LOCALLY HAS AN EFFECT GLOBALLY

If we design a dwelling, we might think we are chiefly concerned with the building's interior environment, as well as interaction with the immediate local environment. But heating or cooling may be needed, resulting in CO_2 emissions, contributing to global warming, affecting the global environment in a chain reaction. The scales of environment are connected: when someone simply switches on a light at home or at work they become a link in that global chain.

Links with rules 1, 8, 15, 45, 67

RULE 9



10. THE GREENEST BUILDING MAY BE THE ONE THAT ISN'T BUILT

We might have a choice about whether we build, restructure, share or change our lives in some way. Consider all options carefully in order to establish the one that best matches needs with environmental impacts. Sometimes the decision not to build a new building is the greenest one.

Links with rules 1, 6, 11, 12, 45

RULE 10

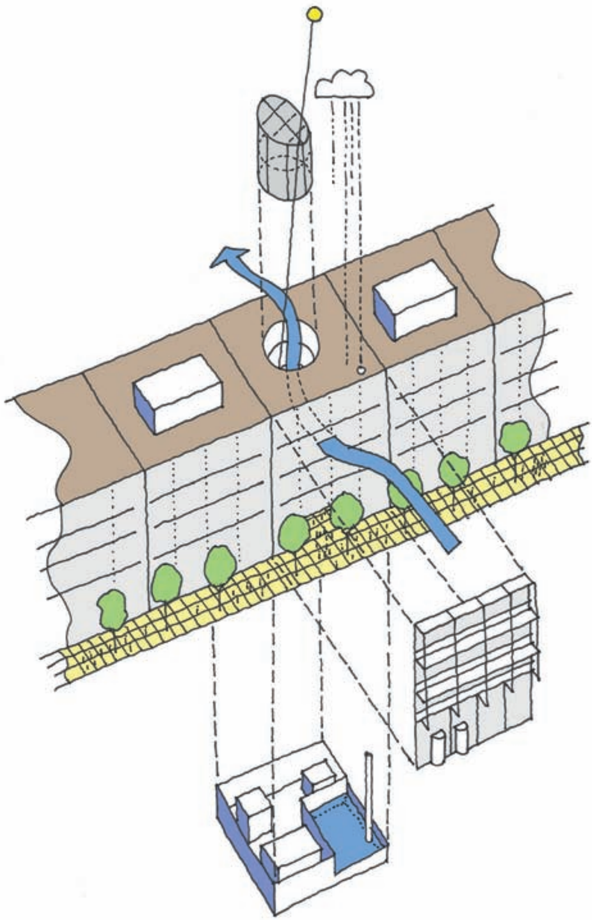

Scale down
Move
Flexible
Hardware
Telework
Open
Mobile
Borrow
Seasonal
Relocate
Re-use
Rationalise
Virtual
Restructure
Extend
Share
Decentralise
Re-think
Stay
Software
People
Downsize
Reorganise
Retrofit

11. THE GREENEST BUILDING MAY BE THE ONE THAT IS ALREADY BUILT

An existing building converted to a new use or upgraded in terms of energy technologies, insulation standards and ventilation performance may provide a healthy, low-energy-use, productive and high-quality spatial environment where one did not exist before, often cost-effectively. If operating energy can be significantly reduced, refurbishment is likely to be the lowest-carbon solution – and the retention of existing fabric can contribute to the quality of the public realm. Too many of our cities' buildings are empty too much of the time: seek innovative long-term, temporary or multiple uses for under-utilised buildings.

Links with rules 1, 6, 10, 24, 25, 38, 45, 76, 86

RULE 11



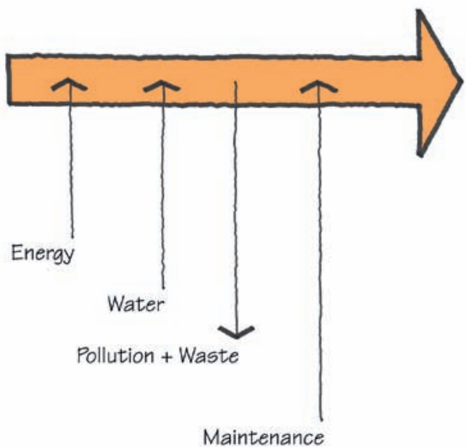
12. THE DECISION TO BUILD IS A LONG-LASTING ONE

It takes time to design and construct a sustainable building or city, but once complete the built environment will last much longer than those few years – perhaps 100 years or more in the case of a building. So the designer's early decisions are important, long-lasting ones with major environmental impacts during the operational phase of a building's life. Make sure you get them right by following the rules of thumb.

Links with rules 1, 2, 6, 10, 13, 19, 45, 69

RULE 12

The operation phase:

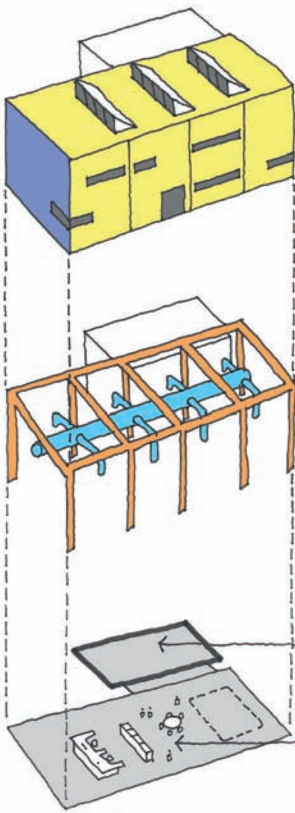


13. 'LONG LIFE, LOOSE FIT, LOW ENERGY'

This saying, a rallying cry for champions and designers of the built environment, has its prophetic origins just before the major world oil crisis of the early 1970s. Consider longevity, flexibility and energy efficiency as the cornerstones of a sustainable architecture. Remember that 'soft' elements and internal finishes will be replaced fairly regularly, services each 10–20 years, fabric elements each 20–30 years and major changes might occur every 30–75 years of a building's life. Each time they do, environmental and low-energy upgrades should also be made.

Links with rules 1, 12, 19, 26, 45, 69, 85

RULE 13



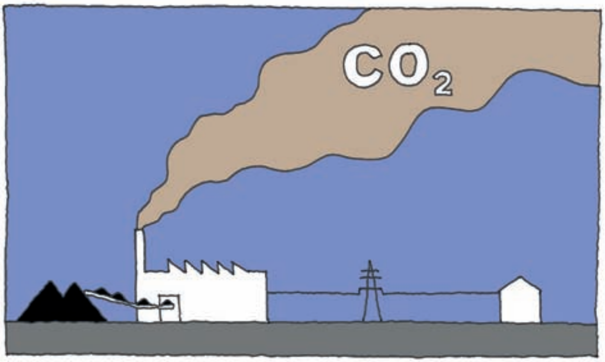
Envelope: robust, low energy, adaptable
Structure: allows spatial flexibility
Services: easily accessed and upgraded
'Hard' (fixed): stairs, lifts, WCs, plant rooms
'Soft' (movable): furniture, walls, equipment

14. TO REDUCE CO_2 EMISSIONS, REDUCE FOSSIL-FUEL USE

More than 80% of global energy demand is supplied from fossil fuels. Most of the rapid increase in the concentration of CO_2 in the earth's atmosphere took place due to industrialisation in the last 150 years, and half of CO_2 from human sources (anthropogenic, rather than natural CO_2) is not reabsorbed in the carbon cycle. As a 'greenhouse gas', it is linked with global warming and climate change. Around half of the UK's CO_2 emissions derive from the construction and operation of buildings.

Links with rules 1, 15, 16, 18, 26, 45, 55, 86

RULE 14



80% of energy is from fossil fuels

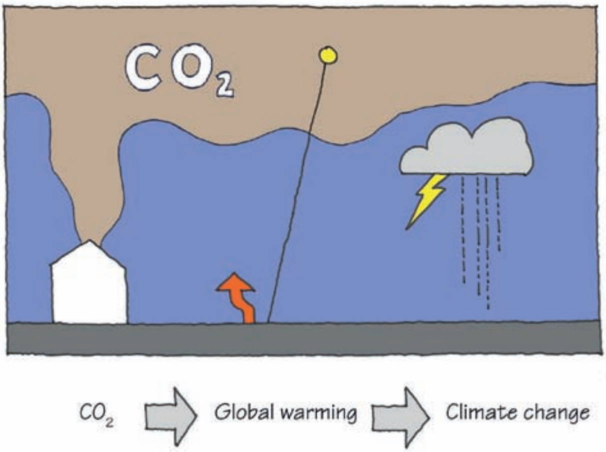
Buildings use 40% of all energy

15. BUILDINGS INFLUENCE GLOBAL WARMING

We use half of the world's energy to heat, cool, light, ventilate and power our buildings. Much of that energy is derived from fossil fuels, with the result that our buildings are responsible for 40% of all CO_2 emissions, contributing to global warming and climate change. We must cut the energy consumption of our buildings as part of the fight against global warming.

Links with rules 1, 2, 5, 9, 14, 16, 17, 25, 45, 85, 91

RULE 15

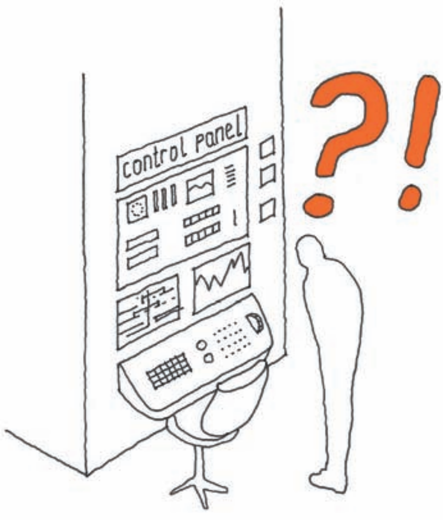


16. IN FACT, BUILDINGS DON'T USE ENERGY; PEOPLE DO

We often hear that buildings use around half of all global energy produced, but the occupants of a building have a major influence on its performance. A poorly designed building will use more energy than a well-designed, low-energy-use building whatever its occupants do, but enabling the user to know where energy is being used, and making it easy to control its use, are key to reduced energy consumption.

Links with rules 1, 14, 15, 24, 45, 67, 68

RULE 16

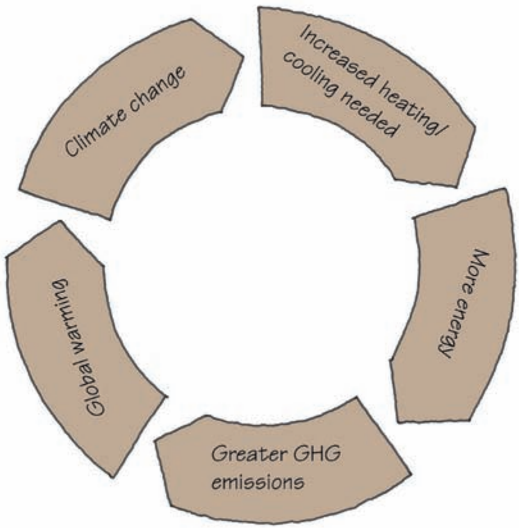


17. BREAK THE URBAN VICIOUS CYCLE

Since the year 2000, for the first time in the history of humanity more of us live in cities than live in rural locations. This trend will continue, increasing stresses on our urban environments, on people and on the planet. Cities produce 75% of the world's greenhouse gases, and global warming is likely to result in increased energy consumption: a vicious cycle results as unpredictable, extreme climate conditions lead to increased energy use, resulting in more greenhouse-gas (GHG) emissions, leading to further changes in climate. We must reduce emissions from our urban environments by intelligent planning and the retrofitting of transportation systems, utilities and buildings.

Links with rules 1, 15, 18, 45, 55, 58, 59, 80, 99

RULE 17

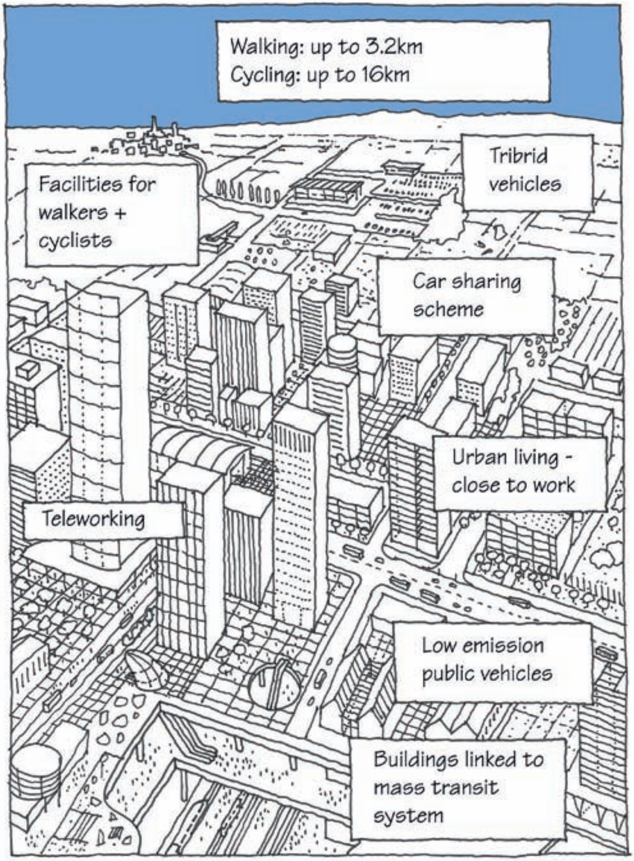

Increased heating/ cooling needed
More energy
Greater GHG emissions
Global warming
Climate change

18. SUSTAINABLE ENVIRONMENTS NEED SUSTAINABLE TRANSPORT

Buildings are responsible for half of all human-generated greenhouse gases, but half of the remainder derives from the transportation of people and products between buildings and within and around cities. An efficient public mass-transportation system linked with compact, mixed-use urban design reduces energy consumption, pollution and greenhouse-gas emissions. Good planning encourages walking and cycling – and working from home twice a month reduces emissions by 10%. For out-of-town developments, transport-generated carbon can be higher than that generated by the operation of buildings, so a sustainable transport system is imperative.

Links with rules 1, 14, 17, 45, 51, 77, 81, 83, 101

RULE 18



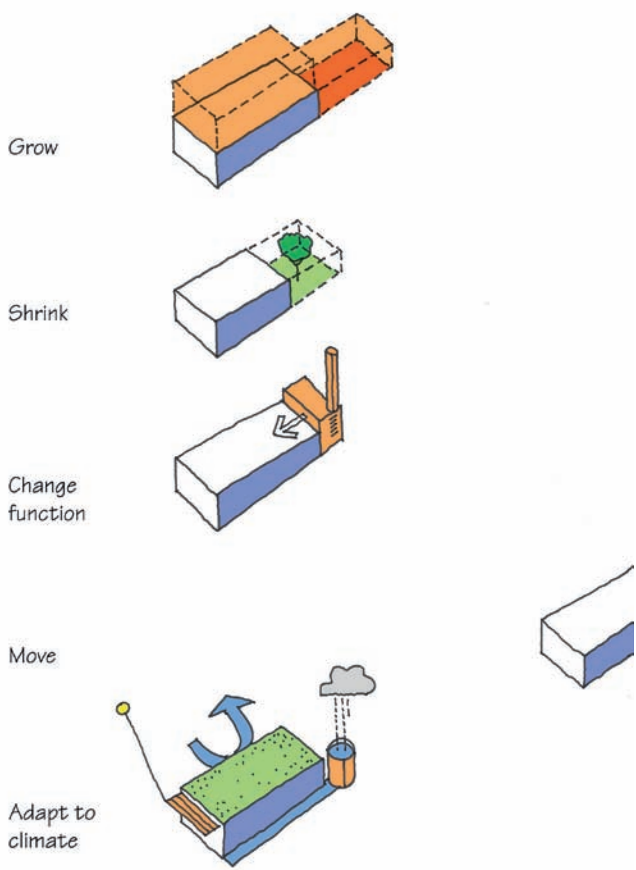
Walking: up to 3.2km
Cycling: up to 16km
Tribrid vehicles
Facilities for walkers + cyclists
Car sharing scheme
Urban living - close to work
Teleworking
Low emission public vehicles
Buildings linked to mass transit system

19. DESIGN FOR ADAPTABILITY

A building must be designed such that it can be adapted for future, unknown needs. Adaptability, built in at the outset, will enable future users to extend the building's life, take advantage of new technologies and modify its spaces, environments and structures to respond to changing requirements. Without adaptability, a building soon outlives its usefulness.

Links with rules 1, 2, 6, 12, 13, 45, 86

RULE 19

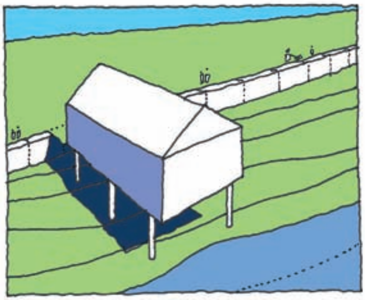


20. DESIGN FOR RESILIENCE

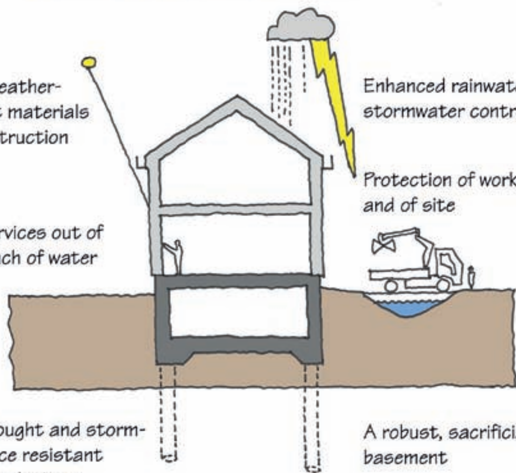
Climate change results in many uncommon conditions in all regions of the world, including increased rainfall, drought, more extreme weather events, warmer and colder temperatures, rising sea levels and floods, and the effects on materials of increased ultraviolet (U/V) radiation and insects. The response is clear: design buildings, cities and their connecting infrastructure to be resilient to predicted future changes in climatic conditions, including the conditions in which the construction itself will take place.

Links with rules 1, 2, 40, 45

RULE 20



Building on stilts
or floating building
in flood-prone areas



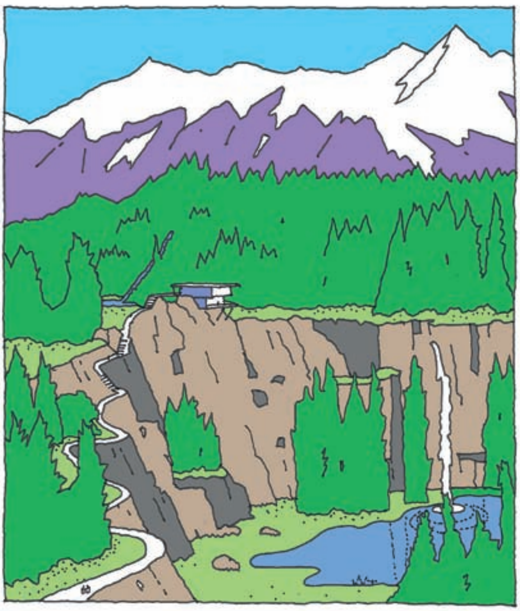
UV and weather-
resistant materials
and construction
Enhanced rainwater and
stormwater control
Protection of workers
and of site
Services out of
reach of water
Drought and storm-
force resistant
foundations
A robust, sacrificial
basement

21. GO OFF-GRID?

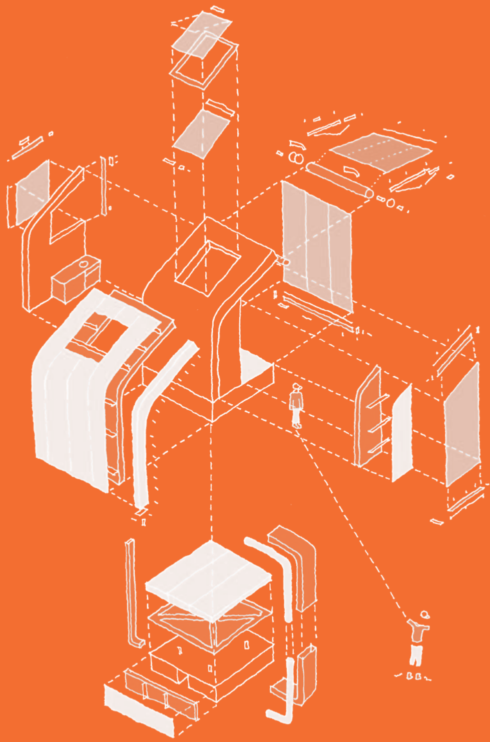
Almost one quarter of the world's population lives without electricity, but this is often not by choice. It is possible (and sometimes necessary) in certain situations, locations and climate regions for buildings to be disconnected from national utilities and to become 'autonomous', or self-sufficient. The decision to go off-grid might be driven by the desire to save money, to reduce dependence on institutions and governments or, sometimes, to reduce carbon footprint. When choosing to live off-grid, aim to ensure no fossil fuels are used, including for transport in remote places, and that there are sustainable local sources of water and sewage treatment.

Links with rules 1, 28–30, 45, 91

RULE 21



CHAPTER 2
RESPECTING GLOBAL RESOURCES



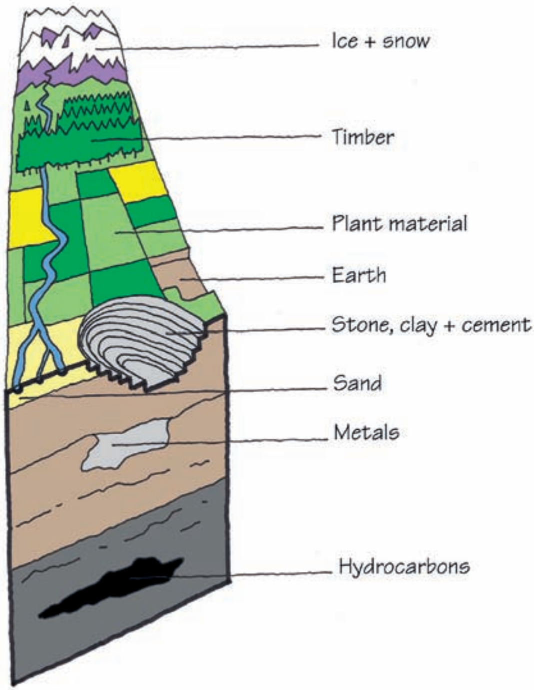
- Materials, energy and water
- Waste
- Resource life cycle

22. THE EARTH IS THE SOURCE OF ALL BUILDING MATERIALS

It is worth reminding ourselves of the basic fact that the earth is the source of all the raw materials from which we make everything used to construct our buildings (and, indeed, everything else we use in our lives). Many of these resources are finite: they will run out. Others may be replenished, but we must manage all the earth's resources with future generations in mind.

Links with rules 1, 2, 23, 45

RULE 22



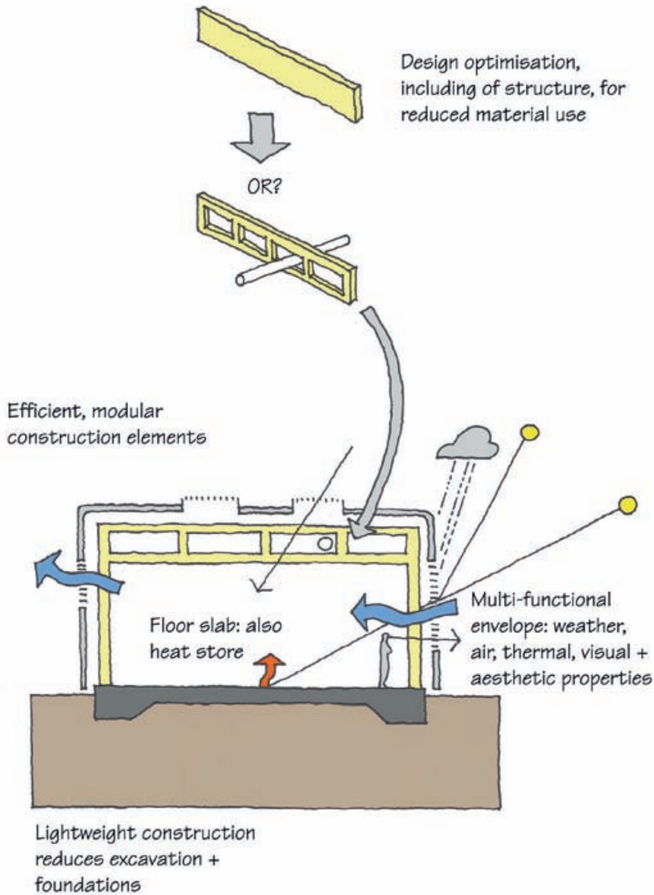
Ice + snow
Timber
Plant material
Earth
Stone, clay + cement
Sand
Metals
Hydrocarbons

23. DO MORE WITH LESS – PRACTISE ECONOMY OF RESOURCES

Buildings consume half of the world's resources and most of these are non-renewable, such as metals and minerals. Our consumption of global resources is set to rise fourfold by 2050, as the population of the world continues to grow. In designing our buildings and cities we must practise economy of global resources, conserving them in both construction and operation. Consider the size of building needed, the efficient use of materials and the reuse of waste. Ensure all components and systems are working hard, preferably with each doing more than one job.

Links with rules 1, 5, 6, 22, 33–37, 42, 45, 91

RULE 23

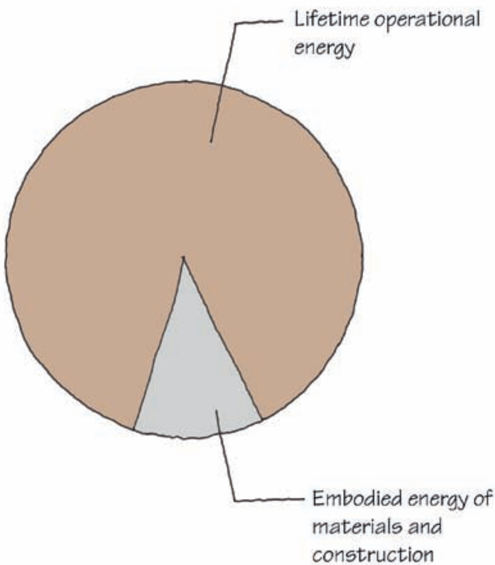

Design optimisation, including of structure, for reduced material use
OR?
Efficient, modular construction elements
Floor slab: also heat store
Multi-functional envelope: weather, air, thermal, visual + aesthetic properties
Lightweight construction reduces excavation + foundations

24. THE AMOUNT OF ENERGY NEEDED TO RUN A BUILDING IS TEN TIMES THE ENERGY USED TO MAKE IT

The operational energy over the lifetime of a typical home will be ten times the energy used to make it – the embodied energy. Make sure buildings are highly energy efficient, then focus on embodied energy.

Links with rules 1, 11, 16, 25, 26, 35, 45, 87

RULE 24



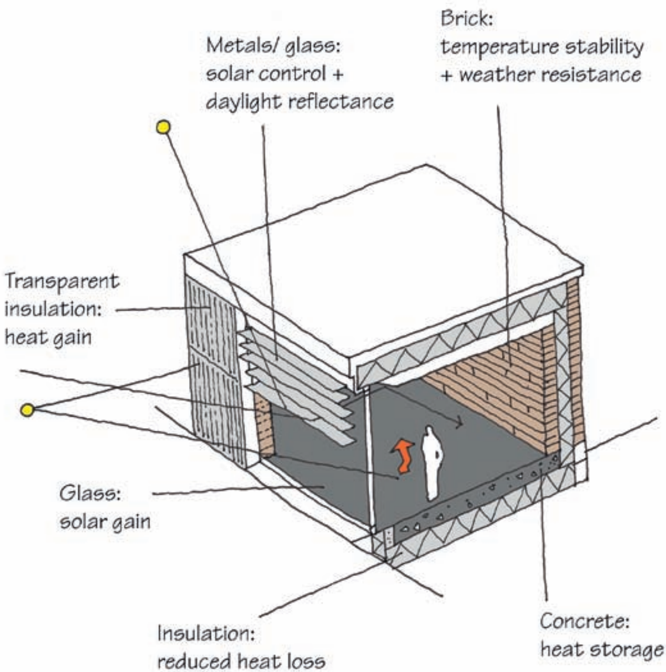
Lifetime operational energy
Embodied energy of materials and construction

25. USE EMBODIED ENERGY TO REDUCE OPERATIONAL ENERGY

Every building material has embodied energy: the energy expended in its extraction, production, transportation, installation and dismantling. We must aim to reduce embodied energy by designing long-life, durable, adaptable and low-energy-use buildings. Use energy-intensive materials like concrete, brick, glass and insulation only sparingly – and when used, they should be employed to help reduce operational energy.

Links with rules 1, 11, 15, 24, 35, 45, 62

RULE 25

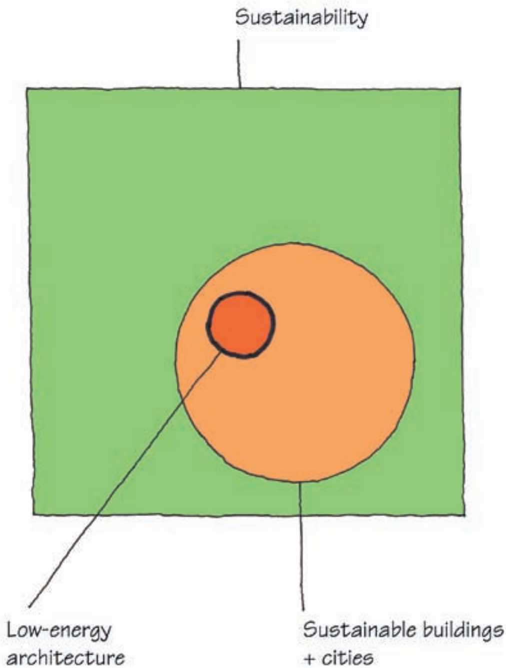

Metals/ glass:
solar control +
daylight reflectance
Brick:
temperature stability
+ weather resistance
Transparent
insulation:
heat gain
Glass:
solar gain
Insulation:
reduced heat loss
Concrete:
heat storage

26. FOLLOW THE RULES OF THUMB FOR LOW-ENERGY ARCHITECTURE

Sustainable architecture must be low-energy-use architecture. There are simple rules of thumb for the designer, which show how to use sun, wind, daylight and building form to reduce energy use.

Links with rules 1, 5, 6, 13, 14, 24, 32, 45, 84, 85

RULE 26



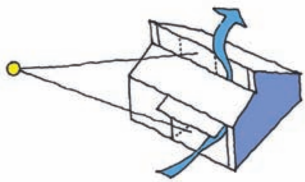
Sustainability
Low-energy architecture
Sustainable buildings + cities

27. LOW-ENERGY DESIGN FIRST, RENEWABLES NEXT: THINK 'FABRIC FIRST'

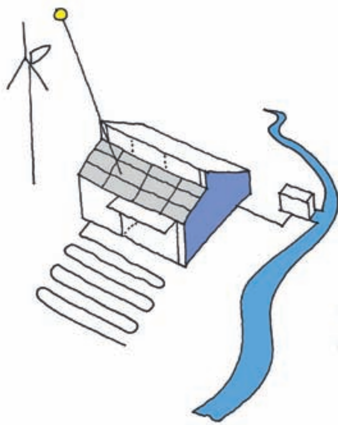
Energy means either electricity or heat. Even for buildings that will rely on renewable or low-carbon energy sources, first design to minimise energy use by maximising on natural and free sources of heating, cooling and lighting and by designing an appropriate envelope. Only then consider renewable energy sources. The maxim to remember is 'Fabric first'.

Links with rules 1, 28–30, 31, 32, 45

RULE 27



Fabric first



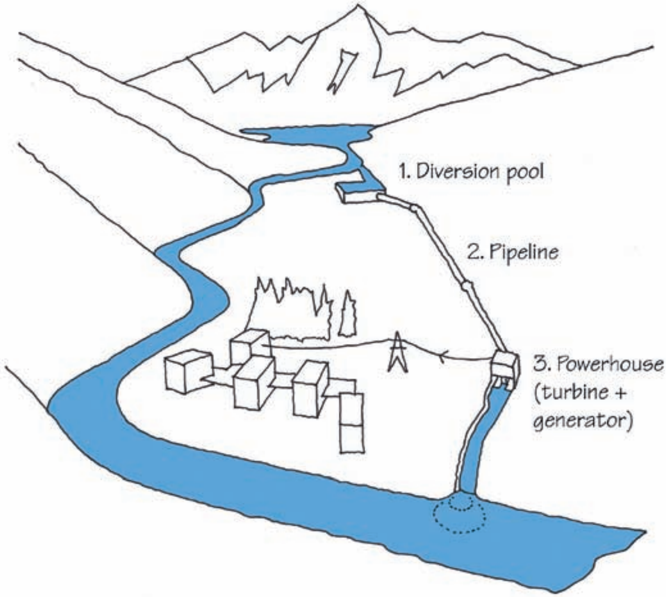
Renewables if needed

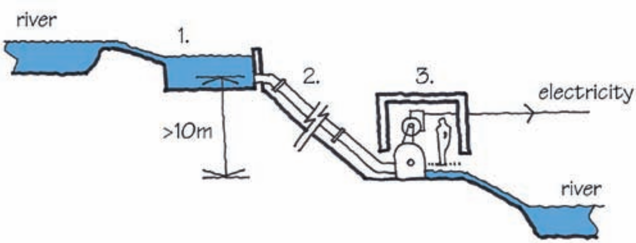
28. RENEWABLE ENERGY SOURCES: WATER

By using the energy of a river to drive a turbine, microhydropower can provide electricity for a house or a small group of buildings. Ideal locations for this application include the world's mountain ranges, which tend to experience year-round rainfall, and other regions whose rivers have a large vertical drop (or 'head') or an adequate flow rate. High rates of water flow tend to be seasonal, so combine hydro with solar generation. Up to 9.8kW can be produced for each m^3/s of water that falls 1m. A head of at least 10m is ideal, with 1.5m as an absolute minimum.

Links with rules 1, 21, 27, 45

RULE 28


1. Diversion pool
2. Pipeline
3. Powerhouse
(turbine +
generator)

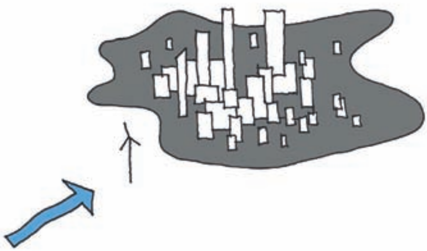

river
1.
2.
3.
electricity
>10m
river

29. RENEWABLE ENERGY SOURCES: WIND

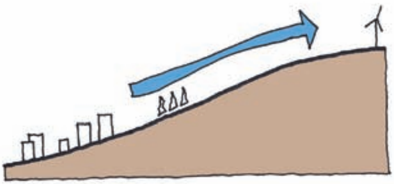
If the average wind speed is more than 5m/s, then consider a wind turbine for electricity generation. In urban areas this will be a challenge, unless your building is 15 storeys or taller. Remember, take a year's wind-speed measurements first, and obtain statutory approvals. A small, 1.5kW turbine can provide one quarter of a typical home's use in the UK, one tenth in the USA and about the average consumed in India today.

Links with rules 1, 21, 27, 45, 53, 64

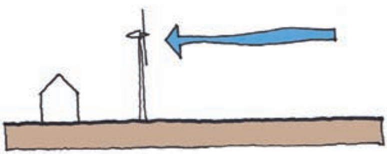
RULE 29



Locate turbines outside urban areas



Or at the top of smooth hills



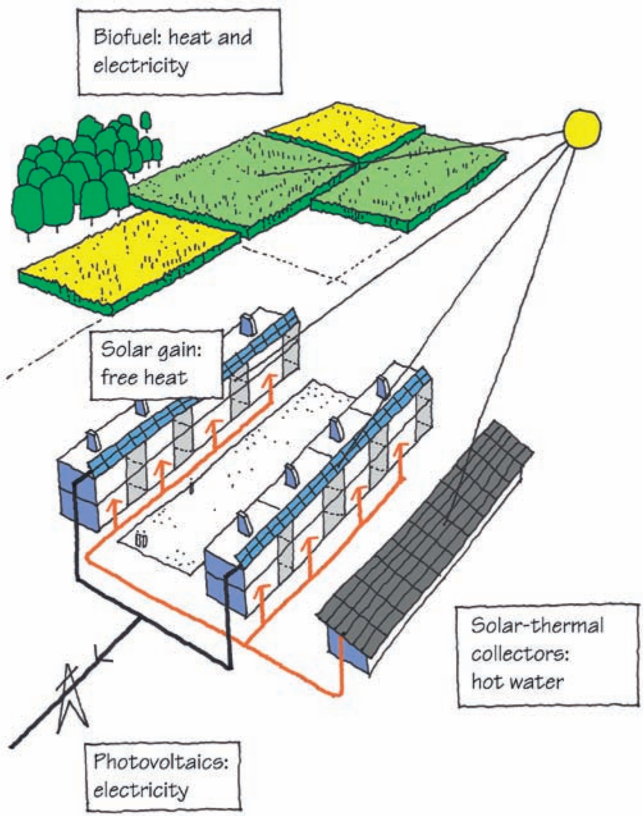
Microgeneration needs velocity and exposure

30. RENEWABLE ENERGY SOURCES: THE SUN

Unlike water and wind, the sun can provide both electricity and heat. Consider electricity-generating photovoltaic (PV) panels and solar-thermal collectors for hot water. Electricity needs to be stored if not used immediately, or else fed into a power grid. Community-wide arrays for heating and electricity will be more efficient than single installations. Biofuels, which can produce both heat and electricity, may be less damaging than fossil fuels in regions where previously used land can legitimately be diverted from food-crop growth, always providing that ecosystems are protected.

Links with rules 1, 21, 27, 45, 53, 60

RULE 30

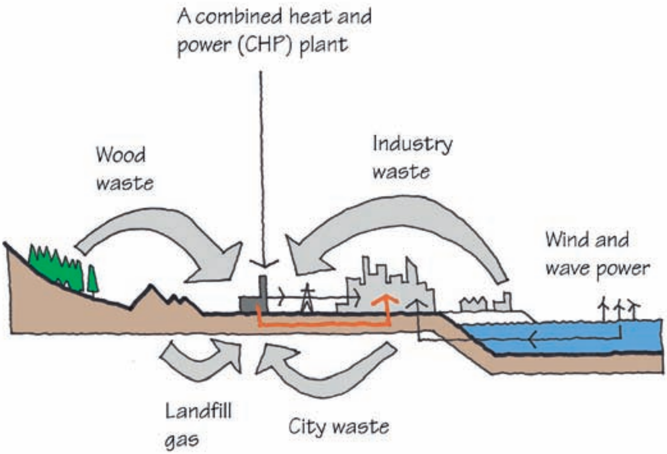

Biofuel: heat and electricity
Solar gain: free heat
Solar-thermal collectors: hot water
Photovoltaics: electricity

31. USE ALTERNATIVE ENERGY SOURCES TO HEAT AND LIGHT CITIES

Districts – and, indeed, entire cities – may be powered by renewable energy sources. Combined Heat and Power (CHP) plants, wave and wind power are all possibilities. Sustainable cities convert their waste into energy, heating and powering the city from a single, large-scale facility. Other forms of biomass, such as landfill gas and wood waste, as well as residue from industrial processes, can be used to power CHP facilities. CHP plant is ideally located on brownfield sites near to the point of continuous energy usage (such as those for hospitals, public buildings or manufacturing), and unlike wind and solar it can operate continuously.

Links with rules 1, 27, 32, 45, 99

RULE 31

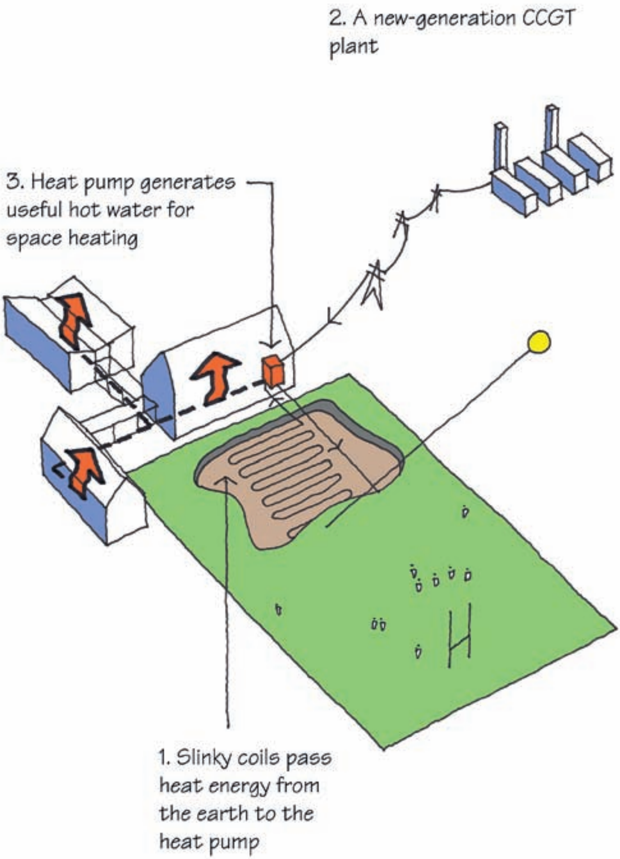

A combined heat and power (CHP) plant
Wood waste
Industry waste
Wind and wave power
Landfill gas
City waste

32. USE EFFICIENT, LOW-CARBON ENERGY SOURCES

There are renewable energy sources (wind, sun and biofuel) and there are low-carbon sources (heat pumps, natural-gas CHP or electricity from a Combined Cycle Gas Turbine [CCGT] plant, which reuses normally wasted heat to generate more power than a traditional plant). Sometimes renewable sources are unavailable or, perhaps in cities, inefficient. Low-carbon sources are the next choice. For the space heating of multiple dwellings or for district-scale developments, a heat pump – powered by electricity from a low-carbon grid source and drawing heat from the earth, air or water – will be more efficient and less polluting than a gas-fired boiler. Remember that for cooling, a heat pump can be reversed.

Links with rules 1, 26, 27, 31, 45, 91

RULE 32



2. A new-generation CCGT plant
3. Heat pump generates useful hot water for space heating
1. Slinky coils pass heat energy from the earth to the heat pump

33. SUSTAINABLE MATERIALS 1: USE RECLAIMED, REUSED, RECYCLED MATERIALS

Our first choice should be materials that are already available. For the innovative designer, waste (reclaimed) materials are still a largely untapped resource. Reused materials are those put to the same use in a new situation; they might include steel or brick. Recycled materials are reprocessed, often requiring the input of energy and additional resources, although they are generally preferable to virgin or scarce non-renewable materials. Non-renewable materials (those that can be 'harvested' only once) should be used sparingly. The ultimate challenge is to use only renewable and reused materials, and no non-renewables.

Links with rules 1, 5, 6, 23, 44, 45

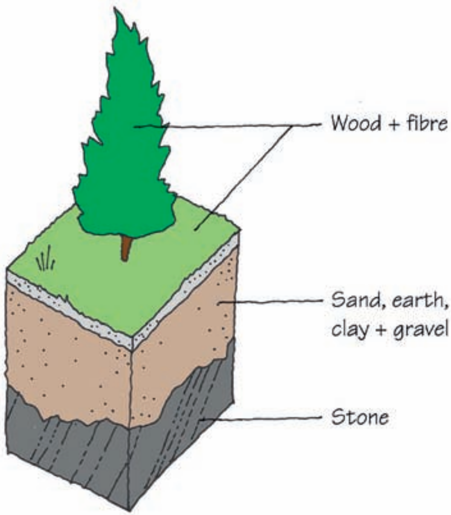
RULE 33

34. SUSTAINABLE MATERIALS 2: USE RENEWABLE AND PLENTIFUL MATERIALS

If virgin materials are needed, use renewable resources such as wood and fibre: renewable, organic materials are environmentally preferable in construction, as long as our rate of usage does not exceed their rate of growth. There are also many materials that exist in the earth in very large quantities, and which will not be exhausted, including stone, earth, clay, sand and gravel.

Links with rules 1, 5, 6, 23, 45

RULE 34



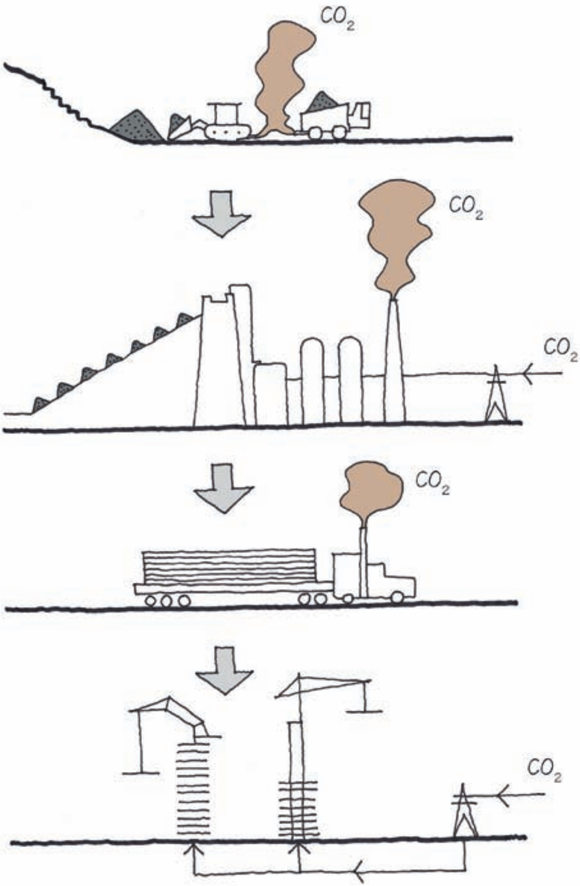
35. SUSTAINABLE MATERIALS 3: USE THE LOWEST-CARBON VERSION OF A MATERIAL

Building materials are responsible for cumulative CO_2 emissions: fossil fuel-derived energy is used at each stage of their life (extraction, production, transportation and incorporation.) So choose organic, not highly processed materials, ensure a high recycled content, and find alternative low carbon constituents. Seek manufacturers who use low carbon energy, and suppliers and contractors who can prove they care about a low carbon world. Consider:

- Zero-cement-content concrete
- Reused timber and steel
- High-reclaimed-content steel, carpet, plasterboard
- Organic alternatives for insulation

Links with rules 1, 5, 6, 23, 24, 25, 45

RULE 35

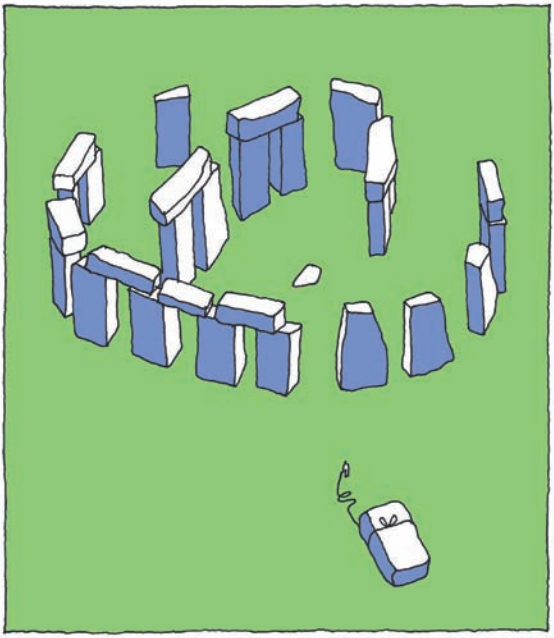


36. SUSTAINABLE MATERIALS 4: SOURCE MATERIALS LOCALLY

In Europe alone, transportation of building materials accounts for nearly 10% of greenhouse-gas emissions. Minimise the energy needed for transportation by sourcing heavy materials which are not made on site, such as stone and brick, from close to where they are needed. Pollution and other environmental nuisances will also be reduced. Lightweight and virgin materials should be sourced within 100km. Reclaimed materials may justifiably be brought to the building site from a more distant source. Always check the environmental credentials of every material, whether sourced locally or globally, before making choices.

Links with rules 1, 5, 6, 23, 45, 98

RULE 36

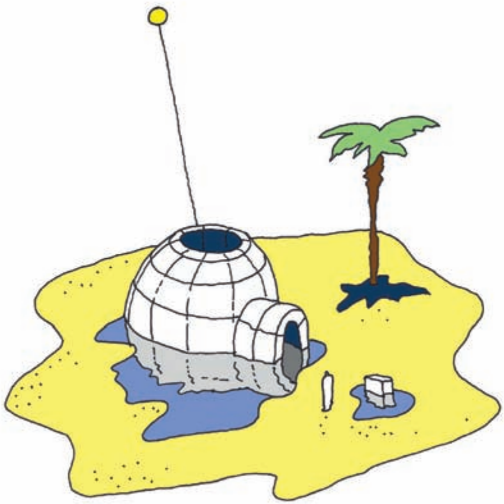


37. SUSTAINABLE MATERIALS 5: USE SUITABLE AND DURABLE MATERIALS

Durability comes from a combination of durable materials, durable design and durable construction. Choose materials based on properties appropriate to place and circumstances, with the health of building occupants in mind (they should be benign in terms of chemical composition and emissions) and where the lifetime ecological profile can be identified as being low-impact. Use published checklists as a guide, and ask searching questions of manufacturers and suppliers.

Links with rules 1, 2, 5, 6, 23, 45, 53, 69, 72, 73, 90

RULE 37

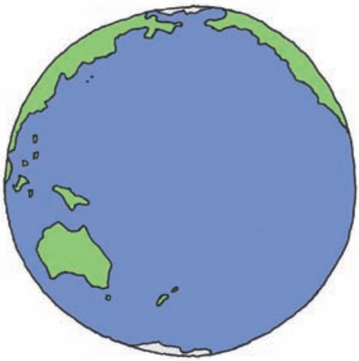


38. WATER, LIKE OIL, IS A FINITE RESOURCE – CONSERVE IT

Earth is a water world; 70% of the planet's surface is water. All we will ever have exists within earth's hydrologic system today, but 97.5% is salt-water and most of the rest is frozen under the earth. Only 0.008% of global water is readily available for human use. In the UK alone, we each use on average 163 litres daily, and there is increasing global pressure on clean supplies. So, firstly reduce water use with efficient taps, showers, toilets and outdoor systems. Then encourage good water-management behaviour with clear instructions. Finally, maintain water systems to eliminate waste.

Links with rules 1, 5, 6, 11, 39, 40, 45, 69, 84

RULE 38

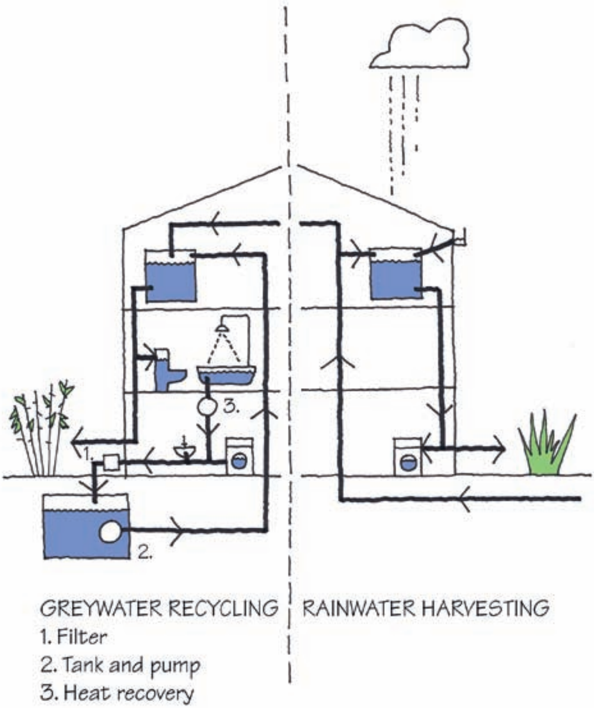


39. USE THE RIGHT QUALITY OF WATER IN THE RIGHT PLACE

After reducing demand (Rule 38), the next step is to reuse recycled greywater (water from basins, baths and showers) for use in toilets, washing machines and gardens instead of the high-quality drinking water we commonly use. Where possible, recover heat from waste water too. Also, in many regions rainwater harvesting can supply irrigation and clothes-washing water, and in some locations on the planet it is of drinking quality.

Links with rules 1, 38, 40, 45

RULE 39



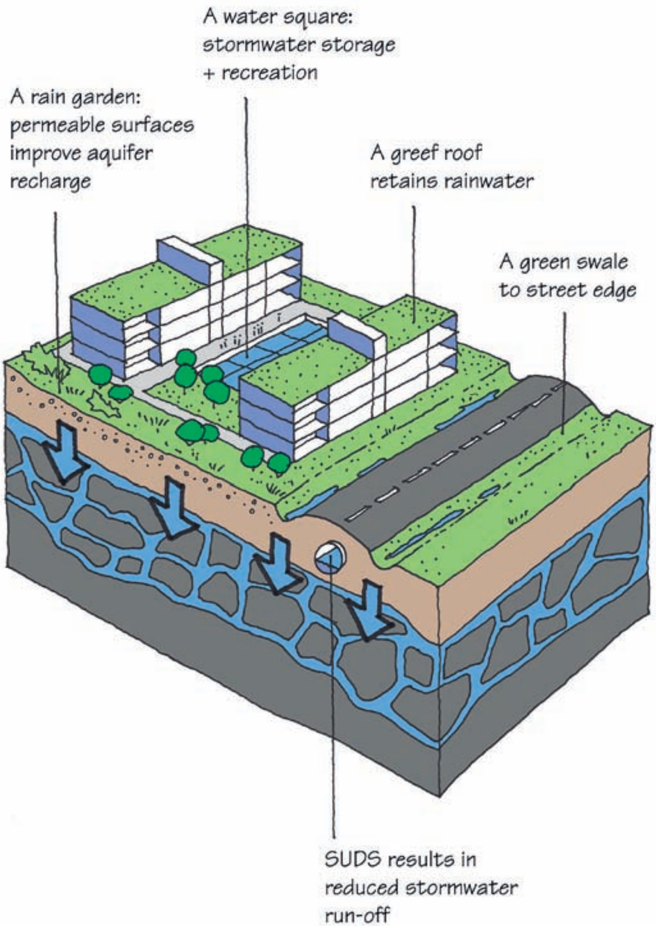
1.
2.
3.
GREYWATER RECYCLING
1. Filter
2. Tank and pump
3. Heat recovery
RAINWATER HARVESTING

40. GATHER WATER IN RAIN GARDENS, WATER SQUARES AND SWALES – USE SUDS

In our cities, we often channel rainwater from hard landscape surfaces into the sewerage system. The result is increased risk of regional drought as groundwater, which is held naturally underground within permeable rock formations known as aquifers, is not replenished. Piping rainwater directly to watercourses also increases flood risk and pollution problems. A Sustainable Urban Drainage System (SUDS) aims to mimic natural water drainage, allowing rainwater to permeate into the ground while safely storing excess. Use permeable surfaces to permit infiltration of rainwater and design inventive, water-retaining landscaping from which rainfall can also be harvested.

Links with rules 1, 20, 38, 39, 45, 58, 66, 80, 99

RULE 40



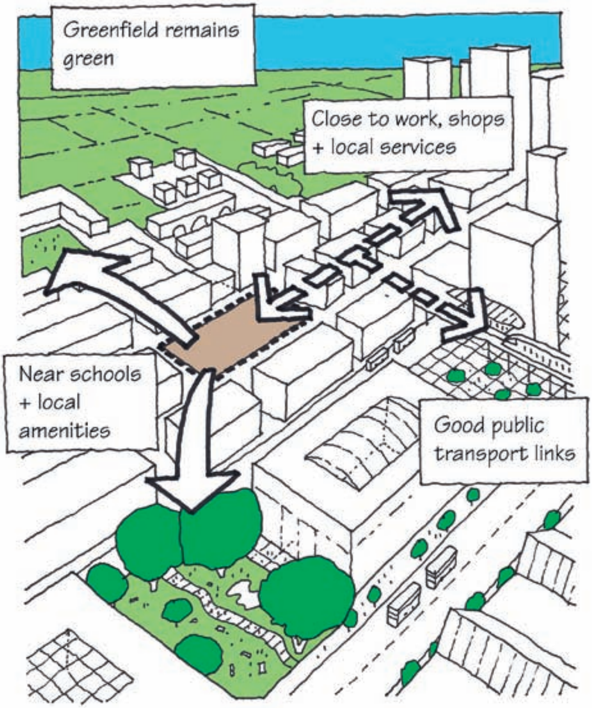
A water square: stormwater storage + recreation
A rain garden: permeable surfaces improve aquifer recharge
A greef roof retains rainwater
A green swale to street edge
SUDS results in reduced stormwater run-off

41. USE BROWNFIELD, NOT GREENFIELD

A greenfield site is unbuilt land; an urban brownfield site has been previously used. Brownfield sites might be polluted but biodiverse, so care is needed in decision-making. Use of greenfield sites will almost always increase transportation and CO_2 emissions, contribute to urban sprawl, impact on biodiversity and lead to the depopulation of city centres. Intelligently developed brownfield sites can form the basis of new urban communities within already established cities. If not built on, and once clean and unpolluted, a brownfield site may be used for urban agriculture.

Links with rules 1, 45, 46, 76, 80, 82, 97

RULE 41



Greenfield remains green
Close to work, shops + local services
Near schools + local amenities
Good public transport links

42. BANISH CONSTRUCTION WASTE

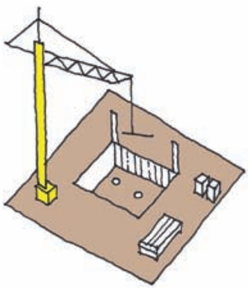
One third of all UK waste sent to landfill comes from construction and demolition sites, and this includes excavation material, materials delivered but never used and general waste from building processes. Waste contributes to air, land and water pollution; it must be banished through good design, specification and construction practices.

Links with rules 1, 5, 6, 23, 43, 44, 45, 47, 86, 92, 99

RULE 42

DESIGN + SPECIFICATION
- Standard sizes
- Recycled + re-used materials
- Design for dismantling

FABRICATION + DISTRIBUTION
- Modular + off-site manufacture
- Order only what is needed
- Minimise packaging



SITE OPERATIONS
- Care with handling + storage
- Packaging returned to supplier
- On-site recycling

43. THINK 'BACK TO FRONT'

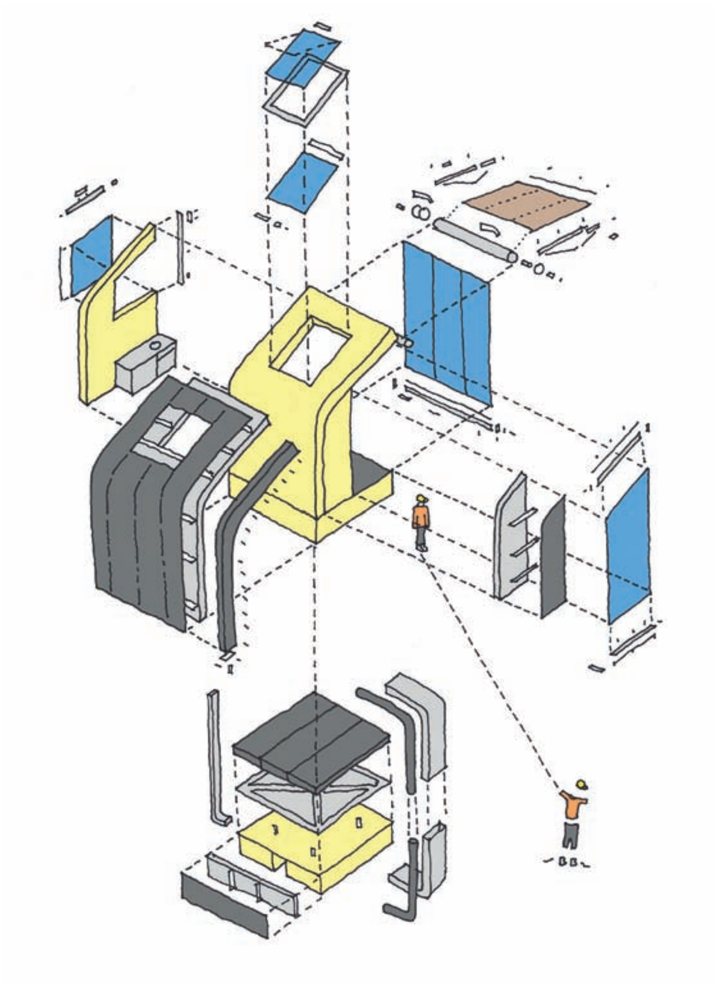
Design with the distant future in mind by asking yourself at the beginning:

- What will happen, at the end of a building's life, to all the materials and components you specify?
- How could they become part of a new process of sustainable design?

Design from the outset for future deconstruction, and reuse of every part.

Links with rules 1, 42, 45, 93

RULE 43



44. RECYCLING IS THE LAST RESORT – REMEMBER THE FOUR 'R'S

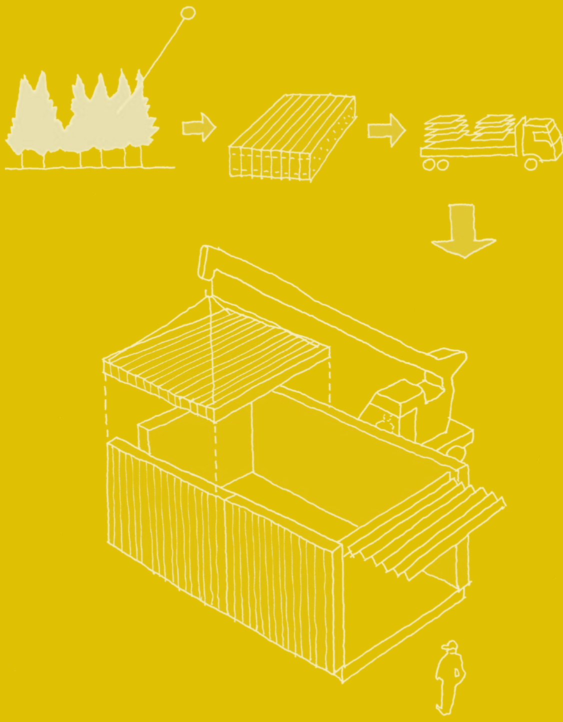
Reduce, reuse, recover and recycle – in that order. This is the mantra for minimising environmental impacts from materials, water and energy usage in sustainable design and construction. Recycling is just one of the four 'R's. Too often, recycling of materials and resources is the result merely of overconsumption or lack of consideration of resource life cycle. It takes further energy inputs to break down waste products, so recycling should be considered in light of the other 'R's.

Links with rules 1, 33, 42, 45

RULE 44

1. Reduce
2. Reuse
3. Recover
4. Recycle

CHAPTER 3
WORKING IN HARMONY WITH THE NATURAL WORLD



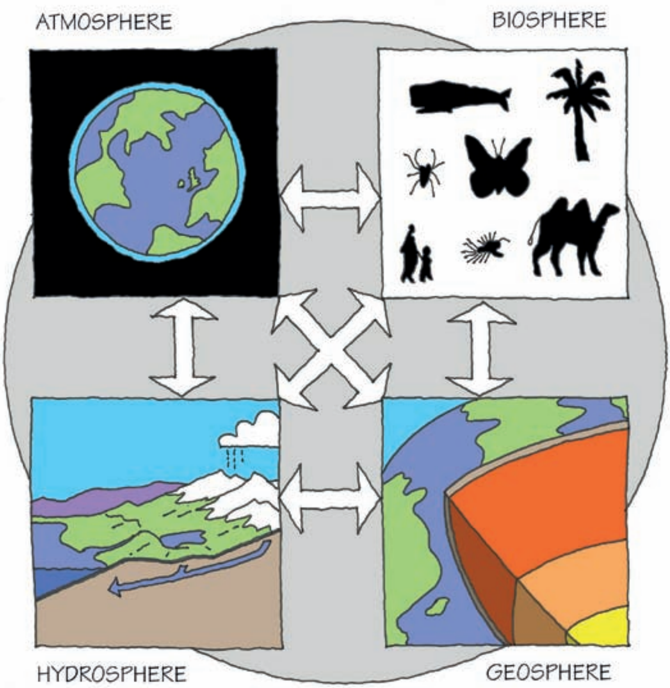
- Ecology and biodiversity
- Climate-responsiveness

45. 'EVERYTHING IS CONNECTED TO EVERYTHING ELSE'

Ecologist Barry Commoner gave us this rule. Earth's ecosystems – communities of living organisms (flora and fauna) and their non-living environments (air, water, earth) – provide everything needed for life on the planet, from clean air and water to food, fuel, medicines, building materials, carbon capture and pollination. The ecosphere is the self-supporting structure of ecosystems, and it is described as being composed of four key domains, or 'spheres': atmosphere, biosphere, hydrosphere and geosphere. We must regain an understanding of their interconnectedness, on which life depends.

Links with all other Rules

RULE 45



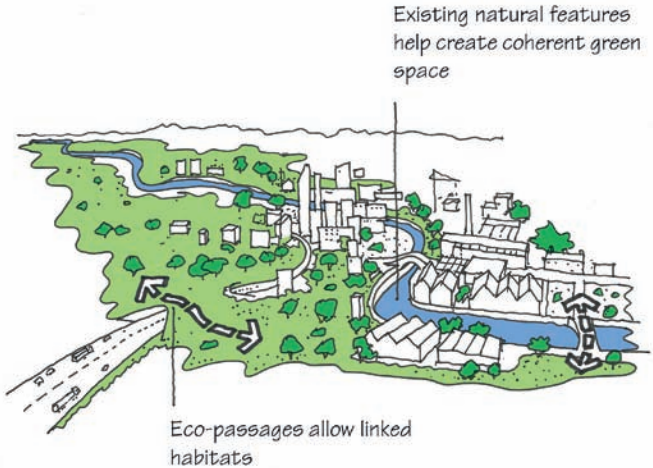
The four spheres of the ecosphere: what affects one affects all

46. BIODIVERSITY NEEDS LINKED HABITATS

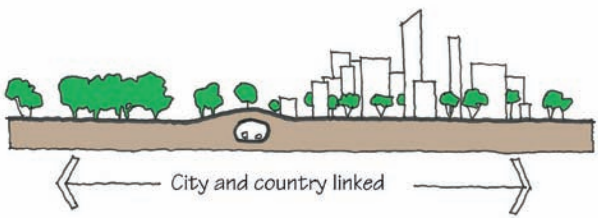
The greater the diversity of species, the greater will be the productivity of the ecosystems on which we rely. Vegetation is the key; varied habitats support a richer variety of life, while loss of biodiversity significantly affects the stability of ecosystems. Designers of the built environment should actively encourage biodiversity by providing opportunities for species to thrive within our cities and to connect with the surrounding countryside. Those interconnected habitats also provide opportunities for the human urban population to enjoy the local sense of place created by biodiversity.

Links with rules 1, 41, 45, 50, 77, 80, 96–101

RULE 46



Existing natural features help create coherent green space
Eco-passages allow linked habitats



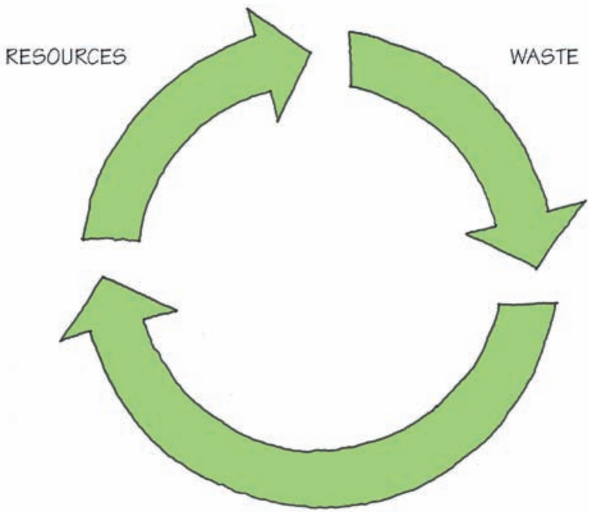
City and country linked

47. THERE IS NO WASTE IN NATURE

A sustainable ecosystem recycles discarded matter and replenishes resources: one species' waste is another's food. So in the natural world, ultimately, there is no waste. All our activities in the built environment – decision-making, site-planning, design, procurement, construction, operation and demolition/reuse – should support and reinforce the ecosystems on which we rely. In the industries associated with building, waste from one should be viewed as a resource for another. We should be able to mimic the diagram of a sustainable ecosystem.

Links with rules 1, 42, 45, 52, 91, 92, 99

RULE 47

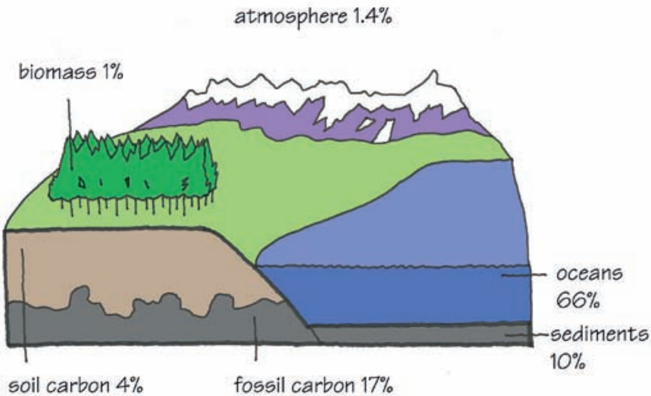


48. ECOSYSTEMS REGULATE THE WORLD'S CLIMATE

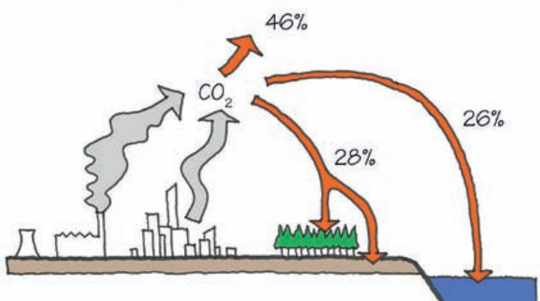
Climate regulation is one crucial service of global ecosytems: CO_2 controls the earth's temperature and terrestrial ecosystems act as a carbon 'sink', sequestering greenhouse gases. If we change land cover from cropland to urban development, or convert peat soil to agriculture, we release greenhouse gases (GHGs), including methane and CO_2, with a resulting increase in both temperatures and precipitation. We must respect the ecosystems that regulate climate.

Links with rules 1, 45, 55

RULE 48



a) natural carbon stores



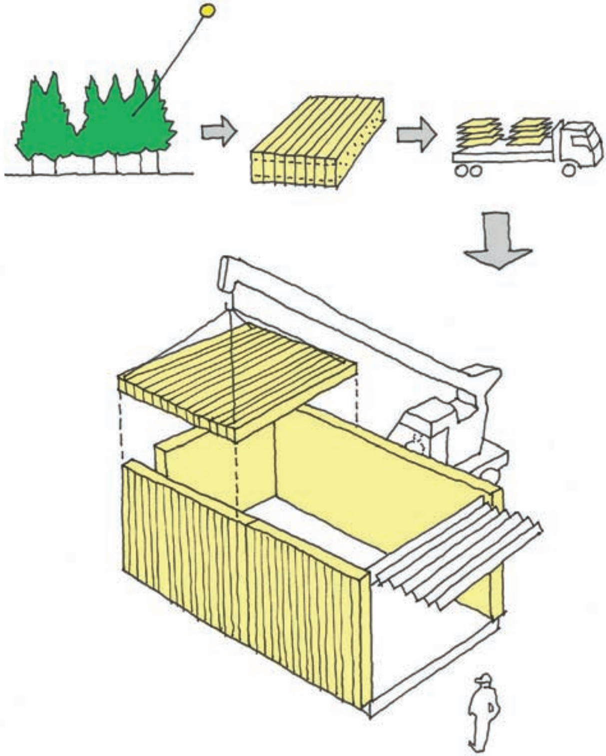
b) where anthropometric CO_2 goes

49. MAKE CLIMATE-NEUTRAL BUILDINGS – MAXIMISE THE STORAGE OF CARBON

Buildings constructed of materials that store carbon can be climate neutral; they do not add to the atmospheric CO_2 which is a cause of climate change. Timber stores carbon (produced during photosynthesis) even after the felling of the tree, and a house constructed of massive timber elements can store four times the carbon of a more typical house. In addition to timber, innovations in mineral and waste materials, which, when combined with CO_2 create inert building blocks, point to the way forward.

Links with rules 1, 45, 52, 55

RULE 49

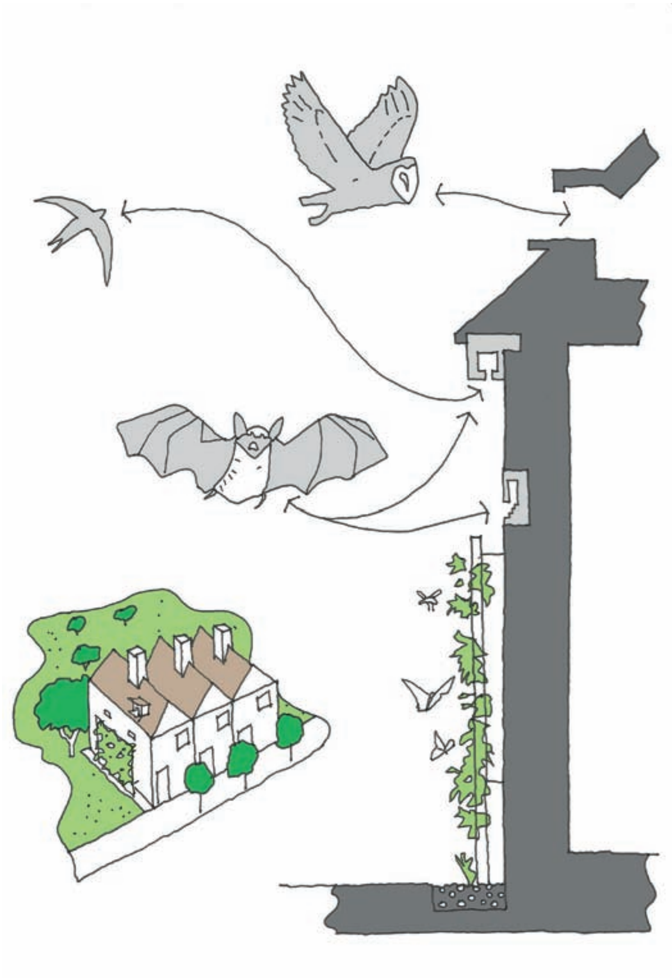


50. NOT ALL BIRDS NEST IN TREES

Some species have, over generations, adapted to life with humans and are building-reliant, but our buildings are becoming unfriendly to roosting and nesting; the airtight envelope lacks traditional opportunities. Many species of bats (mammals that are particularly important for ecosystems) owls, other nesting species as well as slow worms, small lizards and insects may be encouraged to thrive by good design rather than banished by unsympathetic development or otherwise disturbed by human behaviour. Space may be found in roofs, walls or modified building-envelope details. Otherwise, design a detached structure such as a bat house or owl barn.

Links with rules 1, 45, 46, 90

RULE 50

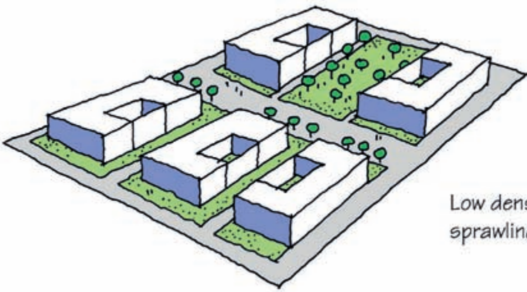


51. HIGH DENSITY LETS NATURE BE

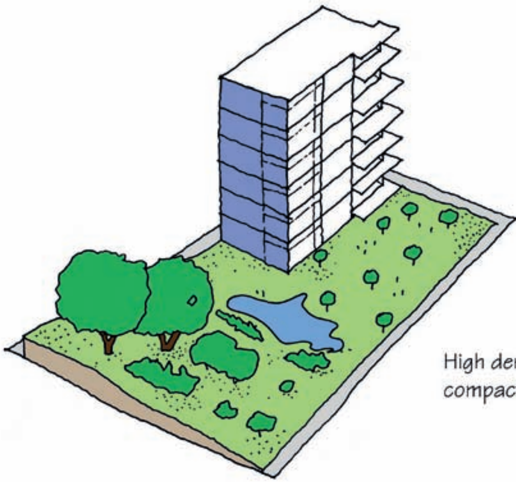
There are many obvious benefits to well-designed, high-density development: efficiencies in transportation and costly infrastructure, reduced energy consumption and land loss. A smaller footprint also releases more unbuilt site area, allowing nature to flourish, increasing opportunities for biodiversity and greater CO_2 absorption from larger trees. The rule of thumb is to aim for 50% of the site to be retained as open space. Remember that good design is still the goal: sustainability is not a guaranteed result of density.

Links with rules 1, 18, 45, 65, 80, 81, 97

RULE 51



Low density, sprawling



High density, compact

52. THE NATURAL WORLD HAS LESSONS FOR DESIGNERS – BE A BIOMIMIC

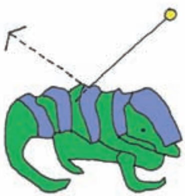
In biomimicry, we seek design inspiration from the processes, structures and forms of the natural world. Flora and fauna use available resources sparingly, are responsive to local conditions and adaptive and resilient to climate and environment. Nature displays extremely high-strength structures and forms, and processes which are energy-producing, carbon-absorbing, zero waste-generating and water-conserving.

Links with rules 1, 45, 47, 49, 93

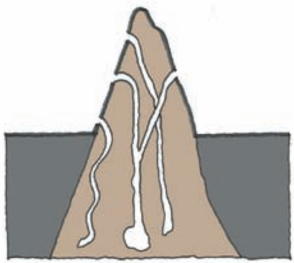
RULE 52

Photosynthesis: an energy - producing skin?

Shell structures: built from CO_2, tougher than ceramic



A lizard: changes skin colour to regulate temperature



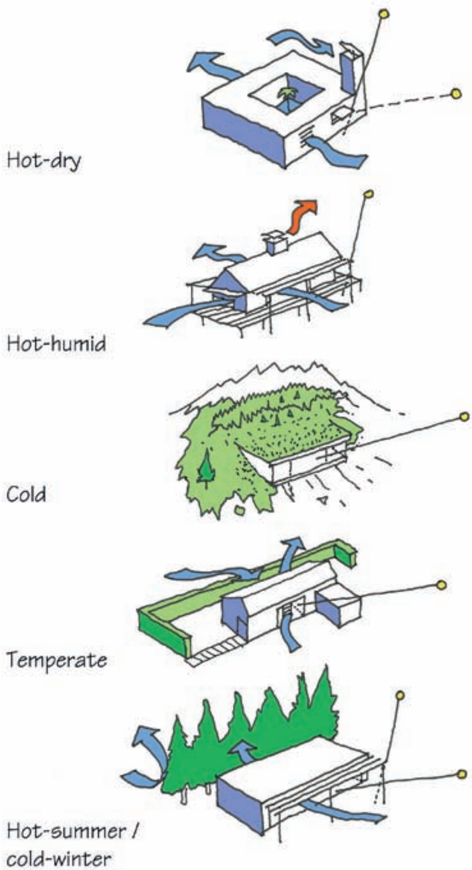
A termite mound : natural air conditioning

53. KNOW YOUR CLIMATE ZONE

Greek philosopher Parmenides proposed that there were five distinct climate zones. Although we can identify around 30 today, designers of the built environment are chiefly concerned with hot-dry, hot-humid, cold, temperate and hot-summer/cold-winter climates. The ancient Greeks knew that buildings and cities must work in harmony with their climate region if they are to provide human comfort sustainably. Knowing the characteristics of your climate remains fundamental today.

Links with rules 1, 29, 30, 37, 45, 54, 59, 67, 70, 96

RULE 53



54. TO DESIGN THE FUTURE, LOOK TO THE PAST

Indigenous populations have adapted to their climate and geographical regions with long-lasting, vernacular building responses. Often using only readily available resources and simple building techniques, their settlements use minimal resources, are low-energy-use and climate-responsive, and display cultural relevance – all traits of sustainable development. We can still learn from them.

Links with rules 1, 2, 45, 53, 69, 70, 76, 86

RULE 54

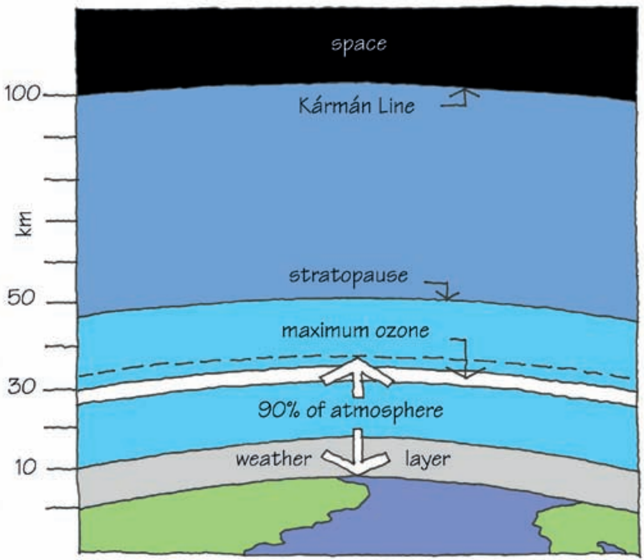
- Cultural lessons
- Construction lessons
- Climatic lessons

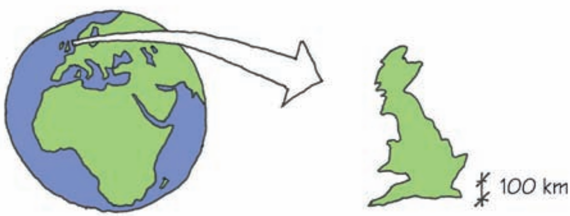
55. OUR ATMOSPHERE IS PAPER THIN

If the earth were the size of a football, the atmosphere clinging to it would be the thickness of a piece of paper. Within the atmosphere is the ozone layer, our shield against dangerous UV radiation, which is readily damaged by CFCs such as those present in the refrigerants in air conditioning, in some insulation products and in the solvents and aerosols used in construction. Most human-generated (anthropogenic) CO_2 resides in the atmosphere, contributing to global warming. Our cities are responsible for 70% of these CO_2 emissions. Buildings and cities can be atmosphere-friendly if they are carbon-neutral and CFC-free.

Links with rules 1, 14, 17, 45, 48, 49, 80

RULE 55


space
100
Kármán Line
km
stratopause
50
maximum ozone
30
90% of atmosphere
10
weather
layer

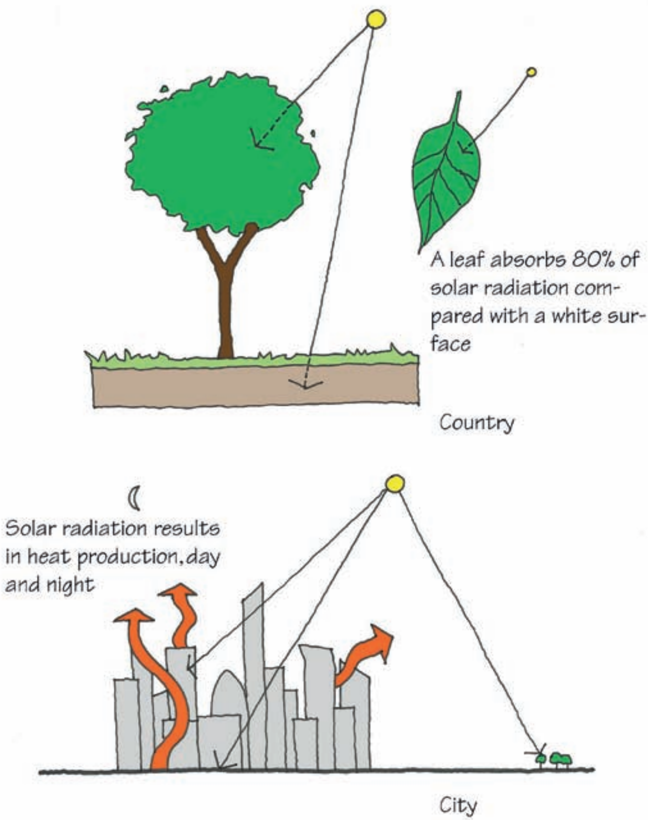

100 km

56. URBAN CLIMATOLOGY – WHY CITY AND COUNTRY ARE DIFFERENT

In cities most of the solar radiation absorbed by buildings and surfaces turns to heat, and heat continues to be re-radiated both day and night. But in rural areas much of the radiation is absorbed by plants and damp earth, and this process of evapotranspiration does not generate measurable heat. This is partly why cities are generally warmer than the surrounding countryside, particularly at night.

Links with rules 1, 45, 57, 80

RULE 56



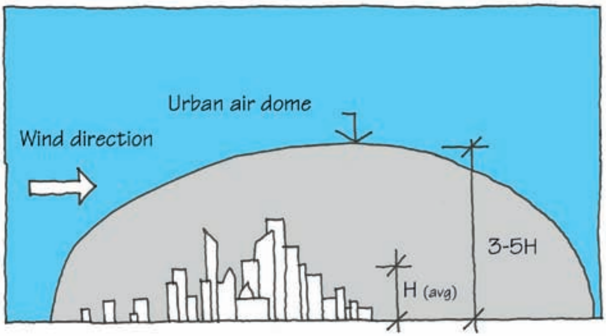
A leaf absorbs 80% of solar radiation compared with a white surface
Country
Solar radiation results in heat production, day and night
City

57. LOOK OUT FOR THE URBAN AIR DOME

A city has its own climate, visible from a distance and known as the urban air dome. The dome is three to five times the average height of the city, and extends downwind. Solar radiation combines with anthropogenic heat to raise the temperature of the air dome, so the city can be 5–10°C warmer than surrounding rural areas at night; this is the ‘Urban Heat Island’ (UHI) effect.

Links with rules 1, 45, 56, 58, 66

RULE 57

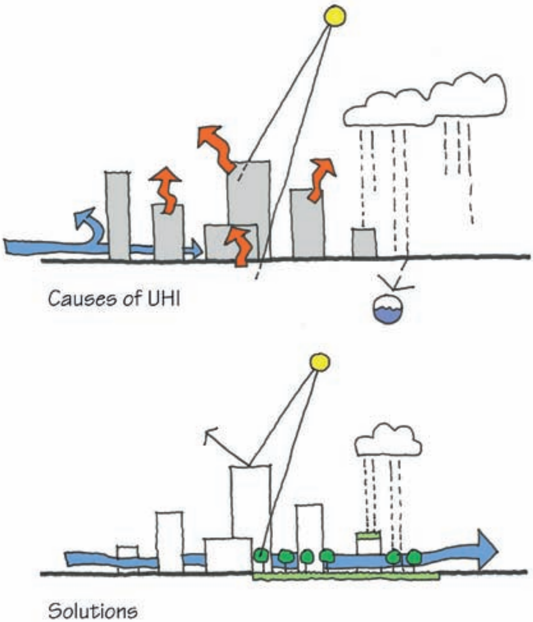


58. COUNTER THE URBAN HEAT ISLAND EFFECT

Buildings release their internal heat and the sun warms the city, which is enveloped in a bubble of trapped warm air: this is the UHI effect. UHI means urban temperatures are higher than rural ones, and cities have more cloud cover and precipitation than the countryside. Often, lack of wind between urban buildings prevents cooling and traps pollution. Counter UHI by insulating buildings and by the use of light colours (known as the 'albedo effect') to reflect radiation. At the urban scale, allow flushing breezes and provide pervious and green surfaces for increased natural, evaporative cooling.

Links with rules 1, 17, 40, 45, 57, 59, 66, 80, 96

RULE 58

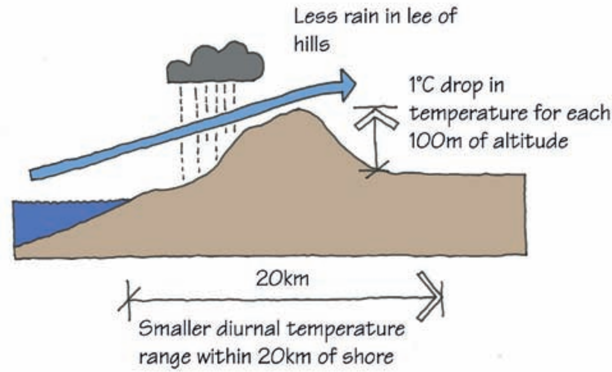


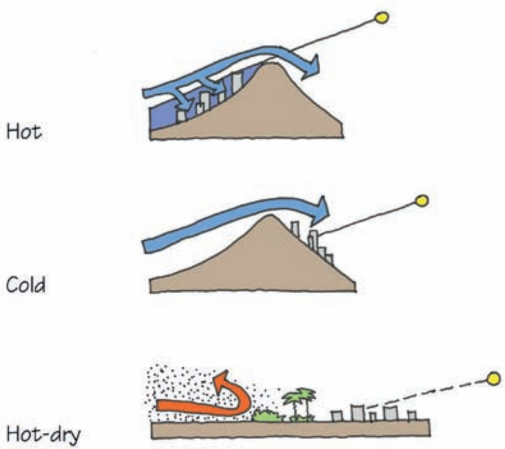
59. USE CLIMATE CLUES FOR CITY PLANNING

A study of a region's climate provides many clues for locating towns and cities. A significant body of water, such as the sea or a large lake, has a moderating influence on the land; within around 20km of the coast, the annual and diurnal temperature range is smaller than inland. Topography also plays a key role: typically, less rain falls in the lee of hills, and air cools with altitude. For communities in hot regions plan for maximum wind exposure, and in cold regions employ effective wind protection. Settlements in hot-dry regions may need protection from dust storms, and remember that they might experience cold nights and winters.

Links with rules 1, 17, 45, 53, 58, 96

RULE 59


Less rain in lee of hills
1°C drop in temperature for each 100m of altitude
20km
Smaller diurnal temperature range within 20km of shore

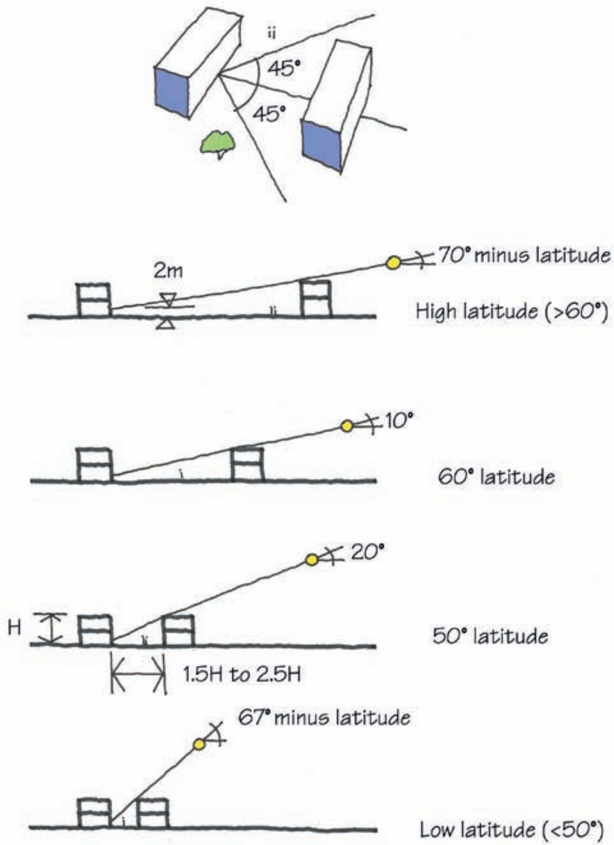

Hot
Cold
Hot-dry

60. PROVIDE SEPARATION FOR SUN AND ENERGY

The distance needed between buildings to permit solar access – allowing the sun to reach the main facade for heating and energy production, without blocking access to neighbours – depends upon latitude. The spacing increases with distance from the equator. If a building or obstruction is sitting within the 90º arc shown, use the angular cut-offs as indicated in the diagrams as a starting point for solar-access planning. In latitudes around 50ºC, building spacing of 1.5 to 2.5 times the height may be used, as shown. In mid and high latitudes, the spacings can become too large, permitting unwanted cold winds and compromising urban scale; in such cases, refer to Rules 61 and 63.

Links with rules 1, 30, 45, 61, 63, 74

RULE 60



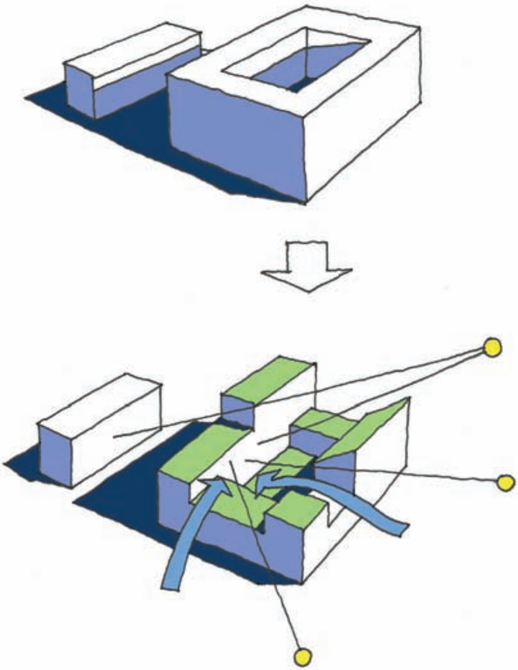
ii
45°
45°
2m
70° minus latitude
High latitude (>60°)
10°
60° latitude
20°
H
50° latitude
1.5H to 2.5H
67° minus latitude
Low latitude (<50°)

61. THE RULE IF RULE 60 DOES NOT WORK – USE URBAN BREAKS

Based upon strict measurement of the sun's elevation, the separation between buildings in high and mid latitudes might be hard to achieve. Urban design considerations such as the human and functional scale of streets, squares and courtyards should not be unnecessarily compromised. Urban breaks are the answer: they are used to improve solar access, ventilation and daylight, particularly in high-density urban schemes. Additional benefits include potential for roof terraces and accessible green roofs.

Links with rules 1, 45, 60, 63

RULE 61



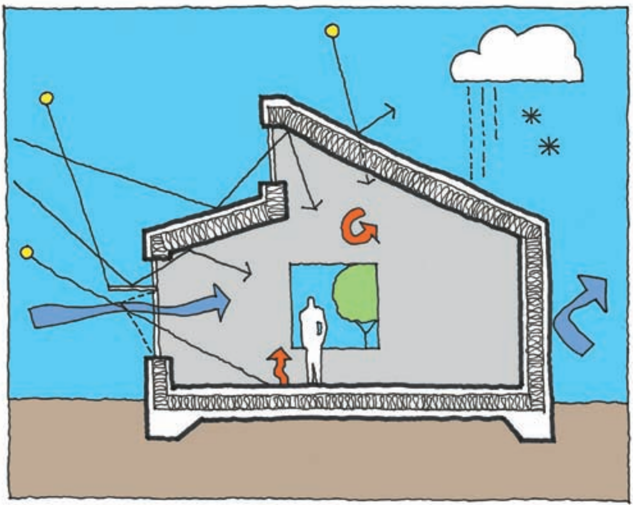
62. THE BUILDING ENVELOPE IS A CLIMATE MODIFIER

The purpose of the building envelope (its walls, roof and floor – also known as its fabric) is to modify external climatic conditions to create comfort conditions within, with little or no energy inputs needed. The designer's main tools, to be employed in relation to the specific climate to be modified, are:

- Envelope construction – for rain and wind protection, insulation, thermal mass, reflectance
- Openings – for daylight, solar gain, ventilation
- Integrated elements – for solar shading, dust and sand protection

Links with rules 1, 25, 45, 63, 66, 74, 88

RULE 62

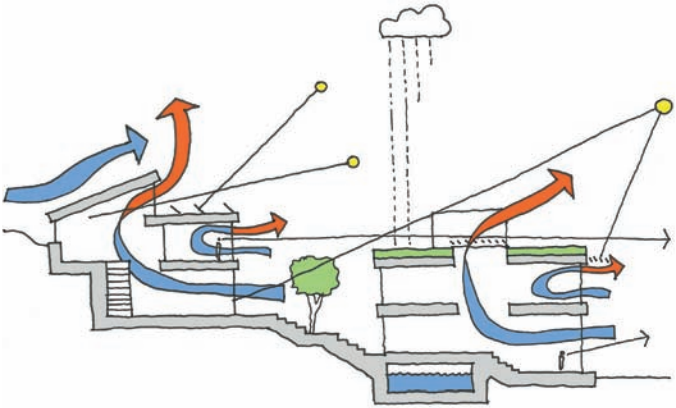


63. THE ANSWER IS IN THE SECTION

The section is a crucial environmental and sustainable design tool. Of course, other drawing types are essential too – but it is the section, of the site or building, that reveals a response to sun, light, ventilation, shading and shelter, and which best explains human interactions with nature and the environment.

Links with rules 1, 45, 60-62

RULE 63

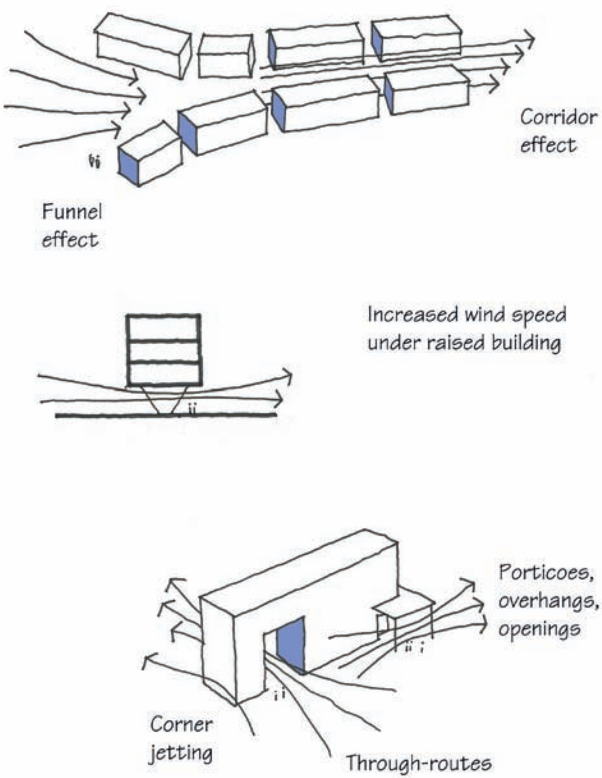


64. THE ANSWER IS BLOWING IN THE WIND

Buildings modify the microclimate in many ways. Wind can be a particular annoyance – even a danger. A building will be unsuccessful if people do not visit it due to adverse wind effects. Avoid the creation of wind-funnels/corridors, and remember that wind speed increases at building corners (known as 'corner jetting'). Through-routes, door openings, porticoes and overhangs also encourage increased wind speed. While this may be useful for cooling in hot and humid regions, it is undesirable in other climate zones and anywhere that uncomfortable wind speeds or storm conditions are common.

Links with rules 1, 29, 45, 65

RULE 64

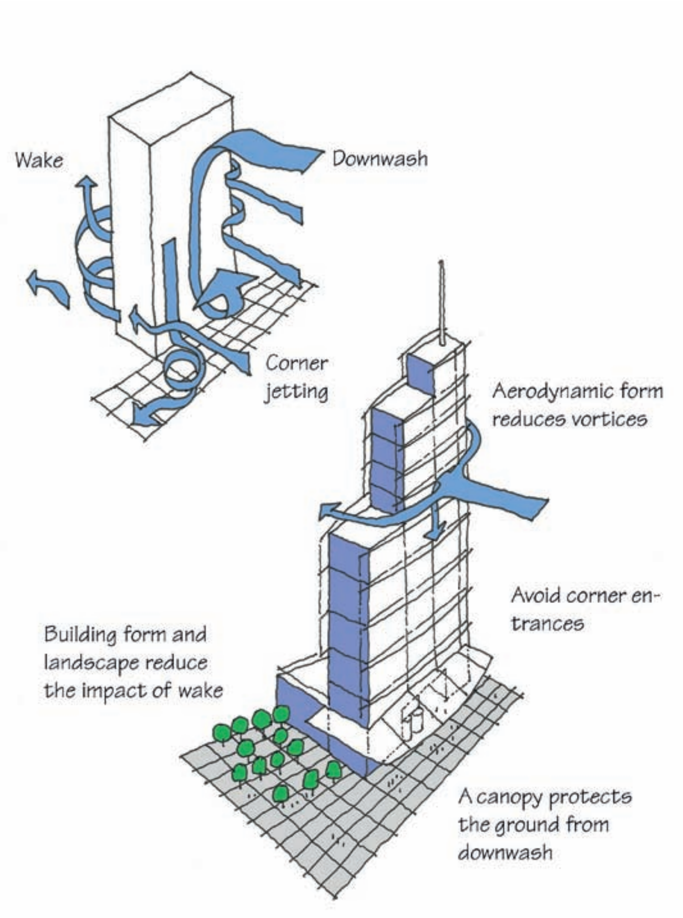

Corridor effect
Funnel effect
Increased wind speed under raised building
Porticoes, overhangs, openings
Corner jetting
Through-routes

65. TALL BUILDINGS: DESIGN OUT DOWNWASH VORTEX, CORNER JETTING AND WAKE

The microclimate around a tall building is significantly influenced by wind vortices: swirling masses of fast-moving air. Tall buildings draw wind down to the ground in an effect known as downwash. Corner jetting occurs as the wind speeds up at the building's edges, and turbulence is generated in the downwind wake of the building. These can cause discomfort, or worse – so design teams must include in their initial work the use of modelling, physical or virtual, to test for and eliminate hazardous wind conditions. No building can be sustainable if it creates unusable urban spaces.

Links with rules 1, 45, 51, 64, 96

RULE 65



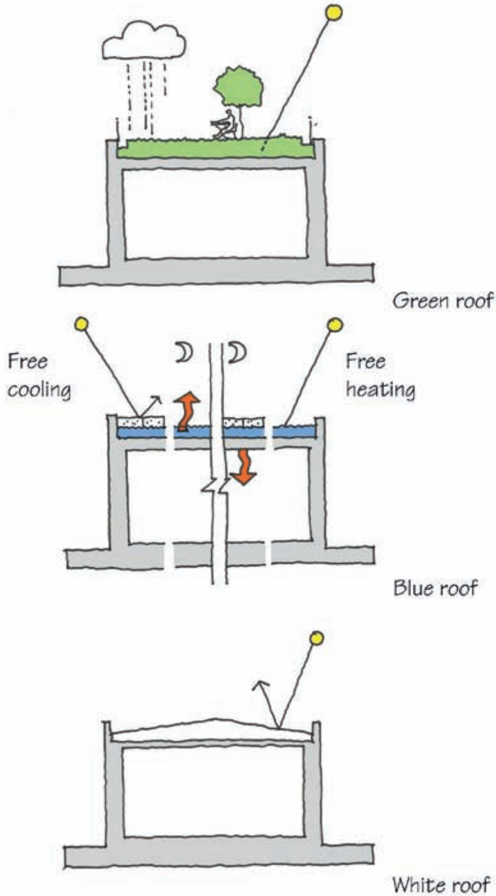
Wake
Downwash
Corner jetting
Aerodynamic form reduces vortices
Avoid corner en-trances
Building form and landscape reduce the impact of wake
A canopy protects the ground from downwash

66. GREEN ROOF, BLUE ROOF OR WHITE ROOF?

Heat generated by buildings and emitted into the atmosphere around the city contributes to the UHI effect. A green roof will reduce heat loss and retain water in cool and temperate climates. A 'blue' (or pond) roof can be used as a free source of either heat or coolth, depending on the climatic region. Especially in regions and seasons where air conditioning has become the normal response to thermal discomfort, a 'white' (or cool) roof will reflect solar radiation (the albedo effect) without raising the urban air temperature, keeping buildings and cities cool and reducing urban energy consumption and carbon emissions.

Links with rules 1, 40, 45, 57, 58, 62, 80

RULE 66



CHAPTER 4
DESIGNING FOR HUMAN WELLBEING

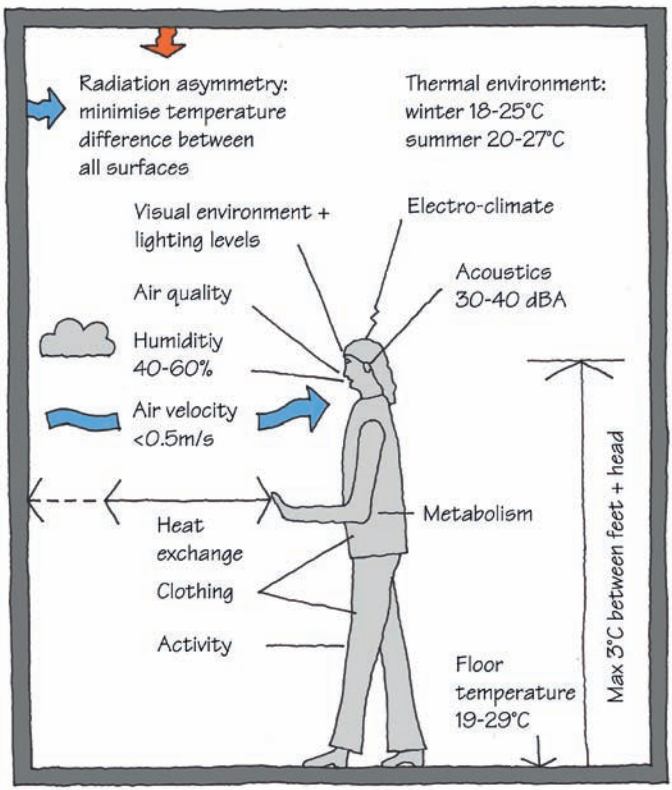
- Human comfort
- Creating healthy, stimulating buildings and cities

67. YOU CAN'T PLEASE ALL OF THE OCCUPANTS ALL OF THE TIME

Because human comfort is a variable, personal state of mind related to the human senses, up to 20% of occupants will at times be unhappy with their environment. But irrespective of building size, function or global location, we can provide interior environmental conditions in which the majority of people do not feel uncomfortable. The factors influencing human comfort need to be understood if our buildings are to provide ever-greater levels of environmental comfort, day and night, in all seasons and regions, while using fewer of the world's resources and less energy.

Links with rules 1, 9, 16, 45, 53, 68, 75, 84

RULE 67



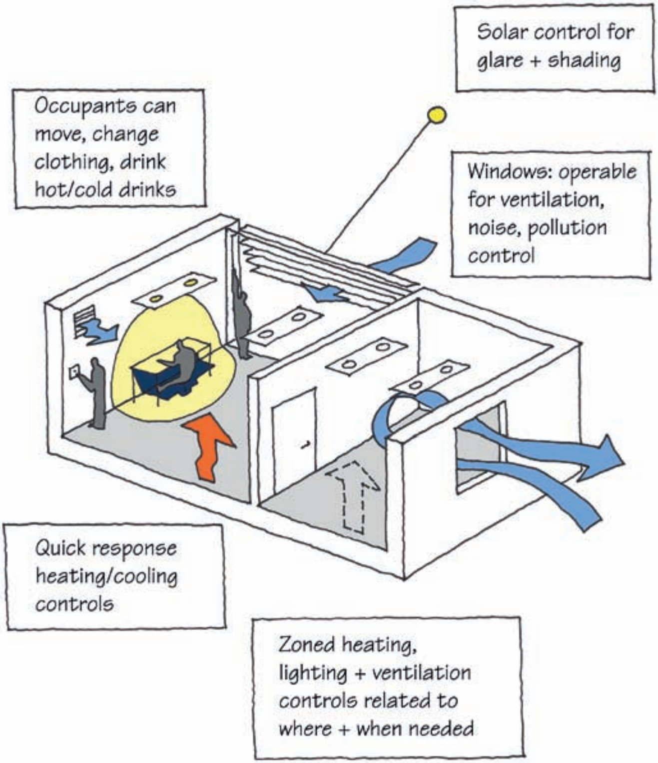
Radiation asymmetry: minimise temperature difference between all surfaces
Thermal environment: winter 18-25°C summer 20-27°C
Visual environment + lighting levels
Electro-climate
Acoustics 30-40 dBA
Air quality
Humiditiy 40-60%
Air velocity <0.5m/s
Heat exchange
Metabolism
Clothing
Activity
Floor temperature 19-29°C
Max 3°C between feet + head

68. OCCUPANT CONTROL MEANS SATISFACTION

People like to be able to control their environment. Even buildings with computer-controlled environmental management systems, designed to the highest standards of energy efficiency, with super-insulation, airtightness, heat-recovery systems and automated solar control incorporated, need to offer user control. If not, they will be perceived as unsuccessful. Controls need to respond quickly and directly to occupants' needs and behaviour, without compromising overall environmental performance, and they need to be easy to use.

Links with rules 1, 16, 45, 67, 75

RULE 68



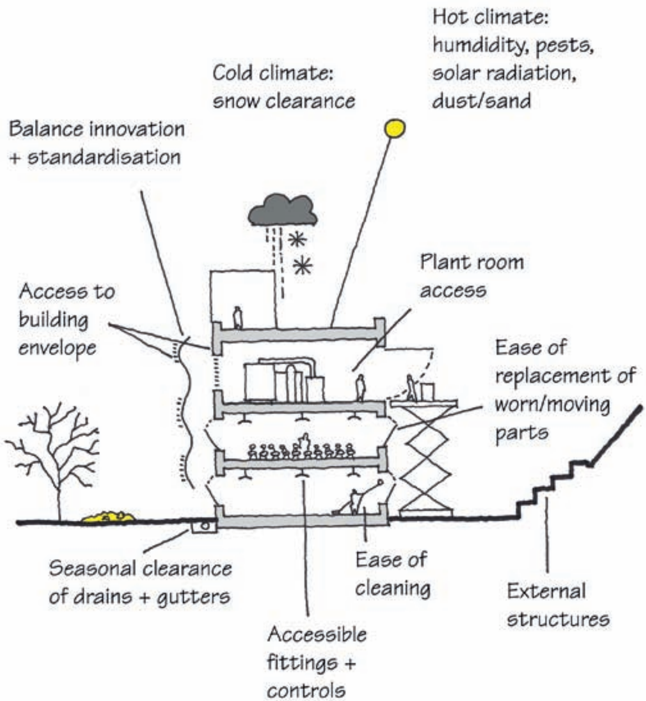
Solar control for glare + shading
Occupants can move, change clothing, drink hot/cold drinks
Windows: operable for ventilation, noise, pollution control
Quick response heating/cooling controls
Zoned heating, lighting + ventilation controls related to where + when needed

69. IF IT'S NOT MAINTAINABLE IT'S NOT SUSTAINABLE

Poorly maintained buildings will fail, wasting resources (materials, energy, water) and damaging the environment. A low-maintenance future must be designed-in from the start of a project, and might require innovation in external structures. Compare options for the initial-versus-operating costs of components, services and materials, remembering that design innovation brings both risks and rewards. Establish a regular cycle for safe, environmentally conscious maintenance and cleaning, inside and outside, with locally sourced materials, parts and contractors, while ensuring the building remains occupied throughout. Design damp and decay-resistant, ventilated construction, appropriate for your climate region.

Links with rules 1, 2, 5, 12, 13, 37, 38, 45, 54, 72, 73

RULE 69



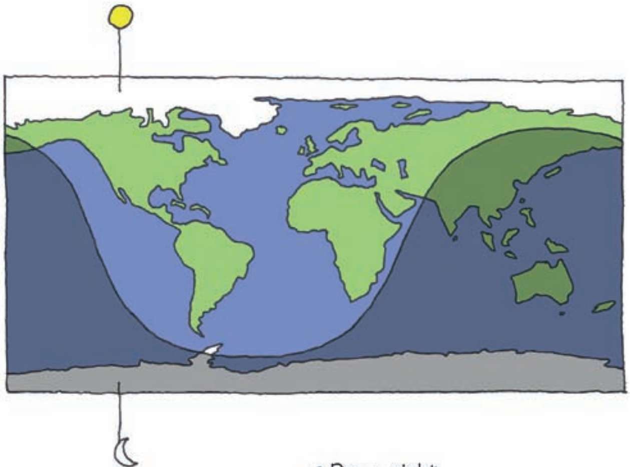
Hot climate:
humdidity, pests,
solar radiation,
dust/sand
Cold climate:
snow clearance
Balance innovation
+ standardisation
Plant room
access
Access to
building
envelope
Ease of
replacement of
worn/moving
parts
Seasonal clearance
of drains + gutters
Ease of
cleaning
External
structures
Accessible
fittings +
controls

70. PROVIDE CONTACT WITH THE RHYTHMS OF NATURE

We have lost contact with the natural rhythms of the world. Contact with nature provides us with a sense of place and of wellbeing. Before we had the power to create tempered, uniform internal environments we would seek out the best place in our buildings to accomplish our tasks, moving in response to varying conditions of the day or the seasons of the year. Ensure, through good design, that opportunities are provided for connections with the natural world in its great variety of ever-changing conditions of sunshine, daylight, wind, weather and sound.

Links with rules 1, 45, 53, 54, 71, 74, 78, 96

RULE 70



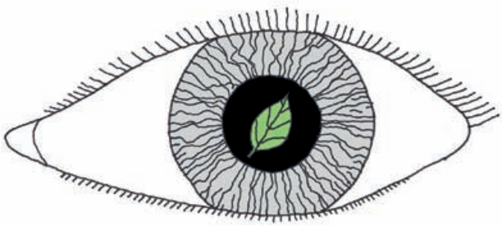
- Day + night
- Sunrise + sunset
- Climate + weather
- Moon + tide
- Daily + monthly, seasonal annual cycles and events

71. LET GREEN BE SEEN

Green is the easiest colour for humans to view, due to its position in the spectrum and the anatomy of the human eye. So green is a restful colour, making it an essential antidote to our hectic lives. Provide green landscaped spaces, no matter how small, to provide relief from the noise and pollution of our frenetic cities.

Links with rules 1, 45, 70, 80, 82, 96

RULE 71

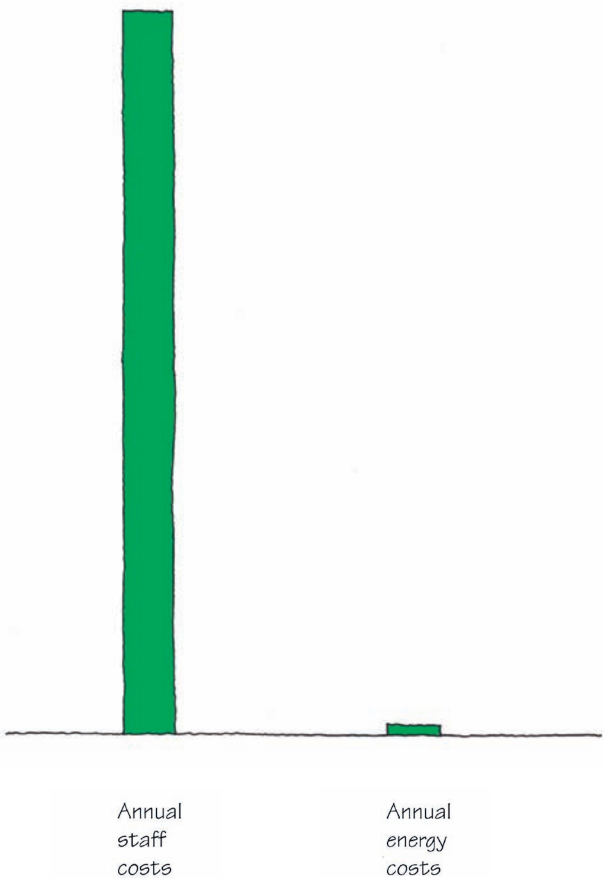


72. HEALTHY BUILDINGS PAY

An organisation's staff bill might be 100 times its energy bill annually. So even if it is energy efficient, a 'sick building', which is unpleasant and unhealthy to work in, causes a loss of staff productivity and high turnover, and so is very costly to operate. These are measures of an unsustainable building. Consideration of both internal and external environmental conditions is essential in the making of healthy buildings in which people will want to work.

Links with rules 1, 6, 37, 45, 69, 73, 74, 75

RULE 72

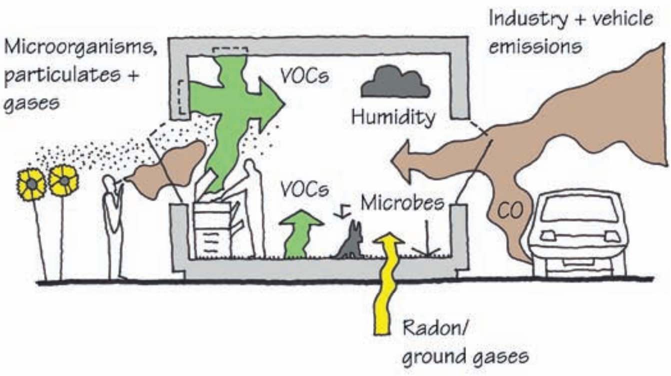


73. RAISE YOUR IAQ

The smell of a new car results from the emission of toxic gases, and something similar is happening in our buildings. Poor Indoor Air Quality (IAQ) contributes to ‘sick building syndrome’. The causes are numerous, including inadequate ventilation, the infiltration of external pollutants such as microorganisms and carbon monoxide (CO), as well as furniture and materials off-gassing. Volatile Organic Compounds (VOCs) emitted by paints, carpets, insulation and photocopiers are particularly unhealthy. Low IAQ is exacerbated by high temperatures and humidity. Its effects can be annoying, debilitating or even life threatening. Raise your IAQ with careful materials specification and adequate ventilation.

Links with rules 1, 6, 37, 45, 69, 72, 75, 80, 88

RULE 73

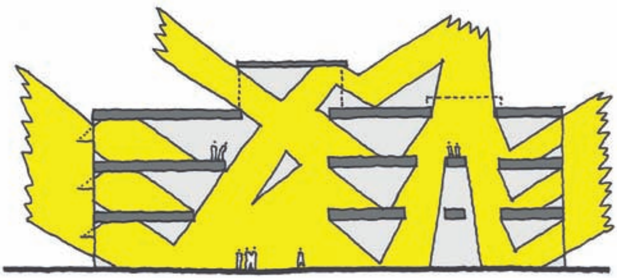

Microorganisms, particulates + gases
VOCs
Humidity
Industry + vehicle emissions
VOCs
Microbes
CO
Radon/ ground gases

74. DON'T BE SAD

Lack of daylight in our buildings disturbs human circadian rhythms and is linked with the medical condition Seasonal Affective Disorder (SAD). Daylit environments reduce stress and improve health and wellbeing. SAD results in fatigue, loss of concentration and disturbance to mental health. Its effects are more extreme the further from the equator we live, and particularly in winter. SAD occurs mostly in buildings where occupants spend many daytime hours indoors and in lighting levels of less than 1,000 lux. Daylight is free and plentiful, so maximise its use while controlling glare and unwanted solar gain.

Links with rules 1, 6, 45, 60, 62, 70, 72, 84

RULE 74

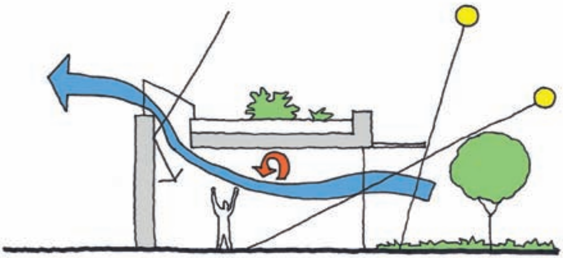


75. PUSH FOR A POE

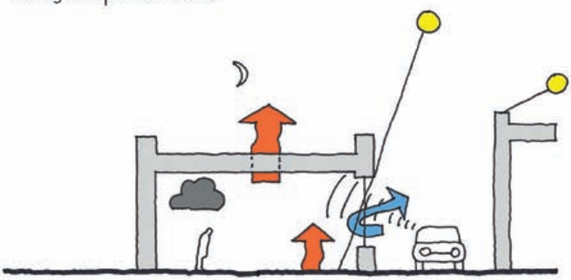
Increasingly, many public institutional as well as private clients demand a Post Occupancy Evaluation (POE). Traditionally, a design-and-construction team, on completion of a building project, disbands and moves on to the next job. There is no evaluation of whether the building achieves what it was intended to, whether environmentally or in terms of occupant satisfaction. Sustainable buildings must operate well at many levels, so it is essential to evaluate and take action on their performance for two years or more after completion. Incorporate cost and time allowances for testing and tuning your building post-occupancy.

Links with rules 1, 3, 5, 45, 67, 68, 72, 73

RULE 75



Designed performance



Actual performance ?

76. HERITAGE OR HISTORY?

Historian Roy Porter wrote, ‘when buildings take precedence over people, we get heritage, not history.’ A sustainable city exists for its citizens and will successfully combine the new and the old, maintaining vitality, linking the present and future with the past in a meaningful way. The built heritage of the city should be part of an ever-developing collage, requiring contemporary judgments about those aspects of history we wish to retain, and how.

Links with rules 1, 2, 11, 41, 45, 54, 81, 83, 86, 100

RULE 76

77. THE ACTIVE CITY IS A HEALTHY CITY

There is a link between active urban living and quality of human health. In many modern, mono-centric, car-dependent cities, ready access to safe opportunities for daily physical activity are limited. Even as they provide compact and dense urban living/working environments, cities must support opportunities for regular physical activity for all of society. People will use their feet if the public realm is attractive: design opportunities for walking and cycling, exercising and sport, gardening and urban farming.

Links with rules 1, 18, 45, 46, 80, 81, 82, 83, 101

RULE 77

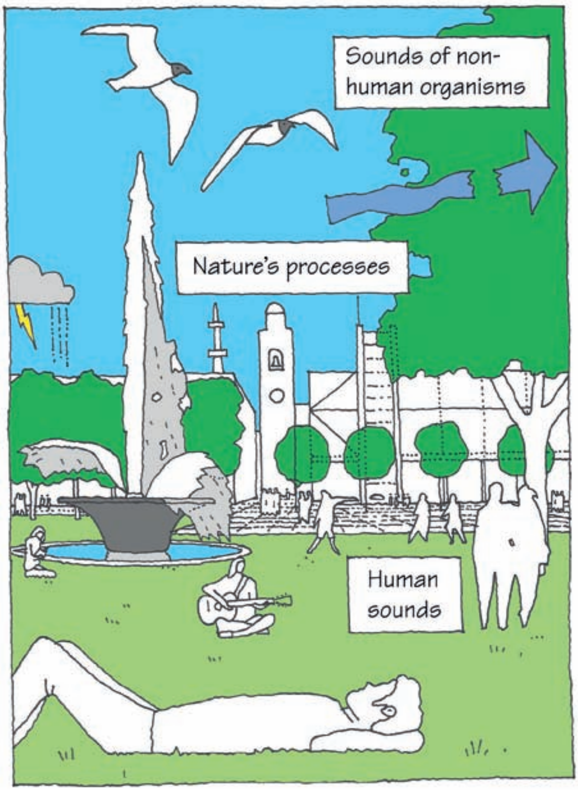
Walk to park/recreation	0.4km
Walk to allotment	1.6km
Walk to work	3.2km
Cycle to work	16km

78. THE AUDIBLE CITY IS A STIMULATING CITY

There is a great variety of exciting and inspiring sounds in our cities, if we wish to hear them. The weather, the activities of people and birdsong provide a poetic acoustic backdrop to daily urban life. The psychologically rewarding soundscape of the city is an integral part of our connection with place. Pleasant natural sounds such as moving water and the wind in trees mask unpleasant sounds. Most of us associate the sounds of nature with tranquility, and human sounds connect us with society; encourage connections between townscape and soundscape.

Links with rules 1, 45, 70, 79, 80, 100

RULE 78



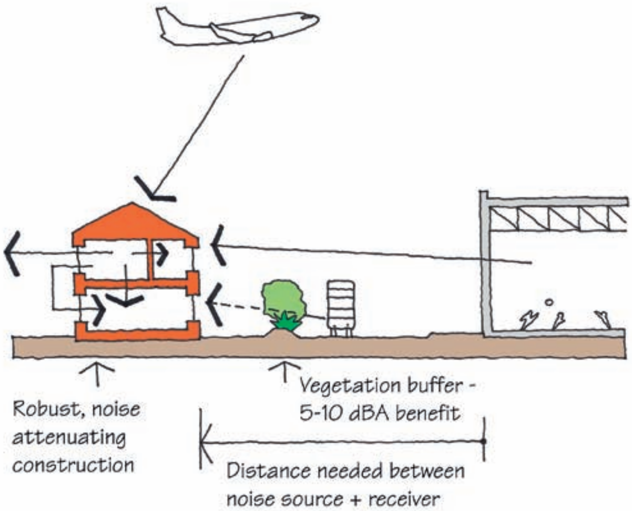
Sounds of non-human organisms
Nature's processes
Human sounds

79. UNWANTED SOUND MEANS A NOISY CITY

Sound that disturbs us is noise: a cause of health and social problems. Noise sources such as traffic, industry, sports and music events can, if poorly planned, disturb other activities in daily life such as working, relaxing or sleeping. Our urban streets, squares and parks also suffer from noise, limiting their usefulness to humans and driving out wildlife. A green buffer near to the source can help reduce noise. Internally, noise travels between floors and walls, creating further disturbance. Put distance between noise-generating and noise-sensitive functions, and attenuate noise both outside and within buildings.

Links with rules 1, 45, 78, 80

RULE 79

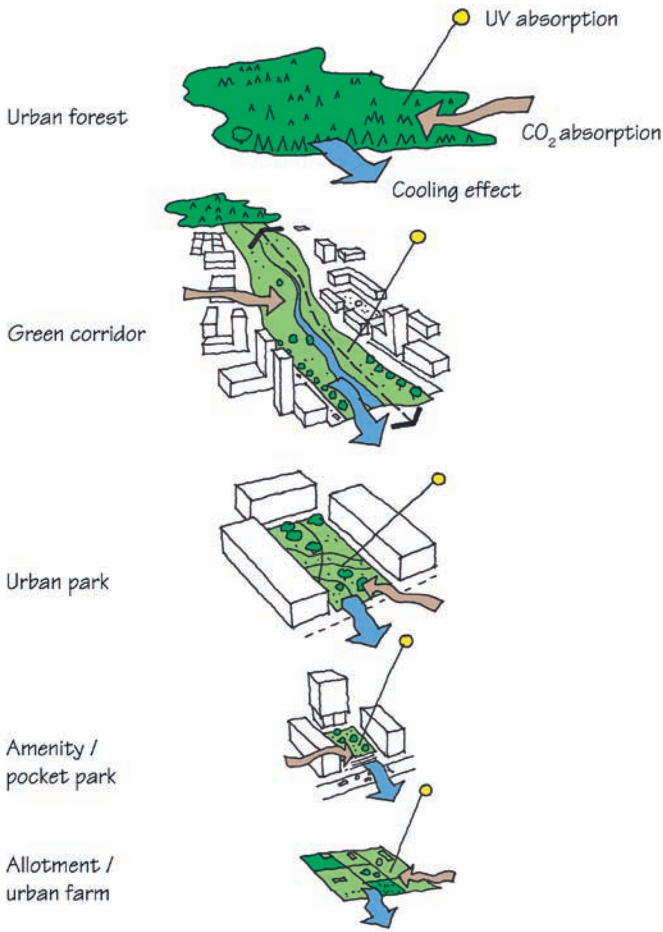

Robust, noise attenuating construction
Vegetation buffer - 5-10 dBA benefit
Distance needed between noise source + receiver

80. THE GREEN CITY IS A HEALTHY CITY

Green spaces are known to be good for city dwellers' mental health and wellbeing. Urban green spaces can take many forms, from the large-scale urban forest to the pocket park. They not only provide for recreation and exercise; urban trees, by absorbing CO_2 and other gaseous pollutants, reduce the UHI effect and improve air quality. Parks along urban watercourses can improve water quality, and urban greening absorbs 85% of damaging UV radiation. Green spaces have a lower temperature than their surroundings: air cooled by them provides a cooling effect for some 150m into the city.

Links with rules 1, 17, 40, 41, 45, 46, 51, 55, 56, 58, 66, 71, 73, 77-79, 82, 96, 100

RULE 80



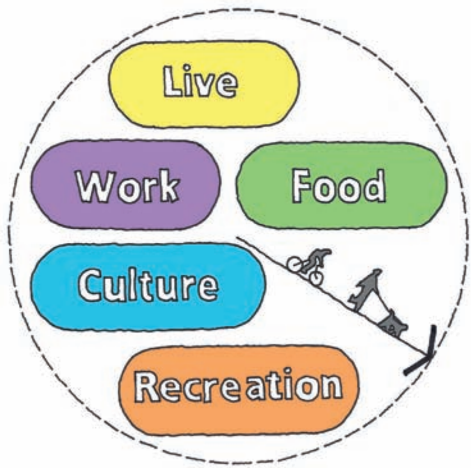
UV absorption
Urban forest
CO_2 absorption
Cooling effect
Green corridor
Urban park
Amenity / pocket park
Allotment / urban farm

81. THE MIXED-USE CITY IS A VIBRANT CITY

Office workers living close to their homes are a market for local retail, fresh-food outlets and recreation. The activity generated, day and night, all year round produces a vibrant mixture of humanity in a safe, living neighbourhood. The vibrancy attracts more people and businesses, and local culture and festivities flourish. Overlapping uses mean shorter travel distances, made within a radius achievable by bicycle or on foot, with access to public transport. A mix of housing types attracts those of all ages and needs, and a strong sense of place develops. These are the foundations of the sustainable city.

Links with rules 1, 18, 45, 51, 76, 77, 83, 97, 100, 101

RULE 81

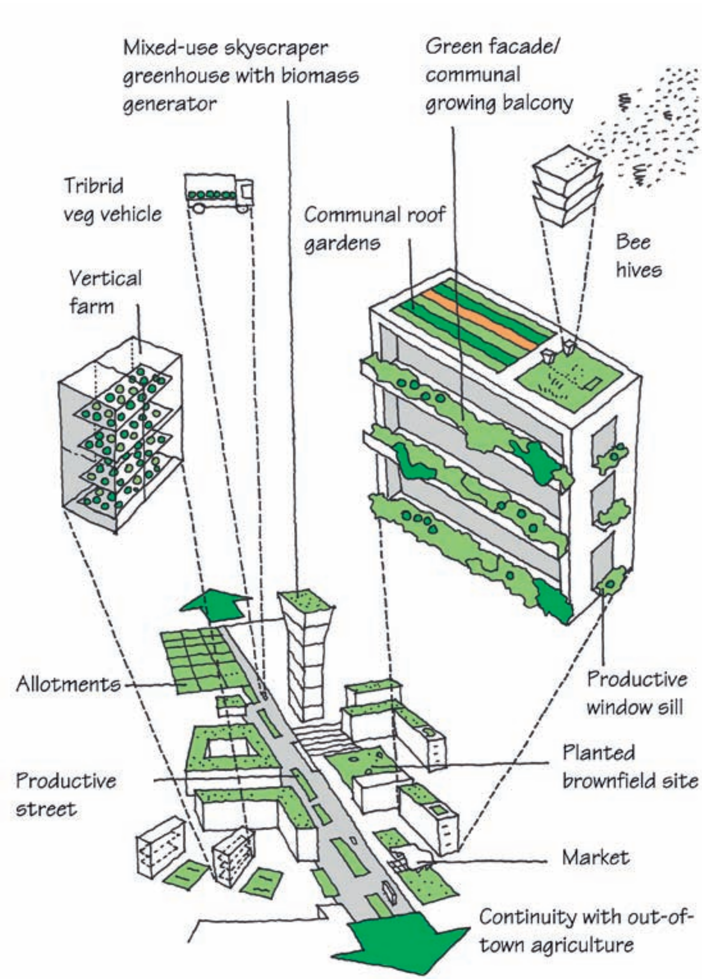


82. THE 'EDIBLE CITY' FEEDS ITSELF

Cities and their citizens are increasingly at risk from global food shortages; water-supply scarcities, pollution and dependence on transportation (with its attendant CO_2 emissions) to feed the urban population are some of the factors. But with innovative approaches to urban agriculture and food gardening, the city can feed itself, providing a substantial part of its food needs while reducing its environmental footprint. Bring agriculture to the city: imagine a future of the 'edible city'.

Links with rules 1, 41, 45, 71, 77, 80, 98, 99

RULE 82



Mixed-use skyscraper greenhouse with biomass generator
Green facade/ communal growing balcony
Tribrid veg vehicle
Communal roof gardens
Bee hives
Vertical farm
Allotments
Productive window sill
Planted brownfield site
Productive street
Market
Continuity with out-of-town agriculture

83. THE CITY IS FOR EVERYONE

Equity, one of the three pillars of sustainability, is in short supply in our cities: they are becoming more unequal, not less. Every citizen should be able to participate fully in all that the city has to offer, under determined city leadership that seeks fairness in justice, food, shelter, health, education, the environment and opportunity for all. People's voices must be heard and respected from the outset if urban development is to be sustainable. The city, its democratic institutions and its built form must be inclusive, accessible to everyone in a humane society.

Links with rules 1, 3, 18, 45, 76, 77, 81, 100

RULE 83

- Affordable, high quality housing transforms lives
- Improved public transport = opportunity
- Urban prosperity is for all

CHAPTER 5
STRATEGIES FOR SUSTAINABLE BUILDINGS AND CITIES

- Sustainable retrofit
- Sustainable architecture
- Sustainable cities

6 STRATEGIC RULES FOR SUSTAINABLE RETROFIT

84. Begin with building performance: how well it works tells us what needs to be done.

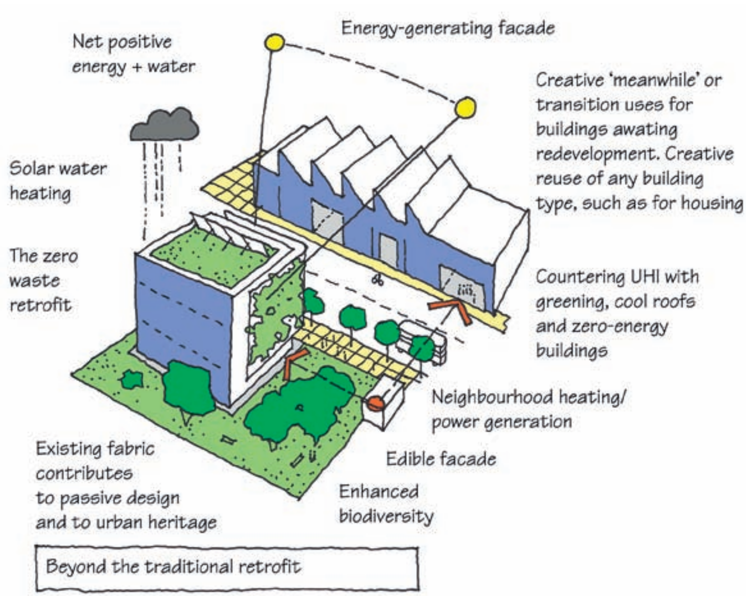
85. Employ integrated thinking: reduce energy use while improving comfort and health.

86. Inventiveness beats wastefulness: employ creative ideas for empty and under-occupied buildings, and to eliminate wasteful fitting-out practices.

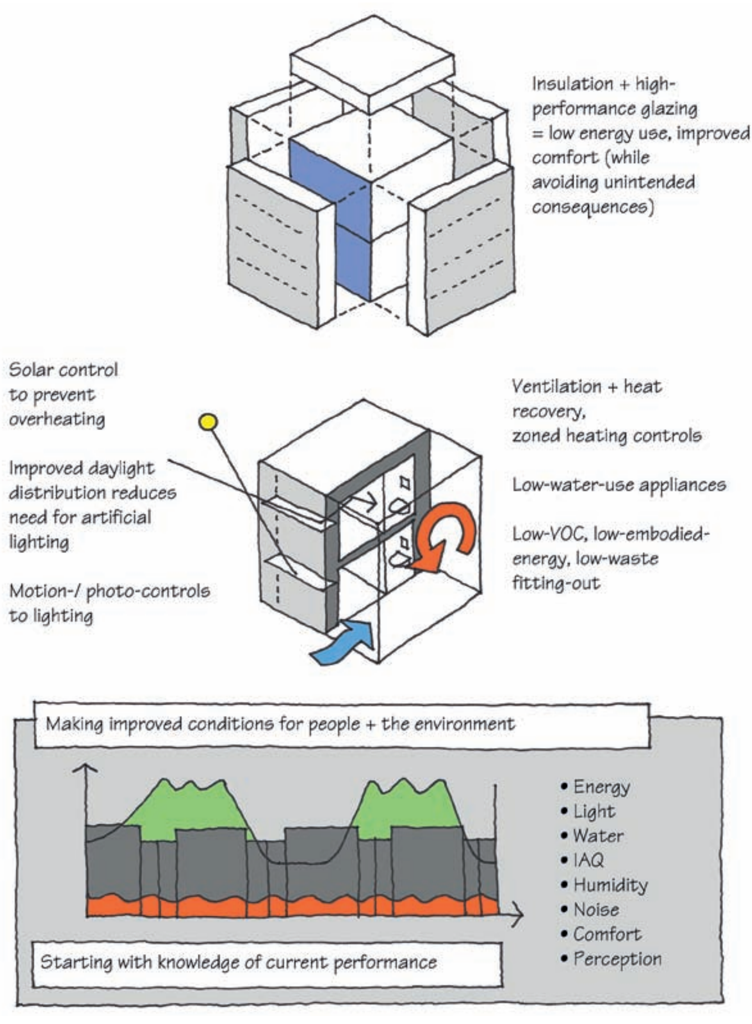
87. Embodied energy recurs: minimise or eliminate the extra embodied energy associated with each re-fit.

88. Avoid unintended consequences: weather sealing and insulation can lead to moisture damage, poor IAQ and overheating.

89. Reject 'greenwash': be wary of false promises of environmental performance.



84 to 89



Insulation + high-performance glazing = low energy use, improved comfort (while avoiding unintended consequences)
Solar control to prevent overheating
Improved daylight distribution reduces need for artificial lighting
Motion-/ photo-controls to lighting
Ventilation + heat recovery, zoned heating controls
Low-water-use appliances
Low-VOC, low-embodied-energy, low-waste fitting-out
Making improved conditions for people + the environment
• Energy
• Light
• Water
• IAQ
• Humidity
• Noise
• Comfort
• Perception
Starting with knowledge of current performance

6 STRATEGIC RULES FOR SUSTAINABLE ARCHITECTURE

90. Think big: the focus must be simultaneously on people, place and planet.

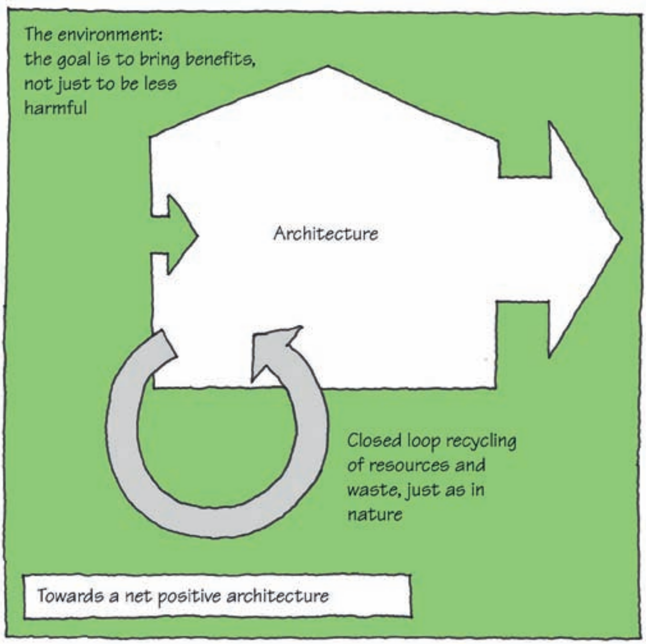
91. Think small: the goal is to reduce resource use, waste and ecological footprint.

92. Think positive: beyond just energy, could a building put back more than it takes out? This would be a 'net positive' outcome.

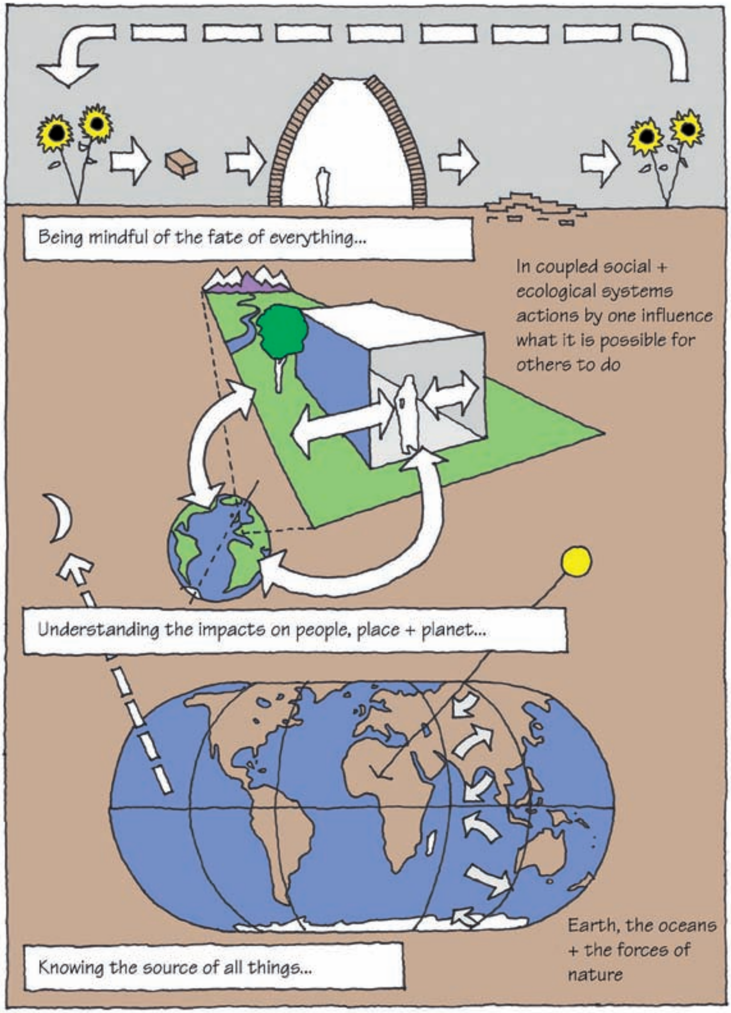
93. Be mindful of the fate of buildings: we know demountable, recyclable, reusable – but what about reversible, exchangeable, compostable, mobile, edible?

94. Be responsible: take on board the ecological, social, ethical and aesthetic responsibilities.

95. Be sensible: apply common sense at all times, and do not be tempted by 'eco-bling'.



90 to 95


Being mindful of the fate of everything...
In coupled social + ecological systems actions by one influence what it is possible for others to do
Understanding the impacts on people, place + planet...
Knowing the source of all things...
Earth, the oceans + the forces of nature

6 STRATEGIC RULES FOR SUSTAINABLE CITIES

96. Nature is the starting point: let place, climate and the forces of nature influence the form of urban (re)development.

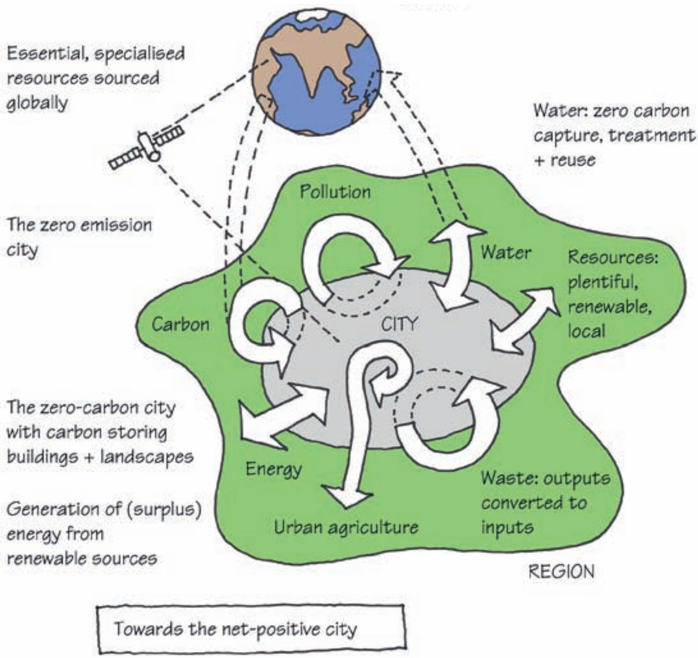
97. Think high-density/low-impact: the goal is a compact city with a compact environmental footprint.

98. Re-establish links between city and region: a symbiotic relationship between the city and its environs benefits citizens, ecology and the environment.

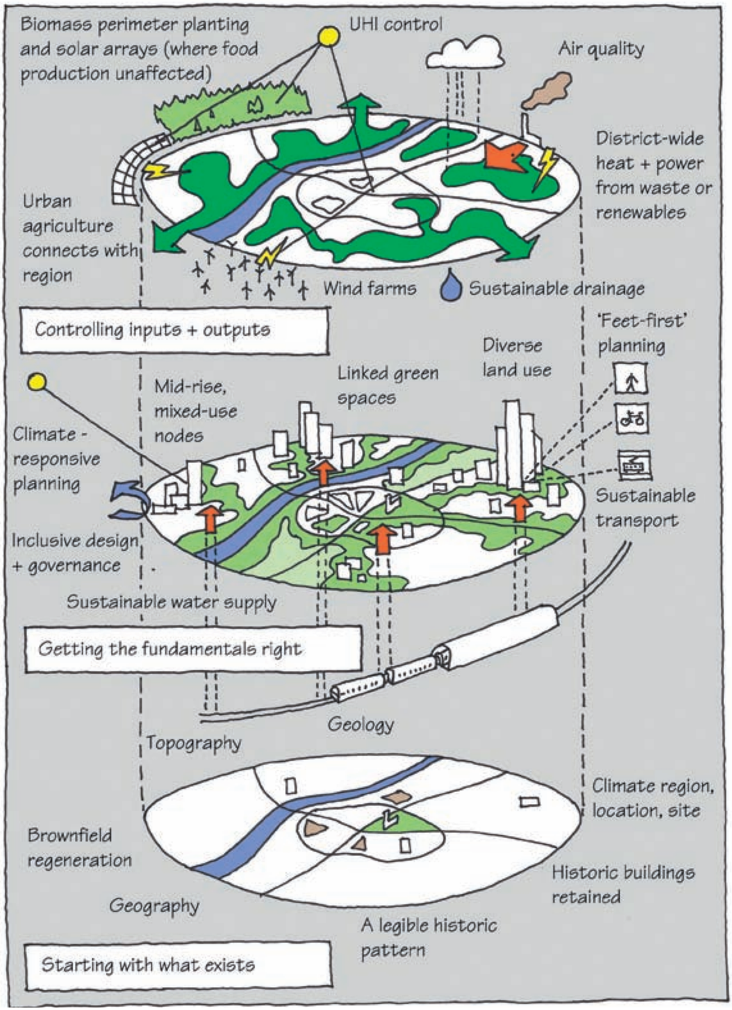
99. Could the city contribute more than it consumes with innovative, 'net positive' solutions to energy, waste, carbon and water?

100. Demand beauty and diversity in the public realm: the liveable city is varied, attractive, biodiverse, walkable, inclusive, connected, clean and safe.

101. Go 'feet first': give priority to cycling and walking in the city.



96 to 101



Biomass perimeter planting and solar arrays (where food production unaffected)
UHI control
Air quality
District-wide heat + power from waste or renewables
Urban agriculture connects with region
Wind farms
Sustainable drainage
Controlling inputs + outputs
'Feet-first' planning
Diverse land use
Linked green spaces
Mid-rise, mixed-use nodes
Climate-responsive planning
Sustainable transport
Inclusive design + governance
Sustainable water supply
Getting the fundamentals right
Geology
Topography
Climate region, location, site
Brownfield regeneration
Historic buildings retained
Geography
A legible historic pattern
Starting with what exists

Notes, observations and references – a narrative bibliography

The books, journals, research papers and websites cited in the following narrative bibliography are a very small selection from a very large pool of resources. They have been chosen because they have been found to be particularly useful in answering this author's inexhaustible questions about sustainability, in explaining things, and as prompts to memory because the subject is too large and complex to keep constantly in mind. Some texts, representing the broad range of topics and issues, sit always close at hand, and these are listed as an author's 'top ten' so that the busy student, professional, client, owner, operator or occupant might find a ready resource to help with any general sustainability-related inquiry.

AUTHOR'S TOP TEN

1. Brian Edwards, *Rough Guide to Sustainability – A Design Primer*
2. Sofie Pelsmakers, *The Environmental Design Pocketbook*
3. Bjorn Berge, *The Ecology of Building Materials*
4. Varis Bokalders and Maria Block, *The Whole Building Handbook*
5. Peter Jacques, *Sustainability – the Basics*
6. Paola Sassi, *Strategies for Sustainable Architecture*
7. Howard Liddell, *Eco-minimalism – the Antidote to Eco-bling*
8. Janis Birkeland, *Positive Development – From Vicious Circle to Virtuous Cycles Through Built Environment Design*
9. Alison Kwok and Walter Grondzik, *The Green Studio Handbook*
10. Adam Ritchie and Randall Thomas, eds, *Sustainable Urban Design – An Environmental Approach*

Two favourite classics:

Bernard Rudofsky, *Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture*

Baruch Givoni, *Climate Considerations in Building and Urban Design*

Two very short 'must-reads':

Camilla Ween, *Future Cities – All That Matters*

Adam Ford, *Mindfulness & the Art of Urban Living*

CHAPTER 1. THE PRINCIPLES OF SUSTAINABILITY

1. Our single, bounded planet

There are limits to the rate at which the planet can support food production (due to availability of land, sun and water), cleansing of air, resource extraction and waste processing in relation to the ever-increasing global population. The international, non-governmental body the WWF estimates that three earths would be needed to support a population where all nations' consumption and waste-generation patterns conformed to those of the UK today. Pooran Desai and Sue Riddlestone, in *Bioregional Solutions For Living on One Planet* (2007, p28), conclude that six planets would be needed if globally we consumed at US levels (the WWF figure is four). Viewed in a different way, it has been stated by the Global Footprint Network that today the earth takes one and a half years to regenerate what we consume in one year. There is much detailed discussion and data on national ecological footprints available on the website of the Global Footprint Network and a good source for global population projections is the United Nations Population Division.

2, 3 and 4. Sustainability: definitions and perspectives, ethics and values

In an excellent introduction to the subject of global human sustainability, Peter Jacques, in the primer *Sustainability – the Basics* (2015, pp1–14 and 39–41), confirms that there is no single, positive definition but suggests that, at one level, to sustain something is simply to keep it going. The author describes (p41) 'weak' sustainability (focused on economics, assuming the market will find solutions) and 'strong' sustainability (focused on ecology, requiring substantial changes in behaviour). There is a very useful glossary of terms in this book (pp205–13). There are many definitions of sustainability in relation to the built environment, and Jeremy Gaines and Stefan Jäger, in their *Albert Speer & Partners – A Manifesto for Sustainable Cities* (2009, p16) suggest that sustainability means acting locally while thinking globally, a phrase in common usage today. Aiming at greater precision, Daniel Williams, in *Sustainable Design – Ecology, Architecture, and Planning* (2007, p3), tells us that sustainability is achieved by using local, renewable resources. The author points out that sustainability must be embedded in the design process (p14) and in Chapter 2 introduces the characteristics and processes of sustainable design, with a very clear and helpful list of criteria that all projects should achieve (p21). The UK Building Services Research and Information Association (BSRIA) tells us that sustainable construction would embody the following principles:

- Minimising non-renewable resource consumption
- Enhancing the natural environment
- Eliminating or minimising the use of toxins

Sustainable design is a multidisciplinary process that must start at the conception of a project, and which cannot be 'bolted on' later. This is true for new-build, retrofit and interior work. Lisa Tucker, in *Designing Sustainable Residential and Commercial Interiors – Applying Concepts and Practices* (2015, p2), confirms also that the whole design team must be involved.

Many authors speak of 'ecological design' when they refer to sustainability, indicating the prominence given to ecological and environmental issues. But sustainability is also viewed as the 'triple bottom line': social, economic and environmental issues being balanced within its remit. A building will not be sustainable if, for example, it is ecologically sound but society cannot afford it or does not have the skills to operate it. In an important discussion of emerging trends, Brian Edwards, in the *Rough Guide to Sustainability* (2014, pp315–28), points out how society currently incorrectly values certain materials and products over others, reminding us that sustainability is a matter of ethical responsibility: for example, it is a professional obligation to source materials which have been won without the exploitation of ecosystems and human labour.

Definitions of sustainable development, and the history of attempting to define it, may be explored in sustainable urbanist Stephen M. Wheeler's comprehensive and well-structured primer, *Planning for Sustainability: Creating livable, equitable and ecological communities* (2013, pp30 and 31). Wheeler's preferred definition (his own) is: 'Sustainable development is development that improves the long-term health of human and ecological systems.' Darko Radovic, in *Eco-Urbanity* (2009, pp9–16), contends that both the 'eco-sphere' and the 'socio-sphere' are currently threatened, but a central, optimistic theme of his essay is that sustainability and urbanism can indeed live together.

5. Design in six dimensions

There are many tools available to assist the sustainable design process. These tools include those used for analysis of options (of orientation, form, sun, wind, daylight, energy use, materials and waste) in a 3D-CAD Building Information Modelling (BIM) model as well as Life-cycle Analysis (LCA), in which the environmental impact of a material is measured. Varis Bokalders and Maria Block, in *The Whole Building Handbook* (2010, pp9–13 and 206-207), consider the applicability of various LCA methods, which will, when used with BIM, ultimately become the norm in sustainable design, and the *BRE Green Guide to Specification* uses LCA to evaluate common materials and components.

In the UK the government will require, from 2016, all its projects to be developed electronically through BIM, with the goal of enabling interdisciplinary design teams to reduce costs and carbon emissions through 5-dimensional project LCA. Eddy Krygiel and Brad Nies, in *Green BIM; Successful Sustainable Design with Building Information Modeling* (2008), provide a very accessible general account of the entire process from a practitioner's viewpoint; theirs is still considered a leading text. Written by and for architects, François Lévy, in *BIM in Small-Scale Sustainable Design* (2012), provides a detailed, illustrated account of the design and documentation processes for all the key aspects of sustainable design with BIM. A 6D model is now described, in which the final built project information and operating instructions are handed to the client for interactive facilities management.

6. How 'green' is your building? (Shades of green)

Ken Haggard et al, in the *Passive Solar Architecture Pocket Reference* (2009, p80), explain that a 'light-green' building will have reduced electricity usage, while a 'deep-green' building would do this and more, but would also be conceptually different, employing an integrated design approach and focusing on passive and renewable techniques. In the *Rough Guide to Sustainability* (2014, pp209–20) Edwards (with Emanuele Naboni) provides us with his own 'Blueprint for Green Design', which deals with the briefing process, flexibility, passive design, simplicity in operation, longevity, renewables and ease of maintenance/upgrading.

Tom Woolley et al, in the introduction to the *Green Building Handbook – a Guide to Building Products and Their Impact on the Environment Vol 1* (1997 Part 1), discuss the use of the term 'green' and provide their explanation of what 'green building' means: an uncompromising, holistic approach to sustainable design and development – although the authors allow that many of the common terms (green, sustainable, ecological, etc) are interchangeable. They set out a useful framework for green building, neatly summarised in four principles:

- Reducing operational energy use
- Minimising external pollution and environmental damage
- Reducing embodied energy and resource depletion
- Minimising internal pollution and damage to [occupant] health

David Clark, in *What Colour is Your Building?* (2013 pp83–231) defines a framework for designing green buildings from the perspective of low-energy use and overall low-carbon footprint, including materials choices.

Retrofitting is discussed by Janis Birkeland in *Positive Development – From Vicious Circle to Virtuous Cycles Through Built Environment Design* (2008, p40), with a very good diagram of the levels of sustainable retrofitting – from minimal to full-scale, regenerative 'eco-retrofit'.

7, 8 and 9. The environment: definition, scales, local and global impacts

Thomas Carlyle is said to have coined the term 'environment' in his translation of Johann Wolfgang von Goethe's phrase *Umgebung* in 1828, in an acknowledgement of humankind's negative influence on the planet. A useful definition in ISO 14001 is 'surroundings in which an organization operates, including air, water, land, natural resources, flora, fauna, humans, and their interrelation'. That interrelation takes place at all scales of the environment.

Researchers in the complex field of scale theory confirm that action at one scale of the environment impacts on other scales, and that those scales have both spatial and temporal parameters. In other words, short-term, local activities in relation to ecology (such as with climate change) have longer-term global consequences. Theory and practice indicate that those consequences may be felt in quite different locations to the source. Further discourse may be found in a study by Thomas Wilbanks in *How Scale Matters: Some Concepts and Findings, in Bridging Scales and Knowledge Systems – Concepts and Applications in Ecosystem Assessment* (2006, Chapter 2).

Desai and Riddlestone, in *Bioregional Solutions For Living on One Planet* (2002, p16), introduce us to their notion of thinking globally and acting locally, evidence of an understanding of the interconnectedness of the scales of environment, and the authors demonstrate, while describing their inspirational entrepreneurism, that what we do locally can have a positive effect globally.

10 and 11. Is the greenest building the one that isn't built, or the one that is already built?

These two phrases have found their way into common usage, and both have their place in the green lexicon. Woolley et al, in the *Green Building Handbook* (1997, p14) are amongst only a few authors who discuss the crucial consideration of whether to build a new building, convert an existing one or, indeed, whether to build at all. Sometimes a new building is the only answer, and sometimes a hybrid solution fits best. Clark, in *What Colour is Your Building?* (2013, p186), concludes that if a building can be refurbished to significantly reduce operating energy then it is likely that refurbishment will be the lowest-carbon solution. Charles Lockwood, an author on green business strategies, tells us in the article *Building*

Retro Fits (2009) that refurbishment is often seen as a lower-risk option, especially in a poor economic climate. Increased workforce satisfaction and productivity are seen as key benefits of retrofit. Edwards, in the *Rough Guide to Sustainability* (2014, p194) gives a useful table with typical timeframes for improvements to the various components and systems within a building, while reminding us that each upgrade provides a parallel opportunity for ecological/environmental upgrading. The need for a focus on retrofitting of the UK housing stock is discussed in detail by Sofie Pelsmakers in *The Environmental Design Pocketbook* (2015, Chapter 8) in a section that includes the measures to be taken, while Penoyre & Prasad (Sunand Prasad et al), in *Retrofit for Purpose – Low Energy Renewal of Non-Domestic Buildings* (2014), illustrate a combination of alternative thinking (such as rethinking of work patterns) and practical retrofit solutions. Bokalders and Block, in *The Whole Building Handbook* (2010, Chapter 4.3), provide information (pp611–24) on assessments, operational issues, maintenance cycles and details of low-energy-use refit techniques.

12 and 13. Longevity and flexibility

Paola Sassi, in the essential reference text *Strategies for Sustainable Architecture* (2006, Chapter 4.1), considers, with the help of case studies, design for longevity and makes a connection between longevity and flexibility. The author reveals (pp154 and 155) how a building might be designed to be flexible socially (such as for an increasing or decreasing family size) or because of new technologies. Bokalders and Block, in *The Whole Building Handbook* (2010, pp646 and 647), discuss the fact that built-in flexibility can be wasteful. Randall Thomas, in *Environmental Design, an Introduction for Architects and Engineers* (2006, p72), offers criteria for longevity of buildings, including:

- Design excellence, leading to public acclaim and therefore to a building that will be maintained
- High-quality and durable materials and design solutions, minimising the need for refurbishment

Further, related narrative may be found in Rule 19 and in Chapter 5 of the current volume.

14, 15 and 16. Carbon dioxide, fossil fuels, global warming and climate change: the influence of buildings, cities and people

The United States Environmental Protection Agency (EPA) has a useful summary of the global CO_2 position in the section Overview of Greenhouse Gases on its website. Clark, in *What Colour is Your Building?* (2013, p12), cites the very significant global reliance on fossil fuels for energy production, and he is one author who makes the point that people (occupants) have a major influence on building energy performance. Reduced energy consumption is the most important strategy (p180), and the author cites the human factor in one of his '10 steps' to reduced energy consumption (p85). Bokalders and Block, in *The Whole Building Handbook* (2010, p277), explain that the variation in energy use in a household due to users' habits is around +/- 50%.

Pelsmakers, in *The Environmental Design Pocketbook* (2015, Section 1.1), provides a neat overview of the relationship between the building industry, CO_2, global warming and climate change. The author reminds us that 50% of CO_2 from human sources is not reabsorbed by forests or oceans. The principle of Contraction and Convergence, an equitable means of reducing total global carbon emissions by considering per capita emissions by country, is also discussed (p15). For more detail, including the science and the political framework, Chapter 1 of the *Rough Guide to Sustainability* (2014, pp3–27) by Edwards gives an excellent account, including the specific challenges for the built environment. Urbanisation is *the* cause of the overall increase in CO_2 emissions (p9), and we are reminded that living patterns have a significant effect, as we consume more and expect more in our drive for an urban life.

17. We are an urban species

Dennis Rodwell, in *Conservation and Sustainability in Historic Cities* (2007, p112), states that environmental consumption and degradation are focused in the city, and Gaines and Jäger, in their well-structured and strongly argued *Manifesto for Sustainable Cities* (2009, p16), remind us that sustainability and urban planning are closely linked because, since the year 2000, more people live in cities than in rural areas. The trend towards urbanisation is set to continue. Edwards provides us, in the *Rough Guide to Sustainability* (2014, pp11–13) with a concise summary titled 'The trouble with cities', in which he identifies the nature of stresses placed on people and the planet in our cities and mega-cities. Clark, in *What Colour is Your Building?* (2013, pp13–15), describes the cycle that connects cities with climate change: swings in temperature leading to increased heating or cooling, requiring more energy, resulting in increased warming, contributing to further climate change. Rob Adams, in his rounded essay on the environmental successes achieved in the Australian city of Melbourne in *Eco-Urbanity* (ed Radovic, 2009, pp33–46), re-establishes the connection between the migration of humanity to cities and cities' CO_2 levels. Strong city leadership is cited as a key strategic tool in reducing a city's emissions, and an interesting aspect is the major benefit of relatively simple solutions: buying-in greener energy sources, switching to reduced-energy-use electrical and lighting equipment, and re-greening streets to create shade, reducing the impact of the Urban Heat Island (UHI) effect.

18. Transportation: the connection between buildings, cities and climate change

The United States Environmental Protection Agency (EPA) states that 95% of the energy used for transportation globally is derived from fossil fuels, mainly petrol (gasoline) and diesel. While buildings are the source of nearly half of all manmade greenhouse gas (GHG) emissions, Edwards reminds us, in the *Rough Guide to Sustainability* (2014, p7), that half of the remaining emissions come from the transportation we use in moving people and products between buildings. Professor David MacKay tells us, in *Sustainable Energy – Without the Hot Air* (2009, p121), that public transport is between five and ten times more energy efficient than car use. There is a very thorough chapter on the issues and solutions by Adam Ritchie and Randall Thomas in *Sustainable Urban Design – An Environmental Approach* (2009, pp21–30), in which the authors conclude that the aim must be to reduce the need to travel, using public, low-emission vehicles in a high-density, mixed-use city. Ritchie, in his introduction to the same book (pp 3–11), makes the important statement that density, transportation (or how we move around the city) and energy are linked, and that energy per capita decreases with urban density (p6). Transport energy, and consequently transport carbon, are further discussed by Clark in *What Colour is Your Building?* (2013, pp70 and 71). From a case study of an out-of-town office, the author concludes that transport carbon can be higher than carbon generated by the operation of buildings. In Chapter 9, Clark provides practical solutions for reducing transport energy, and here the author discusses emissions reductions from home working. Considering the other end of the journey, Desai and Riddlestone, in *Bioregional Solutions For Living on One Planet* (2002, p23), conclude that there is limited value in building energy-efficient housing if we continue to commute by car. The 'Tribrid' vehicle is defined in Ken Yeang and Lillian Woo's *Dictionary of Ecodesign: An Illustrated Reference* (2010, p243).

Energy and carbon data for transportation may be found in the European Environment Agency's report *Energy efficiency and energy consumption in the transport sector* (2012).

19 and 20. Design for adaptability and resilience

Adaptability is a key attribute of sustainable architecture, but it is rarely evidenced in built works. While flexibility, which is the 'loose fit' in Rule 13, refers to the capability of making short-term changes to fabric and systems, adaptability is the facility to accommodate larger, long-term change, such as a major change of use, or even a change of location. Often the two terms are used interchangeably in architecture. Today, adaptability is most often discussed in relation to climate change, although there are other dimensions to it.

Climate-change resilience of cities and their infrastructure (roads, railways and airports) has become a topic of increasing concern to governments and private-sector operators, with sea-level rise and extreme weather events a serious concern. In the book *City Design: Modern, Traditional, Green and Systems Perspectives* (2011, Chapter 3), Jonathan Barnett provides (along with a neat summary of the history of urban design) a useful depiction of the mechanisms and impacts of climate change on cities, with a particular focus on coastal settlements.

There is a relationship between adaptability and resilience because resilience might be planned for but not implemented initially, requiring adaptability in future. Bill Gething and Katie Puckett, in *Design for Climate Change* (2013, p115), identify the issues surrounding construction in a changed climate under the following headings:

- Structural stability (and the particular vulnerability of existing buildings)
- Weatherproofing, details and materials
- Site work

Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp45–57), provides a chapter dedicated to design strategies for climate change. It contains helpful design checklists and discussion on the importance of future-proofing our buildings. Issues of durability of materials in relation to climate change are covered in *The Ecology of Building Materials* (2009, Part 1.1.2) by Bjorn Berge. The author reminds us (pp12 and 13) that there will be an acceleration of decay in wetter climates, and thermal stress and insect problems in hotter and drier regions. Building-materials choices must therefore be climate/region specific. An annual global forum, Resilient Cities, publishes its yearly congress reports containing information on climate-related incidents and success stories, including the outcomes of its building and construction forum.

21. Off-grid

One chapter headline in Vishaan Chakrabarti's *A Country of Cities – A Manifesto for Urban America* (2013 p78) is 'if you love nature, don't live in it', and the author states that urban living is greener and more sustainable than suburban lifestyles. Living in nature is not a sustainable solution: it requires more resources and results in greater land loss and a larger carbon footprint (p81). Desai and Riddlestone, in *Bioregional Solutions For Living on One Planet* (2002, p75), comment that self-sufficiency is an impediment to the creation of specialisms (such as craftspeople, artists and scientists) in a society. The notion of an off-grid lifestyle is thus controversial. Nick Rosen, in his thought-provoking and entertaining exploration *How to Live Off-grid – Ever Wanted to Unplug From the Rat Race?* (2007), defines a version of off-grid living characterised by turning away from society (p35) more broadly than merely in terms of energy. The author rightly points out that concern for the environment might be only one reason for an off-grid lifestyle, and is wise enough to question whether off-grid living can be more ethical than the alternative. The author struggles to find urban off-gridders. The World Bank estimated in 2015 that 20% of the world's population, or about 1.1bn people, live without electricity, in locations, in mainly developing regions, where none is available. In some such locations, there is growing evidence of increasing use of small-scale renewable energy. Entirely off-grid buildings are unlikely to be achievable in dense urban situations, as there is simply not enough footprint available for the solar-power or heat-generation systems required, or for the scale of wind generation needed. See the narrative bibliographical notes for Rules 26 to 32 for more detail and references to the status of renewable energy in the urban environment.

CHAPTER 2. RESPECTING GLOBAL RESOURCES

22. The earth as source of all building materials

Brenda and Robert Vale, in their seminal work *Green Architecture – Design for a Sustainable Future* (1991, pp31 and 32), describe well the relationship between the processes of design and building and the finite nature of the earth's resources, reminding us that 'no material is used in building but has its source in the earth'. Berge, in *The Ecology of Building Materials* (2009, Part 1), provides an indication of the years of reserve for a large number of earth's non-renewable resources; he also reminds us that the building industry is the second-largest consumer of resources after the food industry. To brush up on things geological (and, indeed, geographical and biological), this author finds invaluable the *Dorling Kindersley Visual Encyclopedia* (1996). Those wishing to delve deeper into the geological aspects of the subject will find instructive the text by Peter Fookes et al: *Engineering Morphology – Theory and Practice* (2007), which has excellent illustrations and descriptions of the nature and locations of sub-ground materials and structures (pp30–8).

23. Economy of resources

Berge, in *The Ecology of Building Materials* (2009, pp8–10), gives examples of areas in which designers can economise on the use of materials:

- Optimising the building design, including the size, to reduce the amount of material needed
- Using lattice and hollow structures rather than solid and massive ones
- Using lightweight rather than heavy materials (has the added benefit of reducing excavation and foundations)

Pelsmakers, in *The Environmental Design Pocketbook* (2015, p196), makes the observation that the structural elements of a building are both the most costly and highest in carbon emissions, and so deserve particular attention at design stage. Bokalders and Block, in *The Whole Building Handbook* (2010, p35), discuss options for lightweight beams, and the prefabrication and modularity of construction elements are two commonly cited methods for optimising resources and reducing waste. The WRAP (Waste & Resources Action Programme) website contains much useful information, and has an action plan for resource efficiency in the construction industry. Further commentary may be found in the narrative to Rule 44.

24 and 25. Embodied energy

Embodied energy describes the amount of energy used in the processing and transportation of materials. In fact, two terms are now in common usage: embodied energy and embodied carbon. The distinction is that a material might have been won and processed using renewable (non-carbon based) energy, so it will have the same embodied energy as the same material created with carbon-based energy but a much lower embodied carbon. Clark, in *What Colour is Your Building?* (2013, Chapter 3), provides an excellent overview of what the practising designer needs to know about embodied carbon, and of the relationship between embodied and operational carbon. The author states that, in an office building, more than half the embodied carbon is in the sub-and-superstructure. In *Green Architecture* (1991, p41), the Vales grappled with the difficulties of calculating the energy content of building materials, a problem that still exists today due to questions about what to include. There is a good overview of the pertinent issues in Berge's *The Ecology of Building Materials* (2009 Part 1.2).

In one of the Australian Government's excellent series of online technical manuals, *Yourhome (5.2, Embodied energy)*, the authors point out that quantifying embodied energy is less important than adopting the design principles of longevity, durability and adaptability. The UK green-industry advice group Greenspec has tabulated the embodied energy of common building materials; however, for the designer, the energy intensity of whole assemblies is probably a more useful measure, and some Australian examples are given in the *Yourhome technical manual 5.2*. Thomas, in *Environmental Design* (2006, p73), gives a graph of the approximate embodied-energy content of the elements of a detached house, with concrete being the highest.

The Australian Government states that over 100 years the embodied energy of a typical home today represents 10% of the operational energy (*Yourhome Technical Manual 5.2*). The US Department of Energy gives the figure as 15%. As we move towards much more highly insulated and well-constructed buildings that follow passive design principles, we may shift our focus from operating energy to embodied energy.

The embodied energy of high-thermal-mass materials like concrete and brick is often debated in the subject literature. Pelsmakers, in *The Environmental Design Pocketbook* (2015, p174), estimates that it would take up to 25 years for a building to 'pay back' its embodied energy in high-thermal-capacity materials from operational energy savings. However, most authors on the subject remind us that there are benefits to employing thermal mass in a building, including thermal comfort (from temperature stabilisation) and operational energy savings from solar gain. The embodied energy of insulation products will be saved many times over by the operational energy savings brought by reduced heat loss. Edwards, in the *Rough Guide to Sustainability* (2014, pp163 and 164), discusses 'residual energy': the energy remaining in a material at the end of the life of a building, which should be extracted.

The Waste & Resources Action Programme WRAP has an information sheet with comparative carbon emissions for various transportation types, demonstrating that road transport is significantly more carbon intensive than rail, and that rail is more intensive than transport by sea.

Recurring embodied energy is a further theme, particularly in the literature relating to sustainable retrofit. The choice of durable materials is cited by Jean Carroon in *Sustainable Preservation – Greening Existing Buildings* (2010, p8) as a key factor in reducing the risk of needing to replace materials, resulting in a recurrence of embodied-energy input.

26 and 27. Low-energy architecture and renewable energy

There is a wealth of information on the design and operation of low energy-use buildings, including the first book in this series by Huw Heywood, *101 Rules of Thumb for Low-energy Architecture* (2012). Detailed design strategies, with excellent illustrations, may be found in GZ Brown and Mark DeKay's *Sun, Wind and Light Light: Architectural Design Strategies* (2001). For further practical design guidance and case studies, refer to Alison Kwok and Walter Grondzik's *The Green Studio Handbook, Environmental Strategies for Schematic Design* (2007). Passive solar architecture is the theme of Haggard et al in the well illustrated *Passive Solar Architecture Pocket Reference* (2009).

Energy, whether obtained from renewable or from low-carbon sources, is used for heating and/or for electricity. Bokalders and Block, in *The Whole Building Handbook* (2010, Section 3.2), discuss the problem of electricity production in a sustainable society, pointing out that storage of electricity in a private supply system remains an impediment to use, although in some countries it is possible to take advantage of a form of feed-in tariff and various incentives for microgeneration. Pelsmakers, in *The Environmental Design Pocketbook* (2015, Chapter 12), provides detailed decision-making and design information on renewable technologies. The Energy Saving Trust in the UK is an excellent web-based resource, and the *Green Building Bible Volume 2* (2006, Chapter 2) by Keith Hall and Richard Nicholls contains a good section on renewables for anyone wishing to obtain a technical overview of the options.

28. Renewable energy: water

Large-scale hydropower remains controversial due to its environmental impacts, but substantial quantities of electricity may be generated using it. Wave-power generation is still in its infancy, but offers the same potential globally as large-scale hydropower. Small-scale hydropower is often combined with solar power in many regions of the world where grid power is lacking: in many rural, mountainous places in winter, water flow rates are high but there are fewer days of sunshine. Bokalders and Block, in *The Whole Building Handbook* (2010, Section 3.2), divide the subject into hydro (using reservoirs and rivers) and wave power. In the first category, large-scale, mini- and microhydropower are covered. Further detailed information, useful for the designer, may be found in *The Environmental Design Pocketbook* (2015, pp392-4) wherein Pelsmakers provides some helpful figures for the head requirements and the space needed for turbine housing (9 to 18m^2). Billy Langley and Dan Curtis, in *Going with the Flow: Small Scale Water Power* (2004), provide a wealth of practical detail and case-study-based design data, as well as a fascinating history of microhydropower, with a useful glossary of terms.

29. Renewable energy: wind

Coasts, lakes and mountains are the chief locations for large-scale wind-power generation using wind farms, which are often controversial. The Carbon Trust's guide *Small-scale Wind Energy Policy Insights and Practical Guidance* (2008, p23), has good illustrations and identifies the best conditions and locations for wind turbines, whether building-mounted or freestanding. The Energy Saving Trust recommends taking one year's worth of real-time wind-speed measurements before committing to microgeneration, and the trade association Renewable UK, in its consumer guide Generating Your Own Power gives production figures suggesting that a micro-turbine of 1.5kW might produce 1,000kWh annually. The UK Government's Department for Energy and Climate Change, in a report titled *Energy Consumption in the UK* (2014, p7), states that a typical UK home consumes around 4,200kWh annually. Comparative global consumption indicators may be found on the website of the World Energy Council. Many commentators are less than enthusiastic about the use of small-scale wind; large commercial wind farms and community buy-in programmes are the only cost-effective solutions. There is broad agreement that wind-power generation is unsuitable for urban situations, as only very large arrays of turbines, needing much land, would be effective.

30. Renewable energy: the sun

Edwards, in the *Rough Guide to Sustainability* (2014, pp122–31), provides a balanced view of the state of the art in terms of photovoltaic (PV) power. He supports community-wide use of solar collectors (for heating, not electricity production) to heat large volumes of water, providing winter heating needs. He reminds us that today solar electricity is costly in comparison with fossil-fuel-derived power, and there are still questions about the long-term efficiency of PV panels. Solar electricity, like that produced by wind, may be intermittent. Bokalders and Block, in *The Whole Building Handbook* (2010, Section 3.2.4), provide detailed background information on the science and application of different types of solar cell (also known as photovoltaics, or PVs). Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp408 and 409), introduces the relatively new PV-Thermal (PV-T) panel, which generates both heat and electricity.

Stefan Bringezu et al, in a United Nations Environment Programme paper *Towards Sustainable Production and Use of Resources: Assessing Biofuels* (2009, p13), confirm that population growth leads to a significant increase in land use for crop growth, and that any land for biofuel crop would need to be in addition to this. The report also discusses water, noting that global agriculture is currently responsible for 70% of all fresh-water usage and that the development of biofuel crops would increase this pattern. A key message is that ecological and land-use issues must be addressed in any life-cycle assessment.

31 and 32. Cities and efficient, low-carbon energy sources

Hall and Nicholls, in *The Green Building Bible Volume 2*, (2006, Chapter 2), outline the available renewable energies in a helpful, general account with some basic system-sizing data. Clark, in *What Colour is Your Building?* (2013, Chapter 7), provides an excellent appraisal of the options available for renewable and low-carbon energy (heat and electricity). Although Clark's focus is on energy sources for non-domestic buildings, the principles and themes are likely to be of interest and use to those working in other areas. System-sizing information is given for each type. Pelsmakers, in *The Environmental Design Pocketbook* (2015, Section 11.4), discusses the cost-effectiveness of different energy sources, and there are excellent calculators and checklists for the designer to use in deciding whether the various sources are feasible (Chapter 12).

Heat generated by traditional power stations is normally discarded, but there are ways of using it. Oslo operates a Waste-to-Energy (WTE) plant, incinerating the city's waste and heating the city's public buildings with the resultant superheated water. Demand is greater than supply, so the Norwegian capital now, ironically, imports waste from other countries. An alternative is to obtain energy from landfill, and there is debate about the environmental and financial pros and cons of each approach. The UK Government's Department for Environment, Food and Rural Affairs (Defra) paper, *Energy from waste: A guide to the debate* **(**2014 pp20–3) explains that debate very clearly, and states that WTE will be a better environmental solution than landfill energy providing that the plant is efficient, that the waste input can be correctly sorted and that enough waste is available. Bokalders and Block, in *The Whole Building Handbook* (2010, Section pp345–51), discuss human-generated waste, classifying the types and the various disposal techniques, and they also explain the principles of waste incineration with energy recovery.

There is broad agreement within the subject literature about many of today's key issues, which may be summarised as follows:

- The priority is reduced energy consumption
- Renewable energy sources are difficult to use in cities
- Investment in off-site, community-wide systems is the answer, particularly for wind and Combined Heat and Power (CHP)
- Wind is only effective at a macro scale, and not in cities
- Biomass potentially competes with food production
- Solar-thermal is generally more cost-effective than PV

33, 34 and 35. Choosing sustainable materials

Sustainable materials generally

There is no single, easy-to-use methodology for sustainable materials choices. Edwards, in the *Rough Guide to Sustainability* (2014, Chapter 6), discusses the factors influencing those choices, including performance, availability, embodied energy and the ability to reuse. Bokalders and Block, in *The Whole Building Handbook* (2010, Section 1.1), provide an excellent section on the selection criteria for building materials, containing useful tables relating to building elements that group the options under the headings 'recommended', 'acceptable' and 'to be avoided'. The authors consider two factors as key: the health of occupants (relating to chemical composition and emissions) and the lifetime ecological profile of materials. The issue of environmental labelling of building materials is covered (p8). There is also a checklist for sustainable materials specification in Pelsmakers' *The Environmental Design Pocketbook* (2015, pp196 and 197). Johan Van Lengen, in *The Barefoot Architect* (2008, pp296 and 297), also provides a selection checklist, this time focusing on the practical choices to be made by people in regions with limited access to material and human resources.

Renewable and plentiful materials

Berge, in *The Ecology of Building Materials* (2009, Part 1.1), confirms that the term renewable materials is generally applied to organic materials, including wood and fibres. Many minerals, although not strictly renewable, have extensive long-term future supplies, and these include stone, earth, some clays and gravel. Edwards, in the *Rough Guide to Sustainability* (2014, p165), adds aggregates and softwoods to the list of plentiful materials, and he urges us to specify such materials in place of metals, plastics and hardwoods.

Low-carbon, reclaimed, reused and recycled materials

Clark, in *What Colour is Your Building?* (2013, p210), reminds us that steel and concrete have similar overall carbon footprints; we should aim to use reused steel and to control the mix of materials in concrete to reduce carbon content. There is a very useful section on building materials (Chapter 8), giving us options for reducing the embodied carbon of, amongst others, steel, concrete, timber, masonry and windows. The author states (p187) that reduction in the amount of Portland cement is the key to reduced embodied carbon in concrete, and (p194) that the reuse of steel results in a 96% reduction in environmental impact over a new section. Alternatives to brick and blockwork, and ways of reducing the embodied carbon content of masonry are given (pp197 and 198). The Waste & Resources Action Programme, WRAP, has a very clear and readable article on alternative, low-carbon choices for materials: *Information sheet for construction clients and designers – Cutting embodied carbon in construction projects*, and clients and designers in continental Europe should ask for an Environmental Product Declaration to encourage suppliers towards carbon reductions. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp205–7), details the decisions and requirements for reclaimed/recycled building materials and provides sources of reclaimed materials in the UK.

36. Sourcing materials locally and globally

Berge, in *The Ecology of Building Materials* (2009, p20), writes of a shipment of lightweight concrete blocks transported from Norway to Korea, using three times the amount of transportation energy than their initial embodied energy, thus confirming that heavy materials should be sourced locally. Edwards, in the *Rough Guide to Sustainability* (2014, p162), recommends a reasonable distance for sourcing heavy materials not made on site (eg stone, aggregate and bricks) of 10km. Edwards believes that internationally sourced, specialised, lightweight materials and components combined with local, common heavy materials will form the basis of a new architecture. Howard Liddell, in *Eco-minimalism – the Antidote to Eco-bling* (2013, p91), challenges common assumptions about local materials, reminding us that each material and its application must be considered on its own merits as there might be alternative, overriding concerns that would outweigh transport-carbon considerations. Pelsmakers, in *The Environmental Design Pocketbook* (2015, p204), usefully comments that it may be justifiable to source reclaimed and lightweight virgin materials from a distance, but no further than 100km. The author reminds us that environmental credentials must be checked even for local materials, and an excellent checklist is supplied (pp196 and 197).

37. Suitability and durability of materials

For a very good overview of durability issues, Berge, in *The Ecology of Building Materials* (2009, pp10–13), discusses durability in relation to quality of materials, with an emphasis on using the right quality of materials in the right place. *The Whole Building Handbook* (Section 1.1.3) by Bokalders and Block is organised in such a way that the authors' assessment of materials enables the designer readily to seek suitable materials for particular elements of a project. Damp is discussed in detail (pp174–7), with the causes and solutions given, and the authors state that 90% of moisture problems, which are damaging to human health and to buildings, are caused by faulty construction. The moisture properties of materials and moisture migration are also dealt with (pp104–6).

An overview of the basic properties, including weathering properties, of some of the most common architectural materials may be found in the *Materials for Architectural Design 2* (2014) by Victoria Ballard Bell with Patrick Rand. The book is very well illustrated with global case studies, and the authors preface each material-specific section with the various factors to be considered.

Birkeland, in *Positive Development* (2008, p104), reminds us that durable non-renewable and inorganic materials may be associated with high embodied energy and waste, and that the earth takes an age to heal after their winning from its crust.

38 and 39. Water use and conservation, greywater recycling and rainwater harvesting

Water conservation and greywater

Sassi, in *Strategies for Sustainable Architecture* (2006, Chapter 6), gives an excellent overview of the pressures on global water resources, as well as practical strategies for water conservation and reuse. Reduced demand is the stated key objective. A household greywater-recycling system with a 120 litre storage tank, Sassi confirms, could save 25–30% of the water used by a family of four. Details for sizing greywater-recycling systems may be found in Pelsmakers' *The Environmental Design Pocketbook* (2015, pp133–8). We are reminded that greywater recycling could be a source of *increased* overall CO_2 emissions, and that water-efficient appliances are likely to achieve greater overall energy efficiency. Significant reductions can be made by a combination of appliance choice and behavioural change. Designers and specifiers need to be aware that some appliances that are highly rated for low energy use are not water-efficient, so both must be checked and the appliance sized for user needs. Practical tips on household water-use reduction may be found at on the Waterwise website. Bokalders and Block, in *The Whole Building Handbook* (2010, p21), describe recovering heat from waste water using a simple heat exchanger, and water conservation is also discussed (p227).

In the UK, the Environment Agency tells us the average water use is 163 litres per person per day in a household. Data, using figures from the UN on water usage in various countries, may be found at the Data 360 website. The US uses 575 litres per person per day, Australia 500 litres and China 86 litres. In Australia and the US, 50–70% of this is used outdoors, whereas in the UK, according to Sassi, in *Strategies for Sustainable Architecture* (2006, p258), almost all water is used indoors. Facts and figures regarding the global water crisis may be found on the website of Wateraid.

Embodied water

Liddell, in *Eco-minimalism* (2013, p53), discusses 'embodied water', and takes as an example the high embodied-water content of paper (100 times the amount of water needed to process timber, and 50 times that for steel).

Rainwater harvesting

Haggard et al's *Passive Solar Architecture Pocket Reference* (2009, pp71 and 72) provides practical guidance on rainwater catchment for stormwater and drought management, and on harvesting. The authors give the following landscape rainwater-collection equation:

Water collection (m^3) = Collection Area (m^2) x Annual Rainfall (mm) x Run-off Coefficient (0.8)

(Note that $1m^3 = 1{,}000$ litres)

Ritchie and Thomas, in *Sustainable Urban Design* (2009, pp80–5), consider the benefits of a neighbourhood rainwater-harvesting scheme –

reminding us that contamination of rainwater by airborne and other pollutants needs to be considered, and that seasonal variations in rainfall should be taken into account. For detailed information on rainwater-harvesting systems and the data needed to calculate sizes, see *The Environmental Design Pocketbook* (2015, Section 5.6) by Pelsmakers. Kwok and Grondzik, in *The Green Studio Handbook, Environmental Strategies for Schematic Design* (2007, pp245 and 246), provide a graph for estimating catchment-area yield, and a sample problem is given. Rainwater use might be more appropriate for commercial buildings, which require more toilet-flushing water than domestic properties and which have larger roof areas for collection. The payback period for any system should be studied.

40. Sustainable drainage

A combination of rainwater-collection elements in the landscape (such as swales, channels, ponds, detention basins, reedbeds, green roofs and rain gardens) often form part of a Sustainable Urban Drainage System (SUDS). One key purpose of a SUDS is to slow surface-water run-off, allowing rainwater to filter back into the hydrological cycle and releasing pressure on the mains sewers commonly used to transport surface water. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp124–6), describes and illustrates such a system. Bolkalders and Block, in *The Whole Building Handbook* (2010, Section 4.1.2), provide further, very well-illustrated information on hydrology, detailed design proposals for permeable drainage surfaces and advice for snow management.

41. Greenfield or brownfield?

Pelsmakers, in *The Environmental Design Pocketbook* (2015, p62), points out the paradox that although vacant and previously used, a brownfield site might have developed a strong biodiversity. It is one of Williams' criteria for sustainable development, in *Sustainable Design* (2007, p20), that new projects should ideally be built on brownfield sites within urban areas, whilst acknowledging that such sites need to be cleaned. Edwards, in the *Rough Guide to Sustainability* (2014, pp179–81), adds that in order to bring back into use the 20% of unused urban brownfield land a multiparty, private- and public-sector effort is needed. The advantages of using brownfield sites are given by Sassi in *Strategies for Sustainable Architecture* (2006, section 1.1, table 1.1.3, p17), along with another warning about the importance of managing the clean-up. Bolkalders and Block, in *The Whole Building Handbook* (2010, p517), provide a description of the complex and expensive methods used in the restoration of brownfield sites, reminding us that there are three basic approaches with respect to any contaminated earth:

- Removing it to landfill
- Cleaning it in place
- Removing, decontaminating and replacing it

André Viljoen et al, in *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities* (2005, pxix), state that brownfield sites are suitable for urban agriculture.

42. Banish construction waste

Ritchie, in *Sustainable Urban Design* (2009, Chapter 9), defines the problem: we have become used to an almost-invisible, linear chain of activities, whereas the sustainable process would be cyclical, with resources being returned into the construction stages of other projects. Edwards considers how to design for waste reduction in the *Rough Guide to Sustainability* (2014, pp172–4), the main messages being: ensure that waste is designed out, specify the highest possible percentage of recycled content in materials and components, specify reused materials where possible and design for easy dismantling. The Royal Institution of Chartered Surveyors, in a paper of proceedings titled *Strategies for Reducing Construction Waste to Landfill in the UK* (2012), noted two key findings:

- One third of construction-industry landfill waste emanates from architect's decisions
- The greatest source of waste produced by contractors remains poor storage and handling of materials

The WRAP (Waste & Resources Action Programme) website is well organised and has useful sections on waste prevention and reduction. Bolkalder and Block, in *The Whole Building Handbook* (2010, p6), urge us to check that during the transportation phase of a material's life, distributors will take back packaging material. Birkeland, in *Positive Development* (2008, Chapter 4), challenges the conventional approach to waste, taking a holistic, ecology-centric standpoint.

43. Thinking 'back to front'

Michael Braungart and William McDonough first proposed a new way of thinking about design processes in their influential and highly accessible book *Cradle to Cradle – Remaking the Way we Make Things* (2009). The idea, as it applies to the design, construction and demolition of buildings, is that at the end of their useful life buildings (and every other manufactured product) should be capable, by good design, of being broken down into useful constituent parts and resources with no loss or waste. Often termed Life-Cycle Assessment (LCA), Edwards explains its processes in some detail in the *Rough Guide to Sustainability* (2014 pp65–70). By considering the whole-life material, energy and waste flows, we can determine and mitigate environmental impacts at the outset. The future of sustainable design is linked with the development of BIM, Building Information Modelling techniques in which the co-location, assembly and disassembly complexities of components and their materials can be readily analysed and good design can anticipate planned de-construction and reuse.

44. The four 'R's

Liddell, in *Eco-minimalism* (2013, pp39 and 40), simply states that recycling is a last resort. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp204–9), provides a concise summary with recommendations on building materials' suitability for reclamation and recycling, and the section includes an excellent 'Designing for deconstruction' checklist. The idea of deconstruction (sometimes referred to as 'unbuilding') is gaining ground, for it is an issue with a close association with the idea of life-cycle approaches to the design, construction, dismantling and reuse of buildings and their components. Reclamation (rather than recycling) of bricks and other building materials is the theme in the *Green Building Handbook* by Woolley et al (1997, p59). The authors remind us that the energy stored in a brick is retained if the brick is reused, but lost if the brick is crushed for use as hardcore.

Reduction of resource use and the recycling of waste products from production are themes in *The Ecology of Building Materials* (2009, Part 1.1) by Berge. The author writes on the benefits of standard, monomaterial components (pp16 and 17) for ease of reuse and reduced wastage, as well as the possibilities for disassembly within the different 'layers' of services, structure and skin, which require renewal at different times in the building's life. Urbanist Stephen Wheeler, in *Planning for Sustainability* (2013, p121), proposes further 'R's: 'repurpose, research, rethink, resist and redistribute'.

CHAPTER 3. WORKING IN HARMONY WITH THE NATURAL WORLD

45 and 46. Ecosystems and biodiversity

The UN General Assembly declared 2010–2020 the Decade on Biodiversity, hailing an era of international effort to tackle species loss and ecosystem damage. Not so long ago the secretariat of the UN Convention on Biological Diversity (UN CBD) lamented the fact that few people even knew what biodiversity was, partly because the language used to describe it (even by the CBD itself) was unintelligible. This huge and complex subject is becoming clearer, and biologist John Spicer, in *Biodiversity: a Beginner's Guide* (2006, p2), neatly distills the myriad definitions of biodiversity into the phrase 'the variety of life'. Biodiversity (biological diversity) is also described as a reflection of the number and variety of living organisms in an ecosystem. The CBD, and its excellent website, contains a vast resource of information on biodiversity and ecosystems. Biodiversity loss is explained well in the CBD's very readable booklet *Sustaining Life on Earth* (2000, pp5 and 6). The importance of traditional knowledge and practices is revealed (p15); it remains true that indigenous populations understand and rely heavily on biodiversity. The 'goods and services' provided by ecosystems are listed in the factsheet *Living in Harmony with Nature* (2010, p2) on the CBD's 2010–2020 website, and these include: providing food, fuel and fibre, and provision of materials for shelter and building.

Earth's ecosystems exist within the ecosphere, and earth scientists describe the four most recognisable domains that make up the ecosphere as:

- Atmosphere – the gaseous layer
- Biosphere – all life on earth
- Hydrosphere – all water
- Geosphere – the solid matter of earth

Biodiversity means species, ecosystem and genetic diversity, and it is clear that the ecosystems we are dependent upon are sustained by biodiversity. Naeem Shahid et al, in *The Functions of Biological Diversity in an Age of Extinction* (2012), examine the state of play in their complex field, which seeks to understand the relationships between biodiversity and ecosystem functioning. Christina Von Borcke, in *Sustainable Urban Design* (eds Ritchie and Thomas, 2009, pp 34–6), discusses the importance of the diversity of plant species, which attract wildlife, and reminds us that we should aim to create varied habitats both within and connecting our cities and buildings. Local, native species are often more successful in attracting wildlife and being resilient to regional climatic conditions. The importance of connectivity between habitats is discussed by many authors, including Anne Beer and Catherine Higgins, who, in *Environmental Site Planning for Site Development – a manual for sustainable local planning and design* (2000, p297), consider the use of existing features such as river corridors. The authors explain how improved recreational green space can also achieve enhanced biodiversity. Eco-passages are described in the excellent technical manual by Kelly Gunnell et al, *Designing for Biodiversity: A Technical Guide for New and Existing Buildings* (2013, p28), which also contains a handy glossary. A detailed, ecological consideration of the movements of animals and plants within urban areas may be found in Richard Forman's pioneering work *Urban Ecology – Science of Cities* (2014, Chapter 3).

47. Waste

In Chapter 4 of the seminal work *Cradle to Cradle – Remaking the Way we Make Thing***s** (2009, pp92-117) Braungart and McDonough propose that the very concept of waste must be designed out of our industrial processes, and that by-products in one industry should be viewed as raw material for another, mimicking nature. Now often known as cradle-to-cradle solutions, it is this kind of thinking that is a primary message of Desai and Riddlestone's *Bioregional Solutions For Living on One Planet* (2007). Chapter 1 (pp 15–23) sets out the issues and introduces some of the inspiring innovations that are later detailed within the book. The idea of waste as a resource is commonly described as a biomimetic principle (see Rule 52).

48. Ecosystems regulate climate

Climate on earth is physically regulated by ecosystems. The Biodiversity Information System for Europe (BIDE) states that climate regulation is one of the most important ecosystem services, since the terrestrial ecosystems – including deciduous forests, taiga (coniferous forest), grassland, desert and peatland – provide a carbon sink for up to 12% of European anthropogenic emissions. The relationship between carbon and global temperature control is neatly explained in an article by Holli Riebeek on Nasa's excellent Earth Observatory website (earthobservatory.nasa.gov) titled *The Carbon Cycle* (2011). The Nasa site is a repository of many useful reports and articles, including one by Michael Carlowicz and Robert Simmon titled *Seeing Forests for the Trees and the Carbon: Mapping the World's Forests in Three Dimensions* (2012), in which the authors confirm that forests globally store about 45% of all above-ground carbon. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp9–11), explains succinctly the mechanisms that link natural and anthropogenic carbon with climate change. The oceans also store CO_2, and in the article *How Much CO_2 Can The Oceans Take Up?* (2013) Robert Monroe, writing on the website of Scripps Institution of Oceanography, investigates the carbon uptake of the world's oceans.

49. Climate-neutral buildings – carbon-storing materials

Half of the mass of timber is carbon, created by photosynthesis and stored within the tree. Berge, in *The Ecology of Building Materials* (2009, p35), urges us to maximise the amount of construction material of plant origin as a means of utilisng this natural carbon capture. In addition to massive timber elements, other plant-based materials and methods are discussed in detail (pp272–97), including:

- wood-derived products, such as wood-shaving insulation
- mosses and grasses

- straw bales
- peat
- cellulose

The chapter has a wealth of information on the characteristics and uses of materials, as well as options for such products as fire retardants and water-repellent additives. In continental Europe, construction systems such as Brettstapel, which uses low-grade timber to produce structural panels with no glue or nails, are becoming more common.

Other promising innovations in this field are described in the article *Carbon Capture Pilot Turns CO_2 into Green Building Materials* (August 2013) in the online journal Environmental Leader. In this case, the subject is the capture of carbon in bricks and paving slabs. ClimateTechWiki, in an article on the subject of carbon-sink materials discusses, in addition to timber:

- low-carbon bricks – using 40% fly ash
- 'green' concrete – replacing cement and aggregate with waste and recycled materials
- 'green' tiles – made using waste glass
- recycled metals
- bamboo

50. Building-reliant species

Gunnell et al, in *Designing for Biodiversity: A Technical Guide for New and Existing Buildings* (2013), provide an overview of the part that buildings play in biodiversity, and a detailed commentary on the needs and threats to building-reliant species. Contemporary technical solutions are given, as well as a wealth of references to further information. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp100–3), provides a detailed list of design recommendations for the highest-priority amphibians, birds, mammals and insects in the UK. Much international information on bats may be found at Bat Conservation International, and, in the UK, at the Bat Conservation Trust.

51. Density and nature

When the World Bank hosted a forum in 2012 based upon the idea of the 'smart city' (Smart Cities for All), comparing the US city of Atlanta (large, sprawling) with Barcelona in Spain (compact, dense) the result was an argument for high-density, small-footprint cities with a focus on transportation. The central message of Vishaan Chakrabarti's strongly argued and well-illustrated proposition *A Country of Cities* (2013) is the need for urban density, and another urbanist, Stephen Wheeler, in his essential reader *Planning for Sustainability* (2013, pp137–43), while also pro-density, discusses the advantages and challenges of both over-dense and sprawling cities, and of urban infill sites. Wheeler states that an essential future sustainability goal will be that of preserving green space (p140). Desai and Riddlestone, in *Bioregional Solutions For Living on One Planet* (2007, p75), warn of the potential hazards of urban density, correctly referring to the large resource needs of cities, transportation issues, waste and pollution management. Baruch Givoni, in *Climate Considerations in Building and Urban Design* (1998, pp291), acknowledges that the effects of urban density are conflicting: benefits in transport and infrastructure are set against impediments to ventilation and reduced natural lighting. Liddell, in *Eco-minimalism*, cites the example of Berlin, where half the footprint of any new development is to be given over to biodiverse landscape (2013, p88). The social, economic and environmental benefits of introducing nature into cities are neatly summarised by Pelsmakers in *The Environmental Design Pocketbook* (2015, p87). Adams, in *Eco-Urbanity* (ed Radovic, 2009, pp40–2), gives us a useful summary of the reasons density is essential, including:

- Reduced agricultural land loss
- Reduced travel distances and promotion of public transport
- Optimisation of costly infrastructure (roads, utilities)
- Reduced energy consumption

52. Lessons from nature and biomimicry

Petra Gruber, in the highly absorbing and detailed *Biomimetics in Architecture – Architecture of Life and Buildings* (2011, pp13-17), defines the subject and provides a helpful set of explanations of the terms used in relation to the science and art of seeking inspiration from nature and applying that inspiration to architecture. The author explains the relationships between nature and technology through the theory and practice of biomimicry (or biomimetics). Michael Pawlyn, in his take on the subject in *Biomimicry in Architecture* (2011), examines many inspirational examples of natural processes, structures and forms. Edwards, in an excellent essay in the *Rough Guide to Sustainability* (2014, pp185–91), discusses our distancing from nature, and the lessons we might learn by using nature's successful models as a basis for good design.

53. The world's climate zones

Robert Henson, in the *Rough Guide to Weather* (2007, pp43–7), gives an overview of the history of climate-zone definition and an easy-to-understand explanation of the mechanics of climate. Hocine Bougdah and Stephen Sharples, in their textbook *Environment, Technology and Sustainability* (2010, pp14 and 15), provide a useful, succinct description of the conditions to be found in each of the commonly described climate regions. Givoni, in the in-depth scientific work *Climate Considerations in Building and Urban Design* (1998, pp333–441), adds a fifth climate (cold-winter/hot-summer) to the usual four, and the required responses are described. Detailed strategies relating to climatic factors may be found in Brown and DeKay's superbly illustrated *Sun, Wind and Light: Architectural Design Strategies* (2001). Studies in climate responsiveness can be made using many of the common software packages, and *Climate Consultant 5*, a tool developed by the University of California, Los Angeles (UCLA) into which global weather-data files are input, is intuitive and provides graphical architectural responses.

Factors to examine, as a minimum, in a preliminary study of the climate of a region include:

- sunshine and daylight hours
- diurnal and seasonal temperature range
- precipitation (rain and snow)
- humidity
- winds (direction and speed, diurnal and seasonal)
- beneficial vegetation

54. Learn from vernacular responses

Williams, in *Sustainable Design* (2007, Chapter 5), reminds us that historically communities naturally responded to their local environment in order to create conditions in which to thrive. Reference is made to many relevant vernacular precedents while explaining a very useful method of site analysis for climatic response to site. Wheeler, in *Planning for Sustainability* (2013, p32), is another of those in favour of approaches that learn from indigenous populations. The author points out that there are those who see such approaches as merely romantic. However, in *Lessons from Vernacular Architecture: Achieving Climatic Buildings by Studying the Past* (2014) the editors Willi Weber and Simos Yannas bring together a series of recent case studies that set out to prove that vernacular responses can still provide inspiration for innovation today.

Bokalders and Block, in *The Whole Building Handbook* (2010, pp665–8), touch on the history of traditional and regional responses, particularly in cold climates. The authors refer to Bernard Rudofsky's *Architecture Without Architects: A Short Introduction to Non-Pedigreed Architecture* (1981), which remains a classic in the field. Van Lengen's wonderfully illustrated *The Barefoot Architect* (2008), which focuses on the southern hemisphere, contains many examples of traditional techniques and applications.

55. The atmosphere and the weather layer

Nasa's Jet Propulsion Laboratory at the California Institute of Technology tells us that the exosphere, the outermost layer of earth's atmosphere, extends to 100,000km, but the Kármán line, at 100km from the earth's surface, is usually used to denote the boundary between the atmosphere and space. Almost all the earth's weather exists within the troposphere, which ranges between 7km at the poles and 17–18km at the equator. The ozone layer exists within the stratosphere, the upper boundary of which is the stratopause, at about 50km altitude. The *Rough Guide to Weather* (2007), by Henson, contains further information on the nature of the atmosphere and its relationship to weather, as well discussion on anthropogenic damage caused to the ozone layer. The links between the atmosphere and climate change are concisely described (pp150–68). The author also explains the impact of CFCs (chlorofluorocarbons) on the ozone layer (pp165–7). Gething and Puckett, in *Designing for Climate Change* (2013), succinctly introduce the relationship between CO_2 and climate change; the scenarios for future climate; and then, through a series of contemporary case studies, they identify various design mitigation approaches.

56, 57 and 58. Urban climatology and the Urban Heat Island (UHI)

In hot regions, health and wellbeing may be particularly affected by elevated night-time temperatures (caused by both stored solar energy and human-generated heat) and their detrimental effect on sleep patterns. Conversely, UHI is usually beneficial in winter and in cold climates. UHI may therefore be a positive or a negative influence depending on the climate region and season. Bokalders and Block, in *The Whole Building Handbook* (2010, p544), writing about cities in cold climates, state that the urban temperature in winter might be 5–10ºC higher than the surrounding countryside. Haggard et al also provide some facts and figures in the *Passive Solar Architecture Pocket Reference* (2009, p18): urbanisation, they tell us, leads to reduced heating loads, increased winter temperatures (by 1–2ºC), reduced solar radiation (by 15–20%), increased precipitation (5–10%) and increased cloud cover (5–10%). Mechanical air conditioning (for cooling in hot cities) is specifically cited as a major influence on UHI, by these and other authors; the urban heat island effect increases the need for air conditioning, which in turn amplifies the effects of UHI. Urban climatology and UHI are very well explained by Givoni in *Climate Considerations in Building and Urban Design* (1998, pp241–4), and Givoni reminds us that UHI is essentially a nocturnal phenomenon, with the greatest effect being felt on clear, still nights. Givoni identifies the key contributors to UHI:

- The lower rate of nocturnal radiant cooling compared with the surrounding countryside
- The release at night of solar energy stored in the mass of the city and its buildings in daytime
- Lower evaporation in the city (reducing the effects of evaporative cooling)
- Anthropogenic heat generation in cities (transport, industry)
- Seasonal heat sources, such as heating and air conditioning, which release energy into the urban air dome

The broader effects of urban climate and UHI are discussed further by Ritchie in *Sustainable Urban Design* (2009, p6). Ritchie reminds us about increased air pollution, pressure on drainage systems and the difficulties of achieving natural cooling on hot summer nights. In Chapter 4 of the same text the positive influence of urban landscape on the city's microclimate is addressed by Von Borcke in *Sustainable Urban Design* (eds Ritchie and Thomas, 2009, pp31–3). A more detailed explanation of the link between cities and climate change is given by Edwards in the *Rough Guide to Sustainability* (2014, pp9–13), and here the author states that increased global CO_2 production is a direct result of urbanisation. Although most research has been focused on temperate climate regions and cities with an agricultural hinterland, thus restricting our knowledge, Givoni, in *Climate Considerations in Building and Urban Design* (1998, pp245 and 246), sets out aspects of urban temperature elevation that humans can control:

- Colour (the albedo effect – see Rule 66)
- Vegetation, which can reduce urban temperatures
- Energy used for heating and air conditioning
- Heat loss from the building fabric, which is greatly influenced by thermal performance
- Density of the urban fabric, affecting the amount of solar radiation reaching the ground
- Orientation of streets in relation to wind, influencing wind speed

59. Climate clues for city planning

Bokalders and Block, in *The Whole Building Handbook* (2010, Section 4.1.4), state that temperature is influenced by topography, proximity to coast and building density, and that the temperature-moderating influence of a large body of water will be a few degrees (p543). The authors also propose siting buildings in the warmest locations in cold climate regions, such as where snow first melts in spring. Givoni, in *Climate Considerations in Building and Urban Design* (1998, pp267–80), provides further detail, discussing the effects of topography on wind and rainfall and stating that the temperature-moderating effect of large water bodies, such as oceans and large lakes, reaches 20km inland. Givoni states that controlling wind conditions offers the greatest potential of all interventions for modifying the urban climate and influencing both human comfort and energy consumption (pp256–66).

Beer and Higgins, in *Environmental Site Planning for Site Development* (2000, pp66–91), give an excellent synopsis of climate and microclimate factors in sustainable site planning, including what information the designer needs to gather.

Back at the global scale, in the highly readable, utopian viewpoint found in Richard Register's *EcoCities: Rebuilding Cities in Balance with Nature* (2006, Chapter 11), we find illustrations of imagined cities in three global climate regions, indicating their responses to sun, wind and daylight.

60. Building separation for sun, light, wind and energy

Rules of thumb for separation are some of the most difficult to extract as they are latitude dependent. Also, there is no universal definition of the boundaries of the high, mid and low latitudes. Paul Littlefair, in *Passive Solar Urban Design: Ensuring the Penetration of Solar Energy into the City* (1998), is one of the few researchers who attempts to define separations using solar elevations (degrees of the sun above the horizon) based on high, mid and low latitude bands. In the current book, the bands are explained using the following widely accepted definitions:

- High latitude = 60° magnetic latitude and higher
- Mid latitude = between 50° and 60° latitude
- Low latitude = below 50°

Other authors define separation by relating building heights to distances apart. Both methods may be useful as a starting point for designers, so this author provides rules of thumb for both degrees and distances. The designer should use the most advantageous method in the early design stages, remembering that urban place-making and other environmental matters (eg protection from wind) should not be overlooked.

Brown and DeKay, in *Sun, Wind and Light: Architectural Design Strategies* (2001, p119), provide a table that allows the designer to deduce appropriate distances between parallel building blocks for solar access and solar gain at various latitudes. There are diagrams showing the shading effects of different spatial configurations and street orientations (p129). The overall climatic impacts of street widths and orientations in different climate regions are explained by Givoni in *Climate Considerations* *in Building and Urban Design* (1998, pp286–90). Bokalders and Block, in *The Whole Building Handbook* (2010, Section 4.1.4), give a useful proposal for residential development in Scandinavia (p538) indicating which spaces need how much sunlight, and when. Based on the equinoxes, the designer is urged to provide:

- for kitchens and living rooms: 4 hours
- for outdoor balconies: 4hrs after 12.00 midday
- for open recreation areas within 50m of building entrances: 5 hours between 9.00 and 17.00

61. Urban breaks for solar access

In some cases, the spacings discussed in Rule 60 are unachievable – but there are remedies for the effects of urban density, and Pelsmakers, in *The Environmental Design Pocketbook* (2015, p79), gives a detailed set of recommendations for 'urban break' design. The author also points out that increased complexity of form generates additional surface area, which needs to be offset with increased fabric insulation. Ritchie and Thomas, in *Sustainable Urban Design* (2009, pp46–9), discuss density, spacings and form in relation to energy use – in doing so, reminding us that the simple act of placing taller buildings to the north of a site (or south in the southern hemisphere) preserves solar access.

62. The building envelope as climate modifier

Givoni, in *Climate Considerations in Building and Urban Design* (1998, Chapters 10–13), provides an in-depth appraisal of the conditions in each of the earth's five climate regions and the general performance requirements of the building envelope. Givoni's work greatly influenced Chapter 5 of the first book in this series, *101 Rules of Thumb for Low-energy Architecture* (2012), which explains and illustrates climatic envelope issues – including the glazing types to be considered; where high thermal mass will be beneficial; and the types and uses of openings and integrated elements, such as shading devices and wind catchers. Van Lengen, in *The Barefoot Architect* (2008), deals with simple, practical building-construction methods for hot-dry, humid and temperate regions in the southern hemisphere. He provides a wealth of finely illustrated detail about materials, structures, envelope and openings.

63. The section

Lorraine Farrelly, in *Representational Techniques* (2008, pp78–81), describes the section as one of the most useful drawings in architecture. It is a key design tool, without the use of which the designer will not be able to fully explore spatial possibilities. In addition to being the drawing that makes a connection between two-dimensional plans and three-dimensional volumes, and between outside and inside, the section is the format most used to explain the environmental and sustainable design aspects of a project. Francis Ching, in the seminal *Architectural Graphics* (2009, pp63–73), makes the distinction between the design section and the construction section, and also describes the site section: the drawing that illustrates the connection between a building and its environment.

64 and 65. Wind

Bokalders and Block, in *The Whole Building Handbook* (2010, pp539–42), provide a good explanation of the effects of, and solutions to, wind problems in both rural and urban situations. Brown and DeKay, in *Sun, Wind and Light: Architectural Design Strategies* (2001, pp99–101), deal with the wind effects generated by tall buildings. They provide detailed strategies (pp102–9) for urban wind control through variations in block and street patterns and in building heights. Matin Alaghmandan et al, in a paper titled *Innovative Design Methods for Tall Buildings – a Computational-based Approach in Optimizing the Wind Effects on Tall Buildings* (2013 p527), state that aerodynamic (ie non-rectilinear) forms reduce the formation of vortices around buildings; structural issues relevant to tall-building wind design are also discussed. Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp72–5), explains the UK's wind patterns and provides very clear explanatory diagrams for designing with wind. A detailed research study of the physics and impacts of wind around buildings may be found in a paper by Bert Blocken and Jan Carmeliet (2004), titled *Pedestrian Wind Environment around Buildings: Literature Review and Practical Examples*. The authors draw important conclusions for designers, including that:

- a poor wind environment around a building can lead to unsuccessful and hazardous development
- wind needs to be considered at the outset of a design, as its effects are very hard to mitigate after a building is complete

66. Green roof, blue roof or white roof?

'Green' roof

Kwok and Grondzik, in *The Green Studio Handbook* (2007, pp49–54), explain green roofs, with sizing and materials data. The authors make the distinction between two types of green roof:

- 'Extensive' green roofs, which are shallow (150mm of growing material) with limited plant varieties and usually not accessible
- 'Intensive' green roofs, which are deeper.

Table 4.1 (p52) gives roof depths relating to the type of planting desired; for small trees, 1.0m of soil depth will be needed, and around 1.8m for large trees in an 'intensive' green roof. Insulation, a drainage system and a waterproof membrane are also needed. Some of the many benefits of green roofs are given, such as increased thermal mass; increased insulation value; reduced UHI; rainwater retention; and recreation, biodiversity and flood mitigation.

Pond, or 'blue' roof

A roof pond (also known as a blue roof), typically with a depth of 150–300mm, can be used as a free source of heating or cooling. For thermal storage, the pond must be insulated at night to prevent heat loss. In regions with cool nights, the pond roof may also be used for cooling. In this case, it must be shaded and insulated during the day to stop the water from heating up; with the insulation removed at night, heat from within the building is transferred to the pond via the structure and radiated into the night sky. Design and sizing information may be found in Brown and DeKay's *Sun, Wind and Light: Architectural Design Strategies* (2001, pp176–7). Givoni, in *Passive and Low Energy Cooling of Buildings* (1994, pp152–63), gives scientific study data on roof-pond experiments in various locations. For both green and blue roofs, additional weight and structural needs must be taken into account.

'White', or cool, roof

Givoni, in *Climate Considerations in Building and Urban Design* (1998, p370), states that the main factor in absorption of solar radiation – particularly in hot-dry regions – is the albedo, or reflectance, of the roof. Although high density slows nocturnal cooling near the ground in cities, a cool roof level will result in cool air sinking into the city, increasing the cooling rate. The solar-reflectance values of various common roofing materials are given in Brown and DeKay's *Sun, Wind and Light: Architectural Design Strategies* (2001, p221). The secret is to use materials that reject incident solar heat and which will also not transfer heat into a building during the day; a high Solar Reflectance Index and high infrared emittance are the key properties. A dilemma for the cool-roof designer is that locations with hot summers and cool or mild winters would, ideally, have reflective cool-roofs in summer but absorptive warm roofs in winter.

CHAPTER 4. DESIGNING FOR HUMAN WELLBEING

67 and 68. Comfort, control and satisfaction

Human comfort

The collaborative construction industry website Designing Buildings Wiki proposes that an environment is reasonably comfortable if 80% of occupants are thermally comfortable. The physiology that enables humans to adapt to the environment is discussed by Givoni in *Climate Considerations in Building and Urban Design* (1998, pp3–36). The author also discusses the serious health effects of UHI (p256). Bokalders and Block, in *The Whole Building Handbook* (2010, pp112–16), provide a succinct overview of all the factors influencing the internal climate. These include the Mean Radiant Temperature (MRT) of surfaces, a significant factor affecting thermal comfort. The authors add the electro-climate (electromagnetic fields and static electricity) to the more common comfort factors. To assist in achieving the goal of a good internal environment while conserving resources, a useful checklist is provided (pp115 and 116). Bokalders and Block also confirm that lowering the internal temperature by one degree produces 4–5% savings in overall energy consumption. The authors are proponents of computer-controlled environmental systems, which are well described.

Occupant control and satisfaction

Bill Bordass et al, in *Controls for End Users: a guide for good design and implementation* (2007) confirm, in line with a substantial body of research, that when occupants have control over their internal environment they are more satisfied with it. The authors give five ways in which user controls aid comfort and satisfaction, including the rapid response time of systems (p6), and a designer's checklist is provided (p24). Ritchie and Thomas, in *Sustainable Urban Design* (2009, pp48–55), confirm that occupant control over the internal environment has a bearing on a building's success, and in *Green Buildings Pay – Design, Productivity and Ecology* (2013, p177), Edwards confirms that while occupant control over environmental conditions is desirable, building performance should not be compromised. Recently, Montazami et al, in a conference paper titled *The Relationship Between Peoples' Satisfaction and LEED Building Rating in Jordanian Office Buildings* (2013), reminded us not to focus exclusively on energy whilst ignoring other occupant comfort and satisfaction issues such as lighting and acoustics. Their focus was on the US' Leadership in Energy & Environmental Design (LEED) environmental programme, but the lessons drawn apply equally outside this framework. Active occupant control measures are summarised by Stuart Barlow and Dusan Fiala in *Occupant comfort in UK offices – How adaptive comfort theories might influence future low energy office refurbishment strategies* (2007). Nigel Oseland, in *Adaptive Thermal Comfort Models* (1998, pp41 and 42), examines the temperature effects of various workplace activities, including putting on or removing various items of clothing.

69. Maintenance and sustainability

Liddell, in *Eco-minimalism* (2013, p95), states, 'If something is to be sustainable it must also be maintainable', implying a relationship with longevity and usefulness. Bokalders and Block, in *The Whole Building Handbook* (2010, Section 1.3), consider the care and maintenance of buildings as a function of good design and construction. Ease of cleaning and the environmental credentials of cleaning materials are discussed, and we are reminded that building components must be accessible safely. The relationship between energy efficiency, user satisfaction, ease of maintenance and facilities management is made by Pelsmakers in *The Environmental Design Pocketbook* (2015, p349). There is an excellent maintenance checklist (pp30–1), and maintenance of materials is also covered (p210). Van Lengen, in *The Barefoot Architect* (2008), deals with humid tropical regions (Section 2), and maintenance of materials is the first consideration in the section on materials selection (p296). Sandy Halliday, in *Sustainable Construction* (2008, p132), warns us about claims of so-called maintenance-free construction, which is an impossible state to promise.

70 and 71. The benefits of contact with nature

Mark DeKay, in his highly readable and thought-provoking treatise *Integral Sustainable Design* (2011, pp354–424), states his view that we relate nature to a sense of place and that the cycles of nature provide meaning in our lives. He also reminds us that in a pre-industrial world we would have sought the right environmental conditions that existed at any particular time of day or season, in a particular place within our buildings. Edwards, in the *Rough Guide to Sustainability* (2014 , pp185–91), reflects on the benefits of incorporating an explicit reading of nature into design, with examples of ways in which nature has been used as a source of inspiration to inform design in practical, material, tactile, visual and other less tangible ways. Von Borcke, in *Sustainable Urban Design* (eds Ritchie and Thomas, 2009, pp31–41), writes engagingly on nature in the city and explains how the colour green is linked with human biology and physiology. Urban greening and the benefits of urban landscape are discussed in relation to Rule 80. Very well-described case studies of approaches to nature may be found in Sassi's *Strategies for Sustainable Architecture* (2006, pp32–43).

72. Healthy (and sick) buildings

Bokalders and Block, in *The Whole Building Handbook* (2010, pp1–4), begin with a description of the nature of healthy buildings and the causes of sick buildings. Edwards and Naboni, in *Green Buildings Pay* (2013, pp71–5), discuss occupant satisfaction and the relationship between health and productivity both in mechanically and naturally ventilated environments. The authors confirm (p69) that the cost of employing staff far outweighs the operational energy costs of an office building – so sick buildings, often associated with many attributes of unsustainable design, are extremely costly to operate. The Alliance for Sustainable Building Products (ASBP, reported in January 2014 that Google required a 'declaration of content' of all building products to be used in their new London offices, reminding us that toxicity is also a potential liability issue. Birkeland, in *Positive Development* (2008, pp28 and 29), provides examples of buildings and retrofits, illustrating the benefits of healthy buildings.

73. Indoor Air Quality (IAQ)

The United States Centers for Disease Control and Prevention has an excellent website wherein the document *Factors Affecting Indoor Air Quality* may be found. IAQ features in a practical 'Internal Environment' checklist in Pelsmakers' *The Environmental Design Pocketbook* (2015, pp152 and 153). Good ventilation, and materials that do not emit noxious gases are cited as simple remedies. Edwards, in the *Rough Guide to Sustainability* (2014, pp232 and 233), discusses the dangers of Volatile Organic Compounds (VOCs), which can be 10 times higher inside buildings than outside. The US *Environmental Protection Agency*, which has a good web-based resource on its website, confirms that there are literally thousands of sources of VOCs in the indoor environment. Berge, in *The Ecology of Building Materials* (2009, Part 1, Section 2), provides a detailed review of pollution and pollutants in the construction industry. Some VOCs are highly toxic and carcinogenic, and the UK Government's *PostNote Number 366: UK Indoor Air Quality* (November 2010) has a table of common pollutants, their sources and health impacts with recommendations. The unintended consequences of low-energy retrofit are discussed in relation to air quality in Chapter 5 of this narrative bibliography.

74. Seasonal Affective Disorder (SAD)

Although there is evidence that it can occur in summer too, the illness SAD – sometimes known as 'winter depression' or 'winter blues' – is a medical condition brought about mainly by the reduced availability of daylight. In *A Literature Review of the Effects of Light on Building Occupants* (2002, pp8 and 9), L Edwards and P Torcellini discuss the medical conditions associated with SAD, which can include clinical depression lasting several months. The excellent daylighting textbook by Peter Tregenza and Michael Wilson, *Daylighting – Architecture and Design* (2011, pp6–9), provides further discussion on human physiological responses to daylight, and SAD is discussed in relation to interior lux levels. Although it is thought to be most prevalent in higher northern latitudes (and most of the research has been conducted in these regions), there is evidence that seasonal variations and sunshine hours are factors irrespective of latitude; research by Shrikant Srivastava and Mukul Sharma, *Seasonal Affective Disorder: Report from India* (1998), studied patients at latitude 26° 45' north and found evidence of the existence of SAD there.

75. Post Occupancy Evaluation (POE)

Clients should be appraised of the importance of the building performance evaluation, known as Post Occupancy Evaluation (POE). Bordass et al, in *A Guide to Feedback and Post-occupancy Evaluation* (2006), includes much practical advice and mentions the 'soft landings' approach, whereby the design team assists in the transition from building handover to operation. The UK Government's Cabinet Office document *Government Soft Landings* (2013) details this approach and its relationship to BIM. The approach considers:

- Functionality and Effectiveness
- Environmental factors
- Cost factors

Note that these headings relate closely to the 'Three Es' of sustainability (see Rule 3). The purpose and methods of POE are very well described in the essay by Roderic Bunn, 'From post-mortem to life support' in the book *Retrofit for Purpose* (Ed Prasad, 2014, pp39–53) by the architectural firm Penoyre & Prasad. The author states, rightly, that POE is a process for the whole design team, including the client.

76. Preserving cultural heritage

Gaines and Jäger, in their forthright *Manifesto for Sustainable Citie***s** (2009, p20), confirm that in planning the future of existing cities the past must be taken into account, and Ritchie, in the introduction to *Sustainable Urban Design* (Eds Ritchie and Thomas, 2009, pp4–5), lauds the 'happy accidents' that occur in our cities when a layering of old and new results in an unplanned richness, linking the present to the past and contributing to social sustainability. Ritchie's views concur with ideas proposed by Colin Rowe and Fred Koetter in their seminal critique of urbanism, *Collage City* (1978). Richard Rogers, in *Cities for a Small Planet* (1997, p82), states that preserving heritage is meaningless to society if innovation is lost. An excellent, concise paper by S Mutal for UN-Habitat, *A World Overview on Conservation, Rehabilitation, Development and Management of Historic Cities/Centres* (2004), describes how heritage must be part of the daily life of human beings in the city – and states that new and old can, and should, exist together. History, as the author reminds us, is all-encompassing and includes social and economic factors, urban ritual and physical landscape. This paper (and Rogers, in *Cities for a Small Planet*, too) quotes the historian Roy Porter: 'when buildings take precedence over people, we get heritage, not history'. Rodwell, in *Conservation and Sustainability in Historic Cities* (2007), writes very well about the richness of fabric in an existing city (p114) and approaches to cultural heritage, with numerous case studies (Chapter 9).

77. An active city is a healthy city

Chakrabarti, in *A Country of Cities* (2013, pp75–123), gives compelling evidence for the need for mobility and the opportunities afforded by dense cities. Issues of health and activity are central to Danish architect and urban designer Jan Gehl, in the influential, very readable and well-illustrated work *Cities for People* (2010). Confirming many of Gehl's thoughts, Johan Faskunger, in a research paper titled *Promoting Active Living in Healthy Cities of Europe* (2011) based on a World Health Organization (WHO)-sponsored city study, clearly sets out the problem of our sedentary modern lifestyles. The lack of a coordinated effort within the layers of city governance is cited as a common barrier to promoting active city living. In the *Journal of Urban Health*, Hugh Barton and Marcus Grant, in the paper *Urban Planning for Healthy Cities: A Review of the Progress of the European Healthy Cities Programme* (2011), provide their take on the determinants of the healthy city, as an antidote to the car-dependent and unhealthy lives encouraged by many cities today. They provide us with the 12 objectives of Healthy Urban Planning (HUP) as defined by the WHO, which make interesting reading as they touch on social, organisational and built-environment issues. Camilla Ween, in *Future Cities – All That Matters* (2014, p60), proposes a 'feet first' approach to public transport: citizens will walk if the opportunity exists and if the public realm is attractive. CJ Lim, in *Food City* (2014, p135), states that gardening is also an exercise regime recommended to beat urban obesity. The WHO's Healthy Cities project , a global movement for urban health provides links to news, events and facts sheets within this WHO initiative.

78 and 79. Sound and noise

Authors Katherine Irvine et al, in 'Green space, soundscape and urban sustainability: an interdisciplinary, empirical study' (2009) in the *International Journal of Justice and Sustainability*, cite the almost total lack of natural sounds in a typical city-centre park and the increase in traffic noise in our cities. An interesting conclusion is that the soundscape (the totality of the sound experience) in urban parks is influenced directly by the variety of bird species. Canadian researchers Darren Proppe, Christopher Sturdy and Colleen Cassady St Clair, in *Anthropogenic Noise Decreases Urban Songbird Diversity and may Contribute to Homogenization* (2013), revealed that songbirds were retreating from noisy urban parks. The clear conclusion is that ecology needs to be reinforced in order to enhance the natural elements of the urban soundscape. A fascinating study by William Davies et al, *Perception of soundscapes: An interdisciplinary approach* (2013), distinguishes natural, human and mechanical sounds, and confirms that soundscape connects us with place and society. Sounds, and their part in defining the ecology of a landscape, are the subject of an online article from the Ecology Global Network by Cheryl Dybas of the National Science Foundation, titled *Soundscape Ecology: Studying Nature's Rhythms* (2012). Soundscape is defined as being composed of the following:

- Biophony: the music created by organisms like frogs and birds
- Geophony: the composition of non-biological sounds like wind, rain and thunder
- Anthrophony: the conglomeration of noise from humans

Acceptable noise levels are a factor in HUP, as identified by Barton and Grant, in *Urban Planning for Healthy Cities: A Review of the Progress of the European Healthy Cities Programme* (2011). Ritchie and Thomas, in *Sustainable Urban Design* (2009, pp50 and 51), touch on two key acoustics issues: noise generated by external sources and noise transmission within buildings. Further information, and attenuation details, may be found in *Environmental Design* (2006, pp46–49) in which the author, Randall Thomas, sets out the difficulty of attenuating high levels of external noise. Pelsmakers, in *The Environmental Design Pocketbook* (2015, p95), provides detail on the means of reducing traffic noise with a vegetation buffer. However, the author cautions us that vegetation is unlikely to be effective on its own. Beer and Higgins, in *Environmental Site Planning for Site Development* (2000, p115), comment that people appear to be less disturbed by noise whose source they cannot see, so vegetation might have psychological benefits. The authors also point to the acoustic benefits of the rustling of trees in wind, and of the sound of water moving in the city, masking less pleasant sounds.

80. Greening the city

The benefits of urban greenery are discussed in detail, with useful checklists, by Pelsmakers in *The Environmental Design Pocketbook* (2015, Chapter 4). The 'park cool island' effect is explained, in which temperatures are reduced by 2–3°C compared with surroundings. Urban green spaces provide beneficial cooling for a considerable distance: 150m or more into the urban fabric, according to Givoni in *Climate Considerations in Building and Urban Design* (1998, pp 308–10). The cooling potential of urban spaces is described in detail by Brown and Mark DeKay in *Sun, Wind and Light: Architectural Design Strategies* (2001, pp121–4). Von Borcke, in *Sustainable Urban Design* (Eds Ritchie and Thomas, 2009, pp31–4), identifies the ways in which nature and landscape in cities improve quality of life for inhabitants; these include ecological, social and consequential economic benefits, which even a small outdoor space can bring. Ian Alcock et al, in a paper titled 'Longitudinal Effects on Mental Health of Moving to Greener and Less Green Urban Areas' (2013) in the *Journal of Environmental Science and Technology*, confirm that mental health improves enduringly when people move to greener urban areas. Cliff Moughtin and Peter Shirley, in *Urban Design – Green Dimensions* (2005, p81), provide a useful typology of green spaces of various scales.

81. Mixed-use cities

A very good description of the benefits of what Wheeler terms 'diverse urban form' may be found in his primer, *Planning for Sustainability* (2013, p142). Diversity through mixed uses is a sustainability issue as it leads to a healthy and vibrant overlapping of different groups in society, with reduced car use and pollution and attractive and popular varieties of form and function. The sprawling modern metropolis is the opposite. The influential author and activist Jane Jacobs, in *The Death and Life of Great American Cities* (1961), advocated mixed uses to achieve vital diversity, and diversity is a compelling theme in Rogers' *Cities for a Small Planet* (1997), in which the author argues passionately *against* separation and *for* the humanity manifest in 'living neighbourhoods' (p15). Rodwell, in *Conservation and Sustainability in Historic Cities* (2007, pp117–19), describes the 'urban village' concept of mixed-use development. A very clearly written document explaining the practical benefits of mixed-use cities is provided by Paul Beyer in *Livable New York – Sustainable Communities for all Ages* (2012, Section II.2.g).

82. Feeding the city

Jennifer Cockrall-King, in *Food and the City – Urban Agriculture and the New Food Revolution* (2012, pp78–80), considers the sensible idea of actually planning cities with food in mind. Small- and large-scale case studies illustrate the possibilities (such as the 'edible landscaping policy' in the city of Vancouver) and challenges. An excellent, and entertainingly written, global account of food supply and the status of sustainable urban agriculture (and the culture of food), with many examples of innovation and invention may be found in Lim's *Food City* (2014). Ween writes about 'the edible city' and provides an optimistic account of urban agriculture, including a description of vertical farms, in *Future Cities* (2014, Chapter 6). The author opines that cities are capable of growing within their boundaries a significant proportion of the food that they consume (p 71). Birkeland, in *Positive Development* (2008, pp281 and 282), describes the multiple benefits of an applied 'green scaffolding' approach to retrofitting buildings. The allotment strategies for UK towns and cities such as Oxford, Darlington and Canterbury provide a very useful resource, including the history of allotments and travel distance data, and may be found on the relevant councils' websites. Viljoen et al, in *Continuous Productive Urban Landscapes: Designing Urban Agriculture for Sustainable Cities* (2005), provide a fascinating and very well-illustrated proposition for connections between urban and extra-urban productive greenspace, defined as CPULs. A superbly written, must-read work, *Hungry City* (2013) by Carolyn Steel gives the reader a fascinating and inspirational account of the history and future of how the planet's cities are fed. Forman, in *Urban Ecology* (2014, pp344–9), tells us that in the US (at year 2000) the average distance a piece of food travels to where it is eaten is 2,400km. There is an excellent description of the ecology of agriculture and the relationship between agriculture and the city.

83. Inclusivity

Robin Hambleton, in *Leading the Inclusive City – Place-based Innovation for a Bounded Planet* (2015), states that cities are becoming more, not less unequal – and that this threatens all citizens. The inclusive city – which results from a partnership between citizens, locally-based civic leadership and the environment – is defined (p6), and the author confirms that public transportation improvements are key to inclusivity as they have a transformative influence on lifestyle and opportunity (p314). The author emphasises how the time has come for city leadership to place equity over economic growth. The work uses case studies ('innovation stories') to illustrate key themes for successful, inclusive and sustainable cities.

Wheeler, in *Planning for Sustainability* (2013, Chapter 4), discusses how inclusivity is part of the notion of equity, and explains how varying wealth in urban areas leads to 'social isolation' or exclusion as the rich/poor divide grows. Urban equity is related to affordable social housing. Quoting urbanist Kevin Lynch, Wheeler interprets the importance of 'accessible' cities. Leading on from this, Birkeland, in the optimistic and wonderfully challenging text *Positive Development* (2008, Chapter 13), states that society can only be sustainable if everyone becomes 'better off'. In the academic yet practical text by Susan Fainstein, *The Just City* (2010, Chapter 2), inclusivity is discussed in relation to diversity. We are, however, urged to be wary of the inauthenticity that can result from a planned forcing together of communities.

CHAPTER 5. STRATEGIES FOR SUSTAINABLE BUILDINGS AND CITIES

84 to 89. Strategies for sustainable retrofit

Eco-retrofit and creative reuse

Birkeland, in *Positive Development* (2008, Chapter 2), defines the 'eco-retrofit', which is viewed as an imperative of sustainable development and a key focus of this highly readable and informative treatise. The integrated retrofit is discussed (pp28 and 29). Ween, in *Future Cities* (2014, pp109–10), advocates multi-function buildings as a means of increasing occupancy; many schools, offices and public buildings are only occupied for 30–50% of the time. The author also raises the prospect of 'meanwhile' or 'transition' uses for unoccupied buildings that have been targeted for eventual redevelopment. Rodwell, in *Conservation and Sustainability in Historic Cities* (2007, p57), quoting Sir Bernard Feilden, states that sustainability *is* prolonging the useful life of a building – leading to resource and financial savings. The large resource of empty properties in our cities, and the need for inventive reuse, is discussed (pp127–8). Carroon, in *Sustainable Preservation* (2010, Section 7.4), writes on extending the service life of buildings and on their creative reuse, using well-presented case studies formatted for easy comparison. Describing what makes existing buildings 'green', the author discusses 'passive survivability' (p10), the ability of a building to provide an appropriate environment even if its systems fail, indicating that the passive design principles adopted in many historic buildings provide lessons for today. Regenerative design is defined not as creating a society that is less harmful to the environment, but as achieving one that produces truly restored, sustainable environments (p14).

Interior retrofit is covered well by Siân Moxon, who, in *Sustainability in Interior Design* (2012), provides a comprehensive, balanced and very well-illustrated work with creative case studies. Of interest to interior designers, architects and others involved in the specification of interior work (both new-build and retrofit) is a particularly good section on materials choices and impacts (pp84–106). The dangers of manufacturers' 'greenwash', sources of reliable specification information and green materials' credentials are described (pp100–1). The author is another proponent of rediscovering lost lessons from the past. The benefits associated with reuse, including the connection between life-cycle costing and reuse, are concisely outlined by Tucker in *Designing Sustainable Residential and Commercial Interiors* (2015, Chapter 7), and a very useful 'step-by-step' guide to the process to be followed by the design-team is given. The author also provides an overview of the integrated design process (Chapter 1). Adaptive reuse also features on the online forum of the Sustainable Cities Collective.

Low-energy retrofit

Prasad, in *Retrofit for Purpose* (2014, pp6 and 7), describes the 'deep energy retrofit' and the need for both fabric and systems to be assessed and upgraded in a holistic way. There is a practical list of 'keys to success' in retrofit projects (p11). Case studies illustrate solutions, including the first Passivhaus-standard non-domestic building in the UK (Case Study 8, pp163–73), for which extensive measures were needed to achieve very low energy use without compromising occupant comfort and fabric integrity. There is a strong emphasis throughout the essays and case studies on the need for assessment of building performance and the issue of the 'performance gap' between calculated and actual energy use.

Unintended consequences

Pelsmakers, in *The Environmental Design Pocketbook* (2015, pp282–7), provides an excellent checklist of retrofit measures and, importantly, a concise appraisal of the common, unintended consequences of retrofit decisions – such as reduced, not improved air quality within an envelope that has been made airtight. This issue is increasingly addressed by introducing a mechanical ventilation and heat recovery (MVHR) system: see Prasad (ed), *Retrofit for Purpose* (2014, Case Study 8). Overheating is another consequence of low-energy retrofit that authors commonly discuss. From a paper by Anna Mavrogianni et al, *The Unintended Consequences of Energy Efficient Retrofit on Indoor Air Pollution and Overheating Risk in a Typical Edwardian Mid-terraced House* (2013), it is clear that overheating and indoor air quality are linked phenomena in a retrofit.

The website feature www.responsible-retrofit.org/wheel provides a design tool for exploring retrofit problems and solutions. The Institute for Sustainability in the UK has published a series of guides to retrofitting the UK housing stock, and guiding principles for existing buildings, focusing on an integrated approach, are set out in the US National Institute of Building Sciences Whole Building Design Guide. The sequential approach considers assessment, operations and maintenance.

90 to 101. Strategies for sustainable architecture and cities

Positive strategic thinking

In a refreshingly engaging format, Birkeland, in *Positive Development* (2008), challenges much of the standard thinking about the way in which we conceive of sustainable buildings and cities. The author throws down the strategic gauntlet of 'net positive design' – in which buildings and cities contribute more to ecology and the environment than they consume, and in which 'waste' becomes a resource (pp71 and 341). The author also reminds us that while a focus on reduced energy use has been a central concern in recent years, now both user-centred and environment-centred design are needed (p110). Birkeland also asks whether durability should always be a virtue in architecture: a high degree of adaptability might be best achieved with 'reversible', easy-to-change, organic materials and structures.

Kodama Yuichiro, in *Eco-urbanity – Towards Well-mannered Built Environments* (ed Radovic, 2009, pp178–81), describes his take on the ‘positive spiral’ of benefits to user and the environment resulting from an ecological approach to urbanism. The book’s editor, Darko Radovic, reminds us (pp 9–17) that sustainability is not intrinsically idyllic – its can flourish in the toughest of conditions and in the most undemocratic of cultures.

An essential reader on architectural strategies is Sassi’s *Strategies for Sustainable Architecture* (2006). The work is practical, comprehensive and very well presented, with each topic introduced then supported by a broad range of case studies.

Compostable architecture was featured recently on the website Technology4Change, and further useful discourse on ‘net positive’ thinking may be found on the websites of The Climate Group and the Forum for the Future. There is also a good article in the *Guardian* online newspaper about the challenges of targeting ‘net positive’ in relation to water (6 September 2013).

City, region and planet: energy and resource flows

The relationship between the consumption and disposal of energy and matter is the theme of much contemporary urban-sustainability literature. Jacques, in *Sustainability – the Basics* (2015, p38), describes the ‘metabolism of societies’, in which the consumption of matter and energy and the disposal of waste are, crucially, dependent upon an individual’s or a community’s surroundings – such as, presumably, in the case of the city, its region. Jaques provides his own principles of sustainability (Chapter 2), and his principles for sustainable development (citing ecological economist Herman Daly, p41) require that:

- renewable resources should not be harvested beyond their regenerative capacity
- non-renewable resources should not be used faster than substitutes can be produced
- sinks should not be used beyond their natural assimilative capacity

Ecosystem flows – and the related movements of animals and plant life, microbes and humans within and around cities – are very well described by Forman in *Urban Ecology* (2014, pp68–76). Diagrams of optimum green-space patterns for connected habitats are given (p71).

Gaines and Jäger, in their *Manifesto for Sustainable Cities* (2009, p24), describe an ‘overarching holistic system’ in which a city transforms some of its waste into energy, creating heat, and recycles and reclaims the remainder. With a regional perspective, Birkeland, in *Positive Development*, (2008, p44), views the city’s region as a ‘source and a sink’, and the author explains how positive environmental characteristics (‘flows’) can be increased by good urban design. Mark Whitehead, in *The future of sustainable cities – Critical reflections* (eds J Flint and M Raco, 2012), teaches us that the sustainable city is, almost inescapably, a global city. The socio-ecological footprint of the city today is connected to those of distant cities and, furthermore, to earth's ecosystems (p33). Other themes (many common within the subject literature) of this fascinating collection of essays include the interconnectedness of cities globally, the nature of the 'post-political' world, the uncertain impacts of the early 21st-century global financial crisis and the relationship of 'neo-liberalism' to urban-planning theory. And, in an excellent, balanced essay by Jody Milder in *Sustainable Urban Environments – an Ecosystems Approach* (eds E Van Bueren et al, 2012, pp263–84), the various typologies of city form are discussed and the author sets out well the conflicting issues with regard to compact cities. The water consumption of cities is cited as clearly the most substantial 'material flow'. The author advocates starting with the city as it is and introducing aspects of sustainability without losing essential character/identity. An excellent diagram of the 'ecodevice model' for the relationship between city and region (p288) indicates the different scales of flows, and was a model for the diagram for Rules 96-101 in this book, which adds the next scale: planet earth. So-called 'input-output' ecological flows are discussed in relation to the morphology of the city in the excellent text book by Forman, *Urban Ecology* (2014 Chapter 3).

In his final chapter in *City Design: Modern, Traditional, Green and Systems Perspectives* (2011, pp 203 - 211), Barnett concludes with a six-point manifesto for the future of city design, including car-free, compact business centres and walkable neighbourhoods. New economic systems, we are told, relate regional cities to their super-regional context within a changed social geography; we can expect to see a growth in the specialisation of centres within a multi-region city.

Starting with what's there to create a high-quality public realm

Rodwell, in *Conservation and Sustainability in Historic Cities* (2007, Chapter 6), states that the starting point for cities and their localities should be proximity and access. London's environmental footprint, we learn, is 125 times its actual surface area, a fact leading the author to state that key sustainability issues are: land use, water, non-renewable raw material and energy resources, airborne pollution and health, waste and the quality of both the physical and socioeconomic environments (p112). Rodwell describes the historical city model (which some authors term 'the pre-automobile city'), which was in a sustainable relationship with its surroundings (p114), a condition that the future city needs to return to – in turn, a theme common to much contemporary thinking. Beer and Higgins, in *Environmental Site Planning for Site Development* (2000, p260), give the key factors to be understood before making decisions about site development as: water, waste, energy, transport and biodiversity.

Sustainability goes hand-in-hand with a high quality of urban environment, and quality is a theme within most, if not all, of the texts cited in this volume. Works on urban planning and design, on how to create a high-quality physical environment are beyond the scope of this book; nevertheless, the importance of high-quality public realm, and of public ownership of that realm, is well described by Hambleton in *Leading the Inclusive City* (2015, pp102–7). The qualities of a desirable urban environment are eminently well captured by Rogers in *Cities for a Small Planet* (1997), and the qualities of the future city are succinctly summed up by Ween in the conclusion to *Future Cities* (2014).

Responsibility and ethics

Whereas only a few generations ago we were an outdoor, rural species, we now spend around 90% of our time inside buildings according to the United States Environmental Protection Agency in a paper titled *Buildings and their Impact on the Environment: A Statistical Summary* (2009, p4). Reliable and comparable figures for the number of qualified built-environment professionals designing those buildings globally are more difficult to obtain. However, considering only the UK, around 0.05% (or 1 in 2,000) of the population is a registered architect (the figure is about 0.03% in the US). The responsibility to design our built environment is therefore held by only a few. Sustainability is an ethical matter, and ethics are at the heart of much of the subject literature. Birkeland, in *Positive Development* (2008, p220), discusses how dealing with basic ethical issues is fundamental to sustainability, and Edwards, in the *Rough Guide to Sustainability* (2014, pp327–8), focuses on ethics in a forward-looking essay about sustainability education.

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Huw Heywood is an architect with over 25 years' experience in practice and teaching internationally. He has taught at undergraduate and postgraduate levels, most recently as Principal Lecturer at Portsmouth School of Architecture in the UK, where his particular teaching and research focus was environmental and sustainable design.

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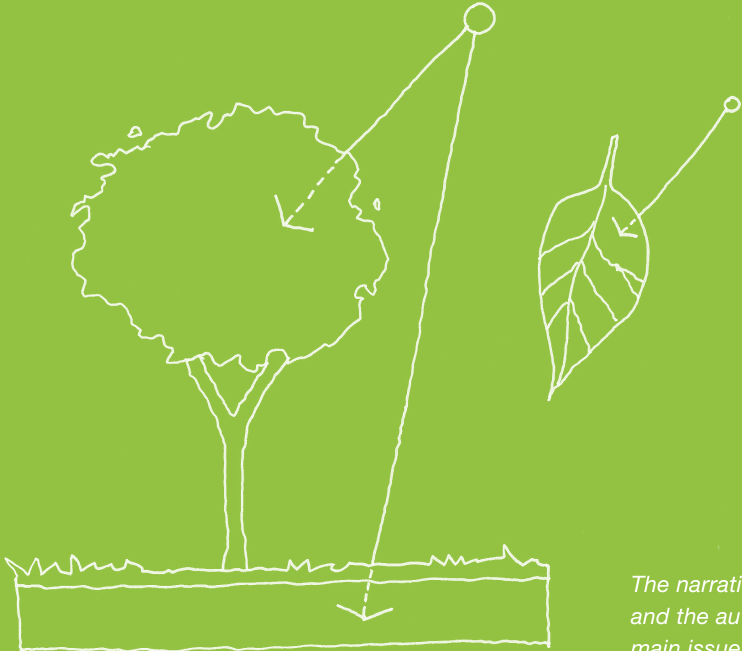

Working out how to be sustainable is complicated. Find out where to start, what to focus on and what works with these ***101 Rules of Thumb for Sustainable Buildings and Cities***.

The narrative bibliography is overall outstanding and the author's discipline to draw out the main issues from key texts for the reader is to be applauded.

Sofie Pelsmakers,
Sheffield School of Architecture

Very accessible and refreshing for the initiated as well as those who are less familiar. A good present too.

Lynne Sullivan OBE, sustainableBYdesign

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