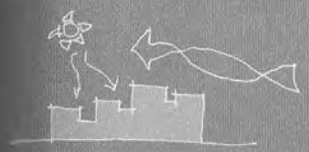
Chapter 3

Environmental site planning



A building's performance is not only determined by local climate conditions and operational energy efficiency. Site location and urban design approach also have a major impact. Rather than working against the urban grain, we need to work with it by using environmental site planning principles; we can then promote occupant comfort and health as well as minimising operational and transportation energy use.

Instead of endlessly repeating historical patterns, site planning should respond to climate change predictions. This chapter considers the implications of a warmer climate and Chapter 5 discusses flood risk.

It is crucial to get the environmental basics right on the site. Then whoever 'plugs into' the urban grain in the future has a better chance of achieving high environmental building standards.

Symbol indicates relevance to the Code for Sustainable Homes, EcoHomes & BREEAM.

3.1 ENVIRONMENTAL SITE CHECKLIST 49

3.2 BROWNFIELD: INFILL DEVELOPMENT 50

3.3 DESIGNING FOR URBAN DENSITY 51

3.3.1 What are sustainable densities? 52
3.3.2 Regional recommended densities 53
3.3.3 Zero carbon versus density paradox 54

3.4 DESIGNING FOR CYCLISTS AND PEDESTRIANS 56

3.4.1 Car-free developments 57

3.5 PLANNING FOR URBAN OPEN SPACES 58

3.5.1 Plan continuous green corridors 59

3.6 CREATING A POSITIVE URBAN MICROCLIMATE 60

3.6.1 Designing with the wind 60

3.7 USING SUNSHINE IN URBAN AREAS 64

3.7.1 Urban breaks 66
3.7.2 Rethinking single-aspect dwellings 67
3.7.3 Spacing for good daylighting: the Vertical Sky Component 68

3.8 FUTURE-PROOFING THE SITE 69

3.8.1 Planning for infrastructure 69
3.8.2 Planning for low and zero carbon technologies 69

3.9 APPLICABLE LEGISLATION AND GUIDANCE 70

3.10 FURTHER READING 70

3.1 ENVIRONMENTAL SITE CHECKLIST

Refer to	Biodiversity	☑ ☒
4.4	Do the proposals enable the existing wildlife and biodiversity to be conserved, protected or enhanced?	☐
3.5.1, 4.4.1	Is there space for the creation of green corridors?	☐
	Site planning	
3.3	Are public transport facilities easily accessible?	☐
3.3	Can the site be located close to community facilities and services?	☐
3.3	Is the development density appropriate? Is the mix of uses and tenure suitable to the locality? Can density be increased around transport nodes, overlooking parks, waterways and other amenities?	☐
3.4	Movement strategy: can new access routes be connected with existing routes?	☐
3.4.1	Prioritisation of pedestrians and cyclists: are there bicycle parking spaces, safe crossings/walkable streets and good connections through the city centre rather than around it?	☐
3.5	Are there easily accessible communal open spaces (within 300–400 m)?	☐
3.6, 3.7	Has the impact of new development on existing community and buildings – traffic/noise/overshadowing etc. – been minimised?	☐
3.7	Have local solar access and average seasonal temperatures been checked and responded to, and is winter solar gain maximised?	☐
3.7.1	Have 'urban breaks' (variety of building heights, providing better solar access and ventilation) been provided?	☐
4.2	Has vegetation been used to reduce air pollution, moderate the urban heat island effect and increase thermal comfort?	☐
	Flood protection (See detailed checklist Section 5.1.4.)	
5	Has a minimum of 5% of the site area been set aside for sustainable urban drainage systems (SUDS)?	☐
	Future-proofing	
3.8	Is there enough space for urban infrastructure, including renewables? Is there enough space for community energy schemes?	☐

3.2 BROWNFIELD: INFILL DEVELOPMENT

A brownfield is a site that has been previously developed. It may be contaminated if its prior use was industrial – docks, gasworks, petrol stations, etc. Most UK cities have policies to protect greenfields (undeveloped land) from development. This pushes developers to use brownfield sites instead. Often brownfields are considered to be of low ecological value compared to rural or suburban greenfields. However, an urban brownfield site which has been derelict for a few years actually provides an excellent habitat for vegetation to grow undisturbed and for wildlife to settle.

Key recommendations

- Undertake site contamination testing at feasibility stage.
- If it is contaminated, liaise with the local authority and specialist agencies about suitable strategies, such as:
  - removing contaminated topsoil from site, capping or chemical cleansing
  - bioremediation – cleansing certain pollutants from soil using plants such as willows and reeds; this method is preferred but it may not remove all pollutants.
- Undertake ecological site survey and identify protected species.
- Undertake site planning to protect as much ecology as possible. Incorporate ecology into new design.
- Introduce plant species to support wildlife habitats.
- Uncontaminated rubble and soil can be relocated to green/brown roofs.

→ Jump to Sections 7.1.8 & 9.3.

Advantages of developing on brownfields:

- usually central location
- protects the sprawl of cities onto greenfields
- existing infrastructure (roads, energy, water connections)
- sites can be of higher ecological value than greenfields: ecology can be retained if sensitively developed.

Disadvantages of developing on brownfields:

- possible disturbance of valuable biodiversity
- remediation of contaminated land will add to construction costs and may cause delays
- clients often unwilling to do extensive site contamination testing before planning consent has been obtained
- if high biodiversity, it may be difficult to obtain maximum ecology credits under EcoHomes/Code for Sustainable Homes (Eco 1 to Eco 4) and BREEAM (LE 2 to LE 5); in BREEAM, credits can be obtained for developing on brownfields (LE 1).

3.3 DESIGNING FOR URBAN DENSITY

The more compact a city, the more environmentally sustainable it is. However, environmental considerations must go hand in hand with concern for inhabitants' preferences and well-being. People will be driven away from high-density urban areas if they lack spacious, high-quality dwellings and open spaces.

To counter this, high residential densities should always incorporate a range of mixed-use facilities.

The environmental benefits of medium/high density

- uses land efficiently, avoiding sprawl into greenfields
- supports public transport strategies – economies of scale for infrastructure/numbers of users
- shared and efficient energy/water supply, waste infrastructure and services
- easy access to facilities and public transport
- reduces parking demand and car ownership, which decreases local noise/air pollution and carbon emissions
- enables shared energy strategies such as community/district heating schemes → Jump to Chapter 10
- energy-efficient building typology: more compact with lower space heating and infrastructure requirements.

Disadvantages

- open space and biodiversity compromised within cities
- perceived overcrowding where insufficient open space is provided
- higher embodied energy due to taller building typology
- potentially compromised access to passive solar gain, daylight and natural ventilation – needs careful design → Jump to Chapter 6
- urban heat island effect may be exacerbated and make summer cooling more challenging under certain conditions → Jump to Chapter 4
- zero carbon developments are difficult to achieve at high densities (Section 3.3.3) → Jump to Chapter 11.

Credits under EcoHomes/Code for Sustainable Homes (Eco 5)

3.3.1 What are sustainable densities?

Minimum densities of around 80 dwellings per hectare (dw/ha) are recommended. This is a healthy density for public transport use and it supports close walking proximity to community services and facilities.[1] For car-free developments, densities should increase to 200–250 dw/ha (see Section 3.4). Maximum sustainable densities are 400–450 dw/ha. Such high densities should be limited to only part of a development.[2]

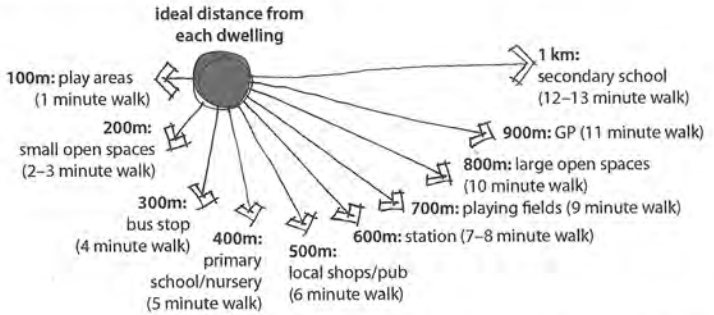


Fig. 3.3.1 Proximity of facilities and ideal distances from each dwelling[3]

Key recommendations

Always accompany sustainable densities with:

- easy access to open spaces and facilities such as GPs, supermarkets and schools
- minimum 15% open space provision – see Section 3.5
- neighbourhoods designed for walking, cycling and good public transport access
- ideally a mix of densities in each development to create variety and open spaces, reduce risk of perceived overcrowding and allow solar access – see Section 3.7
- higher localised densities around transport nodes, overlooking parks, waterways and other amenities
- high four+ storey density developments – may be suitable for communal or district heating plants (at least 200 units in the development)
- a good mix of housing sizes and typologies to support the community through different stages of life.

3.3.2 Regional recommended densities

Each city's Local Development Framework (LDF) (or Unitary Development Plan, UDP) makes recommendations for minimum and maximum densities. These are directly related to city location and public transport access. This is also referred to as PTAL (Public Transport Accessibility Level). The higher the PTAL, the better the public transport access.

Avoid development in areas with little or no public transport access, unless provision is part of the development proposal. Otherwise this will only encourage car usage, increasing pollution and negating any energy savings made by low carbon developments.

The minimum recommended densities are often below 'sustainable' densities. This means that they are unlikely to support good public transport and other facilities. From 30 dw/ha, only bus services are sustainable.[4] The shaded areas in the table below are those densities at which zero carbon developments are likely to be feasible. → Jump to Chapter 11.

Fig. 3.3.2 Densities recommended in Local Development Frameworks[5]

Location	Dwelling typology	PTAL	Glasgow	Edinburgh	Manchester	Belfast and Cardiff	Birmingham	Plymouth	London
city centre	flats: 4–6 storeys and taller	high	30–100 max.	50–100+	75	50+	100	150	80–210
suburban	terraced houses & flats; 3–4 storeys	average	75	25–50	75	30–50	50	70	55–145
rural	detached/ semi detached houses; 2–3 storeys	low	<50	<25	40	30	40	40	40–80

3.3.3 Zero carbon versus density paradox

There is a known conflict between zero carbon standards for buildings and large-scale development sustainability. For a development to rely only on on-site renewable energy generation, maximum densities must drop to 35–40 dw/ha. This is below the 'sustainable density' required to support public transport and other facilities. It is also below the density of existing urban areas in the UK.[6] It is difficult to meet zero carbon standards at 'sustainable densities' in urban areas because:

- There are higher energy needs per site area, owing to the large number of residents; at the same time, there is significantly less space to generate on-site energy.
- Renewable energy technologies are particularly inefficient in urban areas; for example, solar panel technologies are at risk of shade, and wind energy is rarely suitable owing to lower and unpredictable wind speeds.
  ⟶ Jump to Chapter 12.
- A high-density development combined with off-site energy generation may be more appropriate but off-site energy generation may not be allowed as part of the zero carbon definition. ⟶ Jump to Chapter 11.

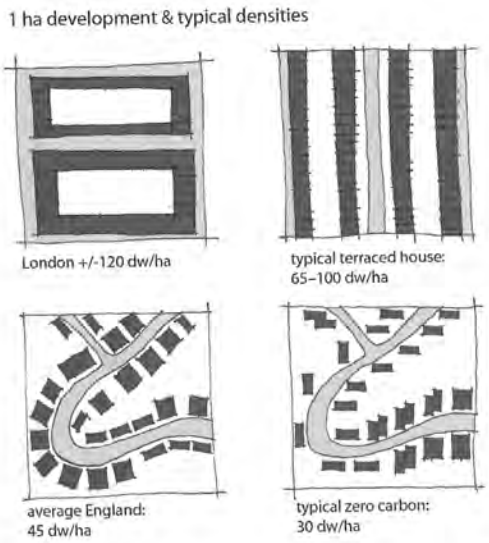


Fig. 3.3.3 1 ha development and typical densities

If off-site carbon offsetting is used, densities around 50 dw/ha are likely to meet the zero carbon standard. However, such low densities are not recommended as they create sprawl and increased energy use for transport. This negates the buildings' zero carbon status.

Fig. 3.3.4 Feasible zero carbon strategies in relation to development density

Development density	Current feasible zero carbon strategies[7]
Rural ≤50 dw/ha max.	Gas boiler with PV and solar thermal panels on individual roofs. If development ≥50 dwellings: communal plant with solar panels on individual roofs may be feasible. Other technologies, such as ground/water source heat pumps, wind turbines, micro-hydro and locally sourced biomass, may also be feasible. ⟶ Jump to Chapters 11 & 12. Likely to meet zero carbon standards with on-site measures.
Suburban >50 and ≤100 dw/ha	Increased Fabric Energy Efficiency Standards (FEES). Individual dwelling approach with PV and solar thermal panels and gas boilers or air source heat pumps. ⟶ Jump to Chapters 11 & 12 for other suitable technologies. Where ≥50 dwellings in the development: building block approach with shared gas, district heating or CHP. Difficult to meet zero carbon standards with on-site measures only.
Urban >100 dw/ha	Increased Fabric Energy Efficiency Standards (FEES), with PV and solar hot water panels on roof and communal gas heating. ⟶ Jump to Chapters 11 & 12 for other suitable technologies. Unlikely to meet zero carbon standards with on-site measures only.

3.4 DESIGNING FOR CYCLISTS AND PEDESTRIANS

Encouraging residents to walk or cycle not only reduces carbon emissions: it brings streets to life, builds safer neighbourhoods and improves health for city inhabitants. Distances less than 2 km are suitable for walking and cycling, although the average distance people are prepared to walk is 1.25 km (roughly a 15-minute walk). Ideally, local facilities should be located within a 1.25 km radius from residential neighbourhoods. The energy used to access buildings by car can be 30% higher than the energy used to run the buildings.[8]

Fig. 3.4.1 Carbon emissions from different modes of transport

Travel mode	kg CO_2 per km travelled
walking/cycling	0
train	0.07
bus	0.133
car	0.214

Key recommendations[9]

- Provide good connections and short routes through the development to facilities, transport and open spaces (max. 300–400 m).
- Conduct wind modelling of long, straight routes to avoid unpleasant wind tunnels. Provide wind breaks or buffers as needed.
- Ensure safe and regular crossings to areas of interest.
- Introduce interesting features along the way, e.g. shops. Design irregular façades and allow for seating areas and arcades.
- Do not randomly place seating in the middle of squares. Place seats in niches, ideally facing the sun, with back protected. This offers protection, security and a good microclimate.
- Provide alternative routes with small squares (20–25 m radius) on the edges of pedestrian routes.[10]
- Avoid squares over 100 m in length.
- Avoid tall, freestanding buildings as they catch wind and direct it downwards. See Section 3.6.1.
- Avoid level differences and stairs; always provide ramps.
- Encourage people to cycle by introducing cycle lanes and parking where possible. Always introduce separate lanes where vehicular speeds ≥ 30 kph (20 mph).[11] Vegetation may act as a barrier. —→ Jump to Chapter 4.

Code for Sustainable Homes credits (Ene 8, Man 1) and EcoHomes credits (Tra 1, Tra 2) and BREEAM credits (Tra 3, Man 4)

3.4.1 Car-free developments[12]

Generally, the single biggest source of urban air pollution is car use. Around 15% of the UK's carbon emissions are related to individual car use.[13] Developments with no car ownership or parking provision may be feasible where the development:

- encompasses minimum 20 dwellings
- has a high density of at least 200–250 dw/ha
- consists of building typology of flats, terraced houses and mostly narrow fronts with 4–6 storey buildings
- is located within 300–400 m radius of regular public transport – local authority classified high Public Transport Accessibility Levels (PTAL)
- is located within 300–400 m radius of mixed use facilities
- includes a car club as part of the development – one car club vehicle replaces on average five individually owned cars[14]
- implements the ten key design recommendations for cycling/walking.

3.5 PLANNING FOR URBAN OPEN SPACES

Green space is particularly important in dense urban areas. It should be an essential part of city and site planning. Protection of open space is also important: any space lost during redevelopment needs to be reallocated elsewhere on the site or in the vicinity.

Urban open spaces are necessary to:

- contribute to the urban dweller's mental and physical health; they have a positive impact on mortality[15, 16]
- store incoming flood waters and protect built-up areas —→ Jump to Chapter 5
- contribute to a positive urban microclimate —→ Jump to Section 4.2.1
- support biodiversity. —→ Jump to Section 4.4
- alleviate urban density pressures.

Key recommendations

- Consult each region's local development framework and open space standards.
- Allocate minimum 15% of each site to open space provision, of which at least 5% is for sustainable urban drainage systems (SUDS). SUDS can be incorporated creatively to offer both water storage in the event of flooding and open space throughout the rest of the year (e.g. 'water squares'). —→ Jump to Chapter 5.
- Locate open spaces within a 300–400 m (5–6 minute) walk from each dwelling.[17] These parks should include outdoor sports areas/playing fields, wildlife areas and landscaped seating areas. Parks should be at least 2 ha in size.
- Small parks and open spaces under 2 ha are still valuable in densely built-up areas and will be well used by the elderly and people with children.
- An urban grid of about 90 × 90 m with public open space at the centre is the best compromise between wildlife support, accessibility and pedestrian permeability.[18]
- Open spaces are not always purely recreational. They can be squares, allotments, rivers, waterways, ponds and reservoirs and can even be incorporated into buildings.

3.5.1 Plan continuous green corridors

City-scale networks should interlink open spaces to form continuous green corridors which reach from the city centre to the edges. This maximises urban residents' access to large and varied open spaces. Interesting cycle and walking routes can be provided and biodiversity is better supported. Where disruptive new roads and passageways are proposed, undercrofts or green bridges can be introduced to interconnect the spaces. Always ensure greenery is interlinked at macro, micro and building scale.

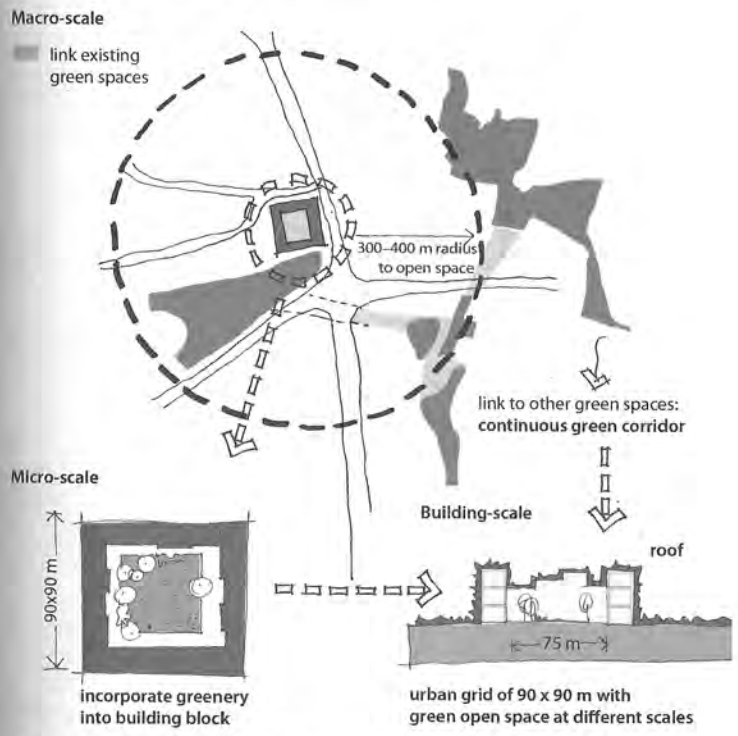


Fig. 3.5.1 Scales of open spaces and linking into continuous green corridors at macro, micro and building scale

3.6 CREATING A POSITIVE URBAN MICROCLIMATE

Because of the dense congregation of buildings, people and activities, urban areas have a different local climate from the surrounding countryside. This manifests itself in lower humidity levels, higher air pollution due to lower wind speeds and higher temperatures by 4–7°C which are felt most keenly during summer nights.[19] This is referred to as the urban heat island effect (UHI).

In winter, the local climate is buffered by the heat island effect. However, it can exacerbate overheating in summer. One of the most effective solutions is to increase green space in urban areas as it reduces local summer temperatures yet buffers winter temperatures. ⟶ Jump to Section 4.2.1.

A positive urban microclimate can be created through careful master planning which takes into account local and seasonal wind/solar pathways. There are many parameters to take into account, discussed throughout this book:

- urban surfaces (roofs, streets, buildings) ⟶ Jump to Sections 4.2.2 & 9.3
- vegetation: proportion, type & location ⟶ Jump to Section 4.2
- noise sources ⟶ Jump to Section 4.2.5
- rainfall and water runoff ⟶ Jump to Section 5.6
- flood risk ⟶ Jump to Chapter 5
- wind speed and wind direction (Section 3.6.1)
- solar access throughout the year, taking surrounding buildings into account (Section 3.7)
- other site conditions such as geology and topography.

3.6.1 Designing with the wind

Working with the wind is crucial for successful urban environments. The closer the buildings, the more they protect each other from winds, but also the more they reduce each other's solar gain. Buildings too close together will lack summer ventilation and street pollution may not disperse.

In the UK, the winds come from over the Atlantic. The influence of this huge sea mass explains the frequent and heavy rainfall on the western side of the UK. The air from the European mainland is less moderated, temperature-wise, as the North Sea/Channel is too small to have an effect. As a result, the south-westerly prevailing winds are less problematic than the colder north-easterly or south-easterly winds over mainland Europe.

The main wind direction in the UK is from the south-west. In Regions 1 and 3, the prevailing summer wind direction is from the north-east.

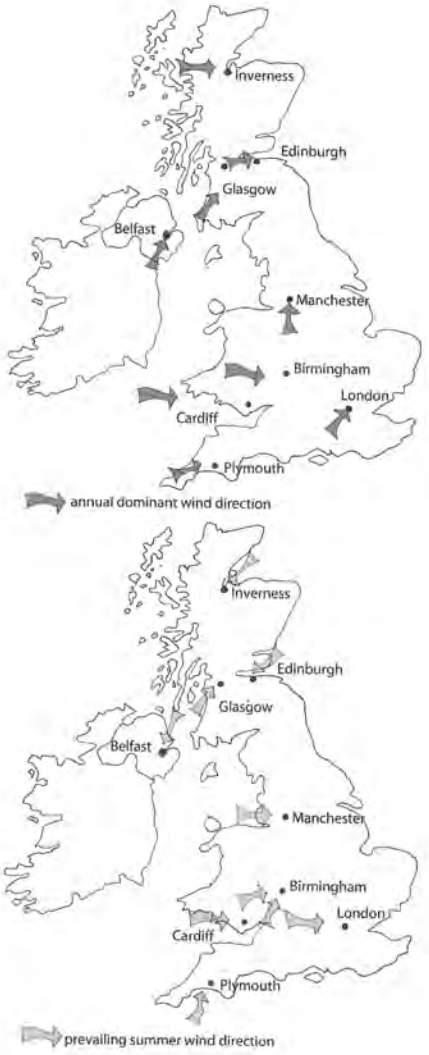
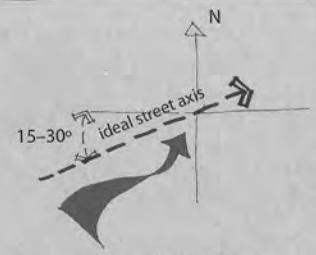


Fig. 3.6.1 UK map of dominant wind directions and summer prevailing wind

Key recommendations

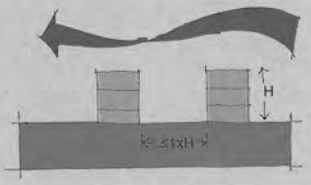
Determine wind direction and existing shelter or obstructions. See www.windfinder.com



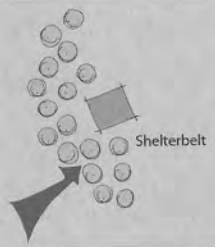
South–westerly main wind direction

For best building ventilation and protection, it is recommended that buildings are skewed by 30° to the prevailing yearly or summer wind direction. Taking into account prevailing south-westerly winds in most UK locations and best winter solar gain opportunities, this means:

- a street axis 15–30° from the west axis, towards west-south-west orientation in most UK locations
- exceptions to this include Edinburgh and Plymouth. Owing to these cities' prevailing wind patterns, they would benefit from a street pattern on the east–west axis.

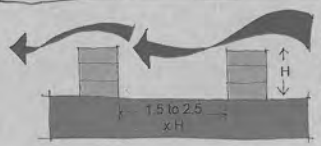


Courtyard width should equal height of building if enclosed on all sides. This will provide wind buffering and allow sufficient ventilation and winter solar gain.[20]

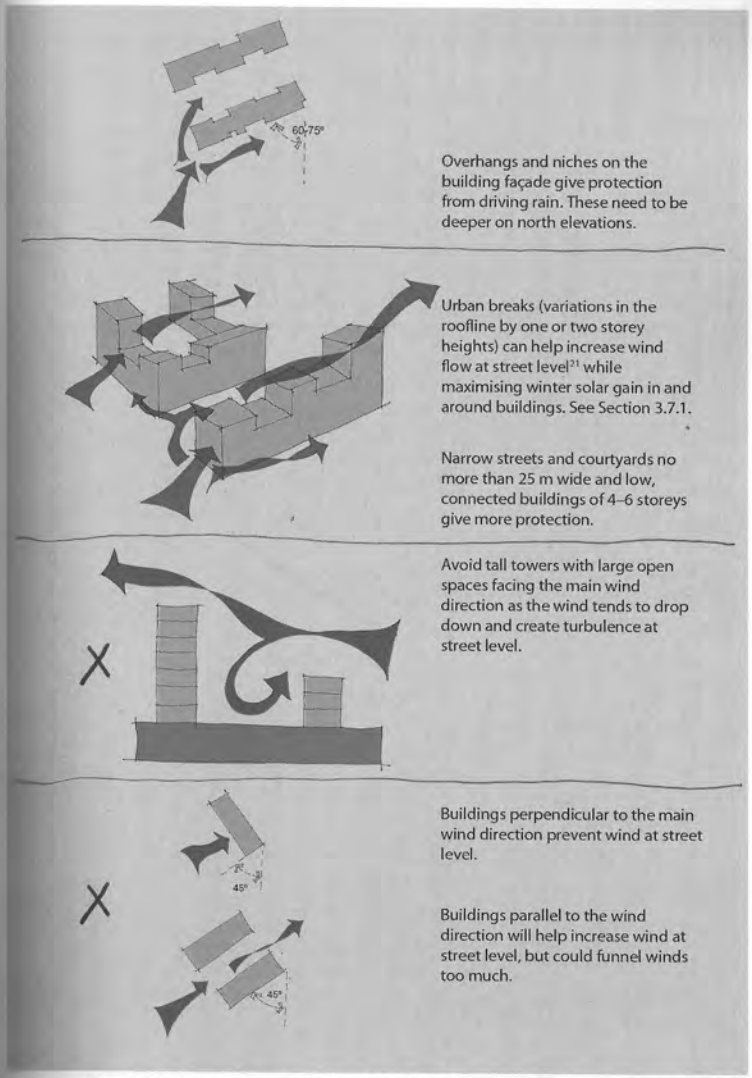


Trees and shelterbelts placed to the north-east and skewed by 30° from the main wind direction will protect buildings from cold winter winds.

Jump to Section 4.2.3.



If heights of buildings are greater than their spacing, there is little wind penetration. This can be a problem for dispersal of air-borne pollutants. Spacing of 1.5–2.5 times the building height is recommended for good natural ventilation, daylighting and solar gain.



Overhangs and niches on the building façade give protection from driving rain. These need to be deeper on north elevations.

Urban breaks (variations in the roofline by one or two storey heights) can help increase wind flow at street level[21] while maximising winter solar gain in and around buildings. See Section 3.7.1.

Narrow streets and courtyards no more than 25 m wide and low, connected buildings of 4–6 storeys give more protection.

Avoid tall towers with large open spaces facing the main wind direction as the wind tends to drop down and create turbulence at street level.

Buildings perpendicular to the main wind direction prevent wind at street level.

Buildings parallel to the wind direction will help increase wind at street level, but could funnel winds too much.

Fig. 3.6.2 Recommended street and building configuration in relation to prevailing winds

3.7 USING SUNSHINE IN URBAN AREAS

Taking advantage of passive solar gain reduces a building's energy consumption. It also helps to create enjoyable outdoor spaces. Low buildings and open spaces which are oriented to the sun create a positive microclimate in winter. This extends the 'outdoor season' and reduces space heat demand in dwellings by around 15%.[22]

Free heat coming from the sun is important but it is not essential for designing low carbon dwellings. It should not be maximised at the expense of good urban design or if it will jeopardise other factors such as good views, enclosure, existing urban grid, accessibility and security. There's also a risk of summer overheating.

Jump to Chapter 6.

Reduced solar gain can be offset by higher fabric energy efficiency standards. Uses such as dwellings, nurseries and housing for the elderly should be prioritised for sites with solar gain.

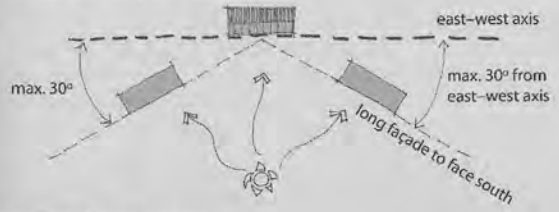
To illustrate: 1 m^2 of a double-glazed, unobstructed window facing directly south in Region 4 (South of England and Wales) typically receives an amount of heat energy (190 kWh/m^2)[23] from the sun in the course of one year equivalent to the amount released from the body of a single person working within that space. This illustrates that it is not always demanding to offset reduced solar gain by other measures.

In well-insulated buildings, solar gain can provide 10–20% of yearly space heating demand.[24] However, design should not rigidly prioritise southerly orientation. Urban breaks can be a good compromise: they add interest and also aid urban ventilation. See Section 3.7.1.

Key recommendations

- Determine sun path and existing shelter/obstructions..
- Design with solar access during February–October in mind but accept that in mid-winter this may not be possible.
- The façade should face directly south, ideally no more than 30° off the east–west axis. However, in most UK locations, after taking prevailing wind conditions into account, this means a predominant west-south-west streetpattern, within 15–30° from the east–west axis. See key recommendations Section 3.6.

Ideal residential building orientation



Ideal residential street orientation

See also Figure 3.6.2.

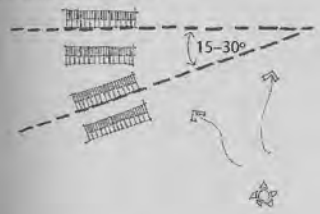


Fig. 3.7.1 Urban solar access

- Recommended street spacing is 1.5–2.5 times the building height. In a typical development with 2–4 storey buildings, streets and open spaces have to be 25–30 m wide to prevent overshadowing. However, distances should not be increased to the extent that they create 'rural' wind conditions and over-exposure and jeopardise positive overlooking. Instead, open space width should be:
  - mews: 7–8 m width but maximum 2 storey height
  - typical residential street: 10–15 m
  - squares: 25 m and 4–6 storey height is appropriate.
- Land use on the north–south street axis is ideally suited to commercial or other facilities which do not require solar gain. These east–west facing buildings will also temper the south-westerly winds.
- Alternatively, distant spacing can create squares and open spaces with a side elevation to the south. But this will impact on sustainable building densities and walkability. See Sections 3.3. and 3.4.
- Locate entrances on north/north-east and allow for larger windows and greater floor-to-ceiling heights on the ground floor.
- Introduce urban breaks to increase solar access on street level and between buildings. See Section 3.7.1.
- Plan to allow a view of the sky.

3.7.1 Urban breaks

Urban breaks allow sunlight into buildings, streets and open spaces. They allow air pollution to dissipate from between buildings at street level and increase ventilation both at street level and within buildings. Different building heights also add interest to urban spaces, but this less compact building form needs to be offset with high fabric energy efficiency standards.

If finished in light or reflective surface materials, side elevations of urban breaks can very effectively reflect daylight and sunlight back into spaces.

Key recommendations

- Use them particularly in mews and standard streets (if the street is narrower than 25 m width).
- Use them to provide variety and a useful and accessible roofscape.
- Locate slightly taller buildings to the north-east of the site: this protects from winds without overshadowing. Lower buildings should be on the south with flat or low-pitched roofs. Height difference is ideally only one or two storeys, but less than twice the average surrounding building height to avoid wind turbulence at higher levels.
- The width of the urban breaks should be 3–5 m minimum to avoid wind funnelling and to allow good solar access between and beyond the breaks. They can also be used as open spaces, roof terraces, play areas, etc.
- This also aids good Vertical Sky Component (VSC). (See Section 3.7.3.)

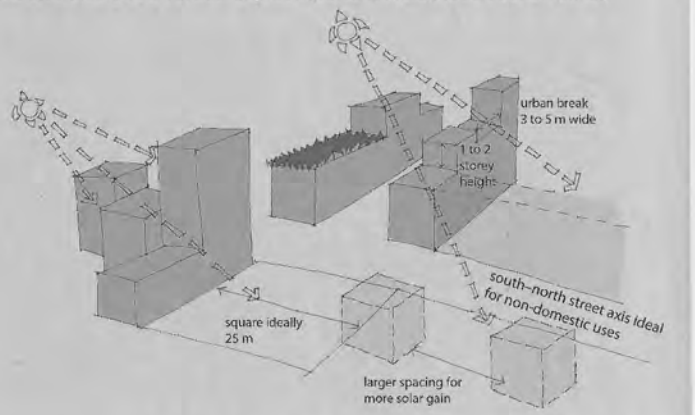


Fig. 3.7.2 Urban breaks and land use related to solar access

3.7.2 Rethinking single-aspect dwellings

Ideally, each building should have two orientation aspects. These should maximise passive solar gain and allow cross-ventilation. Many design and local authority guidelines recommend that single-aspect units should face south or south-west. North-facing single-aspect dwellings are usually not allowed. However, this can lead to excessive solar heat gain, particularly given our increasing temperatures.

Key recommendations

- Depth of plan should never exceed 6 m.
- Single-aspect is only ever suitable for one-bedroom dwellings and buildings not requiring solar gain. It is inappropriate for larger dwellings.
- Increase fabric efficiencies and particularly window performance in single-aspect units.
- Always provide external solar shading unless facing north.
  → Jump to Chapter 6.
- Where solar gain is undesirable, orient single-aspect buildings or spaces to face east or north.
- In winter, an additional 10–15% (on average) of passive heating energy can be gained by maximising solar gain in single-aspect units.
- Where solar gain is desirable, such as in dwellings (see Fig. 3.7.3):
  - in Region 1, orient single-aspect dwellings south to east
  - in Regions 2, 3 and 4, orient dwellings to south-east and north-east
  - avoid single western aspects to prevent night-time overheating in bedrooms.

Ideal single-aspect orientation

Fig. 3.7.3 Single-aspect dwellings

3.7.3 Spacing for good daylighting: the Vertical Sky Component

The Vertical Sky Component is a measure of daylighting potential. It is expressed as the percentage of daylight falling from an unobstructed sky onto a vertical window, in comparison to the amount of daylight falling onto a horizontal plane under the same sky and at that same point. It is usually measured at 2 m from the ground. Ideally it should be as close to 40% as possible,[25] although this is usually only achieved in rural areas and in high-rise blocks with unobstructed windows. It is indicative of good daylighting in the following conditions (Fig. 3.7.4):

- Region 1 (Scotland): angle h is minimum 22°. This correlates with a vertical sky component of 29%.
- Regions 2, 3 and 4: angle h is minimum 25°. This correlates with a vertical sky component of 27%.

Often this cannot be achieved in urban areas, particularly on lower floors. However, good daylighting can be achieved by:

- angling the window to the sky
- increasing floor to ceiling heights
- increasing height of window
- reflecting daylight with nearby obstructions.

A Vertical Sky Component calculator is available at: www.waterslade.com

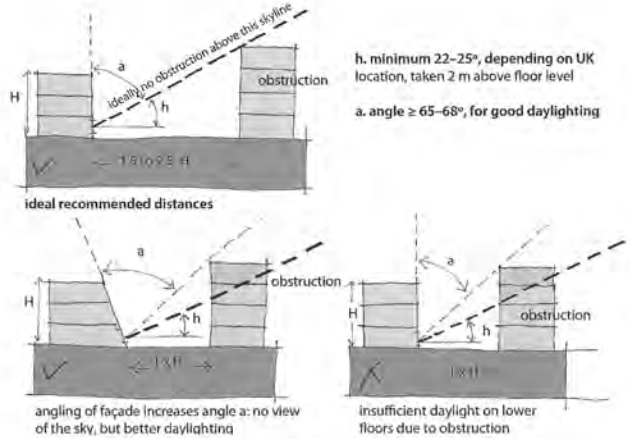


Fig. 3.7.4 Vertical Sky Component diagram and ideal building spacing

Code for Sustainable Homes credits (Hea 1, Ene 9), EcoHomes credits (Hea 1) and BREEAM credits (Hea 1)

3.8 FUTURE-PROOFING THE SITE

At the master planning stage, not all environmental considerations can be implemented owing to financial and technological constraints. This doesn't mean that they can't be planned for. Getting the basics right is crucial; it will allow future generations to 'plug into' a sustainable master plan.

In particular, the potential for renewable energy technologies can be designed for today but not implemented until such technologies become financially/technically viable.

3.8.1 Planning for infrastructure

In developments where roads are either being laid out for the first time or being significantly reconfigured, there is an opportunity for new infrastructure and utilities such as:

- dual greywater and mains water pipework provision
- district heating pipework
- sufficient space for plant rooms ⟶ Jump to Chapter 6
- space for SUDS and longer-term water storage ⟶ Jump to Chapter 5
- space for innovative waste collection and treatment such as vacuum chutes and on-site waste separation
- space for local waste processing, leading to local energy production (e.g. Biogas) ⟶ Jump to Chapters 10 and 12
- space and infrastructure for alternative transportation modes, including cycle lanes, car pools and electric car charging points.

3.8.2 Planning for low and zero carbon technologies

Always allow for the future addition of low and zero carbon technologies. It is recommended to:

- orient roof angle due south, taking overshadowing from adjacent buildings into account
- provide primary energy infrastructure so that minimal connections and adaptations will be required
- provide sufficient space for plant rooms

3.9 APPLICABLE LEGISLATION AND GUIDANCE

- BREEAM2011 Technical Manual www.breeam.org/BREEAM2011SchemeDocument/
- *Code for Sustainable Homes Technical Guide*, November 2010
- Department for Communities and Local Government (England, Wales and Northern Ireland)
- EcoHomes 2006 – The environmental rating for homes: The Guidance – 2006/ Issue1.2 April 2006 (Scotland)
- England and Wales: Building Regulations A, C, L
- Northern Ireland: Technical booklet A, C, D, L
- Planning Policy Guidance 17: Planning for open space, sport and recreation 24 July 2002
- PPS1 Climate Change Supplement, 17 December 2007 (England)
- Scotland: Sections 1; 3.1, 3.4, 6 of the Technical Handbooks

3.10 FURTHER READING

- Barton & Tsourou (2000), *Healthy Urban Planning*, Taylor & Francis Ltd
- BRE, Potential implications of climate change in the built environment, 2000
- CE257, Daylighting in Urban areas: A guide for designers, Energy Saving Trust, September 2007, www.energysavingtrust.org.uk
- CIRIA, 2005, C638, Climate change risks in buildings – an introduction
- CLG 2007,'Improving the flood performance of new buildings – Flood resilient construction'
- Climate Change Toolkit 07, Designing for Flood Risk (RIBA)
- Eco-towns Prospectus, Department for Communities and Local Government 23 July 2007, www.communities.gov.uk
- Erell *et al.* (2011), *Urban Microclimate: Designing the spaces between buildings*, Earthscan, London
- *Facing up to Rising Sea Levels*, RIBA, ICE, www.buildingfutures.org.uk
- Garmory *et al.* (2009), *Landscape Architect's Pocket Book*, Architectural Press
- GLA, 2005, Adapting to climate change: a checklist for development. Guidance on designing developments in a changing climate. Improving the flood performance of new buildings
- Good Practice Guide 245 *Desktop guide to daylighting – for architects*, 1998, Building Research Energy Conservation Support Unit
- Improving the Flood Performance of New Buildings, Flood Resilient Construction, (2007), DEFRA, CIRIA
- Littlefair *et al.* (2000), Environmental Site Layout Planning, BRE
- Llewellyn-Davies (2007), Urban Design Compendium, English partnerships www.urbandesigncompendium.co.uk/
- Pedersen (2009), *Sustainable Compact City*, Arkitektens Forlag
- Pitt review recommendations. Learning lessons from the 2007 floods (June 2009), www.environment-agency.gov.uk
- www.architecture.com/climatechange

Chapter 4

Urban greenery and biodiversity

Biodiversity is an important facet of sustainable building, bringing social, economic and environmental benefits to any development. Not only can energy consumption in buildings be reduced by thoughtful planting, but urban greenery can also improve residents' well-being and provide a crucial habitat for local wildlife.

Provisions for biodiversity need to be carefully thought through, if the benefits are to be maximised. The positioning of vegetation in relation to buildings and green corridors needs to be closely considered, as does the type of vegetation. Native plants are essential for supporting indigenous wildlife habitats, while on the other hand some native plant species will not survive or thrive in a changing climate.

Urban vegetation also contributes to CO_2 sequestration. In addition, the principle of 'food miles' illustrates the carbon reductions that can be achieved by growing food locally.

Symbol indicates relevance to the Code for Sustainable Homes, EcoHomes & BREEAM.

4.1 URBAN NATURE AND BIODIVERSITY BENEFITS 73

4.2 EFFECT OF VEGETATION ON ENERGY CONSUMPTION 74

4.2.1 Impact of vegetation in urban heat islands 74
4.2.2 Benefits of green roofs and green walls 75
4.2.3 Impact of vegetation on wind speeds 76
4.2.4 Vegetation as solar shading 77
4.2.5 Vegetation and noise buffering 79

4.3 OTHER CONSIDERATIONS FOR THE POSITIONING OF TREES CLOSE TO BUILDINGS 80

4.4 NATURE AND BIODIVERSITY IN URBAN AREAS 81

4.4.1 Continuous green corridors 81
4.4.2 Amphibians – detailed design recommendations 83
4.4.3 Birds – detailed design recommendations 84
4.4.4 Mammals – detailed design recommendations 85
4.4.5 Insects – detailed design recommendations 86

4.5 LIST OF PLANT SPECIES TO ATTRACT BIODIVERSITY 87

4.6 CO_2 ABSORPTION OF URBAN/SUBURBAN TREES 89

4.7 CO_2 ABSORPTION OF SHRUBS AND OTHER PLANTS 92

4.8 CO_2 REDUCTIONS FROM URBAN AGRICULTURE/ FOOD GROWING 92

4.9 CO_2 REDUCTIONS FROM 'FOOD MILES' 93

4.9.1 Which vegetables can be grown in urban gardens? 94
4.9.2 Typical urban food-growing yields and carbon reductions 94
4.9.3 Composting bins: size guide 95

4.10 APPLICABLE LEGISLATION AND GUIDANCE 96

4.11 FURTHER READING 96

4.1 URBAN NATURE AND BIODIVERSITY BENEFITS

There are many benefits to introducing nature into urban areas:

Social sustainability
- improved quality of life and a more attractive environment
- provides relief from built-up areas and gives human scale
- educational value
- marks the changing seasons with leaf changes and floral displays

Economic sustainability
- areas that are more desirable and can increase property prices by 8%[1]
- reduced energy cost, if strategically located/placed

Environmental sustainability (see Section 4.2)
- creates local microclimate by buffering extreme seasonal temperatures
- absorbs CO_2 – and generates O_2
- traps pollution from car exhausts
- can act as solar shading, reducing cooling energy needs
- buffers noise and wind, thereby reducing energy needs
- absorbs rainwater ⟶ Jump to Chapter 5
- supports wildlife habitats to provide a thriving ecosystem (see Section 4.4).

4.2 EFFECT OF VEGETATION ON ENERGY CONSUMPTION

4.2.1 Impact of vegetation in urban heat islands

Urban areas are usually around 4–5°C warmer than the surrounding countryside. While this may be beneficial in the winter, in summer it may lead to overheating in buildings and exacerbate health issues. Reducing CO_2 locally and globally benefits the environment as well as human health, while providing active cooling is likely to increase CO_2 emissions. During the daytime, soil evaporation and the shade from trees creates a 'park cool island' effect, with temperatures in parks 2–3°C lower than the surroundings.[2] The larger the green space, the greater its tempering effect, although this effect can still be felt with spaces as small as 10 m diameter.[3]

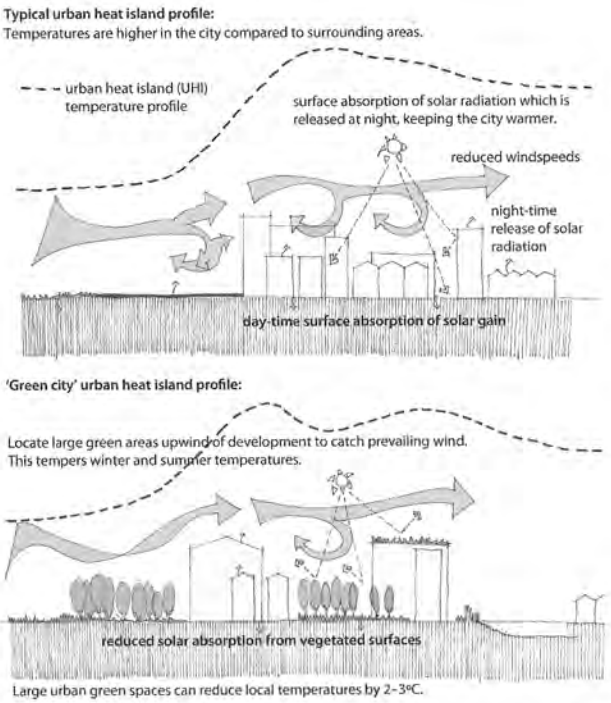


Fig. 4.2.1 Urban heat island profile of a typical city and of a 'green' city

4.2.2 Benefits of green roofs and green walls

A cooler' city is one where light surfaces and vegetation are combined to create shade, reflect sunlight and provide cooling through evaporation. Urban vegetation, combined with light and reflective surfaces, can reduce surface temperatures by 10–20°C. There are also winter benefits if the vegetation is evergreen and sufficiently dense.

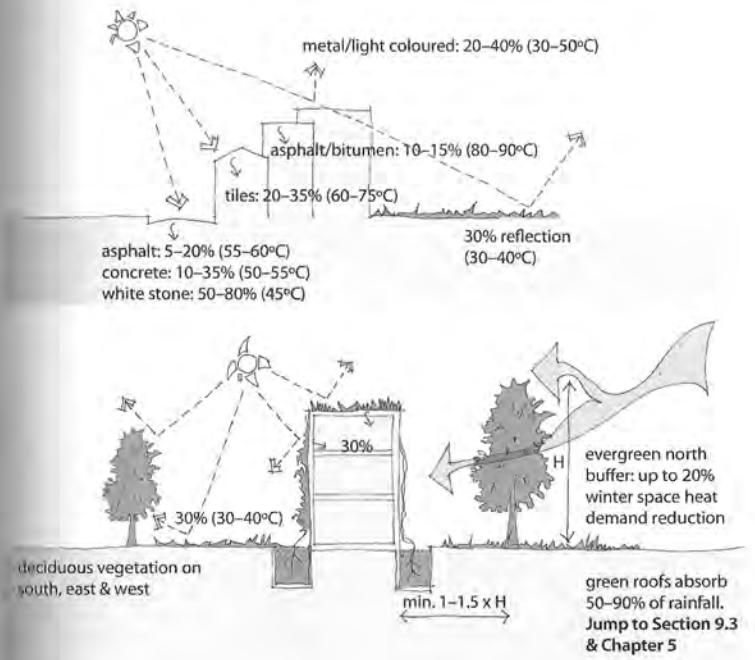


Fig. 4.2.2 Typical solar absorption and benefits of green roofs and walls[4]

Key recommendations

- Roofs with a south-west orientation are ideal for food growing and biodiversity. Where exposed to the north-east, they are ideal for biodiversity.[6]
- Several green wall proprietary systems on the market require the plants' root systems to grow horizontally. These systems should be avoided since they require a vast amount of water, energy and resources to keep the plants alive.
- Most vegetation is not suited to growing horizontal roots. Instead, allow plants to naturally grow from the ground or soil upwards.
- Place vegetation at least 400 mm away from walls or buildings to avoid a rain shadow.
- Evergreens, such as ivy, are suitable for buffering north façades.
- Plant deciduous vegetation elsewhere (virginia creeper, wisteria, vines).

4.2.3 Impact of vegetation on wind speeds

Evergreen vegetation can reduce wind speeds in winter. This minimises unwanted air-infiltration, particularly for badly insulated/non-airtight buildings. In summer, however, vegetation should not prevent natural ventilation which relies on wind speeds and air-infiltration through open windows. Year-round natural daylight and solar gain in winter should not be compromised.

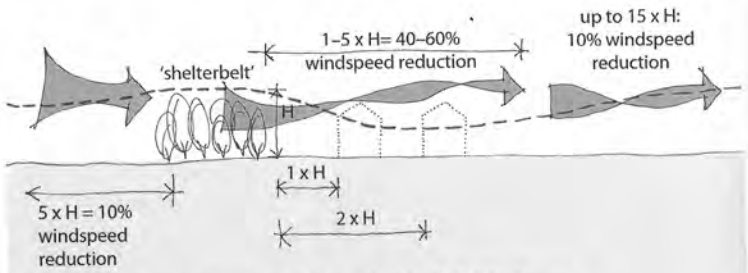


Fig. 4.2.3 Wind speed in relation to distance from trees[7]

There is a clear correlation between the location of a dense, mostly evergreen, 'shelterbelt' and the reduction of space heating demand. This is because the vegetation barrier reduces wind speeds, minimising draughts and heat losses.

Key recommendations

- The closer the building to the shelterbelt, the greater the heating energy reduction. This can be as much as 20% at a distance of 1–2 times the shelterbelt height (H). See Fig. 4.2.3.
- Ideally buildings are located within 2–5 × H.
- Vegetation must be carefully placed: too much shade will mean that buildings and external spaces no longer receive the benefit of free solar gain (see Section 4.2.4). ⟶ Jump to Section 3.6
- The shelterbelt width should be 2–5 m where 5 m high, and 10–15 m wide where 25 m high.[8]
- Leaves should cover around 50% of the area, and should be more dense at the bottom than the top.[9]
- Shelterbelts with vegetation of the same height are preferable to shelterbelts which gradually increase in height.[10]

4.2.4 Vegetation as solar shading

Vegetation can be used as summer solar shading. Transparency and solar shading capacity are dependent on the species of tree and how it changes throughout its lifetime. Sufficient solar shading must be provided regardless of vegetation maturity. On average, deciduous trees provide around 80% reduction in summer solar gain but decrease desirable winter solar gain by only 30%. For tree-specific shading factors, ⟶ jump to Section 6.5.

Key recommendations

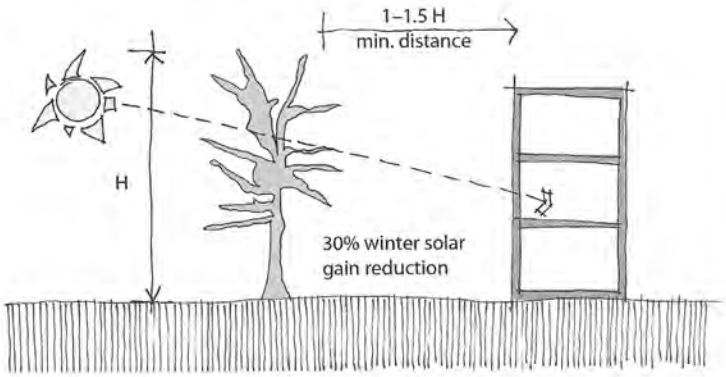
To allow for winter solar gain (see Fig. 4.2.4):

- Locate deciduous trees 1–1.5 times their height away from the building. This reduces winter solar gain by 30%.
- Increasing this distance to 4–5 times the tree height allows for 100% winter solar gain, especially with evergreen trees.

For summer solar shading (see Fig. 4.2.4):

- Trees are ideally the same height as the building they are shading.
- Ideal distances are 1–1.5 times the tree height away from the building, certainly not closer. See Section 4.3.
- More than 4–5 times the tree height away is unlikely to have any summer solar shading effect.

WINTER (Solar gain with deciduous vegetation)



SUMMER (Solar shading with vegetation)

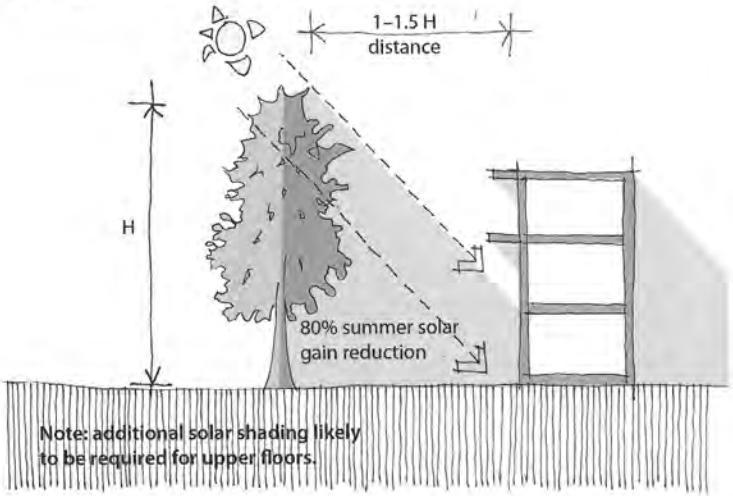


Fig. 4.2.4 Tree distance for winter/summer solar shading impact[11]

4.2.5 Vegetation and noise buffering

Vegetation helps to screen noise but it is not a sufficient noise barrier on its own. This is particularly the case in winter when there are no leaves on deciduous plants. The presence of trees does have a psychological impact: they may visually screen the source of noise and distract from it with the sound of leaves in the wind.[12]

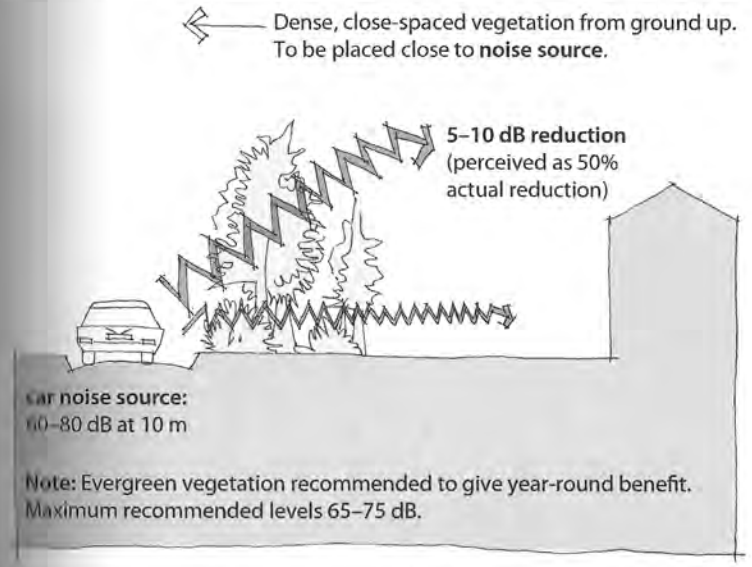


Fig. 4.2.5 Distance noise source and vegetation and dBA reduction[13]

Noise reductions up to 5–10 dBA can be achieved if dense evergreen vegetation is located near the noise source.[14] Often this is enough to eliminate the noise as a perceived problem.

In selecting planting and location for noise buffering, remember also to:

- select native species which support local biodiversity (see Section 4.5)
- take into account distance between vegetation and buildings with regard to daylight, winter solar gain and structural considerations
- appoint an acoustic consultant if the development is within 20 m of a bus route, 50 m of a major road or 150 m of a railway line, industry or outdoor leisure facility.

4.3 OTHER CONSIDERATIONS FOR THE POSITIONING OF TREES CLOSE TO BUILDINGS

Alongside wind, solar and noise buffering considerations, the protection of the trees and buildings themselves must be considered. A tree protection plan needs to be submitted to the local authorities. However, given the practicalities of construction and site access, this is often not enough to protect on-site vegetation.

Appropriate minimum distances are needed in order to:

- protect the tree with temporary scaffolding during site works and avoid compaction of its roots from excessive traffic
- protect building foundations – distances are dependent on tree species, but generally 1–1.5 times its mature height
- control street level pollution through wind dispersal:[15]
  - allow for at least 1.5 m between crown and building façade
  - allow for 5–8 m between trees
  - mature tree not to be taller than the building

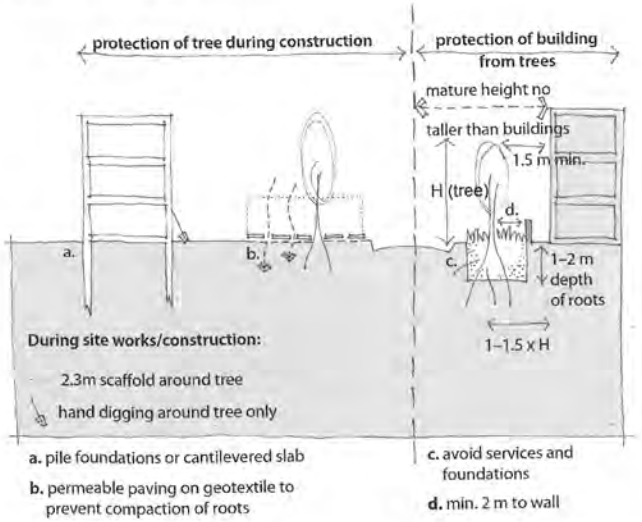


Fig. 4.3.1 Distance of trees from buildings and protection during construction

Code for Sustainable Homes and EcoHomes Credits (Eco 3); BREEAM credits (LE 2)

4.4 NATURE AND BIODIVERSITY IN URBAN AREAS

Native plant species support a diverse native wildlife. They provide food, shelter and nesting places for small mammals, amphibians, birds, butterflies, bees and other insects.

4.4.1 Continuous green corridors

Most UK cities suffer from biodiversity loss and fragmentation of wildlife habitats. The increase in hard/built-up areas leads to loss of vegetation which provides food and nesting sites.[17]

Most regions and cities have a Biodiversity Action Plan (BAP) which sets out at-risk species and ways to support their habitat. Usually this is by creating habitat corridors which connect smaller green areas with larger, more undisturbed city edge habitat areas. → Jump to Section 3.5.

Examples of wildlife-friendly green corridors:

- wild river, pond or lake
- railway, road and footpath edges
- wildlife-friendly hedgerows (instead of fencing)
- parks and meadows
- back gardens and allotments
- trees and urban forests
- green roofs and walls.

Fragmentation occurs when patches of green are interrupted by roads and traffic. This isolates species from their habitat and other food or nesting sources, which affects their breeding gene pool and survival rate.[18]

Well-kept gardens and parks are not always the ideal breeding or nesting places for wildlife. Small areas such as unattended wildflower meadows and steeper or less accessible areas are better suited to providing undisturbed habitats.

Key recommendations: Site

- An ecological consultant should be appointed. They will advise on how best to protect and upgrade existing habitat.
- Define important and locally protected species and ways to support their habitat. Consult local and regional Biodiversity Action Plans. www.ukbap.org.uk
- Alleviate the impact of urban fragmentation: retain and strengthen/extend existing habitat edges and increase density of greenery. Larger open spaces support a larger and more stable wildlife population.[19]
- Create continuous green habitat corridors on site, linking to larger habitats within the city and beyond.
- Interlink green corridors to provide safe crossing points for wildlife and allow dispersal of seeds and plants.[20] (Use undercrofts/green bridges to connect.)
- Specify a diverse planting selection and leave some areas/edges undisturbed.
- To avoid disease/pests and to support biodiversity, select plants from a maximum 30% of the same family, 10% of same genus and 20% of same species.[21] Always aim to select native species. Where exotic plants are chosen, ensure that they support native wildlife and do not have an invasive growth that would be a potential threat by spreading and out-competing native flora (see Section 4.5).
- Minimise light pollution/street lighting. Keep lighting away from ponds, tall trees, hedges and green corridors. Lighting should be low wattage/UV emission with bulbs protected and directed downwards.[22]
- Consider safety, accessibility and maintenance of green spaces for city inhabitants.[23]
- Consider hedges instead of constructed fences to reduce the embodied energy of landscaping.

Code for Sustainable Homes and EcoHomes Credits (Eco 1 to Eco 4); BREEAM (LE 1 to LE 5)

Key recommendations: Building

- Birds nest and bats roost in the cracks and roof voids of existing buildings. This opportunity for nesting will disappear with our current drive towards higher airtightness standards in both new and existing buildings.[24]
- We need to turn the negative impact of development into a positive support for biodiversity by creating habitat opportunities and migration routes in the landscapes and buildings we design.
- In addition to continuous green corridors at the city/site master planning scale, intentional nesting and roosting areas should be provided in the walls and roofs of buildings. These must be incorporated while maintaining high Fabric Energy Efficiency Standards (FEES).
→ Jump to Section 9.3.
- There are a large number of proprietary wall and roof nesting and roosting products available. Be sure, however, to specify UK-manufactured products to support native species nesting and roosting and to fit with UK standard construction/material dimensions.[25]

The following pages list species currently considered a top priority for habitat support.

4.4.2 Amphibians – detailed design recommendations

Species	Recommendations
frog, toad great crested newt, smooth newt	• Create more ponds, ideally surrounded by tall herb plants.[26] Improve the quality of existing ponds – decrease the levels of nitrogen and tree shading. • Use diverse plant species, but decrease invasive plant species.[27] • Ensure management of wildlife along canals by leaving wildlife edges undisturbed/inaccessible and by marking toad crossing points on roads.[28]
	Provide one water feature/pond per dwelling where individual housing, or a larger one per development.

4.4.3 Birds – detailed design recommendations

Species	Recommendations
house sparrow	• Increase suitable habitat through creation of brown roofs,[29,30] green walls and native shrub specification (see Sections 4.2.2 and 4.5). • Increase nesting places in roofs and elsewhere.[31] • Position nesting boxes 2 m above ground, ideally facing east and 1.5 m apart.[32] • A range of manufactured systems can be embedded into walls.[33] **Provide one nesting space for every 40 buildings.[34]**
black redstart	• Increase suitable habitat through creation of green and brown living roofs.[35] • Allow for typical brownfield features, such as remnants of stony ground, vertical structures and ledges.[36]
starling	• Provide nesting and roosting opportunities at least 3 m above ground. • Place boxes 1.5 m apart. Position them on east-facing walls to prevent overheating.[37] **Provide one nesting space for every 100 buildings.[38]**
skylark	• Retain or introduce grassland, pasture, hedgerows and green/brown roofs.[39]
linnet	• Create green roofs.[40] • Leave the natural build up of moss and sedums on roofs and other surfaces where possible. • Allow for plant diversity.[41] **Provide one nesting space for every 20 buildings.[42]**
swallow	• Create more nesting opportunities inside roof spaces, particularly in outbuildings. • All that is required for access is a small opening 60 mm high and 80 mm wide. • Nests are used every year between April and September – construction activity should not disrupt during this time.[43] • Distance the nesting boxes to avoid house martins colonising them.[44] **Provide one nesting space for every 50 buildings.[45]**
peregrine falcon	• Provide nesting ledges on tall buildings of 20+ metres. • Ideally position north-east facing and with some protection from prevailing winds.[46] • Peregrines hunt the feral pigeon population. **Provide one nesting/roosting space for every medium-sized development and two for a large development.[47]**
nightjar	• Restore mossland. • Use peat-free substitutes. • Control invasive plant species such as birch.[48]

song thrush	• Likely to nest in gardens. They eat worms and snails, so limit pesticide use. • Provide tall, thick hedges for cover and nesting opportunities. • Plant wild, seed-producing plants.[49]
barn owl	• Create nesting places in tall buildings, at least 3 m above ground. • Position them facing away from prevailing winds and towards open grassland.[50] • Increase habitat in suburban and rural areas. **Provide two nesting/roosting spaces for every medium-sized development and three for a large development.[51]**
swift	• Increase nesting opportunities in roofs, eaves and under tiles. • Minimum height of 5 m for nesting boxes or access points in roofs 65 mm (w) x 30 mm (h). • Ideally position facing east and avoiding direct sun to prevent overheating.[52] • A range of manufactured systems can be embedded into walls. • Nests are used every year between April and July,[53] so avoid building work during this period.

4.4.4 Mammals – detailed design recommendations

Species	Recommendations
bats	• Avoid use of pesticides and chemicals in roof timbers.[54] (see National Trust guidelines for safe chemicals). • Create roosting places and provide bat boxes in roofs and gardens at 2–7 m height, ideally facing south.[55,56,57] • A range of off-the-shelf systems can be embedded into walls and roofs.[58] • Introduce/retain broad leaf trees. **Provide one roosting space for every 20 buildings; one for every five public buildings for horseshoe bats and bats requiring flight space to enter.[59]**
hedgehog	• Hedgehogs will avoid areas frequented by badgers. • Provide a wildlife corner with piles of leaves and wood. • Avoid using slug pellets and insecticide. • Avoid any netting. • Use ramps to create access to raised ponds.[60] • Avoid nest disturbances and site works October to April.
water vole	• Protect waterside habitats and conserve wetlands.[61] • Ensure management of wildlife along canals.[62]

4.4.5 Insects – detailed design recommendations

Species	Recommendations
butterflies	• Create brown roofs or roof wildflower meadow – even up to 20 storeys high. • Provide suitable habitats of grouped plants with sequential flowering. • Leave areas of grass undisturbed and uncut, particularly in urban areas.
	Provide a diversity of flowering plants in each development, such as a wildflower meadow, either on the roof or at ground level. To be located in sun.
stag beetle	• Create heaps of dead wood in shaded areas of parks and gardens. • Avoid wood chipping of felled trees.
bee, bumble bee, solitary bee	• Provide wild flowers and sedum on vegetated roofs.[63] • Plant nectar-rich crops with sequential flowering throughout the year. • For solitary bees position undisturbed wood piles and bundles of bamboo (4 mm sections) in sunny areas.[64]
	Provide a diversity of flowering plants in each development, such as a wildflower meadow, either on the roof or at ground level. To be located in sun.

4.5 LIST OF PLANT SPECIES TO ATTRACT BIODIVERSITY

Often the seeds and flowers of exotic plants are useless to our native wildlife. Exotic plants should only be used in combination with native species. Sadly, around 10% of the UK's garden plants are exotic and this has had a negative impact on pollinating insects such as bees, bumble bees and butterflies.[65]

At the same time, not all native plant species will thrive and continue to support wildlife in the hotter and drier summers predicted for most of the UK.

Key recommendations

- Landscape irrigation requires large amounts of water. Rainwater harvesting is recommended. → Jump to Section 5.6.
- Usually energy is used to pump rainwater. It is more energy-efficient to design landscapes which include drought-resistant species as well as native moisture-loving species.
- Generally, plants whose leaves are small, glossy, grey-coloured, leathery or hairy can withstand drought and heat better.
- Always check local soil conditions and plant suitability.
- In wetter Scotland and Northern Ireland, it is appropriate to use mostly native drought-resistant species (see Fig. 4.5.1).
- In the drier south-eastern UK areas, however, these native species should be combined with more drought-tolerant Mediterranean plants (see Fig. 4.5.2).

Below is a list of suitable native and non-native plant species, which support UK wildlife habitats.

Fig. 4.5.1 2080 predicted climate & recommended plant species for Regions 1 & 3

Region 1 & 3 (Scotland & Northern Ireland)	**2080 predicted climate: 15–20% less rain in summer and 20–25% more in winter**

Specify native planting, with increased specification of more native drought-resistant species. Plants listed below are all beneficial to native wildlife.

Native drought-resistant species		Native trees ranked in order of biodiversity benefit	Native shrubs, climbers, flowers	
honeysuckle	yew	oak	bramble	violet
ivy	broom	willow	dogwood	wood anemone
roses	heather	alder	gorse	mallow
juniper	privet	hawthorn	hazel	wild marjoram
sea holly	buckthorn (rhamnaceae)	blackthorn fruit trees	wild angelica bluebells	meadow saffron

Fig. 4.5.2 2080 predicted climate and recommended plant species for Regions 2 & 4

Region 2 & 4 (Wales & England)	**2080 predicted climate: 25–30% less rain in summer and 25% more in winter**

Specify plant species as Region 1 & 3, but combine with more drought-resistant Mediterranean species (those listed below are suited to UK wildlife & winter conditions).

buddleia	echinops	phlomis	fennel
boston ivy	escallonia	potentilla (rosaceae)	oregano
virginia creeper	geranium san-guineum	exotic rose (i.e. asia/persia)	rosemary
ceanothus	helichcrysum	St John's wort	sage
caryopteris	honeysuckle	santolina	thyme
cistus	jasmine	sea holly	chamomile
clematis	juniper	sedum	
cotinus	lavender	snapdragon	

Place drought-resistant plants in areas that receive most sunshine, with native plants nearer to buildings to allow shade and ease of watering. Only water native species – water them in the morning using harvested rainwater. Water 'deep' (i.e. large amounts of water infrequently, rather than daily sprinkling).

4.6 CO_2 ABSORPTION OF URBAN/SUBURBAN TREES

Planting and protecting urban trees is crucial for CO_2 absorption: the older the tree, the more carbon sequestered over its lifetime. In a large, mature urban tree, this is on average 110 tonnes of CO_2 over its lifetime. This is why timber is such a sustainable building material and why we need to protect trees during construction and development (see Section 4.3). Note that forest trees absorb less CO_2: greater competition for space means that they do not grow as large as urban trees.

Broadleaf trees, particularly fast-growing ones, absorb more CO_2 than coniferous trees (coniferous trees may even increase CO_2 in a warming climate). Native broadleaf trees generally also support a wider range of biodiversity (see Fig. 4.6.1 & 4.6.2). As they are deciduous, they can provide summer shading but still allow winter solar gain (see Section 4.2.4).

Excellent CO_2 absorbers such as the London plane are non-native and limit UK wildlife. This is actually the main reason why they are popular as urban street trees: avoiding wildlife foul the pavement or cars parked underneath, which is less of an issue with non-native trees. Non-native trees should always be combined with UK native species.

Urban trees need to live for at least 5–10 years before their initial planting and 'maintenance' embodied carbon is paid back.[66]

When a tree dies, a strategy for its removal needs to be put in place. Mulching or burning will release all of the sequestered CO_2 back into the atmosphere. Landfill retains most sequestered CO_2.[67] However, if the tree is harvested for use in building/furniture industries, around 80% of the tree's sequestered carbon can be retained[68] (see Fig. 4.8.1).

Fig 4.6.1 CO_2 absorption accumulated in trees, taking survival rate into account[69]

Tree species	After 60 years	Over a lifetime	Listed in order of biodiversity ranking
	tonnes CO_2		
broadleaf, slow growing: oak, beech, hornbeam	1.8	123 (oak: 350 yrs old)	Oak is the best UK tree for supporting native wildlife, but is not a good street tree. Beech and hornbeam are average.
broadleaf, moderate growing: hawthorn, maple, most fruit trees, silver birch	4	118 (maple: 250 yrs old)	Very good, particularly birch and hawthorn. Birch reaches 50–80 years; fruit trees 20–50 years. Note that birch is not drought-tolerant.
conifer, slow growing: Scots pine	1.4	49 (250 yrs old)	Good wildlife support: mainly birds and small mammals such as protected red squirrel.
broadleaf, fast growing, native: willow, alder, elm, ash, poplar, linden (small-leaf lime tree)	7.1	123 (200 yrs old)	Willow is particularly good but, like poplar, it is not a good street tree (invasive roots). Other species listed are average. Linden is a good pollution-resistant street tree. Elm trees are sensitive to Dutch elm disease.
conifer, fast growing: Douglas fir (non-native), pine	5.9	126 (200 yrs old)	Average wildlife support: mainly birds and small mammals such as protected red squirrel. Usually found in urban parks rather than on streets.
conifer, moderate growing: European spruce (Christmas tree), cedar	3.2	120 (250 yrs old)	
broadleaf, fast growing, non-native: London plane, horse chestnut, sycamore	7.1	123 (200 yrs old)	Limited support for native wildlife, particularly the London plane. Sycamore supports aphids and so attracts birds and bats. (All non-native trees; London plane is a particularly good street tree.)

Fig 4.6.2 CO_2 sequestration rates by tree type (cumulative total by age of tree)[70]

	Broadleaf trees speed of growth			Pine/conifers speed of growth		
	Slow	Moderate	Fast	Slow	Moderate	Fast
	oak, hornbeam, beech	hawthorn, maple, silver birch, most fruit trees	horse chestnut, London plane, sycamore, willow, alder, elm, ash, poplar, linden	Scots pine	European spruce, cedar	Douglas fir, pine
Age	Total accumulated CO_2 absorption ($kgCO_2$)					
1	5	8	11	3	4	6
5	22	39	63	13	23	37
10	60	115	192	36	72	123
15	119	237	403	74	155	273
20	199	409	706	129	277	497
25	303	634	1106	202	443	804
30	433	916	1611	295	658	1204
35	589	1258	2225	409	924	1703
40	772	1663	2954	548	1246	2307
45	984	2132	3801	710	1627	3024
50	1225	2668	4771	898	2069	3860
55	1496	3274	5868	1112	2577	4819
60	1799	3951	7097	1356	3154	5911

4.7 CO_2 ABSORPTION OF SHRUBS AND OTHER PLANTS

Shrubs and other plants also absorb CO_2. However, they are regularly pruned (to contain growth) and are usually short lived (5–15 years). As wood from shrubs cannot be harvested for long-term uses, the biomass of the dead/discarded shrub is usually composted or chipped and burned. This is why shrubs and other plants are carbon neutral: they will eventually release the CO_2 they absorbed over their relatively short lifetime.

Green roofs and grass areas tend to be long lived. Owing to regular cutting and specific soil behaviour, a carbon equilibrium is reached whereby the plant growth is equal to the plant decomposition.[71] This means that their contribution to CO_2 absorption is minimal and they should be considered carbon neutral.[72]

4.8 CO_2 REDUCTIONS FROM URBAN AGRICULTURE/FOOD GROWING

Seasonal vegetable plants grow fast and absorb CO_2 during this process. However, they die at the end of each season and all of this absorbed CO_2 is released back into the atmosphere. Vegetables are therefore carbon neutral. The only exception to this are fruit trees: they last 20–50 years and their wood can be used for building interiors. A typical cherry tree will absorb around 400 $kgCO_2$ over its lifetime, while apple and pear trees sequester around 2.5 tCO_2. They are particularly suitable in gardens where fruit can be harvested by users.

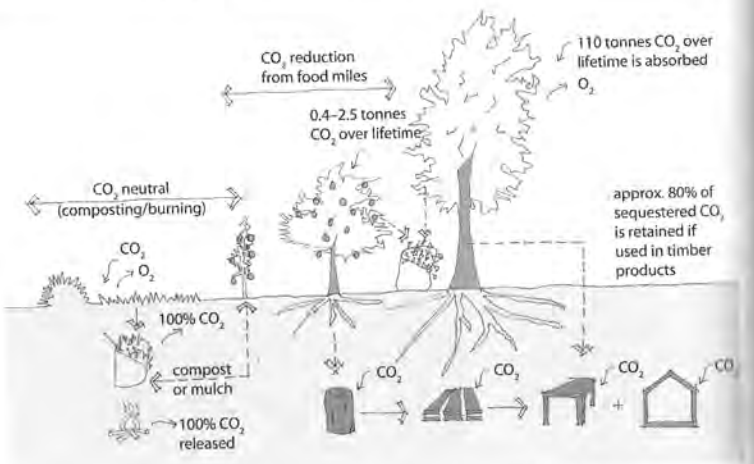


Fig. 4.8.1 CO_2 absorption from different urban vegetation

4.9 CO_2 REDUCTIONS FROM 'FOOD MILES'

Some 8% of the UK's total carbon emissions is associated with food consumption; 2.5% is from fruit and vegetable consumption.[73] In London alone, 10 million tCO_2 emissions yearly are food related.[74] This means that, annually, each household contributes around 1000 $kgCO_2$ from fruit and vegetable consumption and around 2000 $kgCO_2$ from meat, dairy and other processed foods.

Clearly, some CO_2 reductions can come from 'food miles' savings. This means growing seasonal food at or near its place of consumption instead of importing it from faraway regions. However, urban food growing is limited in its CO_2 reductions, as meat, dairy and other processed foods have the largest CO_2 impacts. This is illustrated by a 'fractional' vegetable shopping basket and its modest carbon reductions of 79 $kgCO_2$ per household per year (see Fig. 4.9.1).

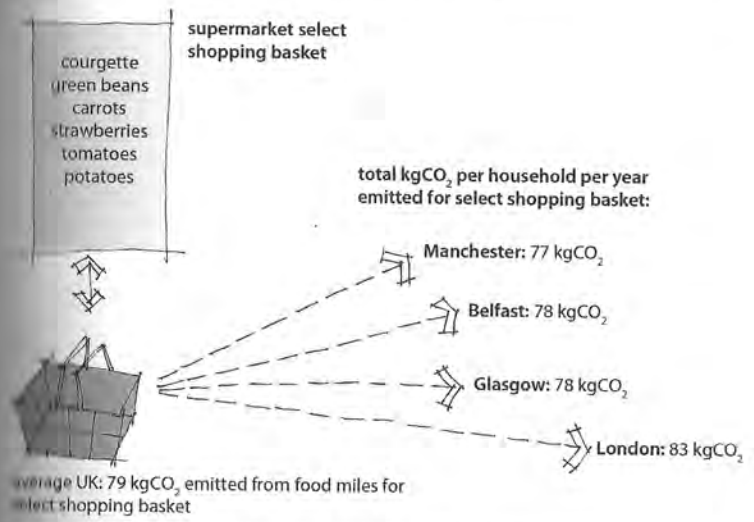


Fig. 4.9.1 Food mile reductions from a select 'fractional' shopping basket in different regions. Based on typical average UK consumption patterns[75]

4.9.1 Which vegetables can be grown in urban gardens?

For small gardens: aubergine, beets, broccoli, cabbage, carrots, courgette, English peas, garlic, green beans, lettuce, onions, radishes, spinach, tomatoes. All herbs.

For bigger gardens or allotments: as above, plus cantaloupes, cauliflower, cucumbers, mustard, okra, potatoes, pumpkins, runner beans, southern peas, sweetcorn, sweet potatoes, squash.

4.9.2 Typical urban food-growing yields and carbon reductions[76]

On average, 1 m^2 of land provides approx. 0.85 kg of food per year, grown in a typical suburban garden or allotment.[77] Of this yield, 90% occurs in summer. Figure 4.9.2 lists five vegetables that account for 85% of a typical yield of an urban allotment and can lead to food miles reductions of 1.5–1.6 $kgCO_2$ per m^2 of urban arable land.

Fig. 4.9.2 Typical urban food growing yields and carbon reductions

Five urban growing vegetables – approx. nr. plants	Typical Region 1 yearly 'top five' yields on a 100 m^2 plot	Approximate yearly CO_2 reductions from food miles savings if grown locally (garden/allotment)[78] $kgCO_2$ per year	Typical supermarket country of origin[79]
courgettes (8 plants)	40 kg	3	Spain (rail + road)
squash (6 plants)	18 kg	59	Greece (air + road)
tomatoes (in cold greenhouse) 25 plants	14 kg	61	Canary Islands, Spain (air + road)
runner beans (20 plants)	8 kg	34	Nairobi, Kenya (air + road)
chard/pak choi (15 plants)	5 kg	0.3	Spain (rail + road)
yearly total	85 kg	157 $kgCO_2$	
yearly CO_2 reduction:		• 1.5–1.6 $kgCO_2$ reduction per m^2 of urban food growing • 1.85 $kgCO_2$ is reduced per kg of locally grown food	

4.9.3 Composting bins: size guide

An average UK household wastes around 5 kg of organic matter per week. This takes 6–9 months to break down (leaves take 1–2 years).[80, 81]

Compost bin sizes:
- per household, 200–300 litres minimum, with ideally 750 litres[82] (0.2–1 m^3)
- for larger developments, allow minimum 100 litres per person (10 m^3)

Place communal composting facilities within 30 m from building/site entrances and provide small kitchen containers. Do not place near windows, doors or any ventilation intake.

Code for Sustainable Homes (Was 1 mandatory to Was 3 and Man 1)
EcoHomes credits (Man 1 and Mat 4), BREEAM credits (Wst 3)

4.10 APPLICABLE LEGISLATION AND GUIDANCE

- Biodiversity Action plans (BAP), Habitat Action Plan (HAP), Species Action Plan (SAP)
- BS 5837 (2005) 'Trees in Relation to Construction'
- CIRIA, C567/C502 & C503
- Conservation (natural habitats) Regulations 1994 & Nature Conservation & Amenity Lands Order 1985; The Conservation (natural habitats) Regulations 1995 and Environment Order 2002 (Northern Ireland)
- Natural Environment and Rural Communities Act 2006 (England & Wales)
- NPPG4, Natural Heritage & PAN 60 Planning for natural heritage (Scotland)
- PAS 2010:2006: Planning to halt loss of biodiversity
- PPS2, Planning and nature conservation (Northern Ireland)
- PPS9, Biodiversity & geological conservation (2005) (England)
- RSPB (1997), Good practice aid for prospective development
- TAN5 nature conservation and planning (Wales)
- The nature conservation Act 2004 (Scotland)
- Wildlife and Countryside Act 1981 (as amended) and Wildlife NI Order 1985 (Northern Ireland)

4.11 FURTHER READING

- Beer & Higgins (1999), *Environmental Planning for Site development*, Taylor and Francis
- Defra, 2005, The Validity of Food Miles as an Indicator of Sustainable Development Final Report
- Erell (2011), *Urban microclimate, designing the spaces between buildings*, Earthscan Ltd
- Filipi (2008), *The dry gardening handbook, plants and practices for a changing climate*
- Goddard (2009), *Scaling up from gardens: biodiversity conservation in urban environments*, Trends in Ecology and Evolution, Elsevier
- Hessayon (2009), *The green garden expert*, Expert Books
- McMahon & Signoretta (2009), *Urban Design – Health & The Therapeutic Environment*, Architectural Press
- Natural England, Standards for accessible Urban Greenspace (ANGST)
- Natural History museum – native plant finder by postcode: www.nhm.ac.uk/nature-online/life/plants-fungi/postcode-plants/
- Santamouris (2000), *Energy and Climate in the Urban Built Environment*, James & James Ltd
- Steel (2009), *Hungry City, How food shapes our lives*, Random House
- Trees in Towns 2, 2007 (Dept of Communities and Local Government)
- UKGBC (2009), Biodiversity and the built environment.
- US Department of Energy, 'Method for calculating Carbon Sequestration by trees in urban and suburban settings'
- Vernont et al. (2009), *Landscape Architect's Pocketbook*, Elsevier
- Viljoen (2005), CPULS: *Continuous Productive Urban Landscapes, Designing Urban Agriculture For Sustainable Cities*, London, Elsevier
- Williams (2010), *Biodiversity for Low and Zero Carbon Buildings: A Technical Guide for New Build*, RIBA Publishing

Chapter 5

Water and flooding

Environmental design must work with water rather than against it. This is a primary consideration which will become even more important in a changing climate:

- Increased flooding due to extreme rainfall events is anticipated.
- At the same time, increased periods of drought and water shortages are expected.

Careful consideration is no longer a luxury: where to build, which building typology, how much land to set aside for water storage and which surface finishes are more resilient are now vital decisions for design. Allowing water run-off to soak-away on site instead of connection to sewers is nearly always the preferred option.

Water efficiency inside buildings is also starting to be regulated. Water-efficient appliances, rainwater harvesting systems and greywater recycling will eventually become embedded in building design. However, not all such systems are sustainable: it is energy intensive to treat and pump water around, and the embodied energy of the system can be significant.

Hence, careful building-specific design specification is required to avoid increasing carbon emissions in the quest to save precious water. Usually, connection to mains water supply and sewers is the most suitable option.

Symbol indicates relevance to the Code for Sustainable Homes, EcoHomes & BREEAM.