A number of other initiatives exist including the use of large-scale water butts to capture urban or hillside run-off and to replenish aquifers, and the use of solar panels and wind turbines to generate and export renewable energy.

The use of **biodigesters** is another useful initiative. Biodigesters convert manure into biogas. The biogas can be used as a clean cooking fuel and waste from the biodigesters can be used to fertilize kitchen gardens or fields, saving money.

HL

HL

8.2.11 Principles of ecological urban planning

1.3 Sustainability
6.3 Climate change – mitigation and adaptation
7.1 Natural resources, uses and management

Ecological urban planning follows the principles of urban compactness, mixed land use and social mix practice. The sustainable advantages of these practices include reduced urban sprawl, less car dependency, reduced energy consumption, better public transport, increased accessibility and social equality. Avoiding social inequality in access to green areas is a matter of environmental justice.

HL a Environmental law
HL c Environmental ethics

Urbanization is one of the defining features of the modern age, but urban development has had a major negative impact on the natural environment, reducing biodiversity and threatening human wellbeing. In contrast, ecologically based urban planning considers the impacts on the natural environment, including impacts on ecosystem services, socio-ecological systems, resilience, biodiversity, landscape and green infrastructure, and therefore will have a more positive overall effect on the natural environment.

Reducing urban sprawl

Urban sprawl mainly occurs in HICs and MICs. Reducing urban sprawl can be achieved through the use of green belts and green wedges, new towns and expanded towns. Green belts (and wedges) are areas of land surrounding or penetrating a city, where development of the natural environment is largely controlled. Some low-density developments may be allowed such as parks, hospitals and cemeteries, but large-scale residential developments are not generally permitted. Housing developments are generally diverted to other existing towns (expanded towns), or new developments are built elsewhere to form new towns. Urban sprawl has largely occurred due to the increase in private car ownership and the construction of low-density suburbs. To prevent any further expansion in urban sprawl, housing in urban areas will need to be built at higher densities and there will need to be improvement and investment in public transport.

Reducing car dependency

There are several options for reducing the use of cars including the use of public transport, walking, cycling or micromobility involving the use of electric bikes and scooters. The aim is not to ban cars altogether but instead to channel them to places where options for other forms of transport are reduced such as remote or peripheral areas. Increases in vehicle tax, along with the introduction of congestion charges and low emission zones all help reduce the number of vehicles entering urban areas. In London, the revenue from the congestion charges is used to fund public transport. Reallocating road space from car use to use by bicycles and buses could also reduce the number of cars on the road. Similarly, a reduction in car parking spaces and an increase in the cost of car parking may make the use of cars less desirable. For example, in Waltham Forest,

a suburb in north-east London, a series of road closures were introduced to reduce non-local traffic. These closures resulted in a decline in the daily flow of vehicles from around 8500 to around 4800, a 22% reduction in the number of vehicles and a reduction in the average speed of vehicles. Some 74% of residents supported the scheme.

Elsewhere, a variety of schemes have been used. In Singapore, residents need a permit to own a car and are charged for using selected roads. Charges vary by vehicle size, the day of the week and the time of driving. In Mexico City, the pedestrianization of Madero Street led to a 30% increase of commercial activity and a 96% fall in reported crime. In Auckland, New Zealand there are plans to increase residential density both vertically and horizontally and to increase the usage of public transport and electric vehicles. Greater use of public transport could reduce carbon dioxide (CO_2) emissions by 40% and the use of electric vehicles could reduce emissions by 30%.

Net zero is achieved when any greenhouse gas emissions are balanced by schemes to offset an equivalent amount of greenhouse gases from the atmosphere, such as planting trees or using geoengineering schemes such as carbon capture and storage.

Reduced energy consumption

Cities use about 66% of the world's energy and create about 75% of the world's greenhouse gases. Energy problems in urban areas include increasing demand, ageing infrastructure, volatile energy markets (e.g. as a result of the conflict between Russia and Ukraine) and climate change. Energy supplies need to be secure, affordable and have a net zero status.

Helsinki in Finland can be used as an example of a city where the provision of energy has been a success, despite rising demand. Helsinki is part of the Decarbon-Home Project, which has the dual aims of reducing the need for energy production and switching to renewable energy resources. The goal is to achieve a status of net zero by 2040. Since 1990, greenhouse gas emissions have decreased by 33%, economic growth has increased by 65% and per capita emissions have decreased by 50%. The total energy usage in Helsinki has remained unchanged despite the increase in population (Figure 8.45). In addition, renewable energy now accounts for around 25% of energy production. The project also targets vulnerable groups such as the elderly and immigrants, adapting their housing to be more energy efficient.

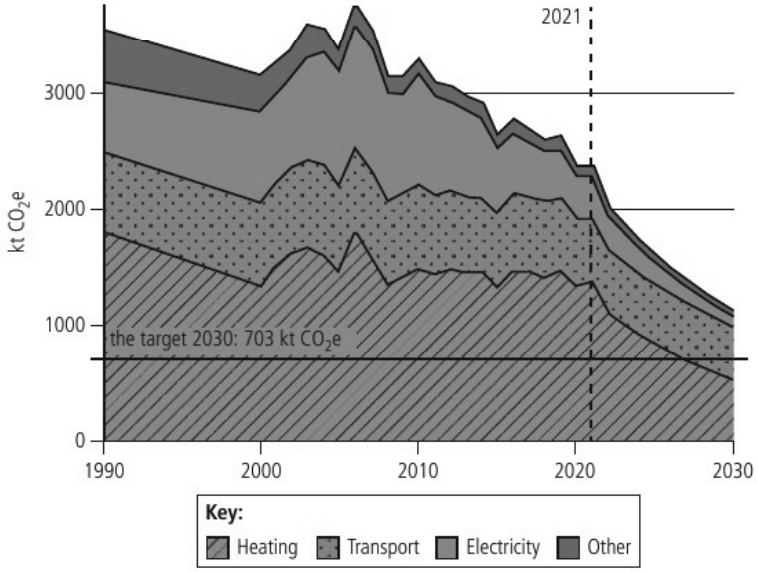


Figure 8.45 Energy emissions in Helsinki, 1990–2030, by sector.

Better public transport

Curitiba, a city in south-west Brazil, is an excellent model for better public transport (Figure 8.46). Curitiba experienced rapid population growth from the 1950s and now has a population of almost 2 million, making it Brazil's eight largest city. Nevertheless, it has managed to avoid all the problems normally associated with rapid urban growth. This success was largely due to innovative planning:

- public transport is preferred over the use of private cars
- the environment is used rather than changed
- cheap, low technology solutions are used rather than high technology ones
- development occurs through the participation of citizens (bottom-up development) rather than top-down development (centralized planning).

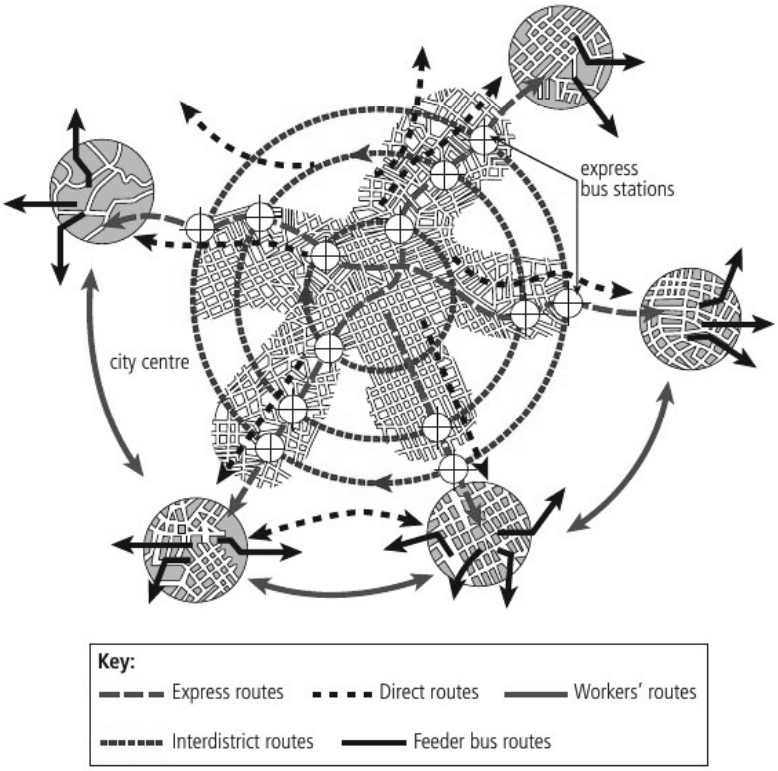


Figure 8.46 Transport network in Curitiba, Brazil.

The approach to transport in Curitiba is very different. The road network and public transport system have structural axes. These allow the city to expand but keep shops, workplaces and homes closely linked. Curitiba's mass transport system is based on the use of buses. Interdistrict and feeder bus routes complement the express bus lanes along the structural axes. The improvements are geared towards the speed of journey and convenience of passengers and include:

- a single fare being charged that allows transfer from express routes to interdistrict and local buses
- extra wide doors allow passengers to crowd on quickly
- double and triple length buses that allow for rush hour loads
- bus routes and bicycle paths that integrate the parks into the urban life of the city.

The rationale for the bus system was economic as well as sustainability. A subway would have cost US$ 70–80 million per km but the express busways only cost US$ 200,000 per km. The bus companies are paid by the kilometres of road they serve rather than the number of passengers they carry. This ensures that all areas of the city are served.

Increased accessibility

Increased accessibility allows people to reach a greater number of locations and activities in a shorter amount of time. It creates more opportunities for employment, social interactions, healthcare, retail and so on. Improved accessibility may therefore bring about improvements in the quality of life. Accessibility may be measured in the amount of time it takes to get to a place or the amount it costs to get to a place.

Social equality

Social equality suggests that all population groups are equal in terms of their rights and status. However, this is often not the case. Certain groups may be disadvantaged or deprived in several ways, including low incomes, a lack of employment opportunities, ill health, poor educational achievement, limited access to housing and services, high rates of crime and a poor living environment. For example, the city of Barcelona has a population of about 1.6 million people – and around 5 million in the wider metropolitan area. The greatest level of deprivation is seen in two main areas – the inner-city district of El Ravel, associated with poor-quality housing built during the industrial era, and the edge-of-town locations of Can Peguara and La Mina, where social housing was built to accommodate migrants to the city during the 1960s. During the 1970s and 1980s Barcelona deindustrialized rapidly. In the 1980s, unemployment in the city was 20% and many locations became derelict. Barcelona still has a large population that are disadvantaged. According to the 2017–27 Strategy for Inclusion and Reducing Social Inequality in Barcelona, the five aspects of social inequality with the most impact on social inclusion/exclusion processes are:

- inequality in income
- inequality in education
- inequalities in access to community assets or networks between people
- the stigmatization and social segregation of people according to income, education, culture or the area they live in
- territorial inequalities.

Avoiding social inequality in access to green areas

Open spaces are important for physical and mental wellbeing, but the amount of open space in urban areas varies enormously. For example, London has 50 m^2 of open space per resident, whereas Mumbai has less than 2 m^2 of open space per resident. India's national building code recommends at least 4 acres of open space per 1000 residents, but Mumbai has just 0.3 acres of open space per 1000 residents. Mumbai now has the second-highest childhood obesity rate in India and some 68% of the city's children are said to have sedentary lifestyles.

It is not just green spaces that are important. In the 1960s in Bengaluru (Bangalore), there were over 280 lakes but now there are fewer than 70 and many of these are biologically dead. The government turned many of these spaces into vehicle parking spaces, a bus station and a sports stadium, while others have been surrounded by slums. In addition, between 2010 and 2014, over 50,000 trees in Bengaluru were cut down to make way for road widening schemes. Some critics have suggested that compensatory afforestation projects should be set up to counter the loss of trees. However, the creation of forests elsewhere will not affect the lives of citizens in Bengaluru (Bangalore), who are affected by air and noise pollution.

Activity

1. Visit the Our Cities page on the Carbon Neutral Cities Alliance website and investigate methods to make cities more sustainable.



HL

1.2 Systems
1.3 Sustainability

8.2.12 Societies are developing systems that address urban sustainability

The linear model of urban systems can be summarized as 'take, make and waste' (Figure 8.47). Cities consume about 75% of the world's natural resources and generate about 50% of the world's waste (Topic 1, Section 1.3.20).

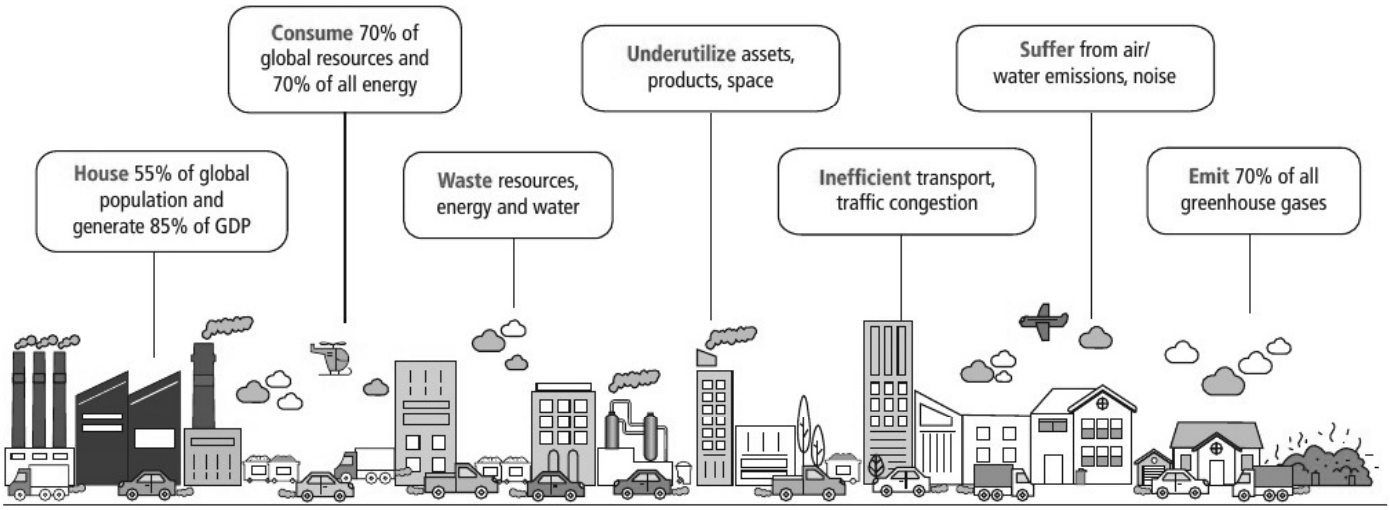


Figure 8.47 A linear city.

The circular economy model (Topic 1, Section 1.3.20) can lead to cities that are:

- thriving – increased economic growth occurs due to reduced congestion, waste and costs
- liveable – improved air quality and reduced pollution
- resilient – because of reduced reliance on raw materials and keeping products in use (Figure 8.48).

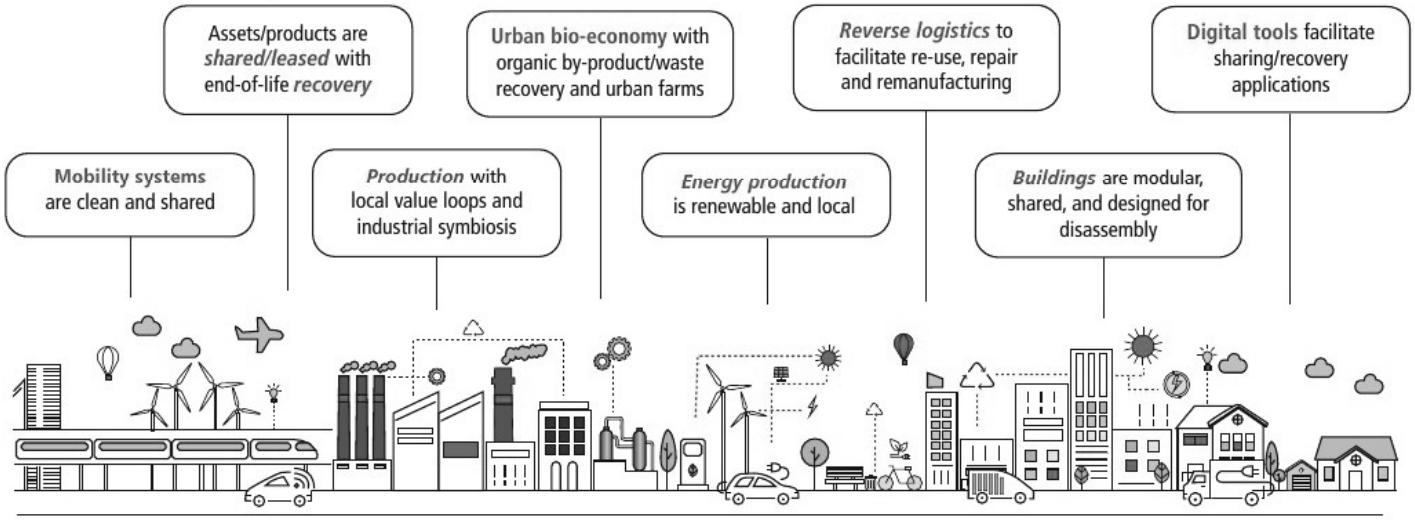


Figure 8.48 A circular city.

Traditional economic theory suggests that there is a circular flow of goods and money. However, it does not consider the negative environmental externalities such as raw material and energy use or the production of waste (HL.b.3 and HL.b.4). Moreover, it does not consider the fact that not all work is paid for, including child-rearing, fuelwood collection and water collection.

HL b Environmental economics

- According to Oxfam (2023) *Survival of the richest*, the richest 1% of the world's population received 63% of the new wealth (worth about US$ 42 trillion) since 2020. Doughnut economics offers a route for humanity in the 21st century (see Figure 1.72, Topic 1). The centre of the doughnut is the 'social foundations', including the basic human needs of water, food, energy and health. The outer part of the doughnut is the 'ecological ceiling', which is the planetary boundaries including climate change, ozone layer depletion and ocean acidification.

Currently, about 12% of the world's population experience severe food insecurity and about 13% do not have access to electricity. Five of the nine planetary boundaries have been exceeded including climate change, biodiversity loss and biogeochemical flows. Arguably, these boundaries have been exceeded as the result of linear economic flows, for example due to a lack of recycling, re-use and reduction.

Whereas traditional models of economic growth may suggest that an increase in GDP per head illustrates economic growth, the doughnut economics model suggests that development is a balance between an increase in the quality of life and the avoidance of depleting the Earth's resources.

Amsterdam has identified a number of issues in relation to becoming a sustainable city and, in some cases, has set targets for how to resolve the issues. For example, the city aims to have a 50% decrease in the use of primary raw materials in industry and for buildings by 2030 and to have a fully circular economy by 2050. In 2018, the Amsterdam Metropolitan Area processed around 8.5 million tonnes of industrial and commercial waste and 1.1 million tonnes of household waste. Amsterdam's target for healthcare is that all people should have an equal chance of a healthy lifestyle. However, 40% of the population are overweight and 49% have a moderate or high risk of anxiety or depression. In addition, the city aims to be an inclusive city with equality in diversity. However, 15% of residents reported discrimination in 2017, with 39% of incidents being related to ethnicity or skin colour and 29% being related to nationality. One area of success for the city is mobility. The city aims to be accessible to everyone via public transport in a safe and sustainable way. There are about 665,000 bike journeys made daily, and the routes taken by trains, buses and trams are integrated to allow people to reach most of the city and its suburbs using a simple fare structure.

Singapore has adopted a compact, biodiversity-rich approach to urban planning. Despite having a population density of over 7000 people per km^2, the city has managed to expand its green areas from 36% of the island in 1970 to 47% in 2020. The city has 72 ha of rooftop gardens (Figure 8.49) and this figure is expected to triple by 2030. The city has over 4000 ha of green space, which provides several ecological services such as climate regulation, flood regulation, space for recreation and increased biodiversity. Singapore is believed to be home to between 23,000 and 28,000 terrestrial species.



Figure 8.49 Green roof in Singapore.

In Sao Paulo, Brazil, the organization Connect the Dots is creating a circular economy that tackles social inequality and supports regenerative farming. The project buys food from local farmers at 30% above the market price and provides food for vulnerable people. They have also helped local farmers to improve soil quality, promote biodiversity, reduce use of chemical fertilizers and pesticides and help to tackle global climate change.

1.3 Systems
6.3 Climate change – mitigation and adaptation

8.2.13 Green architecture

Green architecture is a philosophy focused on designing buildings with the lowest possible negative impact on the surrounding environment by using sustainable materials and energy sources in construction.

Green architecture reduces some of the harmful effects of construction projects on human health and the environment. It aims to safeguard air, water and earth by choosing environmentally friendly building materials and construction practices. Green architecture and civil engineering combine new and indigenous knowledge systems, vernacular architecture, bio-based materials and environmentally friendly (circular) construction.

Green architecture

Green architecture (also called 'sustainable architecture and/or 'green building') refers to buildings that are designed and constructed with environmentally friendly principles. Green architecture uses sustainable energy resources, reduces energy use and updates existing buildings with new technology. It helps reduce pollution, conserve natural resources and prevent environmental degradation. Economically, green architecture reduces the amount of money spent on water and energy. Socially, green architecture places limited strain on local infrastructure. Environmentally, green architecture is resource efficient as it uses traditional design and is built with local materials. Green building materials are generally composed of renewable resources and/or plentiful resources. For example, clay and sand mixed with water and fibres, such as straw, form adobe (clay blocks). Some advantages of green architecture are shown in Table 8.15.

Energy	Natural resources	Pollution
Energy consumption is minimized by using: • ventilation systems with efficient heating and cooling • energy efficient appliances and lighting • renewable energy resources e.g. solar and wind	Natural resources are conserved by: • water-saving features • designing landscape to maximize solar energy • re-use of older buildings • efficient use of space • use of responsibly harvested wood	Pollution is reduced by • more vegetation present, especially trees, so more pollution is filtered out of the atmosphere • reduced carbon emissions through use of renewable energy sources • less use of concrete as a building material and greater use of clay, vegetation and adobe rather than the use of concrete • use of sustainably harvested wood • reduced harm to the natural environment

Table 8.15 Advantages of green architecture.

Individual buildings do not have to have all of these features but will have at least some of them.

The disadvantages of green architecture include limited availability of materials and high cost due to expensive materials and technology.

Bale construction

Bale construction uses bales of straw and other materials to create housing and/or roofing (Figure 8.50). Many traditional homes in rural areas had straw bales in their construction or for insulation. Construction with straw bales has become more popular in places such as Australia, the USA and Europe, partly for environmental reasons (straw is renewable) and partly for cost. Straw bales have also been used to create earthquake-resistant housing in Pakistan, where the compressed bales are held together by nylon netting and sandwiched between layers of plaster.

The use of straw bales can pose problems related to moisture, mould and vermin but some of the bales can be replaced with newer ones if they have deteriorated over time.



Figure 8.50 Use of straw for roofing, South Africa.

Construction using plastic bottles

Bottles made from PET (polyethylene terephthalate) are clear, strong, lightweight plastic bottles that are 100% recyclable and may be able to last for up to 300 years.

Constructing buildings from plastic bottles has several advantages including:

- low cost
- materials are re-usable
- easy to build
- less construction material needed.

3D-printed houses

In 2021, 2.2 million 3D printers were shipped worldwide, and this is predicted to rise to 21.5 million by 2030. The global market was valued at around US$ 14 billion and is expected to grow annually by about 20% until 2030. Materials used for 3D printing include plastics, resins, concrete, mortar and polylactic acid (PLA), which is a bioplastic made from renewable plant-based materials including corn, sugarcane and cassava. 3D-printed houses provide design flexibility, increased productivity and efficiency compared with traditionally built houses, reduced transport costs, and can save time and eliminate waste. Traditional forms of building have faced skilled-labour shortages, housing shortages and impacts from hazards/climate change. There are several examples of 3D-printed houses. 'House zero' is a 186 m^2 3D-printed three-bedroomed house in Austin, Texas, USA. The walls, reinforced with steel, were printed in just three days. 'Project Milestone' is a 94 m^2 boulder-shaped single-storey home and is part of a five-home 3D-printing project in Eindhoven, The Netherlands. 'House 1.0' is a 37 m^2 3D-printed house in Holstebro, Denmark and is more affordable than most conventional housing. 'Kamp C' was printed in one piece using Europe's largest 3D printer and was the world's first two-storey home, built at Westerlo in Belgium.

Vernacular housing

Traditionally, the design of a building is closely related to the local climate. By understanding the potential impacts of local climate on buildings, architects can create safe, efficient, comfortable and sustainable building-types. For example, in many hot, humid areas such as in the Caribbean and southern Asia where flooding was either a seasonal or permanent problem, houses were built on stilts (Figure 8.51).



Figure 8.51 Housing built on stilts, Kampong Ayer, Bandar Seri Begawan, Brunei.

In contrast, nomadic and semi-nomadic peoples needed to create housing that could be moved around the landscape e.g. the Nenet nomadic reindeer herders of the Yamal Peninsula, Siberia with their chums (tents) (Figure 8.52).



Figure 8.52 Nenet's chums.

Climate change has certain easily-observed effects on architectural forms e.g. the relative size of window area to wall area becomes lower as you move to countries that are closer to the equator. In hot environments, people limit the glare and heat of the Sun, by limiting the size of the windows. In addition, projecting balconies and overhangs cast long shadows on walls. Glazing uses materials in walls, windows or roofs to let in natural light while reducing the effect of sunlight. Lattices may fill large openings to reduce glare, while permitting breezes to pass through. Gabled roofs decrease in pitch as the rate of precipitation decreases. For example, in areas that receive heavy snow, gables are steep, while in hot environments, the pitch steadily decreases. In hot, dry countries, roofs become quite flat, even providing a comfortable place to sleep! In contrast, in areas of tropical rainfall, the roofs are again steep to provide protection from the torrential downpours.

In hot, dry areas a major focus of building design is minimizing heat penetration into the house. Walls are commonly painted white to reflect solar radiation and to limit heat absorption. Shady areas are designed for comfort and openings, such as windows, are often very narrow and have shutters that let light but not heat in and are able to withstand strong winds.

In hot, humid climates the impacts of extremely high temperatures can drastically affect the design of a structure. Cool roofs are specially designed to be reflective, thereby lowering temperatures inside the building and reducing the amount of energy needed to keep it cool. Shades, such as awnings, overhangs and trellises, block sunlight from entering a space. An example of adaptation to a hot and humid environment is seen in the Palace of Justice in Klungkung, Bali, Indonesia (Figure 8.53). Built in 1710, the pavilion is surrounded by a moat filled with water. Evaporation from the moat allows moist air to circulate round the pavilion producing a cooling effect. Rooms on the first floor are completely open to the outdoors to allow maximum ventilation. The ceiling is shaped like a tent so that heat accumulates and forms an insulating layer that protects the inside of the building from the sun's heat. The roof has an overhang that protects the base of the walls from rain.



Figure 8.53 Palace of Justice in Klungkung, Bali, Indonesia.



Figure 8.54 Wind tower house, Dubai.

Arabic wind tower houses

Arabic wind tower houses (or windcatchers) are a traditional form of housing that creates cross-ventilation and cooling in buildings. They are common in North Africa and West Asia and have been used for over 3000 years (Figure 8.54). Their popularity has increased in the 21st century as a method to increase ventilation and reduce the use of costly air-conditioning units. There are a number of designs, but the principle of each is the same – catch the wind and transfer it into buildings where it can have a cooling effect (Figure 8.55). Some air filtering may be needed to reduce the amount of dust or insects carried by the wind. Within buildings, warm air rises and escapes through the top of the wind tower whereas denser, colder air sinks to the ground. Wind towers are used in other environments too, for example they are used in the Bluewater shopping centre in Dartford in the UK.

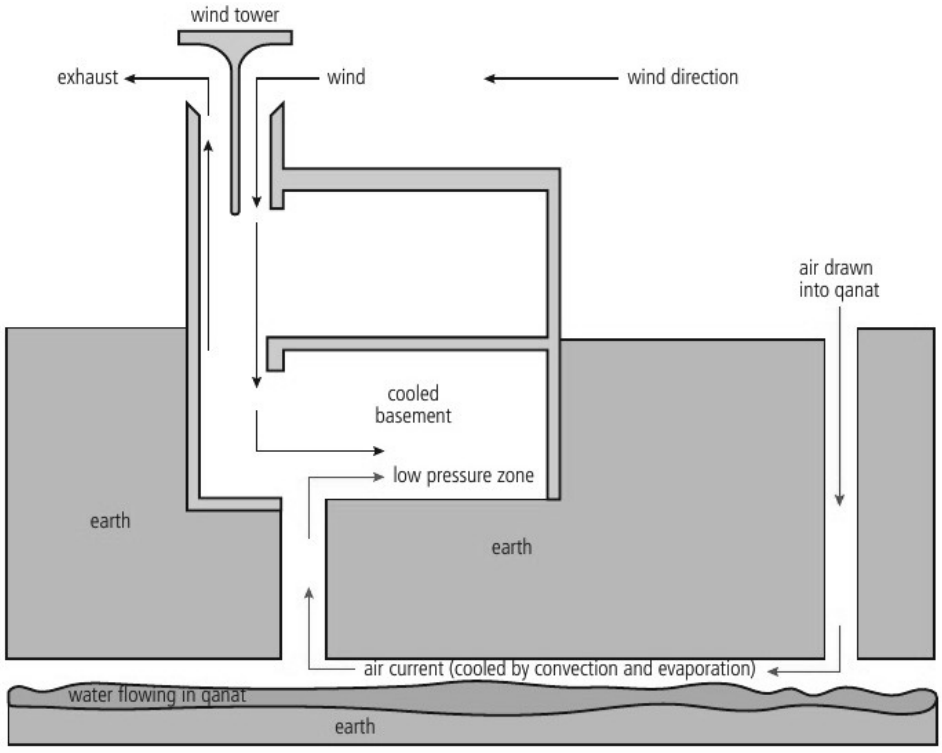


Figure 8.55 The principles of an Arabic wind tower.

Engagement

- Investigate population change in your own country or the country you live in. Have a class discussion on the impacts on society and options for population management.
- Volunteer with a local organization that works to support those people who may have suffered from social and environmental inequity.
- Evaluate the extent to which an urban environment local to your school is sustainable. Write some recommendations to improve the sustainability of a local urban area.
- Investigate what actions and activities to achieve Sustainable Cities and Communities occur in your local area.
- Make a poster including proposals for smart city functionality for your school community. Put copies of the poster in busy places around your school.

Exercise

Q12. Using Figure 8.56 **estimate** the proportion of the population that were urban in 2025 in **(a)** Africa **(b)** Asia and **(c)** Latin America.

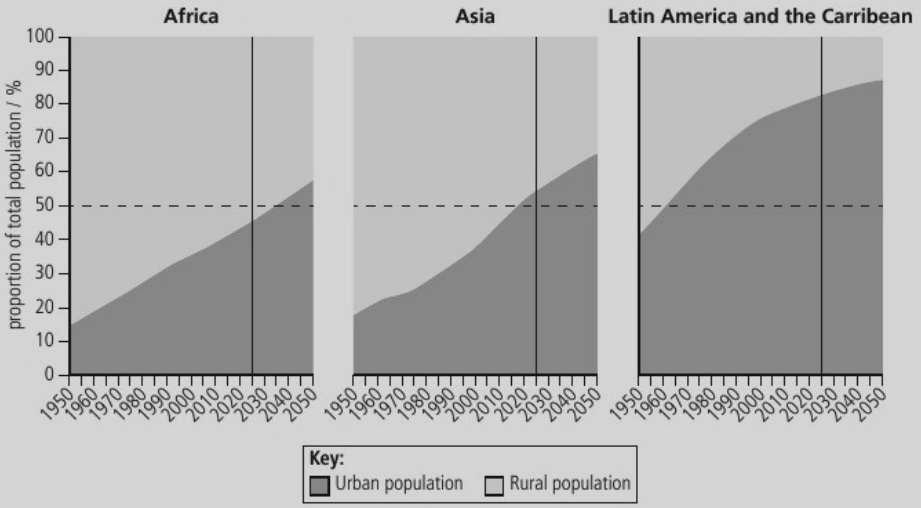


Figure 8.56 Variations in the level of urbanization over time.

Q13. **Distinguish** between push and pull factors.

Q14. **Outline** the advantages of the Garden City as seen by Ebenezer Howard.

Q15. **Describe** an example of urban ecology.

Q16. **Describe** one example of urban farming.

Q17. **Describe** the main characteristics of urban ecosystems.

Q18. **Explain** how urban areas work as systems.

Q19. **Outline** the main characteristics of suburban areas.

HL

Q20. HL **Describe** the main characteristics of an unsustainable (linear) city and a sustainable (circular) city as shown by the Rogers Model.

Q21. HL **Outline** the advantages of green architecture.

HL end