2 How climate change affects the natural world and human beings

Can we adapt to the inevitable consequences of climate change?

Everything in nature is interconnected. Even a small change in one part of the natural world leads to changes in many others. So, as the temperature on the planet rises, we are seeing many other related changes. The level of the world ocean is rising, glaciers and permafrost are melting, the frequency and power of extreme weather events (heatwaves, hurricanes, storms, floods, and droughts) are increasing year by year. New and dangerous infectious diseases and various pests are appearing in places where they were so far unknown. These and other effects of climate change are dangerous to plants and animals, which cannot adapt quickly to such drastic changes. They also cause enormous economic damage and present a threat to human health and even human life.

The recent findings of the IPCC AR6 show that climate change could lead to even more dangerous consequences for people and for the natural world in the future. The scientists concluded that for every 0.1°C that the planet gets hotter, the impacts get worse, and risks get higher (Fig. 2.1). This is why United Nations Secretary-General António Guterres called this report 'a code red for humanity'. But on the flip side, every 0.1°C that's prevented can be crucial in limiting the extent of future damage.

Increased risks with rising temperatures assessed by the IPCC (Fig 2.2) show that even limiting global temperature rise to 1.5°C is not safe for all. At this level of warming, for example, 950 million people across the world's drylands will experience water stress, heat stress and desertification, while the share of the global population exposed to flooding will rise by 24%.

Figure 2.1

The negative impacts of climate change on the environment and human beings by the end of the 21st century, unless we do all we can to reduce greenhouse gas emissions

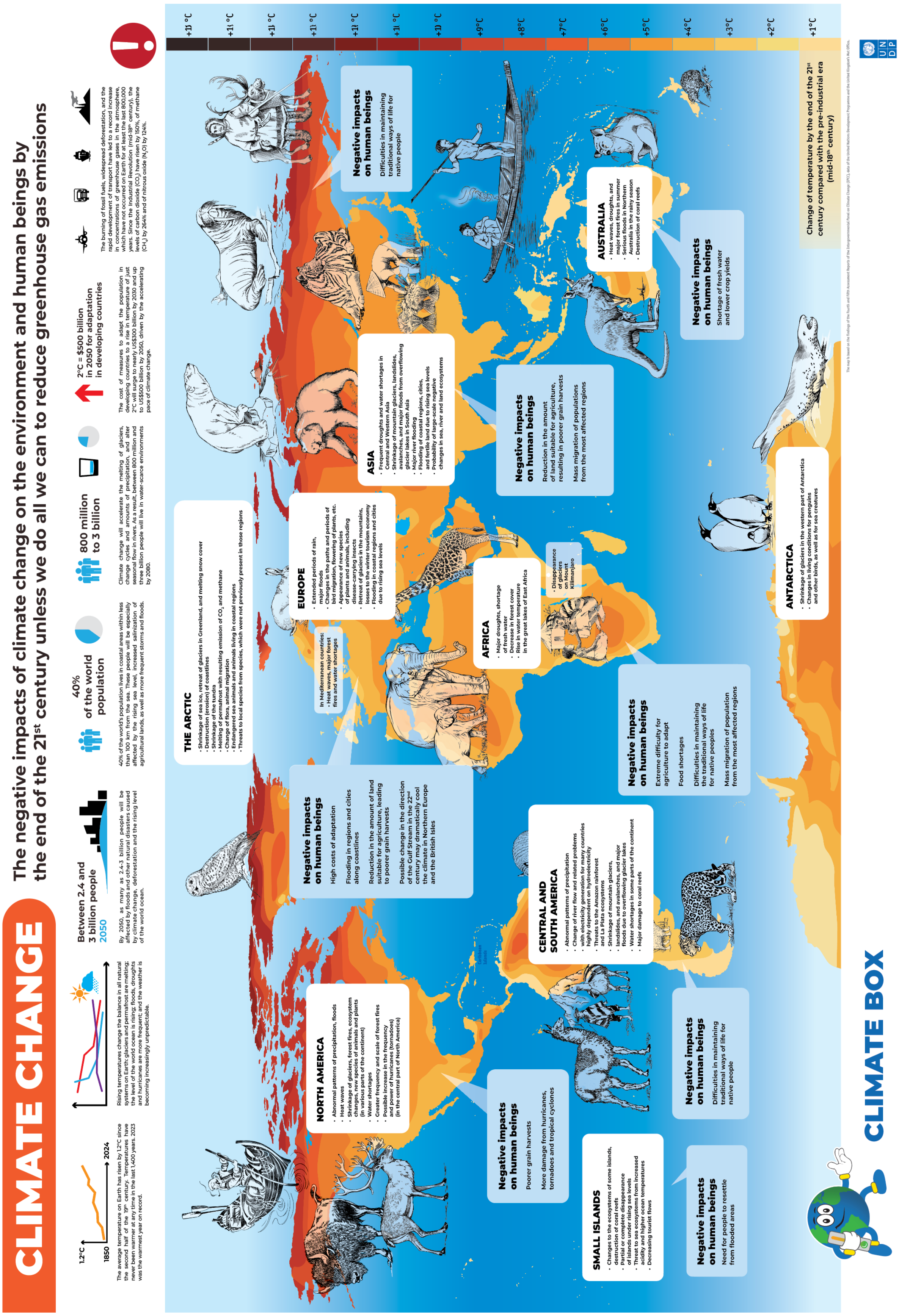
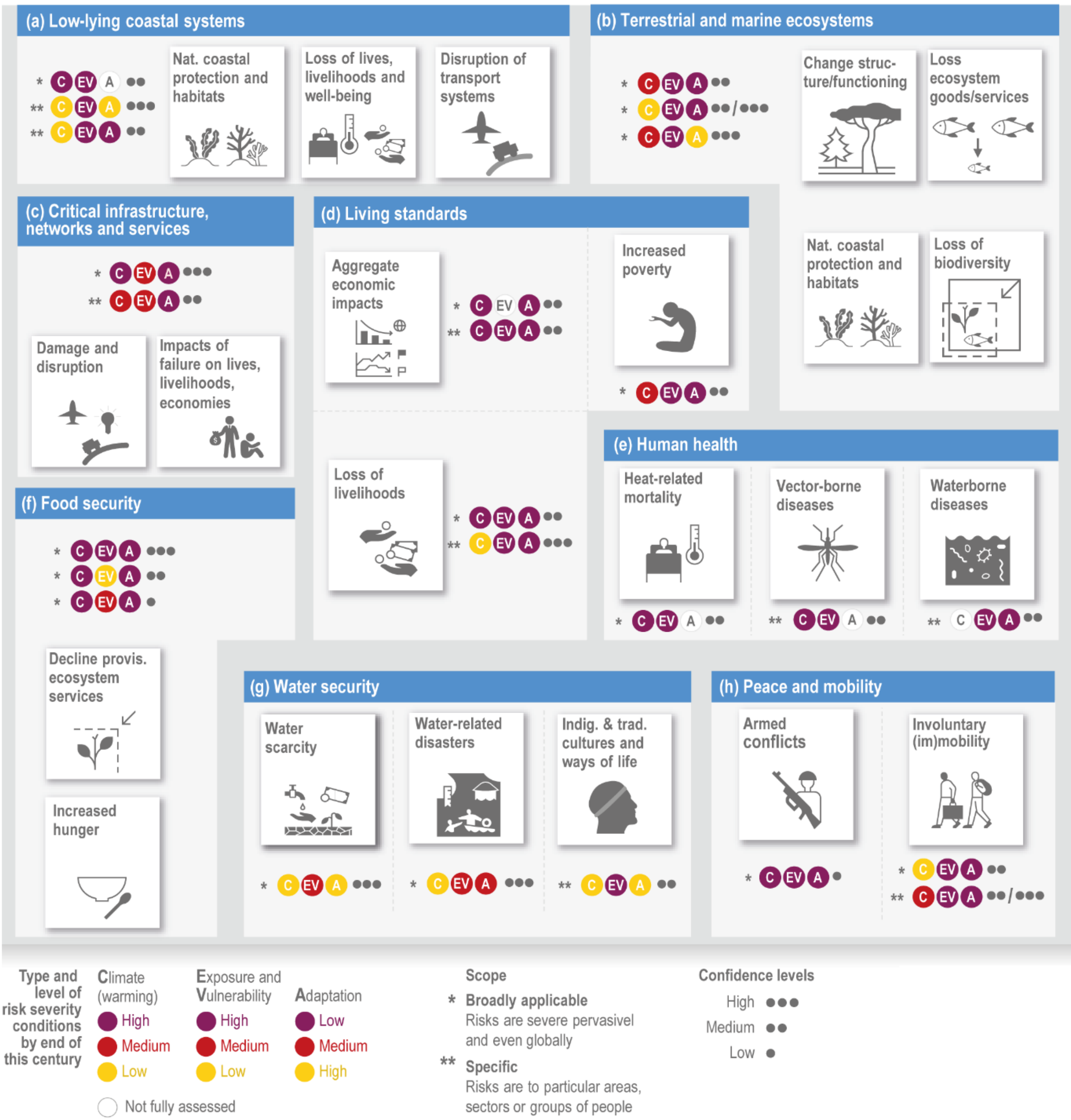


Figure 2.2 Comparing risks at different temperature levels on human and natural systems

	1.5°C	2°C	3°C	1.5°C vs 2°C	1.5°C vs 3°C
BIODIVERSITY LOSS Maximum percentage of species at high risk of extinction across forests and land	14%	18%	29%	1.3x WORSE	2.1x WORSE
DROUGHT Dryland population exposed to water stress, heat stress and desertification	0.95B PEOPLE	1.15B PEOPLE	1.29B PEOPLE	200M MORE PEOPLE	340M MORE PEOPLE
FOOD SECURITY Costs for adaptation and residual damage to major crops	$63 BILLION US	$80 BILLION US	$128 BILLION US	$17B MORE	$65B MORE
FIRES Increases in burnt area across Mediterranean Europe	40-54%	62-87%	96-187%	1.6x WORSE	3x WORSE
EXTREME HEAT Increase in number of days per year with a maximum temperature above 35°C (95°F)	45-58	52-68	66-87	1.2x WORSE	1.5x WORSE
EXTREME HEAT Increase in annual number of heatwaves in Southern Africa	2-4 TIMES	4-8 TIMES	8-12 TIMES	2x WORSE	3.3x WORSE
SEA LEVEL RISE Global mean sea level rise by 2100	0.28-0.55m	0.33-0.61m	0.44-0.76m	1.1x WORSE	1.4x WORSE
FLOODS Increase in global population exposed to flooding	24%	30%	NO DATA AVAILABLE	1.3x WORSE	NO DATA AVAILABLE
CORAL REEFS Further decline in coral reefs	70-90%	99%	NO DATA AVAILABLE	1.2x WORSE	NO DATA AVAILABLE

Today's climate change will indeed reduce agricultural productivity, limit the availability of freshwater, increase the severity of droughts, heat waves and tropical cyclones, and reshape coastal environments on a speed and scale that could provoke destabilizing societal responses. The WMO established that four key climate change indicators – greenhouse gas concentrations, sea level rise, ocean heat and ocean acidification – set new records in 2022. This is yet another clear sign that human activities are causing planetary-scale changes on land, in the ocean, and in the atmosphere, with dramatic and long-lasting ramifications. Unless we do all we can to reduce greenhouse gas emissions, the negative impacts of climate change on the environment and human beings could well be irreversible by the end of the 21st century (Fig. 2.3).

Figure 2.3 Key risks to natural and human systems stemming from climate change by the end of the century



Experiences suggest that exploring the resilience of past populations to climatic changes and anomalies could provide key insights into valuable solutions on how to cope with climate change today and in the future. To reduce the damage caused by climate change, humanity must take appropriate measures, especially by building resilience to the human-caused warming that is already baked into the current climate crisis. The evidence from impacts so far and projected risks show that worldwide climate-resilient development action is more urgent than now than ever before.

Feasible and effective adaptation measures are presented for each of the themes discussed in this chapter. They include measures which can reduce risk, such as considering climate change impacts and risks in the design and planning of urban and rural settlements and infrastructure. They also include measures which can help to safeguard biodiversity and ecosystems that are critical for climate-resilient development, given the threats climate change poses to them and their roles in adaptation and mitigation (Fig. 2.4).

While we all feel the impacts from climate change already, they most hit the poorer, historically marginalized communities. Scientists noted in the IPCC AR6 report that today, between 3.3 billion and 3.6 billion people live in countries highly vulnerable to climate impacts, mostly in the Arctic, Central and South America, Small Island Developing States, South Asia and much of sub-Saharan Africa. Climate change impacts exacerbate existing conflicts, inequalities, conflict, and development challenges (e.g., poverty and limited access to basic services like clean water) across many countries in these regions, and limit communities' capacity to adapt. For instance, from 2010 to 2020, mortality from storms, floods and droughts was 15 times higher in countries with high vulnerability to climate change than in those with very low vulnerability.

This section explores the impacts of climate change on various regions, societies, and economic activities, and presents examples of climate adaptation measures that help mitigate and prepare for some unavoidable negative climate impacts.

Climate change-related hazards, risks, impacts, resilience and adaptation

Today, the Intergovernmental Panel on Climate Change (IPCC) uses the term **resilience** to mean the ability of coupled human and natural systems 'to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity and structure.'

It therefore encompasses **adaptation**, which the IPCC defines as the process of adjustment to actual or expected climate and its effects, to moderate harm or exploit beneficial opportunities. For example, adaptation measures might include the construction of buildings that are more resistant to extreme weather events, building dams to combat floods, developing new, drought-resistant crop varieties, etc.

The IPCC also widely uses the concept of **risks** in relation to the potential for adverse consequences from climate change for human or ecological systems, recognizing the diversity of values and objectives associated with such systems. In the context of climate change, risks can arise from potential impacts of climate change as well as human responses to climate change.

The consequences of realized risks from climate change on natural and human systems define the **impacts**. Impacts generally refer to effects on lives, livelihoods, health and wellbeing, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure.

Hazards are defined as negative impacts from natural or human-induced physical events or trends that may cause loss of life, injury, or other health impacts, as well as damage and loss to property, infrastructure, livelihoods, service provision, ecosystems, and environmental resources.

3

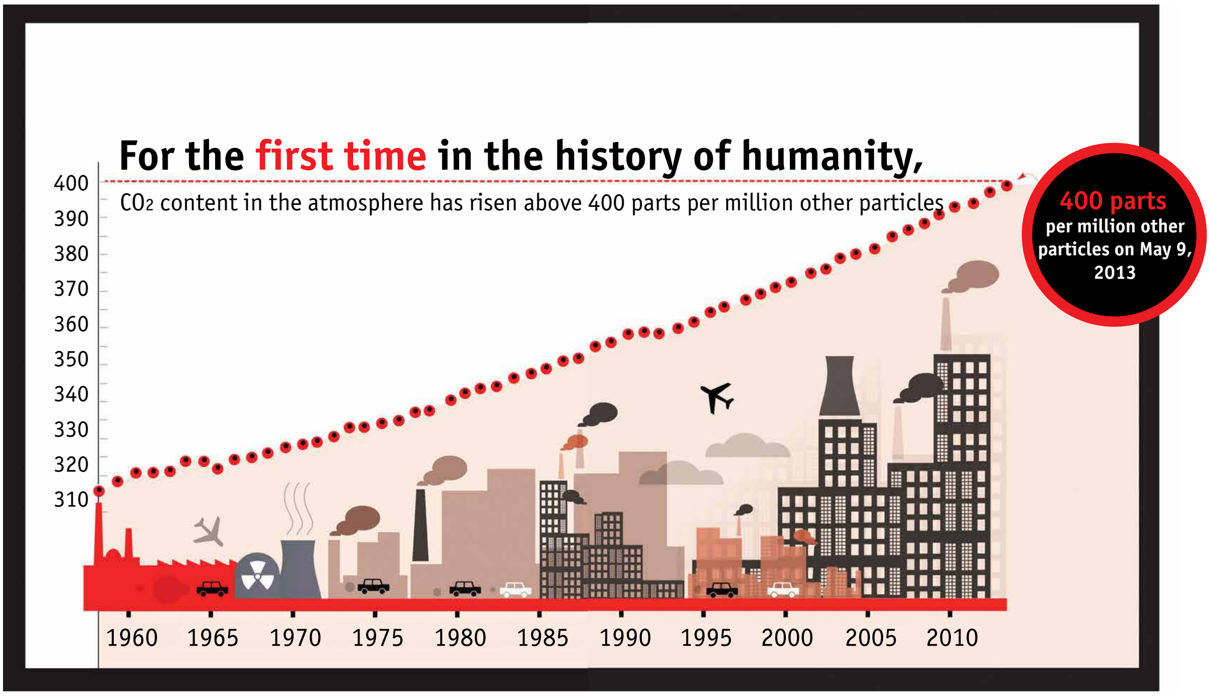
How to prevent dangerous climate change

3 How to prevent dangerous climate change

You already know that the amount of greenhouse gases in the atmosphere has been increasing rapidly in recent years leading to increases of its concentration in the atmosphere (Fig. 3.1.1). The natural content of carbon dioxide in the atmosphere has varied in the last few hundred thousand years (which have included periods of interglacial warming and glacial cooling) between 180 and 300 particles of CO_2 per million other particles.

In 2013, the level of CO_2 in the atmosphere exceeded 400 parts per million for the first time in at least 800,000 years. This concentration continues to grow rapidly, reaching levels of 421 parts per million in 2022. The reason is that globally, net greenhouse gas (GHG) emissions from human activity, defined as a difference between the gross emissions minus removals, for example by forests, have continued to grow. Between 2010 and 2022 the level of GHG emissions was higher than at any previous time in human history. Their concentration in the atmosphere will continue to grow until annual emissions are reduced sufficiently to be balanced by removals.

Figure 3.1.1 Growth of Co_2 concentrations in the atmosphere since 1960



Everyone on the planet contributes to climate change by emitting greenhouse gases into the atmosphere year after year. We are the end users of goods and services, the production of which requires energy, and energy comes mostly from non-renewable fossil fuels (oil, coal, and natural gas). The production of goods and services accounts for 75% of all greenhouse gas emissions associated with human activities.

We already discussed the devastating impacts of climate change on the health of our society and the planet. Scientists confirmed that the recent changes in climate are widespread, rapid, intensifying, and unprecedented in thousands of years. Such changes are expected to continue, as under all emissions scenarios outlined in the IPCC AR6 report, the Earth's surface warming is projected to reach 1.5ºC in the next two decades. Unless there are immediate, rapid, and large-scale reductions in greenhouse gas emissions, limiting warming to 1.5°C or even 2°C will be soon beyond reach.

To decrease the concentration of greenhouse gases in the atmosphere and limit global warming, strong, rapid, and sustained reductions in CO_2, methane, and other greenhouse gases in this decade and reaching net zero emissions by 2050 are critical. Together with reductions of the 'short-lived climate forces' such as aerosols and particulate matter, these would not only reduce the consequences of climate change but also improve air quality, reduce health impacts, and bring other sustainable development benefits. Such reductions need to follow a nature-positive approach, which can help to enrich biodiversity, store carbon, purify water and reduce pandemic risk. In short, reducing greenhouse gas emissions in the atmosphere should also enhance the resilience of our planet and our societies.

Many countries have taken action to reduce emissions. As of 2022, most industrialized countries have steadily reduced greenhouse gas emissions for more than ten years and many developing countries have taken measures to slow down emissions growth. However, scientists have shown us that this is not enough, and we need a system transformation in all countries and in all sectors of economy and society towards net zero emissions by mid-century.

What does this mean in practice and how can we reduce the concentration of greenhouse gases in the atmosphere? There are several ways of doing this.

The first is by switching to **climate-friendly sources of energy**. If we compare the different types of fossil fuel, the most polluting is coal, followed by oil and oil products, and the least polluting is natural gas.

But it is possible to produce energy without using fossil fuels at all. Since ancient times, people have used the heat of the sun, the power of wind and running water, and biomass. These are all renewable energy sources. Modern technologies make it possible to use them more widely. A rapid increase in the use of renewable sources of energy should go hand in hand with the phasing out of fossil fuel energy. Other carbon-free sources of energy, such as nuclear energy, can also help to reduce emissions in many countries, provided that all necessary safety measures are in place.

The second way of lowering greenhouse gas emissions is to **reduce our daily energy consumption**, by developing more energy-efficient machines and household appliances, improving the energy efficiency of buildings, and increasing electrification and energy storage. Current industrial processes, such as iron and steel, and cement, need to be replaced by carbon-free ones, and electrification in transport needs to go faster. We must also change our own habits to save energy and water.

The third way is to get plants to help us or use technologies that **remove CO_2 from the atmosphere**. Plants and trees absorb CO_2, so by reducing deforestation and by planting trees, people can reduce the amount of greenhouse gases in the atmosphere. Using environmentally friendly agricultural practices and restoring and protecting natural ecosystems can help soils absorb more carbon and bring other sustainable development benefits. New technologies that remove CO_2 from the atmosphere, such as carbon capture and storage or CO_2 removal, are at early stages of development and demonstration. They hold the promise that some emissions that cannot be avoided, e.g., some residual emissions from agriculture, will be captured by such emerging technologies soon.

Lastly, climate change is a complex global problem that can be solved only with cooperation among all governments, and an “all-of-society-approach” that especially involves business in efforts to manage the climate risk and disclose such risk as part of their business practices.

3.1 'Green' energy sources

3.1.1 What is energy?

Everything that has ever been created in the world, by nature or by human beings, has been created using energy. To obtain any form of energy, we must get it from somewhere.

Consider a bar of chocolate. It came to the shop from the factory, whose workers produced and packaged it. To do this, they used cocoa beans and sugar, which were brought to the factory from fields where other people grow cocoa beans and sugar cane. All the people who worked on making our chocolate had to eat and buy clothes for themselves. All the machines and devices that were used to make the chocolate bar are made from materials (steel, plastic, etc.) that came from minerals (iron ore, etc.) taken from the earth, and those machines are driven by energy. So, everything that we have was made by using energy. We ourselves grew from a tiny embryo, which took the energy of chemical compounds for its growth.

Can it really be the case that we constantly take from nature and give nothing in return? Of course not! We convert the energy that we receive into other forms and return it to the world. So, the energy itself never disappears, but only changes its state. The science that studies the most general laws of the transformation and transfer of mechanical and thermal energy is called **'thermodynamics'**, which is a branch of physics. The law of conservation of energy is the first law of thermodynamics.

Other laws of thermodynamics tell us that at the moment energy changes its state, a small part of it is lost and dissipated and cannot be 'gathered back'.

Let's see how people today use energy. Why are the consumption of energy and climate change so strongly interrelated?

And can humanity use energy to transform the global economy and society, making life on Earth green, flourishing and happy? Most importantly, how can we all start working towards this transformation today?

3.1.2 Main sources of energy

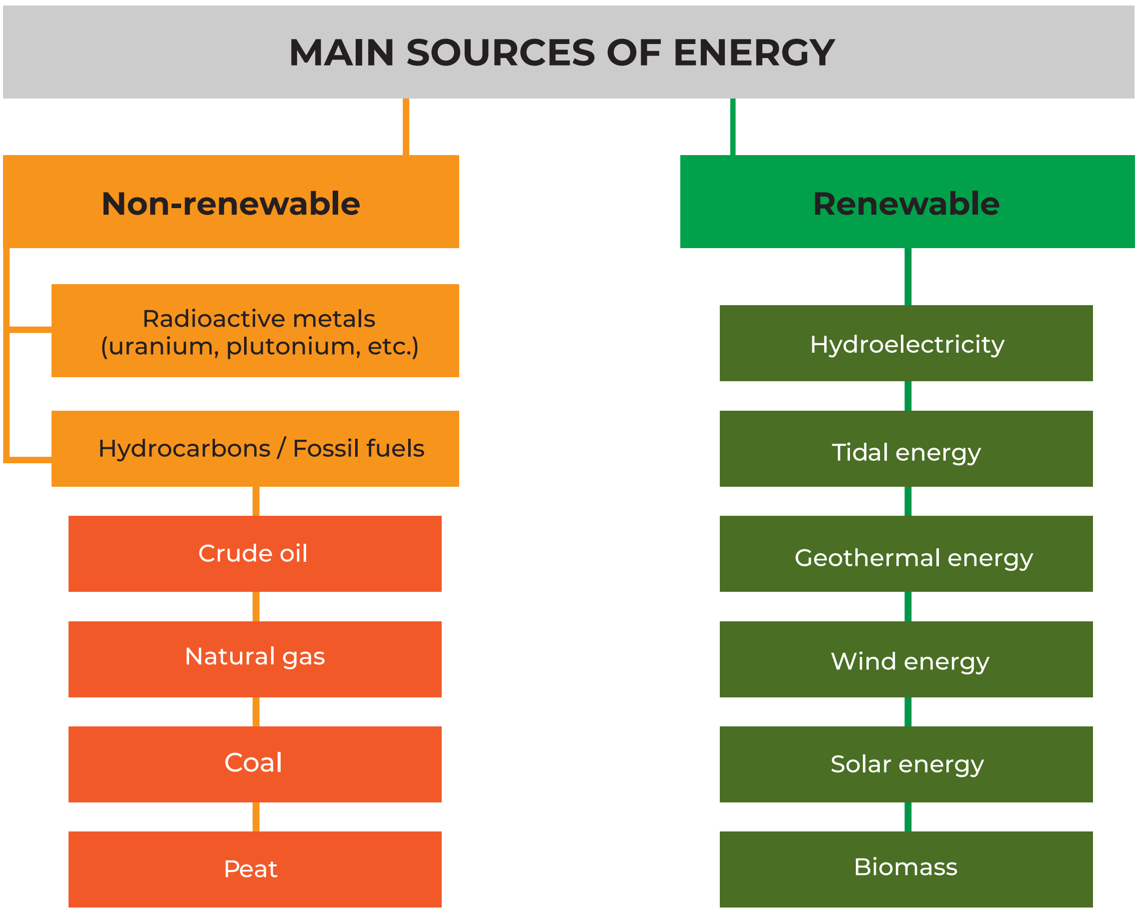
People have always used energy. Scientists began to think about this process in ancient times, when they began to study the simplest form of energy – mechanical energy, which they called a 'living force'. Gradually, other forms of energy were discovered: electrical, electromagnetic, thermal, and nuclear. Discovering new forms of energy, people investigate where they come from and find ways to make use of them.

We use a huge number of devices and appliances in our daily lives. Television sets, computers and refrigerators all work thanks to electricity channelled into our homes, which is the kind of energy we are most familiar with. This means that electricity is central to many parts of life in modern societies and will become even more so as its role in transport and heating expands through technologies such as electric vehicles and heat pumps. The role of electricity in industry will also increase because of the electrification of some industrial processes, such as iron and steel production.

Where does electricity come from?

People learnt to make electricity by transforming types of energy, which they found in nature. Natural sources of energy on our planet are usually subdivided into two major groups: non-renewable (traditional) and renewable (alternative) (Fig. 3.1.2).

Figure 3.1.2 Main natural sources of energy

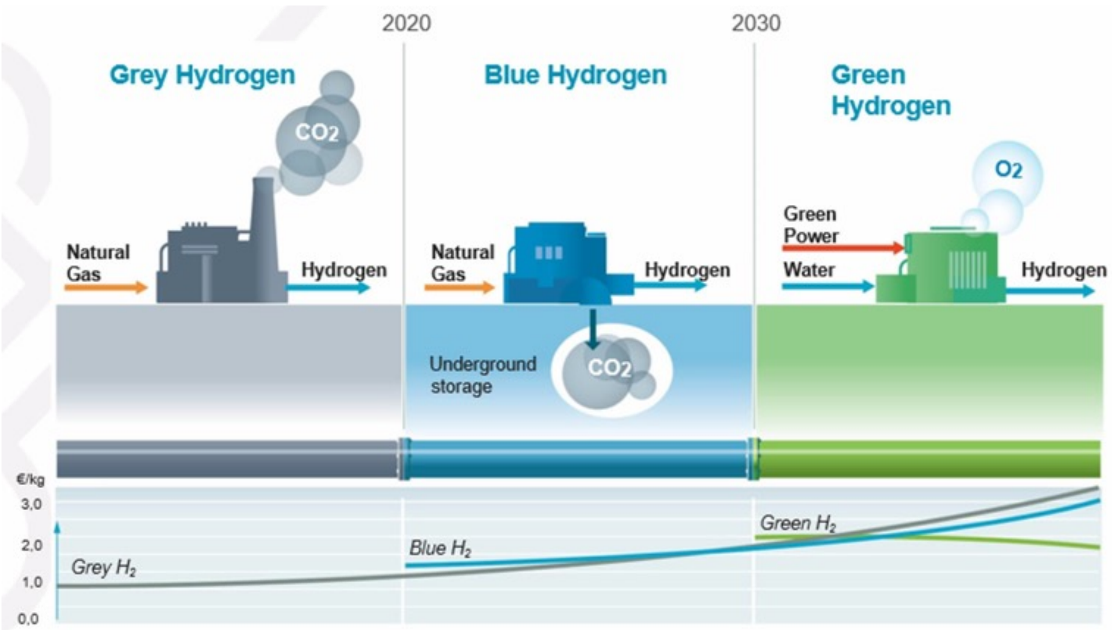


Non-renewable sources of energy are produced or replaced in nature much more slowly than they are consumed by mankind. The main non-renewable sources are coal, oil, natural gas and peat, and they are also called ‘hydrocarbons’ or ‘fossil fuels.’ Non-renewable energy sources also include radioactive metals (uranium, plutonium, and others), which are used to generate nuclear power.

Renewable energy sources draw energy from processes that occur continuously in nature. Sunlight, wind, flowing water, rain, tides, and heat rising from the earth can provide huge amounts of energy. What is more, these resources are practically inexhaustible: they will only run out in the unthinkably distant future when our solar system itself completes its life cycle. Biomass (plant fibre, animal waste, and charcoal derived from wood, which was widely used in the past) is also a renewable source of energy, as it is quickly replaced in nature.

A new fuel with a growing rate of use is **hydrogen**. It could be grey, blue, or green, depending on the sources from which hydrogen is produced – natural gas, natural gas with carbon capture and storage, and renewable electricity respectively (Fig. 3.1.3). While hydrogen was used in the past mostly as feedstock product serving heavy industry, it is now at the forefront of decarbonising the transportation and shipping industries.

Figure 3.1.3 Types of hydrogen, how they are produced and starting year of production



3.1.3 Fossil fuels

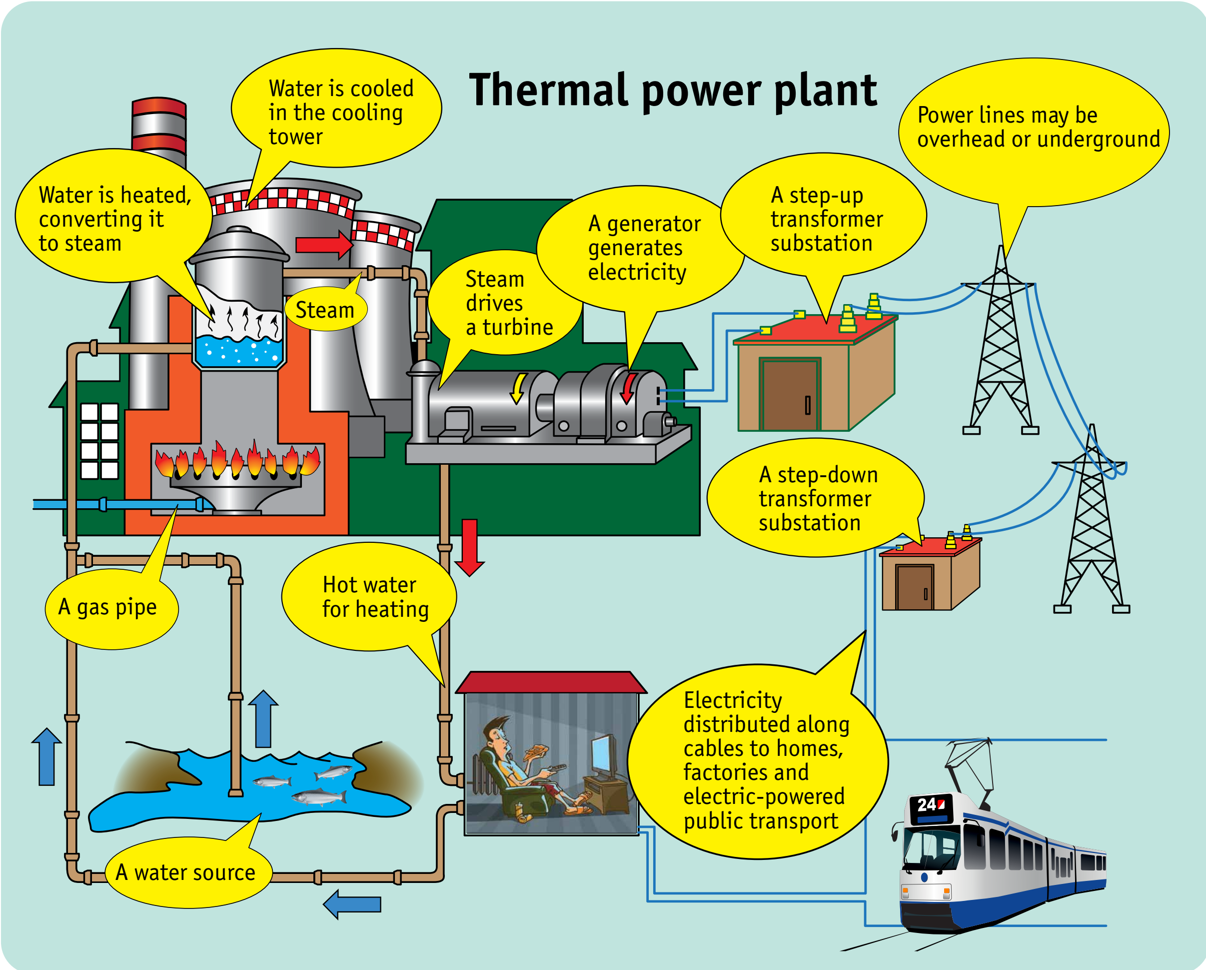
The evolution of living organisms on our planet progresses from the simple to the complex. There was a time when Earth was inhabited by simple organisms and plants, which absorbed the sun's energy and transformed it into live weight - into themselves. And the traces of their existence are still with us today: the energy gathered by these life forms, our predecessors, continues to live in what we call 'fossil fuels', substances formed from the remains of dead organisms. Crude oil, natural gas, coal, and peat are fossil fuels.

Fossils fuels are the legacy of living beings that came before us on Earth, and we should treat them sparingly and with gratitude. We must remember that no legacy is ever infinite. If we spend it unthinkingly, we will have nothing to leave to our children.

The combustion of fossil fuels, also known as hydrocarbons – coal, oil, or natural gas – can be used to produce electricity. This process occurs at thermal power plants. The engine room of a thermal power plant is fitted with a boiler and the combustion of fuel heats the water in this boiler, converting it into steam. The vapour pressure of the steam makes the blade of a turbine rotate and the turbine then drives a generator, which generates electric current. The electricity is carried to homes and other facilities by power lines (Fig. 3.1.4).

Hydrocarbon energy sources (fossil fuels) are crude oil, coal, natural gas (including shale gas produced from coal and shale formations), shale oil and other flammable substances, and minerals produced by underground or open-cast mining. Fossil fuels are formed over millions of years in the Earth's crust from the remains of living organisms. Their combustion extracts and uses their thermal energy.

Figure 3.1.4 How a thermal power plant works



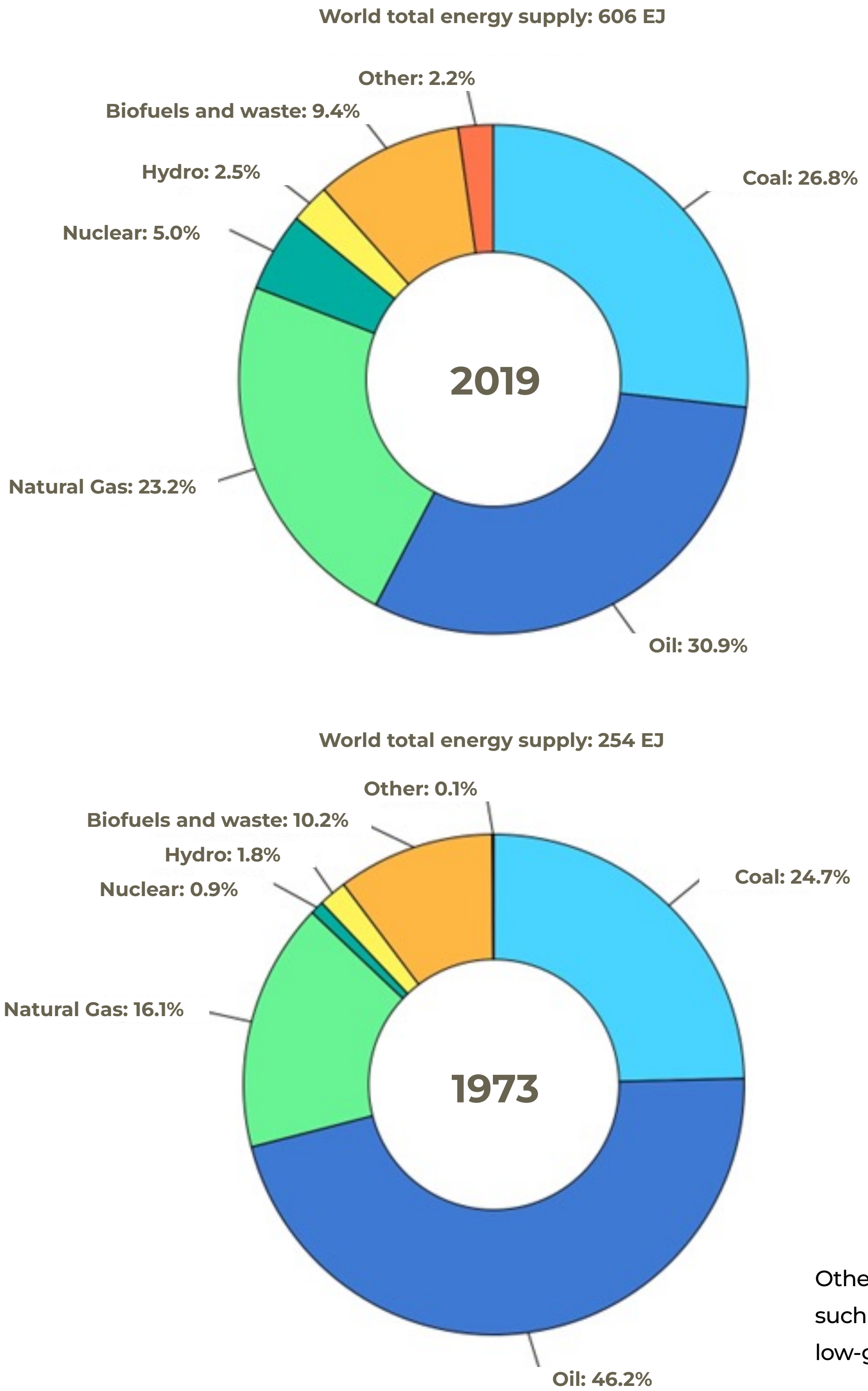
It was found that the production of electricity can be efficiently combined with heating of water, which is then channelled through pipes to the heating and hot-water systems of residential buildings, hospitals, schools and kindergartens, industrial plants, and other facilities. Such plants are called combined heat and power (CHP) plants. Usually, CHP plants are more efficient than plants that only produce electricity, which are called condensation power plants.

It is not always practical to channel hot water to apartment blocks from a CHP plant. In that case a boiler house is built, which uses fuel to heat water for the heating systems of local buildings.

The use of fossil fuels grew with the industrial revolution that began in the late 1700s in England. For many thousands of years earlier, wood, solar energy, wind, and water were the most common energy sources, although fossil fuels were already used in some places.

In 2019, fossil fuels dominated and accounted for 80.9% of all the primary energy supply of the world and their use was as follows: 30.9% for oil, 26.8% for coal and 23.2% for natural gas (Fig. 3.1.5).

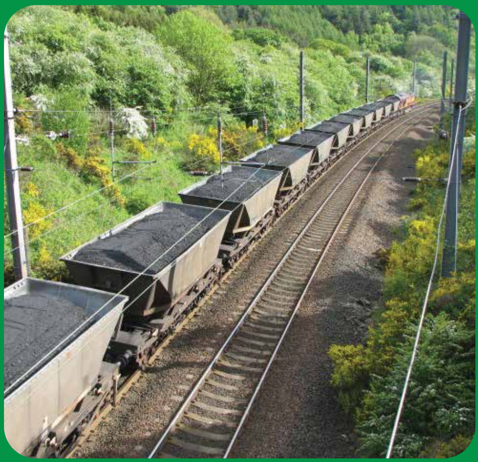
Figure 3.1.5 World primary energy supply in 2019 and 1973



Other: renewable sources such as wind, solar, geothermal, low-grade heat, etc.

There are two major downsides to using fossil fuels. First, they are not inexhaustible, and the world's reserves are being depleted, especially reserves of oil and gas. Second, the combustion of natural gas, oil, and especially of coal, emits large quantities of pollutants and greenhouse gases whose accumulation in the atmosphere increases the greenhouse effect. This leads to a rise in global temperature and other climate changes, and can be harmful to the climate, the environment and human health.

When did people start using fossil fuels?



The world's oldest coal mine was opened in Holland in 1113. But there is evidence of people using coal, lignite, and peat as sources of fuel in the much more distant past.

In the Middle Ages, coal was already being mined in many places in Europe. It became cheaper than wood and was increasingly used in everyday life, even by poor families. But, since houses at the time were not equipped with chimneys, rooms filled with acrid smoke, making it hard to breathe.

The consumption of coal increased dramatically with the start of the industrial revolution.

By the 19^{th} century, 700 million tonnes of coal were being mined each year. Then people turned their attention to oil.

Crude oil was known to mankind since ancient times. But it began to be used as fuel only in the middle of the 19^{th} century, after the American chemist Benjamin Silliman found that kerosene could be obtained from crude oil. The oil boom that followed was also driven by a new way of extracting oil by means of boreholes instead of by simply digging wells. Natural gas came into widespread use as a fuel only in the 20^{th} century.

Assessments by scientists have shown that the combustion of fossil fuels to produce energy substantially increases the greenhouse effect. For the sake of the climate, humanity must reduce its consumption of hydrocarbons and use more climate-friendly sources of energy.

Figure 3.1.6 Emission of greenhouse gases from the use of various hydrocarbon sources of energy

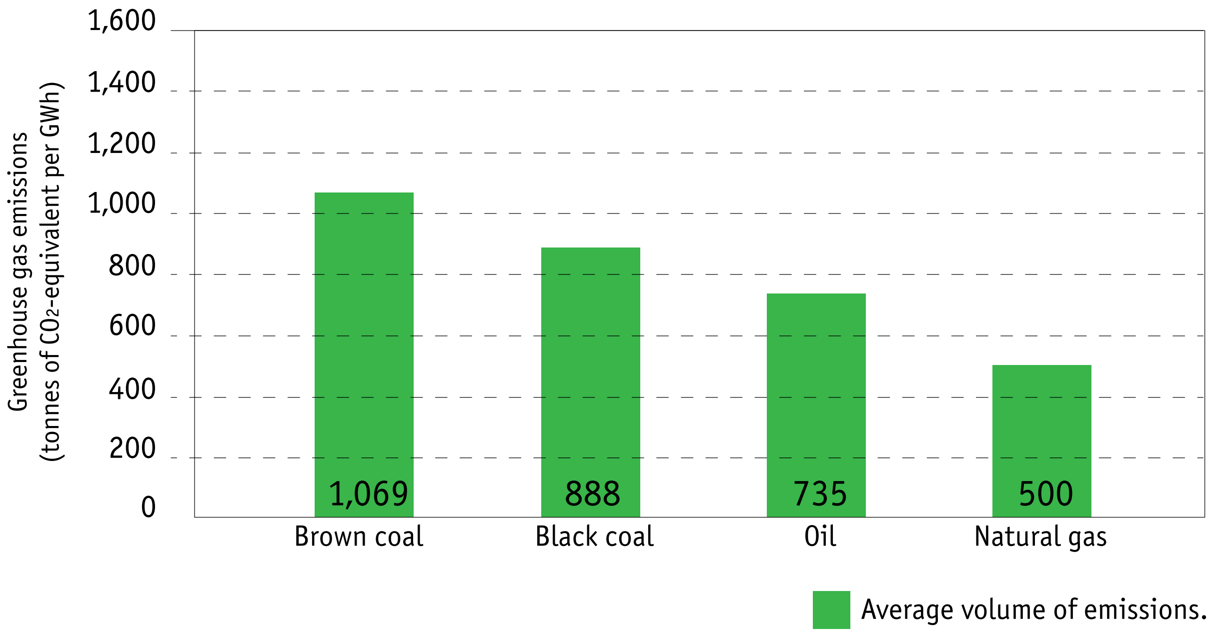


Table 3.1

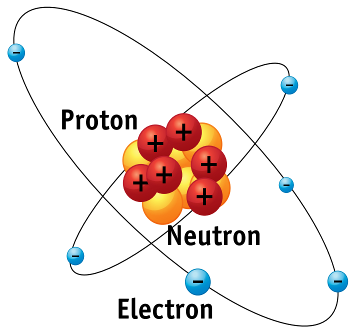
Average pollutant emissions into the atmosphere from power plants using various fossil fuels in the European Union (grammes/gigajoule)

Fossil fuel type	Dust	Carbon monoxide (CO)	Nitrous oxides (NO_x)	Sulphur dioxide (SO_2)
Brown coal	3,254	89	183	1,361
Black coal	1,203	89	292	765
Oil	16	16	195	1,350
Natural gas	0.1	15	93	1

3.1.4 Nuclear energy

Nuclear power plants produce almost zero greenhouse gas emissions. Could they be the answer to the climate change problem? Scientists have gone a long way before they made it possible to use nuclear power to produce electricity for industry and households. First, it was found that all substances consist of many similar particles, called molecules. Then it was discovered that the molecules themselves are constructed from a set of atoms. Different types of atoms were called 'chemical elements.' They were numbered and listed in Mendeleev's Periodic Table.

Under certain conditions the molecules of various substances can break down into their atoms and form the molecules of new substances in a process called a 'chemical reaction'. During a chemical reaction the energy holding the atoms together is released. The new compounds may require more energy or less, so that the chemical reaction may absorb energy from the space around it or may give off energy into space. The combustion of fossil fuel is a chemical reaction that produces heat.



But what would happen if changes occurred within the structure of the atom itself, rather than the molecule? Scientists have found that the atom also consists of particles: it has a nucleus, made of protons and neutrons welded tightly together, around which electrons revolve. The nuclei of some chemical elements can break up. This produces, first, a large amount of heat energy (which can be collected and used), and second, special particles that are called radiation. This phenomenon is called 'radioactive decay' or 'radioactivity'.

Radioactivity is part of the nature of our planet. On average, according to data from the International Atomic Energy Agency, the global annual amount of natural background radiation per individual is about 2.4 millisieverts (mSv) per year. Such low doses of radiation are harmless and even necessary for human beings and the whole natural environment. However, at higher doses radiation can be deadly.

In 1975, experts in the United States made the first attempt to calculate the probability of serious accidents at nuclear power plants. They found that such an accident could happen once every 10,000 years. And yet it was only four years before just such an accident occurred at the Three Mile Island nuclear power plant near the town of Harrisburg. The immediate damage from the accident was estimated at one billion dollars and the indirect damage at $100 billion, although only a few people were affected by radiation leakage. Seven years later, an accident occurred at a nuclear power station near the town of Chernobyl in the former Soviet Union, where nuclear scientists had also insisted that it could only happen once every 10,000 years.

Klaus Taube, the former head of the German company, Interatom, has said that any statistical estimates of the probability of an accident with meltdown of nuclear fuel elements must be considered as pseudo-scientific nonsense.

People have learnt to control nuclear reactions and use the energy they release. This process is the basic mechanism used by nuclear power plants. A nuclear power plant uses the complex process of radioactive nuclear decay as a source of energy. An enormous amount of energy can be derived from a small amount of nuclear fuel without the emission of any GHGs into the atmosphere. In terms of its impact on climate, nuclear power is very safe, although it should be remembered that the extraction of uranium for use in nuclear power plants consumes a lot of energy and emits a lot of greenhouse gases.

The major downside of nuclear power plants is that the new nuclei – called daughter nuclei – formed by the artificially organized, energy-producing decay, may also be radioactive. They are not useful as fuel but cannot be returned to the natural environment since they are dangerous. Scientists have been thinking carefully about different means of safely disposing this 'radioactive waste.' Pilot projects are under way for a new generation of nuclear power technology in which radioactive waste from existing nuclear power stations is used as input fuel with modern technologies based on fast neutron reactors with advanced fuel cycles. There is also ongoing and promising research on small modular nuclear reactors that could provide energy directly to cities. If these methods worked as perfectly as planned, it could indeed be said that nuclear power plants are completely harmless. However, the health and safety issues of nuclear plants remain a major concern. The dangers associated with the use of nuclear energy, which remain even after a nuclear plant is closed, have led to an ongoing debate about whether to develop nuclear power plants further or to prohibit them.

The explosion at the Chernobyl nuclear power plant on 26 April 1986 shocked the world. Many people were killed or seriously injured. About five million hectares of land (comparable in size with a country like Slovakia) became unusable for agriculture. A 30-km exclusion zone was created around the accident site and hundreds of small settlements had to be abandoned and destroyed.

Many years have now passed, and the designers of nuclear power plants now claim that the mistakes of the past will not be repeated with new and better equipment that has been invented.

However, in current conditions, when the climate is undergoing major changes, it is not possible to predict exceptional natural phenomena. During the construction of nuclear power plants in Japan, the frequent occurrence of earthquakes in that country was, of course, considered. Nevertheless, on 11 March 2011, a powerful earthquake and the resulting tsunami led to the failure of all systems for normal and emergency cooling of the reactor core at a Japanese nuclear power plant, and thermal explosions ensued. A large amount of radioactive material was released into the sea and the air, and the effect was felt in many countries. Three years later, the levels of radiation on the coastline where the Fukushima-1 nuclear power plant is located still exceeded normal levels by more than 100 times. As many as 80,000 people had to be moved from the area. Despite assurances from the Japanese authorities that the situation had stabilized, more radioactive substances entered the groundwater beneath the station two years after the accident and their concentrations grew, and there was further leakage from radioactive water tanks.

Nuclear energy is powerful energy, but it is also dangerous. The devastation it can cause if it runs out of control means that it is neither safe, nor cheap. Nevertheless, there is increased attention recently to nuclear energy because of the fast-growing demand for electricity and pressure to reduce carbon dioxide emissions from electricity production.

3.1.5 Renewable energy sources

As we have already seen, renewable energy sources use natural processes and resources that are either virtually inexhaustible or are relatively quickly and naturally restored. They include sunshine, wind, flowing water, tidal energy, and the heat of the earth. All these kinds of energy are often called 'alternative' or 'green' because, unlike hydrocarbon fuels, they do not damage the environment and climate. Biomass is also green energy, although it is a special case, for various reasons.

About 29% of world electricity production in 2022 came from renewable sources, up from 27% in 2019. Where renewable resources are available, it is now cheaper to build a plant using such resources than a plant using fossil fuels. In sub-Saharan Africa, for example, countries are meeting their diverse energy and climate change goals overwhelmingly from renewable energy, which is now 85% of the entire power generation. The massive expansion in the use of renewable energy makes it likely that CO_2 emissions will peak in 2025 and decline thereafter.

Experts have prepared various scenarios for the development of renewable energy in the future. In the most favourable scenario, the share of renewable energy in primary energy supply must grow from 16% in 2020 to 77% in 2050 to keep the rise in temperature below 1.5°C. Importantly, 80% of the necessary reduction in emissions to achieve this goal could come from tripling the capacity of renewable energy and doubling energy efficiency improvements.

Technology improvements, growing markets and climate policies have together helped to bring down the cost of renewable energy and its worldwide expansion. This was despite rising materials and equipment costs. China was the key driver of the global decline in costs of solar PV and onshore wind because of the size of its market.

Figure 3.1.7 Examples of a bioenergy plant and solar power station

Table 3.2 **Comparing costs of different renewable energy technologies**

	Total installed costs (2022 USD/kW)			Capacity factor (%)			Levelised cost of electricity (2022 USD/kWh)		
	2010	2022	Percent change	2010	2022	Percent change	2010	2022	Percent change
Bioenergy	2 904	2 162	-26%	72	72	1%	0.082	0.061	-25%
Geothermal	2 904	3 478	20%	87	85	-2%	0.053	0.056	6%
Hydropower	1 407	2 881	105%	44	46	4%	0.042	0.061	47%
Solar PV	5 124	876	-83%	14	17	23%	0.445	0.049	-89%
CSP	10 082	4 274	-58%	30	36	19%	0.380	0.118	-69%
Onshore wind	2 179	1 274	-42%	27	37	35%	0.107	0.033	-69%
Offshore wind	5 217	3 461	-34%	38	42	10%	0.197	0.081	-59%

Note on terms: total installed cost: cost of building of a power plant; capacity factor: overall time when the plant is in operation; levelized cost of electricity: the average cost of electricity generation for a generator over its lifetime; CSP: concentrated solar power; solar PV: solar photovoltaics.

The sun

The sun is the energy source provided by nature herself for the creation of life on Earth. So why not seek ways of using the sun's energy directly? The midday sun heats every square metre of the earth with a solar capacity of about one megawatt.

Any room with windows grows warm when the sun shines. If the sun is shining in from your window, but it is quite chilly inside the house, open your curtains and wipe any dust off the windowpane, and the sun will bring a little more heat into your room. In the old days, in European villages, people used wooden shutters on windows. In the daytime the window was opened to let in light and at night it was closed with shutters to keep the captured warmth inside the house.

With the advance of science, people have learnt better techniques to 'catch the sun'. There are two main ways of using the sun's energy.

Units of measurement of electric power

Watt is a unit of power. One watt is defined as one joule per second (1 J/s), representing the rate of energy transfer or conversion of one joule of energy per second.

- **1 watt (W):** the power of the transmitter in a standard mobile phone.
- **1 kilowatt (kW, 1,000 W):** the power of a small heater, approximately equal to the heating of one square metre of land by the sun at midday.
- **1 megawatt (MW 1,000 kW):** railway locomotives have average power between three and ten megawatts.
- **1 gigawatt (GW, 1,000 MW):** the unit to measure the power of the largest electricity generating plants in the world.
- **1 terawatt (TW, 1,000 GW):** the peak power of a lightning strike.

Solar collectors capture the heat of the sun. Water flows along tubes inside the collector and becomes warm (air or antifreeze is sometimes used instead of water). Such collectors can be used for heating buildings and to provide hot water.

Photovoltaic cells are another popular method to collect and store solar energy. Photovoltaic cells convert sunlight into electrical energy. We are all familiar with calculators that use photovoltaic cells and garden lanterns that collect energy during the day and provide light at night. Large solar energy power stations – so-called 'solar farms' – operate on the same principle.

Solar collectors are installed on the roofs of houses at an angle to the horizon equal to the latitude of the location where they are being used.

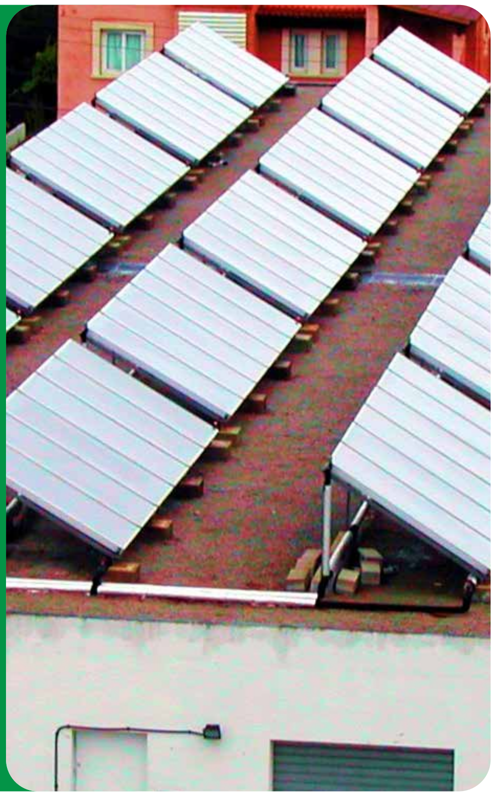
Photovoltaic cells can also be used to power various means of transport: boats, cars and even airplanes! In Italy and Japan, photovoltaic cells are installed on the roofs of trains to produce electricity for air conditioning, lighting, and alarm systems.

The main advantages of solar energy are that it is freely available, inexhaustible, and safe. Solar installations do not emit greenhouse gases or pollutants, so this method of obtaining energy does not harm the climate.

Solar energy: hot water plus electricity

Using the sun's heat to generate energy has long been a common practice in countries with hot climates. In warm countries you often see tanks of water on the roofs of houses, which are heated by sunlight to be used for everyday needs.

In Israel, every building has to be equipped with solar panels for water heating. The city of Freiburg in Germany is a showcase for the potential offered by solar power, which is used to meet the energy needs of entire neighbourhoods. Similar experiments are increasingly frequent all around the world.



The disadvantages of solar energy are its strong dependence on the weather and time of day, and high manufacturing costs due to the use of rare elements in solar panels. However, new technologies are fast reducing the cost of solar installations and broadening the areas of their application. Recent data show that the cost of renewable power has fallen by 80% since 2010, leading to the rapid use of solar for electricity generation worldwide. However, there are problems associated with the disposal of used solar cells, since they contain toxic substances. A market for the recycling of solar panels has not yet taken shape, and panels have useful lives of several decades. Another drawback is the large consumption of energy and clean water to produce solar panels. Engineers are working on new, more environmentally friendly solar cells, and producers need to develop systems for the disposal and recycling of used panels.

How big are the largest solar power plants in the world?
What about solar energy after sunset?

The largest solar power plant is the Talatan PV Power Station in China with a solar park that spans 609.6 km^2. Reflecting the sheer scale of the Talatan PV Power Station is its capacity – a gargantuan 9 GW, which contributes to an average annual power output of 9,600 GWh. But the Talatan PV Power Station isn't just one of the world's leading examples of how the future of renewable energy looks – it's a case study of how solar farms can transform the geographic and economic prospects of an area for the benefit of the people.

The second largest solar thermal power plant in the world as of 2022 is the Bhadla Solar Park, in the Jodhpur district of Rajasthan, India. The Bhadla Solar Park is a 2.25 GW solar photovoltaic power plant and the largest solar farm in the world, encompassing nearly 14,000 acres of land. Its construction cost an estimated $1.4 billion. What are some of its benefits? It helps to reduce India's dependence on imported fossil fuels. In rural areas, solar power provides a much healthier and safer source of indoor lighting than kerosene. Additionally, solar power plants like the Bhadla Solar Park drive economic growth and job creation in surrounding areas.

The Solana Generating Station is located 110 km south-east of the city of Phoenix in Arizona, USA. It can generate up to 280 MW of power from the rays of the sun and is one of the most powerful solar power plants in the world using parabolic mirror technology. But what makes the complex special is not its size, but its ability to continue generating electricity for six hours after the sun has gone down by means of special reservoirs that retain heat. This is a valuable feature, since the time after sun- set is the time of peak electricity consumption in the region.

Many experts view solar power as the energy of the future and as one of the main alternatives to traditional hydrocarbon energy sources. Governments in many countries support the development of solar energy, and private companies are investing much money in the construction of solar power plants. China is the global renewable energy leader, hosting nearly half of the world's total operating wind and solar capacity, followed by the US and India. Although not known as a sunny country, Germany is among the leading countries in the world in the development of solar energy. Other frontrunners are Spain, Sweden, Costa Rica, Iceland, Italy, France, Japan, Kenya, Morocco, New Zealand, Norway, Uruguay, and the UK. This list shows that solar power is becoming increasingly important for developed and developing countries and emerging economies. Importantly, solar power helps to provide distant villages in developing countries that are not connected to the grid with modern, yet cheap energy services.

Wind

Wind is another commonly used renewable energy source. The principle behind wind power is that mechanical energy (the energy of movement) can be converted into electrical energy. Miniature windmills and wind-driven toys are fun to play with, but if you build huge wind turbines and place them together in a windy area, the rotation of turbines can generate electricity for public use.

Windmills have been used since ancient times, but they became especially popular in medieval Europe. For a long time, windmills and water mills were the only machines known to mankind. Windmills were mainly used to grind corn into flour, to process timber or for irrigation. In the Netherlands, windmills pumped water from land that had been reclaimed from the sea so that the land could be used for agriculture.

Modern wind turbines use a principle analogous to that of windmills.

Wind turbines are usually located in coastal areas, where there is constant wind, and it has recently become possible to build such installations at sea as well as on land. So-called 'offshore wind farms' are now built 10–12 km or more from the coast. Wind turbine towers are set on pile foundations that are driven into the seabed to a depth of 30 metres. The latest technologies help the construction of wind turbines installed on floating platforms.

Two offshore wind projects off the east coast of England are now among the largest operating projects in the world. They include the 1.32 GW Hornsea 2 and the 1.2 GW Hornsea 1 which comprise the largest operating offshore wind farm in the world. Hornsea 2 is 462 km^2 and can power more than 1.3 million homes. Together, Hornsea 1 and 2 are capable of powering 2.5 million homes. The planned 2.8 GW Hornsea 3 project is expected to be in operation in the next few years. Another example is the Greater Changhua with a total capacity of 900 MW, making it the largest and first far-shore wind farm in Taiwan. This off-shore wind farm significantly supports Taiwan's fast-track build-out of renewable power and provides it with the much-needed green energy to achieve its net-zero goal.

A large wind farm may consist of several hundred turbines extending over a large territory (up to several hundred square kilometres). Wind farms are connected to a country's electricity grid and transmit electricity over long distances. Smaller wind farms or stand-alone wind turbines can be used to supply electricity in remote districts or to power small facilities.

In 2022, wind power provided more than 2100 TWh of electricity, which was over 7% of the world's electricity production, and more than all other non-traditional renewable energy sources combined. It is a rapidly growing source of power as new, more advanced technologies are invented, which allow wind energy to be used more efficiently.

The share of wind and solar is rising constantly (+1.5% in 2022), reaching 12.2% of the energy mix for electricity generation in 2022. Experts at the International Energy Agency predict that wind and solar power will grow even faster in the current decade and together could produce up to 18% of the world's electricity by 2026. Along with traditional hydropower, the share of wind and solar (also called variable renewables) will reach 37% by that year.

Wind energy already has an important role in some European countries. Denmark has been a global leader in solar and wind power production. In 2023, wind power accounted for over 57% of the country's electricity generation, compared to 1994, when coal accounted for 83% of electricity production.

Figure 3.1.7 Wind farms in Kansas, USA (above) and Austria (below)

Water

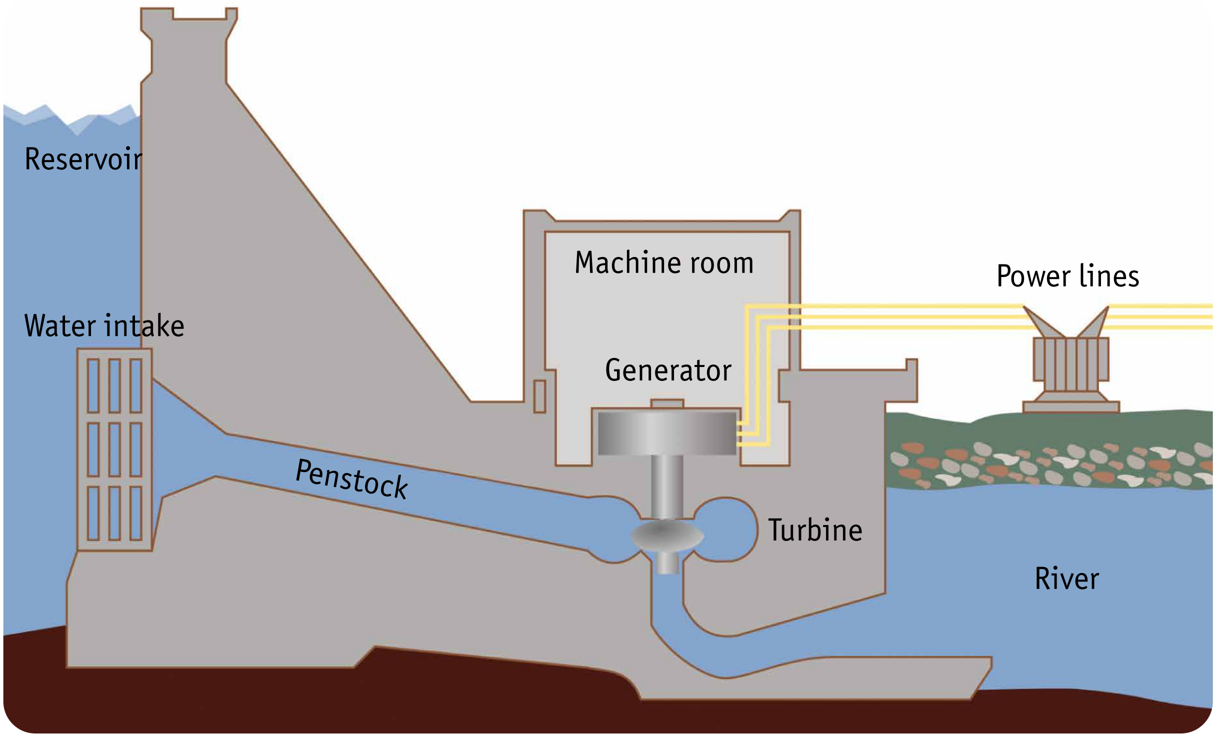
The energy of moving water can be harnessed in many ways.

The most common is **hydropower**: the flow of a river rotates a turbine, which produces electrical energy.

This sounds simple, but hydropower has its drawbacks. To create a powerful and efficient hydroelectric power plant, you must build a high dam so that all the river's power can be channelled to rotate the turbine blades. The construction of such a dam upsets the natural life of the river: it may alter the river's microclimate, destroying or harming the animals and plants that live there. This is why the construction of a hydroelectric power plant must be approached very carefully, paying due attention to environmental balance.

The maintenance of large dams also requires constant attention: if an accident causes the dam wall to burst, the water that is released will gush down the river valley, sweeping away everything in its path, and breaking the banks of the river for miles downstream. For example, the collapse of the Bantsao hydroelectric dam in 1975 in China killed more than 200,000 people unofficially (26,000 according to official sources).

Figure 3.1.8 Schema of a hydroelectric power plant and a dam



Small hydroelectric installations can operate without a dam (Fig. 3.1.9). They are built on small rivers or even on streams, and store energy in a battery. They have limited power but are adequate to meet the needs of a small farm or essential services at a wildlife reserve located by the river.

Hydropower is safer for the climate than traditional thermal power and costs only about half as much to produce. As a result, many countries are trying to maximize the potential of their rivers for energy production. In some countries hydroelectricity provides 90-100% of all electricity (Paraguay, Norway, Tajikistan, Uruguay, Uganda, Zambia, Namibia, Cameroon, and Brazil). China has a strong commitment to hydroelectric power: up to half of all the world's small hydropower plants have been built there as well as the biggest, the Three Gorges plant on the Yangtze River with capacity of 22.5 GW (Fig. 3.1.10). An even bigger plant, called Grand Inga, with capacity of 39 GW is planned on the Congo River in the Democratic Republic of the Congo in Africa. Brazil and Canada are also key producers of hydropower.

Figure 3.1.9

Small hydropower plant on the Kokra River in Slovenia

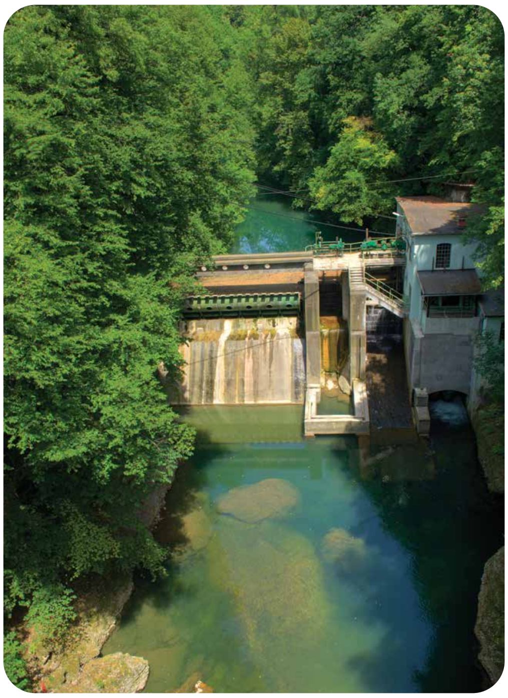


Figure 3.1.10

Three Gorges hydropower plant, China

Figure 3.1.11

Yacyreta Dam on the Parana River, Paraguay, Argentina

Wave power stations use the energy of waves in the ocean, which is essentially the energy of a float bobbing up and down on the sea. Thus, the churning power of the ocean, so dreaded by sailors in the past, can be made to serve us. The power of the waves is dozens of times greater than that of the wind if it can be harnessed.

Tidal power plants use the extraordinary phenomenon of tides. All planets, stars and other celestial bodies are linked by gravity and affect one another. Earth revolves around the Sun and around its own axis, the Moon revolves around Earth, and the positions of the Sun, Earth and Moon change all the time. This affects the ocean.

A dam is built at a point across a bay where tides are strong. Initially it prevents the rising water level from entering the bay, until the tide level is close to its maximum point. Then a valve is opened, and the ocean water rushes through with great force, turning a rotor. When the water level on both sides of the dam has equalized, the valve is closed again. When it is low tide and the ocean is in full retreat, the trapped water presses to leave the bay, and is allowed back out through the valve, turning the rotor once again.

Experiments using wave energy have been attempted since the end of the 18th century: the first patent for a mill driven by wave power was taken out in 1799. But a long time was to pass before this form of power could be used on a large scale. There are also tidal power stations that rely on gravitational forces, unlike wave power stations that rely on wind and waves.

The first large wave power station was opened in 2008 in the Agucadoura region of Portugal, five kilometres from the coast. The station has 2.25 MW capacity.

Another large wave power station with comparable capacity is the Sotenäs wave farm in Kungshamn, Sweden. The plant consists of 36 wave energy converters (WECs), with a total installed capacity of nearly three MW.

The Rance Tidal Power Station in Brittany, France is the oldest tidal installation in the world. Since 1967, it was also the largest tidal power station by installed capacity until the Sihwa Lake Tidal Power Station in the Republic of South Korea surpassed it in 2011. The Rance power station has 24 turbines that reach peak output at 240 MW and average 57 MW, a capacity factor of approximately 24%. At an annual output of approximately 500 GWh, it supplies 0.12% of the power in France. The cost of electricity production is estimated at €0.12/kWh. The difference in level between high and low tide in this part of France averages eight metres and can be as great as 12 metres.

Geothermal energy

Geothermal energy uses heat produced by the earth. It cannot strictly be called 'renewable,' but the stocks of heat in the depths of our planet are immense. Evidence of the heat contained in the earth is visible in areas of volcanic activity, where hot underground water sometimes rises through cracks in the earth's surface and occasionally bursts upwards in the form of jets of water and steam known as geysers.

A borehole can be drilled to hot underwater lakes and their water used for heating or electricity generation, and as a supply of hot water (if the chemical composition of the water is suitable). A key problem with hydrothermal energy is that used water must be returned to the ground, since it often contains chemicals that would be harmful if released into rivers and lakes. Another is that use of water from underground lakes leaves voids, which could lead to surface subsidence.

Another possibility is to pump ordinary water from the surface via a borehole into hot zones under the ground, where it is heated by a 'natural boiler' to boiling point and returns to the surface through an adjacent borehole in the form of steam. This is called petro-thermal energy. Petro thermal projects have been developed in the United States, Australia, Japan, Germany, and France.

The world's largest and most powerful geothermal field is located north of San Francisco in the USA. Called The Geysers, it consists of 22 geothermal power plants with a total installed capacity of 1,517 MW.

In the Philippines and Iceland, both countries with major active volcanoes, geothermal power plants provide about one quarter of all electricity consumption. New Zealand, Indonesia, Japan, and Italy also make extensive use of geothermal energy.

Figure 3.1.12

A pipe at a geothermal power station

Low-grade heat

Refrigerators rely on several principles for their proper functioning. The key principle is this: a liquid cooling agent (the refrigerant) absorbs heat from inside the refrigerator and a compressor then sucks and compresses the cooling agent under pressure, outside the refrigerator, so that (by the laws of physics) the absorbed heat is emitted into the air of the room where the refrigerator is kept.

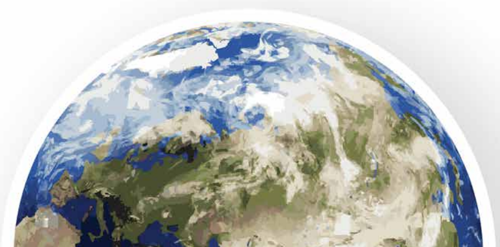
This is why if we touch the outside rear part of a refrigerator, we find that it is hot. It is also why a refrigerator should stand away from heating appliances and not be directly in the sun – because it is important that the heat it emits is quickly dissipated in the surrounding air and not retained in its external walls.

The point of a refrigerator is to retain cold and get rid of heat, but the same operation can also be carried out in reverse, so that heat is retained and cold discarded. A device which does this is called a heat pump.

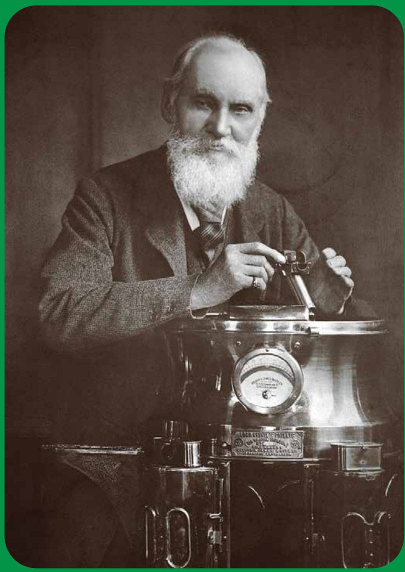
Heat pumps can absorb heat from weakly heated liquid, air or other substances. They can also ‘take up’ the heat of the earth at shallow depths. If in the winter you pass the warm air coming from your apartment or the used warm water draining out of the bath through a heat pump, a substantial part of the outgoing heat can be returned to your apartment. However, a heat pump cannot heat water to a very high temperature. The upper limit is usually no more than 50 or 60°C, which makes it a supplementary and not self-sufficient energy source to reduce fuel consumption for heating.

Nevertheless, scientists consider heat pumps a key technology in practically all future scenarios leading to zero emissions in 2050, as they not only use renewable energy but offer efficiency gains that are two to four times more than conventional heating systems. This is why the number of heat pumps installed is growing fast and by 2050 is expected to see a tenfold increase.

Just in Europe, heat pump sales have soared because of technology improvements and cost reduction. The rapid fall in production costs of PV systems also influences the heating market: using self-produced electricity in combination with a heat pump system provides buildings with a low-cost energy source.



The concept of heat pumps was developed in the 19th century by the British scientist, William Thomson (Lord Kelvin), and was further improved by Peter Ritter von Rittinger of Austria. But the most important practical application of heat pumps was only developed in the 20th century. An inventor, R. Weber, who was carrying out experiments with a freezer chamber, touched the hot pipe of the chamber and began to wonder how this heat could be used. He thought of using the hot pipe to heat water, but that produced too much hot water, so he instead made a pipe coil to warm the air in the house. Weber then found a way of pumping heat from the ground. Soon he was able to sell the old coal burner his family had relied on, as it was no longer needed!



The British physicist, William Thomson (Lord Kelvin).

Biomass

The living plants we see around us today use photosynthesis to accumulate energy from the sun in their bodies. A bonfire or the fire in a fireplace warms us because a tree that people cut down for firewood spent years capturing energy from the sun and gathering carbon dioxide from the air. Trees have worked for us storing up energy when they were alive, and they finally yield that energy to us when they burn in a fire.

It takes nature several hundred million years to create fossil fuels, so (at the rate we are using them) they are not being replaced. But biomass fuel can be easily replaced: if we cut down an old tree for fuel, we can plant a new one in its place, which will grow into a new tree in a few decades. Some plants and agricultural crops used to make fuel grow in one summer or even faster.

But let's think: many of us have been kept warm and had a nice time sitting around a campfire, or looking at the flames dancing in an outdoor stove in the summer, but how many trees have we planted to pay nature back for that wood? It is simple enough to cut down forests and use the wood. But how often do we plant new trees to make up for the ones cut down?

It is not just trees that can be used as fuel. Parts of plants generally considered to be waste – e.g., husks from cotton plants, straw from wheat, stones from fruit – are also good for fuel. Plants absorb about the same amount of carbon dioxide during their lives as they release when they are burnt. If they had died in the natural environment instead of being used for fuel, roughly the same amount of gas would have been given off gradually as was obtained from their combustion. Biomass is a relatively safe source of energy, but it is not always a good option: for example, it makes good sense to use the offcuts from woodworking as fuel, but if we cut down healthy trees for firewood, we are wasting valuable natural resources.

Biofuel is fuel obtained from vegetable or animal raw materials, from the waste products of organisms or from organic industrial waste, i.e., from biomass. Science has now made it possible to make liquid biofuels for internal combustion engines (bioethanol and biodiesel) as well as hard biofuels (firewood, briquettes, pellets, wood chips, straw, husks, and shells) and gas fuel (biogas).

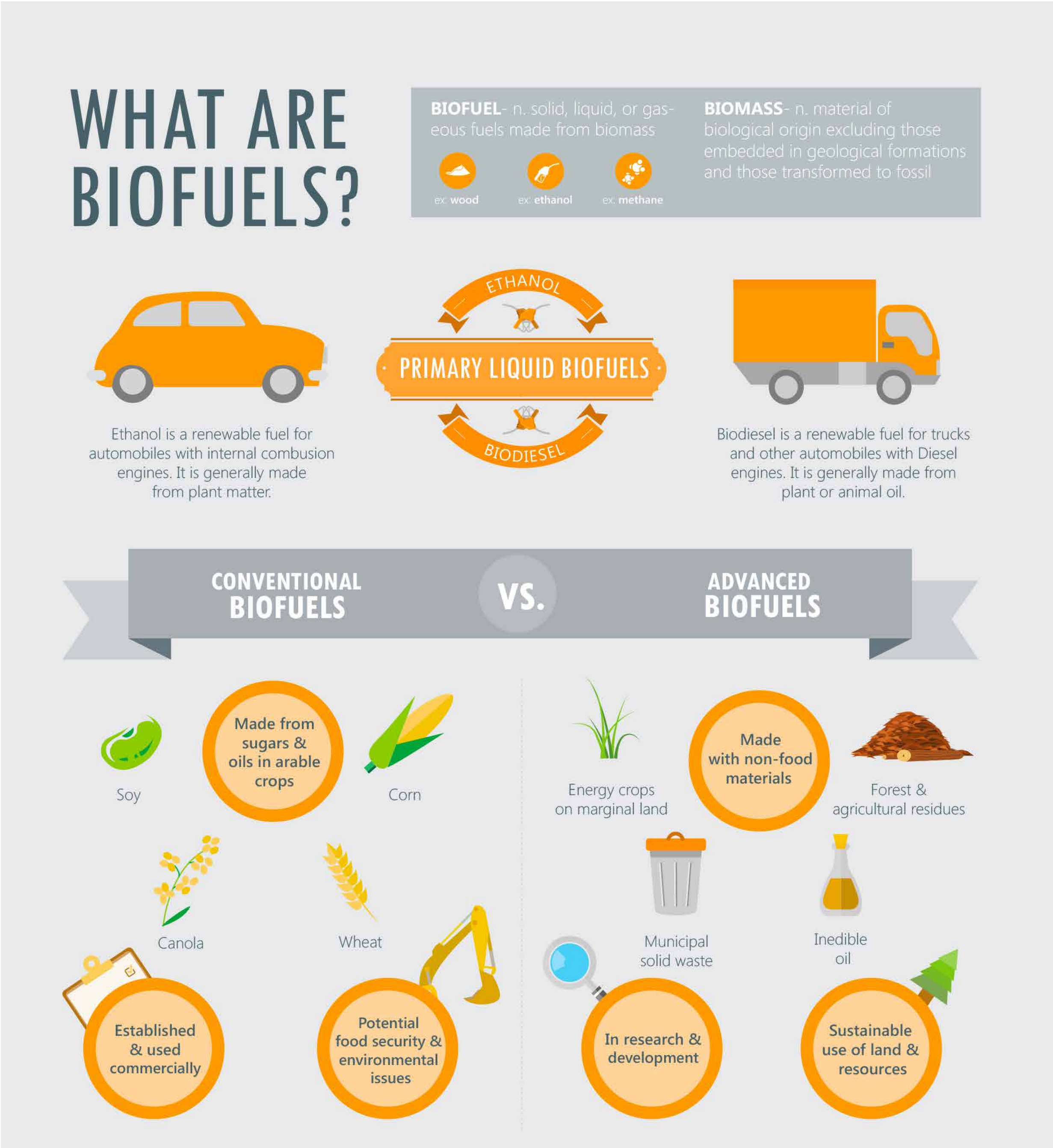
The easiest and most common way of producing energy from biomass is by burning it. But you can only make a bonfire with dry and resinous wood, and you must make sure that the bonfire is laid in a way that will let it burn. So, scientists are working to design more economical technologies, which will let us burn raw biomass that is damp or has mixed ingredients in a more efficient and environmentally friendly way.

Plant fibre can be burnt to obtain energy directly, or transformed into a universal fuel that is easier to transport and use in various existing machines and devices. Plants containing oil can be used to produce various liquid diesels (biodiesel). Plant products that contain sucrose and starch can be used to produce alcohol (ethanol), which is also used as fuel.

There are different types of biofuels. Ethanol and biodiesel are the primary fuels used by cars and trucks. There are also conventional biofuels produced from sugar and oils in arable crops, as well as advanced biofuels produced from products such as forest and agricultural residuals.

Concerns over the sustainability of production of biofuels and competition for land for food production is increasingly shifting attention to advanced biofuels. In addition to saving on CO_2, these fuels are also part of the so-called circular economy.

Figure 3.1.13 Types of biofuels



Brazil is among world leaders in the production and use of ethanol from sugarcane. The ethanol produced in the country meets 18% of its automotive fuel needs.

Figure 3.1.14

Bioethanol plant in Brazil

Figure 3.1.15

At a filling station in Brazil you can fill your car with biofuel.

Amazing sources of energy

Australia now has the world's first electric generating facility that uses nutshells as fuel. Its construction cost AU$3 million, but it should pay for itself quite quickly: the high-performance power plant can process up to 1,680 kg of nutshells per hour to produce 1.5 MW of electricity.

Indian scientists have come up with another alternative energy source, using bananas, other fruits and vegetables, and their inedible parts (peel, seeds). Four batteries powered by these fuels can operate a wall clock, an electronic game, or a pocket calculator. This energy is primarily for people in rural areas who have an abundance of their own fruit and vegetables to recharge the batteries.

In the not-too-distant future, people might be able to generate electricity from the movement of their own bodies. US researchers are developing special shoes with plastic inserts: when a person walks, their feet alternately press and release the inserts, causing them to shrink and expand. This movement can be used to generate up to three watts of electricity, enough to listen to the radio or to music as you walk, saving on batteries.

Fermentation is another way to use biomass.

Farm animals, which eat and digest plants, produce manure that can be used to generate energy. If manure and food waste are collected in a closed container which is then heated to 50–60°C, bacteria will break down the organic matter to produce methane gas, which can be collected and used as fuel.

Every year the world produces and uses or destroys about 170 billion tonnes of primary biomass.

3.1.6 The advantages and disadvantages of various energy sources

Now that we have learned about different sources of energy, we might ask which of them is the best? Which is the most environmentally friendly and which the least harmful for the climate? And which is the cheapest?

The answers to these questions are not as simple as might seem at first glance. We must consider a lot of factors when we compare different fuels.

Criteria for comparing energy sources

- Greenhouse gas emissions in their production and use.
- Emissions (during production and use) of harmful substances that are hazardous to human health and the environment.
- The cost of transporting fuel from the place it is produced to an electricity generating plant.
- The cost of distributing heat and electricity to consumers at a distance from where the heat and electricity is generated.
- The cost of building and operating a power plant and dismantling it at the end of its service life.
- Environmental and human costs (dealing with accidents, treating victims, compensating their families, and planting trees to offset greenhouse gas emissions).
- The climatic and geographical location of electricity generating plants. What source will they use for their water needs and how will the water be cleaned? What are the prevalent winds at the location and are there any critical weather or seismic conditions? Are there convenient transportation routes for the supply of raw materials? What natural habitats and landscapes and human settlements are in the vicinity?
- Purification equipment and recycling. Does the generating plant use up-to-date equipment? Is the system to prevent pollutant emissions up to standard, and has a sufficient area been set aside for the storage and recycling of waste? Perhaps there will be no serious problems with waste in the early years of the plant's functioning, but the question of what to do with them may arise at some point in the future.

It makes no sense to discuss the efficiency of technology and the cost of energy in isolation from issues of climate change, the environment and health. So, before deciding what kind of power stations need to be built and operated, a wide variety of assessments (technical, economic, environmental, etc.) must be carried out.

Let's recall and compare the advantages and disadvantages of the main natural sources of energy once again.

Coal

Coal is a universal fuel: it can be used in any climate, at large and small power plants and even to heat water in boilers.

Coal is the 'dirtiest' fuel for power generating. A coal-fired power plant with 1 MW capacity emits 36.5 billion m^3 of hot gases containing dust and harmful substances each year. It also produces a large amount of ash that mustbe stored. And, most importantly, the amount of CO_2 emissions from coal-fired power plants per unit of energy produced is the biggest in comparison with other hydrocarbon energy sources.
Coalmining is also a dangerous business. The release of natural gases underground can lead to explosions that are fatal for coal miners. The salty and dirty water pumped out of coal mines often finds its way into rivers and lakes (on average 3 tonnes of water has to be pumped out per tonne of coal produced), doing harm to plants and animals, and polluting local water and soil.

Oil

Oil is very easy to use, it can be transported over long distances through pipelines as well as in tanks. Oil is used to produce rubber, plastics, dyes, detergents and other products.

Oil reserves are being depleted and the costs of producing oil are on the increase. Oil is highly flammable, and spillages of oil are disastrous for the environment, since it covers all living things with a thin film that is highly destructive for ecosystems. Such a spill in a river or the sea can spread over great distances. The combustion of oil produces large amounts of CO_2.

Natural gas

Natural gas is the cleanest and most environmentally friendly hydrocarbon fuel. It is easy to transport.

Gas is explosive, even in relatively small quantities. Greenhouse gas emissions from the combustion of natural gas are less than from other hydrocarbon fuels, but are still significant. Also, gas reserves are not infinite, although the development of shale gas technology has added to them.

Nuclear power

☺ Nuclear power generation does not emit greenhouse gases. Stocks of nuclear fuel are quite large, since large amounts of energy can be obtained from a small amount of fuel.

☹ Nuclear energy must be produced at very large plants and can only be transported in the form of electricity (not heat), because the danger of radiation leaks makes it essential to position nuclear plants far from any big city, where consumers of hot water and heat are concentrated. Nuclear power plants produce waste, which remains hazardous for many centuries and must therefore be disposed of in a special way. Although it produces zero greenhouse gas emissions, nuclear generation does produce spent, radioactive water. The main disadvantage of nuclear energy is that even minor accidents can have disastrous consequences.

The sun

☺ Solar energy is renewable. It can be used in many places around the world. It produces no harmful pollutants or greenhouse gases.

☹ Solar energy flows are uneven, and additional batteries are needed to convert the energy flow at night or in cloudy weather. Solar cells remain expensive, although scientists are looking for ways to reduce the cost of their production. There are problems associated with the disposal of spent solar cells, since they contain harmful substances, and solar power plants take up large areas of land.

Wind

☺ Wind power is renewable and produces no emissions of greenhouse gases and harmful pollutants.

☹ Wind plants need constant strong wind. Additional batteries and transformers are required for a wind farm to be able to function during light wind. The rotation of the blades creates vibrations and noise that can frighten animals and create an annoyance to people, who may also object to the sight of giant windmills, which transform the landscape. A system is also needed to scare away birds, which could otherwise fall into the spinning blades.

Water

☺ Hydropower, tidal power and wave power, are renewable, freely available and create no emissions of greenhouse gases and pollutants.

☹ Waterpower can only be produced where there are water bodies. The construction of large hydropower plants requires flooding of the land around the reservoir, which is a very difficult and expensive process. The construction of hydroelectric plants adversely affects river and coastal ecosystems. Accidents at hydropower plants can lead to flooding of towns and villages downstream.

The heat of the earth and low-grade heat energy

☺ The energy that comes from inside the earth is renewable and available everywhere. It emits no greenhouse gases or pollutants.

☹ The process of extracting energy from deep underground sources remains expensive and complicated at present. Long-term use of geothermal reservoirs (pumping of water and steam) leads to ground subsidence. Such heat can only serve as an auxiliary source of energy.

Biomass

☺ Biomass is freely available and easy to use. Its emissions of CO_2 into the atmosphere are no greater than the emissions that would be generated by the natural decomposition of plants. The use of biomass in the areas where it is created (agriculture and logging areas) solves the problem of waste disposal. Biomass fuels are, essentially, a way of extracting energy from garbage. Manure can be used to obtain both gas fuel and fertilizer.

☹ Raw biomass is difficult and expensive to transport. The production of gas fuel from biomass requires maintenance of fermentation temperature, and care to avoid explosions and the escape of bacteria to become a source of disease. Also, the gas has an unpleasant smell!
Some enterprising producers of agricultural products now want to use their fields to produce biomass, instead of traditional food crops as it brings more income. This reduces food production, threatening food security.

If renewable energy is inexhaustible and environmentally friendly, why not change over completely from coal, oil, gas, and nuclear power to green technologies?

The fact is that there are still limitations to the mass development of renewable energy. The operation of power plants using renewable energy sources depends on climate conditions, which is why they are called variable sources of energy (wind strength, the presence of rivers, the number of sunny days). Renewable energy-generating plants usually have their own site-specific design. So, the successful use of renewable sources requires a high investment of effort and money at the time of their design and construction. When the capacity of renewable generation plants reaches a certain level, further expansion requires large investment in the electricity network and gradual transition to the so-called ‘smart grids’. Nevertheless, new technologies are steadily making energy production from renewable sources more efficient and driving down the production cost and expanding the market.

Energy is always in demand, so the energy industry, particularly the production and trade in oil, gas, and coal, is very profitable. The huge amounts of money in this industry result in frequent and serious disagreements between government, business, and environmental civil society organizations. This is a global problem. But in the long term, people are moving towards an understanding of the urgent changes needed for the future of humanity and of the planet. The introduction of new, climate-friendly technologies is delayed by the inertia of human thinking. Our planet and the universe are ready to give us their energy, but in return we must learn to use our natural resources in a way that helps the climate and does not destroy it for the sake of short-term benefits.

QUESTIONS

1. What sources of energy were used in ancient times?

2. What ways do you know of using solar panels?

3. List all the factors that must be taken into account if we are to determine the total cost of generating electricity from one or other source of energy.

4. Electric engines do not produce harmful emissions. So can we consider them to be the most environmentally friendly type of engine?

5. Flat solar cells are installed on the roofs of houses at an angle to the horizon equal to the latitude of the place where they are installed. Why do you think that is?

6. What are the main barriers to the fast growth of renewable energy capacity?

TASKS

1

Experiment
Purpose of the experiment: to build a light using renewable energy.

Materials: a transparent plastic bottle with water in it, a small table, blankets.

The experiment. Make an opening in a blanket where a bottle can be placed. Cover the table with blankets so that no light penetrates the little 'house' you have created under the table. What do you think will happen when you enter the 'little house' and place the bottle in the opening you have made on the cover? What did you notice? How do you explain the phenomenon you observed? Suggest an alternative to the water bottle as a handy tool. What are your ideas for lighting the little house you made?

What do you think will happen when you enter the 'little house' and place the bottle in the opening you have made on the cover?

2

Divide into groups by different ways of producing electricity.

Each group should prepare a report to defend its way of producing energy, including information about problems associated with all the other ways. Then prepare and hold a discussion about the benefits and harm caused by different types of power-generating plants, making it relevant to the area where you live.

3.2 Energy efficiency and energy saving

The first way to mitigate climate change is to use energy sources that least damage the environment and the climate, as discussed in the previous section.

The second way is to reduce our overall energy consumption. In this chapter we will look at two similar, but different concepts: energy efficiency and energy saving.

A device is energy efficient if it uses less energy than other similar devices to do the job it was designed for. For example, two lamps may give an equal amount of light in your room but may consume different amounts of electricity. The lamp that consumes less energy will be more energy efficient. We can save a lot of energy by turning off lights when they are not needed, keeping windows, light, and lamps clean, and installing bulbs that are more energy efficient. Instead of taking a car, we can walk and use bicycles, where possible.

Figure 3.2.1 Comparison of the energy efficiency of different lamp bulbs

Traditional incandescent bulb | Fluorescent bulb (contains mercury; special disposal required) | Light-emitting diode (LED)

ENERGY EFFICIENCY
is the ratio between the amount of energy consumed and the useful result that is obtained from its consumption, such as lighting or energy for cooking. In recognition of the importance of energy efficiency, it is sometimes called 'the first fuel.'

ENERGY SAVING
are all measures taken to reduce the amount of energy consumed.

So, most of the time, there is no need to invent anything to save energy. We simply need to change our habits, so that we stop wasting it.

Electricity for lighting accounts for 15-20% of global power consumption. In the EU, lighting represents around 10% of electricity consumption in residential buildings and is the third consumer after electricity for heating and cold appliances. In office buildings, lighting can use even more energy – 30–40%. But it is possible to reduce the energy used for lighting in both commercial and residential buildings without making rooms darker, while significantly cutting electricity bills by choosing appropriate light bulbs based on light emitting diodes (Fig. 3.2.1).

For example, we all brush our teeth in the morning. Do we need to leave the tap running while we do? No, we only need the tap on when we rinse our mouth. But watch yourself and your family: do they all clean their teeth with the tap off? A lot of energy is used to make water come out of our taps, from operations at the water treatment plant to the pumping system, not to mention the water itself.

When you turn off the TV (and some other electronic devices), you leave it on standby. What a lot of people don't know is that the TV goes on using energy when it is on standby, though not so much as when it is working, and that pushes up the family's electricity bill by a few cents every month. It may not seem worth bothering about, but think how much energy is being wasted, if you count in terms of a whole neighbourhood, a whole city, or a whole country! So, in countries where energy saving is taken seriously, people are advised not to leave appliances on standby, but to switch them off.

Charging a mobile phone emits about 0.3 kg of CO_2 a year. If a mobile phone charger is plugged in all the time (without being used), 2.4 kg of CO_2 are emitted.

CO_2 emissions from the use of mobile phones

- Two minutes' use per day produces 47 kg of CO_2 per year
- One hour's use per day produces 1,250 kg per year
- One minute's use produces about 57 g
- One text message produces 0.014 g
- One Google search produces 0.2 g (total annual emissions from the use of Google are 1.3 million tonnes)

The demand for digital services is growing rapidly. The IEA estimated that since 2010, the number of internet users worldwide has more than doubled, while global internet traffic has expanded 25 times. Rapid improvements in energy efficiency have, however, helped moderate growth in energy demand from data centres and data transmission networks, each of which accounts for 1–1.5% of global electricity use. Overall, the IT industry is responsible for about 2–2.8% of global carbon dioxide emissions, with some scientists putting the figure at around 3.8%, including emissions from the use of personal computers.

You may have heard of 'green hosting', a kind of internet hosting service that uses green technologies to reduce negative impacts on the climate and the environment. Green hosting works by compensating for the carbon dioxide emissions caused by its hosting service. It does this by using renewable energy sources (solar, wind, water, geothermal), planting trees and other plants, and through other actions that save energy. Some experts point to cloud technologies as a promising form of green hosting. Cloud technologies that became widespread enable much more efficient use of computing power, mainly by reducing power consumption.

Human invention makes new progress every day. But only a small part of it is used. Before new technology can replace an old one, people must change their habits.

Cloud technologies

It is not only the real world that is changing, but also the virtual world. Internet users have recently been given a new tool, called 'cloud computing', which is already used by Facebook, Twitter, and the 'engines' that drive services such as Google Docs, Gmail, and the like.

Most websites and server applications run on specific computers or servers. The cloud is a network of computers, constituting a system that lets people use certain applications or store data. You could call it a global, virtual computer where applications run independently of each individual computer with its specific configuration.

As broadband Internet develops, it becomes less and less important to have an application installed on your computer. Because all 'clouds' are configured to work together, the total power of these computers is available to the applications as if the application was running on just one individual computer. An increasing share of today's software is based on web technologies, and 'clouds' are just lifting the advantages of web applications to a new level.

Changing habits means first finding the time to get acquainted with the invention.

Second, you need to spend money and effort to replace the old machine with a new one and teach people how to use it. This effort and money will pay off, but not straightaway, and not everyone wants to go to this trouble for future gain.

Third, people who earn money by selling the old technology do not want to lose their business, particularly if it brought in more money than the new technology. They might even do whatever they can to obstruct the invention, preventing it being widely used, persuading people that it is harmful, or even threatening the inventor.

A summary of all energy-efficient technologies would require a thick volume. Whatever you do in the future, it will be important to have a good knowledge of the equipment you use, and to support efforts to make it better. And you should remember that the way forward is not always by making machines more efficient – a lot also depends on how people's work is organized.

Energy efficiency and energy saving are very important. For families they mean savings on gas and electricity bills. For electricity companies, they mean reduction of fuel costs and supplying consumers with cheaper electricity. For the country, they mean spending less on resources, and making industry more productive and competitive. For the climate, they mean a reduction of greenhouse gas emissions into the atmosphere.

Reducing electricity consumption in different countries will lead to different amounts of saved emissions as it depends on the mix of fuels used for electricity generation. The ratio of CO_2 emissions per kW hour produced or saved is known as the grid emission factor. Countries with a hydro-based power system, such as Bhutan, have a zero-grid emission factor. UNFCCC provides a harmonized set of grid emission factors for more than 200 countries (see https://unfccc.int/documents/198197).

For example, each person in Russia consumes about two kWh each day on average. An economical citizen manages with one kWh, while a more wasteful energy user might be consuming three kWh per day. Fig. 3.2.2. shows how the average Russian in an apartment uses energy for various purposes over a year. On average, the generation of one kWh of power results in 800g of CO_2 emissions. Emissions from power generation in the European part of Russia are twice lower, because a large part of energy needs in that part of the country are met by power plants using natural gas, hydroelectric and nuclear-powered generation, while coal is hardly ever used. CO_2 emissions from natural gas combustion are much less than from coal combustion, and newer combined heat and power plants emit less CO_2 than older plants.

In Russia's northern and far eastern regions, where coal is much used for power generation and fuel must be carried over large distances, reducing electricity use by one kWh yields a reduction of emissions of about three kilogrammes of CO_2. So, the annual CO_2 savings of three people who change from being 'average' to being 'economical' consumers would be three tonnes.

Figure 3.2.2 **Potential energy savings in residential buildings**

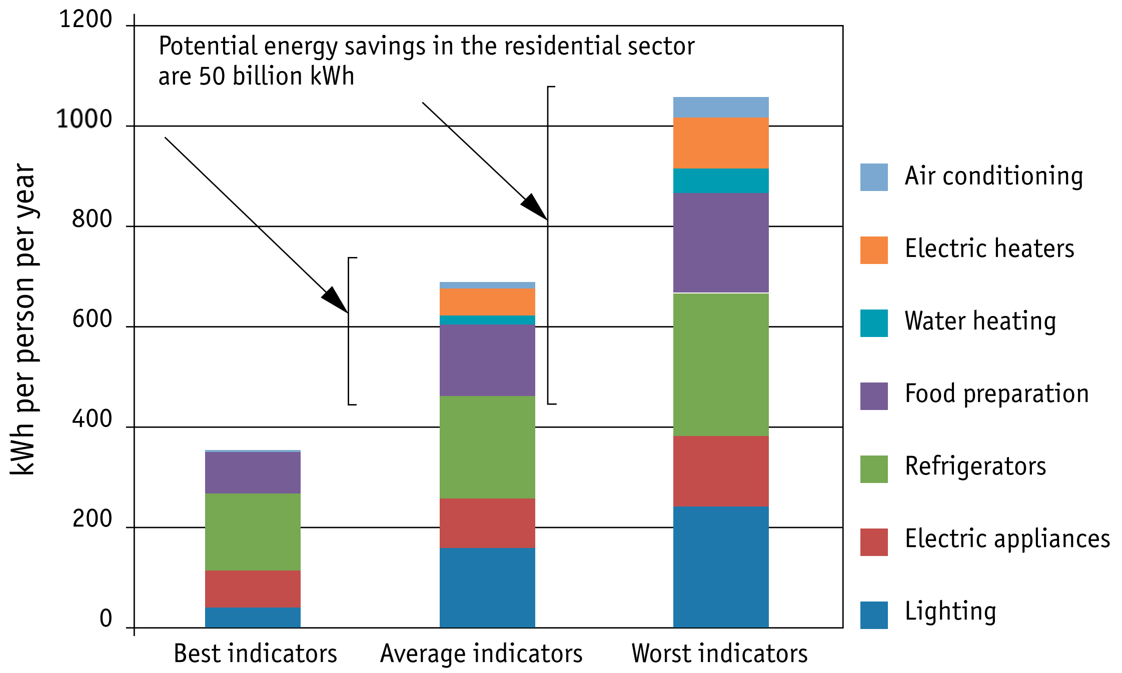


Figure 3.2.3

Coal-fired thermal power plant

Figure 3.2.4

Natural gas-fired thermal power plant

Figure 3.2.5

Nuclear power plant

3.2.1 Environmentally friendly transport

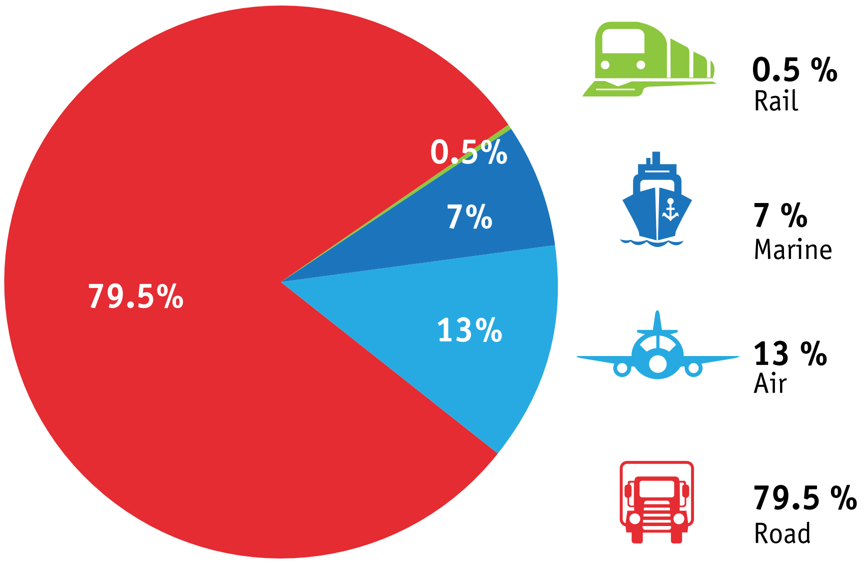
From cars to aircraft, transport uses as much fossil fuels as electricity-generating plants. Of course, the fuel needs of a single car are negligible in comparison with the enormous needs of a power plant. But the number of cars is many times greater than the number of power plants. In total, transport accounts for about 14% of global greenhouse gas emissions.

Most cars still run on petrol. Burning one litre of petrol produces approximately 2.3 kg of CO_2. For example, the average Canadian vehicle, which burns 2,000 litres of petrol every year, releases about 4,600 kg of CO_2 into the atmosphere. The internal combustion engine, which powers motor vehicles, releases exhaust gases into the atmosphere, containing nitrogen, water vapour, and CO_2 (between 1–12% of the emissions volume), as well as toxic and even carcinogenic compounds (soot and benzopyrene).

Overall, CO_2 emissions per tonne of gasoline, from the extraction of crude oil from an oil well to combustion of the refined gasoline in an engine, total 3,769 kg.

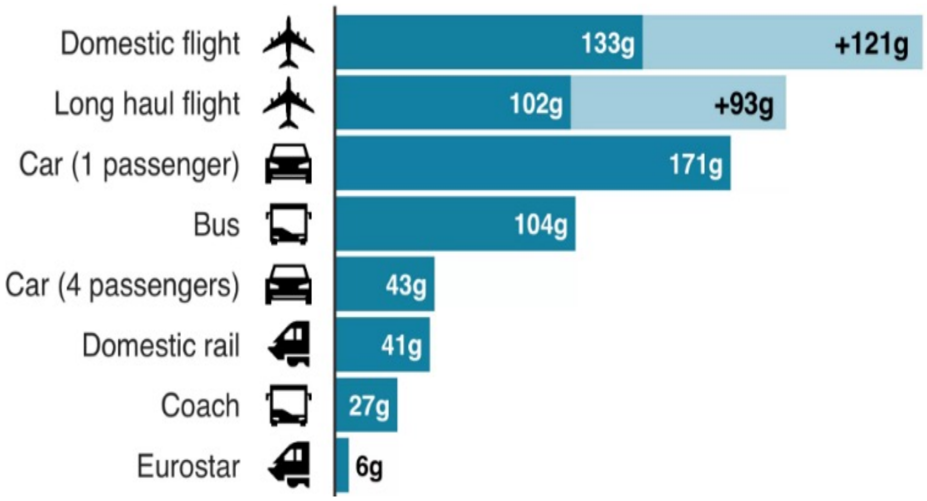
The impact of transport on climate change is huge, as most forms of transport use fossil fuels, the combustion of which releases CO_2 into the atmosphere. However, different types of transport have different impacts. Railways are the most environmentally friendly, while air flights are considered the most carbon intensive. Overall, cars are responsible for more than 80% of greenhouse gas emissions from transport (Fig. 3.2.6).

Figure 3.2.6 Breakdown of GHG emissions by different modes of transport



The UK estimated the emissions per passenger per kilometre travelled in different modes of transport. It shows that taking a flight leads to more than 20 times more emissions than taking the train, Eurostar (Fig. 3.2.7).

Figure 3.2.7 UK estimates of GHG emissions (gCO_2e) from different modes of transport per passenger per km travelled



What can be done to reduce the impact of transport on the climate?

An obvious and highly effective method is to connect with people far away by telephone or video/audio communication instead of travelling to them. The most popular ways are various applications, such as Skype, Zoom, Viber, Telegram, and WhatsApp, which let you communicate with friends anywhere in the world where there is Internet.

The best way to reduce climate impacts from transport is using public transport. If you and your parents can choose how you travel, choose a train. Trains are a more environmentally friendly way to travel long distances than airplanes.

Railway transport technologies have made significant advances in the last decade. Locomotives and rolling stock are built from materials that are less heavy and bulky, and engines have become more efficient.

The number of high-speed trains and networks are growing worldwide, further improving the most energy-efficient mode of transport. The high-speed rail (HSR) network in China is the world's longest and most extensively used – with a total length of 42,000 kilometres by the end of 2022. HSR is also an increasingly popular and efficient means of transport in Europe. Several countries have built extensive high-speed networks, e.g., Germany, France, the Netherlands, Spain, Italy and the UK, and there are now several cross-border high-speed rail links. Railway operators frequently run international services, and tracks are continuously being built and upgraded to international standards on the emerging European high-speed rail network.

Japan's high-speed rail, called **Shinkansen** (Fig. 3.2.8), has recently increased its speed, and cut back its energy consumption by 40%. By reducing the bullet train's weight and redesigning the shape and length of the nose to be more aerodynamic, the trains are now far more efficient and their use results in less emissions from transportation.

Figure 3.2.8

Energy-efficient 'Shinkansen' high-speed train in Japan

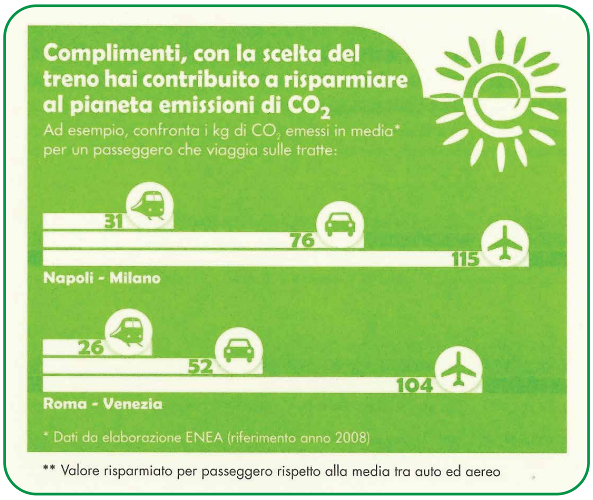


Figure 3.2.9

The back of this train ticket in Italy informs passengers of their contribution to combating climate change by choosing train travel

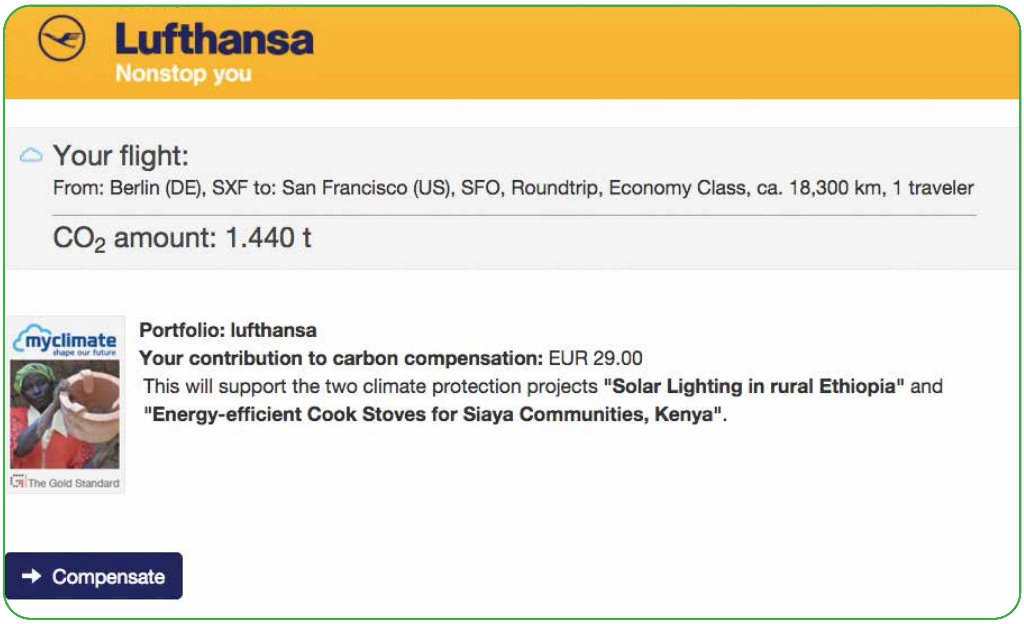
Many railway companies take the trouble to remind their passengers of the fact that rail travel is environmentally friendly (Fig. 3.2.9).

If you fly somewhere by plane, then choose airlines that use up-to-date aircraft: modern aircraft do less damage to the environment than older ones.

Speed is no longer the only, or even the main consideration in designing new models of aircraft. Designers today use a more holistic approach that takes account of the aircraft's fuel efficiency as well as its carbon footprint during manufacture. Developers are looking again at turboprop aircraft, which seemed a thing of the past 20 years ago, as jet aircraft are faster. With improved design, turboprop aircraft could offer good air transport solutions.

Several airlines nowadays offer services to compensate CO_2 emissions by their aircraft; there are Internet services that calculate CO_2 emissions by all flights and invite passengers to compensate them. For example, a long-distance flight from Berlin to San Francisco by Lufthansa produces 1.4 tonnes of CO_2 emissions per passenger. The suggested contribution for carbon compensation with a round trip in economy class is EUR29, which is used to help finance environmental projects related to climate change (Fig. 3.2.10).

Figure 3.2.10 **Calculation of CO_2 emissions and appropriate compensation for a Berlin–San Francisco return flight in economy class with Lufthansa**



The International Civil Aviation Organization is working with its members to find the best ways to reduce emissions from the aviation sector. Along with efficiency improvements, one option is the use of Sustainable Aviation Fuel (SAF) – fuel that does not come from fossil fuels. Airlines already use it, usually blended with regular jet fuel. But many doubt whether SAF can be produced cheaply enough, or in large enough quantities, to meet the needs of the airline industry.

This is why there is growing interest in hydrogen as a fuel for aircraft. Hydrogen can store a lot of energy, e.g., from renewable electricity outside the peak hours of consumption and, when used as fuel, does not produce any CO_2.

Reducing carbon emissions from car trips

If your parents are planning to buy a car, tell them about the energy efficiency of different motor vehicles. Suggest that they buy a car that at least meets Euro-4 standards (the Euro standards for vehicles regulate the content of hydrocarbons, nitrogen oxides, carbon monoxide and particulate matter in vehicle exhaust fumes).

The impact of cars on the environment can also be reduced by following 'eco-driving' rules, which reduce the carbon footprint from vehicle transport. Eco-driving does not just make sense for the environment – it is also cost-effective for car owners. Explain that to adults who drive cars!

The efficiency and environmental performance of vehicle engines is crucial. Until recently nearly all motor vehicles ran on fuel oil, diesel, or petrol, but now an increasing number of vehicles are running on gas. Fuel consumption using gas is much the same as with traditional motor fuels, but pollutant emissions from gas are much less.

You have probably also heard of 'hybrid' cars, electric cars and cars that run on bio- fuel. There are even exotic vehicles that can operate on nothing but water and air movement to make them go ('wind-mobiles'), as well as solar-powered electric cars. A solar car racing championship held regularly in Switzerland is the best place to see all the latest solar-powered vehicle technologies in action. They are no longer a rarity: there are now solar filling stations in the USA, Bulgaria, Switzerland, Germany, and other countries.

Figure 3.2.11

Parking for electric vehicles

Eco-driving rules: how to reduce a vehicle's carbon footprint

- Turn off the engine at stops and in stationary traffic jams.
- Look after your car properly: correct adjustment of the wheels reduces fuel consumption by 5-10%, and regular maintenance saves up to 10% of fuel.
- Check tyre pressure regularly: even in urban environments, tyre pressure 25% below the recommended level requires 10% more fuel to make the car move.
- Use climate control and air conditioning sparingly. Do not use them if the outside temperature makes them unnecessary. Don't open the car windows if the climate control is operating.
- Brake smoothly to use the car's inertia to best effect, reducing fuel use.
- Carry passengers. This is called 'carpooling'. If you give a lift to three or four people going the same way, you reduce emissions by three to four times.
- Stay in the same lane: weaving from lane to lane increases fuel consumption and therefore CO_2 emissions.
- Start out early, avoid travelling at peak travel times, and plan your route in advance.
- Drive at a moderate and steady speed. Use the brake pedal less and use the car's momentum more, brake and accelerate smoothly, watch the road ahead (don't accelerate if there is a red light in sight). Smooth driving saves fuel.
- Do not carry excess loads on the roof. At speeds of 120 km/h an empty luggage carrier on the roof increases fuel consumption by 5–10%, a ski-carrier adds 10–20%, a bicycle 30%, and carrying a case full of luggage uses 35–40% more fuel.

Figure 3.2.12 **An electric car**

All leading car manufacturers today are designing cars that are more environmentally friendly compared to the previous models. Fuel consumption and environmental impacts have become as important to buyers as quality, safety, and price. Companies are competing with one another to save energy and reduce negative impacts on the environment.

Even though electric vehicles (EVs) have been in use since the beginning of the car industry in late 1900s and early 2000s, it was not until Tesla's arrival in 2003 that the battery-electric revolution began in earnest. This provided a viable alternative in the efforts to decarbonize road transport and propelled EVs from 0.2% of new car sales a decade ago to 13% in 2022. Sales tripled between 2018 and 2022 and are expected to grow by around 30% annually in the next decade, making up half of all car sales by 2035. By 2025, EV sales are expected to reach almost 40% in Europe and China.

Greenhouse gas emissions in a city can be reduced by encouraging people to use public transport instead of cars. But that is possible only if public transport is fast and convenient, serves all parts of the city, links the centre with the suburbs, and is a more reliable and cheaper alternative to private cars. The use of gas, hybrid and electric engines in public transport can greatly reduce greenhouse gas emissions and improve air quality in cities.

Carpool: sharing journeys by car

Carpooling means carrying other people (including strangers) in your car, usually on regular (daily) journeys.

It is a good way of reducing pressure on the transport system in cities.

Carpooling dates from the 1940s when the Government of the USA was trying to save fuel for World War II needs by requiring car owners to carry passengers on any journey. The policy was successful in reducing fuel use, but its impact was limited because most car owners at the time were well-off and unwilling to share their cars with strangers.

In the 1970s, the city of Los Angeles introduced separate lanes on roads for use by car poolers. Nowadays they exist all over North America and in Europe as well (they are marked by road signs and a white rhombus on the road surface). Carpooling reduces the number of cars on the roads, reduces the demand for parking places and cuts down greenhouse gas emissions. The gains for passengers are evident: they spend less on fuel, vehicle repairs and parking.

Figure 3.2.13

Special carpool lanes on roads in the USA

Bicycles: the most environmentally friendly transport

Bicycles are the most environmentally friendly and healthy form of transport. Scientists have calculated that a person who travels to school or work every day by bicycle instead of using a car saves a tonne of greenhouse gas emissions every year.

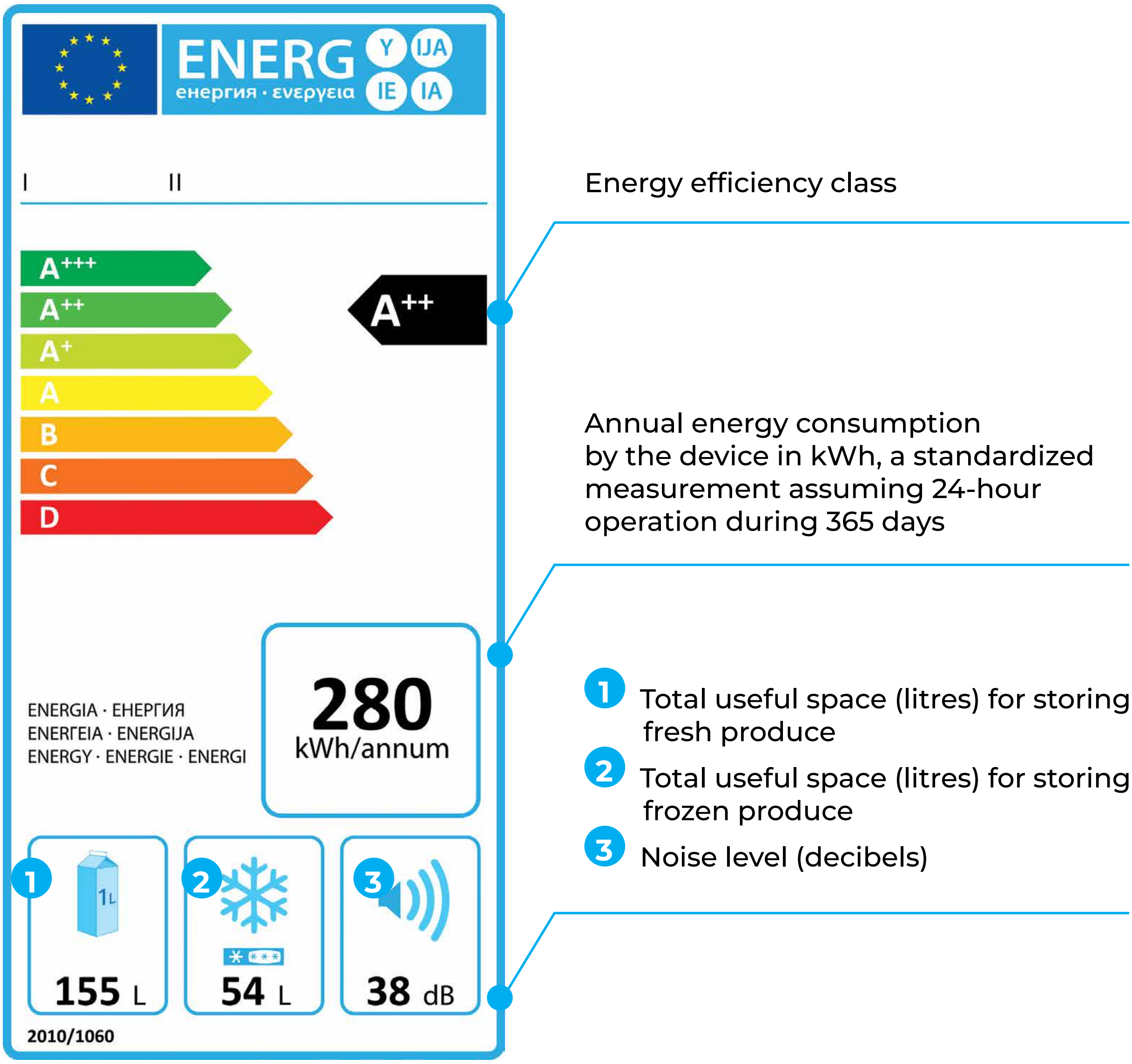
Bicycles are the preferred means of transport in the Netherlands, Denmark, Norway, Sweden, and Germany. In Copenhagen, one in three people commute to work by bicycle. In Amsterdam, 40% of people use a bicycle every day, and the total length of bicycle lanes in the city is 400 km.

3.2.2 Household appliances and electrical devices

Many countries have a special system for standards and labelling of household appliances by their energy efficiency. The European energy label is obligatory for certain electrical household appliances and light bulbs sold in the EU since 1995 (Fig. 3.2.14).

The label is intended to let consumers compare the energy efficiency and some other features of similar products made by one or several manufacturers. The most energy-efficient products are those in energy efficiency classes ‘A’ or ‘A +’, ‘A++’ and ‘A+++’.

Figure 3.2.14 **New energy efficiency labelling for refrigerators sold in the European Union**



Energy Star is a programme for energy efficiency certification developed by the US Environmental Protection Agency in 1992 for computer monitors with low power consumption. Monitors that meet certain energy efficiency criteria have the right to bear the Energy Star label and as many as 98% of all computers today do so. Use of the label has been extended to 65 other types of goods, from appliances to buildings, which are now assessed using the Energy Star system (more than 1.4 million buildings and over 20,000 factories in the USA today are Energy Star-certified).

Figure 3.2.15

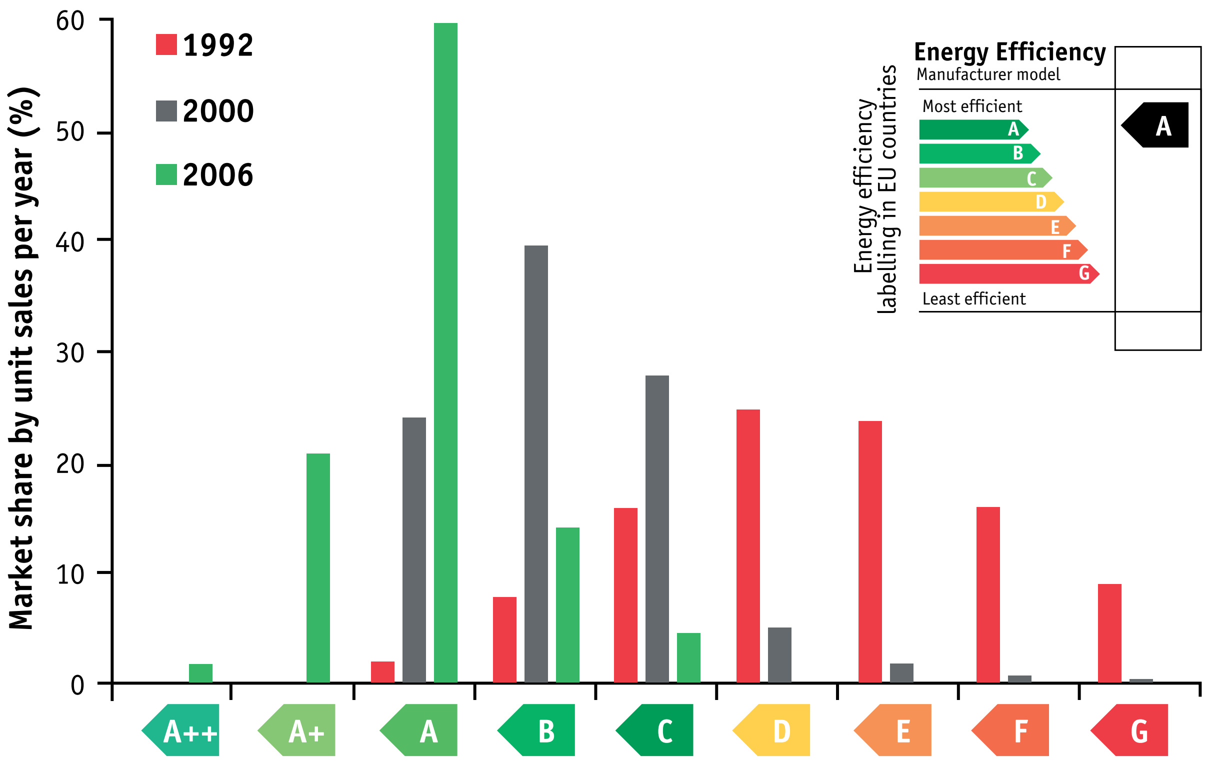
The US Energy Star label

Energy Star is one of the key programmes that the USA reported in its 2022 Climate Ambition Report (eighth national communication under the UNFCCC), which outlines advances in its climate policies under the Paris Agreement. It stated that since 1992, Energy Star and its partners have helped American families and businesses save five trillion kWh of electricity, save more than $500 billion in energy costs, and achieve four billion tons of CO_2-equivalent greenhouse gas reductions. In 2020 alone, savings resulted in emissions reductions of more than 400 million tons of CO_2-equivalent greenhouse gases, roughly equivalent to more than 5% of total greenhouse gas emissions in the country.

More and more countries are recognizing the benefits of energy efficiency standards and labelling programmes to effectively reduce energy bills, drive product innovation, create jobs and reduce the cost of CO_2 emissions. Such programmes for appliances and equipment now operate in more than 120 countries around the world and are the cornerstone of most national energy efficiency and climate change mitigation programmes. Such programmes have been operating the longest in the USA and the EU where, by IEA estimates, they have delivered annual reductions of around 15% of total current electricity consumption.

An energy efficiency label doesn't just tell the consumer about the energy efficiency of a device, but also about what it can do. After all, the main task of a washing machine is to wash and rinse clothes, and its ability to save energy is secondary, though important. In recent years consumers have been increasingly keen to choose devices and technologies that not only do their job well, but also use less energy and resources and thereby save the consumer money (Fig. 3.2.16).

Figure 3.2.16 **Impact of energy-efficiency labelling and minimum energy-efficiency standards on the EU market for refrigerators and freezers**



The impact of an electrical appliance on human health is at least as important as its energy consumption. We must remember that health hazards from new inventions might only be detected after some time. The discovery of such problems doesn't mean that new technology cannot be used: a design improvement might be enough to set the problem right. But we must approach new technologies carefully: without prejudice, but with caution.

For example, a new device that has recently gained popularity is the induction cooker, which is very easy to use and very economical in its consumption of energy, since it only heats the bottom of the pan and not the whole space around it. However, the impact of eddy-current magnetic fields on human beings has not yet been properly studied.

3.2.3 Green construction: passive and active buildings

People have different lifestyles – not every family has a car or a complete set of home appliances. But everyone needs a roof over their heads. So, the idea of building an energy-efficient home has always been of interest. Peasant huts in Europe and the tents of nomadic peoples were built using special know-how, even if was not always given scientific explanation. A masonry heater, which was traditionally used in houses in Eastern, Northern Europe and North Asia, was a fine example of energy efficiency (Fig. 3.2.17). The thick walls retained heat and the chimney with its different sections extracted heat from the smoke before it left the building.

Figure 3.2.17

The traditional masonry heater, a fine example of energy efficiency

More recently, in 1974, a sharp jump in oil prices made it much more expensive to provide buildings with energy and heat, inspiring architects and engineers to take a new look at building design. Houses started using new environmentally friendly technologies and alternative energy sources. Special demonstration buildings were built to show what could be achieved, and governments in some countries actively encouraged such projects.

The World Green Building Council was formally established in 2002 to facilitate the global transformation of the building industry towards sustainability. The council brings together more than 30,000 property and construction companies from 80 countries. Its members are constantly seeking new ways to reduce the resources needed at all stages of the life of a building: during its construction and use, when it is repaired and when it is finally dismantled. Green construction strives to reduce greenhouse gas emissions and water pollution, minimize waste, and protect nearby natural habitats. Such buildings are somewhat more expensive to build, but the extra investment pays for itself in five to 10 years.

Energy-saving buildings are called 'passive' or 'active', depending on their efficiency. A passive building may not need any heating or may consume just a tenth of the energy that an ordinary building does. But an active building not only requires very little energy, but produces energy – perhaps even surplus energy to feed into the central electricity grid. You may have heard of the expression, 'smart building.' What this means is that the building in question automatically analyses its energy consumption and carries out automatic control of various energy-using systems in the building.

Figure 3.2.18

Several low-energy buildings have been constructed in the Viikki district of Helsinki, the capital of Finland. Panels that store energy from the sun have been built into the facades

Passive buildings

One of the main objectives of a passive building in northern countries with colder climate is to reduce heat loss. Ideally, a passive house is heated solely by the heat given off by its occupants and by the appliances used there. If additional heating is needed, preference is given to renewable energy sources.

Bricks made from recycled materials are often used for the construction of such a house.

It is not only the building's walls that require thermal insulation, but also its floors, ceilings, attic, basement, and even the foundations. It is important to ensure that the design does not permit so-called 'cold bridges': apparently minor details and connecting points in the construction that can drain heat from a generally well-insulated building. These techniques can reduce heat loss from a building by almost 20 times!

Environmental certificates for buildings

Environmental certification standards for buildings have become widespread in recent years. The best-known and most used systems in the world are BREEAM (UK), LEED (USA) and DGNB (Germany).

The BREEAM environmental certification system, developed in 1990, has certified more than 200,000 buildings worldwide. The criteria for certification are the quality of building management, the health and well-being of its residents, energy efficiency, transport, water, materials, waste, use of the land plot where the building stands, and the pollution that it generates.

The LEED environmental certification system was devised in 1998 with the following criteria: sustainable site development, water consumption efficiency, energy efficiency, air protection, materials and resources, internal environment quality, and innovations. Buildings can qualify for four levels of certification: Certified, Silver, Gold, and Platinum, depending on the criteria they meet.

The DGNB system of environmental certification, introduced in 2009, uses an integrated planning concept to assess ecology, economy, sociocultural and functional aspects, as well as a building's location.

The first LEED Platinum building in the Middle East

Originally constructed in 1995, the head office of the Dubai Chamber of Commerce and Industry is a shining example of how an existing high-rise building that consumes a lot of energy and water can be transformed into a healthy, green skyscraper.

Between 1998 and 2013, energy and water consumption per person in the building was reduced by 63% and 92% respectively, saving almost $5.8 million through low and no-cost initiatives. After the renovation, the building earned the Energy Star label and the LEED Platinum certification.

In a passive house, careful design of windows is highly important: double-glazed window units are hermetically sealed, panes of glass are covered with a special film that admits light and warmth from outside but reflects them back when they attempt to pass outwards. The biggest windows face the direction from which sunlight mainly comes.

The system of heating, air conditioning and ventilation uses resources more efficiently than in conventional buildings. For example, in winter, air leaving the building is ducted alongside air that is entering it, in a special heat exchanger, so that the warm air transfers its heat to the cold air. In the summer, hot air from outdoors is ducted underground where is cooled. Similar principles are used to take heat from used water.

Of course, even such carefully designed buildings sometimes need additional heating or cooling, but much less energy is required to provide it. Such advanced design has inherent problems: the air duct must be carefully monitored as accumulations of dust, use of artificial materials, or a conduction fault can affect air quality. It is also important to ensure that furniture in such buildings does not release any harmful substances into the air.

Solar cells and (if appropriate) small wind turbines are installed on the roof. The most economical lighting system (LED) is used, and it may even be possible to light the building by means of sunlight alone.

Added together, these and various other devices produce savings.

There is rising construction of passive energy-saving houses. Estimates suggest that in 2022, there were more than 120,000 passive house buildings around the world, including office buildings, shops, schools, and kindergartens (mostly in Europe). Begun as a concept implemented only in Germany or regions with similar climate conditions, it has now been adopted worldwide, with clearly defined applicability criteria for different climates.

Under cold climate conditions, the design process typically is focused on minimizing heat losses and optimizing solar gains. In milder climates, moderate insulation, including windows with improved performance, is sufficient, though building performance during summer requires more careful consideration. For hotter climates, the insulation requirements increase, and solar loads through windows, walls and roofs must be limited. In hot and humid climates, humidity loads need to be minimized. Examples of passive houses in climates as varied as Canada, the USA, Germany, China, Greece, Spain, Taiwan, Mexico, and the United Arab Emirates illustrate the range of possible solutions.

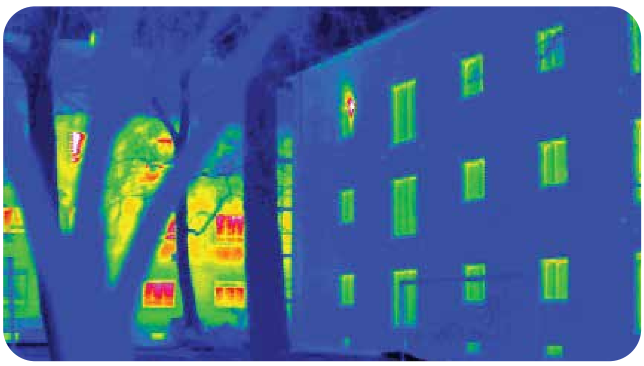


Figure 3.2.19

An infrared picture shows how effective the heat insulation of a passive house (right) can be in comparison with a conventional house (left)

Energy-efficient residence of the British prime minister

10–12 Downing Street is famous in London as the residence of the British prime minister.

The 300-year-old building has been undergoing a phased modernization and refurbishment programme to become more energy efficient. Environmentally friendly initiatives introduced have included the following:

- controlled lighting using motion detection and low energy lamps
- waste heat recovery from IT equipment to heat water
- thermal insulation
- low water-use fittings
- rain water harvesting for garden irrigation
- building management system with utility monitoring
- timber sourced from legal and sustainable sources
- more than 90% of construction waste recycled.

These renovations have earned 10 Downing Street a 'Very Good' BREEAM rating.

Climate-friendly school in the United States

The Sidwell Friends School in Bethesda, Maryland, and Washington, D.C has succeeded in reducing its energy consumption by 60% and water consumption by 90%.

Vegetables grown by students on the building's roof using rainwater are served in school lunches. Water that is good enough to drink is only used for drinking.

The school is in a part of the USA that is often very hot, so the school building has its own system of cooling towers, which lower the temperature of warm air from outside before it reaches the interior. Air conditioning is only needed in the classrooms on exceptionally hot days.

Optical systems have been installed that regulate the flow of sunlight, channelling it to darker rooms in the building. Windows on the sunny side of the building have special shades to protect the interior from overheating.

Active buildings

The active building incorporates some of the same concepts of the passive, such as insulation, or optimal solar exposure of the windows. But it also promotes renewable energy systems, such as solar water heaters and/or geothermal heat pumps. The world's first active energy-saving building was built in Denmark (which has an Internet portal for active buildings: www.activehouse.info). A draft EU directive from 2023 that regulates energy performance of buildings calls for all new buildings to be emissions-neutral as of 2030, with the aim of having emissions-neutral building stock by 2050. That means that such buildings need to have features of both passive and active buildings.

Active house in Denmark

'Home for Life' in Denmark is an example of CO_2-neutral active house. It produces nine kWh/m^2 energy per year – more than it consumes. A solar heat pump and 7 m^2 solar collectors generate energy for heating and hot water, while 50 m^2 solar cells generate electricity. Floor-to-ceiling windows cover 40% of the facade – twice the area of a traditional house – and help to illuminate and heat the rooms from the sunlight. All rooms are equipped with sensors that register heat, CO_2 levels and humidity, and an intelligent control system makes sure that the house adjusts to the family's need for a healthy, comfortable indoor climate. Automatic window opening mechanisms let in fresh air, while sensors turn off lights when you leave the room.

Optical systems have been installed that regulate the flow of sunlight, channelling it to darker rooms in the building. Windows on the sunny side of the building have special shades to protect the interior from overheating.

3.2.4 Green cities

There are many examples of the use of energy-efficient technologies in buildings around the world and, more recently, people have started implementing larger projects at the city level. One ambitious objective is the creation of environmentally friendly cities. Imagine a whole city designed in harmony with the environment, whose inhabitants only consume resources they really need, and do everything they can to protect the natural world. All the energy in the city is produced using renewable energy sources. Waste is recycled and reused. People in such a city fully understand the importance of caring for the planet and for one another, and therefore live in peace and harmony.

More and more of the world's population wants these dreams to come true, so the design of green cities is being given ever greater thought. Such cities have clean air and clean water. Waste and wastewater are recycled and re-used. Rooftops are used for gardens or solar panels and have tanks to collect rainwater. Active- and passive-house technologies are used in the construction of residential, public, and commercial buildings.

It is impossible to make all cities environmentally friendly straight away, but these dreams are becoming a reality little by little all over the world.

SamsØ, Denmark

The inhabitants of the Danish Island of SamsØ are self-sufficient in energy from renewable sources and even sell some of the energy they generate. This result took 10 years and investments of $80 million, but the money has already been repaid from electricity sales. The islanders built 10 wind turbines on land and 11 at sea, which produce 28 gigawatt-hours of energy each year in total.

Heating on the island comes from renewable biomass: straw, sawdust and other plant waste is burned in boiler plants.

The island has an area of 114 km^2, stretching about 50 km from north to south and with a breadth of more than 20 km at its widest part. There are 4,000 inhabitants, most of them engaged in agriculture. The largest settlement, Tranebjerg, has a population of only 800 people, but proudly calls itself a town.

Masdar City, United Arab Emirates

Masdar City ('masdar' is Arabic for 'source') is a new eco-city in the United Arab Emirates (UAE). It is in the Emirate of Abu Dhabi, 17 km from the capital and close to the international airport.

The Government of Abu Dhabi put forth the idea of building a green city in the desert and launched it in 2006 with a budget of $22 billion. The new city when completed is expected to have a population of 45,000-50,000 and about 60,000 more will commute to work every day. Most companies and industrial plants in Masdar will specialize in the development and production of environmentally friendly technologies and products. Vehicular transport is not permitted in Masdar City: residents will move around on foot, by bicycle, by public transport or using new, computer-controlled taxis. A high wall is being built around the city to protect it from the hot desert wind, and its streets will have abundant shade.

Masdar City is designed to be a hub for clean technology companies. The Masdar Institute of Science and Technology has been operating in the city since September 2010. The city also hosts the headquarters of the International Renewable Energy Agency.

The experience of Masdar City illustrates how living sustainably has its difficulties and challenges. From electric scooters, autonomous green vehicles to future tech, the city not only showcases its solutions to make living sustainably easier, but also smart choices that lead to a better world.

Treasure Island, San Francisco, California, USA

Treasure Island is an artificial island created in California in 1939 as the site of an airport. These plans were changed with the outbreak of World War II, and the island was instead used as a military base, which remained there until 1996. Now Treasure Island is being used as a testing site for a highly sustainable urban community that will draw more than 50% of its energy from renewable sources such as rooftop solar panels and windmills. Citizens will be able to buy fruits and vegetables from an organic farm on the island, all cars will be eco-friendly, and buildings will be energy efficient. Buildings on the island are certified under the LEED energy efficiency standard.

Sherford, England

Sherford in England is a new eco-friendly town to be designed in traditional English style. The project was launched in 2015 and has the support of King Charles III. All its buildings will be made from environmentally friendly materials, produced in England, no more than 80 km from the construction site. This will reduce the carbon footprint from construction work by avoiding transport of materials over long distances, emitting greenhouse gases from the combustion of vehicle fuels.

Sherford will follow traditional urbanization to make the town carbon-neutral by constructing energy-efficient buildings and laying out the town so that people live close to a main street. This makes it easy to travel on foot and on bicycles easily and quickly, so that residents will have no need for motor transport in some parts of the town. Space on rooftops will also be used for solar panels and for growing plants. About a fourth of the houses will be 'low cost' due to the high discrepancy between house prices and wages in the area.

The City of Vancouver, Canada

The City of Vancouver in Canada is known as one of the most environmentally friendly cities in North America. The city has adopted an ambitious plan to become the greenest city in the world. Developed by city authorities in collaboration with local people, the plan includes such measures as a shift toward 100% renewable energy power by 2050, a zero-waste programme, expanding walking and cycling networks, developing green buildings and public transportation, expanding green areas, as well as increasing farmers markets and community gardens. The city administration has established a two million Canadian dollar Greenest City Fund in collaboration with The Vancouver Foundation to support community-led projects to green the city. When all these measures are fully implemented, the City of Vancouver aims to reduce community based GHG emissions by 80% below 2007 levels by 2050.

QUESTIONS

1 What time of day is the peak of electricity consumption?

2 Do you think that hot countries need to worry about saving energy?

3 How does a city need to be designed if it wants to be a 'green' city?

4 Where do you think your home loses most of its heat in winter and coolness in summer? How could this be avoided?

5 What is the difference between 'passive', 'active' and 'smart' buildings?

TASKS

1

Ask your parents to let you see the electricity bills for your house or apartment for the past year, write down how many kilowatt-hours were used, and build a graph.

Find out how much electricity is used by your main household appliances: refrigerator, washing machine, vacuum cleaner, TV, lights, etc. You can do this by: 1) finding the power of each device in the technical information that came with it; 2) calculating roughly how many hours a day the device operates; 3) multiplying that time by the number of days in a month; 4) multiplying the power of the device by the time it operates.

Draw a second graph on the same piece of paper, summarizing total power consumption by your domestic appliances. Analyse the graph, see which appliances use more power and think why that is. Together with your parents, think what you can do to reduce energy consumption.

2

Draw a large map of an environmentally friendly city where you would want to live. What will it be called? Where in the world will it be?

How will its streets be laid out? Will motor vehicles be allowed to drive around the city? What companies and industries will it have (if any)?

Where will the residential district be located and why will it be located there? Draw what your own home in this city will look like. What sort of a building will it be and what will it be made of? Write an essay about this.

3

Find out about the environmental initiatives in various cities around the world from the 'Sustainable Cities' page in Wikipedia and other online resources. Find detailed information about the status of any ecological city and give a report about this city in school.

3.3 Carbon footprint and how I can help the planet by reducing my footprint

3.3.1 Carbon footprint

Any human activity that uses energy has an impact on the climate.

We drive cars, travel to other cities and countries by aircraft, use the TV and computer, cook food, and put food in the refrigerator. We cut down forests to make paper and furniture. We switch on the heating in winter and air-conditioning in summer, and we use electric lights in our homes all year-round. By doing all these things, we each leave our own personal carbon footprint in the world.

The **carbon footprint** of a city or country is the total amount of all greenhouse gases that all individuals and organizations within the city or country produce by the things they do, events they take part in and products they consume directly or indirectly.

Figure 3.3.1 Examples of greenhouse gas emission sources

Environmentally responsible behaviour means thinking about how you can reduce greenhouse gas emissions and your own carbon footprint.

It is common practice to translate all GHG emissions into CO_2 equivalent for ease of understanding and calculation. This amount is shown as units of CO_2 equivalent.

Carbon footprint

- E-mail-message – 4 g
- The same message with a large attachment – 50 g
- A plastic bag from a shop – 10 g
- A 0.5-litre bottle of water (local production) – 110 g
- An average bottle – 160 g
- An ice cream – 500 g
- A pair of jeans – 6 kg

Direct emissions are the amounts of carbon dioxide generated from the use of fossil fuels – for example, the amount of greenhouse gases emitted during operation of a factory or a vehicle engine.

Indirect emissions are the amounts of CO_2 released into the atmosphere when energy is produced and transported to make the products you buy and the services you need. This is the part of the carbon footprint we can influence: we can think twice and not buy disposable cups, think twice and walk instead of going by car, think twice and not use the washing machine at half load.

Calculating the size of our carbon footprint (especially indirect emissions) is difficult, because we must consider many different factors and find a lot of information. In addition, the carbon footprint of a product will always be the same for the producer, but it will be different for different consumers because transport and other costs of delivering the product to the consumer must be considered.

For example, the carbon footprint of an apple from the garden, eaten under the tree where it grew, is 0 g of CO_2. If you buy apples grown in your region in season (i.e., in the summer and early autumn), the carbon footprint of an apple is 10g of CO_2. The carbon footprint of an imported apple (for example, one brought from Italy) will be 150 g of CO_2.

Environmentally responsible firms can offset their carbon footprint by investing in climate projects, by planting trees or obtaining certificates from reputable carbon-offsetting companies.

Products or services with low or zero CO_2 emissions, or whose emissions have been offset, can receive low-carbon or carbon-neutral labeling to demonstrate their climate-friendliness. Such labeling influences the choice of consumers in favor of this particular product or service.

Examples of carbon-neutral labels:

3.3.2 How can I help the planet? Reducing your carbon footprint

Greenhouse gases influence the planet's climate, and emissions of greenhouse gases depend on our habits. Let's see how we can reduce our carbon footprint and help the planet.

Indoor air temperature and comfortable temperatures

In countries with colder climates almost all buildings need heating and heat insulation. Most heating systems in old buildings were built at a time when prices for heat energy were low and energy efficiency was not a priority. In many cities thermal energy is generated by burning gas or coal, which causes greenhouse gas emissions that affect the climate.

Alternative ways of producing heat energy include solar collectors and heat pumps, but these technologies remain expensive and are not easy to apply for an old multistorey apartment building.

The easiest solution is to improve heat insulation. Heat loss depends on two factors: the difference in temperature between indoors and outdoors and the heat-insulating properties of walls, ceilings, windows and floors. Buildings lose a significant part of their heat through the ventilation system. Heat loss can also occur due to latent defects, design errors, poor quality of construction, and due to ageing of the building and of thermal insulation materials. It is possible to see how well walls, ceilings and windows retain heat, and to detect where leakage of heat is occurring by means of thermal imaging, carried out by a special visual recording device that shows the temperature distribution on any surface, such as the wall of a house. The temperature distribution is shown on the display (and recorded in the memory) of the device camera as a colour field, where a certain temperature corresponds to a certain colour. Alongside the image there is always a scale showing the correspondence between colours in the picture and specific temperature ranges.

The greatest heat loss in any prefabricated building occurs at the joints between the panels of the outer wall. The only remedy (short of demolition) is full-scale repair of the facade using the latest heat-retaining plasters. The quality of window installation can be decisive for levels of heat loss, even in new and renovated buildings.

Figure 3.3.2

A five-storey apartment building from the 1960s 'glows' where heat floods out at the joints between prefabricated panels

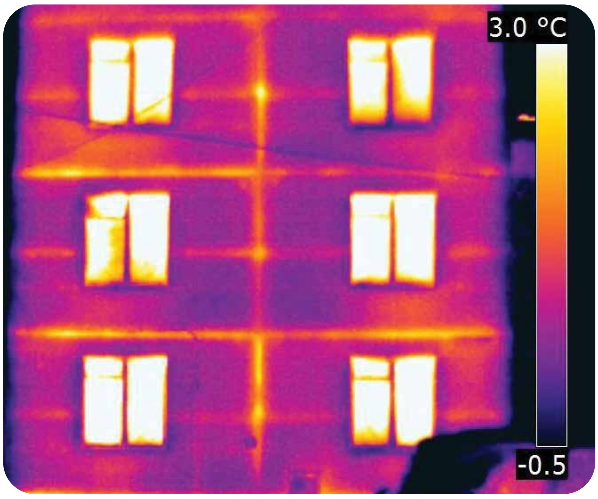


Figure 3.3.3

Heat loss on the corner of this brick building is intense at the junction of balcony glazing and the wall, and also where ceilings meet the walls

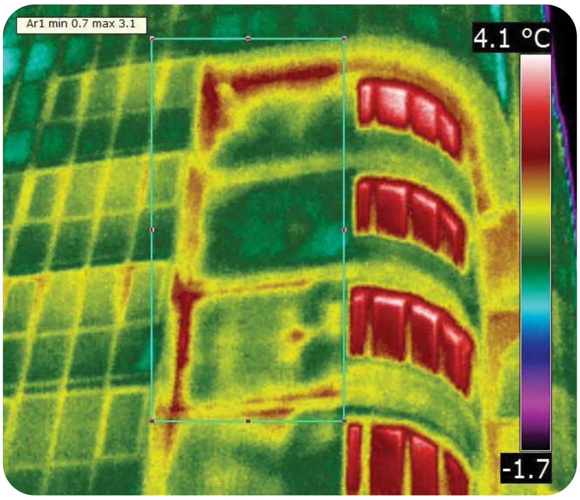
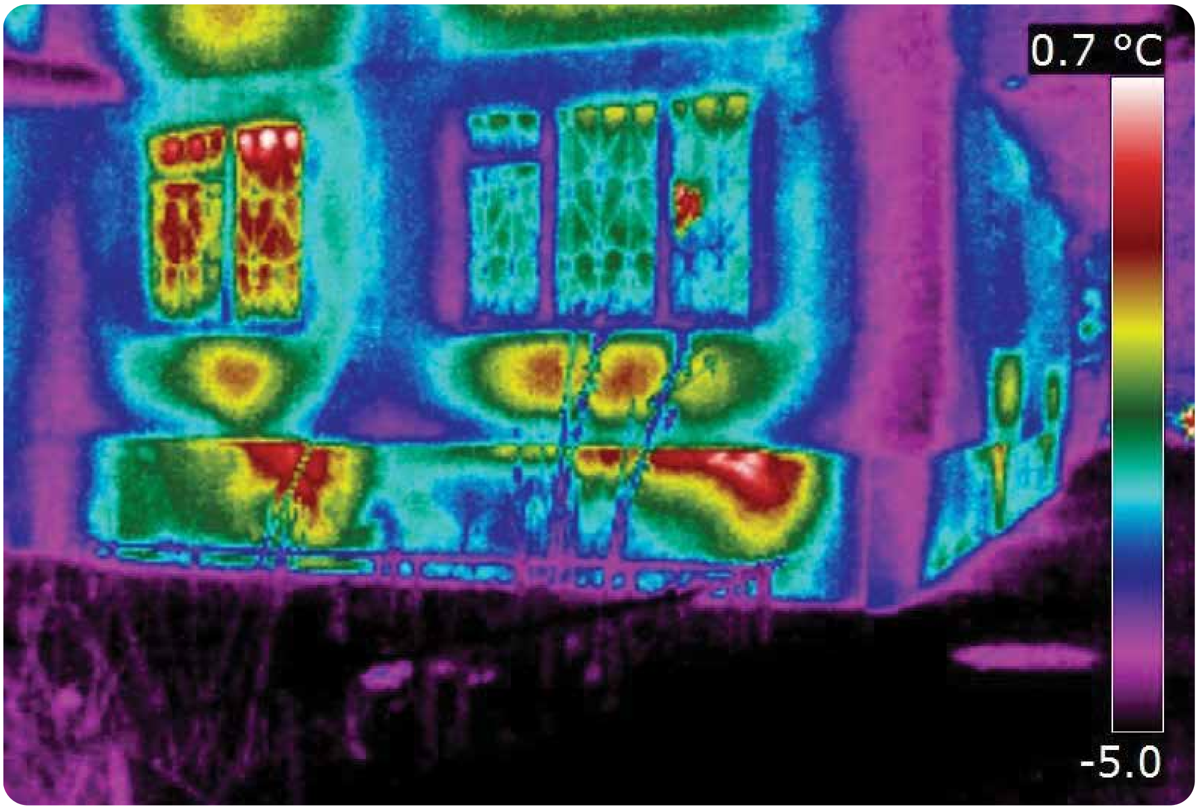


Figure 3.3.4

The red spots are where radiators are fixed to the wall in this old apartment building



Heat insulation for apartments

Options to save energy by improving heat insulation for apartments range from replacing windows with modern that have double and triple glass packages to better doors, improved insulation of walls, floors and ceilings and replacing heating radiators with more efficient ones.

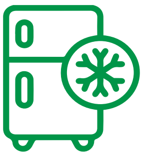
- Modern window designs, made from plastic or wood, offer excellent protection from the cold. They are easy to maintain and easy to operate.
- If you cannot replace the window with one that is more modern, do your best to insulate it. Pass a lighted candle or a thin feather along the frames and fill the gaps causing draughts. The best time to do this is in the autumn, as the plaster will not set properly if the temperature is too hot or cold. Be sure that the frame is dry when you apply it.
- Seal the windows for the winter. One advantage of modern insulation systems is that you can still open and close windows even after draught excluders have been fitted.
- If the room is still difficult to keep warm, use heavy curtains on the windows.
- You can purchase heat-reflective film that adheres to the inside of the double panes and reflects heat back into the apartment. Some of these films are removable in the summertime. However, the film lets only 80% of daylight into the room, and that can be a critical loss for apartments that are short of light (e.g., those on the ground floor, or north-facing, or with a balcony overhang from the next storey, or in the shade of a tree). But it is worth weighing the pros and cons: adults may rarely be at home in daylight hours during winter and children are at school or elsewhere, so a reflective film can be a definite advantage.
- If the front door lets in the cold, the best thing to do is to replace it, but take care to choose a good installer. There is not a great deal to choose between different doors, but the quality of their installation makes all the difference for reducing heat loss, and for noise insulation.
- If the door cannot be changed, you can improve its insulation by sticking a sheet of polystyrene or other insulating material to it and then covering it with synthetic leather. You should also close the gap under the door, through which heat escapes, by fixing a draught excluder or raising the threshold under the door.

- If it is cold inside a building, the walls require insulation. External walls can be best insulated using a 'wet facade' technology: a thermally insulating material (based on mineral or glass wool) is fixed to the wall and coated with paint or plastered over.
- Another way of retaining heat is by careful arrangement of furniture. Place wardrobes along the coldest walls: they will serve as an additional barrier against cold penetrating into the room. The furniture in the room should not hinder the circulation of warm air, so do not put any furniture near to the radiator.
- The easiest and cheapest way to insulate the floor is to put down linoleum on a felt base. But do not use glue, or the felt will lose its insulating properties. You can also lay an insulating film or a special insulating material under any floor surface.
- The most obvious way to improve the quality of heating in a room is to replace old radiators with modern bimetallic radiators. This must be done before the start of the heating season. When buying new radiators, choose those with adjusters.
- If replacement is not possible, the old radiators can be made to operate more efficiently. Remove old paint, scrape the surface, and paint them in dark colours: a dark and smooth surface gives five to 10% more heat. You can also take a sheet of plywood, paint it with silver paint or cover it with metal foil and place it behind the radiator to reflect heat back into the room instead of heating the walls. It is also important to keep radiators free of dust, which hinders heat transfer. Make sure that curtains and furniture are not preventing the flow of heat from the radiator into the room.
- Don't overheat your room! Wear something warmer rather than overheating the air.
- When you ventilate the apartment, do it quickly and completely: open the window and door wide to make air circulate.

Cooking

Your electric cooker is the most powerful appliance in your home: with all burners and the oven switched on, it can consume up to 20 kw of power, which is 10 times more than a large electric kettle or iron.

- Remember that the bottoms of the pots and pans you use on the cooker must be smooth and thick. It takes up to 40% longer to cook food in a pan with an uneven or concave bottom.
- The pan should be the same size as the burner to avoid heat loss.
- Use a lid! Energy consumption is 2.5 times greater when you cook food in an open dish.
- You can often turn off the burner on an electric cooker five minutes before the food is ready: the residual heat will complete the cooking process.
- Special appliances (coffee makers, pressure cookers, multicookers) can prepare food using 30–40% less energy than an ordinary cooker and in half the time.
- If you pour water over the cereal a few hours before cooking porridge, it will cook more quickly and contain more vitamins. Buckwheat can be soaked for about an hour, rice for longer, and beans or peas can be left to soak overnight. This also saves you time – if food cooks more quickly, you don't have to spend time watching it.
- Don't use too much water when you are boiling food.
- Don't fill the kettle to the brim if you only need water for one cup.



Refrigerators

The refrigerator is the most energy-intensive appliance in your home, and the size of your electricity bill depends on how good it is and how you use it. A modern refrigerator uses three or even five time less energy than one manufactured 20 years ago with the same size and features, especially if the old seals have lost their elasticity, so that warm air is getting into the refrigerator. For an economical family of one or two people, a new refrigerator can lower electricity bills by 1.5 times.

- Before opening the fridge, think about what you need from it. Just a few seconds is enough for warm air from the room to displace the cold air inside it.
- If the fridge is large, it is a good idea to fill it up with jams and pickles: when you open the fridge warm air quickly displaces the cold air, but if the fridge is full, then less warm air gets in.
- Never put food into the fridge when it is still warm! And position the fridge as far as possible away from radiators, the cooker and direct sunlight.
- Make sure that containers with produce are covered when you put them into the fridge so that moisture does not evaporate and condense on the fridge walls.
- If the fridge needs to be defrosted manually, do it often.

Lighting

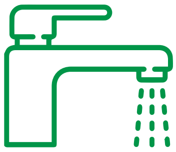
You can make energy savings of up to 40% by using modern lighting equipment and applying some practical tips.

- Spotlighting in places where we work or read often works better than powerful ceiling lights. Use portable lamps and fixtures.
- A smooth white surface reflects 80% of the light directed at it, while a dark green surface reflects only 15%, and a black surface just 9%. When choosing furniture, wallpaper, and curtains for a room, give preference to lighter colours.
- There is a very simple and highly effective way of improving lighting efficiency: wipe the dust from light bulbs and glass windows regularly.
- Most of the daylight comes into a room through the upper part of the window, so it is particularly important not to block it.

Appliances

You can reduce your energy consumption by learning how to make better use of household appliances.

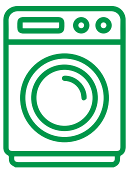
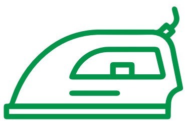
- When choosing new audio, video, or computer equipment, give preference to those with lower power consumption. Of course, purchase decisions in the family are up to parents, but you can always help them to decide by telling them what you know – they may well take notice.
- Turn all electrical appliances right off when you are not using them. When you turn off the TV using a console, it goes into 'sleep' mode, which uses less electricity, but still some electricity.
- Do not leave chargers for mobile devices permanently plugged in.
- Use high-quality plug extensions with wide-gauge cords. Narrow cords will grow warm, which means that electricity is being lost as heat instead of powering your devices.



Water consumption

Actions relating to water consumption can save both, energy, and water.

- Wash in the shower and only take a bath on special occasions.
- Ten drops per minute from the tap add up to 263 litres of water in a year. Mend the leaky tap.
- There are different types of taps. Taps with rubber washers may leak more often, but that little piece of rubber is easy to replace. Ball and ceramic taps may last a very long time, but only if the pipe that carries water to them has filters installed, because the polished parts in such taps are very sensitive to rust particles in the water. Ceramic taps must be closed gently. Thermostatic taps, which appeared on the market recently, are more expensive, but they can adjust the water temperature quickly and accurately, which reduces unnecessary expense.
- Get into the habit of closing a tap when you don't need water to run continuously. Some families peel potatoes and wash them under running water, but you can do just as well using basins or buckets. Washing dishes is easier if you wash them all together and then rinse them all together. Modern sinks often have plugs, so you can use the sink itself as a basin.

Washing and ironing

Reducing emissions from washing and ironing can help to save energy, emissions, your time and keep your clothes longer.

- When you wash clothes in the washing machine, there is no need to heat the water to 90°C and run a full cycle: that is only necessary for very dirty items. For linen or only slightly soiled clothes, an economy wash cycle is quite sufficient (every machine offers a choice of economy or quick washes) and modern detergents contain enzymes that ensure a proper wash even at low temperatures. Such a wash uses nearly 10 times less power than a half-hour wash at 90°C.
- Wait until you have a full load before using the washing machine – it is uneconomical to wash one pair of jeans.
- Make sure that the items to be washed are spread evenly in the drum of the machine. Otherwise, the machine will not be able to provide rapid rotation of the drum. If the load is evenly spread, there will be less strain on the machine, the wash cycle will take less time and parts of the washing machine will last longer.
- When ironing washed clothes, sort them by different materials: you can start with lower temperatures and then move on to things that require high temperatures, and small items can be left for ironing after the iron has been turned off.
- Some things do not need ironing – it is enough to hang them neatly on clothes hangers.

Recycling and re-using

We are used to seeing an abundance of things around us, but they do not appear from nowhere. Everything we use has been produced using energy and by the work of many people. Waste from the production of things and ever larger rubbish heaps worsen our living conditions and affect the climate.

- Before you buy something new, think to yourself whether you really need it. Perhaps you only need it for a short time and would be as well borrowing it from someone else.
- Look after things to make them last longer.
- If you have something that you no longer need, think whether it could be useful to somebody else. We can give toys or clothes we have grown out of to the kindergarten, the orphanage or just to other children we know. There are sites on the Internet where people offer things they don't need for free and other people are often ready to take them. Packing tubes or boxes can be turned into something new, old dolls and toys can be restored, and there are people who can fix a broken appliance and make it work again.
- You can donate old books that you won't read again to the library or to book-exchanges, which have become popular in recent years: these are special shelves in some bookshops and libraries where you can bring any book of your own and exchange for it a book that someone else has brought there.
- If a thing is completely broken, the material from which it is made can be recycled. You can check on the Internet whether there is any reception point in your town or city for recyclable objects – you may be lucky and find such a point near to where you live. You can also put up notices to bring people in your neighbourhood together for recycling waste and unwanted items, or team up with friends, or talk to teachers at school. Together, you might gather enough plastic, paper, and metal to make a trip to the recycling centre worthwhile.
- Take your own bags when you go shopping, so that you don't have to use new ones at the checkout (save that convenience for when you really need it). Plastic bags for shopping are now freely available in shops, and they are sometimes convenient and necessary, but you can always tell the checkout staff that you don't need them. Several countries are now introducing a charge for plastic bags, which makes it worth your while to take your own bags to use.
- It makes sense to buy everyday goods that keep for a long time (detergent, shampoo, some cereals, etc.) in large bulk packages. Remind your parents of that.

Figure 3.3.3

Metal recycling bales

Table 3.3.1 **Comparison between paper entirely produced from virgin pulp and from recycled materials (per tonne of paper)**

	Paper made entirely from virgin pulp	Paper made entirely from recycled materials	Saving
Timber	3 tonnes	0 tonnes	3 tonnes
Energy	11,140 kWh	6,450 kWh	4,690 kWh
Greenhouse gas emissions	2,581 kg of CO_2	1,625 kg of CO_2	956 kg of CO_2
Waste water	72,000 litres	39,100 litres	33,100 litres
Solid waste	1,033 kg	506 kg	528 kg

If we save one tonne of paper, we also save 13 tonnes of oil, 4,100 kilowatt-hours of electricity and 32 tonnes of water. The production and printing of one sheet of A4 paper generates 28 g of CO_2, and copying a single sheet of A4 380 g of CO_2.

Energy savings in production using recycled materials

Aluminium – 95%
Zinc – 60–70%
Paper – 64%
Copper – 70–85%
Magnesium – 95%
Plastic – 80–88%
Lead – 60–80%
Steel – 70%
Glass – 68%

So, you can reduce your carbon footprint by using less energy and not wasting energy and water, by not buying things you don't need and things with excess packaging, by getting your rubbish recycled, by walking and using a bicycle whenever possible, by buying locally produced food. And finally, remember that our main allies in helping the climate are plants. Take care of them and plant new ones whenever and wherever you can.

Figure 3.3.6 Climate change: How to reduce your carbon footprint

QUESTIONS

1 What is a carbon footprint?

2 What units are used to measure a carbon footprint?

3 Which of these has a bigger carbon footprint: strawberries grown in the garden at the local farm, or strawberries brought from abroad and beautifully packaged? Why?

4 It's cold outside, and the heating isn't working indoors. Which of these would be most useful to keep warm at home and why?
a) wear a warm sweater and socks;
b) put a carpet under your feet;
c) have something to eat;
d) drink hot tea;
e) turn on an electric heater;
f) dance, jump or run;
g) light a fire in the stove or fireplace;
h) take a hot bath;
i) sit in the sun.

5 What is more economical and when is it more economical – taking a bath or taking a shower?

6 Can installation of water meters help to save energy? Why?

7 Do we use energy when we use water in an apartment building? What sort of energy do we use?

8 What do you already do in your home to save energy?

9 What important things do you need to remember when using a fridge?

TASKS

1

Test your carbon footprint

A. When you buy fruits and vegetables in a shop, what do you usually choose:
– local, unpackaged produce (1 point)
– unpackaged produce from the southern regions of your country (2 points)
– unpackaged produce from France, the Netherlands, Argentina and other countries (3 points)
– imported produce, individually pre-packed (4 points)

B. The bag you use for shopping is:
– linen or cotton (1 point)
– paper (2 points)
– a plastic bag that I take from home (3 points)
– a plastic bag that I take or buy when I pay for goods in the shop (4 points)

C. When you buy drinks, what sort of container are they usually in?
– paper (1 point)
– glass (2 points)
– aluminium (3 points)
– plastic (4 points)

D. What book do you prefer to read:
– a new one, bought in a shop (4 points)
– an electronic one (3 points)
– one that has already been read (2 points)
– one from the library (1 point)

E. When you give someone a present, do you prefer:
– bright and attractive wrapping paper, whatever it is made of (4 points)
– paper with an environmental label to show that it is recyclable (2 points)
– a used box or bag that I specially decorate (2 points)
- to give the present without packaging (1 point)

Answers

- **From 14 to 16 points:** An elephant's carbon footprint!
  Better put all that weight into saving energy.
- **From 11 to 13 points:** The carbon footprint of a horse's hoof!
  Put on your harness and get down some energy saving.
- **From 8 to 10 points:** You have the carbon footprint of a cat's paw!
  But don't sit purring – you could do even better.
- **From 5 to 7 points:** Great! You have the carbon footprint of a mouse!
  You can be proud of yourself – all you need to do now is persuade others to be like you.

2

Draw a table with four columns. Use the first column to note down cases of inefficient energy use that you see around you (on the street, at home, at school). In the second column explain how energy could be saved or used more efficiently in all these cases. In the third column, write down cases you have seen of efficient energy use. And in the fourth column, write down one occasion each day when you personally used energy more efficiently and did the planet some good. Compare your table with the tables of your classmates. Make a report on the results.

3

Go through all your things (preferably with your parents), find out where they came from and mark that place on the world map. Put things you bought or were given, but don't use, into a separate group. Calculate how far they travelled to reach you. Now you can make a chart (diagram, map) of what you have found out, showing where things were made, what use they are to you (necessary, unnecessary, useful from time to time, good for recycling, good for making something else out of, etc.).

4

Divide the class into seven groups. Each group draws a straw to select a focus group: younger students; older students; housewives; pensioners; industrialists; politicians; teachers. Each group has to develop a project to promote energy saving and energy efficiency for its focus group.

Your tasks are to:

1) think of a slogan or slogans for an information campaign
2) design a poster to encourage energy saving in your group
3) develop a programme that will help your focus group to grasp the principles of energy saving and carry them out

Put some original ideas into your programme – from a puppet show to publishing a book, to proposals for reform of the state (depending on the focus group).

After the projects have been presented, display the best posters at school.

3.4 Global cooperation on climate change, sustainable development, and all-of-society approach to deal with climate change

Global cooperation and negotiations on climate change

Until the end of the 1970s, the only people who took an interest in climate change were scientists.

In 1979, reports presented at the first World Climate Conferenceprovided evidence that human activity has major impact on climate. This attracted the attention of journalists, then of the public, and finally of governments.

In 1988, the United Nations recognized climate change as one of the most pressing global challenges for humanity.

Some of the best scientific minds in the world began to work on the issue of climate change.

In 1988, the Intergovernmental Panel on Climate Change (IPCC) was set up by the International Meteorological Organization and the United Nations Development Programme. The panel was asked to review the available scientific evidence and show how human activity affects the climate.

The first IPCC report published in 1990 confirmed that the threat of climate change was real and that there was a direct connection between human activity and processes in the global atmosphere. Since then, five more IPCC reports have been released, the latest in 2021-2022, which assess climate change using the most recent research by scientists from around the world.

Since the first IPCC report, most scientists have increasingly agreed on the man-made nature of climate change and that we can and must find ways of combating it. This will only be possible if countries all over the world work together, and the best way of doing that is under the auspices of the United Nations.

In 1992, the countries of the world agreed at a United Nations conference dedicated to environment and development held in Rio de Janeiro, Brazil, on the need to cooperate on climate, biodiversity and forests, and desertification issues. The agreement on climate issues was reflected in an international treaty, the United Nations Framework Convention on Climate Change (UNFCCC) that was negotiated within a record time of 18 months.

The Climate Convention entered into force in 1994, but it only set out general actions to limit and reduce greenhouse gas emissions and cooperate on adaptation to climate impacts. So, in 1995, at the first Conference of the Parties to the Convention (i.e., the countries that had signed the Convention), it was decided to prepare a further international legal instrument to regulate concrete actions by the Parties into the 21st century.

The negotiations to prepare this new instrument were complex and difficult. Yet, the countries came to agreement. And in December 1997 in Japan, they adopted a new international treaty, the Kyoto Protocol to the UNFCCC, named after the city of Kyoto, where it was signed.

The Kyoto Protocol was revolutionary because it contained quantified commitments by each developed country not to exceed a certain level of greenhouse gas emissions in the period 2008-2012 relative to 1990, which was taken as the baseline. It also introduced innovative market-based mechanisms that attached a price to carbon dioxide emissions.

United Nations
Framework Convention on
Climate Change

For example, the European Union pledged to reduce its emissions by 8%, Japan by 6%, and Russia and Ukraine not to exceed the level of their emissions in 1990.

The United States, which had the largest amount of greenhouse gas emissions in the world at that time, took an active part in the negotiations on the Kyoto Protocol, but later, in 2001, did not ratify it.

At the end of 2012, there were two international treaties in force: the Climate Convention, as an international treaty defining the general strategy for humanity to combat climate change, and the Kyoto Protocol to the Climate Convention, which established specific commitments of industrialized countries, such as the European Union, and countries with economies in transition, such as Russia and Ukraine.

The period of the first commitments made by industrialized countries and countries with economies in transition under the Kyoto Protocol expired at the end of 2012 and a new round of negotiations was needed for the next period, beginning in 2013. In 2013, developed countries that remain part of the Kyoto Protocol agreed on further commitments to reduce greenhouse gas emissions in the second commitment period from 2013 to 2020, promising more substantial reductions than before.

But the attitude of several countries towards the Kyoto Protocol has changed. The USA, Canada, Japan, New Zealand, and Russia have not joined the agreement for 2013–2020. Their argument is that the world has changed since the 1990s, and that almost all the growth in emissions today comes not from developed countries, but from major developing countries with emerging economies (China, India, Brazil, South Africa, and others), whose emissions are not regulated by the Kyoto Protocol.

The solution that was found at that time was for these developed countries that are not part of the second commitment period of the Kyoto Protocol to take on voluntary commitments for emission reduction by 2020 and for developing countries to implement Nationally Appropriate Mitigation Measures in form and scope that they define by themselves.

Figure 3.4.2

Adoption of the landmark Paris Agreement at COP21 in Paris in 2015

Milestones in addressing climate change

- 1992 - Climate Convention, when countries agreed to formulate and plan actions to return emissions to 1990 levels;
- 2008-2012 - The first commitment period of the Kyoto Protocol, when 37 developed countries and the European Community committed to reduce greenhouse gas emissions to an average of 5% against 1990 levels;
- 2013-2020 – The second commitment period of the Kyoto Protocol, when developed countries committed to reduce greenhouse gas emissions by at least 18% below 1990 levels. However, the developed countries that did not participate in the second commitment period took on voluntary commitments to reduce emissions by 2020, and developing countries agreed to implement Nationally Appropriate Mitigation Measures (NAMAs).
- 2015 – Adoption of the Paris Agreement that includes Nationally Determined Contributions (NDCs) of countries, with ambitious long-term measures to curb greenhouse gas emissions.
- 2016 – Entry into force of the Paris Agreement with the first commitments to reduce emissions (NDCs) between 2020 and 2025, or 2020 and 2030.

In December 2015, the countries met at the United Nations Climate Change Conference in Paris to achieve a new universal agreement on climate that was implemented from 2020 and applied to all nations. In preparation for Paris, governments submitted their climate pledges, the **Nationally Determined Contributions' (NDCs)**, outlining their mid-term national emission reduction targets. The goal is to limit global average temperature well below 2°C and towards 1.5°C compared to pre-industrial levels.

The Paris conference looked at a broad range of climate change challenges and solutions including mitigation of greenhouse gas emissions, adaptation to climate change impacts, loss and damage from climate change as well as technological, capacity-development and financial support for such actions. The Paris Agreement is a legal framework for climate change actions beyond 2020; more detailed decisions on its implementation have been formulated and agreed upon at subsequent climate conferences.

Effective international cooperation can help the world develop along a 2°C and towards 1.5°C pathway and adapt to climate change that is already happening. It can also help countries grasp the many opportunities and benefits associated with the transition to low-carbon and climate resilient economies.

Importantly, the Paris Agreement does not impose emission limitation or reduction targets on countries. Rather, it encourages countries themselves to set targets that represent their best possible effort to contribute to the temperature goals of the Paris Agreement. Such efforts are reflected in the national climate plans that are submitted periodically by countries as NDCs. The first set of NDCs was submitted in 2015-2016, and the second in 2021-2022.

To ensure that NDCs pledged by countries collectively bring down emissions well below 2°C and towards a 1.5°C pathway, a new mechanism was introduced in the Paris Agreement, known as the Global Stock Take (GST). The GST will assess the collective progress towards the goals of the Paris Agreement, considering the best available science and equity. It will help to encourage and inform countries to increase their ambition and scale up their actions in line with what science requires when they update their NDCs. The next NDCs due in 2025 are expected to include targets for 2035.

The first GST took place in 2022-2023 and culminated at the Conference of Parties (COP28) held in December 2023 in Dubai, the United Arab Emirates. Countries reached a consensus that the world is not on track to achieve the 1.5°C goal of the Paris Agreement and must take urgent and ambitious actions on mitigation and adaptation and reflect them in the next NDCs in 2025.

The stock take recognizes the science that indicates that global greenhouse gas emissions need to be cut by 43% by 2030 and by 60% in 2035 compared to 2019 levels, to reach net zero emissions by 2050 and limit global warming to 1.5°C.

The stock take asks countries to a) take concrete actions towards achieving a tripling of renewable energy capacity and doubling energy efficiency improvements by 2030 globally and reducing methane emissions; and b) accelerate efforts towards phasing down unabated coal power, phasing out inefficient fossil fuel subsidies, and transition away from fossil fuels in energy systems in a just, orderly, and equitable manner. It calls on developed countries to continue leading the transition to an emissions-neutral and resilient future.

The COP28 also reached a consensus on stepping up support to developing countries to enable such ambitious action. For example, the GST assessment led to the establishment of funding mechanisms and tools to help deal with events such as the extreme flooding in Sylhet, Bangladesh in 2022 that led to a shortage of clean drinking water (Fig. 3.4.2). The GST outcome thus givescountries a fair chance to achieve the goals of the Paris Agreement in this critical decade for climate action.

Figure 3.4.2

Women seeking drinking water in Sylhet, Bangladesh, after extreme floods in 2022

The Paris Agreement also requires developed countries to support developing countries by providing them with financial, technological, and capacity development. As part of the GST, countries recognized the need to provide developing countries with climate finance in the range of $5.8–5.9 trillion for the pre-2030 period.

COP28 was also the first to spotlight the impact of climate change on human health. Ministers of health, environment, finance, and other related sectors set out a roadmap and opportunities for actions to deal with this issue. Countries adopted the first Declaration on Health and Climate Change, where they committed to join forces and work to transform health systems to be climate-resilient, low-carbon, sustainable and equitable, and to better prepare communities and the most vulnerable populations for the impacts of climate change.

Climate change and sustainable development

International cooperation on climate change is closely linked with the other principal concern of humanity – how to achieve sustainable development for global prosperity. Sustainable development requires mutually supporting actions in three domains: economic, social, and environmental. And climate change impacts all three of them.

At the United Nations General Assembly in September 2015, 193 countries adopted the 2030 Development Agenda and its 17 **Sustainable Development Goals (SDGs)**. Goal 13 aims at 'Taking urgent action to combat climate change and its impacts' (Fig. 3.4.3).

Figure 3.4.3 17 Sustainable Development Goals of the United Nations

Many other SDGs also address climate change, for example, Goal 7, 'Ensure access to affordable, reliable, sustainable and modern energy for all'.

In our modern world of technological progress, about 1.3 billion people, 80% of them in rural areas, have no access to electricity. These people, the world's poorest, make up more than 16% of the eight billion people now living on the planet.

Even more people, about three billion, use traditional biomass (wood and firewood) for cooking and heating. Pollutants emitted into the atmosphere from the combustion of biomass in inefficient cooking devices may be causing the premature deaths of 1.5 million people every year, or more than 4,000 a day. That is more than the total number of people who die each day from malaria, tuberculosis and AIDS combined. These poor people live in Africa, south of the Sahara Desert (the largest desert in the world), South Asia and Latin America.

This problem has been called **'energy poverty'**.

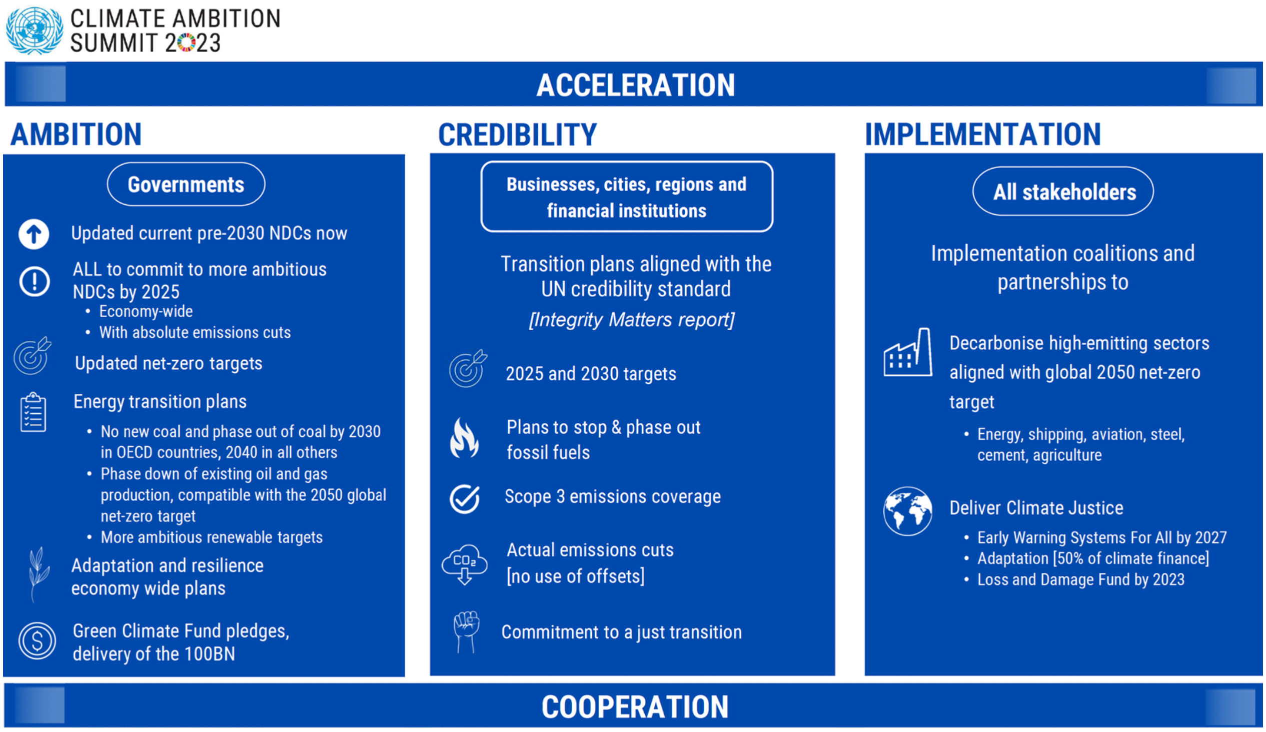
Achieving climate change goals and the goal of providing electricity access to all is mutually reinforcing. Clean, efficient, affordable, and reliable energy is key to global health and prosperity, and the efficient use of energy resources combats climate change. This is why it is vitally necessary to promote the rational and efficient use of energy resources.

All-of-society approach to climate change

Representatives of business, cities, regions, investors, civil society, academia, and organizations of women, youth, and indigenous peoples, or non-governmental actors, have been increasingly engaged in climate change negotiations since the 1990s.

It was at COP21 in Paris that governments formally agreed that it was urgent to mobilize stronger and more ambitious climate action to achieve the goals of the Paris Agreement. Everyone has a role to play. Society and other non-governmental actors engage in climate action by creating their own climate plans, setting goals to reduce emissions, disclosing climate risks, enhancing technical proficiency and capacity, and assisting with the local execution of national policy objectives. They also work together and often with national governments in transnational climate initiatives or international cooperative initiatives. The United Nations Climate Ambition Summit in 2023 gave particular attention to the roles of governments, business, cities, regions, and financial institutions, and how they can work jointly in making the decarbonization of society and economy a reality (Fig. 3.4.4).

Figure 3.4.4 **How different stakeholders join efforts to fight climate change: UN Climate Ambition Summit 2023**



The UNFCCC provides information on more than 32,000 initiatives and actors engaged in climate action. In October 2023, these included 15,590 companies, 1,654 investors, 3,443 organizations, 282 regions, 11,354 cities and 194 countries. High-level champions at the UNFCCC guide actions by non-governmental actors to enable collaboration between governments and the cities, regions, businesses, and investors that must act on climate change. Most notable recent initiatives are the 2030 Breakthroughs, the Sharm-el-Sheikh adaptation agenda, Race to Zero and Race to Resilience campaigns.

Recognizing the importance of engaging young people in climate action, COP28 in Dubai created the position of a Youth Climate Champion. The champion is tasked with enhancing the meaningful participation and representation of young people in future COPs.

TASKS

1

In this set of tasks, you can try playing the role of an international negotiator. Read these ten tips and learn them by heart.

Ten tips for an international negotiator

1. Focus on the issue that is being discussed. Don't get diverted and don't pursue sidetracks or jump to other topics.

2. Try to find and distinguish the key idea, and focus on content, not on form. However, when engaging with others, do not forget that in diplomacy, the form or the way you present your ideas matters a lot.

3. Paraphrase what the other person has said and check that you understood them correctly ('If I'm not mistaken, you mean that...', 'Do I understand rightly that ...').

4. Ask questions.

5. Respect the silence of the person you are talking to, don't rush to fill pauses in the conversation.

6. Interpret information both from the point of view of your own culture, and from the point of view of a culture of your counterpart.

7. Try not to read your own meaning into someone e se's behaviour.

8. Don't hurry to make assessments and value judgments.

9. Learn to recognize non-verbal messages of the person you are talking to (facial expressions, gestures, posture, intonation, etc.).

10. Don't jump to conclusions based on a single gesture or sign.

It is interesting that one of the most successful strategies in dealing with people from other cultures is simply to imitate them. Copying the way your negotiating partner behaves significantly increases the chances of a positive outcome for both sides. So being a chameleon can help you to succeed in international negotiations. In any case, courtesy, respect for the person you are talking to and their culture, and openness in communication can work wonders. (The same applies in daily life.)

2

Game

Imagine that you are taking part in a United Nations Conference on Climate Change, and you are going to discuss the problems of different countries related to climate change.

Prepare a brief welcome speech that the head of your state will read to conference participants. The speech should mention:

– the climate and main natural resources of your country

– how people in your country live

– the chief sectors of your country's economy

– the impact of climate change on nature, people and the economy

– what your country expects the conference to achieve

After the welcome speech the conference participants express their views on how to prevent the negative impacts of climate change on the environment and people in the countries taking part in the conference.

At the end of the game, the participants select a winner – the student who contributed the most to the discussion, and who said the most relevant, well-argued, and interesting things

3

You are a governmental officer in a small island state in the Pacific region. You are preparing a proposal to apply for international financial support to help your country cope with the negative impacts of climate change. Include the following issues in your funding proposal:

1) What expected effects of global warming represent the greatest threat to your country?

2) What is to be done if rising sea levels threaten to engulf the whole of your island?

3) What international organizations and states will you apply to for help?

4) How do you plan to preserve the culture of your country, if your island disappears under the sea?