CLIMANTOPIA: THE SCHOOL BOOK

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EduCinema Clima Tour Action:
Collective Creativity and Community Education in Film Literacy for Climate Action Tourism

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1.1. THE ORIGIN OF COAL COMBUSTION SINCE THE WOOD CRISIS

In the final scene of the film "*Cinema Climantopia*", the projection of the video "*A future without carbon*" is shown, for which students from Poland were awarded the prize at the school short film summit held by UNESCO in the Canary Islands. The video shows an active thermal power plant with emissions in which the protagonists analyse the sequences of these emissions, which are related to the onset of climate change, with significant repercussions still in terms of greenhouse gas emissions.

Image 1: *Still from the short film "A Carbon-Free Future" showing a thermal power plant with two large chimneys emitting greenhouse gases in the background.*

Coal in Poland is a fuel widely used for electricity, but also for industrial purposes and even for heating buildings. This use has been important in Europe since the industrial revolution, especially in the northern part of Europe, which is more industrial and colder in winter than the southern part of the Iberian Peninsula. In this region of Northern Europe, where Poland is located, the ecological transition to which the European Union is committed is going slower than is being hoped for. However, thermal power plants are being closed down, especially those closest to the villages. The video shows the closure of the thermal power plant currently located in the city centre of Lodz in order to build a cultural centre and one of the city's main social meeting places. This closure not only stopped the air pollution in the city of Lodz, but also made it possible to locate a planetarium, a science and technology centre, a museum and a centre for contemporary art. Through the use of these facilities and the organisation of exhibitions, artistic events inside and various activities on the square, it became a symbol of the development of Lodz and a driving force for the cultural and tourist development of the city.

Image 2: Still from the short film "A future without carbon."

Respond with what you know now:

1. Look for information on active thermal power plants near your city and indicate whether there are plans for their closure. If so, state steps that have already been taken from mining for coal to modifications that have taken place to address the negative effects of emissions.
2. Look for information on a thermal power plant that ceased to be used in your country, such as the cor- tometraje thermal power plant, which is now integrated in the urban centre of Lodz. Express the strategies that have been followed to integrate its mines and installations into other types of uses, as has been done with this Polish power plant. If you do not find alternative uses, make proposals that could be attractive and useful to the population, in coherence with the characteristics of the environment in which it is located.

How might the emergence of charcoal use be related to the fuelwood crisis?

At the end of the 11th century, waterpower made it possible to improve the forging of steel by means of a new technological innovation involving the movement of a water wheel driven by waterfalls, which in turn generated blows from a sledgehammer on a mixture of wood ash and molten iron. With the introduction of water to strike the steel in the forging process, human power was freed from the pounding in the forges to achieve the alloying of carbon with iron. This new technology facilitated the mixing of burning charcoal coals with the molten iron. This improved striking by harnessing waterpower made it possible to produce stronger and lighter steel.

in much larger quantities than in manual forges, which have been in operation since the transition from bronze to steel around 1,500 BC.

With this technology, the use of steel was improved and amplified, and this led to the development of an incipient steel industry linked to waterfalls and fuelled by wood as a raw material and energy source. For this reason, the forests surrounding these new hydraulic forges were deforested to make it possible to obtain steel in these hydraulic forges.

Figure 3: *Representation of the two key processes in the hydraulic forging industry: striking the hammer on the carbon-iron alloy and obtaining the charcoal by combustion and the molten iron.*

At the same time, the deforested area was used to generate new crop fields that were needed for a growing population.
This was also facilitated by steel, since at that time the transverse iron plough was devised, which made ploughing more efficient than the old Roman wooden plough and could even remove stumps from cut trees.
The spread of the use of the iron plough gave rise to what is known by some authors as the first industrial revolution in European history, which led to a real agricultural revolution in Europe in the sense of an increase in crops and a parallel increase in the population.

This historical context of agricultural development in parallel with the extension of the production of steel by hydraulic forging, together with the development of fleets and equipment for the conquest of European countries in America, meant that in the 15th and 16th centuries wood, which was Europe's energy base, became scarce because of what can be understood as the first great industrial crisis.

Image 4: *Photograph of a plough.*

Image 5: *Representation of the deforestation of a forest to feed the hydraulic forge and the process of transforming the deforested area into a cultivated field through the use of the iron plough.*

According to what we have seen so far about the iron plough, it responds:

1. Western European soils are heavier than Eastern European soils. Explain the differences in water retention, taking into account the percentage of clay, temperature and precipitation in both regions.
2. The iron plough was more successful in Western Europe than in Eastern Europe. What reasons can you think of given the answer in the previous activity?
3. The stage known as the first industrial revolution led to a significant increase in the area under cultivation in Western Europe. Apply the answers from the two activities to explain this.

Wood became the universal material of the pre-industrial economy because industry depended on it. At the same time, however, the machines of industry were also made of wood, as were ships, which also grew to meet the needs of overseas shipping. At that time, wood played the role that metals play today in industry and at the same time occupied the space that fossil fuels do today. Therefore, wood was not only consumed out of direct necessity as a raw material for the forging and smelting industry, but was also used indirectly in mining, in navigation, in the beams used to line mine galleries and to build wooden wagons for transporting ore.

The development of overseas expeditions gave impetus to the manufacture of the three-masted ship, which made it possible to make deep-sea voyages and thus to search for resources elsewhere. The growth of this fleet consumed enormous quantities of timber. At the same time, and especially with the discovery of America, the development of armaments that required light and resistant steels boosted hydraulic forging. Thus, although the felling of forests for cultivation considerably reduced the amount of timber available, the final crisis was triggered by the increase in iron production and shipbuilding.

This abuse of wood led to an increase in freezing deaths in cities with harsh cold and wet winters, such as Newcastle, due to a lack of wood for heating. To deal with this crisis, the King of England authorised the extraction of coal as an alternative energy source. This crisis grew and spread to other regions. Thus, in the 15th century, Pope Pius II wrote that, during a visit to Scotland, he was surprised to see at the doors of the churches, rows of
of people who received fragments of a black stone as alms, referring to coal.

This coal was authorised by the king to cover survival needs because, although its calorific potential was known, it was treated with contempt as an inferior source of energy, being dirty and producing a lot of pollution. It was also unaffordable until adequate mining for its extraction was developed.

Figure 6: *Representation of people collecting charcoal to make up for the lack of firewood.*

Based on what has been seen so far on the use of coal:

1. He comments on the text which takes up part of an account by Pope Pius II of his visit to Scotland: "*[...] They received as alms pieces of a black stone with which they retired satisfied. This kind of stone they burn instead of wood, of which their country is devoid*".
2. He comments on Edmund Howes' 1631 statement, bearing in mind the previous answer: "*The inhabitants are compelled to make fire with peat and coal, even in the chambers of honourable personages*".
3. Compare 1 kg coal with 1 kg wood in terms of their availability, ease of procurement, emissions and the heat capacity they provide. On the basis of this comparison, what is the point of Britain's switch from burning wood to coal?

How were the difficulties in procuring coal solved as the solution to the timber crisis?

Coal was obtained by mining. These became deeper and deeper to search for useful rock in the harsh winter regions of Britain. As it became necessary to drill deeper mines to extract the coal, it became more difficult to vent shafts and raise coal to the surface. The difficulty of coal extraction due to the depth of the mines over the course of the 17th century was compounded by the ingress of water from the water table or deep groundwater, which seeped through the cracks. This meant that, in addition to the need to extract the coal to the surface, it was also necessary to extract the water infiltrating into the galleries. All these problems derived from extracting the coal at greater depths required technological solutions that were solved with the invention of the steam pump. This technological innovation was the first steam engine in which the pressure of water vapour generated by combustion in boilers moved the pulleys that generated the ascent.

The first steam pumps were powered by wood. Over time, as trees were cut down close to the areas of use of these steam engines, the crisis of firewood led to the use of coal combustion to generate steam. With this invention, coal became available above ground in significant quantities for consumption and its marketing to other areas of Britain was encouraged. Initially, this distribution was done by horse-drawn wagons. But this transport was severely hampered by the muddy soils resulting from the rainy winters typical of the region. The need to improve the transport of coal led to the invention of the steam locomotive and the railway first, and then the steamship, which allowed the steam engine to be extended from pumps, initially used for coal extraction, to transport systems.

The railway, which represented an important technological innovation, began to be used massively for the transport of passengers as early as the 19th century. This meant that towns were linked by railways, which became an extension of the coal mine, enabling coal to reach the different points of demand that were increasing as the industrial revolution derived from the industrial use of this fossil fuel accelerated. As the cost of transporting the ore increased with the distance, the industrialised countries were able to use these routes as an extension of the coal mine, making it possible to access the coal to the different points of demand.

Heavy mining tended to concentrate near the coal seams. This century also saw the introduction of the steamship, which progressively increased in size, so that by 1858 the Great Eastern, known as the "monster of the Atlantic", 691 feet long, 22 500 gross tons and 1600 hp developed by its propeller engines and 1000 hp in its paddlewheels, was sailing.

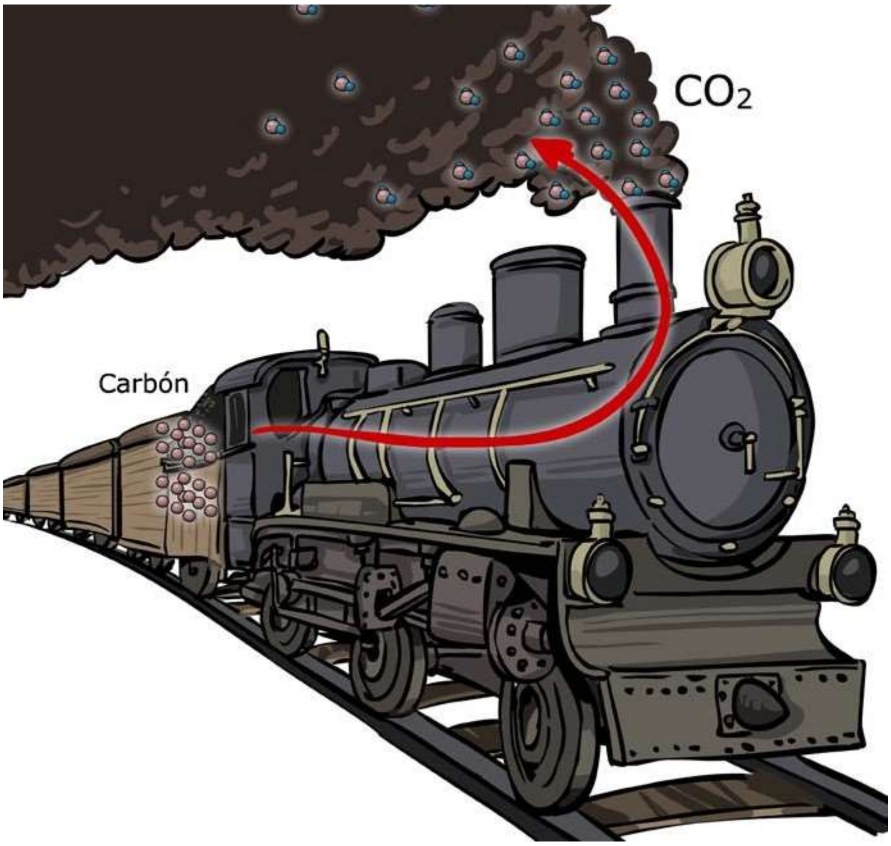


Figure 7: *Representation of a steam locomotive showing the combustion model in which the bonded C atoms in the coal rock combine with O_2 to give rise to the CO gas$_2$ which is released as a result of combustion.*

According to what we have seen so far about the technological innovation of the steam engine:

1. What role did coal mining in England play in laying the technological foundations for the industrial age?
2. Twenty times as much crop can be harvested from a hectare of field today as in the Middle Ages, but twenty times as much energy is used to produce one calorie of grain. How does the use of fossil fuels affect energy consumption today in terms of cultivation, care, fertilisation, irrigation and harvesting?

3. Comment on the sentence: "*Technological advances have meant greater energy power at the cost of increased environmental disruption and resource consumption*".
4. Express the connections you can think of between the invention of the steam engine and the origin of climate change.

1.2. THE PRODUCTION OF STEEL BY THE COMBUSTION OF COAL

The universalisation of the steam engine in locomotives and ships increased the demand for coal - even in areas of the West where access to wood was still possible at the end of the 18th century, as was the case in Russia and America - and populations grew in areas with access to railways and ports. In this way the towns, in a way, became an extension of the coal mine. As steam engines had a low efficiency at speeds above 2%, this meant that new lines followed rivers and valley bottoms. This tended to move people to terminal towns, junctions and port towns, also increasing the tendency to establish new urban communities along the main transport lines. From the second half of the 19th century, the railway reached the East, India, China and Japan, bringing with it practices, methods and ideas from the European mining civilisation in which it appeared. This type of settlement and population resettlement brought with it processes of readjustment and social tensions.

Figure 8: *Representation of the urban complexity associated with the extension of coal use.*

The urban planning tensions, the increase in working time in closed environments demanded by the activity in the industries based on energy derived from combustion and the accidents derived from the extraction, transport and combustion of coal increased social conflict, as the

The trend to locate industries in the centre of cities has increased urban pollution.

In the quest to increase quantities by reducing transport time, larger machines were sought, and transport networks were increased, both overland by rail and by sea by steamship. In the case of railways, tunnels and large bridges were developed in order not to exceed a gradient of 2%. For these large new machines, communication routes and large bridges, the construction of malleable and resistant structures was of interest. The material par excellence to meet these requirements was wrought iron or steel, which, through hydraulic forging, had been the driving force behind what many authors refer to as the first industrial revolution. Steel is very strong and light, so it was used to build railways and large ships capable of accommodating large steam engines to achieve maximum efficiency.

Steel was also used to build important iron bridges and railway tracks that allowed locomotives to travel horizontally. This culture of iron engineering gave rise to the first skyscrapers in Chicago and monuments such as the Eiffel Tower, which at the time represented the tallest building in the world and marked the end of the 19th century, leaving the expression of a tribute to the significance of steel obtained from the steam engine industries. These constructions were made with steel obtained from coal-fired steelworks, which meant an increase in the consumption of fossil fuels, with the consequent increase in CO_2 emissions from the use of coal rocks with C coming from the fossilisation of plants.

At the same time, the strength and lightness of steel made it possible to extend its use throughout the second half of the 20th century. At this time, steel made possible the development of important iron bridges that facilitated the development of horizontal railways.

This culture of iron engineering gave way to the first skyscrapers built on tall steel structures made possible by their strength and lightness. A good example of this urban development based on steel structures at the end of the 19th century can be found in the city o f Chicago. The production of these structures in coal-fired industrial steel mills marked the beginning of an industrial process of high fossil fuel consumption, which increased emissions throughout the second half of the 20th century.

Image 9: *Photograph of an old railway passing over a steel bridge.*

Image 10: *Chicago skyscrapers built on steel frames.*

According to what we have seen so far about the technological innovation of the steam engine:

1. How did the steam engine influence the development of urban planning?
2. What changes did the first industrial revolution bring about in the way steel was produced?
3. Explain what the construction of the Eiffel Tower as the tallest building in Paris was intended to symbolise at the 1889 World's Fair in Paris.
4. What was the main cause of the increase in emissions in the late 19th century?

1.3. THE SPREAD OF COMBUSTION WITH THE ENERGY CARRIERS OF THE 20TH CENTURY

How could the electricity vector end up being a problem for climate change if it appeared with the use of renewable hydropower?

In the first half of the 19th century, two scientific and technical advances made the hydraulic dynamo possible. The first breakthrough that made it possible was Faraday's work on electromagnetic currents in 1831. This work led him to discover that a conductor cutting the lines of force of a magnet creates a potential difference. Shortly afterwards he received an anonymous letter suggesting that his discovery could be applied to build large machines.

Image 11: *Tambre I Power Station - Noia (A Coruña). Built in 1932 and designed by the architect Antonio Palacios using Galician historicist architecture applied through a Romanesque-style façade transferred to an industrial building.*

The step towards the hydraulic dynamo was achieved by adding this discovery to the refinement of the water turbine made by Fourneyron in 1832, who built a 50 hp turbine. This turbine was combined with the dynamo invented by Werner Siemens (1886) and also incorporated Nicola Tesla's al- ternator (1887). In addition to these technological advances, the distribution system invented by Edison (1882) was added to the hydroelectric power plant, thus establishing the technological progress towards the development of the hydroelectric power plant at the end of the 19th century.

Image 12: Dynamo of the old Tambre I power station, exhibited for museum purposes in front of the main façade of the power station.

The advent of electricity was a technological breakthrough and brought about revolutionary changes that affected the situation and concentration of industries. Until the advent of electricity, industries were entirely dependent on coal mines as a source of energy. Before electricity, industries had to be located close to the mines or to cheap means of transport such as ports or railways. Electricity is an energy carrier that transports energy from power plants to consumption points. With alternating current and high voltage, energy can be transported to any location to meet the needs of the people who need it. The electric motor thus made it possible to work in independent units with territorial disconnection, being able to work at the necessary speed and to start and stop according to energy needs and requirements, increasing performance by at least 50%.

Figure 13: Transformation of electricity generated in a power plant for high-voltage transmission.

During the second half of the 20th century, electricity increased significantly because of the advantages of access at any point, the possibility of individualising and coordinating production units and of interrupting it when not needed. This immediate availability of energy anywhere and in the power required allowed electricity to be abused to extremes that can border on energy hedonism, which can easily lead to the conclusion that the energy problem is more one of abuse in consumption than of lack of production.

Figures 14 & 15: *Composition of two illustrations showing bad practices leading to excessive electricity consumption.*

The increase in domestic and especially industrial electricity demand in the first half of the 20th century led to the overexploitation of river basins. Once all possibilities for building new large reservoirs had been exhausted, thermal power plants were developed to further increase availability and output. Thermal power plants generate steam with the necessary pressure to drive the turbines, thus ensuring constant power generation. This is an advantage over hydroelectric power plants, which depend on the water regime and the state of the reservoirs, which is becoming increasingly erratic as the climate changes. This form of electricity generation has thus become established, making it possible to meet all increases in demand. On the other hand, the final energy uses that the energy vector of electricity allows are multiple, with the paradox that the final energy is the calorific energy, just like the primary energy used in the combustion of the thermal power plant, reaching this calorific energy through long transports and transformations.

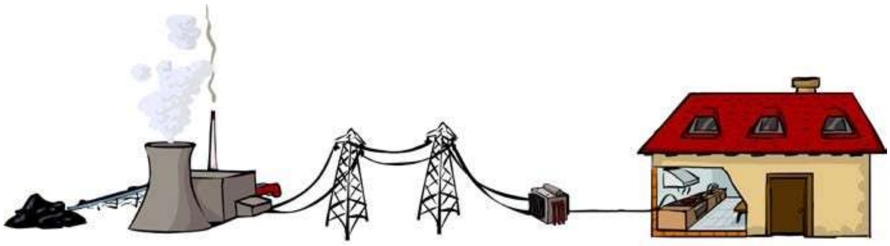


Figure 16: *Illustration showing how electricity allows energy to be transported over long distances by means of voltage transformations, with the consequent losses in order to obtain a final energy of the same nature as the initial thermal energy that generated the electricity.*

Since the 20th century, electricity has become a source of emissions responsible for increasing climate change. Electricity consumption has increased significantly, as is the case with the increased use of air conditioning and in desalination processes. Desalination is becoming increasingly important, especially where there is a decrease in rainfall levels and a greater irregularity in its distribution throughout the year as the population increases. These circumstances occur in the Canary Islands where, because of droughts in general, consequences can be observed such as the reduction of flows in ravines, the reduction of water levels in aquifers and reservoirs and the scarcity of water resources for human consumption. To combat this problem of scarcity of water resources for human consumption, determined by the increase in drought as climate change advances and tourism increases, Gran Cana- ria has had a seawater desalination plant since the 1970s, whose facilities have been growing and improving over the years. Today, this desalination and water treatment plant is a vital infrastructure for the supply of drinking water on the island of Gran Canaria, playing a fundamental role in the treatment and distribution of safe, quality water to the island's population. It currently has a production capacity of approximately 56,000 m3 of water per day. Now this quantity is sufficient to supply a large part of the island's population, even in times of drought or when the demand for water is high. This process is carried out using reverse osmosis technology, a process in which seawater is subjected to a series of semi-permeable membranes that remove salt and other pollutants, thus producing fresh, drinkable water.

The desalination plant uses electrical power to drive the reverse osmosis process and ensure efficient and continuous production of drinking water. This electricity comes from the Canary Islands power plant, which runs on fossil fuels, releasing a large amount of greenhouse gases into the atmosphere that contribute to climate change.

Image 17: *Photograph of a desalination plant with its thermal power station on the island of Gran Canaria.*

What did the emergence of the internal combustion engine with vectors from oil refining mean?

Oil was first extracted from drilled wells in 1859. This made it possible in the second half of the 19th century to experiment with the gas engine using the lighter distillation products, until it was perfected by Otto in 1876.

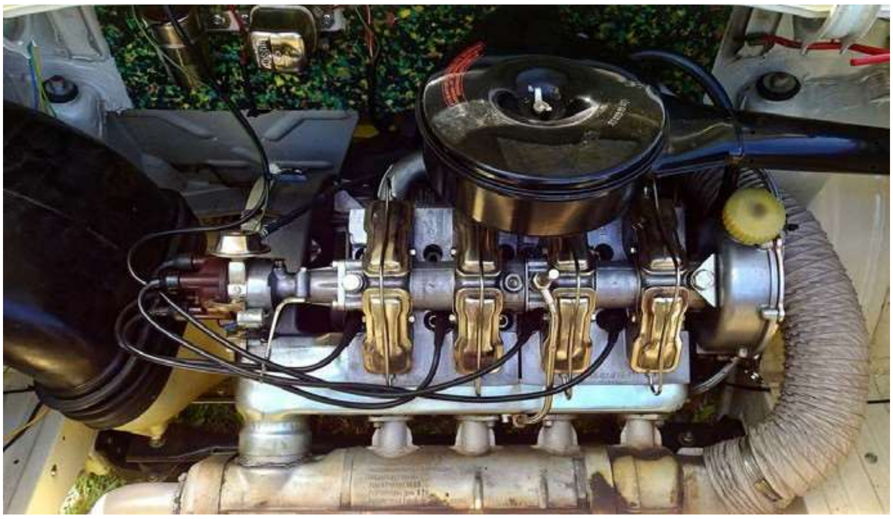


Figure 18: *Photograph of an internal combustion engine.*

The development of the internal combustion engine opened up a new source of energy, with the use of refined petroleum hydrocarbons as an energy vector, which very soon equalled in importance the use of mobile phones.

The use of petrol and diesel fuels was not a substitute for the old coal seams, although, as time would show, it was destined to be consumed at a faster rate, because these petroleum derivatives are very easy to transport and very efficient energy carriers for vehicle transport. Petrol was more transportable than diesel. In addition, oil allowed transportation through permanent pipelines while oil tankers transport it in large quantities and over long distances to refineries. It also leaves a minimal residue when burned, unlike coal, and is also much easier to store.

Image 19: *Photograph of an oil platform.*

Initially, the internal combustion engine did not achieve high power and efficiency, so it was unable to compete with the steam engine in its early days. Therefore, at the end of the 19th century, the internal combustion engine was unable to compete. In the 20th century, when the invention of the diesel engine led to the development of heavy oil-fuelled combustion engines with high thermal efficiency that could produce power outputs of up to 15,000 hp, the internal combustion engine gained the upper hand. Engines of this type were more efficient, so that the weight of the fuel itself (vector) was used for mobility, instead of carrying, like the steam engine, the additional load of water.

With the automobile, movement is no longer chained to rails and very little gradient. As a result, a vehicle can travel as fast as a train, being as it is a much smaller mobile unit and capable of going anywhere. The only condition it requires is to travel on roads. The first roads were shared with horse-drawn carriages. After 1910 they started to be paved with concrete. Like the electric vector, these easily transportable cars with the vector fuel in the tank can allow us to live anywhere.

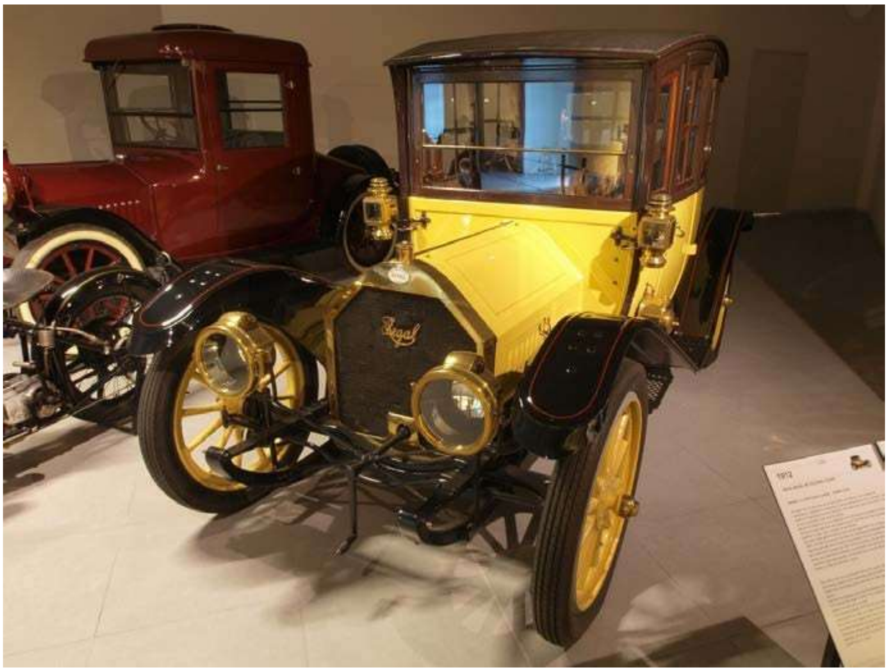


Image 20: *Photograph of vintage cars.*

Figure 21: *Illustration showing the two major energy vectors that enable living anywhere.*

The qualities of fast and safe transport caused the automobile to expand very rapidly, initially linked to businesses and then entering every household. This introduction of cars into families, often with more than one car per household, was due to the fact that cars became cheap with the emergence of the automobile industry.

Henry Ford, which facilitated their mass production. Over time, this increase led to large losses due to traffic jams, especially in large cities, which increased emissions, in addition to those resulting from the increase in units.

Image 22: *Photograph of a frequent traffic jam in cities.*

The introduction of the internal combustion engine in ships went hand in hand with the development of the automobile. In 1903, the American Wright brothers invented the aeroplane, which they also fitted with an internal combustion engine. These combustion-engine aeroplanes were not produced on a large scale until 1910. The expansion of this form of travel was encouraged by the expansion of anormal developed centres with vast and distant landing grounds. From these aeroplanes, propeller-driven aircraft developed into today's fuel-intensive jets. The development of aerospace technology led to the production of aircraft capable of exceeding the speed of sound, such as Concorde and fighter planes, as well as spacecraft and modern shuttles, all of which consume enormous amounts of energy.

This spread of internal combustion devices involves mobile sources with diffuse emissions which are therefore difficult to control, together with emissions from thermal power stations producing the electricity vector, and the growth of industries such as cement factories, have led to a significant increase in CO_2 in the atmosphere, which can lead to a rise in temperature. This is increasing, with mobility becoming more and more dependent on oil for more than 65% of its emissions, accounting for approximately 25% of emissions, which in absolute terms means 7 200 000 tonnes of CO_2, of which cars and lorries are responsible for more than 94%.

***Images 23 & 24:** Photographic composite of an aircraft and a cruise ship as other high-emission means of transport.*

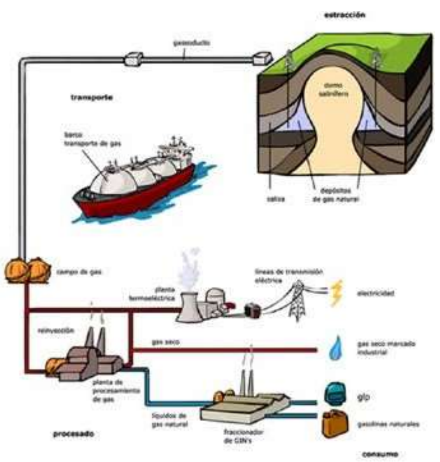
Each litre of petrol produces 2.5 kg of CO_2 and it is estimated that an average car during its lifetime produces 15 000 kg of CO_2 . This consumption is variable depending on the average speed: instead of going at 120 km/h, if you go at 100 km/h, it consumes about 50% less. The number of vehicles is well over 50 million. At this rate of growth in consumption, and also taking into account the large amounts of road, ocean and air travel, it is estimated that oil will be used up in about 50 years' time.

***Figure 25:** Illustration showing the daily transport of goods over intercontinental distances using internal combustion engine transports.*

Why is natural gas said to be the last vector of the 20th century?

Natural gas is the last carrier to be exploited in the 20th century. In many ways it is considered the ideal fossil fuel and is used to produce electricity in gas turbine power plants that are compact, highly efficient and can be built close to population centres, taking advantage of town gas distribution to produce electricity and heat.

Its main component is methane, the simplest of hydrocarbons, with only one carbon atom (to generate the same amount of energy as coal and oil, methane combustion produces only half the CO_2), so its use has been boosted in recent years since the Kyoto Protocol. But natural gas has risks, such as leakage, helping to increase the problem. If leakage accounts for 4%, the greenhouse effect is more than 3 times higher than burning coal. This risk is increased by the fact that areas through which gas pipelines pass are prone to attacks and leaks. Furthermore, it is believed that gas reserves at this level of use will not last much longer than 20 years.



Images 26 & 27: *Photograph of a natural gas plant with an illustration of the natural gas transport process.*

The As Pontes de García Rodríguez thermal power station is the largest generating unit in the Spanish electricity system, with an installed capacity of approximately 1,400 MW, demonstrating the commitment that was set in the second half of the 20th century to thermal power stations capable of producing a lot of electrical power. This power station consumed brown lignite from an adjacent mine, which is rich in sulphur. It is 35% efficient and produces 9100 GWh of electricity per year.

Based on what we have seen so far...

1. How did electricity affect industrial activity?
2. How did electricity go from being obtained from the renewable energy of water to being a major contributor to climate change?
3. How can it be explained that expectations for hydroelectric power are falling as climate change progresses?
4. Why did the internal combustion engine triumph over the steam engine?
5. Justify the conclusion: "*The energy carriers of the 20th century were major accelerators of climate change today*".
6. Why is natural gas considered to be an energy carrier that has less impact on climate change than oil refining if it is still a fossil fuel?

2.1. HOW IS CLIMATE CHANGE LIKELY TO AFFECT SEA LEVEL RISE?

In one of the scenes of the film "*Cinema Climantopia*", the Polish pupils arrive at the Lisbon aquarium, where they meet a group of Portuguese pupils with different science demonstration stands. When the Polish pupil asks what they are doing, one of the Portuguese pupils replies, "*showing you what is changing your life*".

Image 28: *Still from the film "Cinema Climantopia."*

Respond with what you know now:

1. In pairs, think about where you live, whether coastal or inland, and answer the following questions: Do you think any impacts of climate change on the ocean will *change your life*? Will it affect other countries in the same way and with the same intensity? What do you think are the main impacts of climate change on the ocean?
2. Once you have answered these questions, you can move around the classroom interacting with other pairs and sharing your answers with the aim of making a final summary as complete as possible, incorporating the information provided by other classmates that you consider correct to answer the initial questions.

Is the sea level rising?

Sea level rise is one of the most obvious impacts of climate change, which will continue to happen for centuries even if we were to abruptly stop greenhouse gas emissions today or reach the 2015 Paris Agreement target of keeping global temperature rise to below 1.5-2°C.

Since 1850, sea level has risen by an estimated 20-24 cm globally and continues to rise at an increasing rate.

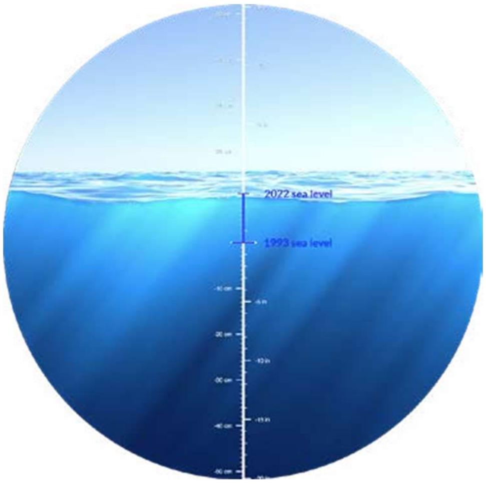


Figure 29: *Sea level rise.*

Respond with what you know now:

1. Why is the sea level rising?
2. Is it increasing evenly across the globe?
3. What do you think are the consequences of rising sea levels and sea temperatures?

Although sea level rise is one of the best-known impacts of climate change, people are often unaware of its true causes. Two drivers are responsible for this phenomenon, both derived from global temperature rise: the melting of continental ice and the thermal expansion of water. We will now take a closer look at each of them:

1. The melting of continental ice is the main cause of sea level rise. This ice, which used to be on the continent, now takes up extra volume in the form of liquid water in the ocean, causing sea level to rise. This is not the case with the melting of floating ice, as in the Arctic, where this ice is already occupying a specific volume and therefore does not contribute directly to sea level rise (although indirectly through a reduction in albedo).

This is the case of the thawing of:

- Greenland. It is estimated that since 2002 Greenland has lost 274 billion tonnes of ice per year, a higher rate than Antarctica, and is one of the main contributors to current sea level rise.
- Antarctica. It is the fourth largest continent after Asia, America and Africa. Its surface is 98% covered by ice. It is estimated that since 2002, Antarctica has lost 151 billion tonnes of ice per year. Remember that only the most vulnerable parts of Antarctica to melting ice protect us from a potential global sea level rise of 20 metres.

  Of particular concern in this regard is the so-called West *Antarctic Ice Sheet* (often referred to as the WAIS), where warming and ice loss have been much more intense in recent years. This melting is facilitated by the global increase in atmospheric temperature and, in addition, by warmer water entering the base of the continent.
- Glaciers. During the summer, large ice formations such as Alpine glaciers naturally melt and during the winter, thanks to the snow, they recover their surface. However, due to the global rise in temperatures, an imbalance between the two processes has been observed, contributing to the rise in sea level.

2. Thermal expansion of water is a phenomenon that is often overlooked because it is not as visible as the shocking images of melting ice, but it plays an important role in sea level rise.

Globally, the ocean has stored more than 93% of the heat resulting from climate change. This has greatly dampened the increase in atmospheric temperature but has also led to major changes in its physical properties and impacts on the living beings that inhabit it. Among these is a process known as thermal expansion or dilation. This phenomenon is based on the tendency of matter to change volume in response to temperature: when a substance is heated, the mobility of its molecules increases, maintaining a greater space between them and, therefore, increasing in volume.

Image 30: *Plaque in honour of the Okjökull glacier.*

So, having seen the different agents responsible for sea level rise, it is time to take a joint view and assess the magnitude of each one. It is difficult to quantify their individual contribution, but according to information provided by recent studies, in the period 1993-2016, the different role of each is represented in the following graph:

Figure 31: *Contribution to sea level rise.*

Based on what we have seen so far...

1. Did you know all the factors involved in sea level rise?
2. Access the following **simulator** and analyse what will happen to your city (if it is a coastal city) or to a representative coastal tourist site in your country if the global sea level were to rise by 0.8 m, as projected at the end of the century if emissions continue at the current rate.
3. Carry out the lab practical entitled "*Why is the sea level rising?*" from the e-book "*Designing lab practices on climate change for dissemination through school stands at tourist sites*" and answer the following questions:

    a. What happens in each of the models with sea level rise? If there are differences, what are they due to?
    b. If any of the models do not influence sea level rise, does their melting have any global impact?
    c. What do you observe in the second part of the practice and how does it relate to the previous practice?
    d. Taking both sides of the practice into account, what are the drivers responsible for sea level rise?
    e. Research on the possible impacts of global sea level rise.

However, in this context of melting ice, it is important to note that this phenomenon also has important consequences for the fauna of these regions.

In the Arctic, the polar bear, the largest predator in this region, stands out. In the Arctic, it has been observed that in recent years the melting cycle has started earlier and lasted longer. In other words, each year the Arctic ice sheet is shrinking, making it more difficult for polar bears to hunt seals and other animals that are their main source of food. Before the onset of the general weakening of the sea ice, polar bears were able to hunt easily on stable sea ice. However, following the melting of the ice, polar bears are forced to swim towards seals in an attempt to hunt them unnoticed while resting on pieces of floating ice, with a high failure rate. In this regard, some researchers suggest that it may be because this technique would require a greater amount of energy. As a result, recent studies have concluded that polar bear populations could be reduced by 30 per cent by 2050.

Image 32: *Polar bear (*Ursus maritimus*) populations could decline by 30% by 2050.*

However, in nature, ecosystem interactions are complex and the impacts of climate change in the Arctic do not only affect polar bears. As Ms. Rojas explains to her students in the film "*Cinema Climantopia*", seals are precisely another species affected by the impact of climate change as one of their food sources is reduced:

LADY ROJAS

That's right. Seals are predators and prey. What is happening is that with climate change the Arctic waters are warming and the cod living under the sea ice are moving north or declining.

FOREIGN PROTAGONIST 2

And do seals eat cod?

LADY ROJAS

That is, as predators they are going to run into that problem.

Image 33: *Still from the film* "Cinema Climantopia."

In the case of Antarctica, there are also relevant impacts on the region's fauna. One example is that of the emperor penguin (*Aptenodytes forsteri*), which depends on the existence of a developed ice sheet for its reproduction process. Its eggs are incubated mainly on firm ice during the Antarctic winter, and it takes several weeks on the ice for the chicks to grow and develop their plumage.

A 2023 study published in the prestigious journal *Nature analysed* the variability of the populations of five emperor penguin colonies located in Bellingshausen (West Antarctica) and the results observed as a result of the intense thaw are alarming: four of these colonies lost all their chicks, with the death of about 10,000 birds. The young die from drowning or even hypothermia because they are submerged in the water without having developed their plumage, so that they are unable to withstand the low temperatures and are abandoned by the adults.


Images 34 & 35: *Illustration and photograph of an emperor penguin with its young.*

After watching the film...

In the film "*Cinema Climantopia*", Miss Rojas explains to her students: "*These penguins live in Antarctica, it is the only pole where we can find them*".

1. The predicted melting of ice by the year 2100 means that the survival of penguin populations is clearly at risk. Research online what the *dispersal capacity* of a species is. Once you are familiar with this concept, answer the following question: in a context of climate change and intense ice melt, do you think penguins could easily find new habitats suitable for their biological cycle?

The consequences of rising sea levels

In the scene of "*Cinema Climantopia*" that takes place in the oceanarium in A Coruña, one of the protagonists states the following: *"Easy. If the sea level rises, the sea reaches more land and, therefore, floods occur".*

After visualising the scene...

1. What do you think are the consequences of flooding in coastal areas?
2. What measures do you think can be taken in coastal areas to address them?

Image 36: Still from the film "Cinema Climantopia."

As a result of these floods, there are many other consequences of sea level rise, including the following:

"Human migration: this gives rise to what we refer to as climate refugees. Some studies suggest that by the end of the century, more than 2 billion people will have had to migrate from their country, most of them from impoverished countries with a significantly lower capacity to respond to the impacts of climate change.

" Loss of coastal areas, habitats and infrastructure.

"Saline water intrusion into coastal aquifers. If sea levels rise, saline water is more likely to enter and contaminate an underground aquifer. If we add to this a decrease in precipitation, as is expected in many areas, we see a scenario in which freshwater supply will be scarce.

" Disappearance of low-lying islands.

" Increased coastal erosion.

"Intensification of river flooding: the sea level sets the base level of the rivers, so if the sea level rises, the river level rises as well. This can intensify the effect of flooding, which is particularly serious in areas already prone to flooding.

However, although sea level rise is a generalised phenomenon, it occurs unevenly across the globe due to multiple causes.

phenomena, among which the topography of the ocean floor itself plays an important role. Thus, for example, some areas such as the westernmost Pacific have experienced an increase 4 to 5 times greater than the global average (up to 15 mm/year), a region where, in turn, the highest percentage of coastal poverty in the world is to be found.

The populations of these countries are particularly vulnerable due to their lower economic development, and are therefore less able to adapt their infrastructures and support their populations in the face of sea level rise. Thus, we can conclude that a country's vulnerability to sea level rise depends not only on its altitude in relation to sea level, but also on its socio-economic development.

It is therefore the most vulnerable populations, with the least responsibility for greenhouse gas emissions, that are most affected by sea level rise.

One of the most extreme cases today is in Kiriba- ti, a country in the Pacific Ocean made up of 33 islands and home to more than 100,000 people. It is considered one of the countries most affected by rising sea levels, where its islands are expected to be submerged within 15 years, which is why the country has set up a programme called "migration with dignity", in which it offers its inhabitants the possibility of moving to other countries such as Australia and New Zealand, and under which it has even bought land in other countries to house its climate refugees. It is one of the examples of how climate change can affect not only people but also the cultural heritage of humanity. The Intergovernmental Panel on Climate Change (IPCC) highlights in its Sixth Report how the forced migration of Kiribati's inhabitants threatens the permanence of its culture, characterised among other things by its traditional martial arts, folk music and dance.

Based on what we have seen so far...

1. The film "*Cinema Climantopia*" shows such different scenarios as the Canary Islands or Poland. Research online how much the sea level is expected to rise in each of these territories by the end of the century and compare the possible consequences for them depending on their geographical characteristics.
2. What adaptation measures can be taken in coastal environments to cope with sea level rise?

Image 37: *Kiribati.*

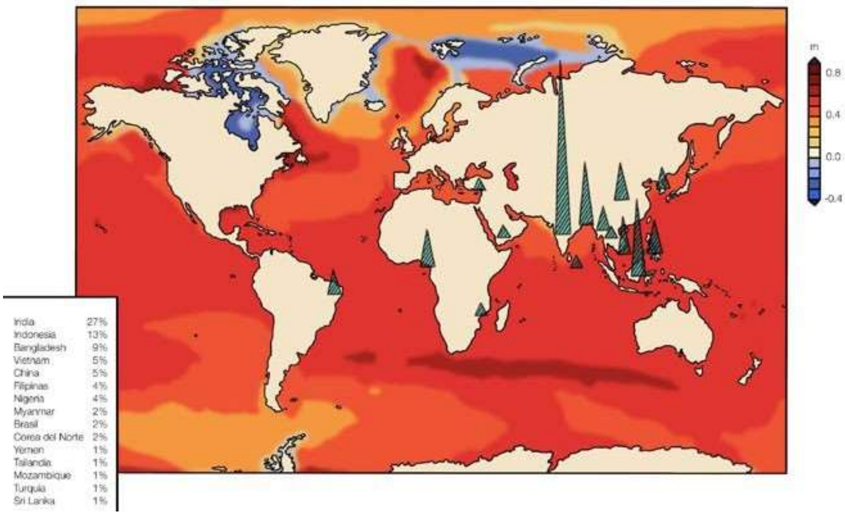


Figure 38: *Percentage of coastal poverty and sea level rise at the end of the 21st century.*

Sea level rise forecasts

The projections for sea level rise are not encouraging. If greenhouse gas emissions continue at the same rate as today, global sea level is expected to rise by 0.84 m by the end of the century compared to the period 1986-2005.

As we indicated at the beginning of this chapter, sea level rise is already an unstoppable phenomenon: the amount of heat injected into the atmosphere is such that even if we were to suddenly stop greenhouse gas emissions, the inertia of the processes already underway is so great that they would not cease for hundreds or thousands of years to come. It is up to us, therefore, to ensure that they do not at least intensify further, with catastrophic consequences.

2.2. WHY DOES OCEAN WARMING DUE TO CLIMATE CHANGE THREATEN OCEAN PRODUCTIVITY?

The oceans cover more than 70% of our planet's surface and, as noted above, according to the latest IPCC data, the ocean stores more than 93% of the heat from climate change.

Image 39: *Where does the heat from climate change go?*

In this section we will focus on two major impacts of this temperature increase.

1. Ocean stratification

If we were to analyse how the heat stored in the ocean is distributed, we would find that most of it accumulates in the upper 700 m of the water column. This results in a decrease in the density of surface water, which will have major implications for oceanic primary production.

The surface layers of the water column are home to phytoplankton - on which oceanic primary production largely depends - because they need to live in the photic zone to carry out photosynthesis. At the same time, it needs certain inorganic nutrients (P, N and S) that come from the ocean floor and reach the surface through a variety of mechanisms.

Because of the decrease in the density of ocean surface water, communication between the surface and deeper layers of the water column becomes more difficult. This has two major implications:

"In mid-latitudes, the resulting oceanic stratification will hinder the upwelling of nutrients to the surface layers where phytoplankton reside, leading to a decline in oceanic primary production.

"In polar latitudes, the limiting factor for oceanic production is access to light. In these areas, stratification is generated mainly by the melting of ice because of rising temperatures, so that fresh (less dense) water enters the ocean, leading to higher densities. As such oceanic stratification occurs, phytoplankton remain longer in the surface layers, so that oceanic primary production is expected to increase slightly at these latitudes in the future.

The impact of oceanic warming is amplified along the food chain, as a decline in phytoplankton availability will mean a decline in the successive trophic links that ultimately depend on it.

Based on what we have seen so far...

Carry out the lab practical entitled "*Why are we so concerned about global warming?*" from the ebook "*Designing lab practices on climate change for dissemination through school stands at tourist sites*" and answer the following questions:

First part of practice:

1. What do you observe when you remove the splitter tank and why does this happen?
2. How do you think this phenomenon can be related to climate change in reality?

Second part of the practical part:

1. How does this second part of the practice relate to the previous one, and to reality?
2. What does the movement of the cards represent in reality?
3. What happens when an oil layer is added, and how will it affect oceanic primary production?
4. At polar latitudes, phytoplankton are subjected to large ocean currents that transport them to deeper areas. How do you think ocean stratification will affect polar areas?
5. How can ocean stratification affect the oxygen concentration of the ocean?
6. Will changes in ocean productivity affect all countries in the world equally? Research the impacts on food security on the web.

2. Oceanic deoxygenation

The ocean, like the atmosphere, contains oxygen. It comes either from the action of photosynthetic marine organisms or from the atmosphere itself. Oceanic deoxygenation is an often neglected but highly relevant phenomenon, by which we mean a decrease in oxygen concentration in the deeper waters. This occurs due to 3 main factors:

"Rising ocean temperature, which reduces oxygen solubility.

"Ocean stratification, which hinders the diffusion of oxygen from the surface layers to the deep layers.

"Eutrophication processes in coastal areas as a consequence of nutrient inputs leading to excessive phytoplankton blooms, preventing access to light and oxygen for aquatic communities. In fact, more than 700 coastal areas and semi-enclosed seas around the world have already been identified as having hypoxia problems.

Globally, it is estimated that the world's oxygen inventory in the ocean has decreased by around 2%. This figure may seem insignificant, but in both coastal areas and open oceans, oxygen depletion results in what are known as dead zones: hypoxic areas that are not compatible with aerobic life.

2.3. SEA LEVEL RISE AND ITS CONSEQUENCES IN EUROPE: EFFECTS ON TOURISM

Islands and coastal areas are among the most vulnerable tourist destinations to the impacts of climate change due to multiple threats such as extreme weather events, sea level rise, changes in the circulation patterns of ocean currents or loss of ecosystems.

Rising sea levels are one of the major threats to the tourism sector due to both the flooding of coastal land and the increase in coastal erosion, as a large part of tourist activities take place in these areas. Thus, increased coastal erosion will put at risk not only the beaches themselves but also frontline infrastructures such as promenades, seawalls, breakwaters, jetties and harbours. In Europe, the EUROSION study found that 20% of the European coastline is receding or is being artificially destabilised.

The Bruun rule, although with limitations and conditioned by the characteristics of each area, allows us to simplify a relationship between the rise in sea level and the retreat of the coastline. It estimates a range of 50-100 m of retreat for each metre of sea level rise.

Using some of the countries in our film *"Cinema Climantopia"* as illustrative examples, we will analyse some of the projections of sea level rise and its impact on tourism in some European areas.

> "The Iberian Peninsula, the Canary Islands and the Balearic Islands, with about 8000 km of coastline, present sun and beach tourism as an important economic driver. Spain has a wide variety of coasts, ranging from impressive vertical cliffs to extensive sandy beaches, so that the rise in sea level will mean a significant retreat of both types of coastlines due to erosion and flooding processes, putting at risk the tourist activity developed in these areas.
>
> In this sense, Spain is one of the most vulnerable countries in Europe to rising sea levels, where it is estimated that the coastline will recede by 3 m by 2040 along the Cantabrian coast, Galicia, and the north of the Canary Islands. In addition, there is a need to invest more resources in the prevention of these impacts and the protection of existing coastal infrastructures.


Images 40 & 41: *Orzán Beach (A Coruña, Galicia) and Las Catedrales Beach (Galicia).*

Image 42: *Maspalomas beach (Gran Canaria).*

"Portugal. The Portuguese coast has been facing an intense process of retreat in recent years due, among other factors, to the reduced rate of sedimentation of rivers because of the construction of dams and other structures.

As the sea level rises, the depth of the sea increases and the waves that reach the coast have greater energy, increasing their erosive and sediment transport capacity. Thus, the rise in sea level, and the consequent intensification of coastal erosion, will have a significant effect on the already sediment-deficient Portuguese coast.

This has important effects on the tourism sector, mainly linked to the reduction or even total loss of sandy beaches and the loss of coastal infrastructure related to tourism activities such as restaurants, bars, houses, etc. This is the case in some of the most touristic areas of Portugal such as the Algarve.

Image 43: *Algarve (Portugal).*

Figures 44 & 45: *Examples of coastal housing protection in Portugal affected by the disappearance of dunes in the context of sea level rise.*

"Poland. Located in Central Europe, Poland has a small stretch of coastline on the Baltic Sea. This coastal area is approximately 500 km long and includes major tourist cities such as Gdansk, Gdynia and Sopot.

This means that rising sea levels pose a threat to the north of the country, putting at risk various tourist areas of great importance to the country, some of which have been the subject of recent studies due to their vulnerability, such as Gdansk, Karwia and the Hel Peninsula. Gdansk is a densely populated rural and urban area that is threatened by potential floods and flooding. The Hel Peninsula consists of a large sandbank, more than 30 km long, used for tourism, which is in danger of disappearing due to the intensification of erosion processes. Karwia, on the other hand, is home to ecologically valuable marshlands that are also threatened by rising sea levels.

Images 46 & 47: *Gdanks (Poland) and receding coastline in Gdynia (Poland). Right image CC licence by Tomasz Sienicki.*

Image 48: *Trzęsacz (north-western Poland) on the Baltic Sea coast. The ruins of a church built in the early 16th century that was destroyed by the advancing sea can be seen.*

2.4. EFFECTS ON EUROPEAN MARINE BIODIVERSITY. CONSEQUENCES ON INVASIVE SPECIES AND FISHERIES IN THE NE, SW AND SUBTROPICAL ISLANDS.

How does ocean warming impact European marine biodiversity?

The ocean is fundamental to life on Earth, harbouring more than 200,000 known species. However, despite its importance, its conservation status is a cause for concern, which is why the protection of its biodiversity is one of the Sustainable Development Goals of the 2030 Agenda: SDG 14 (underwater life).

Figure 49: *SDG 14: Underwater Life.*

Europe's marine biodiversity is currently under great pressure. Many marine species are already at risk due to different impacts such as overfishing, pollution or habitat fragmentation. Ocean warming may intensify the pressure on these species with devastating effects, especially on those already at the limits of their thermal tolerance range and may also lead to the emergence of new species from other areas migrating in search of optimal conditions for their development, although this will depend on their dispersal capacity.

According to a report published in 2019 by the European Environment Agency (EEA), the current state of biodiversity in Europe's seas can be summarised in two main conclusions: almost all marine species are in a poor state of conservation and most of Europe's marine ecosystems are in decline.

In this sense, rising ocean temperatures have allowed species from other warmer regions to populate new marine areas that were previously too cold for them to thrive. Here are some examples from different European regions.

The Mediterranean Sea is an important biodiversity *hotspot*. These are regions that are home to high biodiversity and are highly threatened by human activity. Specifically, the Mediterranean Sea is warming 20% faster than the global average, experiencing in recent years an intense process of tropi- calisation (increase in non-native species of tropical origin), being one of the seas with the highest number of invasive species in the world.

As a result of the increase in temperature in the Mediterranean Sea, species have appeared mainly from the Indian Ocean and the Red Sea via the Suez Canal. This is the case of the rabbitfish (*Siganus rivulatus*), which is particularly harmful to the ecosystem as it tends to feed on marine vegetation cover, converting underwater kelp forests into large areas of bare rock, with the consequent impact on the native species that inhabited or depended on them. A recent study, comparing areas in the Mediterranean where this species was present with others where it was not, showed how its presence led to a 65% reduction in algal cover in the area and a 60% reduction in algal and invertebrate biomass.

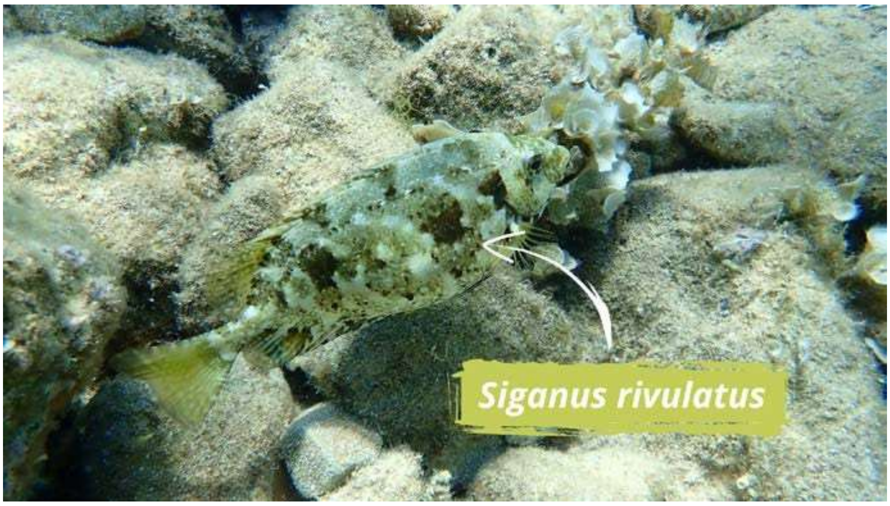


Image 50: *Rabbitfish (Siganus rivulatus).*

The effects of climate change are also palpable in the Atlantic Ocean, where a process of topicalization has also been observed in some regions in recent decades. This is the case of the Greek coasts, where a warming of 0.24 ºC per decade has been observed.

since 1974. Therefore, different species of tropical origin have also settled in recent years. Among the first species to migrate are the triggerfish (*Balistes capriscus*) and the Senegal sole (*Solea senegalensis*).

In recent years, other species have also appeared, among which we can highlight the black polecats *Kyphosus sectatrix* and *Kyphosus vaigiensis*. These species are strict herbivores and similar to the case in the Mediterranean, it is feared that they may have repercussions on the region's own algae, increasing even more the concern about the decrease in temperate-cold algae that has taken place in Galicia in recent years as a result of the increase in water temperature.

Image 51: *Triggerfish (*Balistes capriscus*).*

In the study "*Evidencias e Impactos del Cambio Climático en Galicia*" *(Evidence and Impacts of Climate Change in Galicia*), promoted by the Xunta de Galicia in 2009, more than 50 commercial species from warm water latitudes were already located in Galicia. In contrast, other species such as flounders or laminaria algae are decreasing in density in Galician waters and increasing in more northerly waters, possibly due to the impact of rising temperatures on their distribution.

In the Baltic Sea we also find different consequences of climate change on marine biodiversity, in addition to other environmental impacts such as eutrophication. The Baltic Sea has also undergone a process of subtropicalization which has allowed species of great fishing importance typical of subtropical areas such as sardines (*Sardina pilcardus*) or anchovies (*Engraulis encrasicolus) to* migrate to it in recent years, reducing the abundance of others such as herring (*Clupea harengus*).

Image 52: *Sardine (Sardina pilchardus).*

Ocean stratification: a global food security issue

In a world with such a rapidly growing population as the human population, exceeding the dizzying figure of 8 billion people, an increase in the consumption of fish and other foods from the ocean seems inevitable in order to feed the entire population of the planet. In this regard, according to data from the latest IPCC report on oceans and the cryosphere, a significant reduction in the biomass of marine communities is generally expected to take place during the 21st century, with a consequent effect on potential future fish catches.

Against this backdrop, the effects of ocean stratification on fisheries production are of real concern. A recent study developed a model of how such a change in primary production would affect the fish catches of different countries, outlining a future scenario of uncertain food security. This study revealed that, broadly speaking, those countries with the greatest dependence on fisheries (both in economic and food security terms), which are also home to the largest percentage of the world's population, will see their fish catches decline. On the other hand, a smaller percentage of countries, including several European countries, which are less dependent on fisheries, will see their potential catches increase slightly.

A global vision...

The graph below shows how fish catches are expected to vary in the future in some countries of the world, as well as their dependence on fisheries in food and economic terms. After analysing the graph, answer the questions posed:

1. What trend does each of the quadrants represent in terms of the variables studied?
2. It compares the expected trend for the countries to which the protagonists of the film belong and, based on the contents studied in this chapter, provides an explanation for it.
3. Research the number of inhabitants of each of the countries represented in the different quadrants. What conclusion do you draw?

__Figure 53:__ Percentage change in potential future fish catches in some countries of the world.

Once you have finished the unit, answer the initial questions again using what you have learned:

1. Why is the sea level rising?
2. Is it increasing evenly across the globe?
3. What do you think are the consequences of rising sea levels and sea temperatures?

3.1. SOIL AND FORESTS AS CARBON DIOXIDE SINKS

In the Galician scene of "*Cinema Climantopía*", three students taking part in the school conference on the Ría de Muros and Noia see a eucalyptus tree that seems to them to spoil the landscape and therefore arouses their curiosity. They then approach two shellfish gatherers who are taking a break from their activity to ask them about this species.

Image 54: *Still from the short film "Cinema Climantopía" showing three students participating in the Ría de Muros and Noia school conference taking an interest in the eucalyptus tree on the left of the image.*

The shellfish gatherer Maruxa points out the large number of eucalyptus trees that can be seen from there and explains that the problem with eucalyptus trees is that they absorb all the water, which dries out all the land, making it impossible to grow crops. His colleague adds that they help fires to spread. She tells them that these eucalyptus trees that they visualise are the reason why people say "Galicia is always on fire". The student who takes on the role of journalist adds that they also affect climate change. The shellfish gatherer Maruxa intervenes again to say that they affect the whole ecosystem and describes them as a plague because they are out of control, as are the fires, so we are going to suffer the consequences.

The following day, at the end of the final of the international youth conference volleyball tournament between Spain and Peru, the students take the opportunity to visit Monte Pindo, which can be seen from the tournament court.

There they meet the President of the Monte Pindo Association and two of the students in the role of journalists ask him for an interview, which he grants them, to find out about the great fire of 2013.

Image 55: *Still from the short film "Cinema Climantopía" with two shellfish gatherers explaining the problem of eucalyptus trees in the Ría de Muros and Noia.*

Image 56: *Still from the short film "Cinema Climantopia" showing Spain and Peru playing the final of the Conference tournament on bilateral international work on Europe and America during the pandemic.*

In the interview he explained the alarming consequences of the 2013 fire with the 3 days that terrified the population, damaged houses and generated a large amount of sediment that affected the nearest shellfish bank and left the land eroded. He justified the rapid expansion by the introduction of invasive species, especially eucalyptus. He also referred to the measures taken to minimise these impacts, such as planting grasses and obtaining a germplasm bank to recover lost native tree species. He concluded by imploring that the forest should not be burned and recommending that more thought be given to prevention because the political focus is too much on extinction.

In the current context of climate change, agricultural and forestry soils are subject to impacts that lead to their degradation and may reach points of no return, leading to desertification. The causes of this degradation are diverse and are being amplified by climate change. In the film "*Cinema Climantopía*", this type of problem in Galicia is shown, such as the expansion of pyrophytic species.

such as eucalyptus trees which, with periods of severe drought and heat waves accompanying climate change in the region, increase the risk of fires. At the same time, torrential rains, which are becoming more frequent, cause heavy erosion and the passage of large amounts of sediment that put river and estuarine ecosystems at risk, blocking gills or covering shellfish beds.

Image 57: *Still from the short film "Cinema Climantopía" showing the interview with the President of the Monte Pindo Association explaining the effects of the 2013 fire.*

Image 58: *Illustration of crown fire in eucalyptus (author Sarela Lorenzo Robledo).*

Arable land covers 12-14% of the earth's surface and is essential for the nutrition of a constantly growing population. Soil formation is a process that requires long geological times and in which climate is fundamental, to the extent that different rocks in different climates can give very similar soils, and the same rock in different climates can also give different soils. For this reason, the influences between soil and climate are mutual, with climate change affecting soil structure and productivity.

One of the main problems that climate change brings for the soil is heating stress. This increase in the surface temperature of the soil is the impact of the land-based blind caused changes in the start and end of the growing seasons, reductions in crop yields and a decrease in the availability of fresh water, leading to water stress on vegetation.

Figures 59 & 60: *Climate change induced droughts and floods in the context of climate change.*

The changes that climate change is inducing in the soil are of such a magnitude that they threaten the dynamic equilibrium that has allowed it to sequester approximately 30% of total anthropogenic carbon emissions. Soil warming means an increased risk of mineralisation of the organic matter that fertilises the soil, which may lead to a loss of fertility while at the same time feeding back into the problem, because soil, after the oceans, is the second largest sink for C. Climate change puts this sink role at risk, in which case, as it retains 2/3 of the C in terrestrial ecosystems, it could become a source of C, thereby contributing to an increase in global warming.

Image 61: *Photograph of a soil sample showing its richness in organic matter due to its black colour.*

Another factor in the impact of climate change on soil relates to the effects of increased frequency of extreme precipitation events. Increasingly heavy rainfall leads to increased surface flooding and soil erosion, as well as increased water stress for plants. Heavy rainfall and flooding can therefore delay sowing, increase soil compaction and cause crop losses through anoxia due to root compaction. At the same time, increased rainfall also means an increase in the washing away of soil components, with losses of mineral salts which are necessary nutrients for the quality of soil fertility.

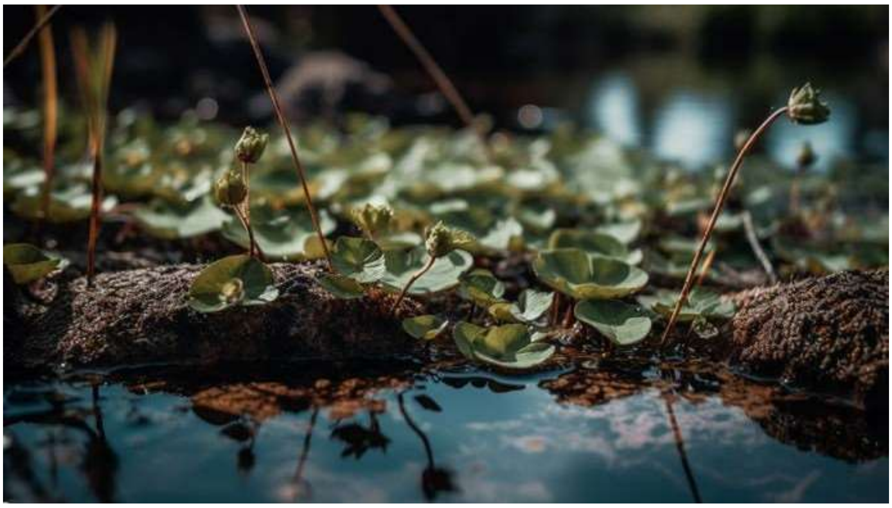


Image 62: *Photograph showing the effects of floods eliminating crops and the emergence of species typical of flooded soils.*

Respond with what you know now:

1. How do high temperatures affect soil carbohydrate loss?
2. How does soil tillage influence soil carbon loss if tillage coincides with warm days?
3. How does continuous torrential rainfall affect soil fertility? Are the effects the same if the soils are very sandy (very porous) as if they are very clayey (not very porous)? Justify the answer.

3.2. RELATIONSHIP OF FIRES TO CLIMATE CHANGE AND THEIR EFFECTS ON SOIL PROPERTIES

Why is climate change considered likely to exacerbate fire risks?

Forest fire regimes are mainly driven by climate and weather phenomena such as heat waves and strong winds, fuels and people. In turn, fire fuels are often increased by climate change because more CO_2 increases the rate of photosynthesis. In addition, alternating heavy precipitation with periods of drought stimulates understory fuels and tree growth.

Image 63: *Photograph showing the importance of undergrowth in the proliferation of forest incentives.*

With climate change, its impact on fuels and the spread of large monocultures of pyrophytic species that facilitate crown fires, such as eucalyptus, there is a greater risk of increased fire regimes in many regions of the planet. This is predicted by current research that suggests a general increase in the area affected and the occurrence of fires. In this line, there are studies linking the increase in affected area over the last four decades to climate change. Studies on the boreal region, which represents one third of the planet's forest area, project a trend that, with the advance of climate change, fires will increase sharply, and may reach up to 4-5 times the maximum values at the end of the 20th century.

Image 64: *Photograph of the 2013 Monte Pindo fire showing the risk of leaving timber stores next to houses, as well as other highly combustible elements.*

Faced with this worrying scenario of the effects of climate change on fires, other fronts must be opened to accompany the now classic one of extinguishing fires. By extinguishing fires, many states and organisations have achieved a very high level of efficiency in fire management. However, in the face of a warmer and drier future climate, it will be necessary to deal with the new challenges that are already emerging.

States that are very well equipped for firefighting, such as Canada, will be significantly surpassed in 2023, starting in an unusual period for fires in the boreal region, coinciding with a spring advance that has been experienced lately in boreal territories. This series began on 1 March 2023, increasing in intensity for three months, until its extinction on 5 June 2023. During this time, there have been
2,214 fires that have destroyed 3,800,000 hectares, which meant the loss of 0.4 of the total area of Canada. On another territorial scale, in the autonomous community of Galicia, from 3 August to 15 August 2006, there were around 2,000 fires, affecting inhabited areas and causing 4 deaths, generating serious respiratory difficulties for many people and a Dantesque scenario. This fortnight of fires throughout the territory remains in the memory of the Galician people, despite the fact that this is a European region with many fires, due to the fact that it has one of the highest densities of forest mass in Europe, with summers prone to fires due to having several weeks of consecutive hot and dry weather, with sandy soil that does not retain water and, therefore, in these circumstances causes the vegetation to dry out, coinciding this dry weather with winds from the NE that can be strong.

Image 65: *Photograph of the 2013 Monte Pindo fire showing a heli-copter acting as a sophisticated and effective technical means of extinguishing the fire.*

Image 66: *Photograph of the 2013 Monte Pindo fire showing the descent of the fire from the summit.*

Examples such as that of Galicia in 2006 showed that, although Galicia is one of the best equipped and prepared autonomous communities in Spain to extinguish fires, effective firefighting disappears in the face of such a concentration of fires. On the other hand, the seasonal decontextualization of fires means that they occur when seasonal operations are deactivated due to the seasonal nature of the weather conditions, which are low risk. This was also the case in Galicia between Friday 13 October and Monday 16 October 2017, in the middle of autumn, an extremely wet season in this region with an influx of Atlantic fronts. In just 4 days, when the special fire-fighting services were already inactive, an area approximately four times the size of Vigo, its largest city, burned. Those uncontrolled fires were

were because of Hurricane Ophelia, whose winds spread the burning ashes that started new outbreaks and put the city of Vigo at risk. But this extreme event, which was totally abnormal for the climate of this region, would not have had these effects if it were not for the anomalous heat of that month of October and the lack of rain. Once again, this wave of fires claimed four Galician lives.

Image 67: *Photograph of the 2013 Monte Pindo fire showing the arrival of the flames in the village.*

Concern for human lives due to fires, in the context of climate change, must enter strongly into political agendas. This was also the view of the Prime Minister of Portugal in 2017, four months before the fires in Galicia in mid-October, during the passage of Hurricane Ophelia. These statements referred to the tragic death of more than 60 people in the Pedrógão Grande fire. The tragedy also resulted in hospitalised injuries. Of the dead, 30 were found in their vehicles on roads in Leiria, where there were eucalyptus plantations.

These examples of fire cases in Canada, Galicia and Portugal are evidence for extending fire suppression policies to new fields such as prevention, bearing in mind the evolving scenarios of climate change. This is because in the future, fire regimes are expected to be temperature driven with warmer conditions and longer fire seasons together with hitherto anomalous weather periods, bringing forward and delaying the usual incentive periods.

Image 68: *Photograph of the fire in Pedrogão Grande by Lucília Monteiro (Source:* Visão) *em Portugal onde se visualizan os coches nos que faleceram os ocupantes.*

Image 69: *Photograph of the 2013 Monte Pindo fire showing how he offers help from the house using a hose from the house itself.*

Climate change is expected to further increase the occurrence and severity of fires, leading to larger fires, in more seasons, with more severity and area affected, and therefore more difficult to extinguish. According to several studies, the area affected in the next century can be multiplied by a factor of 2 to 5 times the area affected in the 20th century. This expected increase in the frequency of fires, which in turn are expected to be of greater magnitude, requires that, without lowering our guard in extinguishing them, the emphasis should be placed on prevention, with an emphasis, from school age, on environmental education on this subject so that they are involved in prevention measures in the localities where they live, but also in those they visit as tourists.

Image 70: *Photograph of the 2013 Monte Pindo fire in which tourists stand to view the effects from a distance.*

Respond with what you know now:

1. Explain the changes in the fire regime in fire timing, increased frequency, and intensity of burning that may be induced by climate change.
2. How is it possible that the passage of Hurricane Ophelia over the outskirts of Galicia in mid-October, an unexpected time for fires in Galicia, could cause fires of such a magnitude as to cause alarm in part of the city of Vigo, and at the cost of four lives?
3. How can 50% of Portugal's victims in the tragic Pedrógão Grande fire be linked to the forest management system in the layout of public roads?

Why are fires considered to increase desertification?

In our area, fires usually occur in summer, a dry and hot season, followed by torrential rains, which can erode large quantities of soil, which is more fragile if it has suffered combustion of its organic matter, in addition to the washing away of large quantities of nutrients mineralised by the combustion. These erosive effects are greater when the burned forests are in mountainous areas, mainly because the subsequent heavy rainfall will generate erosive dragging of the soil.

***Image 71:** Photograph of the 2013 Monte Pindo fire showing how Monte Pindo was left.*

Although heat normally affects the first centimetres of soil, underground fires are frequent and can consume the organic matter of the soil in a slow combustion due to the low availability of oxygen for a long time. This, apart from making it difficult to detect the continuation of the fire and to extinguish it, facilitates the combustion of the roots and increases the risk of erosion. These erosion risks are particularly important on steep slopes. It lies in the fact that heat consumes part of the organic matter, especially the roots, which tend to burn under the soil and can alter the stability of aggregates, eliminating a significant part of the organic matter. On the other hand, water absorption and retention, porosity, aeration and infiltration capacity decrease in bare soil after a fire. Therefore, after a fire there is usually a reduction in the availability of water in the soil and an increase in surface runoff and therefore erosion. When burnt forests are on slopes, with the arrival of heavy rainfall, water generates significant runoff downhill, carrying away all the matter that has lost its hold as a result of the fire, especially due to the loss of roots that retain the matter and the loss.

The desertification process is favoured because part of the total nitrogen is lost through volatilisation. But the magnitude of the temperature is such that other fundamental nutrients such as phosphorus, magnesium or calcium, and partially potassium, can be returned from the burnt organic matter by the ashes, so that after the fire there can be an increase in fertility, ephemeral but crucial for the regeneration of the forest, which is why they recommend massively sowing seeds of grasses in the hope that the first rains will be gentle.

Image 72: *Photograph of the 2013 Monte Pindo fire showing firefighting personnel.*

The greatest risk is the loss of nutrients by washing away when heavy rainfall arrives, either through leaching or surface erosion, especially on steep slopes or when there is no soil structure and vegetation capable of quickly fixing and exploiting this fertility, which should be encouraged by mass sowing of grass seeds. If the sowing of grasses is successful, which can be done with flights over the area, and with luck with the rainfall regime, even in sloping areas it is possible to recover the pre-fire state in terms of nutrient content. If the grasses germinate effectively, the density and height of the scrub can be re-established in a few years, prior to the development of the tree cover, which guarantees effective protection of the soil in order to achieve the incipient regeneration of the trees, which in systems at risk of instability, should be accelerated by reforestation processes.

Soils under arid or semi-arid conditions, such as the sandy soils of granitic origin in Galicia, tend to be more fragile to disturbances, as they tend to have lower organic matter contents than more clayey and basic soils. For this reason, these soils are deprived of plant protection against the erosive power of the torrential autumn rains in this area for a long time, something that is happening more and more frequently in Galicia. In these soil and climatic conditions, vegetation cover does not recover quickly. This leads to the loss of organic matter, which is less subject to the soil's biological activity. This also accelerates physical degradation, which increasingly reduces the regenerative potential of the area. With this erosion, infiltration rapidly decreases, making it directly with the depth of soil that is lost to runoff. In the runoff experienced by these sandy forest soils on slopes, the forest vegetation itself plays a fundamental role, reducing it and increasing the amount of water retained in the soil pores. Forests, especially of hardwood species, facilitate the infiltration of water into the soil, increasing the flow of aquifers and preventing the floods of water and mud that are frequent in autumn.

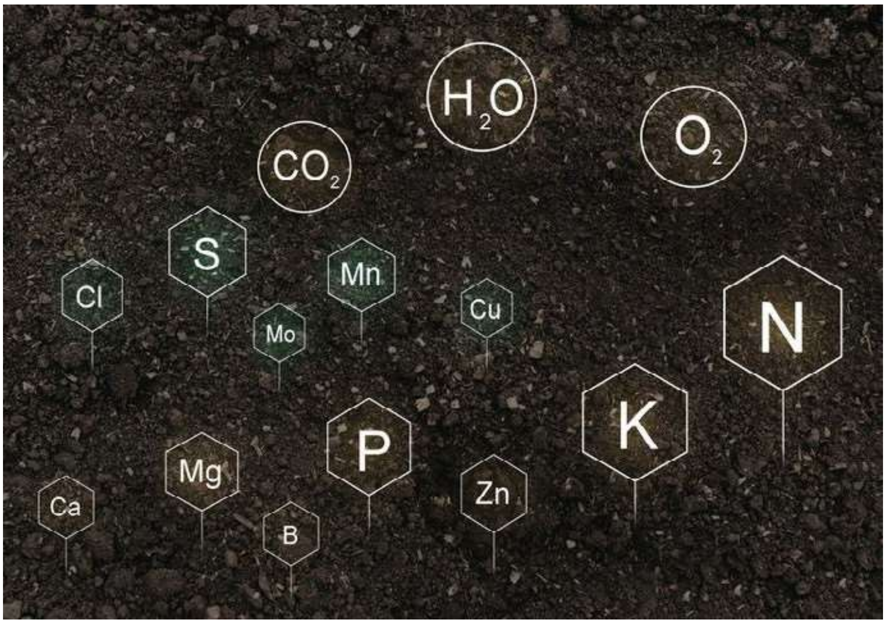


Figure 73: *Inorganic soil composition.*

Image 74: *Burnt forest without vegetation cover.*

In burned soils, in addition to increasing runoff and decreasing infiltration, with the possible increase in hydrophobicity and loss of roots with the fire, if torrential rainfall occurs after the fire, it may also increase the risk of flooding.

In the event of a fire, which is likely before the vegetation cover recovers, the impact of large drops on bare soil will contribute to the destruction of aggregates, the fractions of which clog the pores, further reducing the infiltration rate and, as a consequence, increasing surface runoff which favours the carry-over of soil material, while favouring the loss of nutrients due to their dissolution in the runoff water. Therefore, when soils lose their water infiltration capacity, the proportion of surface runoff increases at the same time, increasing the effects of erosion. On steep slopes, rainfall can trigger an erosive process that leads to the disappearance of the soil and exposes the bedrock. This erosive effect is particularly evident on Monte Pindo, as can be seen in aerial images in the vicinity of the Ézaro waterfall. These erosive processes are favoured by the frequency with which forest fires are repeated in the same place, something that happened with a high frequency in Monte Pindo, as the President of the Monte Pindo Association tells in the film. As he explains in his interview, the debris that is dragged into the rivers and from there into the sea can affect different organisms, including those with gills, which are clogged by the debris and die. Eutrophication processes are also favoured in rivers and estuaries, due to the large quantity of mineral salts dissolved in the runoff water.

Image 75: *Monte Pindo fire 2013. Runoff slope sending debris and mineral salts into the estuary.*

Respond with what you know now:

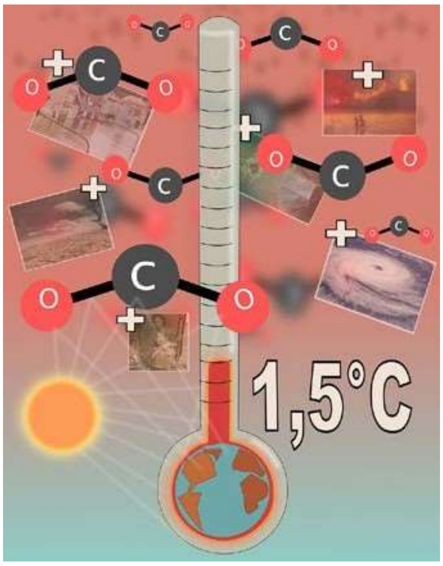
1. How can tree roots disappear in fires if they are underground?
2. Why are burnt forests on slopes planted with grasses?
3. How can it be explained that if the soils are sandy, they are more vulnerable to fires?
4. What explains why burned forests have more runoff and less infiltration than the same soils before the fire?
5. Why is it that after a forest fire in the watershed of a river mouth, as happened in Monte Pindo, it eliminates shell fishing areas for sediment-dwelling bivalves?
6. To what extent is reforestation of a burnt forest worthwhile and what species should be introduced to prevent future fires?
7. What is the relationship between repeated fires on mountain slopes and their desertification?

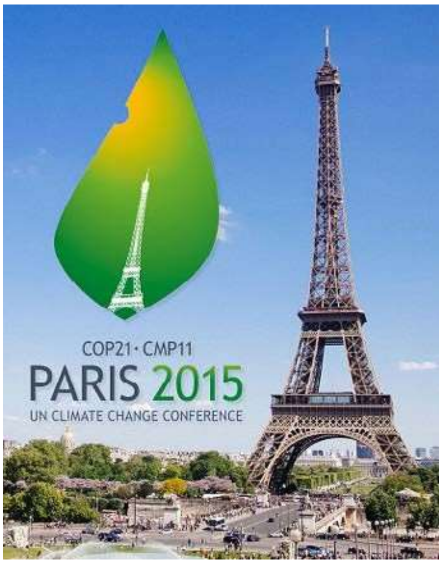
3.3. GOOD PRACTICES FOR SOIL CARBON SEQUESTRATION, IMPROVING SOIL FERTILITY AND REDUCING THE EFFECTS OF FIRES

How can organic carbon be preserved in the soil?

Soil use must be rationalised to achieve soil carbon sequestration through best management practices that tip the balance in favour of carbon fixation or sequestration, aiming to minimise the outflow of carbon from the soil system, placing this non-renewable resource in a sink role, while preserving its fertility and controlling the release of greenhouse gases through inappropriate practices. This will depend very much on climate and soil type. Therefore, carbon dynamics studies of paradigmatic soils in different biogeographic regions should be promoted. In general, the use of compost should be promoted to enrich the soil with organic matter, and traditional techniques such as crop rotation or fallow should be used.

At COP21, within the framework of promoting additional efforts to ensure that global warming does not exceed 1.5 ºC, with the aim of achieving a balance between greenhouse gas emissions and removals in the second half of the 21st century, the "*4 per thousand soils for food security and climate*" project was launched. The aim of this project is to increase organic matter by 0.4% per year worldwide in order to compensate for global greenhouse gas emissions from anthropogenic sources and thus help to halt the increase of CO in the atmosphere.[2]





Images 76 & 77: *Poster expressing the purpose of COP21 and poster announcing COP21.*

To implement it, the 4 per 1000 initiative includes two major programmes of activities.

A programme of actions to improve soil carbon management, combat poverty and food insecurity, and in parallel contribute to climate change adaptation by mitigating emissions. This programme includes practices that restore soil, increase soil organic carbon stocks and protect soils with high carbon stocks. It seeks funding for projects that restore, enhance and conserve soil carbon stocks, with a view to supplying soil-friendly agricultural products.

Figure 78: *Cropland where carbon leakage is occurring.*

A second international research and scientific cooperation programme is aimed at studying the mechanisms and potential for carbon storage in soils for different biogeographical regions. This programme evaluates good agricultural practices and their impact on CO_2 sequestration in the regions studied, promoting policy-relevant innovations in these regions, which monitor and evaluate changes in soil carbon stocks with the interest of producers in mind.

Twenty regions of the world were established conceptualising actions to sequester soil carbon, focusing in each region on soils with low initial carbon content over an estimated 20-year period. Best management practices are established for them, bearing in mind that when they reach equilibrium, they will no longer contribute to the greenhouse gas sink potential.

How can increased fire risks be managed in the context of climate change?

The risks posed by fires in terms of their frequency, virulence, and the length of time they last require territorial management. But there are a series of general criteria to be considered in any territory.

Housing should not be built in forested areas and where urban developments have trees nearby, they should be removed to reduce the risk to housing.

Image 79: *Monte Pino fire of 2013. House at risk.*

Pyrophytic species that facilitate crown fires should be minimised and when they are close to roads and railways, they should be removed to avoid risks to cars. Ditches and nearby areas should be kept clean over time.

Image 80: *Monte Pino fire of 2013. Road with eucalyptus trees on both sides.*

Reforestations with indigenous trees that do not generate undergrowth and do not facilitate the spread of crown fire should be favoured. The development of germplasm banks with seeds of autochthonous species will be favoured. Where monoculture tree plantations are established, they shall be distant from settlements and communication routes. These will have large firebreaks that are always clean. Existing plantations will be treated in the same way.

Figure 81: *Monte Pino fire of 2013. Difference between the burnt forest and the autochthonous forest that did not burn.*

It is important that there are fire remote sensing and fire prevention professionals employed throughout the year, in view of the occurrence of fires in seasons when they did not occur. It is essential to develop annual coordination plans between services in different territories in order to concentrate efforts were fires resist extinction.

Houses must have guaranteed tree-free exits and easy access for fire-fighting services.

In plans for building in nearby forested areas, it is desirable to include hose systems and pumps to allow humidification of the areas near the houses.

Grass seeding, including aerial seeding, should be carried out in burned forests on slopes.

It is in the interest of the population to be prepared to carry out voluntary fire-fighting work so that they can act, under the criteria and instructions of law enforcement agencies, when appropriate and in the most effective non-risky manner.

Image 82: *Monte Pino fire of 2013. Fire close to a house at risk.*

Figure 83: *Sowing grasses on burnt soil.*

Image 84: *Monte Pindo permanently eroded by repeated fires.*

Attention should be paid to avoid repeated forest fires that could lead to desertification, exposing the bedrock.

Respond with what you know now:

1. Develop a plan to avoid carbon losses in growing areas close to where you live, considering climate and trends in climate change impacts.
2. Develop a plan to prevent, extinguish and reduce the risk of forest fires in a place close to your home.

4.1. THE ENERGY TRANSITION AT EUROPE

How is the energy transition conceptualised in the project filmology?

In the short film that was screened as the winner at the end of the film "*Cinema Climantopia*", entitled "*A world without carbon*", the presenters say that Poland is not at the top of the list of countries with the lowest emissions in Europe, but is closer to the bottom of the list.

Image 85: *Still from the presentation of the content of the short film "A world without cars" which appears at the end of the film "Climantopia" as the winner of the Canary Islands youth conference.*

But in this presentation, they already point to important developments in recent years. To illustrate this, they went to interview a friend whose family has decided to install solar panels on their single-family house.

Image 86: *Still from the presentation of the content of the short film "A world without cars" which appears at the end of the film "Climantopia" as the winner at the Canary Islands youth conference.*

This friend explains that they have put 30 solar panels on the house that can produce 10,000 kW, when this family only needs 10 kW per year. What they don't manage to consume they send to the distributor because they don't have acquired the necessary special batteries due to their high cost. The interviewers closed the talk with the fact that in 2022, thanks to families like this one, solar panels supplied around 7% of the energy consumed. On the basis of this data, they concluded that there is hope that one day they will be free of the polluting power plants analysed in this short film.

The film "*Climantopia*" also deals with renewable energy, in particular wind energy. Energy is dealt with in the Polish short film "*A world without carbon*", which is awarded in the film. They do this the day before the awards gala during visits to the islands. As part of this programme, they visited a wind farm that currently produces 54% of the renewable energy.

Image 87: *Still from the film "Cinema Climantopia" in which the group of participants in the short film presented by Poland discuss renewable energies in their territories.*

One of the students from Poland, who plays a presenter in the short film they are presenting at the summit the following day, remembers seeing many wind turbines on top of a Galician Mountain on their way to the international beach volleyball tournament in Ézaro. One of the Galician students took the opportunity to boast that Galicia is only surpassed in renewable energy by Castilla y León. The Polish student then added that, if Poland adapts its legislation to that of the European Union, it could quadruple its wind power capacity. A student from the Canary Islands spoke of the Canary Islands' potential for wind energy due to the trade winds but stressed that its growth should not be on the surface of the islands, because priority should be given to solar energy, which for obvious reasons also has a lot of potential there. She was therefore in favour of putting wind turbines in the ocean. On this idea, the student from Lisbon expressed her government's commitment to increasing its offshore wind potential. However, the Galician students expressed their fear of putting wind turbines in the Galician estuaries because of what it would mean in terms of diminishing their landscape value.

Respond with what you know now:

1. What are the reasons for the differences in the positions of Galician and Canary Islands female students on offshore wind energy?
2. It compares the solar energy potential in the Canary Islands, Poland and Galicia.
3. What is the difference between the position of Polish households and their government regarding the use of renewable energies?

How has the EU approached its current energy transition?

The energy transition began in October 2014, when the European Council agreed on the European Union's targets for 2030. A reduction in carbon emissions of at least 40 per cent compared to 1990 levels was set as a binding target for the European Union as a whole. This energy transition envisaged in the energy union project is based on four pillars: (a) greater weight of renewables; (b) a commitment to energy efficiency; (c) greater integration of electricity markets in Europe through the development of interconnections; and (4) greater citizen participation, in which education plays an important role with the integration of the different Erasmus+ projects oriented towards Horizon 2020.

Image 88: *Picture of the convergence of key renewable energy sources in the European energy transition (source: El Periódico de la Energía).*

With this approach to the energy transition, the European Union aspires to clear world leadership in renewable energies, which in educational terms means that the environment and the fight against climate change are becoming a strategic line for Erasmus+ educational projects. To achieve this leadership, the energy transition focused on the objective of increasing the share of renewables in total primary energy consumption to 27% by 2030. To achieve this goal, the Parliament expressed interest in a commitment to extend the use of renewable energies to a share of around 35%. At the same time, looking to the long term, the 2050 roadmap set a target of a reduction in pollutant emissions of between 80% and 95% compared to 1990, with an intermediate target of a 60% reduction by 2040.

The commitment to renewables was justified based on various criteria, the most important of which were environmental. The environmental reasons are clearly related to climate change: together with nuclear, renewables are the only electricity generation technologies that do not emit greenhouse gases into the atmosphere. Bearing in mind the long-term risks of nuclear power, including the complex and uncertain risky management of nuclear waste, renewables play a central role in achieving emission reduction targets. If the electricity sector is efficiently supplied by renewables, it becomes the main vector for the decarbonisation of the economy, as it is the sector that can most effectively integrate renewables into its production processes.

Thanks to research into renewables, in which Europe is leading many initiatives, electricity production from renewables has experienced sharp reductions in costs. Before 2005, electricity generation from renewables was more than seven times higher than from thermal power plants. However, with the development of the energy transition, the costs of wind power are already in the order of 50% and those of solar photovoltaic is even more relevant, achieving a reduction of around 80% per 100. Other technologies that are in a process of maturity in the most basic research, such as offshore wind, biomass or solar thermal, have also already achieved significant reductions in costs. The reduction in costs is so important and generates so many expectations for the future that it is leading Europe to close very important thermal power plants. In Spain, the most important of these, the As Pontes de García Rodríguez thermal power station, is to be closed.

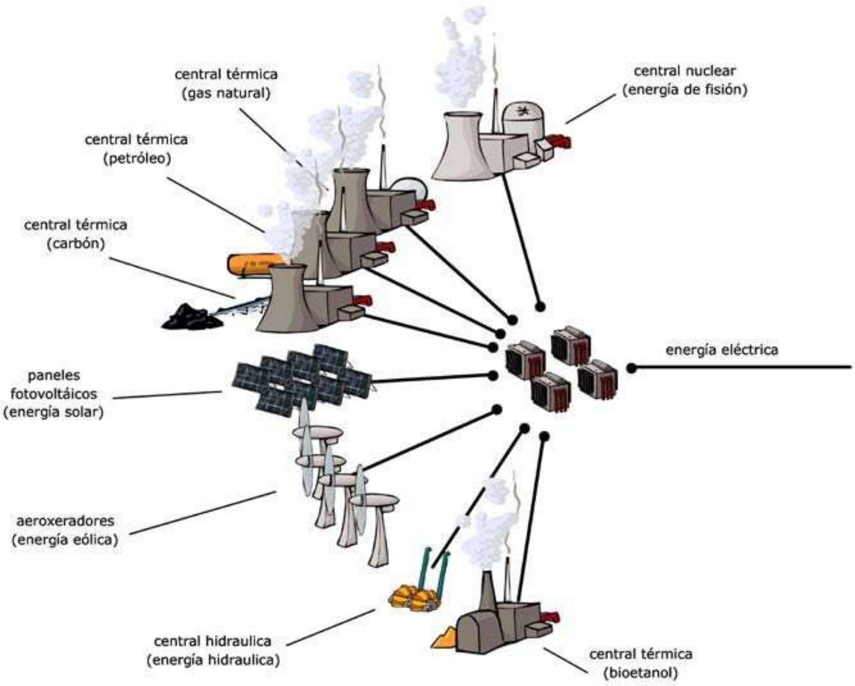


Figure 89: *Illustration of the share of the different energy sources in the energy supply of the electricity sector.*

Respond with what you know now:

1. When does the European Union propose the energy transition and what are its main motivations?
2. What factors are pushing EU countries to close thermal power plants such as As Pontes de García Rodríguez in Spain?
3. How is the energy transition impacting on the Erasmus+ programme and what is its social, economic, and political significance?

4.2. HYDROELECTRIC POWER GENERATION AND ITS UNCERTAIN FUTURE IN THE EUROPEAN ENERGY TRANSITION

Hydraulic energy has been important since prehistoric times, when the transformation of renewable hydraulic energy into kinetic energy was used to generate circular movements of stones that allowed the grain to be ground into flour.

Image 90: *Traditional hydraulic mill in Galicia.*

Hydropower was the first energy source to be used to produce electricity, with the first experimental installation being built to move a turbine that produced electricity through the invention of the hydraulic dynamo in Great Britain in 1980. However, the first construction with an industrial impact was built in Appleton (Wisconsin, USA) two years later.

In Spain, the first power stations were built at the beginning of the 20th century, and already in the first decade large hydroelectric power stations were built, including the Molinar power station on the river Júcar, which supplied electricity to Madrid with a 60,000 volt high voltage line of some 250 km, which at that time, when the hydroelectric power stations were close to the centres of consumption, was one of the longest in Europe, due to the distance from Madrid to large rivers.

In the post-war period, Spain made a firm commitment to make maximum use of the hydraulic potential of its rivers, so that when democracy arrived, Spain already had what could be considered extensive exploitation of its rivers.

large hydro basins, with a productive capacity of more than 14,000 MW. Hydropower accounted for 50% of the total installed power in Spain at the end of the 1970s, despite the increase in the implementation of large thermal power stations and the installation of nuclear plants from the 1950s onwards, when the potential of large reservoirs was already well exploited.

Image 91: *Old turbine and hydraulic dynamo of the Tambre I power station.*

Image 92: *Photograph of a reservoir.*

From the 1980s onwards, in order to increase the power of hydroelectric energy, the peninsular territory was filled with mini-power stations on its small rivers. However, the increase achieved did not reach 5,000 MW, and currently represents less than 20% of the installed capacity.

In Galicia, a highly exploited region with a very high rainfall, wind power output already clearly exceeds that of hydropower.

Figure 93: *Photograph of a mini-hydropower plant.*

In the current context of climate change, reservoirs tend to be undersupplied for many months, and when it rains, the torrential rainfall makes it necessary to facilitate the removal of water that cannot be used for turbining. In addition, reservoirs tend to silt up. As a result, expectations for the future of hydropower are increasingly diminishing with the advance of climate change, leaving an uncertain future for this renewable energy source.

Respond with what you know now:

1. What role did the discovery of the hydraulic dynamo play in the emergence of electricity?
2. Why did the first hydropower plants have to be close to the areas of consumption? How was it possible to move towards distancing?
3. Why did Spain not build large hydroelectric plants from the 1980s onwards, but instead promoted plans for mini-hydroelectric plants?
4. Why is hydropower not considered to be the energy of the future for the era of climate change?

4.3. WIND ENERGY IN EUROPE'S ENERGY TRANSITION

Wind is another classic source of energy in human history. It is known to have been used by the Egyptians as a driving force for sailing ships as long as 5000 years ago. Its use for grinding grain in windmills also dates back to ancient times.

***Image 94:** Photograph of an old windmill in the Galician town of Catoira.*

Nowadays, modern wind power technology has been able to adapt this traditional know-how to large-scale electricity production. Galicia stands out as an autonomous community with wind energy production in Spain, and having a low implementation of solar energy, it is only surpassed in renewables by Castilla y León. However, the tendency is to progressively increase its implementation in different autonomous communities, including the Canary Islands, which is committed to offshore wind research.

The installation of a wind farm is carried out in several stages, including the meteorological study of the wind regime and the assessment of the environmental impact that its installation may produce in high altitude areas of great ecological and landscape fragility. There are risks that may increase with *offshore* technologies (offshore wind farms) if adequate planning and control is not established. The evolution of this resource is linked to the increase in the power of the equipment, and prototypes with a power of over 1000 kW are already being built.

Image 95: *Photograph of a wind farm in the Galician town of Cabo Ortegal (author Makinin on pixabay).*

Wind energy in the European Union was promoted after COP 21 in Paris with the *European Roadmap 2050* study on European policies needed to achieve a decarbonisation target of 80% compared to 1990 emission values, in line with energy security, environmental and economic responsibility and the EU's objectives for the period 2015-2050, which aims for certain renewable energies, including wind energy, to become more efficient than fossil fuel-based energy sources. Also of interest is the implementation of *onshore* and *offshore* wind energy for thermal and energy storage, and for use in CO capture and absorption systems$_2$ and to gain an important space for this type of renewable energy in European grids that incorporate wind energy from various countries such as Denmark, Ireland and Northern Spain, where Galicia has a very prominent role.

The implementation of these European grids, in which wind energy is acquiring more and more specific weight, places wind energy in

The EU has a decisive role to play in replacing electricity production from fossil fuel-based energy sources by electricity generation with virtually zero carbon emissions.

Respond with what you know now:

1. How can it be explained that the Canary Islands, with trade winds blowing NE towards the equator, have less wind energy development than Galicia, where the winds are more intermittent?
2. How could the need to shut down the wind turbine be solved when during periods of high wind, the grid can no longer support the load?
3. What are the advantages of the different EU countries connecting their wind farms to the grid?
4. What is the potential of offshore wind energy and why is there so much reluctance to implement it in G a l i c i a when it has managed to be a pioneering community in the state in this type of energy?

4.4. SOLAR ENERGY IN EUROPE'S ENERGY TRANSITION

Solar energy is a great opportunity for energy efficiency. We receive more than 60 million billion toe per day of radiant energy from the sun, an amount that is very promising for Europe's energy transition, since the combustion of one tonne of oil produces one toe of energy. This energy, if harnessed correctly, could generate about 20 times the energy contained in all fossil fuel reserves. Current technology gives us opportunities in two types of solar energy capture: Photovoltaic or Solar Thermal.

What is photovoltaics?

Image 96: *Photograph of a solar garden.*

Photovoltaic solar energy consists of the direct conversion of solar energy into electrical energy. It is undergoing significant development in some EU countries, particularly in Germany, one of the world leaders, with the world's largest solar power plant, the Bavaria Solar Park, which has a panel area of around 250,000 ^{m2}. One of the main problems facing these solar systems is the need for large surface areas, as the energy is diffuse. The Earth's surface receives a maximum power of 1000 $^{W/m2}$. Another limitation of this energy is the intermittency of the mandatory supply. This makes it necessary to have effective systems for storing or connecting to the general electricity grid the quantities that the owners of the solar photovoltaic panels do not manage to consume, as the Polish student explains in the scene of the Canary Islands wind farms in the film "*Cinema Climantopia*".

Figure 97: *Silicon photovoltaic panels.*

In the 1950s, photovoltaic cells made of silicon were improved. When sunlight hits these silicon cells, a potential difference is generated due to the voltaic effect, which generates a current that can be very useful. In general, photovoltaic cells are composed of semiconductor elements such as silicon. In order to obtain an electric field when the sun shines on these silicon plates, a grid with one negative and one positive side must be used.

What is solar thermal energy?

Solar thermal energy is based on the use of a collector, which, exposed to solar radiation, absorbs its heat and transfers it to a fluid for direct use or transformation into electrical energy. This fluid is usually of an oily nature so that it reaches high temperatures and heats the water circuit that runs in parallel with the tubes of the fluid that is heated by the sun.

One of the most common uses of these systems is to produce hot water in single-family homes and to heat water in swimming pools, which in turn prevents overheating of the water in the swimming pool.
on very sunny days. With a collector surface of about 4 ^{m2}, a production of 200 litres/day of hot water is achieved, throughout the whole year.
per year. This amount is usually sufficient for the use of dwellings. In Europe, its use was recommended in all newly built homes, and therefore in Spain, the technical building code established its compulsory use. This is helping to avoid a significant number of emissions by heating the water in new homes with this system.

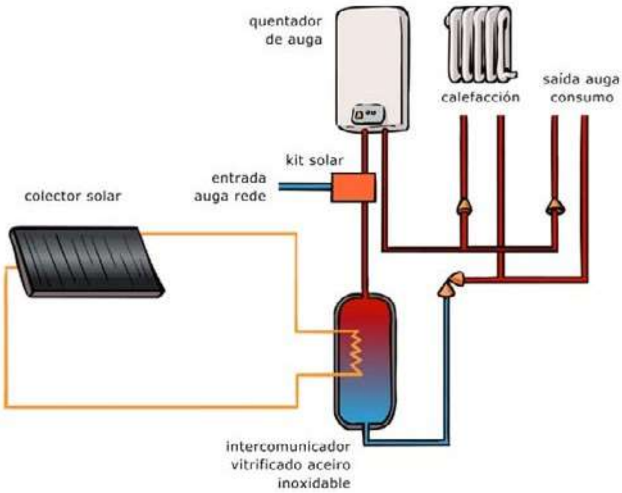


***Figure 98:** Infographic of the operation of a solar thermal solar energy collector.*

***Image 99:** Photograph of solar panels installed on the roof of a house in accordance with the technical building code.*

Respond with what you know now:

1. Why do users of photovoltaic panels feed the overproduction into the grid and do not store it?
2. What is the problem with the guarantee of continuous electricity obtained from photovoltaic panels, and is it the same in the Canary Islands as in Poland? Justify your answer.
3. Why does the technical building code require the installation of solar thermal panels?
4. What is the additional advantage of having a swimming pool connected to the solar thermal panels in addition to having hot water for bathing?

4.5. THE PRESENT AND FUTURE OF MARINE ENERGY, GEOTHERMAL ENERGY AND BIOFUELS

What is the potential of marine energy?

Marine energy has been used throughout human history with the use of tidal mills. As the tide rises for six hours and falls the following six hours, these movements of the water currents were used to grind large quantities of grain.

Image 100: *Photograph of the tide mill in Muros (A Coruña, Galicia).*

Research is currently being carried out into the use of energy from waves and currents, including tidal currents. The energy potential is very large in countries with a long coastline, as is the case in Spain. If research progresses satisfactorily, a maximum installed capacity of 84.4 GW could be reached in Spain by 2050. If this research is successful, 100% of the current state electricity demand could be exceeded.

For the harnessing of wave energy, many expectations are placed on buoy fields. The buoys are placed on the coast at depths that can be anchored to the seabed. The kinetic energy of the waves moves the buoys, which drives a shaft that drives a fluid pump. The fluid reaches the turbine and, as it expands, causes it to rotate and subsequently produce electricity in a generator attached to it. In a field measuring 220 m by 50 m, with 6 to 12 buoys connected to the corresponding systems for obtaining energy, it could generate the electrical energy equivalent to the consumption of more than a thousand families. They could also be used in de-alienization systems and hydrogen production.

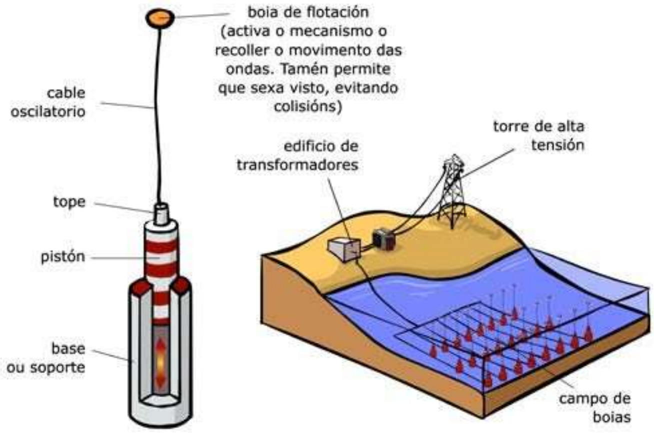


Figure 101: *Infographic of a buoy field for wave energy harvesting.*

What is the potential of geothermal energy?

This is the renewable energy that comes from the earth's internal heat, which has been with the earth since its origin and often manifests itself violently in volcanoes and earthquakes, or less intensely in geysers or hot springs. The geo-thermal potential stored in the top ten kilometres of the Earth's crust far exceeds the world's fossil fuel reserves. But only a small part of it can be harnessed by humans with currently available techniques.

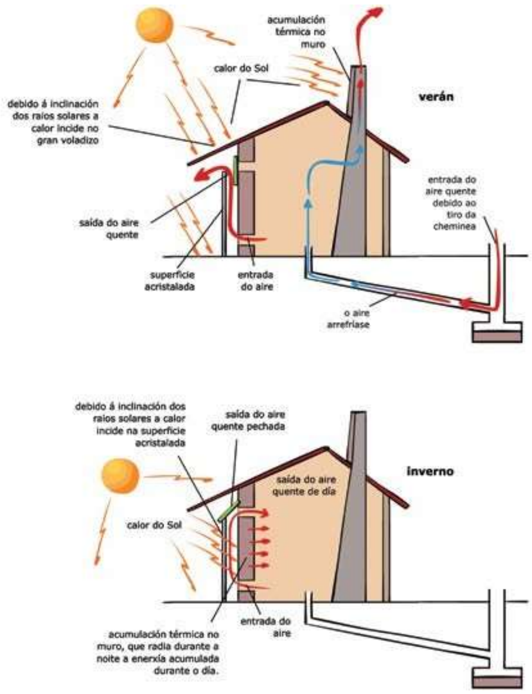


Figure 102: *Use of geothermal energy in bio-construction used for heating in winter and ventilation in summer.*

It is particularly useful for heating homes, farms and winters. In high-temperature deposits, such as those in Iceland, it can be used for electricity production. In Spain, there are very important resources of this type on the Canary Islands of Lanzarote and La Palma. In recent years, its use has been boosted significantly on El Hierro.

Figure 103: *Geothermal power plant in Iceland.*

What is the potential of biofuels and what are the concerns about their use?

The use of primary or vegetable biomass is currently being greatly promoted with the aim of producing so-called biofuels: liquid or gaseous fuels obtained from so-called energy crops by fermentation processes. Worldwide production of biofuels for transport is led by Brazil and the USA (bioethanol). Europe is the world's largest producer of biodiesel.

To obtain them, large areas of wheat, soya, rapeseed or sugar beet crops are needed to produce biodiesel (used to enrich diesel) and bioethanol (used to enrich petrol). Their potential for blending with fuels obtained from oil refining, with falling oil reserves, will make these fuels increasingly competitive, but the development of these new technologies is fraught with uncertainties and unresolved issues.

The energy transition underway in the European Union is driven by the fact that fossil fuels are becoming increasingly expensive and scarce. Their replacement by renewable sources is not without difficulties and conflicts, and biofuels are among the most prominent, especially because of the risks of occupying agricultural fields for biofuel production, increasing the risks of hunger for a growing population.

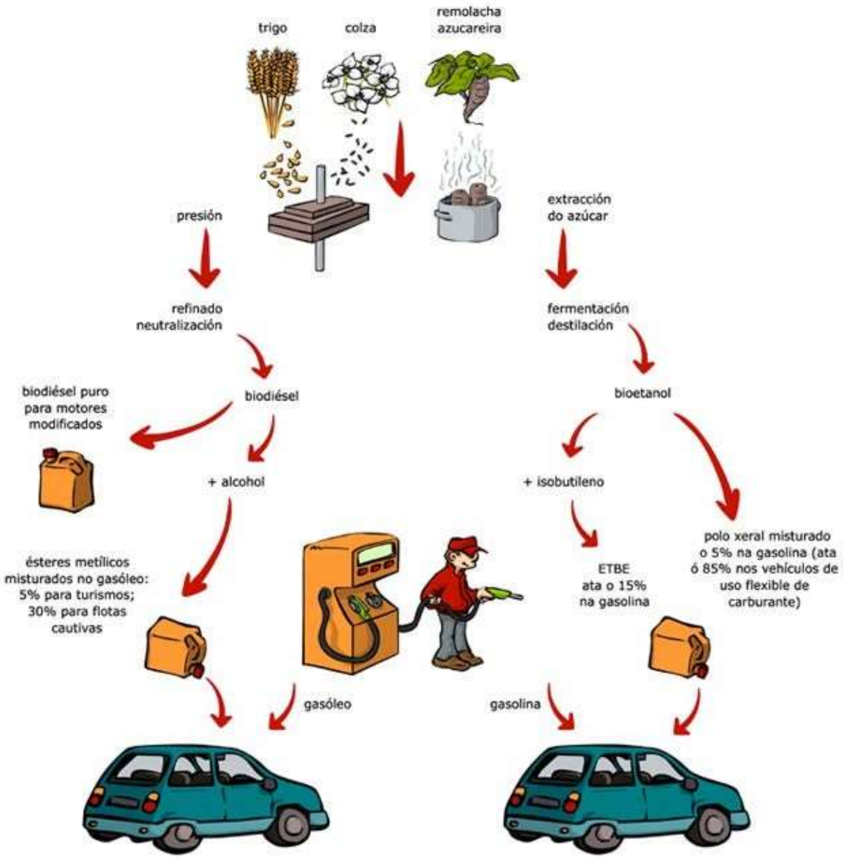


Image 104: *Infographic outlining the process of transformation of vegetables into biodiesel to enrich diesel or bioethanol to enrich gasoline.*

Image 105: *Photograph of a biodiesel plant.*

Respond with what you know now:

1. Why does marine energy have more potential in Vigo than in Alicante?
2. Why does geothermal energy have more future potential in Iceland or the Canary Islands than in Galicia?
3. Why are we concerned that countries like Brazil are betting heavily on biofuel production?

4.6. HYDROGEN'S POTENTIAL AS A NEW VECTOR FOR THE ENERGY TRANSITION

The energy of the society of the future cannot come from fossil fuels because there is an urgent need to tackle climate change and, in addition, natural gas and oil, at the current rate of consumption, are destined to run out in the century. But humanity aspires to have vectors that allow the power, transportability, mobility and globality that oil gives us, and now hydrogen promises to be that vector capable o f taking the place currently occupied by oil derivatives.

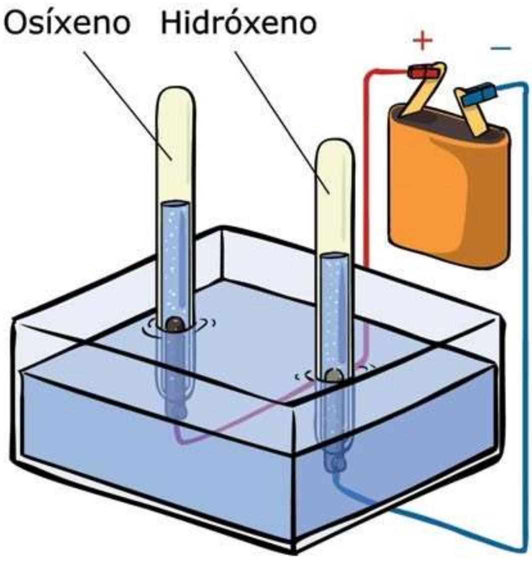


Figure 106: *Illustration of obtaining hydrogen by electrolysis of water.*

Hydrogen is the most common element in the universe, found in a concentration of 75%. On Earth, although it does not occur in a free and isolated state, natural selection led it to make up 70% of organisms. It was discovered in 1776 by Henry Cavendish, who presented an experiment involving the production of water from oxygen and hydrogen by means of electricity, a reaction on which we now have high expectations that it will be the vector that replaces those obtained from oil refining. But it was not until 1920 that the first company appeared to dissociate water into oxygen and hydrogen for commercial purposes by means of electrolysis, which is the reaction on which we have high hopes of being able to obtain it for use as a vector. This process involves introducing two differently charged electrodes (positive and negative) into a tank of pure water in which an electrolyte is dissolved and applying a direct electric current to the electrolyte. The result is that the hydrogen will move towards the cathode (the electrode of different charge).

negative) and oxygen to the anode (positively charged). Electrolysis is not widely used, as this method is more expensive (it can be three to four times more expensive) than using natural gas as a source of hydrogen.

As early as the 1930s, hydrogen was used as a secondary fuel in civil aviation as an alternative to a mixture of gasoline and benzene. Later, the British and Germans were to use it in the same way in submarines and torpedoes on an experimental basis.

The proposals that had emerged in the 1920s for the use of hydrogen as a fuel were not taken up again until 1973, when the oil crisis hit. In that year, groups and associations were formed to defend its use and to get governments to invest in this field of research. Once the oil crisis was over, the possibility of a new energy source was again considered until the 1990s, when there was a proliferation of scientific reports warning of the rapid increase in the concentration of greenhouse gases in the atmosphere as a result of the burning of fossil fuels.

In February 1999, Iceland came forward with a proposal to shift its economy towards hydrogen and thus eliminate its dependence on fossil fuels. It would start with the use of hydrogen in transport, and then generate electricity to power the country's factories and homes. A similar plan emerged in Hawaii in 2001, proposing the harnessing of geothermal and solar energy to convert it into hydrogen fuel.

Therefore, renewable energies, such as photovoltaic, wind, hydro or even geothermal, have enormous potential to generate the electricity needed to be used in the production of hydrogen by electrolysis of water. Hydrogen, in this association with renewables, would act as a store of energy (once the major problems of the cost of the necessary infrastructures have been overcome), which would be available to be supplied when needed.

The fundamental difference between fuel cells and the conventional batteries we use, for example, in our music players is that the latter store chemical energy which they convert into electricity, and once the battery is depleted, it is rendered useless or can be recharged, if necessary, by plugging the charger into the mains. Fuel cells do not store chemical energy but produce electricity from the chemical energy of a fuel provided by an external source. Therefore, they will continue to generate electricity if they are supplied with fuel and oxidant.

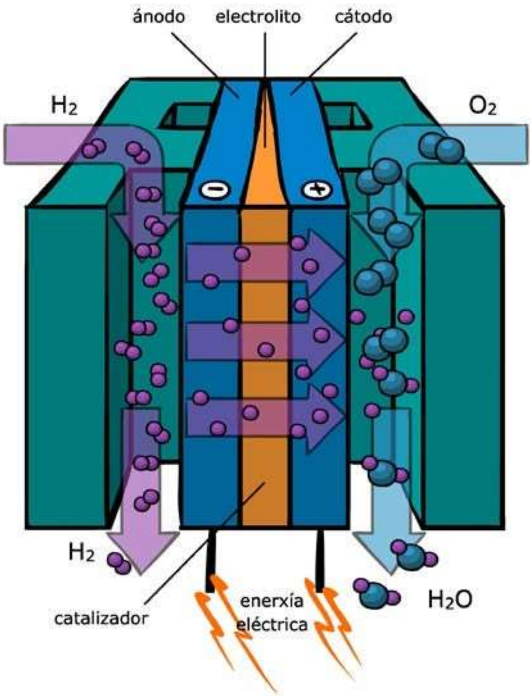


Figure 107: *Illustration of energy storage using the hydrogen fuel cell.*

The reagents used are, on the one hand, hydrogen (at the anode), and as an oxidant, on the cathode side, oxygen. In between is an electrolyte or a semi-permeable membrane that would allow the hydrogen atoms to pass from the anode to the cathode. The electrons released in the chemical reaction that breaks the hydrogen atom into protons and electrons flow out through an external circuit as an electric current. The electrons return to the cathode where they react with oxygen and hydrogen ions to generate water as a waste product.

In the short term, using less fuel is the best way to curb the increase in oil consumption and hence greenhouse gas emissions from internal combustion engines, especially as the vehicle fleet is expected to exceed 2 billion by 2050. With these forecasts, high-performance, zero-emission vehicles should emerge in the 21st century in the long term. This being the case, the vehicles of the future must be powered by systems such as those dependent on grid connections and hydrogen fuel.

With fuel cell vehicles in mind, hydrogen (the fuel) will be combined with oxygen from the air to generate the energy that powers an electric motor. In addition, hydrogen fuel cell vehicles are several times more efficient than today's petrol cars and emit only water vapour from the exhaust pipe, which means they operate with zero emissions.

Figure 108: *Infographic of a futuristic station for supplying hydrogen to cars.*

How can hydrogen be obtained from water? What product will be obtained from the combustion of hydrogen? Why is a hydrogen car said to operate with zero emissions? The energy to break down water into oxygen and hydrogen through electricity can be obtained from solar cells, wind turbines, photovoltaic panels, geo-thermal power plants and other renewable sources. This new hydrogen economy requires R&D&I to develop attractive vehicles, to develop the production of hydrogen in large quantities from renewable energies that will allow a desert to be equipped with photovoltaic panels to obtain and store hydrogen in tanks. This also means developing distribution infrastructures to take over the current petrol and diesel refining and distribution systems. The energy production for electrolysis could be entirely from renewable sources.

Respond with what you know now:

1. Why are expectations high that hydrogen can replace carriers derived from oil refining?
2. Why is it that the thermal energy released from the reaction of oxygen with hydrogen to give water does not concern us in the rise of climate change?
3. How can hydrogen be linked to photovoltaic panels or wind farms for greater energy efficiency?
4. Why would the coast of the Sahara Desert be of interest for bringing hydrogen to Europe using existing pipelines?

5.1. URBAN PLANNING AS A SCIENTIFIC-TECHNICAL DISCIPLINE

Search the Councillor's scene and reply.

1. Think about where you live (city, neighbourhood, village...) and reflect on the places you frequent, how you get there, what the spaces are like, how you use them and what obstacles you encounter. Make a list.
2. Share this list with your colleagues in small groups and compare it with theirs to build a common list of urban spaces that you use.
3. Considering the group's ideas, think together about how you could improve your daily life where you live. What would it take to achieve this?
4. Finally, share your contributions with the rest of the class groups.

What does urban planning have to do with climate action?

In the film "*Cinema Climantopia*", Lisbon's city councillor boasts about her city as a sustainable city made by and for people, while the students reflect on the complex challenge of making such a capital city carbon negative. The councillor explains to the students the steps taken, including the restriction of certain areas to electric and hybrid cars, the improvement of public transport and the plan to move the airport away from the city so that aviation noise does not disturb Lisbon's residents.
Are these actions coherent with sustainable urban policies, are they sufficient, and if so, how much?

To answer these questions, it is interesting to look at the situation of urban sustainability in Europe. In 2021, 74.8%[1] of the European population lived in large cities, peripheral areas and smaller cities, equivalent to more than 332 million people. This situation forces European citizens to face and overcome several environmental challenges that originate in our daily lives and influence the quality of life of the entire population: air and water pollution, high noise levels, difficult access to housing, loss of biodiversity, and many more. In addition, these localities receive dozens of

[1] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Urban-rural_Europe_-_introduction

of millions of tourists throughout the year, increasing the consumption of urban resources such as water, housing and electricity, as well as the use of public spaces such as streets, parks and beaches.

All this places the focus on cities as a determining element for climate change mitigation and adaptation, globally and locally. It is therefore necessary to reflect on the way in which urban development is planned in our cities and towns to be able to propose participatory, sustainable and equitable responses.

Image 109: *Councillor of Lisbon.*

Image 110: *Lisbon (Portugal).*

But what is urban planning?

Urban planners are responsible for planning and designing cities and towns with the aim of improving the quality of life of the people who live in them. Urban planning is a complex and multidimensional discipline that must take into account many aspects of the coexistence of large human groups, as well as their social, cultural and economic activities. Urban planning addresses various aspects of the life of human communities, such as:

"Urban planning, which addresses how urban land is used by establishing regulations based on:

- ę The classification of land, through the planning of the use of urban space, which is generally divided into 3 types: urban land, i.e. constructed buildings; non-developable land, which identifies land where it is not possible to build due to its landscape, historical, environmental, cultural, etc. value; and land for development, which is land that does not belong to urban land or non-developable land and can be subject to transformation and construction.

  - Land classification, which is divided into two categories: general land uses and specific land uses. The use of specific land uses is limited according to the purpose for which they are intended: residential, industrial, green areas, etc.

  - Building typologies, which establish a specific use of the buildings: residential, commercial, office, public, sanitary, industrial, etc.

"The creation and maintenance of infrastructure and public services. Infrastructure is the set of facilities, services and technical means that support the functioning of cities and enable citizens to carry out certain activities. Facilities are easy to recognise as they are made up of roads, buildings, bridges, pipelines, cycle paths, car parks and a long list of others. Services include education, health care, transport, waste management, water supply and care for vulnerable populations, among others. On the other hand, some technical means are less recognisable, but are essential to the functioning of the infrastructure.

These include vehicles and technological devices, as well as all the human personnel who add value to the infrastructure in the form of knowledge and expertise.

"Conservation of cultural and natural heritage. This aspect involves the protection and management of cultural heritage such as monuments, historic buildings, old town, artistic works, archaeological sites, etc., and natural heritage, including parks, emblematic flora and fauna species, landscapes, or eco-systems of the city, ensuring their conservation, maintenance and the appropriate use of this public heritage.

"Citizen participation. This element of urban infrastructure is of particular interest as it is not as visible as the others. As we have seen, all the elements that enable us to carry out our daily lives in the place where we live depend on urban planning and management. Therefore, citizen participation is essential in this work so that the interests and needs of the population can be addressed and guaranteed.

In short, sustainable urbanism is a multidisciplinary discipline based on knowledge and understanding of the needs of the citizenry and the resources available to create more liveable and sustainable cities. We must therefore consider the organisation of our cities and towns as a determining element in climate action. Most of our carbon footprint is generated in the place where we live and in the places, we visit, hence the importance of paying special attention to the use and management of our urban environment in order to build cities and towns based on the co-responsibility and participation of all citizens to respond to the climate emergency.

Image 111: *Infrastructures.*

Image 112: Brøndby Haveby (Denmark).

Image 113: Barcelona (Spain).

Image 114: Milan (Italy).

Based on what we have seen so far...

1. Look up the Latin origin of the word infrastructure (*below).*
   + *structus*) and try as a group to explain its meaning.
2. Considering the list of places that you use in your daily life, and that you have already indicated in the previous activities, identify, as a group, the facilities, services, etc. that you use in your daily life.
   and the technical means necessary to be able to make use of this space in a sustainable way.
3. Have you found any deficits or possible improvements for the use and enjoyment of that place? What solutions would you propose to improve those places? How would you make your proposals known to the town planners of your city or town?
4. The three cities in the pictures show three different types of urban planning, search the internet for information about them and indicate what problems they identified and what solutions they proposed for their urban development.

5.2. LEIPZIG CHARTER ON SUSTAINABLE EUROPEAN CITIES

Since 2000, cooperation between European governments has focused on the sustainability of their cities. Since then, several meetings have been held in Lille, France (2000), Rotterdam, the Netherlands (2004), Bristol (2005) or Leipzig, Germany (2007). In the latter city, the Leipzig Charter on Sustainable European Cities was adopted, which offers recommendations for city planners in European cities that consider simultaneously, and with equal weight, all dimensions of sustainable development: economic prosperity, social balance, and a healthy environment while, at the same time, attention must be paid to cultural and social justice aspects.

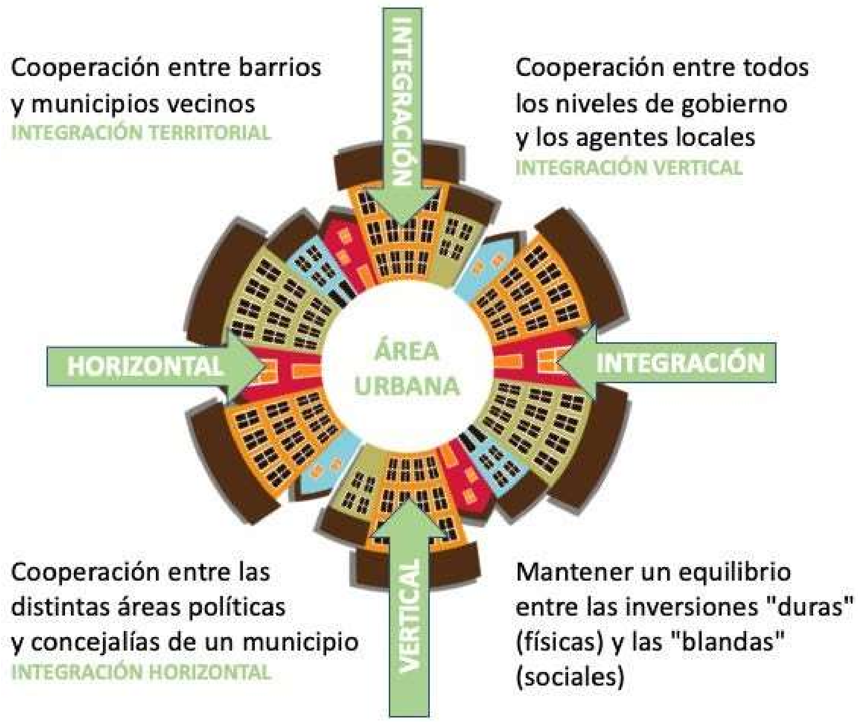


***Figure 115:** Integrated approach to urban development.*

These recommendations are based on two main principles or axes:

1. The first states the need for an integrated approach to urban development. That is, the integrated approach implies considering all actors who have a stake in how a city is planned, developed and lived in. Thus, the state, regions, cities, citizens, and economic actors must be involved and considered in urban development decision-making. This approach aims to promote the

social cohesion and quality of life in our immediate environment through the creation and consolidation of high quality public spaces; the modernisation of infrastructure and improvement of energy efficiency; and proactive innovation and education policies.

An integrated approach cannot be carried out by considering cities as isolated nuclei, therefore, it is necessary to achieve a partnership in terms of equality between cities, their neighbourhoods, and rural areas, as well as between small, medium and large populations.

2. The second axis expresses the need to pay special attention to less favoured neighbourhoods and areas, within the global context of the city. Cities are places where there are different socio-economic realities which, in addition, are accompanied by aspects that condition well-being and health depending on the environmental quality of the neighbourhood or area in which one lives (heat islands, atmospheric pollution, ventilation, green areas, climatic refuges, public transport, etc.). Social and economic inequalities are the most important driving force in the de-spatialisation of a city, therefore, social integration policies aimed at reducing inequalities and preventing social exclusion are the best guarantee for keeping our cities safe. In this sense, the Leipzig Charter recommends: seeking strategies to improve the physical environment of the most vulnerable areas; promoting employment policies that allow these disadvantaged areas to stabilise economically; creating training policies for children and youth; and promoting efficient and affordable urban transport.

Accordingly, it is necessary and urgent that all people and institutions, at local (town or city), national (country) and European level, coordinate their actions so that urban development processes can be developed from a civic and political co-responsibility in accordance with the principles of the Leipzig Charter. To this end, dialogue between the different actors involved is essential, as well as adequate training so that basic knowledge and competences are acquired to make this dialogue possible, together with the skills to build sustainable cities.

1. How would you relate these images to what you have seen so far? Discuss in small groups and then share your conclusions with the rest of the class.

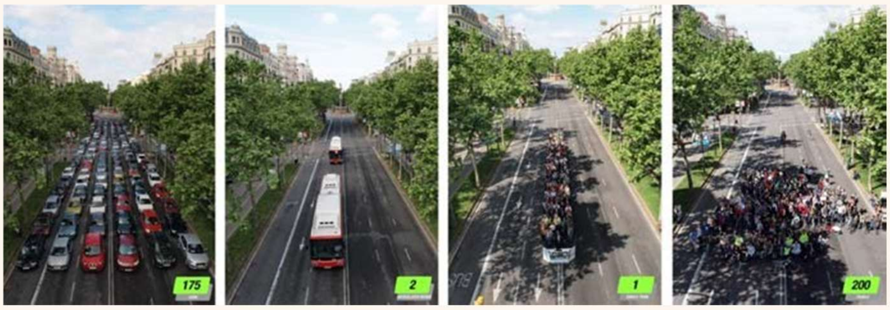


Image 116

Examples of urban sustainability: Green Cities[2]

Returning to the film "*Cinema Climantopia*", Lisbon's councillor for urban planning proudly points out that Lisbon is a European Green Capital. But,

What does this mean? We can find many examples of urban sustainability in the European Union. In fact, in 2008 the European Commission created the European Green Capital and European Green Leaf awards to reward and visualise those European cities that have resolutely approached their urban development from the perspective of sustainability in its three lines of action: social, environmental, and economic.

Image 117: *Logo of the European Green Capital and European Green Leaf Awards.*

[2] https://environment.ec.europa.eu/topics/urban-environment_en

European Green Capital

The European Green Capital Award is aimed at all cities with a population of more than 100,000 inhabitants. The key objective is to send the message that citizens have the right to live in healthy urban areas and therefore the urban development of cities should strive to improve the quality of life of the people living in them, while at the same time reducing their impact on the global environment, i.e. from both a local and global perspective.

For the assessment of candidate cities, the European Commission sets 7 indicators[3] 3 directly related to urban development (*Figure 115*).

The first city to be awarded European Green Capital was Stockholm (2010). Since then, various actions have made it a global benchmark for sustainable urban development. Despite being one of the fastest growing European cities, it aims to achieve a negative carbon footprint by 2040. It has also been chosen as the "Smartest City in the World" for its ability to combine environmental innovations aimed at improving and maintaining the well-being of its citizens. Among its innovations, in one of its neighbourhoods, a system of pressurised pipes transports waste to a processing centre without the need to use trucks that emit greenhouse gases (GHG). They collect sensor data to understand citizens' travel and transport habits and use this information to plan transport more efficiently. In addition, the city has a heating network that, among other energy sources, is supplied by the heat generated in data processing centres or supermarkets, harnessing heat energy that would otherwise be lost at source. To give you an idea, in 2019, 30,000 flats in Stockholm were heated from the heat generated in a single data centre.

The integration and coexistence of the city and nature is one of the main lines of action that the award-winning cities have addressed. In Vitoria (2012) they have been working for decades on the recovery and development of natural spaces that have resulted in a green ring made up of 33 km of parks with several lagoons. A large space that serves as ecological niches for biodiversity, hosting hundreds of species. Citizens can also make use of these green spaces for leisure and free time. In Nantes (2013), a city with

[3] https://environment.ec.europa.eu/topics/urban-environment/european-green-capital-award_es

more than 100,000 trees, anyone living there has a green space within 300 m, as does Valencia (2024), which won the last edition of the prize.

Figure 118: *Evaluation criteria for the European Green Capital Award.*

Image 119: *Stockholm (Sweden).*

The city's traffic management is another of the axes for achieving several of the indicators that are evaluated. In this case, Copenhagen (2014) has long been committed to adapting public spaces and rationalising zero-emission mobility. In this way, public transport has reached 74% of its area, with transport stops less than 1 km away throughout the urban area. This availability and efficiency of their public transport, together with dissuasive taxes on combustion vehicles, allows only 4% of their roads to be congested at peak hours. Ljubljana (2016), on the other hand, modified traffic flow within the city to limit motorised traffic and give priority to pedestrians, cyclists and public transport.

Image 120: *Nantes (France).*

Image 121: *Valencia (Spain).*

Image 122: *Copenhagen (Denmark).*

Image 123: *Ljubljana (Slovenia).*

Climate change mitigation and adaptation is another key strategy within green cities. Other examples include the case of Essen (2017), which was the first mining city to be awarded for its successful transition from a highly polluting and polluted urban centre to a clean and green economy. An example where a combination of measures at national, state and local level have achieved a high reduction of GHG emissions and pollution by reducing the use of fossil fuels. For this, one of the main strategies was to combine central heating systems and renewable energies.

It is also notable for its collaborative culture with the creation of a municipal agency that advises on how to redirect urban development towards greener practices. Other cities, such as Tallinn (2023) or Grenoble (2022), have opted for an economic transition based on new technologies, becoming the headquarters of companies dedicated to R&D&I and information technologies.

Image 124: Essen (Germany) as a mining town.

Image 125: Essen (Germany) today.

European Green Sheet

This recognition is in line with the European Green Capital Award, but in this case, it is urban centres with a population of between 20,000 and 100,000 inhabitants are eligible to apply for the European Green Leaf Award. The aim is to recognise cities that have carried out environmental management actions within their urban development and to help improve their efforts and results. The award was created in 2015 with three main objectives:

1. Recognise and value cities that demonstrate a good environmental record and commitment to generating green growth.
2. Encourage cities to actively develop citizens' environmental awareness and involvement.
3. Identify cities able to act as "green ambassadors" and encourage other cities to move towards better sustainability performance.

Image 126: *Tallinn (Estonia).*

Image 127: *Grenoble (France).*

On the other hand, this award has allowed the constitution of the European Green Leaf Network, made up of more than 20 winning and finalist cities. The network offers its members opportunities for collaboration to exchange ideas and experiences with other municipal administrations, strengthening collective knowledge, innovation, and participation as drivers of sustainable cities. Among its actions, the Network organises thematic meetings to address the seven working areas related to the European Green Capital assessment indicators (*Figure 128*).

Image 128: *European cities awarded with the European Green Leaf Award.*

Image 129: *Torres Vedras (Portugal).*

With the creation of these awards, one of the objectives of the European Commission was to offer recommendations, financial support and international visibility to those European cities that are committed to sustainable urban development and thus, with their recognition, to promote an urban transition that serves as a model for the rest of the cities. In this sense, many of the strategies and actions carried out and proposed are similar, which in turn justifies the success of this call for proposals.

However, attention must be paid to the context of each city, to the needs of each population or to the necessary financing, among other aspects. Furthermore, we cannot forget the educational and awareness-raising processes so that citizens recognise and value the importance of the necessary measures to redirect our urban development towards sustainable positions.

Sustainable cities...

1. Based on the list of 7 indicators by which European Green Capital candidate cities are assessed, find examples of actions and policies that the awarded cities have implemented in the text and relate them to the indicators. Please note that some actions meet more than one indicator.
2. Not all cities recognised as European Green Capital are listed in the text. As a group, find a list of all the cities that have been awarded since 2010. Give an example of urban planning actions carried out in some of these cities that meet each of the seven indicators. Orally share your results with the class.
3. Do you think it would be possible to carry out any of these urban initiatives in your town/neighbourhood/city? What difficulties and obstacles do you think you would encounter in carrying out this action?
4. On this website you can find various data and indices related to urban traffic management https://urbanmobilityindex.here.com/. Explore the website and complete the following table.

Ciduad	Frequency of public transport	Public transport coverage	Traffic congestion index	Percentage of green spaces	Number of public bicycles
Vienna	251 trips per stop/day	71% of the urban area	5.2 out of 10	27%	0.8 for each 1000 inhabitants

5. Do you consider this information valuable to better understand the complexity of urban development? Please answer and justify your answer.

5.3. CLIMATE ACTION TOURISM

Before continuing...

1. Do you think that urban planning has any connection with tourism? Think about the justification of your answer considering one of the seven evaluation indicators of the Green City Awards.
2. Discuss the urban-tourism relationships in the previous question and compile a list of the seven indicators together in class. For each one, point out the possible influences of tourism, positive or negative, on the successful achievement of these indicators.
3. What do you think "climate action" means? Discuss it with your colleagues.

Urban planning and tourism

As you have seen, sustainable urban development is a very complex discipline where many variables must be taken into account: environmental, social, cultural, political and economic, in order to know and understand the needs of citizens and the resources available to rebuild the current cities into more liveable and sustainable cities. Hence, having examples and recommendations, such as the ones we have seen, to respond to the challenges of sustainability is useful knowledge to direct and accompany our efforts, plans and strategies in terms of urban development.

Image 130: *Aveiro (Portugal).*

Urban planning is closely related to tourism, even more so in cities that depend almost exclusively on the tourism sector as their main economic activity. Recalling some of the aspects that urban planning addresses, urban planning has a great responsibility in creating an attractive environment for tourism. Good urban design can make the city more attractive and easier to navigate, with accessible, safe, pleasant, and aesthetically appealing tourist areas. On the other hand, a tourist infrastructure is needed that responds adequately to periods of high occupancy with facilities (hotels, restaurants, parks, information centres, etc.), services (waste management, water supplies, health, transport, leisure, etc.) and technical means (human resources and other means such as ambulances, police cars, new technologies, etc.) that ensure that the needs of visitors are met, not forgetting, of course, the residents themselves.

Tourism and climate change

The tourism sector is highly vulnerable to the consequences of climate change and, at the same time, contributes to the emission of large amounts of GHGs, which contribute to the maintenance and worsening of the climate crisis. Given this situation, it seems necessary and urgent to accelerate climate action in the tourism sector to ensure a sustainable future for the tourism sector itself and for all citizens. Climate action or climate action is understood as efforts to reduce GHG emissions (mitigation) while strengthening adaptive capacities to the impacts of climate change. Considering that human activities are the cause of climate change, achieving these objectives depends on the actions and behaviours of everyone. We all receive tourists in our cities and towns and most of us are tourists at certain times in our lives.

The idea of climate action tourism was officially formalised in November 2020, during the UN COP26 conference, with the signing of the Glasgow Declaration, which set a time horizon of 2050 for achieving net zero emissions from the tourism sector. The declaration proposes five pathways to achieve this.

1. Measurement of travel and tourism related emissions and their accessible and transparent dissemination of recorded data.

2. Decarbonisation, which includes plans to reduce GHG emissions in tourism infrastructure: transport, accommodation, leisure activities, food, or waste management, among others.

3. **Regeneration**, i.e. restoring and protecting ecosystems. Ecosystems can be understood as the natural infrastructure that provides different ecosystem services such as protection from disasters, water and food supply or shelter, among others, and that play an important role as carbon sinks in the atmosphere.
4. **Collaboration**, of all the agents involved.
5. **Funding**, which guarantees the necessary resources to meet the objectives, including training, research and implementation of effective fiscal tools and policies.

For climate action tourism

1. Considering what we have seen so far, think about your holidays, your behaviour as a tourist: how you travel, what resources you use in your tourist destinations, where you stay, what you eat, how you use the infrastructure of the city you visit, etc. Share in small groups what you have thought about and make a list of the changes you need to make to become a sustainable tourist.
2. Now imagine that you are part of the city government. What proposals would you make and what infrastructure changes would be necessary to be able to offer climate action tourism in that city? What obstacles do you think you would encounter?

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