Carbon economics: technology, process and planning

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Chapter 2
Carbon economics: technology, process and planning

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2.1 Introduction

«The present decade has been marked by a retreat from social concerns. Scientists bring to our attention urgent but complex problems bearing on our very survival: a warming globe, threats to the Earth's ozone layer, deserts consuming agricultural land. We respond by demanding more details, and by assigning the problems to institutions ill-equipped to cope with them. Environmental degradation, first seen as mainly a problem of the rich nations and a side effect of industrial wealth, has become a survival issue for developing nations. It is part of the downward spiral of linked ecological and economic decline in which many of the poorest nations are trapped. Despite official hope expressed on all sides, no trends identifiable today, no programmes or policies, offer any real hope of narrowing the growing gap between rich and poor nations. And as part of our "development", we have amassed weapons arsenals capable of diverting the paths that evolution has followed for millions of years and of creating a planet our ancestors would not recognize.»

The Brundtland Report: "Our Common Future" (Keeble, 1988)

What do we mean by climate change?

What are the main global organizations that are taking the lead in communicating information on climate change?

- Greenhouse gases
- Climate change
- Global temperature

The production of a good, the provision of a service or the performance of an activity requires a certain amount of energy. However, energy production emits greenhouse gases (GHGs) into the atmosphere which are affecting the planet's climate. In this sense, in order to limit the increase in global temperature to below 2ºC, agreed by 195 countries at the Paris Climate Conference (COP21), it is necessary to know the carbon footprint of any economic activity in a country, whether agricultural, industrial or in the service sector, and specifically the source of carbon dioxide generation on which to act to reduce, eliminate or offset the carbon footprint.

United Nations defines climate change as "... *a change in climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere in addition to natural climate variability observed over comparable periods*" (ONU, 1992). On the other hand, climate change is directly related to the emission of greenhouse gases (GHGs), generated in the energy production process. Greenhouse gases are the gaseous components of the atmosphere (natural and anthropogenic) which absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface and the atmosphere. This characteristic of GHGs to absorb and emit infrared radiation makes them responsible for being the main cause of global warming. In this sense, the three main gases (Table 2.1) contributing to the greenhouse effect in the Earth are the carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Therefore, due to the importance of greenhouse gas emissions in climate change, reducing and/or eliminating CO_2 emissions can also minimize the risks of future disasters for humanity (Xu, Yao, & Lu, 2014).

Table 2.1. Sources and concentrations of major greenhouse gases

Gas	Source	Lifetime (years)	Contribution to warming (%)	Concentration year 2017 (ppm)
CO_2	Fossil fuels, deforestation, soil destruction	500	78,00%	405,5
CH_4	Livestock, biomass, rice fields, mining	7 - 10	14,00%	1859
N_2O	Fossil fuels, crops, deforestation	140 - 190	8,00%	329,9

Source: OMM, 2018

Observations of climate, which began in the mid-19th century, together with paleoclimatic reconstructions, which provide records going back centuries or millions of years, provide a global view of observed variability and changes in the planet's climate. The global average surface temperature has been rising steadily since the late nineteenth century and each of the last three decades has been warmer than any other decade on record, with the 2000s being the warmest decade on record (IPCC, 2014). The changes observed in the climate have led the states to include climate change in their agendas. In 1992, the first international commitment to address global warming took place with the creation of the United

Nations Framework Convention on Climate Change (UNFCCC). Three years later, and with its origin in the aforementioned Convention, the international agreement on climate change called the Kyoto Protocol (1995) is concluded. The purpose of this protocol was to commit participating countries to stabilize greenhouse gas emissions, whereas the Convention only encouraged them to do so (Chrysanthis, 1991). However, it is in the Paris Agreement of 2015 that it is agreed to keep the global temperature increase in this century below 2°C with respect to pre-industrial levels and to try not to exceed 1.5°C (UNFCCC, 2016). Table 2.2 specifies in more detail the different international agreements that have been concluded, with climate change as the main theme.[1]

Table 2.2. Chronology of climate negotiations

International Climate Conventions	
First World Climate Conference	1979
The Intergovernmental Panel on Climate Change (IPCC) is established	1988
Creation of the United Nations Framework Convention on Climate Change (UNFCCC)	1992
Kyoto Protocol	1997
Marrakech Agreements	2001
Nairobi Work Programme	2005
Bali Road Map	2007
Copenhagen Accord	2009
Cancun Agreements	2010
Durban Platform	2011
Doha Amendment to the Kyoto Protocol	2012
Paris Agreement	2015

Source: United Nations[1]

The countries that emit the most carbon dioxide into the atmosphere are in the northern hemisphere (mainly China and the USA), as they are the most industrialised countries and have the highest energy consumption, while the lowest amounts emitted correspond to the countries on the African continent, with lower levels of development.

Today, there are several international organizations whose main mission is to study climate variations and their effects on the earth's surface, the oceans and living beings:

- World Meteorological Organization (WMO): It is a specialized agency of the United Nations dedicated to international cooperation and coordination on the state and behaviour of the Earth's atmosphere

[1] https://www.un.org/sustainabledevelopment/

- Intergovernmental Panel on climate Change (IPCC): It publishes neutral reports which determine the state of knowledge on climate change. The IPCC numbers 195 member countries and it was created by the United Nations Environment Programme (UN Environment)
- United Nations Framework Convention on Climate Change (UNFCCC): Created in 1994, the Convention established that there was a climate concern that needed to be addressed, indicated a specific goal in this regard and led the responsibility to lead this awareness of climate change in developed countries

2.1.1 Impacts of Climate Change on the Planet

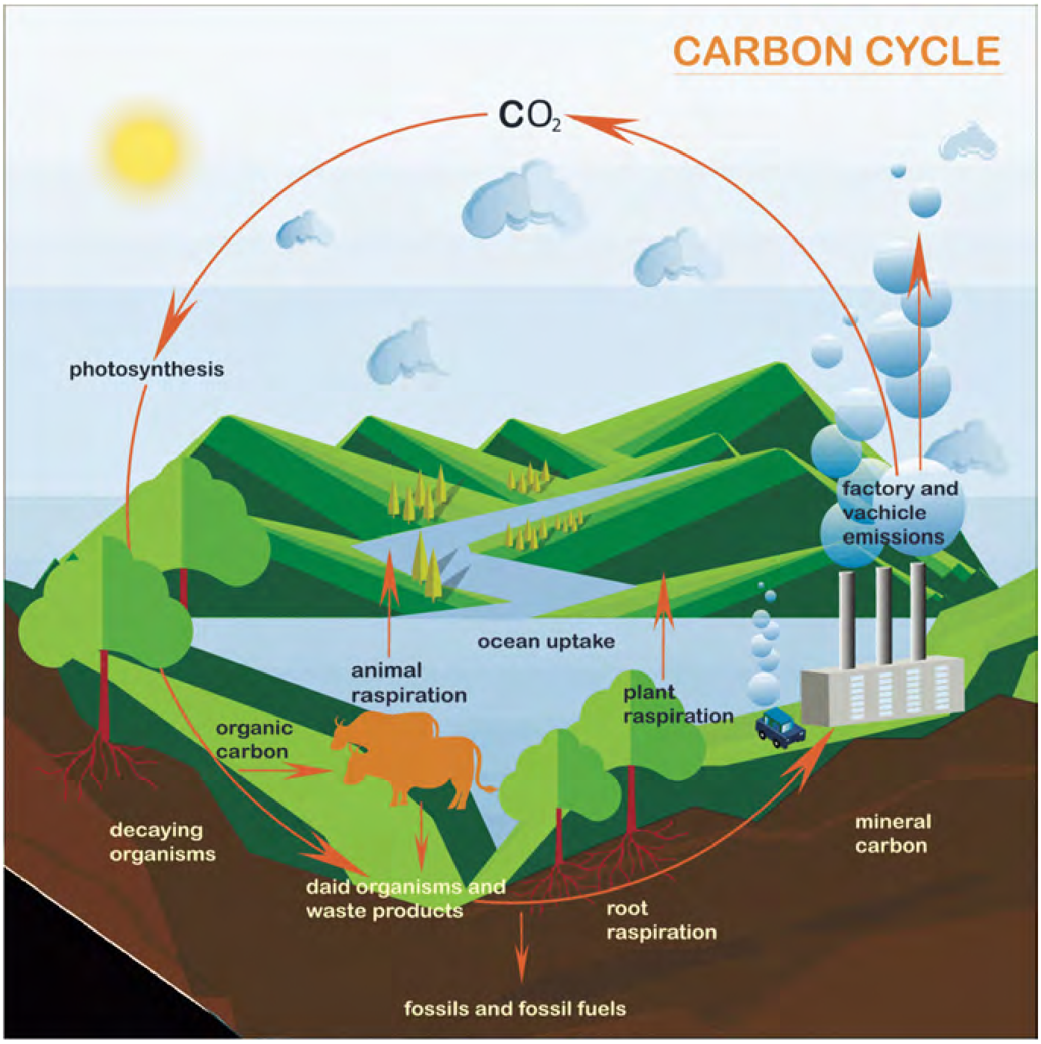
The impacts of climate change can be defined as the effects on livelihoods, health, ecosystems, the economy and society resulting from the interaction of variations in climate and the vulnerability of systems exposed to them (IPCC, 2014), as detailed below:

- *Impacts on livelihoods (agriculture and livestock):* Decreased rainfall and increased temperature lead to the emergence of agricultural pests, displacement of crops from one area of the planet to another, decreased yields due to high temperatures and/or adverse weather events (e.g. heavy rains), variability in water resource availability with consequent risk of water stress to plants, etc.
- *Impacts on health:* the effects on health can be of a direct type, such as a heat stroke produced by an abnormal increase in temperatures, or of an indirect type, such as respiratory diseases caused by air quality.
- *Impacts on ecosystems:* climate change generates physiological and demographic changes that modify the functioning of ecosystems. Among the impacts that are occurring in the habitats we can find the following: alteration of bird migration, defoliation of trees, displacement of plant species, acceleration of the duration of the larval stages of insects and acidification of the oceans and consequent destruction of corals, among others.
- *Impacts on the economy:* The effects of climate change on ecosystems translate into economic losses for the global whole. Both losses due to decreases in agriculture and losses due to destruction caused by adverse weather events (increasingly frequent), alteration of traditional tourist seasons, increased frequency and duration of forest fires, etc.

2.1.2 Carbon cycle

The flow of carbon, mainly in the form of carbon dioxide around the planet, is called the carbon cycle (Figure 2.1). There are two types of processes in the carbon cycle, there being a rapid cycle and a slow one. In the rapid carbon cycle, plants take carbon dioxide from the atmosphere and use it for photosynthesis. The slow carbon cycle begins with rain, which washes away atmospheric carbon and generates a series of chemical processes in the rocks called weathering. In the process of weathering, the rock decomposes, and calcium, magnesium, potassium and sodium ions are released, which end up in the sea and in living marine organisms. Once these organisms die, they are transformed into sediments that give rise to new rocks.

Figure 2.1. Carbon cycle2



In the carbon cycle we can also distinguish between two key concepts: source and sink. Sinks are any activity or mechanism that absorbs a greenhouse gas. For example, plants behave as sinks when they absorb CO_2. Water bodies are also sinks, because as we mentioned before, carbon, which is the result of weathering, dissolves and precipitates as calcium carbonate. The sources are the processes or activities that release greenhouse gases into the atmosphere (e.g. industrial activities, livestock, etc.).

[2] Source: https://www.alevelgeography.com/carbon-cycle/

2.1.3 Anthropogenic climate change

It is about all the effects and consequences of human actions in the natural environment. The human being has always used the natural environment for his own benefit. The resources of the environment have always been available to meet the needs of mankind.

It is since the Industrial Revolution that the use of these resources has increased. In order to carry out industrial activity and supply the needs of a growing population, the consumption of fossil fuels grew rapidly.

There are several human activities causing climate change, which are listed below:

- *Deforestation:* It consists of the elimination of forests by slashing or burning, in order to make the area available for various purposes, such as agriculture, livestock farming, construction, etc. and to obtain wood for use in the timber industry.
- *Fossil fuel burning:* The fuels that are burned are responsible for major environmental problems, such as the accumulation of greenhouse gases, acidification, air pollution, water pollution, etc. Currently, the burning of oil and coal are the most harmful as they contribute a very high percentage of greenhouse gases to the atmosphere.
- *Use of land for urban, industrial or agricultural purposes:* One of the biggest problems today is rapid population growth. In developed countries, due to the powerful economic development, most of the landscape has been transformed. Agriculture, livestock, forestry, industry and construction have drastically reduced soil quality.

Some consequences of climate change that can be seen today are:

- Decreased rainfall
- Alterations in terrestrial ecosystems with risk of increased pests
- Increased desertification due to loss of soil properties
- Reduction of animal and plant species richness
- Increase in pests and emergence of new forest diseases
- Decrease in drinking water
- Increased intensity, frequency and magnitude of fires
- Increased air pollution

In addition to the information contained in this unit, it should be noted that climate change will generate economic costs that cannot yet be accurately estimated. In fact, the latest agreements to confront climate change propose the creation of a Green Fund[3], in order to be able to assume the costs that climate change will entail at an international level.

[3] Website: https://www.greenclimate.fund/

2.2 Definition of Carbon Economics

The concept of a *low-carbon economy* was first mentioned in the United Kingdom's Energy White Paper in 2003 (Great Britain Department of Trade and Industry, 2003) and has since gained increasing importance, with countries such as Germany and Japan setting up national systems to reduce their carbon-related emissions. Scientists around the world have recognized that emissions related to the traditional energy production system have led to serious climate consequences. Therefore, a low-carbon economy is presented as one of the main solutions to curb the climate crisis we are experiencing.

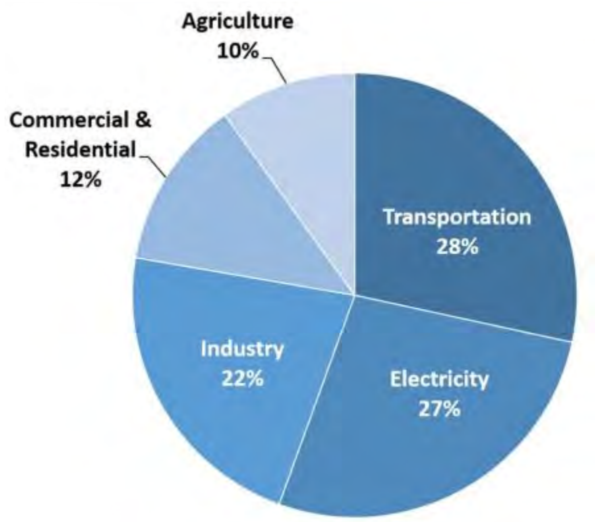
How is defined a low-carbon economy?

Which are the main air emissions from the maritime transport?

- Low-carbon economy
- Case of maritime transport in Europe
- Mitigation

The European emissions market initiative[4] has set a goal of reducing EU emissions by 43%, taking 2005 as a reference year.

Figure 2.2. Total Emissions in 2018 = 6,677 Million Metric Tons of CO2 equivalent



The five sectors that contributed most to greenhouse gas emissions in 2018, at the global level, were transport (28%), electricity generation (27%), industry (22%), residential, commercial and institutional sector (12%) and agriculture (10%) (Figure 2). Within the transport sector, the port system constitutes an essential element of social and economic life, which has made it possible to guarantee the mobility of citizens, to satisfy to a great extent the needs of passenger trans-

[4] https://ec.europa.eu/clima/policies/ets_en

port and to provide the fishing, commercial and industrial sectors with the installations and infrastructures essential for carrying out the tasks of economic exchange and goods traffic. On the other hand, the great development of tourism has led to the appearance of ports and maritime facilities of a sporting or recreational nature, linked to leisure and quality tourism, which have a great impact on the economic model of the municipalities where they are located and on the territory.

The operations in the port that have the greatest impact on the environment are those carried out at the gas oil dispensing stations and the repairs and maintenance of the ships in the dry dock. The products handled in these operations such as petrol, fuel and its derivatives, dirty water, detergents, paints, glue, resin, protectors and used oils have potential negative effects on the marine environment. Dredging activities also cause significant changes in the physical and chemical conditions of the environment closest to the marina (Valdor et al., 2019). Other actions with impacts on the environment are the losses suffered by ships during navigation (Davenport & Davenport, 2006), the management of solid waste, the discharge of used oils or bilge water and the alteration of the sea floor due to anchoring or mooring, the movement of propellers. However, the pressure depends on the density of the boats and the length of the boat, whether the boat is motor or sail, and the number of crew members. Finally, it also depends on the mode of operation. For example, the pressure of marinas differs from that of cargo ports because the latter have associated logistics and industrial services that do not exist in marinas.

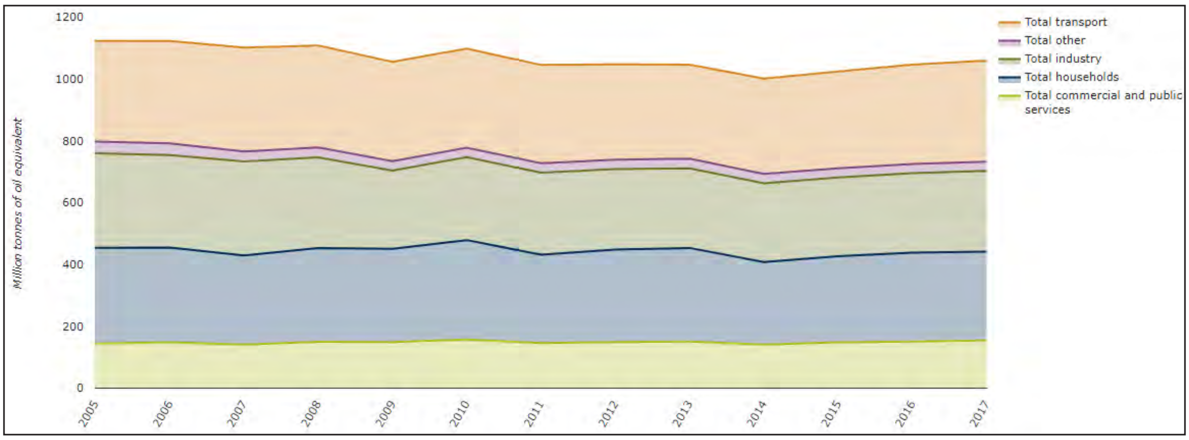
Low-carbon economy is defined by eight mains aspects (Xue, 2013): Low-carbon production; Low-carbon energy; Low-carbon technology; Low-carbon transportation; Low-carbon consumption and lifestyle; Low-carbon housing and building; Low-carbon farming and Low-carbon city. The European Union has launched the EU Emissions Trading System (EU ETS) in 2005 as the cornerstone of its strategy for cutting emissions of carbon dioxide (CO_2), which has become the largest carbon market today. With this programme, the European Union has achieved various objectives: placing climate change as a priority on the agenda of European companies, assigning a value to the carbon emissions emitted and promoting investment in clean energy that does not have an economic penalty associated with its use (Climate Action - European Commission, 2015). The operation of the EU ETS is that companies and firms included in the system can make emissions up to a limit set by the European Union. Therefore, within that limit, companies can buy or receive allowances, trading them if they wish.

The Marine Environment Protection Committee (MEPC) addresses environmental issues under IMO's remit. This includes the control and prevention of ship-source pollution covered by the MARPOL treaty, including oil, chemicals carried in bulk, sewage, garbage and emissions from ships, including air pollutants and greenhouse gas emissions. The main air emissions from the maritime transport sector are: sulfur dioxide (SO_2); nitrogen oxides (NO_x); volatile organic compounds (VOCs); particulate matter (PM) and carbon dioxide (CO_2) (Miola, Marra, & Ciuffo, 2011):

- *Sulphur dioxide (SO2):* it is a colourless gas with a characteristic irritating odour. Combustion of fuels for heating and power generation produces an environmental pollution with sulphur dioxide (Vale, 2012).
- *Nitrogen oxides (NOx):* NO_2 and other NO_x encounters water, oxygen and other chemicals in the atmosphere to form acid rain. Acid rain harms sensitive ecosystems such as lakes and forests.
- *Volatile organic compounds (VOCs):* it is a group formed by organic chemical compounds with significant vapour pressure values (Fellow, 2000).
- *Particulate matter (PM):* particulate matter may have a natural origin or an anthropogenic origin. Its anthropogenic origin lies in the combustion of fossil fuels and biofuels.
- *Carbon dioxide (CO2):* it is an important greenhouse gas that contributes to trapping heat in our atmosphere. However, a gradual increase in CO_2 concentrations in the Earth's atmosphere is helping to drive global warming, threatening to disrupt our planet's climate as average global temperatures gradually rise.

In January 2020, a limit has been set by the European Union for the maximum sulphur content of marine fuels and has been reduced to 0.5%. The Commissioner for Transport in the EU has signed (Virginijus, 2020): *"Maritime transport is a global business, and reducing its emissions requires global solutions. The entry into force of the global sulphur cap is an important milestone for the entire maritime sector; it will contribute to further reduce emissions of harmful air pollutants, directly benefiting cities and communities around the globe, including important ones on our Southern European shores."* These statements are corroborated by the consumption of fossil fuels by transport at the European level (Figure 2.3).[5]

Figure 2.3. Consumption by fuel type and sector



Source: European Union[5]

[5] https://www.eea.europa.eu/data-and-maps/indicators/final-energy-consumption-by-sector-10/assessment

2.2.1 Europe and maritime transport

The European Union historically has had an important connection with the sea, as its trade relations with the rest of the world have depended heavily on its seaports. European Directive 2019/883 states that *"… The Union's maritime policy aims to ensure a high level of safety and environmental protection"* (EU, 2019). If at first consideration was given only to the development of a maritime sector ports focused mainly on trade, this concept has evolved over the years and the knowledge acquired has made possible to see nowadays ports dedicated also to other matters. Hence, ports have been recently developed also for tourism related activities, and cruise ships and maritime passenger transport vessels dock dedicated areas were made available (Paiano et al., 2020). On the other hand, there are the leisure ports, which are those where the boats that dock have a recreational and leisure purpose. In this article, the authors intend to focus on the study of the leisure marinas, because due to their quantity and characteristics, they constitute their own segment within the maritime sector, which has been less studied than commercial ports.

The operations in the port that have the greatest impact on the environment are those conducted at the diesel fuel dispensing stations, and the repairs and maintenance of ships in the dry dock. The impact depends on the density of the ships on each route and the length of the boat, whether the boat is motor or sail, and the number of crew. It also depends on the mode of operation. For example, pressure from leisure marinas differs from that of freight ports because the latter have associated logistics and industrial services that are not available in marinas.

Recent studies carried out by the European Union have analysed which navies hold the Blue Flag in Europe. The results of this study can be seen in Figure 2.4.

2.2.2 Measures for the reduction of greenhouse gases

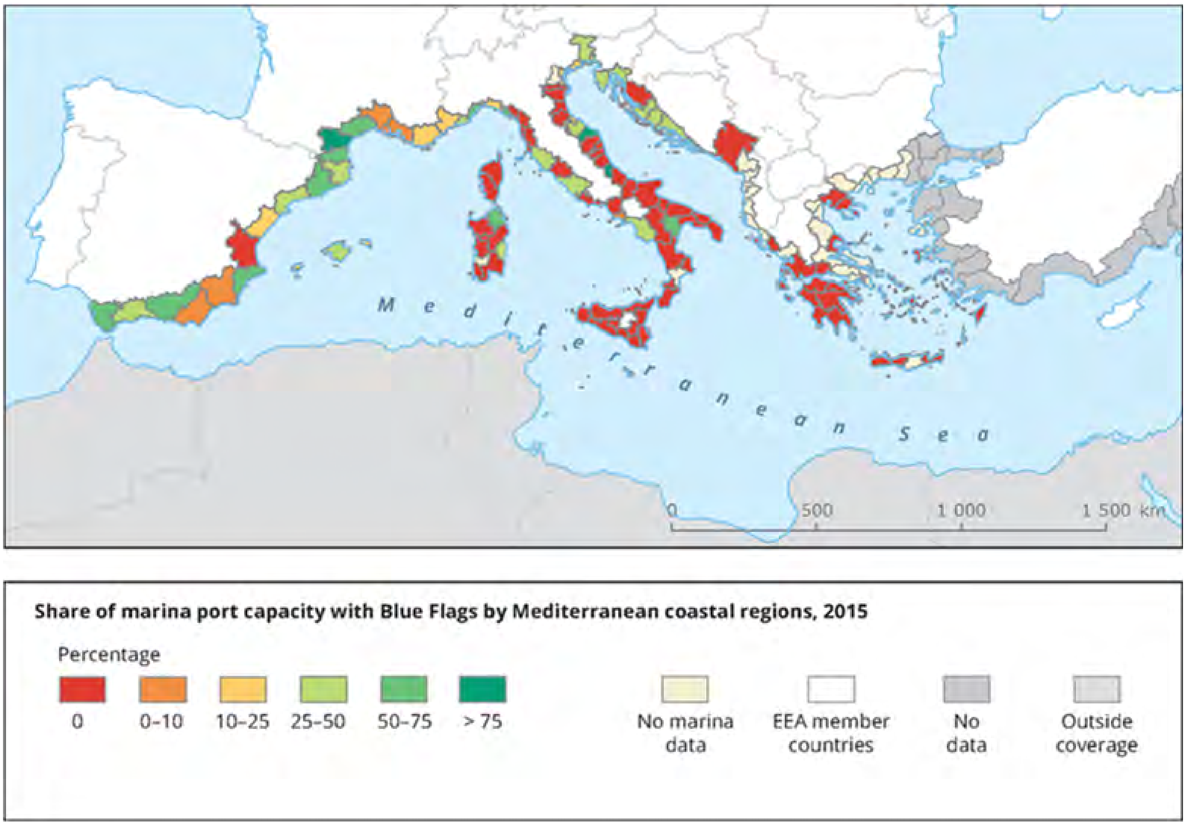
Climate change mitigation can be achieved through different measures such as the following:

- Use of renewable energies
- Prioritizing the use of electric vehicles
- Recycling and reuse
- Increasing carbon sinks

There are production sectors that are worth emphasising more, because a drastic reduction in emissions in these sectors would mean a significant reduction in emissions on a global scale. These sectors are as follows:

- *Energy sector*: as will be seen in unit 4, to produce electricity today, a large amount of coal is required, with the consequent negative impacts of this activity on the environment. Therefore, a greater effort is required at a global level to increase the use of renewable energies in the energy sector.

Figure 2.4. Sport marinas with blue flags in the Mediterranean coast



Source: European Union[6]

- *Transport sector:* the means of transport we use today involve a large consumption of fossil fuels. For this reason, in various sectors, attempts are being made to include renewable measures to improve the sustainability of land, sea and air communications.
- *Industrial sector:* Everything we consume today involves a previous industrial process. Therefore, as industry is such a powerful sector, these activities are increasingly required to be efficient in reducing emissions, recycling, heat and energy recovery to be reused in the production process, etc.
- *Agricultural and livestock sector:* With an effective management of crops, carbon sinks can be achieved, and through agriculture, degraded or disused soils can be recovered, and reforestation can also be practiced.

One of the major United Nations initiatives for climate change mitigation and reduction is Agenda 2030[7]. This Agenda includes 17 objectives, of which the following are expressly related to Climate Change:

- SDG6: Clean Water and Sanitation

[6] Source: https://www.eea.europa.eu/data-and-maps/figures/share-of-marina-port-capacity
[7] https://www.un.org/sustainabledevelopment/

- SDG7: Affordable and clean energy
- SDG11: Sustainable Cities and Communities
- SDG13: Climate Action

These objectives are intended to be a global strategy when undertaking economic and development measures, to ensure a more sustainable and fairer world.

2.3 Renewable Energy

United Nations, in its Sustainable Development Goals (United Nations, 2018), includes energy as one of its priorities from two approaches: on the one hand, by requesting that people who do not have access to electricity have the option of accessing it. On the other hand, it requires countries that already have an energy supply network to make an urgent energy transition to renewable energy sources, since only 17.5% of the total energy consumed worldwide comes from clean energy. Developed countries should be the most involved in taking measures to mitigate climate change, as they are also the ones that generate the most greenhouse gas emissions. Moreover, in this way, a cascade effect can be achieved, whereby developing countries grow by taking ecological measures from the outset.

What are the main sources of renewable energy?

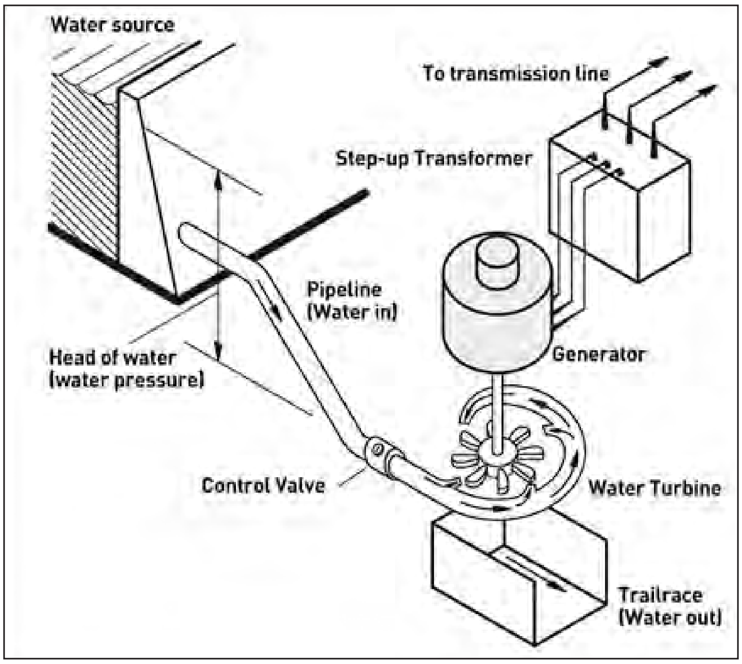
How can we start a transition to renewable energy?

- Clean energy
- Energy supply
- Energy transition

Renewable energies are clean and practically inexhaustible resources offered by nature; whose environmental impact is zero in the emission of greenhouse gases such as CO_2. The various sources of renewable energy that are available in the planet are:

- *Solar:* the solar radiation can be collected by collectors attending to two different types of principles: the photoelectric effect and the photothermal effect. Photovoltaic energy transforms the rays of the sun into electricity through solar panels. Photothermal energy uses the heat of the sun by capturing it with solar collectors.
- *Wind:* is the most efficient renewable energy exploited by humans. The principle of wind energy is to run a wind turbine that produces electrical energy. The wind turbine is activated by the movement of the blades, which are themselves moved by the force of the wind.
- *Water:* hydroelectric plants are in riverbeds to take advantage of the force of the water, which moves the plant's turbines, generating electricity (Figure 2.5). The percentage of energy used worldwide and covered by hydroelectric power is 16% (World Bank, 2015).

Figure 2.5. Operating diagram of a hydropower plant



Source: http://www.veoliawater2energy.com/en/references/micro-hydro-power-plants/

- *Geothermics:* geothermal energy is tied to the heat of the interior of the earth's surface and, if we consider the entire surface of the earth, the geothermal power that arrives from the interior is 4.2 x 1012J (IDAE, 2008). Geothermal energy can be of high enthalpy, when temperatures reached are above 150ºC, or of low enthalpy, when temperatures are below that temperature.
- *Biomass:* biomass is organic matter used as an energy source. These biomass resources can be generally grouped into agricultural and forestry resources. The organic matter in wastewater and sewage sludge is also considered biomass. The valuation of biomass can be achieved through four basic processes by which it can be transformed into heat and electricity: combustion, anaerobic digestion, gasification and pyrolysis. Biomass can result in biogas or biofuels.
- *Tidal energy:* it is a blue energy, since it exploits the energy coming from the tides to generate, through a system of alternators, electrical energy.

2.3.1 Energy demand

Europe plans to become a zero-emission economic powerhouse by 2050. This strategy, in line with the Paris Agreement[8], aims to continue economic and industrial growth, without compromising the state of the environment. To achieve this

[8] https://ec.europa.eu/clima/policies/international/negotiations/paris_en

goal, the European Union needs to reduce emissions from energy production, which currently account for 75% of the continent's total emissions.

In the last European Union progress report[9], corresponding to the years 2015/2016, the following interesting data have been obtained, and they are quoted literally:

- *"In its final energy consumption, the EU achieved a 16% share of renewable energy in 2014 and an estimated 16.4% share in 2015.*
- *Most EU countries are well on track to reach their 2020 binding targets for renewable energy, but all countries will have to continue their efforts to meet these targets.*
- *The transport sector achieved a 6% share of renewable energy in 2015, so some EU countries will have to intensify their efforts to reach the 10% binding target for transport by 2020."*

Since the Industrial Revolution until today, the energy demand of all countries has been covered in a similar way, with a system known as the energy demand curve. This curve (which has its peaks at the times of the day of greatest consumption, varies slightly between countries due to the customs and schedules of each of them) has been fed at its base with thermal energy. One of the main applications of thermal energy is the generation of electricity from heat. Heat is a form of energy that can be converted into electricity in many ways. The main ones are:

- *Burning fossil fuels*: this is the most common way, and not only fossil fuels but also organic waste (biomass) can be burned
- *From nuclear reactions:* uranium, when breaking its atoms and producing fission, gives off an enormous amount of energy

Thermal energy obtained from the burning of fossil fuels is the most common in almost all countries, especially in those where nuclear energy is banned or in disuse. However, thermal energy from fossil fuels is characterized as the least environmentally friendly source of energy. Thermal energy emits high emissions of greenhouse gases into the atmosphere. Figure 2.6 shows the main emissions from Large Combustion Plants (LCP) in Europe.

For instance, if we take the case of the United Kingdom, we can see how its energy demand curve is composed of a large percentage of conventional thermal energy (Figure 2.7).

Traditionally, renewable energies have behaved as a support for conventional thermal energy, occupying a very discreet and unrepresentative percentage of demand. The current trend is trying to be reversed, in fact, there are two leading energies such as solar and wind[10], which are growing by leaps and bounds, and are trying to lead the field of solar energy.

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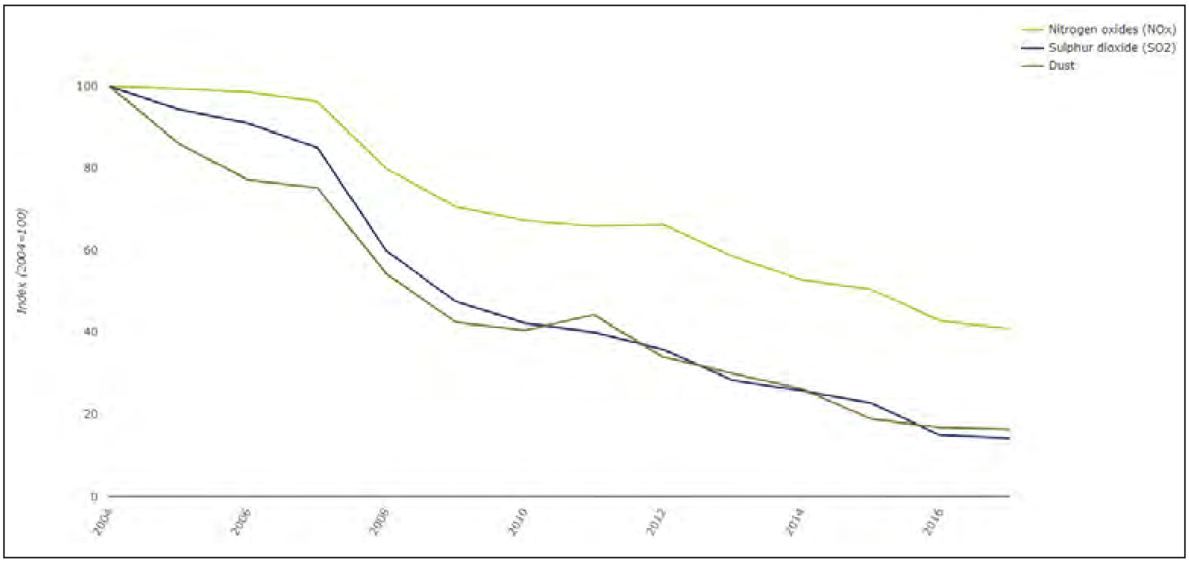
[9] https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52019DC0225&qid=1559033163855&from=EN

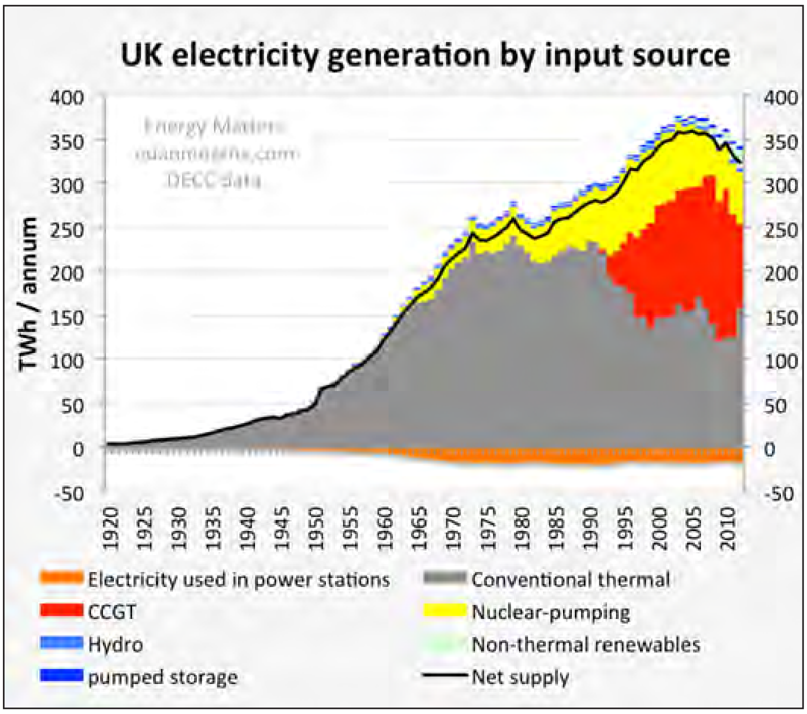
[10] Miller & Carriveau. 2019. Energy demand curve variables – An overview of individual and systemic effects. Sustainable Energy Technologies and Assessments, 35, 172-179

Figure 2.6. GHG emissions from large combustion plants in Europe



Source: European Union[11]

Figure 2.7. Electricity generation in the UK12



[11] https://www.eea.europa.eu/data-and-maps/indicators/emissions-of-air-pollutants-from-16/assessment

[12] http://euanmearns.com/uk-electricity-demand-gdp-and-energy-policy/

Traditionally, renewable energies have behaved as a support for conventional thermal energy, occupying a very discreet and unrepresentative percentage of demand. The current trend is trying to be reversed, in fact, there are two leading energies such as solar and wind[13], which are growing by leaps and bounds, and are trying to lead the field of solar energy.

Another energy that so far has only been used in countries like Iceland, Nicaragua or the Philippines, which is geothermal energy, is trying to be increasingly integrated into the countries' renewable energy systems. Geothermal energy can be called either high-enthalpy or low-enthalpy. The countries mentioned are examples of countries with high enthalpy geothermal energy. However, taking into account that geothermal energy is constant and can be found from a depth of 100 metres below the earth's surface, it is consolidated as a magnificent source for heating homes and buildings. These uses have been in use for a long time in countries such as Sweden, Switzerland and Denmark.

A country's energy consumption is related to its GDP. Therefore, the most developed countries have the highest electricity consumption[14]. That is why it is necessary to focus on the great world powers, demanding them to increase their use of renewable energies, since they are the ones that emit the most and since they can serve as an example for the countries that are currently industrializing.

2.3.2 Transition to renewable energy in ports

There are a series of projects being implemented across Europe to reduce port-related emissions by using renewable energy to power ports. Some of these examples are as follows:

- *Onshore Power Spply (OPS):* The Onshore Power Supply (OPS) means a considerable decrease in the maritime sector, since when ports are berthed they depend entirely on fossil fuels, unless they are connected to the electricity grid of the city where they are anchored. There are successful cases in which the use of PAHOs has reduced a port's CO_2 emissions by 10%. It is therefore important to consider that, for the reduction of emissions to be more effective, the production of this electrical energy, which will replace fossil fuels, should come mainly from renewable energies. Otherwise, we would be transferring emissions from one process to another.
- *Alternative fuels:* Using alternative fuels such as Liquified Natural Gas (LNG) reduces the emission of CO_2. Nevertheless, LNG produces methane, which is a greenhouse gas as well, but it is the cleanest fossil fuel right now.

[13] Miller & Carriveau. 2019. Energy demand curve variables – An overview of individual and systemic effects. Sustainable Energy Technologies and Assessments, 35, 172-179

[14] Mujiyanto & Tiess. 2013. *Secure energy supply in 2025: Indonesia's need for an energy policy strategy*. Energy policy, 61, 31-41

Other measures that can be taken in the meantime to reduce emissions from European marinas are as follows:

a) Promote the use of public transport among marina workers and visitors, indicating on the marina's website the public service line between the marina and different locations on the island.
b) To carry out a supply plan that will make it possible to reduce the frequency of visits by suppliers.
c) Encourage the hiring of distributors with efficient transport fleets such as electric or low emission vehicles.
d) Contracting electricity that comes entirely from renewable sources.
e) Using solar panels to produce hot water for the marina.
f) Use of all possible renewable sources for other uses.
g) Transfer the results of the study to the marine workers so that they make a more conscious and efficient use of energy and resources.

2.4 Environmental impact associated with the production and extraction of coal

According to the ISO 14001:2015 standard, the concept of life cycle is defined as: *"Consecutive and interrelated stages of a product (or service) system, from the acquisition of raw materials or their generation from natural resources to final disposal"*.

What are the main environmental impacts of mining activity on the environment?

What are the 4 main types of pollution produced by mining activity?

- Coal mining activity
- Coal mining impact on the environment

Coal is a fossil fuel, the result of a series of transformations on accumulated plant remains in swampy places or lagoons. Through diverse chemical actions and variations in pressure and temperature over long intervals of time, these plants are transformed into coal in a process called carbonization. There are four different types of carbon, due to the different types of plant from which they come. These are:

- Anthracite: is a hard coal, totally carbonized. With a pearly shine and black colour.
- Coal: it is a hard coal, totally carbonized. Glossy black colour.
- Lignite: it is a soft coal, so it has not suffered the complete carbonization process.

- Peat: it is the most recent of the coals. It is soft, brown in colour and you can still see the remains of plants.

Coal has become the main source of energy; it can supply 29.6% of the world's energy requirements and 42% of the world's electricity requirements (Hasanuzzaman et al., 2018).

The coal mining industry involves four different types of pollution:

- *Air pollution*: The work of extracting coal, as well as the use of explosives in order to advance the drilling, favours air pollution in a mine. The main gases released in these activities are sulphur dioxide, nitrogen oxide and carbon dioxide.

Due to the characteristics and hardness of some materials that are crossed when the mine is executed, it is necessary to use explosives as a system of advance. The use of explosives depends on the type of terrain to be crossed. Therefore, if the rock to be excavated has a high resistance, it is advisable to excavate it by drilling and blasting (Santamarta, 2016).

Initially, the mines were built by hand and with animals used for the transport of tools and utensils. Afterwards, in areas with the presence of massive materials, it was necessary to use very rudimentary explosives, sometimes even manufactured by the operators of the mine themselves. As a complement to explosives, pneumatic hammers and even excavators are also used in drilling. The use of this machinery has obvious advantages in terms of productivity and comfort at work, nevertheless, it is precisely the utilisation of all such machinery that makes the impact of the mining process on the environment more severe.

Figure 2.8. Landslides on slopes due to mining activity

- *Soil pollution:* Coal mining activities generate a progressive loss of soil, due to changes in soil properties (e.g. a reduction in pH and electrical conductivity) turning it into a barren area over time.

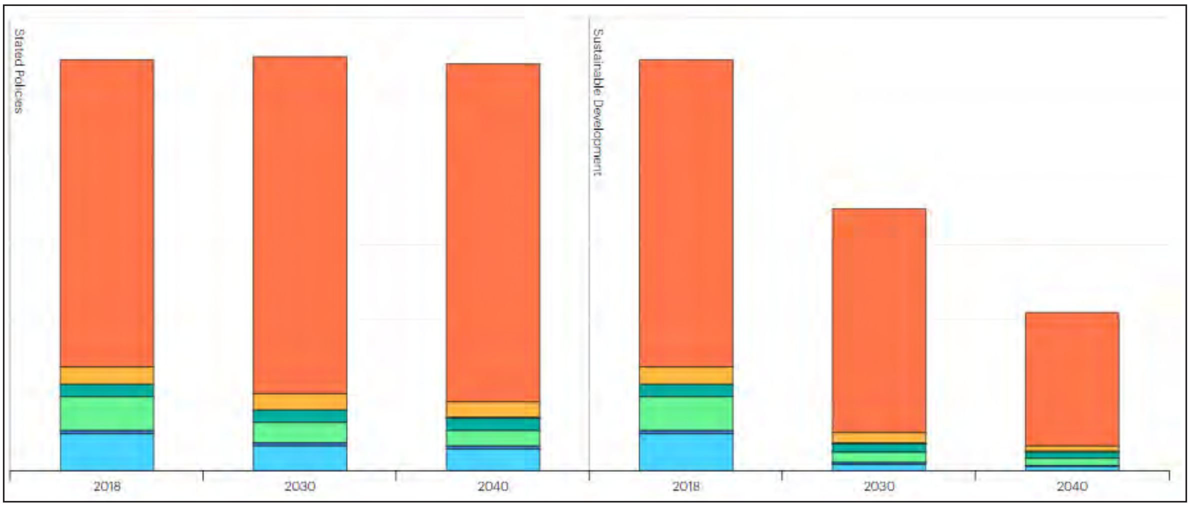
Other environmental consequences associated with coal mining activity include deforestation, loss of fertile soil, erosion and alteration of slope process dynamics (see Figure 2.8):

- *Water pollution*: there are two types of water pollution here. On the one hand, water used in extractive activities, that is, in production work, causing water used in industry to become contaminated after use and to change from drinking water to wastewater. On the other hand, the groundwater in the extraction area. With the rains, the above-mentioned pollutants are carried away, and part of these are infiltrated into the subsoil, causing the contamination of the groundwater (mainly acid contamination).
- *Noise pollution*: a mine at full capacity means the transfer of heavy machinery, generating noise non-stop. It is estimated that on a construction site, with work progressing during the day, it can have values of between 100 and 110 dB (Wang et al., 2014).

All these negative impacts of the mining activity are suffered in the first place by the workers of the sector, who usually present high percentages of lung cancer due to inhaled substances (Yang & Chen, 2015). They also present high levels of stress associated with high noise levels in the workplace. Secondly, the damage is suffered by society in general, since the loss of fertile soil and water pollution are major damages that affect society collectively. The largest coal mines in the world are located in the United States, Russia, China and Australia. However, China is the largest producer and consumer of coal in the world.

Indeed, if we look at the trend proposed by the "World Energy Outlook 2019", we can see how global coal consumption is and will be led by Asian countries (Figure 2.9).

Figure 2.9. Forecasts of world coal consumption to 2040[15]



[15] https://www.iea.org/reports/world-energy-outlook-2019

2.5 Carbon footprint

The carbon footprint accounts for all the greenhouse gases associated with the production of a product, the provision of a service or the performance of an activity, generated both directly and indirectly by the organisation (Blasco Hedo, 2014). Therefore, the carbon footprint makes it possible to measure the impact of a product, service or activity on the environment. In parallel to measuring, an implicit objective in the study of the carbon footprint is to provide recommendations to reduce or compensate emissions. And with the communication and implementation of these recommendations it is possible to act on the planet's climate.

How can we calculate the carbon footprint of an organization?

What is the hydric footprint?

- Carbon footprint
- Hydric footprint
- CO_2 emissions inventory
- Scopes

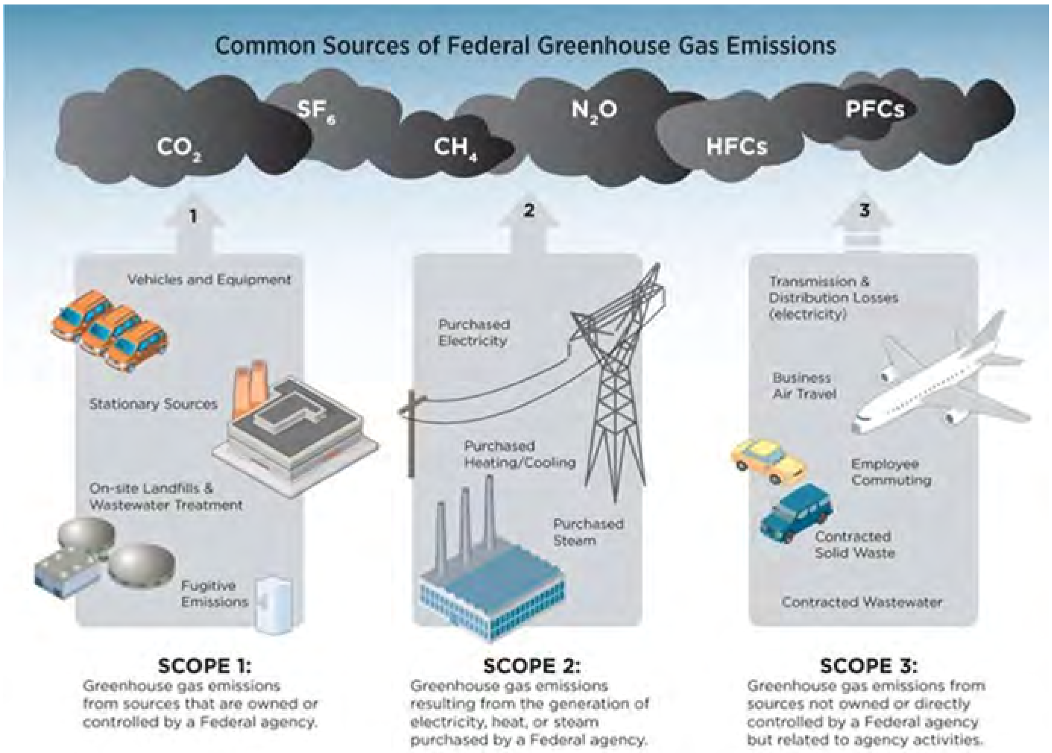
Initiatives to communicate the carbon footprint to society have been undertaken in nearly every country in the world, either in the form of product labelling or in the form of an inventory of the CO_2 emissions of companies and organisations. The carbon footprint is an indicator of the amount of greenhouse gases emitted into the atmosphere as a result of an activity. The accounting of these emissions is governed by various regulations at both international and national levels, and some countries have even devised their own system for calculating the carbon footprint. In this sense, a study promoted by the European Commission in 2010 found more than 140 different methodologies[16].

The calculation of the carbon footprint can be addressed by following two basic methodological approaches. The first is the business-oriented method, which consists of collecting data on the direct and indirect consumption of materials and energy by an organization and translating it into equivalent CO_2 emissions in order to have an inventory of emissions. The Green House Gas Protocol, developed by the Word Resources Institute and the Word Business Council for Sustainable Development, is the most widely used guide for companies, both large and small, to inventory their GHG emissions and thus calculate their carbon footprint. The importance of this protocol is that it has been the basis for many other methods and initiatives. The ISO 14064: 2006 standard (parts 1 and 3) is a second tool following the company's approach. Unlike the Green House Gas Protocol, the ISO standard is an international standard verification guide for companies to prepare and report on their greenhouse gas inventory. This standard is compatible with the Green House Gas Protocol. In addition to these tools, there are other tools that focus on the product. In the latter

[16] For example, France proposes the Bilan Carbone Method, England uses the PAS 2050 System and Germany has developed the PCF Projekt Project (CEPAL, 2008).

case, the calculation consists of collecting all the information on material and energy consumption in each of the stages that a product goes through and translating it into CO_2 emissions. Finally, the composite method of the accounting accounts or MC3 is a mixed approach, oriented both to the organization and to the product, in which the data are obtained from the accounting accounts of the organization.

Figure 2.10. Carbon Footprint Scopes



Source: EPA

Calculating the carbon footprint requires defining the limit of the company's inventory. Organizational and operational boundaries delimit the inventory. The ISO 14064 standard and the Corporate Accounting and Reporting Standard of the GHG Protocol allow a choice from two approaches to setting the organization's limits. The equity approach consists of accounting for emissions from shares, even if the company does not have control over its operations, and the control approach consists of accounting for emissions from operations over which the company has some control, either financial control or operational control. Under no circumstances should issues from operations in which the company has an ownership interest without control of the share be included. Note that the organizational boundaries depend primarily on the size and manner of operation of the company. On the other hand, the definition of operational limits requires determining the type of emissions to be included in the inventory, emissions that, in turn, are related to the scope of these emissions (see Figure 2.10). GHG emissions can be classified into three types. Direct or designated Scope 1 emissions are those that come from the fuels that the organization uses in its processes or in transportation, indirect or Scope 2 emissions are those related to the generation of electricity acquired by the organization and the so-called other indirect or Scope 3 emissions include everything that is not fuel, direct emissions of any type and electricity. Finally, the methodology used can be called complete if it includes the carbon footprint of capital goods, works and all fixed assets.

The emissions inventory requires the identification of the sources of gas emissions. Emission sources are classified into fixed and mobile sources. Among the fixed sources a distinction can be made between point sources derived from the generation of electrical energy and from industrial activities, area sources, which include the emissions inherent to certain activities and processes, and natural sources, which refer to the generation of emissions produced by volcanoes, oceans, ... The definition of mobile source includes all motor vehicles.

Case Study - Company vehicle fleet

The study will use the fuel consumption of an organisation's vehicle fleet. The company has a total of 20 vehicles. The frequency of passage of the vehicles is 30 minutes, in schedule of 07:00-24:00 h. The type of vehicles is known, the fuel used by all vehicles is diesel.

Calculation period: 2018

Operational limits: fossil fuel consumption of the vehicle fleet, electricity consumption in the offices, waste generation in the vehicle maintenance workshop.

The different scopes we comprise them thus:

Scope I: direct emissions are included as well as the diesel consumption of the vehicle fleet. Transport equipment using fossil fuels.

Scope II: Electrical consumption for heating the organisation's facilities, both in the offices and in the maintenance workshop.

Scope III: Production and management of waste in vehicle maintenance.

Methodology: ISO 14064-1.

Scope I calculations:

20 City Buses; 34 trips per day per vehicle; Distance covered per line 8 Km; 365 days worked/year.

Distance travelled = 20 x 34 x 8 x 365 = 1.985.600 Km

Total distance covered 1.985.600 Km. Diesel consumption 31.765 L/100 Km.

Kg CO_2 = 630.720 L x 2.57 KgCO2/L = 1.620.950,4 KgCO_2

Emission factor = 2.57 Kg CO_2/L[17]

[17] Source: https://eur-lex.europa.eu/eli/dir/1999/94/oj

Scope II calculations:

The electricity consumption is obtained from the bills of the electricity supply company.

$KgCO_2$ = 2.150 KW x 0.388 $KgCO_2$/KW = 834.2 $KgCO_2$

Emission factor = 0.388 Kg CO_2/KW[18]

Scope III calculations:

The company has its own workshop where it carries out maintenance operations on the bus fleet. As a result of these operations, a number of waste products are generated. The amount of waste is obtained from the data provided by the authorised waste managers.

Kg CO_2 = 20 TN x 0.2556 $KgCO_2$/TN = 5.112 $KgCO_2$

Emission factor = 0.2556 Kg CO_2/TN

If we intended to calculate the carbon footprint of a marina, we would have to take into account the following considerations: the scope of study of marinas covers the total area of the public port domain, including the water mirror surface and the land surface. The water surface area is defined by the number of berths and the average size of the boats operating. The land surface includes the surface of buildings and facilities. Buildings are those used for administrative activities, toilets and showers, restaurants such as bars, cafes and restaurants and hotels. The facilities include the road network and parking lots, the dry dock, maintenance and sanitation work, the transformer power station, the fuel station, the clean point, the drinking water supply facility, the surface drainage system and the electricity network.

There is no doubt that the scope of the activities is conditioned by the system of exploitation, in rent or ownership, of the places available in the port. Whatever the case, the main services offered by a marina are access to drinking water, electricity, petrol, mooring assistance, crane, waiting dock, maintenance service, weather information, towing, toilets, lockers, mechanics, nautical items, diving service, 24-hour surveillance, laundry, parking and catering. The issuing sources associated with operations of a fixed nature include facilities for administration, maintenance, toilet and shower activities, catering and hotels. In relation to administrative activities, the number of offices and persons working in each of them is counted; in the maintenance activities carried out, a distinction is made according to who carries them out, whether it is the port's own personnel, hired personnel or others. Whatever the case, the frequency with which these activities are carried out on average and the consumption of water and electricity used on average when these tasks take place are quantified. In restoration activities, the number of activities of each modality is quantified, distinguishing whether the power

[18] https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references

source is that of the port, the city, solar panels or others. The way the water is heated will require the port to have solar panels or natural gas or oil boilers. In the toilets and showers is included in the consumption of water, electricity or diesel oil total port. Finally, a boat can be the habitual residence or private recreational environment of its owner. However, they may also be used to carry out some professional activity as a recreational boat or for whale watching. Whatever the use, boats need energy and the way to get this energy can be a solar panel, a generator or by connecting to the port's electricity supply network.

Mobile sources include petrol or diesel vehicles and electric vehicles such as motorcycles, cars, vans and trucks used by navy personnel, visitors, suppliers and waste managers. In the case of vehicles used by navy personnel or visitors, the number of workers, the average number of visitors per day and the average return journey in kilometres of a working day per employee between their usual residence and the marina and the average return journey in kilometres per visitor to the marina have been taken into account. The marinas usually have regular suppliers. Depending on the number of suppliers that operate and the frequency of transport such as vans or trucks, the emissions of this group are counted, taking into account the average number of return kilometres between the marina and the last customer. In the event that the port has a clean point, the tank trucks are included among the mobile sources and their emissions are counted taking into account the percentage of navy ships that dump the waste at the clean point of the port, the frequency of truck collection and the distance in kilometres between the navy and the dump.

Measuring a product's carbon footprint creates benefits for organizations and businesses by identifying the sources of GHG emissions from a product, allowing better targets and more effective emission reduction policies to be defined. In addition, it allows to know the critical points for the reduction of emissions.

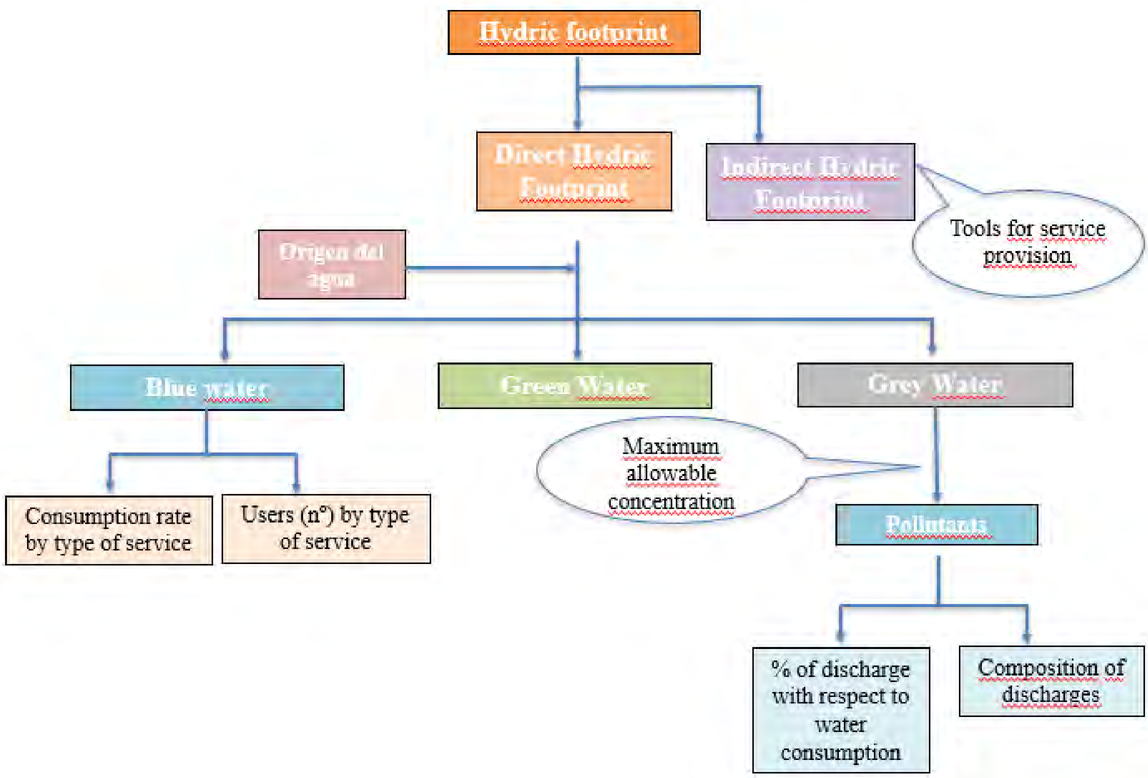
2.5.1 Hydric footprint

The water footprint can be calculated from the point of view of consumption or production. The water footprint as a producer or internal water footprint quantifies the volume of water used within the limits of the defined area in the production of goods. Likewise, the calculation of the water footprint can be focused on a consumer, a producer, a process, a product (IWMI, 2004) or a specific geographical area such as a country, region, watershed, or a specific economic sector (Hoekstra et al., 2011). A product water footprint assessment considers all stages of a product's life cycle, from raw material acquisition to final disposal, and an assessment of an organisation's water footprint takes a life cycle perspective based on all of its activities.

Whatever the case, both the direct and indirect use of water and the impacts resulting from its use are taken into account. Direct water or direct water consumption is defined as the amount of water required only in the production process or provision of a service. However, obtaining a product generally requires the input of several raw materials, intermediate products and a series of services in the different stages of the production process. On the other hand, the provision of a service requires work tools. Well, in the production of these intermediate inputs or means of work, water is also consumed that has not been considered in the final product or service provision. The water associated with these intermediate inputs is indirect water or indirect water consumption.

In both direct and indirect use, the origin of the water is distinguished (Figure 2.11). Green water corresponds to water from rainfall, which is not lost through runoff and is incorporated into the soil or vegetation (Falkenmark, 2003). This water is available for the free use of plants and constitutes the unique water support for rainfed crops, spontaneous vegetation and forests. This source of water is particularly important in crop production. In turn, blue water corresponds to the fraction of the hydrological cycle that is transformed into surface or underground runoff and is consumed by incorporation or evaporation in the process being evaluated. It feeds the flow of rivers and aquifer reserves, while it is susceptible to being naturally dammed in the form of lakes or artificially by means of the construction of reservoirs. Except for the desalination of seawater and other non-conventional water sources, domestic, industrial and irrigated cultivation are always supplied by blue water sources. Finally, grey water is a theoretical concept that refers to the pollution of the resource. It represents the volume of water needed to reduce the load of pollutants until it complies with current regulations on water quality. In view of the origin of the water, the water footprint contains a clear spatial and temporal component that must be considered in its evaluation.

Figure 2.11. Origin of the water for the calculation of the water footprint



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