

الجمهورية الجزائرية الديمقراطية الشعبية  
The People's Democratic Republic of Algeria  
العالي والبحث العلمي وزارة التعليم  
Ministry of Higher Education and Scientific Research  
جامعة عمارثليجي – الأغواط  
University Amar Telidji of Laghouat

Faculty :Science and Technology

Departement : ST

Domain :ST

Field :ST

Speciality :ST

Course Handout (Lectures, Tutorials, Practical Work)

Intended for students of: engineering Level: 2<sup>nd</sup> year

# Lectures on Energy and Environment

Presented by : Dr. Fathi Bendelala

Grade, University of Laghouat

Email : [f.bendellala@lagh-univ.dz](mailto:f.bendellala@lagh-univ.dz)

Academic year : 2025/2026



2025/2026

# Lectures on Energy and Environment

Faculty of Technology. Department of ST



**Dr. Fathi Bendelala**  
U-A-T-L

# Table of Contents

Introduction.....	5
Introduction.....	5
Part 1: General information on energy and the environment.....	7
1.1. Definition of Energy .....	7
1.2. Relationship Between Power and Energy .....	7
1.3. Forms of Energy .....	8
1.4. Energy Converters .....	9
1.5. Energy Categories.....	9
1.6. Energy Sources.....	10
1.7. Definition of Environment .....	10
1.8. Environment and Human Activities .....	11
Part 2: Non-Renewable Energies .....	12
2.1. Definition of non-renewable energies .....	12
2.2. Fossil energies .....	12
2.2.1. Coal.....	12
2.2.2. Fuels derived from petroleum.....	14
2.2.3. Natural gas .....	15
2.2.4. Fissile energies .....	16
Part 3: Renewable energies .....	18
3.1. Definition of renewable energies.....	18
3.2. Wind energy.....	18
3.2.1. Different types of wind turbines .....	18
3.2.2. Key figures .....	21
3.2.3. How a wind turbine works .....	22
3.2.4. Placement of wind turbines .....	24

3.2.5. Conversion of wind energy .....	24
3.3. Solar energy.....	29
3.3.1. Solar thermal energy .....	29
3.3.2. Solar thermal power (Concentrating Solar Power - CSP).....	30
3.3.3. Photovoltaic energy .....	30
3.3.3.1. Photovoltaic system .....	30
3.3.3.2. Photovoltaic cell parameters .....	32
3.3.3.3. Current-voltage characteristic and equivalent circuit .....	33
3.3.3.4. Cell combination.....	35
3.4. Hydraulic energy .....	38
3.5. Biomass Energy .....	39
3.6. Geothermal or aerothermal energy .....	40
Part 4: Energy storage.....	41
4.1. Definition and general information on energy storage .....	41
4.2. Electricity storage .....	42
4.2.1. Direct electricity storage.....	43
4.2.2. Indirect electricity storage.....	43
4.2.2.1. Mechanical storage method .....	43
4.2.2.2. Chemical storage.....	47
4.3. Thermal storage of heat.....	49
4.4. Summary of mass energy storage figures .....	50
Part 5: Consumption, reserves, and trends in energy resources.....	51
5.1. Global energy consumption .....	51
5.2. Share of energy sources in global consumption.....	52
5.3. Energy consumption by region.....	55

5.4. Trends in global energy demand .....	57
5.5. Trends and outlook for energy production and consumption in Algeria.....	57
Part 6: Different types of pollution.....	66
6.1. Introduction.....	66
6.2. Types of pollution.....	66
6.3. Categories of environmental pollution.....	71
6.3.1. Air pollution.....	71
6.3.2. Water pollution .....	75
6.3.2.1. Different categories of pollution.....	76
6.3.2.2. Different sources of pollution.....	77
6.3.3. Soil pollution.....	78
6.3.3.1. Sources of soil pollution.....	79
6.3.3.2. Types of pollutants.....	79
6.3.3.3. Consequences of soil pollution.....	80
Part 7: Detection and treatment of pollutants and waste .....	81
7.1. Introduction.....	81
7.2. Economic models for environmental protection.....	81
7.3. Pollution detection and measurement.....	82
7.4. Waste management.....	83
7.5. Waste categories.....	85
7.6. Waste sorting and recovery.....	86
7.7. Waste management in Algeria.....	88
Part 8: Impact of pollution on health and the environment .....	89
8.1. Introduction.....	89
8.2. Effects of pollution on health.....	89

8.2.1. Effects of air pollution on health .....	89
8.2.2. Effects of water pollution on health.....	91
8.2.2. Effects of soil pollution on health.....	94
8.3. Effects of pollution on the environment.....	94
A comprehensive quiz .....	96
<b>Quiz Part 1: Introduction (Generalities on Energy and Environment) .....</b>	<b>96</b>
<b>Quiz Part 2: Non-Renewable Energies .....</b>	<b>98</b>
<b>Quiz Part 3: Renewable Energies .....</b>	<b>100</b>
<b>Quiz Part 4: Energy Storage .....</b>	<b>102</b>
<b>Quiz Part 5: Consumption, Reserves, and Evolution of Energy Resources .....</b>	<b>104</b>
<b>Quiz Part 6: Different Types of Pollution.....</b>	<b>106</b>
<b>Quiz Part 7: Detection and Treatment of Pollutants and Waste .....</b>	<b>108</b>
<b>Quiz Part 8: Impact of Pollution on Health and the Environment.....</b>	<b>110</b>
<b>References.....</b>	<b>112</b>

## Introduction

### Introduction

This course, "Energy and Environment," is intended for second-year undergraduate students in students in their second year of engineering studies (All sections of the field of science and technology). The purpose of this course is to familiarize students with the *different energies*, their *sources*, and *the impact of their use on the environment*. Thus, the course presents a detailed description of energy resources (*advantages, disadvantages, consumption, reserves, and storage techniques*), as well as different types of pollution (*detection, pollution treatment, waste management, and impacts on health and the environment*). Since the current global challenge is the production of non-polluting energy, we focus in this course on renewable energies, notably photovoltaic and wind energy, while conforming to the official program.

The course is divided into eight parts:

- The first part, **Generalities on Energy and Environment**, introduces basic notions of energy and environment (*relationship between energy and power, energy categories, environment definition, etc.*).
- The second part, **Non-renewable Energies**, describes the two families of non-renewable energies: fossil energies (coal, petroleum, and gas) and fissile energies (nuclear fusion and fission).
- The third part, **Renewable Energies**, focuses on different renewable energies (*solar, wind, hydraulic, biomass, etc.*). Due to the importance of these energies, especially wind and photovoltaic energy for Section A students, and their diversity, this section is more detailed than the others.
- The fourth part, **Energy Storage**, covers current energy storage techniques and the main features of each technique, presenting advantages/disadvantages and data for each technique.
- The fifth part, **Consumption, Reserves, and Evolution of Energy Resources**, presents data on energy use and production by energy type and region (worldwide, continental, and Algeria).
- The sixth part, **Different Types of Pollution**, defines the various sorts and categories of pollution, as well as their sources and types of pollutants.

- The seventh part, **Detection and Treatment of Pollutants and Waste**, describes various techniques for detecting pollutants and managing waste (*treatment and valorization*).
- The last part, **Impact of Pollution on Health and the Environment**, aims at presenting the risks and harmful consequences of pollution on health (*diseases*) and the environment (*ecosystem*).

***Dr. Fathi Bendelala***

## Part 1: General information on energy and the environment

### 1.1. Definition of Energy

Energy is an essential basis for social and economic development. The word "energy," widely used, comes from the Greek word "energia," meaning "force in action." It exists in several forms, such as mechanical energy, chemical energy, electrical energy, radiant energy, wind energy, nuclear energy, etc. In general, a system has energy if it can cause a transformation of its energy (for example, the chemical energy of our cells is converted into mechanical energy in our muscles to move) or exchange energy (for example, heat is transmitted by a radiator). Energy is measured based on its effects and variations. Physicists use the joule (J) as their unit of measurement for energy. Economists use the ton of oil equivalent (TOE), nutritionists use the calorie (cal), and electricity uses the watt-hour (Wh) or kilowatt-hour (kWh).

*Note: Energy cannot be created or destroyed; it can only be transformed. This is the principle of conservation of energy. When a system has no exchange with its environment, its energy remains constant; it is said to be isolated.*

### 1.2. Relationship Between Power and Energy

Power and energy are not synonymous. The relationship between energy and power is similar to the one between distance and speed. Power is a measure of the rate at which energy is produced or consumed. The distinction between distance and speed is that speed is divided by time. During energy exchanges, we measure both the amount of energy transferred or transformed and the time it takes to complete the process. On the other hand, a system's power indicates the rate at which energy is produced or consumed.

#### Example :

- 1) **20 Liters of gasoline contain an energy amount of 250 kWh.**
  - **What is the power developed if these 20 Liters are consumed in 5 hours by a car?**
  - **What is the power released if they are burned in 10 seconds?**
- 2) **What is the energy consumed that increases the electricity bill, by a 100W bulb lit for 30 days?**

### Solution

1)

$$\triangleright P = \frac{250KWh}{5h}; P = 50kW$$

$$\triangleright P = \frac{250KWh}{0.0028h}; P \approx 90MW$$

2)  $E = 100 W * 24 h * 30 j = 72kWh$

## 1.3. Forms of Energy

Energy exists in various interconvertible forms.

- a) **Mechanical energy:** Mechanical energy is due to movements "kinetic energy; for example, the energy of a leaf falling from a tree or a car that comes from the combustion of fuel in the engine" or also due to position "potential energy; for example, the potential energy of water in a dam."
- b) **Chemical energy:** The creation or breaking of chemical bonds results in the release of energy, usually in the form of heat. For example, the chemical energy derived from the respiration process that fuels the human body or the energy derived from gasoline.
- c) **Nuclear energy:** Nuclear energy is energy released by nuclear reactions involving the nucleus of certain atoms "of a radioactive material," either by fission or fusion of the nuclei. For example, the energy of the sun is produced from a nuclear fusion reaction in which hydrogen nuclei fuse to form helium nuclei.
- d) **Thermal energy:** Thermal energy is due to the movements of atoms or molecules in a body, we obtain it from several sources: the sun, combustion of wood and fossils "coal, oil, gas" or electricity "Joule effect".
- e) **Radiant energy:** Radiative energy is very common in our daily lives; the sun illuminates us, a radiator warms us, or a microwave oven heats our food. The sun is an important source of radiation received on Earth. Radiative energy is the only energy that can propagate in a vacuum, in the absence of matter.

## 1.4. Energy Converters

Energy conversion is the process of changing one form of energy into another. This conversion is necessary to make the energy suitable for its intended use. For example, to heat a house, the furnace burns fuel, converting chemical energy into thermal energy, which is then transferred to the house's air, raising its temperature.

Example	
Plants (photosynthesis)	Radiant energy of light → chemical energy.
Human body (muscles)	Chemical energy → mechanical energy
Television	Electricity → Light energy (images) and mechanical energy (sounds).
Nuclear power	Nuclear energy → thermal energy (reactor) → mechanical energy (turbine) → electrical energy (alternator).

## 1.5. Energy Categories

Energy sources include raw materials such as oil, gas, and coal, as well as natural phenomena like sunlight and wind. They are classified into two main types: “non-renewable” and “renewable energy” sources.

Example
What are the four energy categories of a light bulb powered by nuclear-generated electricity?
Solution
<ul style="list-style-type: none"> <li>➤ <b>primary energy</b> corresponds to the potential energy contained in uranium.</li> <li>➤ <b>secondary energy</b> is the electricity produced in the nuclear power plant (about one-third of the primary energy).</li> <li>➤ <b>The final energy</b> is the one that arrives at the consumer's electricity meter (after losses due to transportation).</li> <li>➤ <b>The useful energy</b> is the energy used by the bulb (about half of the final energy).</li> </ul>

## 1.6. Energy Sources

Energy sources are either raw materials "oil, gas, coal, ..." or natural phenomena used to produce energy "the sun, the wind, ...", we can classify these sources into non-renewable and renewable energy.

### ➤ Non-renewable energies

A non-renewable energy is a depletable energy that "disappears when used," it is made up of substances that take millions of years to replenish. There are two families of non-renewable energy.

- ✓ Fossil energy
- ✓ Fissile energy

### ➤ Renewable energies

There are plenty of renewable energies around us, we have been using them for thousands of years, and if we respect nature well, we will continue to do so for a long time. They depend on elements that nature renews daily: wind, sun, wood, water, Earth's heat. But some can also disappear if we don't protect them. They have largely contributed to the development of humanity: water mills, windmills, wood fire, animal traction, and sailboats.

## 1.7. Definition of Environment

The environment has evolved in several conceptions or representations depending on individuals or countries; Geologists understand the environment thru the study of soils, ecologists thru the activity of living beings, geographers thru the management and occupation of the territory, engineers according to their fields, economists thru the management of natural resources, lawyers from the perspective of regulatory constraints, philosophers thru morality and ethics...

The environment consists of all the natural or artificial "physical, chemical, and biological" and cultural "sociological" conditions of terrestrial and marine biodiversity, likely to affect living organisms and human activities.

## **1.8. Environment and Human Activities**

Human activities are degrading the environment by overexploiting resources, deforesting, destroying habitats, and polluting water, soil, and air. The excessive use of non-renewable energy sources leads to their depletion and generates greenhouse gas emissions that warm the planet. These processes threaten biodiversity and ecological balance. To preserve life on Earth, sustainable practices must be adopted—reducing waste, limiting pollution, and conserving resources. Achieving this balance requires firm political commitment, active participation from institutions, businesses, and citizens, and a collective shift toward environmentally responsible behavior.

## Part 2: Non-Renewable Energies

### 2.1. Definition of non-renewable energies

A non-renewable energy resource is a resource that is destroyed during its use and/or that renews more slowly than the rate at which we use it.

### 2.2. Fossil energies

The term "fossil energy" refers to energy produced from raw materials found underground such as oil, coal, and natural gas. These raw materials come from the decomposition of organic matter "plants and living organisms." Fossil fuels today account for more than three-quarters of global energy consumption "transport, industries, heating, etc.".

#### 2.2.1. Coal

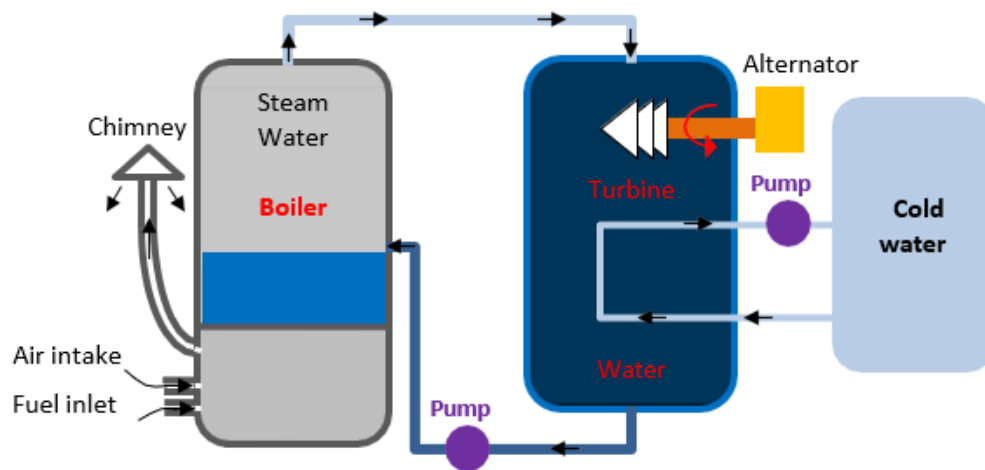
Coal is a sedimentary rock rich in carbon and formed from the remains of plants that accumulated in swamps during the Carboniferous period. Over millions of years, pressure and temperature transformed peat into different types of coal: first lignite, then bituminous coal, and finally anthracite. Coal powered the 18th-century industrial revolution, but was later replaced by oil as the main energy source in the West.



**Fig 1** : Coal-fired power plant

✓ **Electricity generation from coal**

Coal was the energy source of the Industrial Revolution in the 18th century and was only supplanted as the main energy source in the West in the 20th century, with the rise of oil.



**Fig. 2:** Operating principle of a thermal power plant

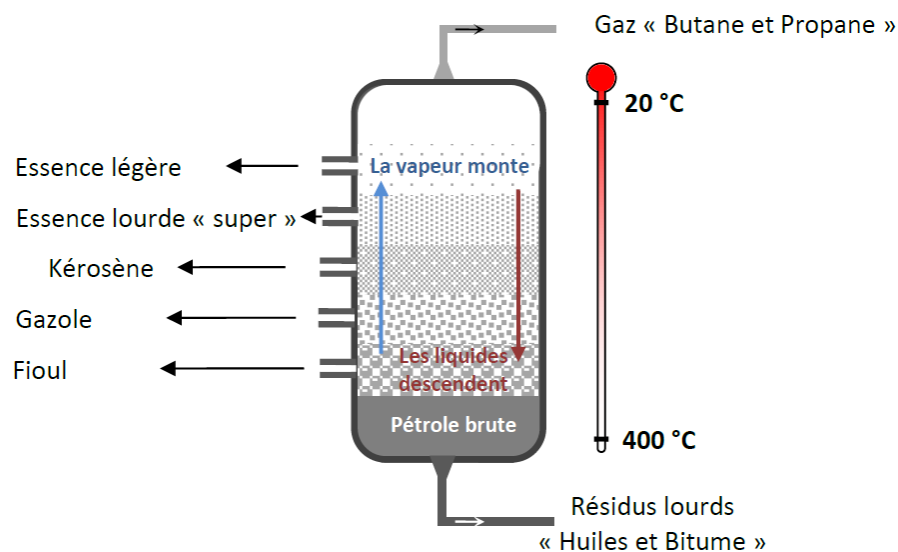
✓ **How a thermal power plant works**

The heat produced in the boiler by burning coal, gas, or other fuels vaporizes water. This steam is then transported under high pressure and at high temperature to a turbine. Under pressure, the turbine blades begin to rotate. Thermal energy is thus converted into mechanical energy. This is then converted into electrical energy via an alternator. At the turbine outlet, the steam is converted back into water.

"condensation" upon contact with cold walls, to be returned to the boiler where the cycle begins again.

### 2.2.2. Fuels derived from petroleum

Crude oil is a dark, viscous mineral oil that comes from underground and is derived from the remains of dead animals and plants. Petroleum is therefore a non-renewable fossil fuel. Refining allows its various components to be isolated and, after purification, fuels to be obtained. The combustion of this fuel creates energy. Crude oil distillation is carried out in two complementary stages. An initial atmospheric distillation separates gases, gasoline and naphtha (light fractions), kerosene and diesel (medium fractions) and heavy fractions. The residues from the heavy fractions then undergo vacuum distillation to separate certain medium products. Gasoline contains metals such as lead, which are released into the air along with exhaust fumes. Lead emissions are harmful to health and the environment. Diesel fuel is used in diesel engines. Diesel engines are much more energy efficient than gasoline engines, but they emit 14 times more particulate matter and contain sulfur, which is responsible for the formation of sulfur dioxide  $\text{SO}_2$ . These particulates are responsible for air pollution. After processing, petroleum can also be turned into kerosene, a fuel that is slightly heavier than gasoline but lighter than diesel fuel, and is used in aircraft.



**Fig. 3:** Oil refining

Table 1 shows the main operations used to transform crude oil into finished products, following rigorous processes.

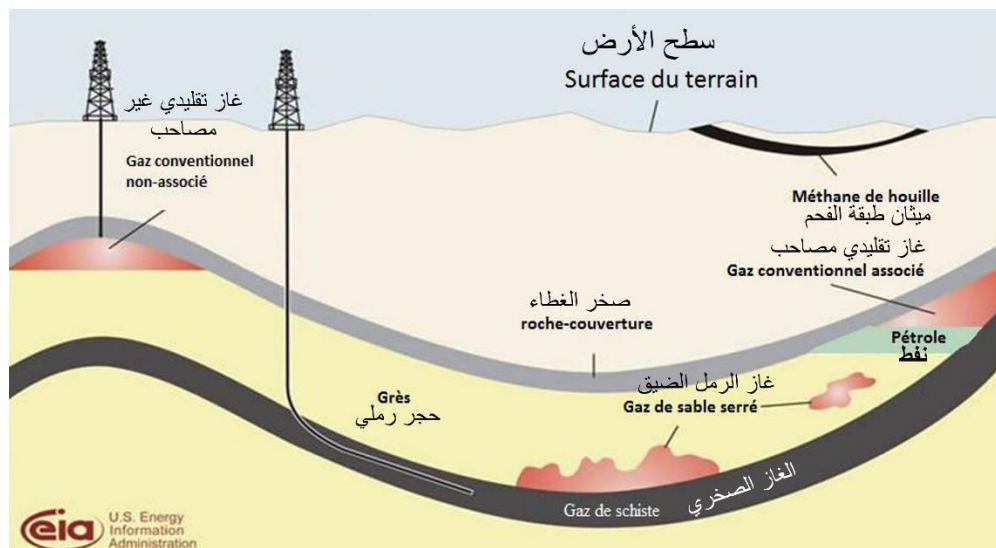
**Table 1: Main operations involved in transforming crude oil into finished products**

		1-Distillation		2-Refining unit		3-Product manufacturing	
		Crude oil	processing	Improvement of cut quality and base stock manufacturing		Base blending and quality control	
Light products	<b>Gas (1%)</b>	Combustible gas propane butane				Refinery furnace Commercial propane Commercial butane	
	<b>Gasoline (22%)</b>	Light gasoline Heavy gasoline	Etherification, Isomerization, Alkylation Reforming and cracking Catalytic		Auto fuel		
Middle distillates	<b>Kerosene (9%)</b>		Softening or hydrotreatment		Sweetened <b>kerosene</b> (aircraft)		
	<b>Diesel fuel (27%)</b>	Light diesel Heavy diesel	Hydrodesulfurization		Diesel fuel (engine fuel, domestic)		
Heavy products	<b>Heavy cuts (41%)</b>	Distillates	Catalytic cracking		Heavy fuels (factories, ships)		
		Vacuum residues "bottom of the barrel"	Viscosity reduction		Heavy fuels and bitumen (road paving)		

### 2.2.3. Natural gas

Millions of years ago, microscopic living organisms were buried in the ground and transformed into natural gas under the influence of high temperatures, high pressure, and the absence of contact with air. Gas is a very good fuel that is used for cooking, heating water in homes, heating, etc. It is found in pockets at depths of between 3,000 and 4,000 meters below the Earth's surface. Shale gas is natural gas trapped deep underground in certain shales in sedimentary basins. It is therefore not trapped under an impermeable layer, as is the case with so-called "conventional" gas or oil deposits, but trapped in the rock itself. To extract it, the rock must be fractured by injecting pressurized water mixed with a few additives, a process known as "hydrofracturing." Shale gas extraction is costly compared to conventional gas and poses risks to the environment, both underground, in groundwater, and on the surface. Gas concentrations are lower than in conventional deposits, but the areas involved are more extensive. The potential of these deposits, which have been exploited for several years, especially in the United States, is enormous. Natural gas is used in some cars in

Algeria, which are called LPG cars "Liquefied propane gas" and in some buses in Europe, called CNG buses "Compressed natural gas."



**Fig. 4:** Geological diagram of hydrocarbon deposits

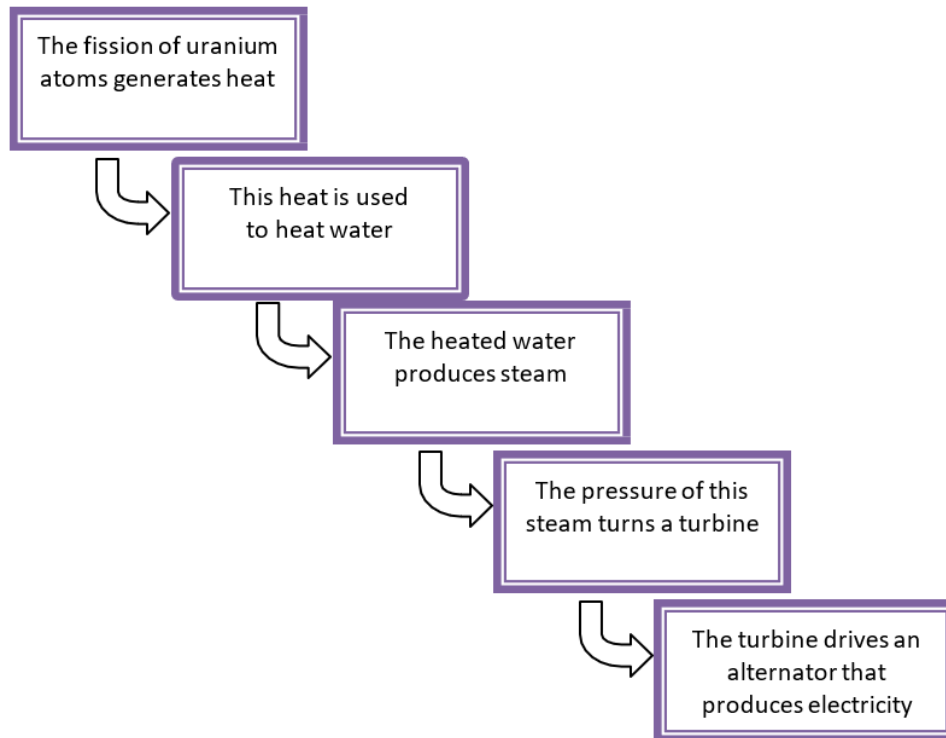
#### 2.2.4. Fissile energies

Nuclear energy is the energy that binds the components of an atomic nucleus together. This nucleus is an assembly of positively charged protons and uncharged neutrons that are very strongly bound together despite the electrical repulsion between protons. The nucleus is extremely compact, measuring  $10^{-12}$ mm, which is 100,000 times smaller than the atom itself. **In heavy atoms**, the nucleus contains many protons that repel each other. Some of these nuclei, such as those of uranium or thorium, can become unstable and break apart, releasing some of their binding energy. This is atomic **fission**.

**In very light atoms**, two nuclei can fuse to form a heavier but more stable atom, releasing considerable energy. This is **fusion**, for example of hydrogen nuclei into helium nuclei. Current projects for this type of energy involve research reactors, evaluators, and prototypes, spread out over time, which could lead to the development of reactors for commercial electricity production around 2100. A nuclear power plant uses the heat released by uranium, which is the "nuclear fuel." The goal is to heat water to produce steam. The pressure of the steam drives a turbine at high speed, which in turn drives an alternator that generates electricity. This operating principle is the same as that used

in conventional thermal power plants running on coal (see Figure 2), oil, or gas, with the difference that the fuel used as a heat source is uranium.

The principle of electricity generation in a nuclear power plant can therefore be summarized as follows:



**Fig. 5:** Schematic diagram of electricity generation in a nuclear power plant

## Part 3: Renewable energies

### 3.1. Definition of renewable energies

A renewable energy resource is one that is not destroyed when used and/or has the capacity to renew itself naturally, at least at the same rate as it is used. There are plenty of them around us, above our heads and even under our feet! These resources depend on elements that nature constantly renews: wind, sun, wood, water, the Earth's heat, etc. We have been using them for thousands of years. They have contributed greatly to the development of humanity: water mills, windmills, wood fires, animal traction, sailing ships, etc. And we will continue to do so for a long time to come if we respect nature. "Some may also disappear if we do not protect them."

### 3.2. Wind energy

The word "wind" comes from the Greek god Aeolus, the god of the winds. The term also means "fast," "lively," or "unsteady." Wind energy is an indirect form of solar energy. The absorption of solar radiation in the atmosphere causes differences in temperature and pressure that set air masses in motion and create wind. Wind was one of the first natural resources to be used, along with water and wood, to make human life easier. By harnessing the power of the wind, humans were able to sail and discover new lands, and even grind grain with windmills. Today, wind energy, also known as wind power, is used to generate electricity. A wind turbine is a machine that converts wind energy into mechanical motion, which is then usually converted into electricity.

**Note:** When only mechanical energy is produced, the term "water pumping wind turbine" is used.

#### 3.2.1. Different types of wind turbines

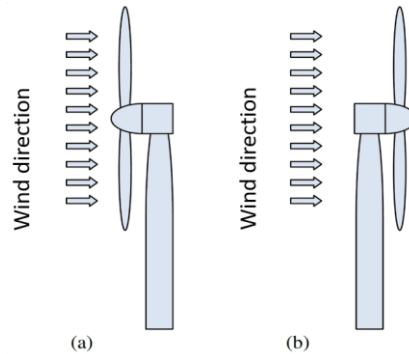
There are two main types of wind turbines, characterized by the position of their axes of rotation in relation to the direction of the wind:

- A. **Horizontal axis wind turbines:** These are currently the most widespread type of wind turbine worldwide due to their higher efficiency. They are adjustable but lack torque when

starting up. They have between one and three blades, most often three, as three blades offer a good compromise between power coefficient, cost, and wind turbine rotation speed. There are two categories of horizontal axis wind turbines:

**Upwind:** the wind blows onto the front of the blades towards the nacelle, **Figure 6 (a)**.

**Downwind:** the wind blows on the rear of the blades, starting from the nacelle, **Figure 6 (b)**.



**Fig. 6:** Horizontal axis wind turbine (a) upstream (b) downstream

**Note:** Horizontal axis wind turbines are more advanced because their technology is used in the aeronautics industry "in the manufacture of helicopter rotor blades" and their aerodynamic efficiency is superior to that of vertical axis wind turbines.

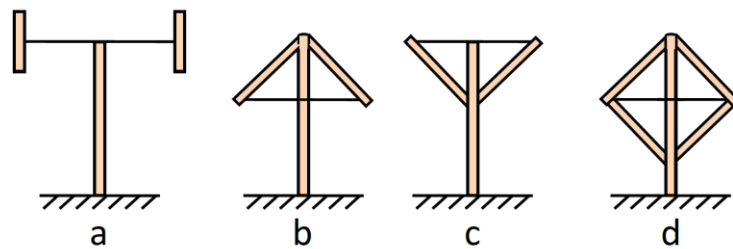
### Horizontal wind turbine

Advantages	Disadvantages
<ul style="list-style-type: none"> <li>➤ They orient themselves to adapt to the direction of the wind.</li> <li>➤ Easy to find a seller/installer.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Less resistant to strong winds.</li> <li>➤ Needs to be reinforced use of guyed masts, installation of a brake on the rotor.</li> </ul>

B. **Vertical axis wind turbines:** The blades of these wind turbines rotate around a vertically positioned shaft. They have a simpler design, lower efficiency, are bulkier, more

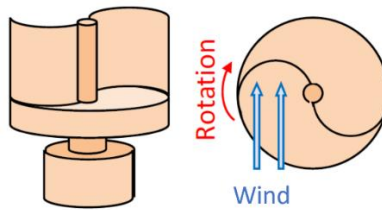
mechanically fragile, and more difficult to maintain. Their main advantage is their ability to capture low winds, meaning they do not need strong winds to operate, as they do not need to be oriented in relation to the wind. In addition, they require less space than horizontal wind turbines and can operate regardless of wind direction. However, vertical wind turbines start up more slowly because the weight of the rotors weighs on the axis, causing friction. There are two types of vertical-axis wind turbines:

**Darrieus:** With vertical, parabolic, or helical blades, this type of wind turbine uses the lift force of the wind, just like classic wind turbines.



**Fig. 7:** Vertical **Darrieus** wind turbine, (a) H, (b) delta, (c) Y, and (d) diamond

**Savonius:** formed of half barrels arranged in an S shape, pivoting around a vertical axis and starting easily in low winds, but unable to withstand strong winds.



**Fig. 8:** **Savonius** vertical wind turbine

Advantages	Disadvantages
<b>Darrieus</b>	
<ul style="list-style-type: none"> <li>• Emits less obstruction than a horizontal wind turbine</li> <li>• takes up less space.</li> <li>• Integrable into the building.</li> <li>• A generator that can be placed on the ground (depending on the models). Thus more accessible, it can be checked and maintained more easily.</li> </ul>	<ul style="list-style-type: none"> <li>• Difficult start due to the weight of the rotor on the stator</li> <li>• Low efficiency.</li> </ul>
<b>Savonius</b>	
<ul style="list-style-type: none"> <li>▪ Esthetics and the possibility of installing it on a roof.</li> <li>▪ Works even with a weak wind (unlike the <b>Darrieus</b> system), regardless of its direction.</li> <li>▪ Emits little noise.</li> </ul>	<ul style="list-style-type: none"> <li>▪ low efficiency.</li> <li>▪ significant weight.</li> <li>▪ the non-constant torque during rotation.</li> </ul>

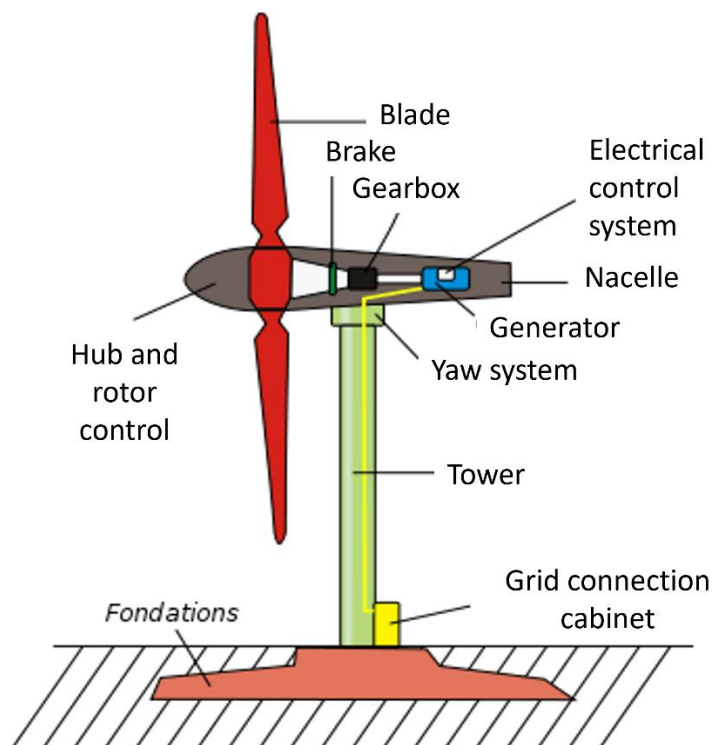
### 3.2.2. Key figures

- ✓ A land-based wind turbine can produce power ranging from a few **kW to 3 MW**.
- ✓ An offshore wind turbine can generate between **3 and 6 MW** of power.
- ✓ A modern wind turbine requires winds of at least **5 m/s (18 km/h)**.
- ✓ A wind turbine requires a minimum wind speed of **11 m/s (40 km/h)** to produce adequate power.
- ✓ At speeds of **25 m/s (90 km/h)** or above, the wind turbine must be shut down as it could be damaged.

**Note:** A wind farm consisting of four to six wind turbines with a capacity of **12 MW** covers the electricity and heating needs of nearly 12,000 people.

### 3.2.3. How a wind turbine works

A wind turbine resembles a propeller and typically has two or three blades. It is made up of a mast (the tower that supports the rotor), a rotor (which rotates due to the wind's force), a nacelle that houses the components responsible for converting the wind's kinetic energy into electrical energy, a gearbox, and a generator.



**Fig. 9:** Diagram of a wind turbine

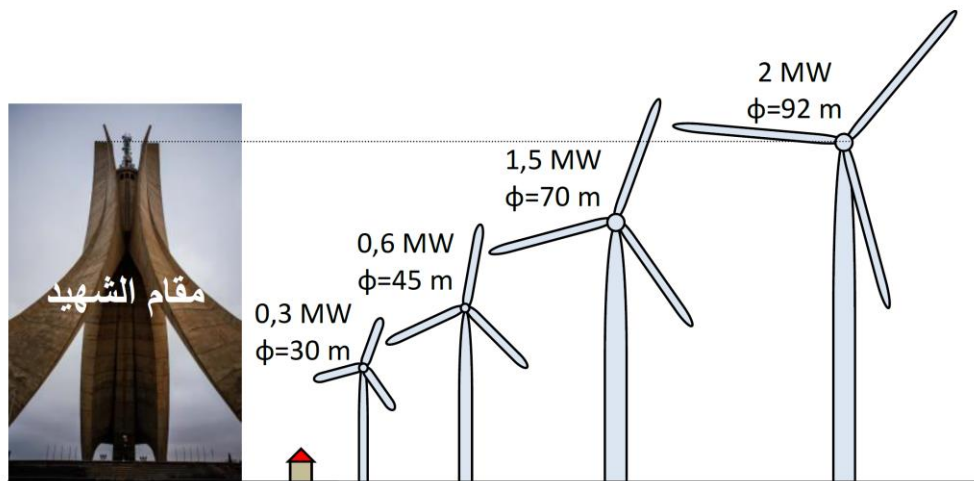
Electricity is generated by a wind turbine through the conversion of the wind's kinetic energy into electrical energy, in several stages:

- a) **energy conversion by the blades:** the blades operate on the same principle as an airplane wing. The difference in pressure between the two sides of the blade creates aerodynamic

force, setting the rotor in motion by converting the kinetic energy of the wind into mechanical energy.

- b) **Acceleration of the rotational movement thanks to the multiplier:** the blades rotate at a relatively slow speed, around 5 to 15 revolutions per minute, which is slower the larger the wind turbine is. Most generators need to rotate at very high speeds (1,000 to 2,000 revolutions per minute) to produce electricity. This is why the slow movement of the rotor is accelerated by a multiplier.
- c) **Electricity generation by the generator:** The mechanical energy transmitted by the multiplier is converted into electrical energy by the generator. Rotating at high speed, the generator produces electricity at a voltage of approximately 690 volts.
- d) **Processing of electricity by the converter and transformer:** the electricity produced cannot be used directly. It is processed by a converter, then its voltage is increased to 20,000 volts by a transformer. The electricity is then transported through an underground cable to a transformer station to be fed into the power grid.

**Note:** The wind turbine's power output increases with the size of its blades.



**Fig. 10:** Relationship between the diameter of the wind turbine rotor and its power

### 3.2.4. Placement of wind turbines

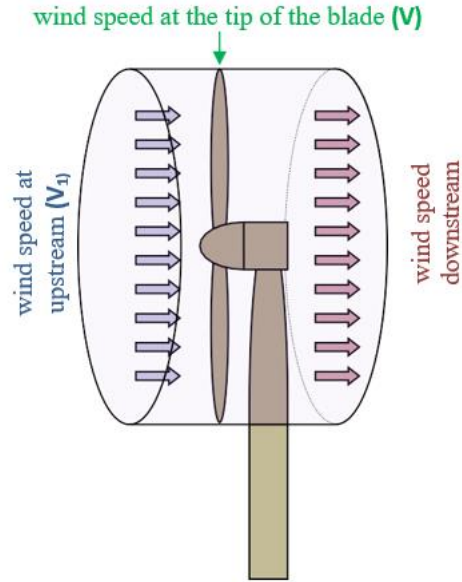
Wind turbines can be placed on land ("**onshore wind power**"). But they can also be placed at sea. This is referred to as **offshore** wind power. The first step before installing a wind farm is to assess the site where the wind turbines are to be placed, including the optimal height, environmental concerns, and costs. It is therefore very important that our site must in particular:

- ✓ be sufficiently windy. Ideally, winds should be steady and sufficiently strong, without too much turbulence, throughout the year. Wind studies at the site are therefore essential;
- ✓ be easy to connect to the high- or medium-voltage power grid;
- ✓ be easily accessible;
- ✓ not be subject to certain constraints such as "aeronautical, radar, etc.";
- ✓ take into account natural heritage, in particular birdlife and marine fauna for offshore wind farms, and avoid protected areas
- ✓ such as reserves;
- ✓ not take place in sensitive architectural or landscape areas "sites
- ✓ listed and classified sites, remarkable landscapes, etc.;
- ✓ be of sufficient size to accommodate the project.

However, it is not prohibited to install wind turbines outside these areas. But these wind turbines will not necessarily be connected to the power grid. They will be used, for example, to supply electricity to a farm. Offshore wind turbines must be installed at a depth of less than 30 m and more than 30 km from the coast. They benefit from more consistent and stronger winds.

### 3.2.5. Conversion of wind energy

A wind turbine captures and converts part of the kinetic energy of the wind into mechanical energy ("rotating rotor"). In order to estimate the electrical power produced by a wind turbine, it is necessary to know the power of the wind and how much of it can be recovered by the wind turbine. Let us assume that a wind current is passing through a wind turbine.



**Fig. 11:** A wind vein passing through a wind turbine

Consider a mass of air  $m$  moving at velocity  $V$ . The kinetic energy  $E_C$  (in joules) of the mass of air  $m$  (in kg) moving at the instantaneous wind speed  $V$  (in m/s) is equal to:

$$E_c = \frac{1}{2} m V^2 \quad (1)$$

Assuming that the speed is constant, the recoverable power  $P$  (in watts) is expressed as:

$$P = \frac{dE_c}{dt} = \frac{1}{2} \frac{dm}{dt} V^2 \quad (2)$$

Where  $dm/dt$  is the mass flow rate, which can be expressed as:

$$\frac{dm}{dt} = \frac{d(\rho V_{ol})}{dt} = \frac{d(\rho S L)}{dt} = \rho S \frac{d(L)}{dt} = \rho S V \quad (3)$$

Where  $m$  is the mass of the air volume (in kg),  $\rho$  is the density (in kg/m<sup>3</sup>),  $V_{ol}$  is the volume of air occupied (in m<sup>3</sup>),  $S$  is the surface area crossed by the wind (m<sup>2</sup>), and  $L$  is the distance traveled (m) by the wind during the time ( $dt$ ). Combining equations (2) and (3) gives:

$$P = \frac{1}{2} \rho S V^3 \quad (4)$$

**Note:** Energy is proportional to the cube of wind speed and the square of the length of the wind turbine blade.

However, it is not possible to recover all of the wind's kinetic energy as rotational kinetic energy using a wind turbine. If this were true, not even the slightest breeze would pass between the rotor blades. The wind speed behind the rotor would therefore be zero. This would mean that the wind would stop moving and no other wind would flow through the rotor: the wind turbine would then have the effect of a wall. In 1919, German engineer **Albert Betz** showed that there was a theoretical maximum efficiency for an incompressible fluid.

### 3.2.6. Betz limit

The kinetic energy of the wind absorbed by the wind turbine is equal to the kinetic energy lost by the wind as it passes through the surface delimited by the blades. The kinetic energy transmitted by the wind to the blades is therefore the difference between the kinetic energies upstream "index 1" and downstream "index 2" of the blades, see Figure 11.

Assuming that the downstream velocity of the blades is lower than the upstream velocity, that the blades "brake the wind," that the mass of the air volume remains constant, and that there is no turbulence, then the recovered power ( $P_r$ ) is:

$$P_r = \frac{d(E_{c1} - E_{c2})}{dt} = \frac{1}{2} \frac{dm}{dt} (V_1^2 - V_2^2) \quad (5)$$

Where  $V_1$  and  $V_2$  are respectively the horizontal component of the wind upstream of the blades and the horizontal component of the wind downstream of the blades, in (**m/s**), and  $P_r$  in (**watts**).

Assuming that the rotor speed  $V$  is the average of speeds  $V_1$  and  $V_2$ , then the mass flow rate is expressed as:

$$\frac{dm}{dt} = \rho V S_r = \rho S \frac{V_1 + V_2}{2} \quad (6)$$

If we introduce the ratio  $\lambda = \frac{V_2}{V_1}$ , then we obtain the following for the recovered power:

$$P_r = \frac{1}{2} \rho S V_1^3 \left[ \frac{1}{2} (1 + \lambda)(1 - \lambda^2) \right] \quad (7)$$

This gives us:

✓ the wind power:

$$P = \frac{1}{2} \rho S V_1^3 \quad (8)$$

✓ the fraction extracted by the wind turbine, denoted  $C_p$  :

$$C_p = \frac{1}{2} (1 + \lambda)(1 - \lambda^2) \quad (9)$$

$C_p$ : represents the efficiency of the wind turbine "power coefficient, performance coefficient" or (aerodynamic coefficient). It is defined as:

$$C_p = \frac{P_r}{\frac{1}{2} \rho S v^3} \quad (10)$$

By solving the equation:  $\frac{1}{2} (1 + \lambda)(1 - \lambda^2)$

We find that the power is maximum for  $\lambda = \frac{1}{3}$  Basically,  $V_2 = \frac{V_1}{3}$  For this value  $C_p = \frac{16}{27} \approx 0,593$

✓ Thus, the theoretical maximum efficiency for an incompressible fluid is ( $\frac{16}{27} \approx 59\%$ ) of the kinetic power of the wind.

✓  $C_p$ : characterizes the maximum limit of energy, due to the upstream air mass, that can be captured by a wind turbine.

✓ **The maximum recoverable power is:**

$$P_{max} = \frac{16}{27} \cdot P = \frac{8}{27} \rho \cdot S \cdot V^3 \quad (11)$$

**Note:** The power coefficient is used to classify different types of wind turbines according to their nature.

✓ Electrical power is:

$$P_e = \eta_e \cdot P_r \quad (12)$$

**Note:** The power coefficient is used to classify different types of wind turbines according to their nature.

With  $\eta_e$  being the overall efficiency of the wind turbine, losses due to the machine itself must be taken into account, i.e., "losses in each transmission or transformation element."

The operating parameter  $\lambda$  "specific speed parameter" is the ratio of wind speed  $U$  to wind speed  $V$ :

$$\lambda = \frac{U}{V} = \frac{\omega R}{V} \quad (13)$$

$U$ : the peripheral speed "or tip speed,"

$\omega$ : the rotational speed of the wind turbine,  $R$ : the tip radius of the blade.

- The best horizontal axis "two-blade or three-blade" machines are at 60-88% of the Betz limit, meaning that only **52%** of the energy generated by the wind is recovered overall.
- Betz demonstrated that recoverable energy was maximized when:  $V_{aval} = \frac{V_{amount}}{3}$

<i>Example</i>
<p>A wind turbine with a blade radius <math>R = 25</math> m operates at a site where the upstream wind speed is 11 m/s. If the density of air is <math>\rho = 1.25</math> kg/m<sup>3</sup>.</p> <ul style="list-style-type: none"> <li>➤ What is the power of the wind?</li> <li>➤ What is the recovered power if the power coefficient <math>C_p</math> is equal to 0.3?</li> <li>➤ What is the rotor speed <math>\omega</math>? If the wind speed at the tip of the blade is 7.33 m/s and the recovered power is at its maximum?</li> <li>➤ What is the wind speed downstream?</li> </ul>
<i>Solution</i>
<ul style="list-style-type: none"> <li>➤ <math>P = 0.5 \times \rho \times S \times V_1^3 = 0.5 \times \rho \times \pi \times R^2 \times V_1^3 = 0.5 \times 1.25 \times 3.14 \times 625 \times 1331 \approx 1.63</math> MW</li> <li>➤ <math>P_r = C_p \times P = C_p \times \frac{1}{2} \times \rho \times S \times V^3 \approx 0.3 \times 1.63 \approx 0.49</math> MW</li> <li>➤ <math>\omega = \frac{V \times \lambda}{R} = \frac{7.33 \times \frac{1}{3}}{25} \approx 0.097</math> rad/s</li> </ul>

$$\begin{aligned} \text{➤ } \lambda &= \frac{1}{3} \Rightarrow V_2 = \frac{V_1}{3} = \frac{11}{3} = 3.66\text{m/s} \\ \text{➤ } V &= \frac{V_1 + V_2}{2} \Rightarrow V_2 = 2V - V_1 = 14.66 - 11 = 3.66\text{m/s} \end{aligned}$$

### 3.3. Solar energy

Solar energy, produced by the sun's rays on Earth, is an inexhaustible and 100% green natural resource. It is used directly in three ways: thermodynamics, thermal energy, and photovoltaics, which are the focus of new developments aimed at improving their performance and economic competitiveness. Research in this area has been focused for several years on expanding applications and reducing costs.

Solar energy		
<b>Thermal</b>	<b>thermodynamic</b>	<b>Photovoltaic</b>
sensor (flat, tubular) solar water heater	concentrators → intense heat → turn a turbine	Solar cells
heat	electricity	electricity

#### 3.3.1. Solar thermal energy

Solar thermal energy uses solar collectors to capture the sun's rays and convert them into heat. This heat is mainly used to heat domestic hot water (4 m<sup>2</sup> for a family of four) and to heat buildings (20 to 40 m<sup>2</sup> for a **four-room apartment** measuring 75 m<sup>2</sup>).

The installation of solar thermal panels can meet part of the demand for domestic hot water and heating, and also generates significant savings, with relatively low maintenance and operating costs. This technology is inexhaustible, non-polluting, clean, and does not emit greenhouse gases.

However, the investment cost of a solar thermal installation is relatively high and requires auxiliary heating for the most unfavorable climatic periods.

### **3.3.2. Solar thermal power (Concentrating Solar Power - CSP)**

Thermodynamic solar energy is one of the ways in which solar energy can be used directly. This technique involves converting solar radiation energy into heat using "parabolic or cylindro-parabolic collectors," whose role is to concentrate solar radiation on a single focal point known as a "tower plant," to heat a fluid (oil or molten salts at 250 to 1000°C) and generate electricity using a thermodynamic cycle. This fluid vaporizes water, which drives a turbo generator, as in conventional thermal power plants.

**Note:** However, solar thermal power remains limited to countries without clouds. The Saharan region of Algeria is one of the best places in the world for implementing this type of solution for electricity generation.

The largest commercial development has been achieved by **Luz Corp**, which has built three power plants with a total rated electrical capacity of **354 MW** in Los Angeles. These plants demonstrate the relative maturity of this sector. Research into this technology is being conducted jointly by the United States, the Zionist entity, Germany, and Spain. The future of solar Thermodynamics is being challenged by the development of photovoltaic technology (simpler and more reliable), even though the latter remains more expensive.

### **3.3.3. Photovoltaic energy**

Photovoltaic energy is based on the photoelectric effect, discovered in **1839** by **Edmond Becquerel**, to create direct current from radiation. The first photovoltaic cell appeared in **1954**. It uses photovoltaic panels, composed of solar cells that convert light energy into electrical energy. Photovoltaic conversion is based on the absorption of photons in a semiconductor material that supplies electrical charges, and therefore current, to an external circuit.

#### **3.3.3.1. Photovoltaic system**

Any photovoltaic system can be divided into three parts. Figure 12 shows the parts of a photovoltaic system:

1. **Energy production section:** consists of one or more photovoltaic modules, which convert solar energy into electricity. This module consists of small cells, which produce a very low electrical power output of "**1 to 3 W**" with a continuous voltage of less **than 1 V**. These cells are arranged in series to form a module capable of producing a higher power output.

2. **Energy control section:** consists of a **battery** energy storage system and an "**impedance adaptation**" regulation system.

a) **Energy storage** that meets demand despite the unpredictable nature of solar energy. Batteries for photovoltaic installations must have the following qualities:

- ✓ have a large **reserve** and **good** charge and discharge **efficiency**;
- ✓ **low self-discharge** rate and long **service life**.
- ✓ have **low internal resistance**;
- ✓ require **little maintenance**;

b) **Impedance matching:** allows the photovoltaic field to be used in the optimal operating range.

3. **Part of the use of the energy produced:** consists of several receivers "*users, for example: lighting, pumping, etc.*"

Other components can be added to maintain the photovoltaic system, such as module cleaning tools.

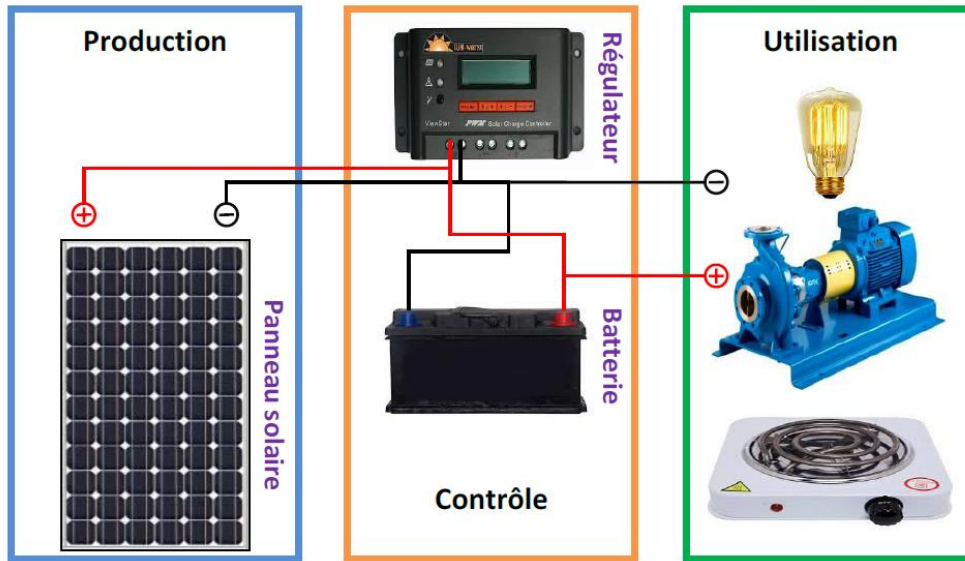


Fig.12: Components of the photovoltaic system

### 3.3.3.2. Photovoltaic cell parameters

A photovoltaic cell consists of a **PN** junction. This cell contains electrical charges due to the doping of electrons in the **N** zone and holes in the **P** zone. These charges create an electric field at the junction. When the surface of the cell is illuminated, photons with energies greater than the energy gap **E<sub>g</sub>** excite the electron-hole pairs and create positive and negative charges in the quasi-neutral **P** and **N** regions, Figure 13. The charges are set in motion and "cross the transition zone" by the electric field created by the junction. If the sides of this junction are connected to a load **R<sub>c</sub>**, an electric current **I** is produced and a potential difference appears.

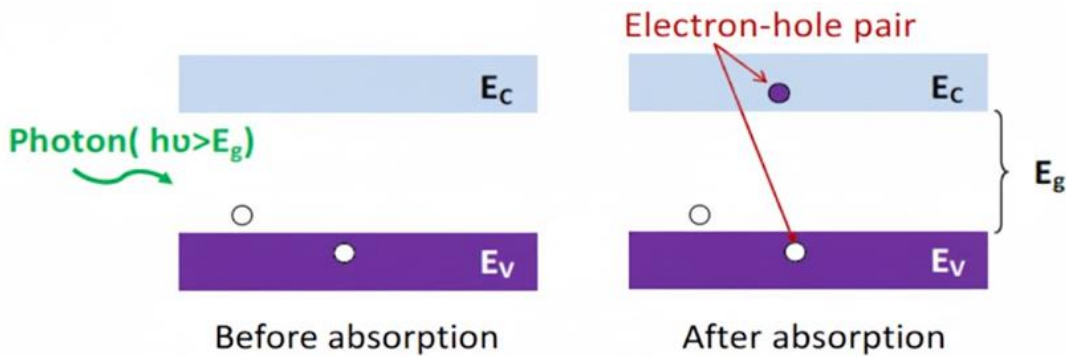


Fig. 13: Creation of electron-hole pairs by photoexcitation

### 3.3.3.3. Current-voltage characteristic and equivalent circuit

A photovoltaic panel delivers a current under a potential difference. The I(V) characteristic describes the current-voltage relationship, Figure 14 (a):

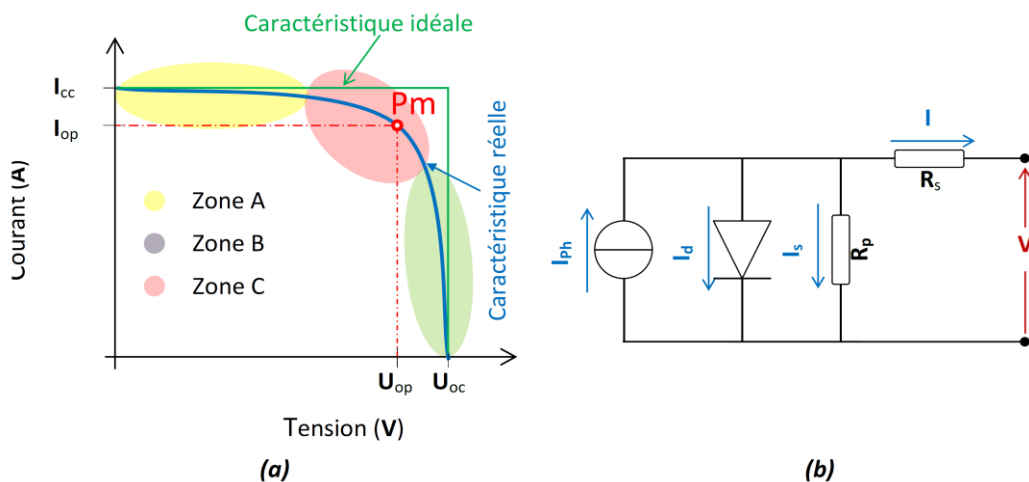
$$I = I_{ph} - I_d(V) \tag{14}$$

Where:  $I_{ph}$  is the photocurrent and  $I_d(V)$  is the dark current of the diode

The photovoltaic panel is considered a power source because it is difficult, over the entire range of the current-voltage characteristic, to assign a current or voltage source characteristic to a photovoltaic panel.

The optimal use of a photovoltaic cell consists of supplying a load at maximum voltage and maximum current " $P_m = U_{op} \times I_{op}$ ". In this context, the role of solar regulators is to adapt the impedance so that at any given moment, the system is close to this maximum power point.

The equivalent circuit diagram is shown in Figure 14 (b). The values of the various elements in the equivalent circuit determine the performance of the cell.



**Fig. 14:** (a) Characteristics of a photovoltaic cell (b) Equivalent diagram of a photovoltaic cell

The equivalent diagram of the solar cell takes into account the series resistance  $R_s$  and parallel resistance  $R_p$  and the saturation current of the diode  $I_s$ .

The characteristics of the photovoltaic cell can be divided into three parts according to its behavior:

- ✓ **Zone (a)** where the cell behaves as an  $I_{cc}$  current generator,
- ✓ **Area (b)** where the cell behaves as a voltage generator  $V_{oc}$ ,
- ✓ **Area (c)** where the internal impedance of the generator varies rapidly.

The relationship between  $I$ ,  $I_{ph}$  and  $I_d$  (V) represents the current-voltage characteristic, which can be used to determine the four main parameters of solar cell operation:

➤ **Short-circuit current  $I_{CC}$**

This is the current generated by an illuminated cell connected to itself, short-circuiting the cell terminals, " $V = 0$  in the equivalent diagram."

➤ **Open-circuit voltage "no-load voltage"  $V_{OC}$**

This is the voltage generated by an illuminated cell that is not connected. In other words, it is the voltage obtained when the current flowing through the cell is zero.

$$V_{oc} = \frac{kT}{e} \ln \left( \frac{I_{cc}}{I_s} + 1 \right) \quad (15)$$

Where:  $k$  is Boltzmann's constant,  $T$  is the temperature in Kelvin, and  $e$  is the electron charge.

➤ **Form factor  $ff$**

The power supplied to the external circuit by a photovoltaic cell under illumination depends on the load resistance "external resistance placed across the cell terminals." This power is maximum for an operating point  $P_m$ , Figure 15 (a). This point is obtained by modifying the value of the external resistance and is defined by the following relationship:

$$ff = \frac{P_m}{V_{oc} I_{cc}} = \frac{V_{opt} I_{opt}}{V_{oc} I_{cc}} \quad (16)$$

**Note:** According to the **maximum power transfer** theorem, maximum power is transferred from a generator to a load when **the impedance of the load** is equal to **the internal impedance of the generator**.

➤ **Conversion efficiency  $\eta$**

The power conversion efficiency of photovoltaic cells  $\eta$  is the ratio between the maximum power delivered by the cell and the incident light power  $P_{in}$ .

$$\eta = \frac{P_m}{P_{in}} = \frac{ff \times V_{OC} \times I_{CC}}{P_{in}} \quad (17)$$

The incident power density is equal to  $P_{in}/A$ . " $A$  is the cross-sectional area of the cell."

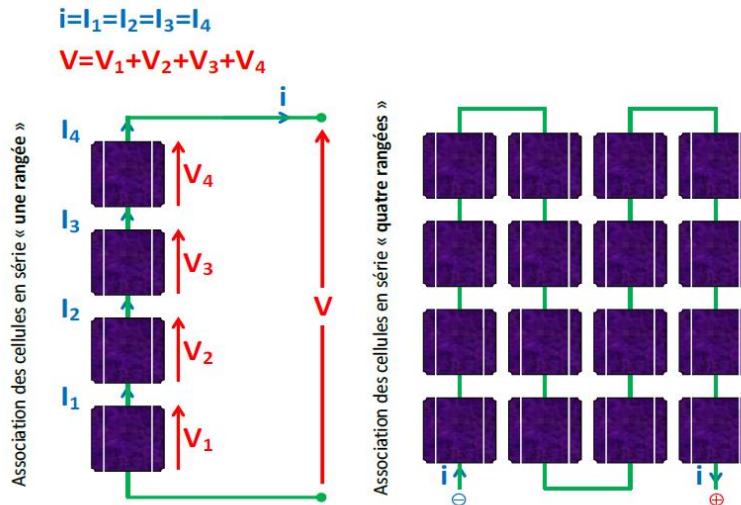
**Note:** Temperature has a negative effect on cell efficiency. As the cell temperature increases, its power output decreases. Cell efficiency is equal to the ratio between the cell's power output and the incident solar power. Efficiency can be improved by increasing the form factor, short-circuit current, and open-circuit voltage.

### 3.3.3.4. Cell combination

Solar cells are sold in the form of photovoltaic modules, combining these cells, generally in series, to increase the voltage." Depending on the requirements of the application, "the desired voltage and current," these modules are then combined in a series-parallel network.

#### A) Series cell combination

The same current traverses cells connected in series, and their resulting characteristic is obtained by adding the voltages at a given current.



**Fig. 15:** Series connection of cells

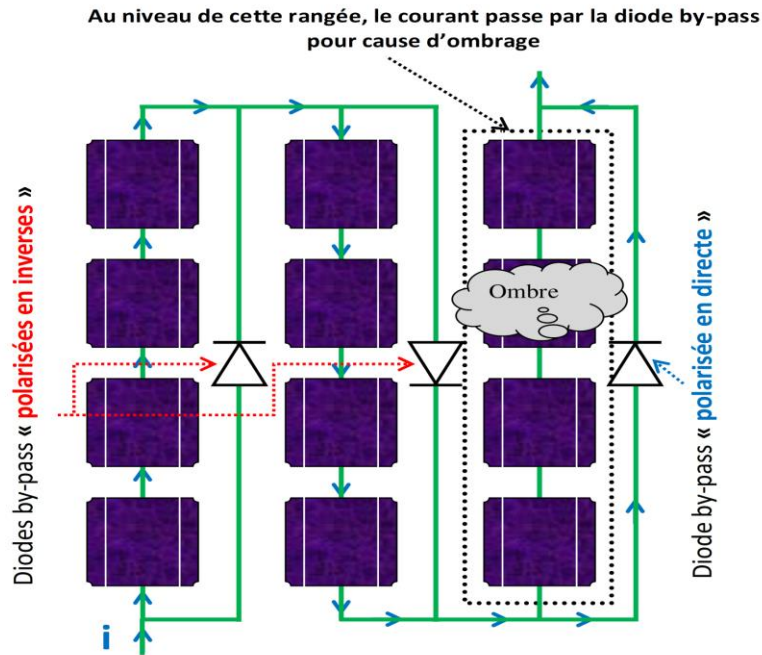
Connecting cells in series poses a problem: when a cell is in the shade, "it will heat up and may be destroyed." This "masked" cell blocks the flow of current produced by the other cells. The voltage at the terminals of this cell increases.

"overheating." This is the reverse self-polarization effect known as a **"hot spot."** To protect the masked cell and eliminate this problem, diodes are placed

**"Bypass"** in anti-parallel on 18 or 24 cells in order to short-circuit the shaded cells. A solar panel has one to three bypass diodes, depending on the number of cells it has (on average, 36 cells for 3 bypass diodes).

In the event of shading:

- ✓ For a solar panel with one diode, all the cells in the panel are bypassed,
- ✓ For a solar panel with two diodes, 50% of the panel's cells are bypassed.
- ✓ For a solar panel with three diodes, 33% of the panel's cells are bypassed.



**Fig. 16:** Placement of bypass diodes

### B) Parallel cell connection

Cells connected in parallel are subjected to the same voltage, and their resulting characteristics are obtained by adding the currents at a given voltage.

<i>Example</i>
<p>1) A solar panel delivers a power <math>P = 25 \text{ W}</math> when it receives a maximum light power <math>P_L = 1000 \text{ W/m}^2</math>. It consists of photovoltaic cells connected in both series and parallel. In each branch, the cells are connected in series, and the different branches are connected in parallel. The voltage across the panel terminals is <math>10 \text{ V}</math>; each cell delivers a voltage of <math>0.5 \text{ V}</math> and a current of <math>500 \text{ mA}</math>.</p> <ul style="list-style-type: none"> <li>➤ What is the intensity of the current <math>I_T</math> delivered by the panel?</li> <li>➤ What is the total number of cells <math>N</math> in the panel?</li> <li>➤ What is the energy efficiency <math>\eta</math> of the panel, if its surface area is <math>800 \text{ cm}^2</math>?</li> </ul>
<i>Solution</i>

$$\text{➤ } I_T = \frac{P}{V_T} = \frac{25}{10} = 2.5\text{A}$$

➤ N=Number of cells in a branch x Number of branches

$$N = \frac{V_T}{V_{Cel}} \times \frac{I_T}{I_{Cel}}$$

$$N = \frac{25}{0.5} \times \frac{2.5}{0.5} = 250 \text{ cellules}$$

$$\text{➤ } \eta = \frac{P}{P_i \times S} = \frac{25}{1000 \times 800 \times 10^{-4}} = 0.3125 = 31.25\%$$

### 3.4. Hydraulic energy

Hydropower is the world's leading renewable energy source, accounting for nearly 90% of global renewable electricity production. Hydropower generates electricity by harnessing the kinetic energy of flowing water. Water at high altitudes has potential gravitational energy; this energy is captured and converted in hydroelectric dams. When the water is stored, the valves are simply opened to start the electricity production cycle. The water rushes through a pipe to the hydroelectric power plant below.

#### Hydropower

advantages	Disadvantages
<ul style="list-style-type: none"> <li>➤ It is a clean, renewable energy source that does not produce smoke or pollution.</li> <li>➤ River management allows flood control:               <ul style="list-style-type: none"> <li>✓ during periods of drought, water is released;</li> <li>✓ during floods, excess water is retained.</li> </ul> </li> <li>➤ There is also an economic benefit: tourism thanks to lakes and seaside resorts.</li> </ul>	<ul style="list-style-type: none"> <li>➤ Cost of development.</li> <li>➤ Risk of dam failure.</li> <li>➤ Disruption of the ecosystem.</li> <li>➤ Geological and geographical requirements:               <ul style="list-style-type: none"> <li>✓ reservoir: wide, open area</li> <li>✓ Dam: narrow area</li> </ul> </li> <li>➤ modification of the natural appearance of the site.</li> </ul>

### 3.5. Biomass Energy

Biomass energy is the second-largest renewable energy source globally, representing solar energy stored in organic matter through photosynthesis. It produces electricity and heat by combusting organic plant or animal waste and residues. Biomass encompasses a wide range of materials including wood and forestry residues, agricultural waste (straw, manure), household and agri-food industry waste, and biogas from landfills and methanization processes. It is classified into three main categories: natural biomass (produced without human intervention), residual biomass (organic waste from human activities), and energy crops (specifically grown for energy production).

It comprises three main categories:

- a) **Solid biomass energy from wood** refers to the use of wood and its residues as a source of energy, and it is considered one of the oldest forms of bioenergy.
- b) **Wet biomass energy (biogas)** is a form of renewable energy derived from organic materials with high moisture content, such as agricultural waste, animal manure, and food scraps, through a biological decomposition process.
  - ❑ **Biogas** is a flammable gas composed mainly of methane ( $\text{CH}_4$ ) and carbon dioxide ( $\text{CO}_2$ ), and it is produced through:
  - ❑ **Anaerobic digestion:** a process in which bacteria break down wet biomass in the absence of oxygen.

The resulting gas is used for:

- ✓ Electricity generation
- ✓ Heating
- ✓ Fuel for vehicles after purification (biomethane)

**Note:** Digesters are typically situated in agricultural areas, converting manure and agricultural waste into biogas energy. The remaining undigested material, called digestate, settles at the bottom of the tanks and serves as nutrient-rich fertilizer for soil enrichment.

- c) **Biofuels:** Biofuels are plant-based renewable fuels produced from agricultural crops such as corn, wheat, rapeseed, sunflower, and sugarcane. When burned, they emit primarily  $\text{CO}_2$  and water

vapor with minimal nitrogen and sulfur oxides (NO<sub>x</sub>, SO<sub>x</sub>), making them cleaner than fossil fuels. These fuels are created by converting non-fossil organic materials through processes like fermentation and transesterification. Biofuels are categorized into multiple generations based on their feedstock and production technology.

There are three generations of biofuels:

- **First-generation biofuels:** First-generation biofuels, "the only generation produced on an industrial scale," are mainly of two types:
  - ✓ **Bioethanol:** Alcohol used in gasoline engines, produced from plants rich in sugar or starch, such as sugarcane, cereals, and sugar beets.
  - ✓ **Biodiesel:** a fatty acid derivative used in diesel engines, produced from oil-rich plants such as rapeseed, sunflower, soybeans, peanuts, etc.
  
- **Second- and third-generation biofuels:** technologies are currently being developed to use non-food **cellulosic** raw materials such as straw, wood, or algae for second-generation biofuels, and microorganisms such as microalgae for third-generation biofuels. With more favorable energy balances, these technologies also help limit problems associated with extensive use of agricultural land and competition with food markets.

### 3.6. Geothermal or aerothermal energy

Geothermal energy uses the highest temperature in the Earth's subsoil to produce heat or electricity. Low-temperature geothermal energy is used to heat buildings such as greenhouses or homes. High-temperature geothermal energy is used to produce electricity. There are three types of geothermal energy exploitation:

- **Very low temperature geothermal energy:** used for heating and air conditioning, thanks to a heat pump that exploits reservoirs located less than 100 m away and whose water temperatures are below 30°C.
- **Low-energy geothermal energy:** used for district heating or in industrial processes, it uses aquifers with temperatures between 30°C and 100°C.
- **Medium- and high-energy geothermal energy "up to 250°C":** used to generate electricity via turbines.

## Part 4: Energy storage

### 4.1. Definition and general information on energy storage

Energy storage depends on the type of energy; fossil fuels such as coal, gas, and oil are stored naturally in reservoirs or aquifers, and once extracted, they can be easily converted or transported from a technical standpoint. Storage for intermittent energies mainly concerns the storage of electricity and heat. This is more complex and requires specific systems because their production depends on energy carriers such as electricity, heat, or hydrogen. However, electricity is generally converted into mechanical, thermal, or chemical energy for storage. In contrast, heat is generally stored in its original form.

The main purpose of energy storage is to **balance electricity demand and production**. "It allows supply and demand to be adjusted over time," and this balance is necessary for the functioning of electricity grids. These grids are designed to withstand a number of climatic hazards, loss of production facilities, etc.

One of the major drawbacks of renewable energy in general is its intermittency due to the intermittent nature of wind, solar, or geothermal energy. This is why storage systems will play an important role in the development of these energies in the future.

Electricity generated by solar panels or wind turbines during periods of low consumption or overproduction can be stored and then released during periods when production does not meet demand ("low production or high demand").

### Examples

According to a press release from Sonalgaz:

➤ on July 30, 2017, following a rise in temperature, electricity consumption peaked at **13,881 MW**.

According to ENEA, which supports all players in the industrial energy sector:

➤ In France, a **1°C** drop in winter temperatures leads to a **2.3 GW** increase in consumption.

➤ On February 8, 2012, a peak consumption of **102 GW** in France temporarily pushed the price per **MWh** on the markets to **€2,000**.

➤ Conversely, episodes of negative prices at **-€500/MWh** were observed in Germany in 2010, caused by wind power surpluses.

There are many different types of storage, depending on the discharge time, power, and duration required. Storage can be:

- ✓ **fixed or centralized:** this is referred to as stationary storage
- ✓ **mobile:** this is referred to as embedded storage ("means of transport, electronic devices, etc.").

Storage is also differentiated according to its capacity, or "amount of electrical charge available":

- ✓ Storage is considered **low capacity** when it is in the order of **kWh**,
- ✓ high capacity when it exceeds **10 MWh**. In this case, we refer to **mass energy storage**.

## 4.2. Electricity storage

To date, direct storage of electrical energy is limited and costly. Some systems allow energy to be stored directly in electrical form. These are mainly large capacitors or supercapacitors. This storage difficulty means that large-scale direct storage cannot be considered. On the contrary, indirect electrical energy storage accounts for the lion's share of the massive energy storage capacities installed worldwide. This electricity storage aims to address four main issues:

- ✓ the recovery of excess energy production relative to current demand.

- ✓ Supplying energy to compensate for shortfalls due to the intermittent nature of supply.
- ✓ Supplying energy to meet occasional peaks in demand.
- ✓ Supplying energy in the event of a power system failure or poor local grid quality.

#### **4.2.1. Direct electricity storage**

Direct electricity storage is achieved through the use of large capacitors—electrical components consisting of two conductive plates that store opposite electrical charges—whose capacity is measured in microfarads, which have limited storage capacities, and which are relatively expensive.

Another avenue for direct electricity storage is storage using supercapacitors, which are capacitors made from superconducting materials. However, these superconductors require operating temperatures close to absolute zero ( $-273^{\circ}\text{C}$ ), which are technically difficult and costly to maintain. However, supercapacitors are used more for power than energy, as they are capable of delivering high power for a very short time. They can therefore be an interesting complement to batteries. The battery/supercapacitor combination can be particularly effective in hybrid vehicles.

#### **4.2.2. Indirect electricity storage**

Except in capacitors or supercapacitors, electricity cannot be stored directly. It is therefore necessary to convert electricity into another form of energy that can be controlled. The different storage methods are classified according to the primary energy sources used for conversion.

##### **4. 2. 2. 1. Mechanical storage method**

This method of electricity storage encompasses all types of large-scale energy storage, whether potential or kinetic.

##### **A- Pumped storage power stations (PSPS)**

This storage system is based on the principle of gravitational energy, i.e., hydraulic energy from dams. It is the most commonly used solution for storing energy from power plants and allows large amounts of electrical energy to be stored. It uses two reservoirs at different altitudes. Surplus electricity from the grid is used to pump water from the lower reservoir to the upper reservoir. In

the event of a shortfall in electricity production, the water pumped into the upper reservoir drives a turbine by gravity and releases the stored energy.

With an efficiency of over 80%, this type of storage accounted for nearly 99% of the massive energy storage capacity installed worldwide at the end of 2011, with a total capacity of around 140 GW provided by almost 400 pumped storage plants. However, prospective studies predict that global pumped storage capacity should be around 400 GW by 2050.

Pumped storage power stations (PSPS)

advantages	Disadvantages
<ul style="list-style-type: none"> <li>➤ They are one of the most reliable large-scale storage solutions;</li> <li>➤ They can move massive amounts of energy;</li> <li>➤ They have a long lifespan of 40 years.</li> <li>➤ They are one of the least expensive means of storage;</li> <li>➤ They are currently valued as a means of arbitrage on electricity markets.</li> </ul>	<ul style="list-style-type: none"> <li>➤ The need to find a suitable geographical site, combining two overlapping basins, makes the construction of new wastewater treatment plants increasingly difficult and costly. The best sites are used first, leading to a scarcity of available capacity and an increase in construction costs.</li> <li>➤ Issues of societal acceptance, inherent in any new water development filling of reservoirs Cost of development.</li> </ul>

The PSPS power plant on the island of El Hierro in **the Canary Islands, Spain**, is a prime example of this technology. It ensures the island's energy independence and avoids the importation of **6,000 tons of oil** per year. The plant consists of five **11.2 MW** wind turbines and two reservoirs.

"Lower basin of 50,000 m<sup>3</sup> and upper basin 700 meters higher of 550,000 m<sup>3</sup>" of "11.3 MW" hydraulic turbines for pumping and turbinng. Wind turbines and turbines can generate electricity simultaneously to manage peak consumption.

**B- Compressed Air Energy Storage (CAES) stations**

Compressed air storage stations are designed, quite simply, to store compressed air "in the form of pressure in underground cavities instead of pumping water," using a compressor during off-peak hours. This air is released to turn turbines that generate electricity, which is then delivered during peak hours.

Today, two facilities linked to salt cavities are in operation, one in Huntorf, Germany, with a capacity of 290 MW, which has been in operation since 1978, and the other in McIntosh, Alabama, Germany, with a capacity of **290 MW**, has been in operation since 1978, and the second in McIntosh, Alabama, United States, with a capacity of **110 MW**, has been in operation since 1991.

Unfortunately, CAES efficiency is reduced to "less than 50%" because the heat from the post-compression gases is lost. In order to improve performance, thermal storage systems are being developed to recover heat ("adiabatic storage").

### **C- Advanced adiabatic CAES AA-CAES "Advanced Adiabatic CAES"**

The adiabatic CAES system was studied at **Clausthal University of Technology** in Germany. Its principle is to prevent heat loss, but there is no reservoir capable of withstanding both high pressure and high temperature. However, this system has never been tested.

The AA-CAES principle is based on this idea, but uses two reservoirs: one for storing compressed air, "similar to conventional CAES reservoirs," and one for thermal storage, which recovers heat from the compressed air. During the release phase, this heat is returned to the compressed air before it passes through the turbine. Thanks to this system, advanced adiabatic CAES achieves an efficiency of around 70%.

AA-CAES stations still require further research to reduce thermal storage costs. The largest CAES station in the world is under construction in Ohio, USA, with a capacity of 0.8 to 2.7 GW, 16 hours of storage, a pressure of around 55 to 110 bars, and a reservoir consisting of a 670 m deep limestone mine cavity.

**Note:** A process is said to be adiabatic when the two systems that comprise it do not exchange heat between them.

#### ➤ **Key figures**

- ✓ power: 10 to 300 MW;
- ✓ annual production: 10 MWh to 10 GWh;
- ✓ response time (time required to switch the system from a storage state without discharge to full-power discharge): a few minutes;

- ✓ efficiency: ~50% for conventional systems, ~70% for adiabatic systems, and ~95% for isothermal systems (for the expansion valve/compressor system);
- ✓ lifespan: potentially greater than 30 years;

➤ **Area of use**

There are currently a few CAES facilities in operation around the world. These include:

- ✓ **Huntorf in Germany: 290 MW** in 1979, using a salt mine, 3 hours of storage;
- ✓ **Alabama in the USA: 110 MW** in 1991, using a salt mine, 26 hours of storage;
- ✓ **Hokkaido in Japan: 2 MW** in 2001, using a coal mine, 4 hours of storage;
- ✓ **New Hampshire, USA: 1 MW** in 2011 above ground, 4 hours of storage;
- ✓ **Hydrostor in Canada: 1 MW** in 2013 underwater, 4 hours of storage;
- ✓ **Texas, USA: 2 MW** in 2014, using a salt mine, 16 hours of

storage; Under construction:

- ✓ **ADELE in Germany: 90 MW** planned for 2018, using a salt mine, 4 hours of storage;
- ✓ **California, USA: 300 MW** planned for 2021, using a salt mine, 10 hours of storage;
- ✓ **Ohio, USA: 2,700 MW**, using a limestone mine, 16 hours of storage.

## D- Flywheels

Flywheels have long been used to regulate steam engines. Today, their principle allows energy to be stored in the form of mechanical rotation. Electricity causes a mass to rotate at very high speed around a cylindrical axis in an insulated chamber, which converts electrical energy "in the event of surplus production" into kinetic energy. This stored kinetic energy can then be recovered in the form of electricity using an alternator based on the "dynamo principle."

### Flywheels

Advantages	Disadvantages
------------	---------------

- High efficiency "around 80%,"
- Very fast storage phase "compared to an electrochemical battery,"
- Very short response time "allows grid frequency to be regulated,"
- No pollution "no fossil fuels or chemicals,"
- Reliable technology "low maintenance."

- Limited storage time "approximately 15 minutes."

The two largest flywheel energy storage facilities are located in the United States, each with a capacity of 20 MW.

**Note:** Flywheel energy storage does not provide long-term storage like pumped storage hydroelectricity or CAES. However, it is useful for regulating and optimizing a system's energy.

#### 4. 2. 2. 2. Chemical storage

The principle of this method of electricity storage is based on the conversion of chemical energy into electrical energy, mainly involving batteries and hydrogen.

##### A- Batteries

Electricity is stored through electrochemical reactions that involve the flow of ions and electrons between two electrodes. The chemical components can vary from one technology to another, resulting in a wide variety of batteries. The batteries used for large-scale storage to date are mainly flow batteries, which are the subject of most studies. The use of lead-acid, sodium, or lithium-ion batteries used more at the scale of a building or small community, where they can optimize management of renewable energy sources, solar or wind power "or other," particularly for smoothing out daily stationary loads. They can deliver power for a few hours or over several days and withstand a certain number of charge/discharge cycles.

##### ➤ Flow batteries

These batteries are rechargeable and enable the storage of electrochemical couples.

"Electrolytes" outside the reaction cell, in separate reservoirs separated by a membrane, in liquid form. The electrolytes circulate through an ion exchange cell. There are various types of flow

battery technology.

- ✓ Redox reduction-oxidation technology "conventional NASA technology in 1976."
- ✓ Hybrid technology
- ✓ Membrane-free technology
- ✓ Organic technology
- ✓ Nanogrid technology
- ✓ Energy density

Flow batteries offer the advantage of rapid recharging, as "the system replaces electrolytes with reservoirs." They can withstand more than 10,000 charge cycles and have virtually no self-discharge effect. However, the presence of reservoirs and the need to use a circulation system (pumps, sensors, etc.) are major drawbacks of these batteries.

➤ **Advanced" lithium-ion batteries"**

The operation of lithium-ion batteries is based on the reversible exchange of lithium ions between a positive electrode and a negative electrode. One example of this is the largest system to date, located in Zhangbei, China, in 2011, with a capacity of 20 to 36 MW over 4 to 6 hours, with 100 MW of wind power and 40 MW of solar power.

➤ **Zn-Br batteries**

These batteries are based on the zinc/bromine "Zn<sup>+</sup>/Br<sup>-</sup>" pair. Several demonstrators have been built, including a 400 kWh system in Akron, Michigan, USA. A few commercial installations are now operational.

## **B- Hydrogen vector**

Hydrogen is not a direct source of energy like wind power, for example, but rather an energy carrier. It does not occur in its pure form in nature, but must be extracted from water (H<sub>2</sub>O) through electrolysis. Hydrogen gas can be used directly "as fuel" or stored and converted back into electricity "by a fuel cell."

The principle of the fuel cell is to convert chemical energy into electrical energy using hydrogen as fuel. This cell only emits water, so it does not pollute. The electrolysis process requires rare and precious metals, and the difficulties involved in industrialization increase the price of the

device, which remains too high and causes storage problems. Overall efficiency is less than 50%, and their lifespan is insufficient for applications connected to the electrical grid. In short, progress in this technology is not for tomorrow.

### **4. 3. Thermal storage of heat**

The development of thermal storage is directly linked to the development of solar thermal farms. Storing this solar thermal energy would reduce the effects of its intermittency and the gap between the most productive periods (daytime/summer) and periods of peak demand (evening/winter). This storage mainly concerns the heating or cooling of buildings. All materials have the ability to release or store heat through thermal transfer. This transfer can be:

#### **A- Sensible heat storage**

Raising the temperature of a material allows energy to be stored in the form of heat. This is the case, for example, with a stone placed near a fireplace: once it has stored heat, it can be moved and release its heat. The same principle applies to solar water heaters: they collect heat during the day and then release it, with an average efficiency of around 40% for the latest systems. The preferred materials are water, synthetic oil, rock, and concrete.

#### **B- Latent heat storage**

This storage method is based on phase change materials (**PCMs**), which store energy when they change state (e.g., from solid to liquid). The reverse transformation releases the accumulated energy in the form of heat or cold, with an efficiency of around 60%. Several types of these materials—organic (**fatty acids and paraffins**) or inorganic (**hydrated salts**)—are used as thermal regulators depending on the heat provided by the sun to temper buildings.

To date, there are no large-capacity storage facilities based on this principle, but numerous projects are underway.

#### 4.4. Summary of mass energy storage figures

Table 2 summarizes the figures for mass energy storage and the main characteristics of the technologies.

**Table 2:** Summary of mass energy storage figures

	Capacity (MWh)	Discharge time (in hours)	Efficiency(%)	Number of cycles	Lifespan (in years)
STEP	1,000-20,000	6	70-85	>13,000	>40
CAES	120-1,800	5-24	50-70	>13,000	> 35
Sensible heat	40,000	6	75	>10,000	
Latent heat	10		85		> 15
Li-ion batteries	< 100	0.2-4	85-95	10,000	
Flux batteries	< 200	A few seconds to 5 hours	70-80	14,000	10-20
Hydrogen	10 to 10,000	A few hours	40		25

## Part 5: Consumption, reserves, and trends in energy resources

### 5.1. Global energy consumption

Global primary energy consumption reached approximately 15,500 million tons of oil equivalent (Mtoe) in 2025, up from about 8,700 Mtoe in 1990—reflecting a substantial increase of nearly 78% over the past 35 years. This growth was driven by rising demand across all major energy sources, with coal and oil continuing to dominate but renewables contributing an expanding share, especially in the last decade. Throughout this period, the efficiency of energy conversion improved, yet a significant proportion of the primary energy produced—nearly one-third—is still lost during transformation into usable final energy, mainly due to power generation and conversion losses in industrial facilities. The graph below illustrates the evolving composition and growth of global primary energy consumption by source from 1990 to 2025, highlighting both the magnitude of total energy usage and how the mix of energy sources has changed over time.

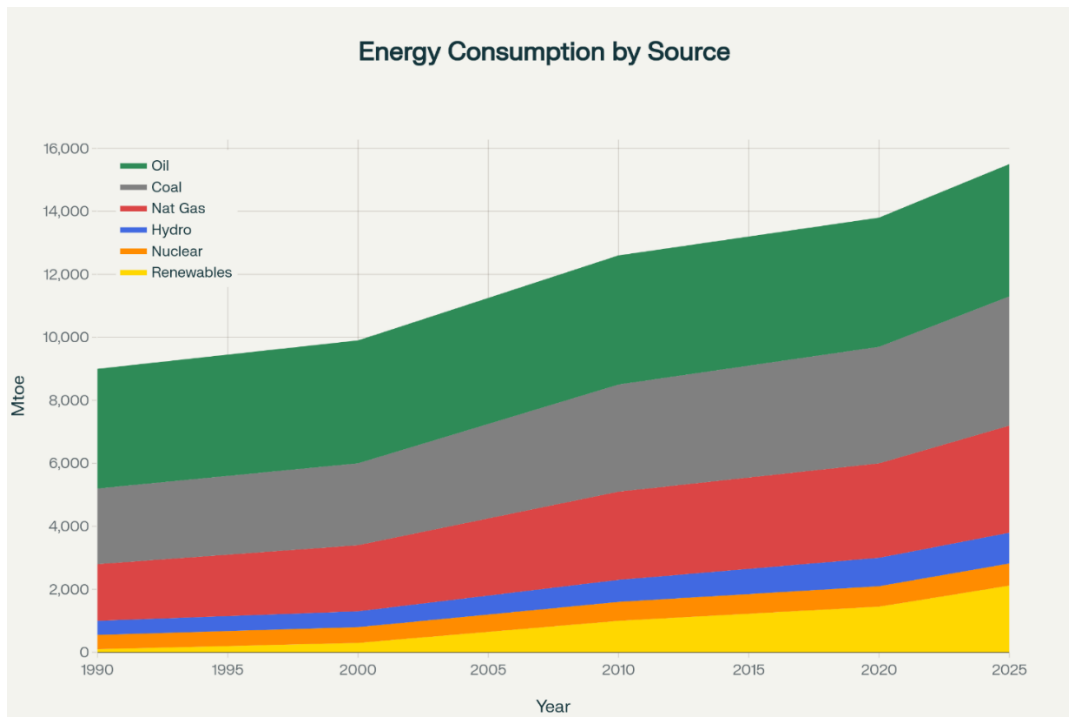


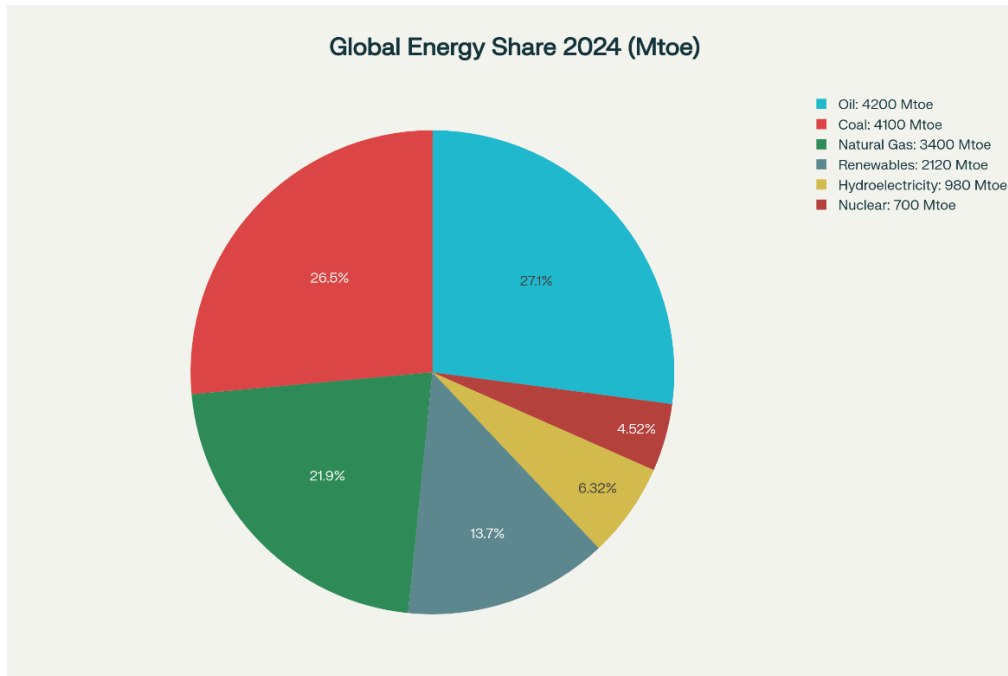
Fig. 17: estimation of the development of global primary energy consumption in Mtoe, 1990-2025

## 5.2. Share of energy sources in global consumption

Between 2023 and 2024, all major energy sources contributed to the continued growth in global primary energy consumption. In 2024, oil retained its position as the world's leading energy source, accounting for about 27% of total global consumption and maintaining its long-standing dominance in the energy mix. Coal remained the second-largest contributor, with market share stabilizing after years of fluctuations, while natural gas continued its steady rise, providing over one-fifth of total energy.

Renewable energy sources—driven by advances in solar and wind—made notable gains, reaching nearly 14% of global consumption, an impressive increase compared to previous years. This growth in renewables marks a shift towards more sustainable energy systems, although fossil fuels still account for the majority of supply. Nuclear and hydroelectricity also saw modest increases, together making up about 10% of the total.

At the end of 2024, global oil reserves were estimated at roughly 1,730 billion barrels, equivalent to about 46 times the yearly production rate—demonstrating robust resource availability despite ongoing efforts towards energy transition. The chart above illustrates how oil continues to dominate, but with coal, gas, and renewables increasingly shaping the future of the global energy landscape.



**Fig. 18:** Share of energy in "Mtoe" in global consumption in 2024

**Tab 3: Oil: proven reserves (billion barrels) Years 2005–2024**

Year	2005	2015	2024 (est.)
Proven reserves	1,374.4	1,697.6	1,730

**Tab 4: Oil: Production (millions of barrels/day) Years 2005–2024**

Year	2005	2010	2015	2020	2024 (est.)
Production	81.18	83.24	89.78	88.35	93.2

**Tab 5: Natural gas: proven reserves (trillions of cubic meters)**

Year	2005	2015	2024 (est.)
Proven reserves	157.5	186.9	192

**Tab 6: Natural gas: Production (billion cubic meters/year) Years 2005–2024**

Year	2005	2010	2015	2020	2024 (est.)
Production	2,790.9	3,283.5	3,642.2	4,068	4,320

**Tab 7: Coal: proven reserves (billion tons)**

Year	2005	2015	2024 (est.)
Proven reserves	909	891.5	870

Between 2005 and 2024, coal production has fluctuated but shows a net increase, rising from 3,326.7 Mtoe in 2005 to an estimated 4,100 Mtoe in 2024. This indicates continued reliance on coal, especially in rapidly developing economies, even as global policy and energy markets increasingly emphasize decarbonization.

**Tab 8: Coal: production (millions of tons of oil equivalent) Years 2005–2024**

Year	2005	2010	2015	2020	2024 (est.)
Production	3,326.7	3,862.7	3,988.0	3,700	4,100

Nuclear energy production, on the other hand, has remained relatively stable during this period, ranging from 622 Mtoe in 2005 to an estimated 700 Mtoe in 2024. While there was a slight decline around 2015, recent years have seen modest growth—reflecting new reactor additions as well as life extensions of existing facilities, though overall expansion remains constrained by high investment costs and regulatory factors.

**Tab 9: Nuclear energy: production (millions of tons of oil equivalent) Years 2005–2024**

Year	2005	2010	2015	2020	2024 (est.)
Production	621.8	630.0	583.1	650	700

**Tab 10: Renewable energy production (millions of tons of oil equivalent) Years 2005–2024**

Year	2005	2010	2015	2020	2024 (est.)

<b>Hy-E prod.</b>	697.7	797.7	892.9	940	980
<b>Non-Hy-E prod</b>	47.6	178.2	364.9	1,050	2,120
<b>Renewable total</b>	745.3	975.9	1,257.8	1,990	3,100

These trends highlight that traditional energy sources are still major contributors to the global energy mix, despite growing interest and investment in low-carbon technologies. Sustained coal use poses ongoing environmental challenges, while nuclear energy provides consistent, low-carbon baseload power but faces barriers to rapid growth.

### **5.3. Energy consumption by region**

In 2024, global energy production is estimated at around 15,500 Mtoe, with oil (4,200 Mtoe) and coal (4,100 Mtoe) remaining the two largest contributors. Natural gas ranks third at about 3,400 Mtoe, reflecting its increased role in both electricity generation and industry. The combined share of low-carbon sources continues to rise: nuclear energy contributes an estimated 700 Mtoe, hydroelectricity 980 Mtoe, and renewable energy more than 2,100 Mtoe—a dramatic increase compared to a decade prior. Renewables now account for roughly 14% of global energy production, which indicates accelerating progress in the energy transition towards cleaner sources. Despite these gains, fossil fuels still supply the majority of global energy, underscoring the scale of ongoing challenges in reducing global carbon intensity and supporting sustainable growth.

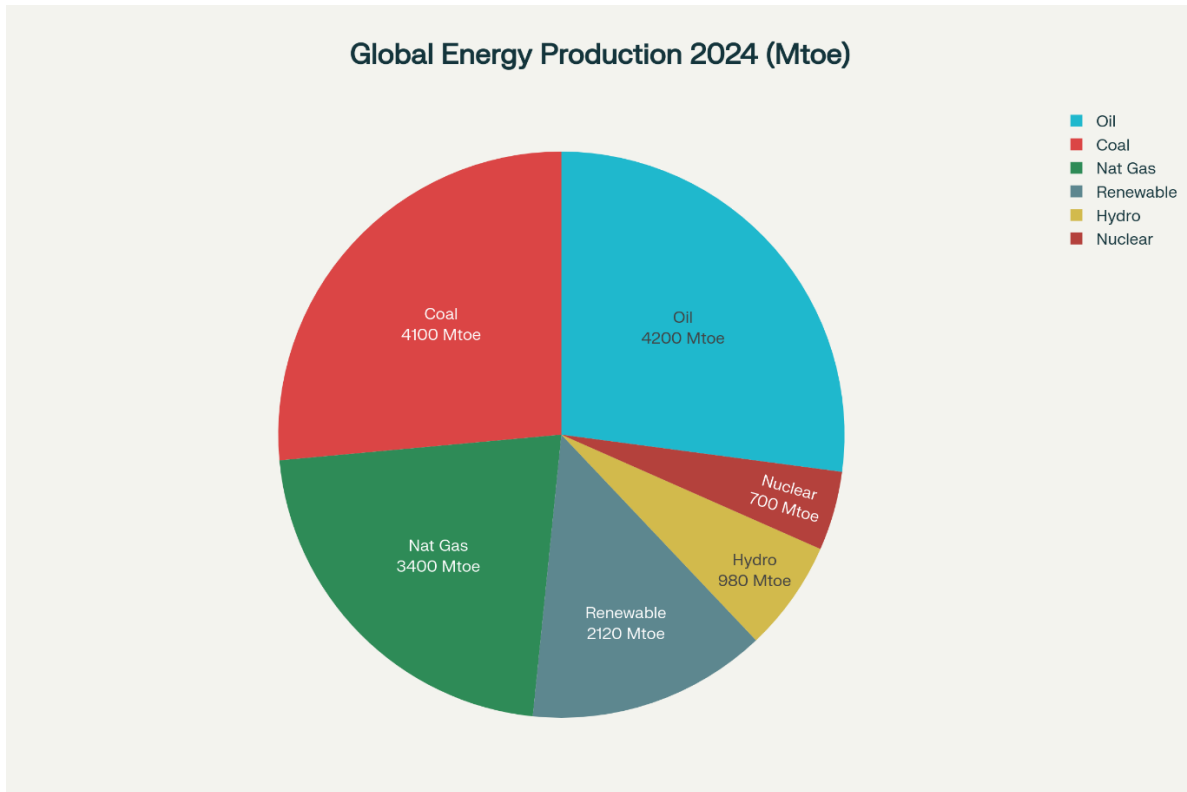
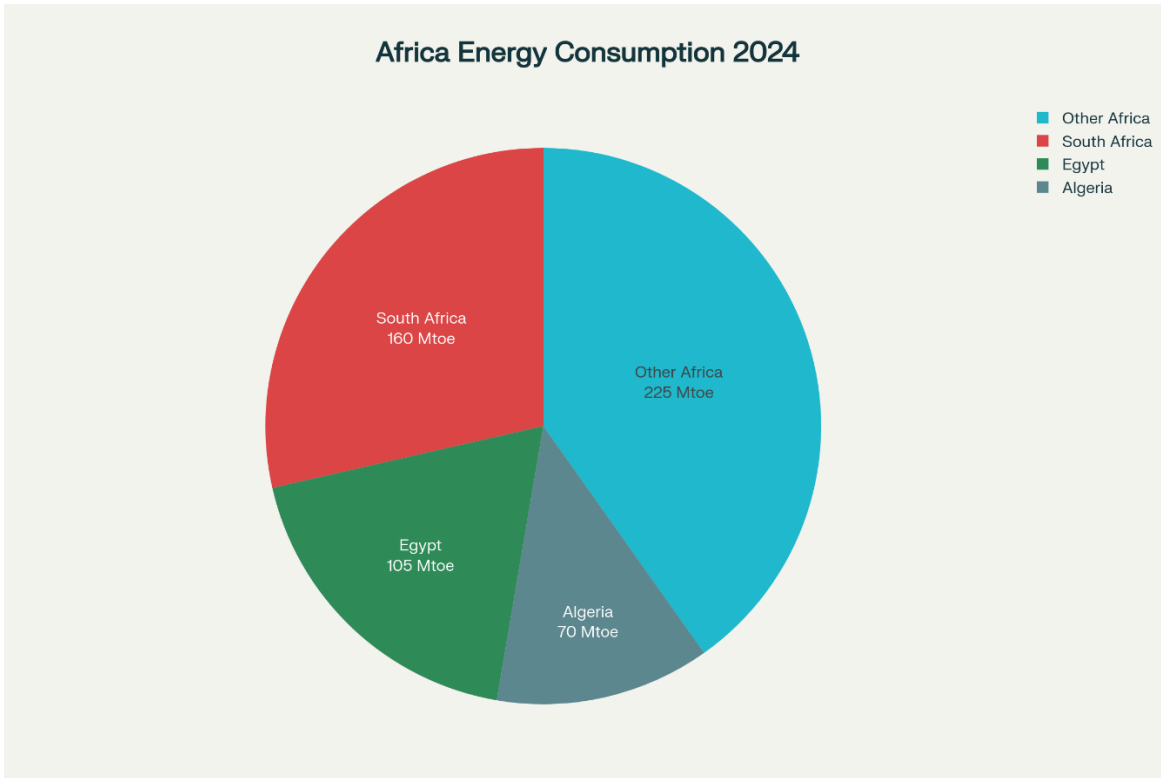


Fig. 19: Global energy consumption in Mtoe in 2024

In 2024, Africa's total energy consumption is projected to reach about 560 Mtoe, reflecting ongoing growth as economies expand and access improves. South Africa remains the continent's largest energy consumer with around 160 Mtoe, driven by its industrial and mining sectors. Egypt, the region's second-largest consumer, accounts for roughly 105 Mtoe due to strong manufacturing, transport, and urban demand. Algeria's consumption, at approximately 70 Mtoe, reflects its substantial oil and gas sector as well as residential growth. The remainder of Africa—including Nigeria, Morocco, Kenya, and many others—collectively accounts for about 225 Mtoe, highlighting both the diversity and potential for future energy growth across the continent. Despite these increases, Africa's share of global energy consumption remains relatively modest compared to its population share, indicating significant scope for further development and electrification.



**Fig. 20:** Estimated energy consumption in Africa by region/country for 2024 (Mtoe)

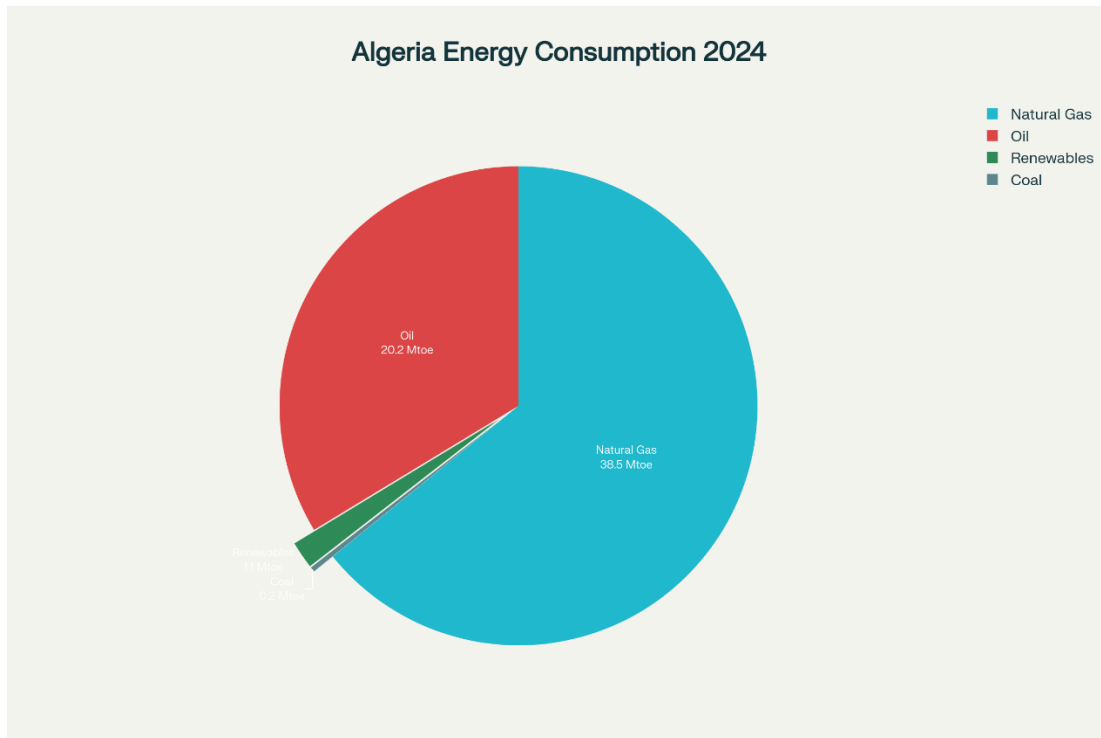
#### 5.4. Trends in global energy demand

- Total energy demand rose from ~8,700 Mtoe in 1990 to ~15,500 Mtoe in 2024 (+78%).
- Renewables' share increased from <2% in 1990 to ~14% in 2024 (2,120 Mtoe).
- China and India accounted for >50% of global demand growth since 2010.
- Fossil fuels remain dominant: oil (4,200 Mtoe), coal (4,100 Mtoe), gas (3,400 Mtoe) in 2024.
- Global electricity demand grew about 4% annually from 2021–2024.

#### 5.5. Trends and outlook for energy production and consumption in Algeria

Between 2015 and 2024, Algeria's energy consumption continued to rise, reaching nearly 60 million tons of oil equivalent (Mtoe) in 2024, with an average annual growth rate of about 1.1%. Natural

gas remains the overwhelmingly dominant energy source, accounting for approximately 64% (38.5 Mtoe) of total consumption due to its abundance and widespread use for electricity production and heating. Oil is the second primary source (20.2 Mtoe, about 33.5%), while coal remains negligible (0.2 Mtoe).



**Fig. 21-a:** Estimated share of energies in Algeria's energy consumption for 2024 (Mtoe)

The share of renewables, although still modest (1.1 Mtoe, nearly 2%), is increasing as Algeria advances its clean energy initiatives and solar capacity expansions. This energy mix underscores the country's ongoing reliance on hydrocarbons but also signals a gradual, policy-driven transition towards more sustainable energy solutions.

#### **a) Algeria and Coal (2015–2024)**

Algeria's coal reserves have remained stable at about 250 million tons throughout this period, but both production and consumption continue to be negligible—less than 0.2 Mtoe in 2024. Coal's role in the energy mix remains marginal due to environmental concerns and the high cost of coal-fired power generation.

**Note:** With very limited economically viable coal and environmental priorities, coal-fired plants continue to play a negligible role for Algeria between 2015–2024.

**b) Algeria and Oil (2015–2024)**

Proven oil reserves decreased slightly from 12.2 billion barrels in 2015 to approximately 12.0 billion barrels in 2024 (about 1.64 billion tons). Oil production remained relatively stable, typically between 1.55 and 1.60 million barrels/day, reflecting cautious resource management despite market volatility. Refining capacity also changed little, staying near 655 thousand barrels/day.

**Note:** Even in 2024, reserves represent over 20 years of production at current rates, providing a secure basis for domestic markets and exports.

**Tab 11: Oil - proven reserves (billion barrels), 2015–2024**

Year	2015	2018	2021	2024 (est.)
Reserves	12.20	12.12	12.08	12.00

**Tab 12: Oil Production (million barrels/day), 2015–2024**

Year	2015	2018	2021	2024 (est.)
Production	1.586	1.565	1.570	1.600

**Tab 13: Refining Capacity (thousand barrels/day), 2015–2024**

Year	2015	2018	2021	2024 (est.)
Capacity	651	652	655	655

**c) Algeria and Natural Gas (2015–2024)**

Proven natural gas reserves stayed stable at about 4.5 trillion cubic meters. Gas production grew modestly due to new discoveries and improved exploitation, reaching almost 90 billion cubic meters by 2024. Domestic gas consumption rose from 39 billion cubic meters in 2015 to around 50 Bcm in 2024, propelled by industrial and power sector expansion.

**Tab 14: Natural Gas - proven reserves (trillion m<sup>3</sup>), 2015–2024**

Year	2015	2018	2021	2024 (est.)
<b>Reserves</b>	4.5	4.5	4.5	4.5

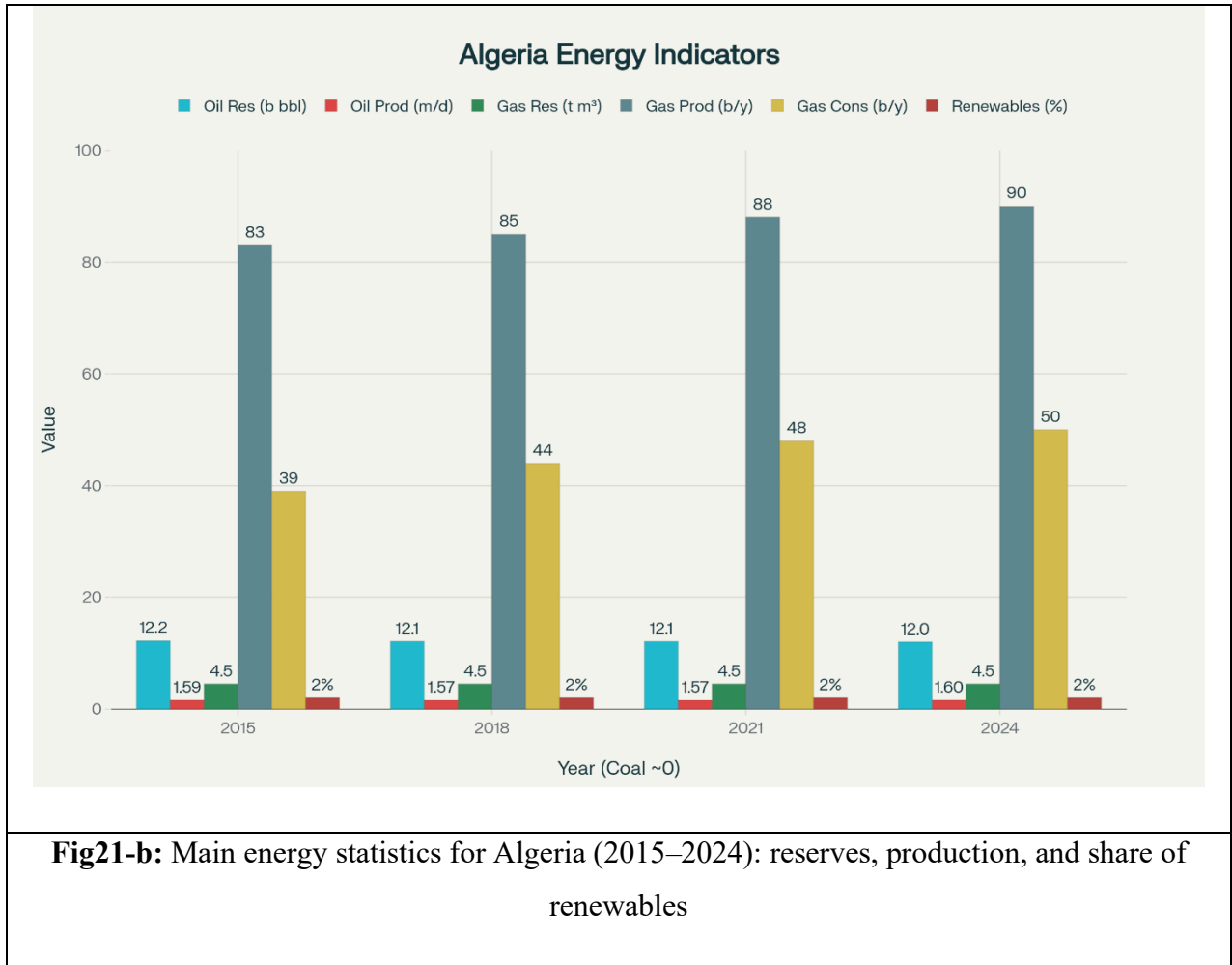
**Tab 15: Natural Gas Production (billion m<sup>3</sup>/year), 2015–2024**

Year	2015	2018	2021	2024 (est.)
<b>Production</b>	83.00	85.00	88.00	90.00

**Tab 16: Domestic Gas Consumption (billion m<sup>3</sup>/year), 2015–2024**

Year	2015	2018	2021	2024 (est.)
<b>Consumption</b>	39.00	44.00	48.00	50.00

Between 2015 and 2024, Algeria’s energy strategy continued to rely heavily on hydrocarbons, which accounted for over 98% of total consumption. Ample oil and gas reserves ensure medium-term energy security. Modest but steady growth in production and consumption was recorded, particularly in natural gas, while renewables—despite new initiatives—accounted for only around 2% of the energy mix by 2024. The period saw a greater policy emphasis on clean energy and resource diversification, laying foundations for Algeria’s upcoming energy transition.



➤ **Wind energy in Algeria**

- Algeria’s first connection of wind turbines to the national grid dates back to 1957, but industrial-scale development has been slow.



**Fig. 22:** Algeria's first wind farm, "Adrar"

- The nation's first wind farm was inaugurated in Adrar in 2013, featuring 10 MW of installed capacity over 30 hectares.
- As of 2024, installed wind power capacity in Algeria remains limited but is set for rapid growth: the government is currently studying the launch of a major 1,000 MW wind power project, targeting 10 promising sites for future wind farms.
- Overall, the country's renewable energy capacity (mostly solar, but including wind) exceeded 600 MW by early 2024 and is expected to reach ~4,000 MW by early 2025, with wind becoming a significant share for the first time.
- The government aims for at least 260 MW of wind capacity in the medium term, with national renewable energy plans envisioning a total of 15 GW (15,000 MW) of renewables—including both solar and wind—by 2035.
- Algeria's pivot to wind and solar is motivated by both domestic energy needs and the goal of reducing carbon emissions. New industrial projects are in place to manufacture turbine components locally.
- Recent partnerships with international companies have aimed to boost local content and create jobs in renewable energy.



**Fig. 23:** Wind pump in Adrar

**Key Milestone :**

- In 2024, the government initiated a feasibility study with the World Bank for a 1,000 MW wind farm, highlighting Algeria’s increasing focus on wind power as part of its national strategy.

Algeria’s wind energy sector has thus entered a phase of acceleration, with new megaprojects poised to shift the renewable energy balance from “insignificant” toward substantial contributions by the end of the decade

**Note:**

GEAT is a Sonelgaz–GE Vernova joint venture in Ain Yagout (Batna) comprising four plants that manufacture 100–300 MW gas turbines, 50–160 MW steam turbines, alternators, and control systems.

By 2024 the site's remit includes assembling turbines, producing modules/auxiliaries, digital solutions, and maintenance services, with about 146 employees listed.

In 2023, GEAT announced its first export of high-power equipment: two GE 9F.04 gas turbines, alternators, and Mark VI control systems delivered to a Middle East customer (Iraq), marking a first for end-to-end high-power turbines made in Africa.

In April–July 2024, Sonelgaz and GE Vernova expanded GEAT's mandate to develop grid solutions and high/extra-high-voltage substation equipment, including a major order covering equipment and automation for 134 substations by 2028 to be integrated at the Ain Yagout facility.

Corporate records indicate GEAT operates as an SPA created in 2017, confirming industrialization beyond the planned 2017 start.

Local business press further reports a new production line for high-voltage transmission equipment targeted for August 2025, with additional jobs expected, reflecting continued scale-up.

### ➤ **Solar energy in Algeria**

Algeria has solar radiation potential across almost the entire country, reaching up to 3,900 hours annually, with annual energy received at nearly **3 KWh/m<sup>2</sup>** in the north and exceeding **5.6 KWh/m<sup>2</sup>** in the far south. The solar thermal potential in the far south is also very high, equivalent to **10 times** global consumption.

Algeria's energy strategy is based on accelerating the development of solar energy. The government plans to launch several solar photovoltaic projects with a total capacity of around 800 MW by 2020. Other projects with a capacity of 200 MW per year are expected to be completed between 2021 and 2030.

Algeria intends to develop its solar thermal potential, one of the largest in the world, by launching major projects. Two pilot projects for concentrated solar power plants with storage facilities have been completed, each with a total capacity of around 150 MW. These projects will complement the 150 MW hybrid power plant at Hassi R'Mel, 25 MW of which is solar power.

Over the period 2016-2020, four solar thermal power plants with storage facilities and a total capacity of around 1,200 MW are expected to come online. The program for the 2021-2030 phase calls for the installation of 500 MW per year until 2023, then 600 MW per year until 2030.

## Part 6: Different types of pollution

### 6.1. Introduction

The term pollution comes from the Latin "**pollutio**," which means dirt or stain. This term could refer to a phenomenon or element that disrupts an established balance. Therefore, pollution is the introduction into the air, water, or soil of foreign substances "not naturally present in the environment" or a change in their levels of existence. This leads to environmental degradation or disruption of the ecosystem and can even result in the migration or extinction of certain species unable to adapt to the change. Human industrial, urban, or agricultural activity produces pollutants that are the source of organic, chemical, or radioactive pollution. These pollutants are emitted into the atmosphere ("**air pollution**"), discharged into water ("**water pollution**") or spread over the soil ("**soil pollution**"). They may exist in the form of gases, dissolved substances or particles.

### 6.2. Types of pollution

There are essentially four types of pollution:

#### ➤ **Organic pollution**

**Organic pollution** is the contamination of the environment (especially water bodies like rivers and lakes) by pollutants primarily composed of **organic matter**. These are chemical compounds containing carbon and hydrogen, and they are usually **biodegradable**.

This type of pollution occurs when these materials are discharged in amounts and concentrations that exceed the capacity of the natural ecosystem to process and break them down naturally.

**Note:** in the absence of contamination, the nitrate content of groundwater is between 0.1 and 1 mg/L. This contamination began in 1950 and has only increased since then. However, today it often exceeds the standard set for drinking water, which is 50 mg/L.

### ✓ **Environmental Impact (The Most Significant Effect on Water)**

The most notable effect of organic pollution is the **reduction of Dissolved Oxygen (DO)** levels in the water, which occurs through the following process:

- **Oxygen Consumption (BOD):** When organic matter enters the water, aerobic microorganisms (bacteria) begin to break it down chemically (biological oxidation).
- **This decomposition consumes large amounts of the dissolved oxygen in the water.** The amount of oxygen consumed is referred to as the **Biochemical Oxygen Demand (BOD)**, which is a key indicator of the degree of organic pollution.
- **Oxygen Depletion:** The high consumption of oxygen leads to a sharp decrease in its concentration, threatening the survival of other aquatic life (like fish) that need oxygen to survive, and potentially leading to their death.

### ➤ **Chemical pollution**

**Chemical pollution** is the **contamination of the environment** (air, water, and soil) by the presence or increase of **chemical pollutants** that are either not naturally found there or are present in amounts significantly higher than their natural background values.

The term primarily refers to **human-made (anthropogenic) chemicals** that result from various activities such as industrial processes, agriculture, transportation, and household use.

### ✓ **Impacts of Chemical Pollution**

Chemical pollution has dire consequences for both the environment and human health:

- **Environmental Effects:**

- **Ecosystem Disruption:** Pollutants can poison marine and terrestrial organisms, affect soil fertility, and lower oxygen levels in water, putting entire ecosystems at risk.
- **Air Quality:** Gases and particulate matter can contribute to smog, acid rain, and climate change.
- **Human Health Effects:**
  - Exposure can occur through inhaling contaminated air, ingesting polluted food or water, or skin/eye contact.
  - Health impacts can be immediate (e.g., irritation, poisoning) or delayed (appearing weeks or months after exposure).
  - Long-term effects are severe and include:
    - Cancer
    - Organ damage (especially to the liver and kidneys)
    - Endocrine disruption (hormone imbalances)
    - Neurological damage and developmental problems

### ➤ **Radioactive pollution**

**Radioactive pollution**, also known as **radiological contamination** or **nuclear pollution**, is the introduction or presence of **radioactive substances** into the environment (air, water, soil, and living organisms) where they are **unintended or undesirable**.

The core danger of this pollution comes from the spontaneous decay of unstable atomic nuclei, called **radionuclides**, which emit **ionizing radiation** (alpha, beta, and gamma rays). This radiation carries enough energy to cause physical damage to living cells and DNA.

#### ✓ **Effects on Health and Environment**

Radioactive contamination is particularly hazardous because radionuclides can remain radioactive for extended periods—from hours to hundreds of thousands of years—and can be transported over large distances.<sup>5</sup>

#### ✓ **Human Health Effects**

The harm is dependent on the type and amount of radiation exposure, which can occur through ingestion, inhalation, absorption, or injection.

- **Acute Exposure (High Dose):** Can cause immediate **radiation sickness**, leading to symptoms like nausea, vomiting, cellular decay, organ damage, and potentially rapid death.
- **Chronic Exposure (Low Dose):** Damages the genetic material (**DNA**), leading to:
  - Increased risk of **cancer** (especially leukemia and thyroid cancer).
  - **Genetic mutations** that can result in birth defects and hereditary diseases in future generations.
  - Impaired immune function.

#### ✓ **Environmental Effects**

- **Ecosystem Disruption:** Damages the cells of plants and animals, leading to mutations, reduced fertility, and mortality.
- **Contamination:** Pollutes soil, air, and water, making land infertile or unsafe for agriculture and habitation for decades or centuries.
- **Bioaccumulation:** Radioactive isotopes like Strontium-90 can be mistaken for calcium and incorporated into bones, causing specific harm.

#### ➤ **Solid waste pollution**

**Solid waste pollution** refers to the contamination of the environment (air, water, and soil) resulting from the improper collection, storage, treatment, and disposal of **unwanted or discarded solid**

**materials.** These materials are generated primarily from human activities and are neither liquid nor gaseous.

The problem stems from poor **solid waste management (SWM)** practices, such as open dumping and inadequate landfilling, which allow harmful components of the waste to interact negatively with the natural environment.

### ✓ **Major Environmental and Health Impacts**

Improper solid waste disposal leads to multi-faceted pollution:

- **Land and Soil Contamination:**
  - Waste dumped on land occupies valuable space and degrades the aesthetics of an area
  - **Leachate**, a toxic liquid formed when water passes through decomposing waste in landfills or open dumps, seeps into the soil, altering its chemical properties and decreasing fertility.
- **Water Pollution (Surface and Groundwater):**
  - Leachate is a major source of **groundwater contamination**, especially near poorly engineered landfills.
  - Surface water bodies (rivers, oceans) are polluted by litter and plastic debris, harming aquatic life and clogging drainage systems, which can lead to flooding.
- **Air Pollution:**
  - The anaerobic decomposition of **organic waste** in landfills releases **methane** (CH<sub>4</sub>), a potent greenhouse gas that contributes to climate change.
  - The practice of **open burning** of waste releases harmful pollutants like **dioxins**, **furans**, carbon monoxide (CO), and particulate matter into the atmosphere, causing respiratory illnesses.
- **Health Risks:**
  - Accumulated waste creates breeding grounds for **vectors** (rodents, mosquitoes, flies) that transmit diseases such as malaria, dengue, cholera, and dysentery.
  - Scavengers and workers exposed to waste, particularly hazardous and medical waste, face direct risks of poisoning and infectious diseases.

## 6.3. Categories of environmental pollution

Pollution exists in all three states of matter, so that we can distinguish between three Categories of pollution:

### 6.3.1. Air pollution

Air is composed of 78% nitrogen, 21% oxygen, and 1% other gases. Changes to this composition, caused by human emissions, lead to a deterioration in air quality. Humans release substances into the atmosphere that have harmful effects on living organisms and the environment. These substances are emitted by industrial, domestic, and agricultural activities, as well as by passenger and freight transport.

There are too many polluting gases, and we are currently unable to identify or measure the impact of all the polluting gases emitted into the atmosphere, including the most polluting gases on-site.

#### ✓ **Impacts on the Environment and Climate**

- **Acid Rain:** Formed when sulfur and nitrogen oxides react with water droplets in the atmosphere, damaging plants, soil, water bodies, and buildings.
- **Smog:** Formed in cities due to the reaction of vehicular and industrial pollutants with sunlight, reducing visibility and causing respiratory issues.
- **Climate Change and Global Warming:** Certain air pollutants (such as methane CH<sub>4</sub> and carbon dioxide CO from fuel combustion) contribute to the greenhouse effect.
- **Vegetation Damage:** Ground-level ozone and high pollutant concentrations can damage plant leaves and inhibit growth, thereby reducing crop yields.

#### ➤ **Carbon monoxide CO**

Carbon monoxide is formed during incomplete combustion. Approximately 55% comes from motor vehicles and 26% from heating and industrial combustion facilities. It inhibits the transport of oxygen in the blood.

**Note:** Carbon monoxide claims many victims during the winter months each year in Algeria. This colorless, odorless, non-irritating gas is toxic to the body and can cause serious complications at certain doses.

➤ **Sulfur Dioxide SO<sub>2</sub>**

Sulfur dioxide SO<sub>2</sub> is a colorless gas with a pungent odor that irritates the eyes and respiratory tract. Ninety-one percent of this gas is produced by the combustion of fossil fuels used by domestic heating and industrial boilers, with the remainder produced by transportation and the smelting of iron ore containing sulfur.

➤ **Nitrogen dioxide NO<sub>2</sub>**

Nitrogen dioxide, NO<sub>2</sub>, is a toxic, suffocating gas with a pungent odor. It is formed from nitrogen monoxide NO. Fifty-six percent of this gas is produced by internal combustion engines and 30% by combustion plants.

**Note:** Sulfur dioxide SO<sub>2</sub> and nitrogen dioxide NO<sub>2</sub> contribute to the formation of acid rain, which mainly threatens vegetation, soil acidity, and water acidity. This can change soil characteristics, particularly those of acidic soils such as granite and sandstone.

➤ **Volatile organic compounds (VOCs)**

Volatile organic compounds (VOCs) include several compounds that result from the incomplete combustion of fuels in transportation vehicles, industry, crafts, and households, as well as from the evaporation of solvents. They can be biogenic (natural origin) or anthropogenic (human origin). The best-known VOCs are butane, propane, ethanol, acetone, solvents in paints, solvents in inks, etc.

➤ **Tropospheric ozone O<sub>3</sub>**

Tropospheric ozone is a secondary pollutant formed when two primary pollutants, nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs), react under the effect of photochemical processes, i.e., it results from the action of sunlight on polluted air. Ozone is one of the main components of summer smog.

**Note:** Tropospheric ozone, the "polluting gas," is different from stratospheric ozone, the "protective layer of the atmosphere."

➤ **Particulate Matter (PM10)**

PM 10 encompasses a wide range of physical and chemical compositions with a diameter of less than ten micrometers. These atmospheric pollutants originate from primary emissions, mainly from combustion and industrial processes, as well as from the abrasion of roads, rails, brakes, and tires, and from secondary aerosols.

➤ **Lead Pb**

Lead enters the environment mainly through car exhaust fumes. Large particles fall to the ground, while small particles enter the air and remain in the atmosphere. Leaded gasoline is not the only contributor to increased lead concentrations in the environment; other activities such as the combustion of fossil fuels, industrial processes, and the incineration of solid waste also increase these levels.

➤ **Ammonia NH<sub>3</sub>**

Ammonia NH<sub>3</sub> is a pollutant that mainly comes from agriculture. It's released when storing and spreading manure and slurry from animal farms, but also when making ammonia fertilizers. It's a waste product that's dangerous for the environment and health, and can cause burns and lung irritation.

➤ **Trace Metal Elements "TME"**

Heavy metals are defined physically as having a density greater than  $5 \text{ g/cm}^3$ . They occur naturally in soil, and some are essential for plants. The heavy metals best known for their dangerous properties are cadmium, mercury, chromium, zinc, and scrap metal containing heavy metals. These metals are present in the air we breathe, emitted from the chimneys of household waste incineration plants and steel mills. Some of them are highly toxic.

### ➤ Tobacco

Tobacco smoke is the leading source of pollution in the home and the main nuisance in indoor spaces. More than 3,000 substances have been identified in tobacco smoke, including nicotine, tar, carbon monoxide, etc. These harmful substances are responsible for several diseases, including cancer, addiction, asthma, respiratory diseases, etc.

### ➤ Greenhouse gases

The presence of small amounts of gases in the atmosphere, known as **the "natural greenhouse effect,"** such as water vapor or carbon dioxide " $\text{CO}_2$ ," increases the average temperature of our planet, making it habitable. In addition to water vapor and carbon dioxide, the main natural greenhouse gases are methane ( $\text{CH}_4$ ), nitrous oxide ( $\text{N}_2\text{O}$ ), and ozone  $\text{O}_3$ .

Nevertheless, the slight increase in these gases due to human activities ("**anthropogenic or additional greenhouse effect**") is cause for concern. The contribution to the greenhouse effect of human origin is due to: carbon dioxide  $\text{CO}_2$  "responsible for just over **55%**," methane  $\text{CH}_4$  "generates just over **15%**," halocarbons "generic formula of type  **$\text{C}_x\text{H}_y\text{Hal}_z$**  where **Hal** represents one or more halogens" "account for just over **10%**," tropospheric ozone  $\text{O}_3$  "accounts for about **10%**," and nitrous oxide  $\text{N}_2\text{O}$  "accounts for about **5%**."

**Note:** Some natural sources of gas are classified as air pollutants, for example:

- volcanoes eject large quantities of sulfur dioxide and particles into the atmosphere.
- Plants release gases into the air that can cause problems.

### 6.3.2. Water pollution

The Earth is also known as the blue planet because approximately 71% of its surface is covered by water (oceans, seas, rivers, etc.). Water also exists in the aquifers of the soil. "groundwater" and also exists in the air in the form of "vapor." However, contrary to popular belief, water is a rare and precious commodity, as all the water on Earth represents only about 0.13% of its total volume "volume of water 1,400 million km<sup>3</sup>, volume of the Earth 1,083,320 million km<sup>3</sup> ," the preservation of which is the responsibility of each and every one of us, and it is not appropriate to waste this water "even if you were standing at the edge of a river overflowing," according to our prophet, "blessings and peace be upon him."

#### *Example*

##### **Did you know?**

- Producing **1 liter** of **gasoline** consumes **10 liters of water**.
- The production of **1 kg of potatoes** consumes **1,000 liters of water**.
- Manufacturing **910 kg of paper** consumes **295,000 liters of water**.

Water pollution is any "chemical, physical, or biological" alteration of its quality and nature that has a harmful effect and makes its use dangerous and/or disrupts the aquatic ecosystem. This pollution affects both surface water and groundwater and is mainly caused by domestic and industrial waste disposal, industry, agriculture, and other human activities. This pollution manifests itself in water through a decrease in dissolved oxygen content, the presence of toxic products, algae blooms, physical changes to the receiving environment, and the presence of dangerous bacteria or viruses.

**Note:** Groundwater pollution is characterized by slow and sustained spread "taking several decades," making it very difficult to remediate or treat contaminated aquifers.

There are two types of water pollution sources: **localized sources** and **non-localized sources**. If pollutants are discharged in a specific location, it is a localized source of pollution, such as sewers, factories, mines, oil tankers, and agriculture. Otherwise, if the specific location of the pollutant discharge cannot be identified, it is a non-localized source of pollution, such as acid deposition from

the air, traffic, pollutants from groundwater or spread by rivers." In most cases, the perpetrators of this pollution cannot be identified, making it difficult to control.

### **6.3.2.1. Different categories of pollution**

The different categories of pollution are:

#### **➤ Disease-causing pollutants**

This category includes pollutants that cause disease, such as bacteria, viruses, and parasitic worms that thrive in untreated wastewater.

**Note:** 80% of diseases in developing countries are caused by water.

#### **➤ Waste pollutants**

This waste requires oxygen to decompose, which can lower the oxygen level in the water, affecting other species living in the water.

#### **➤ Water-soluble inorganic pollutants**

This category includes water-soluble inorganic pollutants such as acids, salts, and toxic metals, which render water unfit for consumption and cause the death of aquatic life.

#### **➤ Nutrient pollutants: water-soluble nitrates and phosphates**

These pollutants cause excessive growth of algae and aquatic plants, which also reduces the amount of oxygen in the water.

#### **➤ Organic compound pollutants**

This category includes organic pollutants such as oil, plastics, and pesticides, which are harmful to humans as well as all plants and animals living in water.

➤ **Suspended sediment pollutants**

These pollutants reduce the absorption of light by water and release dangerous compounds such as pesticides into the water.

➤ **Radioactive compound pollutants**

These pollutants are the most dangerous; they can cause cancer, birth defects, and even genetic changes.

**6. 3. 2. 2. Different sources of pollution**

The different sources of pollution are:

➤ **Agricultural pollutants**

The agricultural sector uses chemical fertilizers that pollute groundwater after irrigation of the land through infiltration. This sector also pollutes rivers through animal waste. "manure and slurry" which increase the amount of nitrates and chlorides.

➤ **Urban pollutants**

In a city, families, businesses, schools, hospitals, etc. use water for various purposes. After use, the water flows away carrying organic debris, grease, solvents, detergents, nitrogenous organic matter, and fecal germs. In addition, rainwater that runs off impermeable surfaces such as roofs and asphalt and ends up in sewers or rivers is also a source of pollution, as it picks up organic and mineral matter along the way from vehicle traffic and industrial activity.

➤ **Accidental pollutants**

**Accidental pollutants** are harmful substances released into the environment as a result of an **unforeseen, unplanned, or sudden event** rather than through routine, continuous, or authorized discharge. These incidents are often characterized by their rapid onset and potential for severe, localized, and immediate environmental damage.

The distinction between accidental and routine pollution is crucial, as the former requires immediate emergency response and cleanup, while the latter requires regulatory compliance and long-term control measures.

### ➤ **Industrial pollutants**

**Industrial pollutants** are the harmful substances released into the environment (air, water, and soil) as a direct or indirect result of **industrial activities** such as manufacturing, resource extraction, processing, and energy generation.

Industrial pollution is a pervasive environmental issue because industries often use complex chemical processes and consume large amounts of resources, resulting in massive outputs of unwanted byproducts and waste.

<i>Example</i>	
<b>Did you know that the daily pollution produced by one person is estimated at?</b>	
➤	<b>70 to 90 g</b> of suspended solids.
➤	<b>60 to 70 g</b> of organic matter
➤	<b>12 to 15 g</b> of nitrogenous matter
➤	<b>3 to 4 g</b> of phosphorus
➤	<b>several billion</b> germs per 100 ml
<b>Did you also know that?</b>	
➤	<b>One drop of oil</b> can render up to <b>25 L of water</b> unfit for consumption.
➤	<b>One gram of 2,4-D "herbicide"</b> can contaminate up to <b>10,000,000 liters of drinking water.</b>
➤	<b>1 liter of oil</b> can contaminate up to <b>2,000,000 liters of water.</b>

### **6. 3. 3. Soil pollution**

Soil performs a multitude of complex functions, and its pollution directly or indirectly affects water and air, as it represents an interface between the earth, air, and water. This pollution is mainly due to: deposits of pollutants, the use of pesticides and chemical fertilizers, infiltration, the spreading of

chemicals, fallout from atmospheric emissions, wars, and even some sports and leisure activities (golf spreads arsenic and pesticides, hunting spreads lead, etc.).

### 6. 3. 3. 1. Sources of soil pollution

#### ✓ Diffuse Pollution (Non-Point Source)

This type of pollution is **widespread and difficult to control** because it affects a large area through the regular repetition of small doses.

- **Nature:** It involves small amounts of pollutants spread over a vast area.
- **Sources:** Linked to a **multitude of sources**, making it challenging to pinpoint the origin. Key contributors include **agricultural practices** (e.g., repeated use of fertilizers and pesticides) and **atmospheric fallout** (pollutants settling from the air).

#### ✓ Point Source Pollution

This type of pollution is **highly localized and intense**, originating from a single, identifiable source.

- **Nature:** The contamination is concentrated in a specific, contained area.
- **Sources:** Stems from a single source, such as **industrial sites**, **accidental spills** (like chemical or fuel leaks), or **chronic industrial pollutants** that are identifiable. This is often the **most polluting in the short term** due to the high concentration of toxins.

### 6. 3. 3. 2. Types of pollutants

The categories of products likely to be found in the soil are:

- ✓ Inorganic
- ✓ Organic
- ✓ Radionuclides "nuclear radioactive products"

### **6.3.3.3. Consequences of soil pollution**

The consequences of soil pollution are:

- ✓ changes to flora and the food chain
- ✓ the penetration of pollution into the water cycle, which disrupts the ecosystem and harms human life.
- ✓ Decrease in the amount of usable land.

## Part 7: Detection and treatment of pollutants and waste

### 7.1. Introduction

The environment—air, water, and soil—is polluted when it contains pollutants that exceed its capacity to eliminate them naturally. This makes it harmful to people, animals, and plants. In other words, the balance of the ecosystem is disrupted.

In the context of environmental protection, most governments have identified technical standards with the aim of reducing pollutant emissions and the harmful effects of human activities on the environment. Detecting and measuring pollutant concentrations is essential for monitoring these standards. Legislative and regulatory processes are developed by governments to minimize the impact of human activity on the environment, such as the application of eco-taxes or the polluter pays principle.

**"The polluter pays for the costs of pollution control measures and prevention."** At the global level, the **Kyoto** Protocol, for example, imposes maximum emission quotas for greenhouse gases.

**Note:** In France, for example, an eco-tax is applied to emissions of eight polluting metals "arsenic, cadmium, chromium, copper, mercury, nickel, lead, and zinc."

### 7.2. Economic models for environmental protection

Two economic models are most commonly cited for reducing energy consumption, raw material consumption, and human impact on the environment:

#### ✓ Sustainable development

This term first appeared in 1980. Its standard definition, according to the 1992 Brundtland Report, is: **"development that meets the needs of the present without compromising the ability of future generations to meet their own needs."**

**Note:** Economic is central to the principle of sustainable development, while opponents believe that it is economic growth itself that causes environmental degradation.

### ✓ **Degrowth**

The principle of this model is to reduce human impact on the environment through economic degrowth. This idea originated in 1972 in Meadows' report "The Limits to Growth."

growth," which states that human population growth is the cause of increased consumption of energy, natural resources ("raw materials") and the resulting pollution. Proponents of this model are convinced that zero growth is the solution to preventing the depletion of natural resources.

## **7.3. Pollution detection and measurement**

Environmental assessment requirements, impact studies, and the application of eco-taxes or the polluter pays principle require recognized and/or standardized pollution indicators. These indicators are used to detect pollution or environmental degradation. There are several indicators, such as:

### ✓ **Apparent pollution**

It is not difficult to detect several pollutants in the natural environment: on the ground, "solid waste"; in water, water quality, "smell or color"; and in the atmosphere or air quality, "dust."

### ✓ **Non-visible pollution**

The environment may contain invisible and odorless elements that can have undesirable effects. Therefore, periodic analysis of water "for drinking or other uses" from "wells, valleys, rivers, beaches, etc.," as well as of the air and soil, is essential for preserving the environment.

### ✓ **Loss of biodiversity**

Biodiversity is an indicator of the state of the environment, and species are fragile: "the entire ecosystem is at risk if one link in the chain is destroyed."

✓ **Scarcity of natural resources**

The scarcity of natural resources, whether renewable or not, is another indicator of the state of the environment.

✓ **Effects caused by pollution**

Effects such as "climate change, holes in the ozone layer, metal corrosion due to sulfur dioxide, encrustations on buildings due to fuel dust, necrosis on plants, etc." can indicate the state of the environment or the existence of pollution.

✓ **Bioindicators**

Some plant and animal organisms are used as bioindicators because of their growth rates and reproductive capacities. Plants such as nitrophiles detect nitrate-rich waters, tobacco and clover are very sensitive to ozone, and animals such as snails indicate the chromium content in soil, and bee activity (colony and/or significant mortality) can indicate atmospheric pollution. 53

**Note:** It is very difficult to measure the impact of multiple pollutants acting synergistically.

## **7.4. Waste management**

Waste is a product, substance, or material that is no longer used and is intended to be discarded or disposed of. It is generally produced by urban areas, industry, and even agriculture. This waste creates a real concern for hygiene and environmental cleanliness.

Nearly a century ago, nature was able to digest our waste. Today, nature alone is unable to digest the enormous amount of waste, which is difficult to biodegrade and rich in chemicals.

Previously, at the beginning of the industrial revolution, waste management was carried out by a landfill system that consisted of storing waste in a site far from residential areas. Then, in the 1960s,

incineration developed due to the increasing difficulty of finding landfill sites and new equipment that could burn these large quantities of waste. In recent years, the idea of circular economy management to combat waste has emerged. This idea promotes the recovery of waste through recycling to extract raw materials, composting, methanization, or burning to produce electricity or heat. Waste management involves the following steps:

✓ **Waste collection**

This is usually carried out by garbage trucks that collect waste from collective collection points or door-to-door. In developed countries, collection is generally carried out on a selective basis.

✓ **Waste sorting**

Waste sorting is carried out daily using different colored bins, where citizens sort their waste before throwing it away. This operation limits pollution and opens the door to waste recovery.

✓ **Waste recovery**

This is the ideal solution for waste disposal, transforming "material or organic" waste into a valuable "tangible object or energy."

✓ **Waste incineration**

Incineration is a thermal treatment that involves burning as much of this waste as possible at temperatures ranging from 700°C to 900°C, effectively reducing its mass and destroying the hazardous chemicals and pathogens present in the waste. In most developed countries, the recovery of energy produced by incineration is mandatory, and incineration centers must be equipped to treat the fumes released.

**Note:** In most developing countries, these stages are summarized by landfill disposal without any treatment or recovery, or by simple incineration "without energy recovery," and recycling is only informal recovery.

## 7.5. Waste categories

Waste can be classified into several categories according to its nature:

### ✓ **Household waste**

They are produced in cities "in everyday life" and consist of food scraps, packaging, tin cans, as well as waste from shops, craftsmen, public administrations, and educational and healthcare establishments.

**Note:** in Algeria, each person in urban areas produces **0.8 kg/day** of waste, or more than 292 kg per year!

### ✓ **Industrial waste**

There are two types of industrial waste: ordinary industrial waste, which is similar to household waste and consists of cardboard, paper, plastic, metal, textiles, etc. The other type is more hazardous or special industrial waste that requires special conditions for disposal or storage, such as solvents, adhesives, chemicals, etc.

### ✓ **Inert waste**

This waste consists of demolition rubble such as bricks, concrete blocks, soil, glass panels, etc. It is non-biodegradable and cannot be burned or undergo chemical reactions. It is not hazardous, but it poses a risk of landscape degradation due to the enormous quantities involved.

### ➤ **Other categories of waste**

There are other types of waste that require specific treatment.

### ✓ **Waste from wastewater treatment plants**

These plants produce between 2 and 4 g/L of sludge, meaning that  $1,000 \text{ m}^3$  of discharged water produces between 2 and 4 tons or 75 to 150  $\text{m}^3$  of sludge, making the disposal of this waste a challenge for plant managers.

### ✓ **Radioactive waste**

This waste is classified according to its activity level. High-level or long-lived waste is incorporated into molten glass paste, poured into stainless steel containers, and stored in wells. Low- and intermediate-level short-lived waste is first solidified, then encased in concrete or bitumen, and finally placed in containers. Very low-level waste activity are compacted and packaged in parcels and stored in storage centers.

## **7.6. Waste sorting and recovery**

Waste is sorted after collection according to its hazardousness in order to reduce risks and impacts on health and the environment. The most hazardous types of waste are:

### ➤ **Used oils**

These oils are considered hazardous and toxic waste and require special treatment to be either regenerated or recycled as fuel. They include oils used for engines, compressors, the manufacture or preparation of lubrication additives, greasing, gears, petroleum jelly and petroleum jelly oils, insulation, turbines, quenching and cooling, etc.

### ➤ **Polychlorinated biphenyls "PCBs"**

A family of more than 200 organochlorine aromatic compounds derived from biphenyl, with a substance content of these compounds greater than 50 ppm by mass. Given their good dielectric and thermal characteristics, these compounds were widely used as electrical insulators, especially between 1930 and 1970, in the manufacture of electrical transformers, capacitors, very high voltage environments, etc. They were also used in microwave ovens, certain adhesives and paints, etc. These products produce dioxins and furans when burned. They are carcinogenic, reprotoxic, non-

biodegradable, fat-soluble, and, in addition, they are susceptible to entering the food chain and accumulating in organisms. For this reason, these products are classified as persistent organic pollutants (POPs) and their production was banned worldwide in 2004 in Stockholm, Sweden, in a convention on persistent organic pollutants.

➤ **Solvents and paints**

Most solvents and paints are hazardous waste that is "volatile, toxic, and ecotoxic." Therefore, they require treatment to neutralize their undesirable effects and, if possible, regenerate them, "generally through distillation."

➤ **Batteries and accumulators**

The difference between batteries and accumulators is that batteries are single-use and accumulators are rechargeable. The most dangerous are: batteries containing mercury, lead-acid accumulators "car batteries," and nickel-cadmium batteries.

**Note:** in developed countries, manufacturers have been required to collect and process these products for several years.

➤ **Other hazardous waste**

There are other types of waste classified as hazardous waste, such as hospital waste (radioactive waste, infectious waste, and medicines), all waste containing asbestos or mercury, phytosanitary waste, contaminated packaging, treated or contaminated wood, etc.

Waste is sorted into categories—household waste, plant waste, and industrial waste—in order to be recycled.

➤ **Recycling**

Recyclable waste is collected and sorted by material (glass, plastic, paper, aluminum, copper, etc., and then reintroduced into a production cycle.

➤ **Recovery through methanization**

Certain types of plant and household waste undergo a fermentation process to produce biogas.

➤ **Recovery through composting**

Some waste is used for composting, undergoing controlled aerobic fermentation to produce an organic compound used in agriculture to regenerate soil.

➤ **Energy recovery**

Incineration with energy recovery is another recovery strategy. Thermal treatment allows certain types of waste to be burned in furnaces capable of recovering the energy released during this operation, either as heat from steam or electricity from turbines.

## **7.7. Waste management in Algeria**

In Algeria, the government adopted a national waste management program. based on the national environmental strategy (SNE) and the national action plan for the environment and sustainable development (PNAE-DD), which resulted in the enactment of Law 01-19 of December 12, 2001, on waste management. This program provided for the establishment of a system for prevention, reduction of production and harmfulness at source, selective sorting and recovery of waste, and eradication of illegal dumping.

Today, after many years, the recycling sector remains untapped, "even though it could generate 38 billion Algerian dinars, according to a statement made by the Minister of Water Resources and the Environment in 2016." Energy recovery through methanization and composting is completely absent. According to a study conducted by a group of South Korean experts in 2015, this delay in recycling is due to: a lack of cultural acceptance of this practice, low collection rates due to insufficient bins, irregular collection frequencies, and a lack of or outdated collection methods.

## Part 8: Impact of pollution on health and the environment

### 8.1. Introduction

The impacts of pollution on our health and the environment are certain. Pollution is considered a source of external pathogens that affect health, such as toxic chemicals, ionizing radiation, germs, microbes, parasites, etc. On the environment, pollution can have harmful consequences on resources that are essential to life, such as water and air, and in the longer term, on soil. However, a polluted environment is considered a source of internal pathogens that impact health, such as hereditary, congenital, functional, lesion-related, psychosomatic causes, etc.

### 8.2. Effects of pollution on health

The effects of pollution on health have been known for a long time, with numerous medical studies and research confirming the link between pollution and disease causation. Air pollution contributes to cancer, respiratory diseases, and neurological problems. Contaminated water causes cholera, typhoid, polio, hepatitis, diarrhea, yellow fever, dengue fever, malaria, etc. Soil pollution affects neuromuscular development in children and causes liver and kidney damage.

#### 8.2.1. Effects of air pollution on health

Air is as essential as water, food, or heat. Each of us consumes approximately 15,000 liters of air every day. When this air is of poor quality, it means that there is a high level of pollutants in the air, which increases the risk of adverse effects on our health. The effects of this pollution are known to affect the lungs, heart, brain, and hormonal system. In 2012, the World Health Organization estimated that 3.7 million premature deaths worldwide were caused by air pollution.

##### ➤ Acute and chronic bronchitis

Bronchitis is an inflammation of the bronchi, "the tubes that carry air from the trachea to the lungs." It is caused by a weakening of the bronchi due to chemical pollutants. According to some estimates, there are approximately one million cases of acute bronchitis attributable to air pollution each year. This pollution is also responsible for 134,000 new cases of chronic bronchitis per year.

### ➤ **Pollen allergy**

Pollen allergy, which is often hereditary, is a reaction of the immune system to one or more types of pollen. This reaction leads to inflammation of the conjunctiva of the eyes and the nasal mucosa. Fine dust particles caused by air pollution play an important role in aggravating pollen allergies. "Pollen in regions with high levels of air pollution is covered with pollutant particles, which increases its allergenic effect."

**Note:** 40% of the world's population "live in densely populated areas or near busy roads" and regularly breathe in excessive amounts of fine particulate matter, which is harmful to health and, above all, causes respiratory diseases.

### ➤ **Cancer**

In 2013, the International Agency for Research on Cancer (**IARC**) classified air pollution as one of the leading environmental causes of cancer deaths. However, the number of cancer cases attributable to this pollution is difficult to estimate, as this disease is associated with several risk factors.

### ➤ **Other diseases linked to air pollution**

Air pollution can be responsible for "triggering or aggravating," directly or indirectly, coughs, headaches, eye irritation, rhinitis, and damage to the body's defenses. However, it is also implicated in cardiovascular diseases such as myocardial infarction, stroke, and angina pectoris, as well as in several reproductive system disorders, including reduced male fertility, increased intrauterine mortality, and premature births. Table 17 shows the areas of the body that may be affected by certain pollutants.

**Tab 17: Areas of the body that may be affected by certain pollutants**

Pollutants affected	Area of the body
Lead, mercury, and their compounds.	Brain
Nickel, chromium, and their compounds.	Nasal cavities
Ammonia, asbestos, sulfur dioxide, nitrogen oxide, toluene diisocyanate, and coal dust.	Lungs
Ethylene, hydrochloric acid, dioxane, and chlorinated hydrocarbons.	Liver
Chlorinated hydrocarbons, mercury, and their compounds.	Kidneys
Auramine, benzidine, and beta-naphthylamine.	Bladder
Benzene.	Bone marrow
Mercury, cadmium, and their compounds.	Nerves
Diisocyanate, chlorinated hydrocarbons, detergents, acids, and mineral oils	Skin

### 8.2.2. Effects of water pollution on health

Water-related diseases are a real concern in developing countries and constitute one of the most serious global health problems. Cholera and other diarrheal diseases are responsible for 1.8 million deaths per year. Unsafe water "Due to the lack of sanitation and difficulties in water supply" in developing countries, this plays a very important role in personal and food hygiene. This increases the risk of infection. The main waterborne infectious diseases are:

➤ **Waterborne diseases**

Waterborne diseases are diseases caused by water contaminated with human, animal, or chemical waste. They affect developing countries due to the lack of sanitation (wastewater treatment facilities), clean water supplies, and medical infrastructure.

Waterborne diseases include:

- ✓ Cholera
- ✓ Typhoid

- ✓ Polio
- ✓ Meningitis
- ✓ Hepatitis A and E
- ✓ Diarrhea

**Note:** Diarrheal diseases kill 6,000 people worldwide every day, "approximately 2 million per year, more than half of whom are children." However, with simple hygiene measures, many of these deaths could be prevented.

➤ **Diseases caused by poor hygiene**

Poor hygiene, mainly due to a lack of clean water, is a serious problem in developing countries, where water contaminated by human, animal, or chemical waste provides an opportunity for bacteria to spread and increases the risk of contracting diseases and infections. Diseases linked to poor hygiene include:

- ✓ Cholera
- ✓ Hepatitis A
- ✓ Typhoid

➤ **Waterborne diseases**

Aquatic diseases are diseases transmitted by organisms that spend the early part of their lives in water and then spread as parasites, such as worms, mosquitoes, and tsetse flies. These organisms infect humans without necessarily being fatal, but they do significantly reduce physical capacity.

- ✓ Schistosomiasis "bilharzia" is caused by the schistosomiasis worm
- ✓ Yellow fever,
- ✓ Dengue fever: "the most virulent form causes severe and even fatal hemorrhaging."
- ✓ Sleeping sickness,
- ✓ Filariasis
- ✓ Malaria

➤ **Diseases transmitted by aquatic insects**

Aquatic insect-borne diseases are infectious diseases in which the pathogen (virus, bacterium, parasite) is transmitted by an insect intermediary (the vector). These insects (mosquitoes or flies) reproduce in or near stagnant water. For this reason, these diseases are widespread in tropical and subtropical areas.

Aquatic insect-borne diseases include:

- ✓ River blindness or onchocerciasis.
- ✓ Malaria,
- ✓ Filariasis,
- ✓ Yellow fever,

Table 18 shows the health effects of certain pollutants.

**Table 18:** Effects of water pollutants on health

Pollutants	Health effects
Suspended solids (minerals, sand, mud, clay)	These materials increase the risk of human contamination "through the transport of pollutants."
Organic pollutants in organic matter (manure, sewage sludge, etc.), organochlorines (DDT), polychlorinated biphenyls (PCBs).	Promotes the development of pathogenic organisms
Nitrogen (nitrates, phosphorus) Metals (arsenic, nickel, and chromium)	Blue disease in children and cancer risks Respiratory, digestive, nervous, or skin disorders and cancer risks
Pesticides	Malformations, infertility, reproductive disorders, and cancer risks

### **8.2.2. Effects of soil pollution on health**

Contaminated soil is caused by inadequate sanitation and/or lack of waste treatment. It is an indirect consequence of the diseases mentioned above ("diseases caused by polluted air and polluted water"), the inhalation of dust from polluted soil and the ingestion of polluted water. However, it is difficult to determine whether soil pollution is directly responsible. health effects on a population living on or near a polluted site, but it is often possible.

### **8.3. Effects of pollution on the environment**

Pollutants not only have negative effects on human health, but also on the environment. Animals, plants, and even buildings can also suffer the repercussions of pollution.

Whether chronic or sporadic, pollutants have an impact on ecosystems and even crops. Rain, snow, and fog become more acidic "due to the presence of pollutants such as O<sub>3</sub> , NO<sub>x</sub> , VOCs, NH<sub>3</sub> , etc." and therefore alter the soil and waterways, causing a "loss of mineral nutrients." This transformation of the environment causes an imbalance in the ecosystem, through a reduction in biodiversity and then a general disruption of the functioning of the ecosystem. "affects wildlife, alters the physiology of organisms, etc."

The impacts of pollutants can also indirectly influence the environment through the destruction of stratospheric ozone and global warming or climate change. Table 19 shows the effects of certain pollutants on the environment.

**Table 19: Effects of pollutants on the environment**

Pollutant	Effects on the environment
Tropospheric ozone <b>O<sub>3</sub></b>	In high quantities or concentrations, ozone contributes to environmental acidification, which disrupts the composition of the air, water, and soil, damaging the ecosystem (forest dieback, freshwater acidification, damage to the food chain, etc.) and even degrading buildings and crops.
Nitrogen oxides <b>NO<sub>x</sub></b> , Volatile organic compounds <b>VOCs</b> , Ammonia <b>NH<sub>3</sub></b>	These contribute to the formation of O <sub>3</sub> and contribute to environmental acidification.
Dust or suspended particles " <b>PM10</b> and <b>PM 2.5</b> "	They absorb and scatter light, thereby limiting visibility and causing dirt to form through deposition, and may have an unpleasant odor.
Carbon dioxide carbon Carbon « <b>CO<sub>2</sub></b> »	It increases the greenhouse effect and contributes to global climate change.
Sulfur dioxide " <b>SO<sub>2</sub></b> "	It forms sulfuric acid " <b>H<sub>2</sub>SO<sub>4</sub></b> " with water, which contributes to environmental acidification.

## A comprehensive quiz

This is a comprehensive quiz, drawing on the course material, designed to test understanding of the key concepts presented in each of the eight parts of the "Energy and Environment" course.

---

### Quiz Part 1: Introduction (Generalities on Energy and Environment)

- 1. Which Greek word does the term "energy" come from, and what does it mean?**
  - A. *Dynamis*, meaning movement
  - B. *Ergon*, meaning work
  - C. ***Energia*, meaning "force in action"**
  - D. *Kinesis*, meaning change
  
- 2. The relationship between power and energy is described as being similar to the relationship between:**
  - A. Time and distance
  - B. ***Distance and speed***
  - C. Mass and acceleration
  - D. Voltage and current
  
- 3. Which of the following is *not* a standard unit of measurement for energy mentioned in the sources?**
  - A. The joule (J)
  - B. The ton of oil equivalent (TOE)
  - C. The kilowatt-hour (kWh)
  - D. ***The volt (V)***

4. **In the four energy categories (Primary, Secondary, Final, Useful) derived from nuclear-generated electricity, the electricity produced in the nuclear power plant itself is classified as which type of energy?**
- A. Primary energy
  - B. *Secondary energy*
  - C. Final energy
  - D. Useful energy
5. **The environment consists of all the natural or artificial conditions of terrestrial and marine biodiversity, likely to affect living organisms and human activities, including which non-physical category?**
- A. Economic conditions
  - B. Regulatory conditions
  - C. *Cultural (sociological) conditions*
  - D. Geological conditions
-

## Quiz Part 2: Non-Renewable Energies

- 1. A non-renewable energy resource is defined as one that is destroyed during its use and/or renews how quickly compared to its usage rate?**
  - A. At the same rate
  - B. Faster than the rate of use
  - C. *More slowly than the rate of use***
  - D. It does not renew at all
- 2. The two families of non-renewable energy are:**
  - A. Thermal and Mechanical energy
  - B. Solar and Wind energy
  - C. *Fossil and Fissile energy***
  - D. Chemical and Electrical energy
- 3. Which raw material is a sedimentary rock rich in carbon that powered the Industrial Revolution and is transformed from peat into lignite, bituminous coal, and finally anthracite?**
  - A. Petroleum
  - B. Natural gas
  - C. Uranium
  - D. *Coal***
- 4. The process of atomic fission involves:**
  - A. Light atoms fusing to form a heavier atom
  - B. Converting thermal energy directly to electrical energy
  - C. *Heavy atomic nuclei (like uranium or thorium) breaking apart and releasing binding energy***
  - D. Burning fossil fuels to heat water

5. In a conventional thermal power plant running on coal, gas, or oil, the heat is used to vaporize water, converting thermal energy into what form of energy via the turbine, before generating electricity via the alternator?
- A. Chemical energy
  - B. Electrical energy
  - C. Potential energy
  - D. *Mechanical energy*
-

## Quiz Part 3: Renewable Energies

- 1. Renewable energy sources depend on elements that nature constantly renews. Which of the following is *not* listed as one of these elements?**
  - A. Wind
  - B. Sun
  - C. Earth's heat
  - D. *Uranium*
- 2. Wind energy is considered an indirect form of what?**
  - A. Hydraulic energy
  - B. Geothermal energy
  - C. Chemical energy
  - D. *Solar energy*
- 3. Which type of wind turbine is currently the most widespread worldwide due to its higher efficiency, despite lacking torque when starting up?**
  - A. Savonius vertical axis wind turbines
  - B. Darrieus vertical axis wind turbines
  - C. *Horizontal axis wind turbines*
  - D. Water pumping wind turbines
- 4. The theoretical maximum efficiency for capturing the kinetic energy of the wind using a wind turbine, known as the Betz limit, is approximately:**
  - A. 95%
  - B. 80%
  - C. 52%
  - D. *59.3%* (or 16/27)

5. **Photovoltaic conversion is based on the absorption of photons in a semiconductor material to supply electrical charges. This phenomenon is known as:**

A. The Joule effect

B. The greenhouse effect

C. *The photoelectric effect*

D. The conservation of energy

---

## Quiz Part 4: Energy Storage

1. **What is the main purpose of energy storage in relation to electricity grids?**
  - A. To increase the overall efficiency of energy production
  - B. To reduce the cost of energy transportation
  - C. *To balance electricity demand and production*
  - D. To allow direct storage of electrical energy
2. **Which indirect electricity storage method utilizes two reservoirs at different altitudes and accounted for nearly 99% of the massive energy storage capacity installed worldwide at the end of 2011?**
  - A. Flywheels
  - B. Compressed Air Energy Storage (CAES)
  - C. *Pumped Storage Power Stations (PSPS)*
  - D. Flow batteries
3. **The efficiency of conventional Compressed Air Energy Storage (CAES) is reduced to less than 50% primarily because:**
  - A. The air reservoir is too deep underground
  - B. *The heat from the post-compression gases is lost*
  - C. The turbines are too small
  - D. The salt cavities degrade over time
4. **Which chemical storage technology involves storing electrolytes in separate external reservoirs, can withstand more than 10,000 charge cycles, and has virtually no self-discharge effect?**
  - A. Lead-acid batteries
  - B. Lithium-ion batteries
  - C. *Flow batteries*
  - D. Hydrogen fuel cells

5. **Sensible heat storage is a thermal storage method that works by:**

A. Utilizing phase change materials (PCMs)

B. Converting heat into electrical energy

C. *Raising the temperature of a material (like water, rock, or concrete) to store energy*

D. Using geothermal heat pumps

---

## Quiz Part 5: Consumption, Reserves, and Evolution of Energy Resources

- 1. Global primary energy consumption reached approximately 15,500 million tons of oil equivalent (Mtoe) in 2025, representing a substantial increase of nearly 78% since what year?**
  - A. 2010
  - B. 2005 C. **1990**
  - D. 2020
- 2. Which energy source retained its position as the world's leading energy source in 2024, accounting for about 27% of total global consumption?**
  - A. Natural gas
  - B. Coal
  - C. **Oil**
  - D. Renewables
- 3. In 2024, what was the estimated combined share of renewable energy sources in global consumption?**
  - A. About 2%
  - B. About 10%
  - C. **Nearly 14%**
  - D. Over 25%
- 4. Which fossil fuel overwhelmingly dominated Algeria's energy consumption in 2024, accounting for approximately 64% of the total?**
  - A. Oil B.
  - B. Coal C.
  - C. **Natural gas**
  - D. D. Biomass
- 5. According to 2024 estimates, what percentage of Algeria's total energy consumption was accounted for by renewables (including solar and wind)?**

- A. About 10%
  - B. About 5%
  - C. ***Nearly 2% (1.1 Mtoe)***
  - D. Less than 0.5%
-

## Quiz Part 6: Different Types of Pollution

- Pollution is defined as the introduction into the air, water, or soil of foreign substances or a change in their natural levels, which leads to:**
  - Increased nutrient cycling
  - Enhanced biodiversity
  - Environmental degradation or disruption of the ecosystem*
  - Natural chemical filtration
- Which type of pollution results from the daily activities of human beings (excrement and corpses), industrial activities related to agri-food, and agricultural activities?**
  - Chemical pollution
  - Radioactive pollution
  - Solid waste pollution
  - Organic pollution*
- Which colorless, odorless, non-irritating gas is formed during incomplete combustion (55% from motor vehicles) and is toxic because it inhibits the transport of oxygen in the blood?**
  - Nitrogen dioxide (NO<sub>2</sub>)
  - Sulfur Dioxide (SO<sub>2</sub>)
  - Carbon monoxide (CO)*
  - Tropospheric ozone (O<sub>3</sub>)
- Tropospheric ozone (O<sub>3</sub>) is a secondary pollutant formed when sunlight acts on which two primary pollutants in a photochemical process?**
  - Carbon dioxide (CO<sub>2</sub>) and Methane (CH<sub>4</sub>)
  - Sulfur dioxide (SO<sub>2</sub>) and Ammonia (NH<sub>3</sub>)
  - Nitrogen oxides (NO<sub>x</sub>) and volatile organic compounds (VOCs)*
  - Lead (Pb) and PM<sub>10</sub> particles

5. **What is the term for pollutants that are discharged in a specific location, such as sewers, factories, or oil tankers, making them identifiable?**
- A. Diffuse pollution
  - B. Chronic pollutants
  - C. Non-localized sources
  - D. *Localized sources*
-

## Quiz Part 7: Detection and Treatment of Pollutants and Waste

1. **According to the 1992 Brundtland Report, sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." What concept is central to this principle?**
  - A. Waste minimization
  - B. Technological innovation
  - C. *Economic consideration*
  - D. Zero population growth
2. **The economic model of "Degrowth," originated by Meadows' 1972 report "The Limits to Growth," proposes that the solution to preventing the depletion of natural resources is:**
  - A. Increased industrial production
  - B. *Economic degrowth (or zero growth)*
  - C. Rapid technological development
  - D. Exclusive reliance on renewable energy
3. **Which organisms are used as bioindicators to detect nitrate-rich waters?**
  - A. Snails
  - B. Bees
  - C. *Nitrophiles (plants)*
  - D. Clover
4. **What is the ideal solution for waste disposal, which involves transforming material or organic waste into a valuable tangible object or energy?**
  - A. Landfill disposal
  - B. Incineration without energy recovery
  - C. Waste collection

D. *Waste recovery*

5. **What category of hazardous and toxic waste includes oils used for engines, compressors, turbines, greasing, and cooling, which require special treatment for regeneration or recycling as fuel?**

A. Polychlorinated biphenyls (PCBs)

B. Phytosanitary waste

C. *Used oils*

D. Inert waste

---

## Quiz Part 8: Impact of Pollution on Health and the Environment

- 1. In 2012, how many premature deaths worldwide were estimated by the World Health Organization (WHO) to be caused by air pollution?**
  - A. 1.8 million
  - B. 3.7 million**
  - C. 6,000 per day
  - D. 134,000 per year
- 2. What is one of the ways air pollution aggravates pollen allergies?**
  - A. It increases the natural production of pollen by plants
  - B. It prevents the immune system from identifying the allergen
  - C. Pollen in polluted regions becomes covered with pollutant particles, increasing its allergenic effect**
  - D. It reduces humidity, making respiratory tracts more susceptible
- 3. The International Agency for Research on Cancer (IARC) classified which environmental factor as one of the leading causes of cancer deaths in 2013?**
  - A. Soil pollution
  - B. Exposure to metals
  - C. Air pollution**
  - D. Waterborne diseases
- 4. Which waterborne disease is transmitted by organisms that spend the early part of their lives in water (like worms or mosquitoes) and then spread as parasites, significantly reducing physical capacity?**
  - A. Cholera
  - B. Typhoid
  - C. Hepatitis A**

D. *Schistosomiasis (bilharzia)*

5. **High concentrations of tropospheric ozone (O<sub>3</sub>) negatively impact the environment by contributing to:**

A. Global warming

B. Stratospheric ozone destruction

C. *Environmental acidification*

D. Metal corrosion

## References

1. Miller, Jr., G. T., *Living in the Environment*, Seventh Edition, Wadsworth Publishing Company, 1992.
2. Kerr, R. A. (2019). *Introduction to Energy and Climate: Developing a Sustainable Environment*. Boca Raton, FL: CRC Press.
3. Tester, J. W., Drake, E. M., Driscoll, M. J., Golay, M. W., & Peters, W. A. (2012). *Sustainable Energy: Choosing Among Options* (2nd ed.). Cambridge, MA: MIT Press.
4. Celik, S. (2023). *Sustainable Energy*. Cambridge, UK: Cambridge University Press.
5. Manoylov, K., Rick VandeVoort, A., Mutiti, C., Mutiti, S., & Bennett, D. (2017). *Introduction to Environmental Science* (2nd ed.). Milledgeville, GA: University System of Georgia.
6. Withgott, J., & Laposata, M. (2020). *Environment: The Science Behind the Stories* (7th ed.). Boston, MA: Pearson.
7. Jones, C., & Mayfield, S. (2011). *Our Energy Future: Introduction to Renewable Energy and Biofuels*. Berkeley, CA: University of California Press.
8. Wolfson, R. (2023). *Energy, Environment, and Climate* (4th ed.). New York, NY: W. W. Norton & Company.
9. Manoylov, K., VandeVoort, A. R., Mutiti, C., Mutiti, S., & Bennett, D. (2024). *Introduction to Environmental Science* (2nd ed.). Minneapolis, MN: University of Minnesota Libraries Publishing.
10. Mulvaney, D. (2021). *Sustainable Energy Transitions*. New York, NY: Palgrave Macmillan.
11. Celik, S. (2023). *Sustainable Energy*. Cambridge, UK: Cambridge University Press.
12. IOZONE International. (2023). *Earth's Systems and Global Change* (Environmental Science series). Auckland, New Zealand: BIOZONE International.