People's Democratic Republic of Algeria

Ministry of Higher Education and Scientific Research

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Course Handout

ENERGIES AND ENVIRONMENT

Course Intended for L3 Electrotechnics,

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This course will be divided into six chapters, structured as follows:

I. General information

Energy & Environment — what is it exactly?

Energy and environment are inseparable: every energy system (extraction, conversion, transport, and use) interacts with natural systems. Understanding these interactions requires both physical concepts (how energy is stored, transferred, and transformed) and environmental concepts (how pollutants move through air, water, and soil, and how ecosystems and health respond).

In this course, we study (i) what energy is, its forms and units, (ii) major energy resources and technologies, and (iii) environmental impacts and mitigation strategies, from local pollution to global climate change.

1. What is energy?

1.1. Definitions

Several definitions can be attributed to the term "energy", depending on the field and/or the study context. Commonly, energy is described as the ability to produce change. It can be transferred between systems and converted between forms, but (in closed systems) it is not created or destroyed.

- Energy is everything that makes it possible to act: without it, nothing happens—no motion, no light, no life.
- Energy characterizes the ability to change a state, produce work, or generate heat, light, or electricity.
- Many natural phenomena exist only due to energy: plant growth, wind, river currents, waves, falling objects, …
- In technology and economics, "energy" also refers to resources and their use (consumption, development, depletion, ecological impact).

Key idea: Energy chain

Primary energy → Secondary energy → Final energy → Useful energy.

Example:

crude oil (primary) → gasoline (secondary) → fuel at the pump (final) → vehicle motion (useful).

1.2. Characteristics of energy

1.2.1. Primary energy

Primary energies are those found in nature in their raw state. They are the starting point of the energy chain, before human conversion or processing.

- Muscle energy (from food).
- Hydraulic energy (moving water).
- Wind energy.
- Energy from fuels (oil, natural gas, coal, biomass …).

Static electricity and lightning are not considered exploitable primary energies at industrial scale because they are not controllable or harvestable in a reliable way.

On an industrial scale, primary energies are divided into renewable and non-renewable categories:

- Renewable energies (sun, water, wind, …).
- Nonrenewable energies (fossil fuels: oil, coal, gas; and nuclear energy).

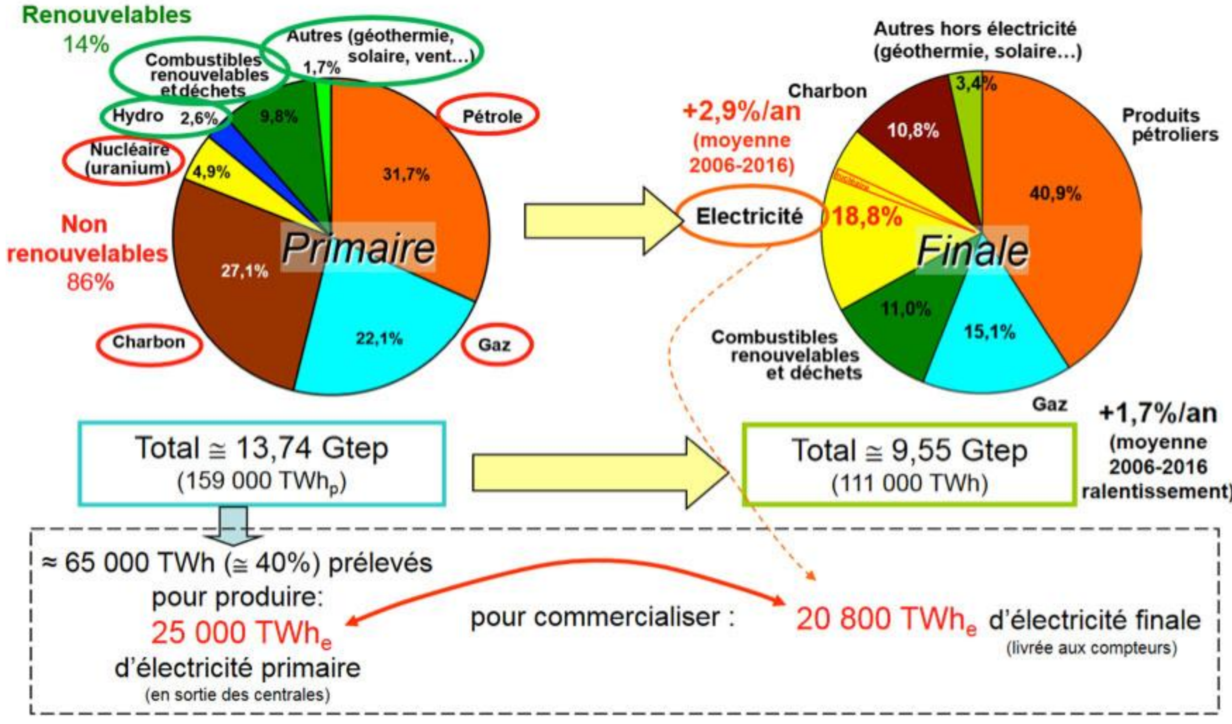

Fig. 1 : Global overview 2016 of primary resource consumption to final distributed energy, including the share of electricity – Source: IEA (2018). Key World Energy Statistics 2018.

A useful way to interpret such figures is to distinguish (i) the dominance of fossil fuels historically, (ii) the role of nuclear and hydropower as low-carbon sources, and (iii) the growth potential of modern renewables (wind, solar) depending on policy, investment, and grid integration.

1.2.2. Secondary energy

Secondary energies result from transformations performed by humans on primary energies. Conversion improves usability, transportability or controllability.

- Electricity (from gas, coal, hydro, wind or sun).
- Refined fuels (gasoline, diesel, kerosene).
- District heat or steam (from boilers, CHP).

Secondary energy becomes final energy delivered to users (electricity at the socket, fuel at the station). The "useful" energy is what finally performs the intended service: illumination, heat for comfort, mechanical work in machines.

1.2.3. Amount of energy

The amount of energy stored in a system depends on variables such as mass, position and velocity. This introduces the central idea of state variables: the energy content changes when the system changes state.

- Compressed spring: stored energy increases with deformation.
- Elevated mass: gravitational potential energy increases with height.
- Moving object: kinetic energy increases with the square of velocity.

In engineering, these relationships are used to size devices (springs, dams, flywheels) and to estimate performance and safety limits.

1.2.4. Energy transfer and transformation

Energy is often invisible in storage, but visible through its effects (light, motion, heat). A key property is that energy transfers between bodies or systems by mechanisms such as work, heat, radiation, or electrical transfer. When we say "energy production", we generally mean conversion from one form to another (e.g., chemical → thermal → electrical).

A practical method is to draw an energy balance: identify inputs, outputs, and losses. Losses are not "lost energy" in physics; they are energy transferred to the environment (often as low-temperature heat) where it is less useful.

1.2.5. Units of energy

Energy is a measurable quantity. The SI unit is the joule (J). In real systems, other units are used for convenience in specific sectors.

- 1 J = 1 N·m (work of a 1-newton force over 1 meter).

- Multiples: 1 kJ = 10^3 J, 1 MJ = 10^6 J, 1 GJ = 10^9 J.

Common alternative units:

- 1 kWh = 3.6×10^6 J (electricity billing).
- 1 BTU ≈ 1055 J (historical, heating).
- 1 toe (tonne of oil equivalent) for energy balances; 1 ktoe = 10^3 toe, 1 Mtoe = 10^6 toe.

Power vs Energy

Energy (kWh, J) = “how much” is used or stored.

Power (kW, W) = “how fast” energy is transferred or converted.

Example: a 2 kW heater running for 3 hours uses 6 kWh.

1.3. Forms of energy

Two broad ways energy crosses a system boundary are work (W) and heat (Q). Work is an ordered energy transfer (e.g., shaft turning), while heat is a disordered transfer driven by temperature difference.

- Mechanical/kinetic energy (motion).
- Potential energy (position, elastic).
- Chemical energy (bonds).
- Thermal energy (internal motion of particles).
- Electrical and electromagnetic energy (fields, charges).
- Nuclear energy (binding energy).

1.3.1. Mechanical energy

Mechanical energy is the sum of kinetic and potential energy: E_mechanical = E_kinetic + E_potential. In hydropower and wind power, nature provides kinetic energy that is captured by turbines and converted to electricity.

Examples of conversions: water flow → turbine rotation → generator → electricity; wind → rotor → generator. Each step has an efficiency below 100%, so system design aims to reduce losses.

1.3.2. Thermal (calorific) energy

Thermal energy is associated with the random motion of molecules. It is central in combustion and power plants. Because of thermodynamic limits, converting heat to work cannot reach 100% efficiency; some heat must be rejected to a colder sink (cooling water/air).

This is why combined heat and power (CHP) can be more efficient: it uses the “waste” heat for heating, improving overall useful energy output.

1.3.3. Chemical energy

Chemical energy is stored in molecular bonds. Combustion is an exothermic reaction that releases chemical energy as heat. Batteries convert chemical energy directly into electrical energy through electrochemical reactions, often with high efficiency at the point of use.

1.3.4. Radiant energy

Radiant energy travels as electromagnetic waves. Solar energy can be harvested as electricity (photovoltaic) or as heat (solar thermal). Understanding the difference helps choose the right technology: PV is flexible and modular; solar thermal can be advantageous for hot water and industrial heat.

1.3.5. Nuclear energy

Nuclear energy is stored in the atomic nucleus. Fission in reactors releases heat, which is then converted into electricity via steam cycles. Nuclear’s high energy density reduces fuel volume, but introduces special requirements for safety, waste management, and governance.

1.3.6. Electrical energy

Electrical energy is transferred via electric current and voltage. It is highly versatile, enabling lighting, electronics, and motors with high efficiency. Because electricity is difficult to store at large scale without conversion (batteries, pumped hydro, hydrogen), modern energy systems must balance production and consumption in real time.

2. What is the environment?

2.1. Definitions

The environment can be defined as the set of biotic (living) and abiotic (non-living) elements surrounding organisms, including humans, and the interactions among them. Environmental quality includes objective factors (air and water quality, noise) and subjective factors (landscape quality).

- Environment = elements surrounding an individual/species, some meeting its needs.
- Environment = natural (physical, chemical, biological) and cultural (sociological) conditions.
- Environment = objective elements (air quality, noise) and subjective elements (site/landscape quality).
- Environment = neighbors of living beings and their direct/indirect interactions.
- Environment = global ecological context including air, land, water, resources, flora, fauna, humans and social interactions.

2.2. Environmental sciences

Environmental sciences integrate ecology, chemistry, physics, geology, and public health. Modern monitoring tools and models help quantify human impacts (emissions, exposure) and support mitigation policies (regulation, cleaner technologies).

Environmental challenges scale from local (waste, noise) to global (ozone depletion, climate change). Systems thinking is therefore essential: local actions can have distant effects through atmospheric circulation, rivers, supply chains, and economic feedbacks.

2.3. Environmental management

Environmental management aims to identify impacts, comply with regulations, and continuously improve performance. It often uses the management cycle: plan → do → check → act.

- Identify needs and constraints of studied systems.
- Seek new solutions for daily environmental management.
- Identify environmental aspects and impacts of activities.
- Analyze legal requirements.
- Implement management systems to reduce impacts.

Typical environmental compartments

Air (gases, aerosols)

Water (surface/groundwater)

Soil (contamination, fertility)

Noise

Waste streams

CHAPTER I

DIFFERENT ENERGY RESOURCES

1. Introduction

Industrial societies require large and reliable energy flows for transport, housing, industry and services. Historically, fossil fuels have dominated because they are energy-dense, relatively easy to transport, and usable in many technologies. However, they create environmental pressures: greenhouse gases, air pollutants, and ecological disruption from extraction and transport.

The transition toward renewables seeks to reduce emissions and resource depletion. This transition also raises technical questions (intermittency, storage), economic questions (costs, markets), and social questions (jobs, land use, acceptability).

2. Nonrenewable energy resources

2.1 Oil

Oil is a naturally occurring liquid mixture of hydrocarbons. It formed over geological time from organic matter buried in sedimentary environments. Oil is refined into fuels (gasoline, diesel, kerosene) and petrochemical feedstocks.

Key steps in the oil chain

- ✓ Exploration and drilling (onshore/offshore).
- ✓ Extraction and separation (oil, gas, water).
- ✓ Transport (pipelines, tankers).
- ✓ Refining (distillation, cracking, reforming).
- ✓ End use (transport fuels, chemicals).

Environmental risks include spills, methane leakage from associated gas systems, and air pollutants from refining and combustion. Energy policy often focuses on improving efficiency and reducing emissions in transport, the main oil-consuming sector.

2.2 Coal

Coal is an organic fossil fuel rich in carbon. It exists in several ranks (lignite, sub-bituminous, bituminous, anthracite) reflecting carbon content and energy density. Coal combustion is a major source of CO_2 and can emit particulate matter, sulfur oxides, nitrogen oxides, and trace metals, depending on coal composition and pollution controls.

Why coal remains used

- Large proven reserves in many regions.
- Historically low fuel cost.
- Dispatchable power generation (not weather-dependent).

Modern approaches include pollution control (desulfurization, filters), efficiency improvement (supercritical boilers), and in some contexts carbon capture and storage (CCS), though each has costs and technical constraints.

2.3 Natural gas

Natural gas is mainly methane with other hydrocarbons. It burns more cleanly than coal at the point of combustion (less SO_2 and particulates), but methane leakage across extraction and transport can reduce climate advantages because methane is a potent greenhouse gas. Gas is used for heating, electricity generation, and as industrial feedstock (e.g., ammonia production).

Gas types

- Conventional non-associated gas.
- Associated gas (with oil).
- Biogenic gas.
- Coalbed methane.
- Shale gas.

From a systems perspective, gas can support variable renewables by providing flexible generation, but long-term decarbonization requires reducing emissions and considering alternative low-carbon flexibility (storage, demand response).

2.4 Nuclear energy

Nuclear fission splits heavy nuclei (e.g., uranium-235) after neutron absorption, releasing heat and more neutrons. Reactors control the chain reaction using moderators, control rods, and engineered cooling systems.

Fuel cycle overview

- Mining and milling of uranium.
- Conversion and enrichment.
- Fuel fabrication.
- Reactor operation and electricity generation.
- Spent fuel management: storage, reprocessing (in some countries), disposal.

Nuclear energy offers high energy density and low operational CO_2 emissions, but requires strong governance for safety, radioactive waste, and non-proliferation. Decisions depend on national context, regulation, and societal acceptance.

3. Renewable energy resources

Why exploit renewable energies?

- They reduce greenhouse gas emissions by replacing fossil combustion.
- They promote local resource use and can create jobs in installation, operation, and maintenance.
- They diversify supply and can improve energy security.

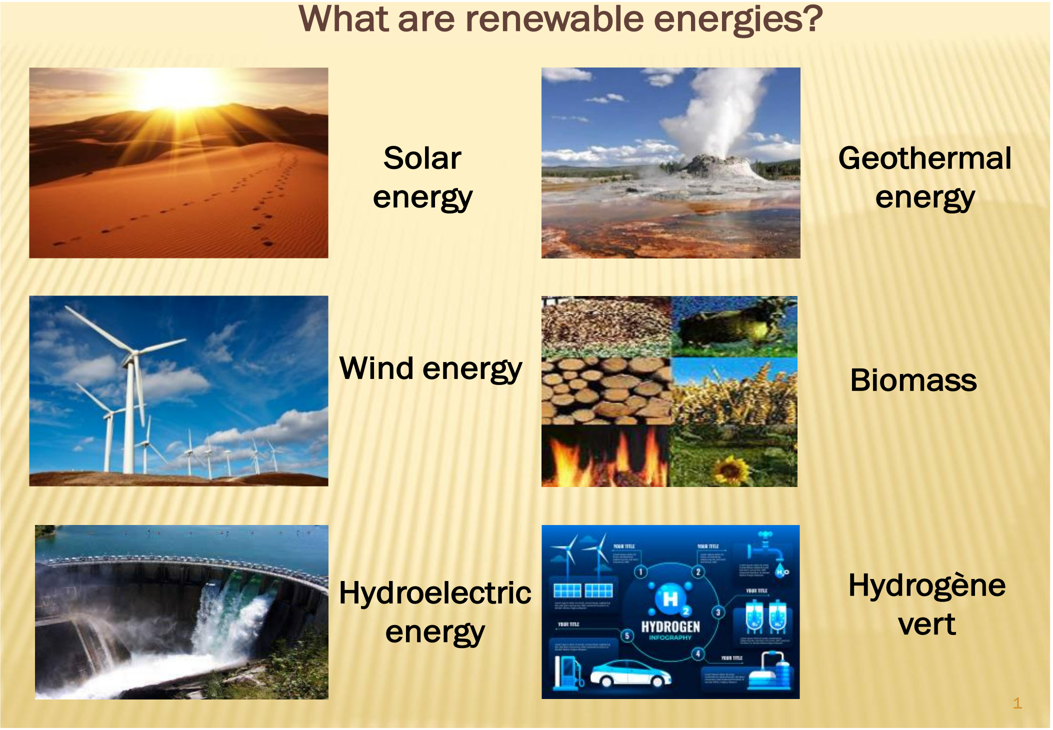

Fig 2. The different forms of renewable energies

3.1 Solar energy

Solar photovoltaic (PV)

PV converts light directly into electricity using semiconductor junctions. Output depends on irradiance, temperature (efficiency decreases as temperature rises), and system losses (inverters, wiring, shading).

Solar thermal

Solar thermal collectors capture sunlight as heat. Low-temperature systems provide domestic hot water; higher-temperature systems can support industrial heat or power generation in concentrated solar power (CSP) plants with thermal storage.

PV vs Solar thermal

PV: electricity, modular, easy to install.

Thermal: heat directly, often higher efficiency for hot water/space heating.

3.2 Wind energy

Wind turbines convert kinetic energy from airflow into electricity. Power increases rapidly with wind speed (approximately proportional to the cube of speed), making site selection crucial. Modern wind farms use power electronics and control to integrate with grids and manage variability.

3.3 Hydropower

Hydropower converts potential and kinetic energy of water into electricity. It can provide both energy and grid services (frequency control, reserves). Large dams have ecological and social impacts (river ecosystems, sediment transport, displacement), so impact assessment and mitigation are important.

3.4 Marine energy

Marine energy includes tidal range, tidal stream, wave energy, and ocean thermal energy conversion. These technologies are site-specific and often at earlier stages of deployment compared with wind and solar.

3.5 Geothermal energy

Geothermal uses heat from the Earth. Shallow systems (heat pumps) exploit stable ground temperature for heating/cooling. Deep geothermal can provide district heating or electricity where geological conditions allow.

3.6 Biomass

Biomass is organic material used for energy. It can be burned directly, converted into biogas via anaerobic digestion, or transformed into biofuels. Sustainability depends on land use, harvesting practices, and competing demands (food, ecosystems).

Comparative discussion: Choosing an energy mix

No single energy source is perfect. Decision-makers balance criteria such as reliability, cost, emissions, land use, resource availability, and social acceptance. For example, solar and wind are low-carbon but variable; hydropower is dispatchable but site-limited; nuclear is low-carbon and dispatchable but requires long-term waste management.

Common evaluation criteria

- Carbon intensity
- Local air pollution
- Water use
- Land footprint
- Resource depletion
- Dispatchability (controllability)
- Investment and operating costs
- Safety and societal acceptance

CHAPTER II

ENERGY STORAGE

1. Introduction

Energy storage enables energy systems to decouple supply and demand in time. This is especially important when integrating variable renewable energy (solar and wind), managing peak demand, ensuring reliability for isolated systems, and improving power quality in electrical grids.

Energy storage is the placement of a quantity of energy in a given location for later use. This is necessary for the efficient utilization of alternative, safe, and renewable but intermittent energies (wind and solar). In order to stabilize energy grids and smooth out production/ consumption irregularities in the context of renewable energy development, and to supply energy to island or isolated sites, the storage of heat or electrical energy is practically essential.

With the future and the planet in mind, humanity must draw its energy from sources other than oil. But this necessary transition to renewable sources, which is currently the subject of national debate, will only happen under one condition: the ability to store energy. Indeed, while it is now more or less simple to produce electricity, heat and even hydrogen, storing these three energy carriers sustainably remains a real scientific and technological challenge.

2.1. Why storage is needed

- Short-term balancing: seconds to minutes (frequency control).
- Daily shifting: store midday solar for evening demand.
- Backup and resilience: maintain supply during outages.
- Mobility: store energy onboard vehicles (batteries, fuels).

2.2. Key performance indicators (KPIs)

Storage technologies are compared using a small set of metrics:

- Energy capacity (kWh, MWh): how much energy can be stored.
- Power rating (kW, MW): how fast energy can be delivered or absorbed.
- Round-trip efficiency (%): delivered energy divided by stored energy.

- Response time: how quickly the system reacts (ms to hours).
- Cycle life and calendar life: durability over use and time.
- Self-discharge and standby losses: energy lost when idle.
- Safety and environmental impacts: materials, fire risk, end-of-life.

2.3. Mechanical storage

2.3.1. Pumped hydro storage (PHS)

Pumped hydro stores energy by pumping water to an upper reservoir when electricity is abundant, then releasing it through turbines when needed. It is the most mature large-scale storage technology and can provide multi-hour to multi-day storage where geography permits.

2.3.2. Compressed air energy storage (CAES)

CAES stores energy by compressing air into underground caverns or tanks. Later, the air is expanded through turbines to generate electricity. Advanced designs aim to store compression heat (adiabatic CAES) to increase efficiency.

Flywheels

Flywheels store kinetic energy in a rotating mass. They are well suited for fast response and high cycling (frequency regulation), but typically have limited energy capacity (minutes).

2.4. Electrochemical storage (batteries)

Batteries store energy in chemical form and deliver electricity through electrochemical reactions. They are used in portable electronics, electric vehicles, and grid storage.

Main battery families (overview)

- Lead-acid: mature, low cost, heavy; used in vehicles and backup.
- Lithium-ion: high energy density and efficiency; dominant in EVs and many storage applications.

- Sodium-based (NaS, Na-ion): promising for stationary storage in some contexts.
- Flow batteries (vanadium, Zn-Br): scalable energy capacity; suited for long-duration stationary storage.

Operational considerations

Battery systems require management electronics (BMS) to control temperature, state of charge, and safety limits. For grid applications, power electronics (inverters) are also critical for providing reactive power and grid-support services.

2.5. Thermal storage

2.5.1. Sensible heat storage

Sensible thermal storage increases the temperature of a material (water, molten salts, rocks). It is simple and widely used in hot-water tanks and some industrial applications.

2.5.2. Latent heat storage (phase-change materials)

Latent storage uses phase change (solid↔liquid) to store heat at nearly constant temperature. It can improve compactness and match specific temperature levels needed for buildings or processes.

2.5.3. Thermochemical storage

Thermochemical storage stores energy in reversible chemical reactions, potentially enabling long-duration storage with low losses, but it is generally less mature.

2.6. Chemical storage: hydrogen and e-fuels

Electricity can be converted to hydrogen via electrolysis. Hydrogen can be stored and later used in fuel cells, burned for heat, or converted into ammonia or synthetic hydrocarbons. Chemical storage can provide seasonal storage, but requires infrastructure and careful handling.

2.7. Storage applications and system design

Selecting storage depends on application duration, required response time, scale, and cost. A typical approach is to combine multiple storage types: fast batteries for seconds/minutes plus longer-duration storage (pumped hydro, hydrogen, thermal) for hours/days.

Rule of thumb (conceptual)

Short duration (seconds–minutes): flywheels, supercapacitors, batteries.

Medium (hours): batteries, pumped hydro, thermal tanks.

Long (days–seasonal): pumped hydro (where possible), hydrogen/e-fuels, large thermal/thermochemical.

CHAPTER III

CONSUMPTION, RESERVES AND TRENDS OF ENERGY RESOURCES

1. Introduction

Energy systems evolve with population, economic activity, technology and policy. Understanding consumption patterns and resource availability helps anticipate constraints and design sustainable strategies.

2. Energy demand: where and why energy is used

End-use demand is usually grouped into sectors: buildings (heating/cooling, appliances), industry (process heat, motors), transport (road, air, maritime), and services/agriculture. Demand depends on activity levels (e.g., km traveled, tonnes produced) and efficiency (energy per unit service).

Drivers of demand

- Population growth and urbanization.
- Economic growth and industrial structure.
- Technology efficiency (vehicles, motors, insulation).
- Lifestyle and behavior (comfort, mobility).
- Energy prices and policy (subsidies, standards).

3. Reserves vs resources (critical distinction)

A resource is the total amount of a material that exists and could potentially be used. A reserve is the portion that is economically and technically recoverable under current conditions. Reserves can increase with higher prices, better technology, or new discoveries; they can decrease with extraction and stricter environmental constraints.

Reserve terminology (simplified)

Proved reserves: high confidence, economically recoverable today.

Probable/possible: additional quantities with lower confidence.

Resources: broader geological occurrence, may not be recoverable.

4. Energy intensity and efficiency

Energy intensity measures energy use per unit of economic output (e.g., MJ per GDP). Economies often reduce energy intensity over time through improved efficiency and a shift from heavy industry to services. However, total energy can still grow if economic activity expands faster than efficiency improves.

5. Typical trends in the energy transition

Across many countries, three macro-trends are common: electrification of end uses (vehicles, heat pumps), growth of variable renewables (wind/solar), and digital control of grids and demand. These trends increase the importance of flexibility: storage, demand response, grid interconnections, and dispatchable low-carbon generation.

6. Environmental constraints and carbon budgets (conceptual)

Climate policy introduces a constraint on cumulative greenhouse gas emissions. This encourages decarbonization strategies: energy efficiency, renewable deployment, low-carbon electricity, electrification, and in some cases carbon capture. Local air-quality rules also influence technology choices (e.g., low-sulfur fuels, particulate filters).

7. Simple scenario thinking (qualitative)

Rather than a single forecast, planners often consider scenarios: for example, (i) business-as-usual, (ii) accelerated renewables, (iii) high electrification with strong storage, or (iv) mixed strategies including nuclear and CCS. The goal is to test robustness under uncertainty (fuel prices, technology costs, climate policy).

8. Energy security

Energy security concerns the reliability and affordability of supply. It includes diversity of sources, resilience of infrastructure, and management of geopolitical risks in fuel import chains. Renewables can improve security by using domestic resources, while critical materials for technologies (battery minerals) create new supply-chain considerations.

CHAPTER IV

DIFFERENT TYPES OF POLLUTION

1. Carbon dioxide (CO_2) and climate change

CO_2 is essential for photosynthesis and life, but its rising concentration in the atmosphere contributes to climate change. Major sources include fossil fuel combustion, cement production, and land-use change. In many countries, transport is a major CO_2 contributor.

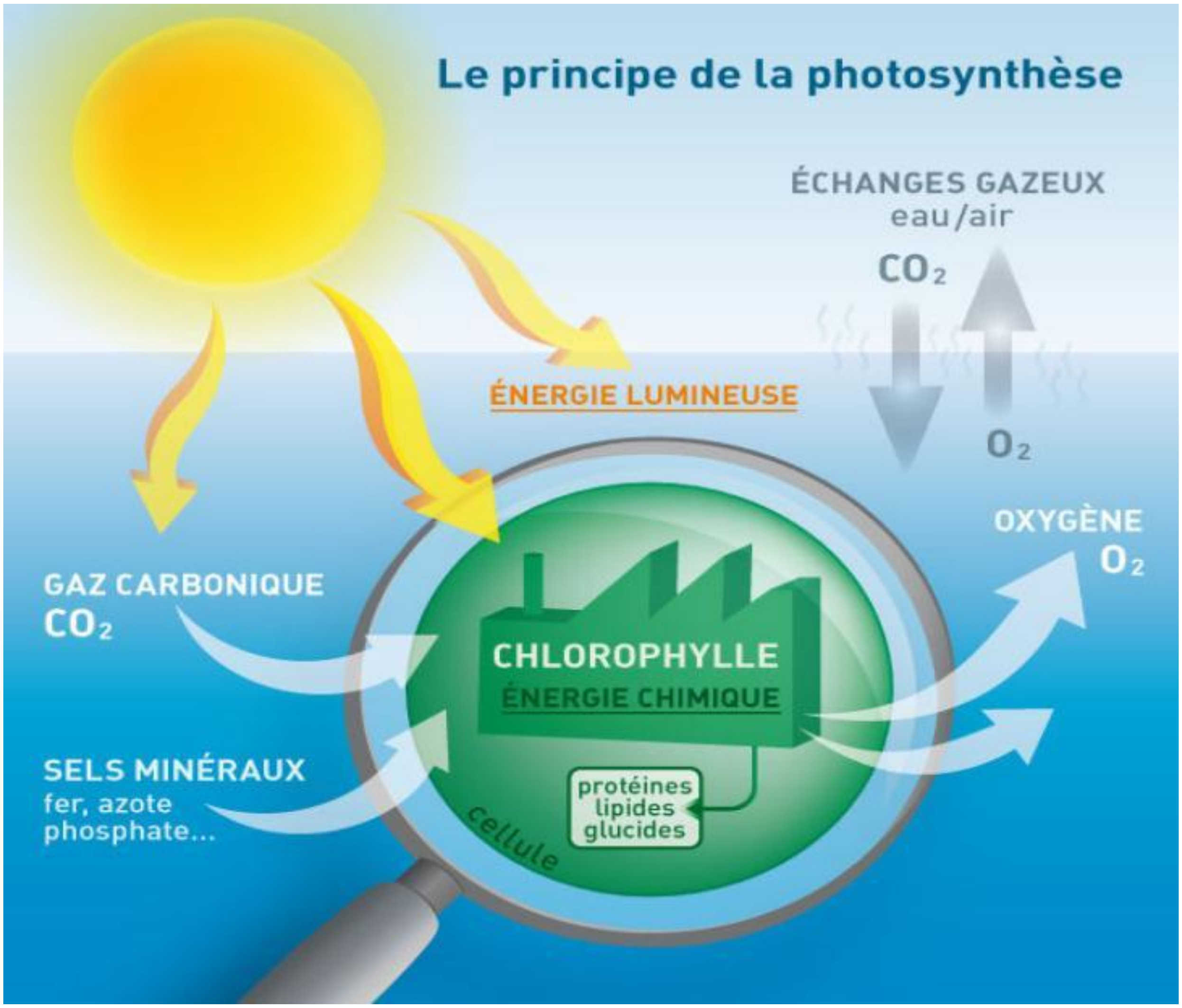

Fig. 1 : Photosynthesis effect.

Greenhouse effect (mechanism)

Solar radiation warms the Earth's surface; the surface emits infrared radiation. Greenhouse gases absorb part of this infrared radiation and re-emit it, warming the lower atmosphere. This natural effect makes Earth habitable; the problem arises when greenhouse gas concentrations increase, enhancing warming.

CO_2 is responsible for a significant share of the enhanced greenhouse effect, alongside water vapor, methane (CH_4), and nitrous oxide (N_2O). Consequences include global temperature increase, sea-level rise, and altered precipitation patterns.

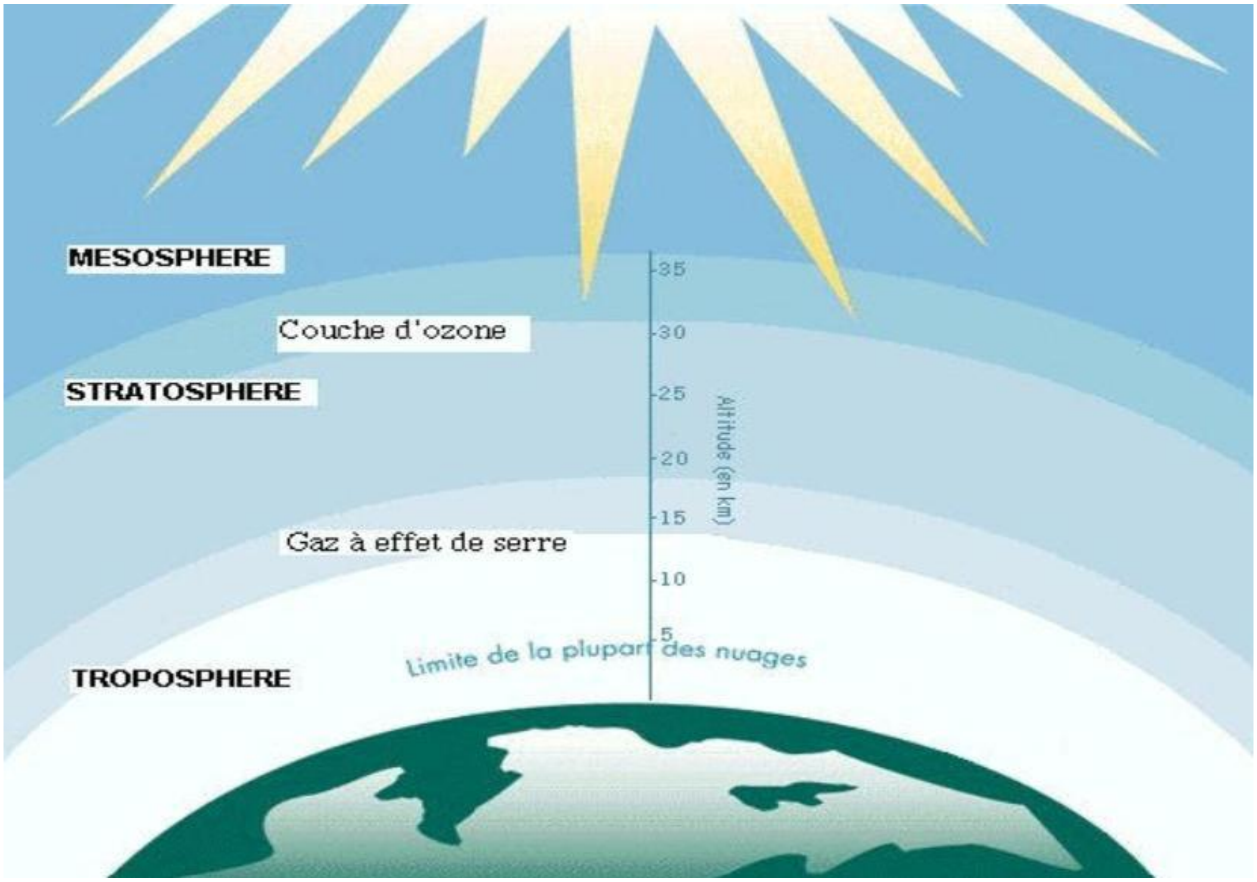

Fig. 2 : Atmospheric layers.

2. Greenhouse effect vs ozone layer depletion

These are distinct phenomena occurring in different atmospheric layers. Ozone depletion occurs mainly in the stratosphere and increases UV radiation at the surface, while greenhouse warming is driven by gases in the lower atmosphere that trap infrared heat.

Gases involved

- Greenhouse: H_2O vapor, CO_2, CH_4, N_2O, tropospheric ozone, CFCs.
- Ozone depletion: CFCs, halons, some chlorinated solvents.

Fig. 3 : Greenhouse effect.

Fig. 4 : Ozone hole.

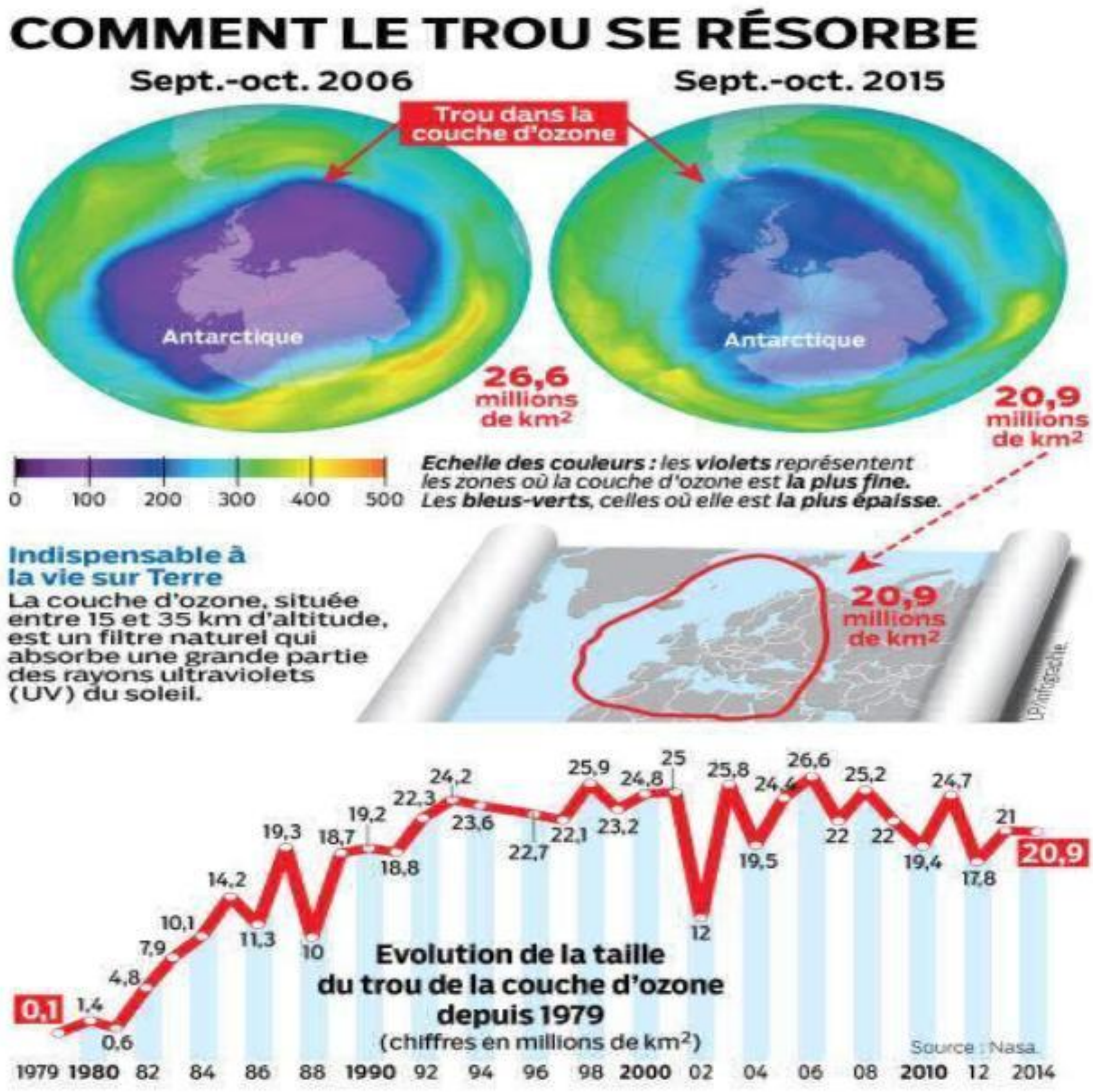

Fig. 5 : Ozone hole size evolution.

3. Tropospheric ozone and photochemical smog

Tropospheric ozone is a secondary pollutant formed from nitrogen oxides (NOx) and volatile organic compounds (VOCs) under sunlight. It can irritate the respiratory system and also contributes to greenhouse forcing.

4. Hydrocarbons and VOCs

Hydrocarbons include methane and many VOCs. VOCs originate from fuel evaporation, solvents, incomplete combustion, and industrial processes. They participate in photochemical smog formation and some are toxic (e.g., benzene).

5. Nitrogen oxides (NOx)

NOx are produced by high-temperature combustion (vehicles, thermal power plants) and also by natural processes (lightning). They are direct irritants and contribute to secondary pollution (ozone formation and acid rain). N_2O is a greenhouse gas.

6. Sulfur oxides (SOx) and acid rain

SO_2 and SO_3 originate from sulfur in fuels and some industrial processes, as well as volcanoes. They irritate lungs and contribute to formation of acid rain when converted into sulfuric acid in the atmosphere.

Acid rain damages forests and aquatic ecosystems and accelerates degradation of buildings and monuments. Control strategies include low-sulfur fuels, flue-gas desulfurization, and industrial emission regulation.

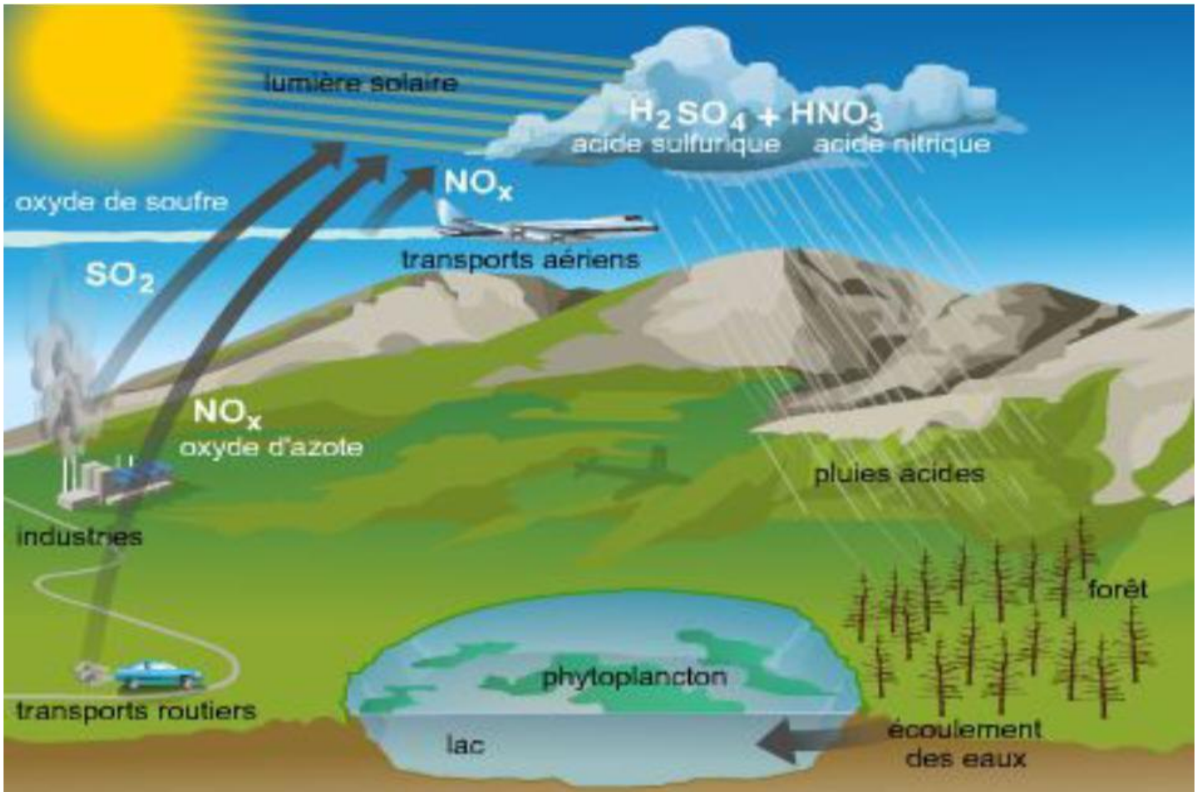

Fig. 6 : Origin of acid rain.

Fig. 7 : Consequences of acid rain.

7. Particulate matter (PM) — added section

Particulate matter (PM10 and PM2.5) consists of fine solid or liquid particles suspended in air. Sources include diesel engines, biomass burning, coal combustion, industrial dust, and secondary formation from gases (SO_2, NOx, ammonia). PM2.5 penetrates deep into lungs and is linked to cardiovascular and respiratory impacts.

8. Indoor air pollution — added section

Indoor pollution can be significant because people spend much time indoors. Sources include cooking, heating, tobacco smoke, building materials (formaldehyde), and poor ventilation. Mitigation includes clean stoves, ventilation, and careful material selection.

CHAPTER V

DETECTION AND TREATMENT OF POLLUTANTS AND WASTE

1. Introduction

Waste and pollution management aims to prevent harm, recover value, and protect ecosystems and health. Modern management prioritizes prevention at the source, then reuse and recycling, and finally safe treatment and disposal of residuals.

2. Measuring and detecting pollutants — added section

Effective management begins with measurement. Monitoring can be continuous (fixed stations) or campaign-based (sampling).

Air

- Gases: CO_2, NOx, SO_2 measured by analyzers.
- Particles: PM mass and composition.
- Meteorology: wind, temperature for dispersion analysis.

Water

- pH, conductivity, dissolved oxygen, turbidity.
- Chemical pollutants: nitrates, heavy metals, hydrocarbons.
- Biological indicators: bacteria, algae.

Soil

- Sampling and laboratory analysis for metals, hydrocarbons, persistent chemicals.
- Risk depends on land use and exposure pathways.

3. Waste definition and classification

Legal and functional definitions guide responsibility and treatment choices. Wastes are often classified by origin (urban, industrial, agricultural) and hazard level (inert, non-hazardous, hazardous/special).

4. Treatment pathways and the waste hierarchy — added section

- Prevention (avoid generation).
- Reuse (use again without major processing).
- Recycling (material recovery).
- Energy recovery (thermal valorization).
- Disposal (landfill, secure storage).

5. Internal vs external treatment

Internal treatment reduces transport but requires expertise and investment. External treatment uses specialized centers with permits and controls. The best choice depends on waste quantity, hazard, local regulations, and available infrastructure.

6. Key treatment technologies — added section

Physical treatments

- ❖ Filtration and separation (screens, membranes).
- ❖ Sedimentation and flotation for water treatment.
- ❖ Adsorption on activated carbon for organics.

Chemical treatments

- ❖ Neutralization (acids/bases).
- ❖ Oxidation/reduction (e.g., advanced oxidation).
- ❖ Precipitation of metals.

Thermal treatments

- ❖ Incineration with flue gas cleaning.
- ❖ Pyrolysis/gasification for some wastes.
- ❖ Cement kiln co-processing in some cases.

Biological treatments

- Composting of organic waste.
- Anaerobic digestion producing biogas.
- Bioremediation for contaminated soils (where applicable).

7. Functional view and life cycle

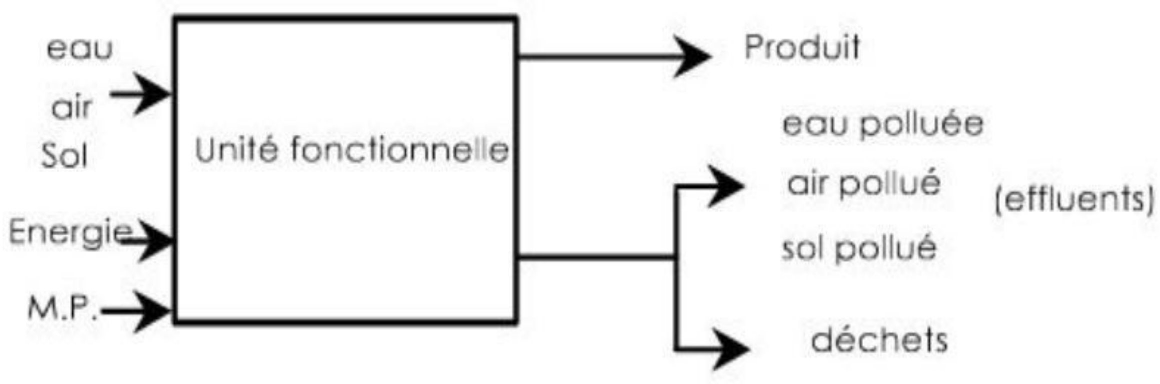

Fig. 8: Functional definition of waste.

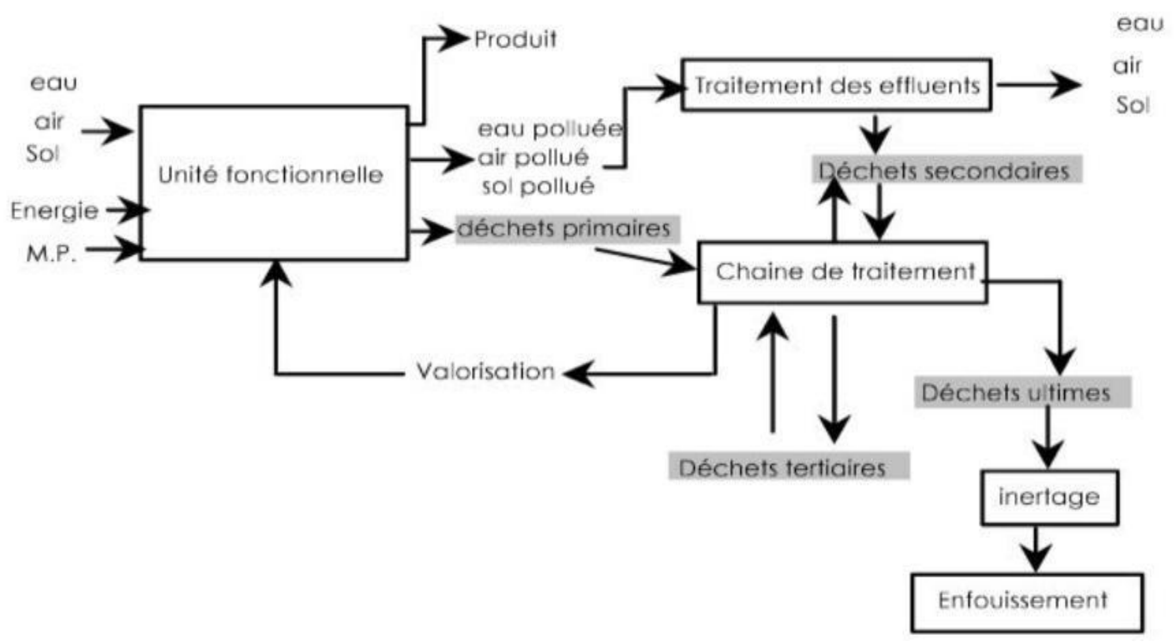

Fig. 9 : Waste life cycle.

8. Waste as a resource (circular economy)

Waste can contain valuable materials and energy. Recovery reduces raw material extraction, can save energy, and decreases landfill use. However, recovery itself can be energy-intensive or costly, so feasibility depends on technology, contamination, and market demand.

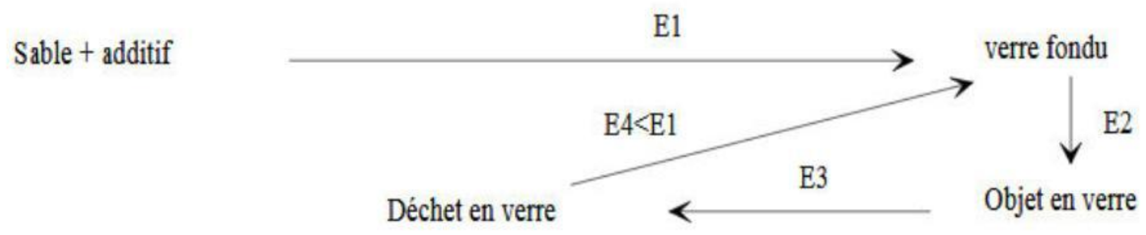

Fig. 10: Energy cycle of glass.

9. Safety labeling and hazard communication

Hazard pictograms communicate chemical risks to users and workers. Correct labeling supports safe storage, handling, and emergency response.

Fig. 11: Chemical pictograms: meaning.

Table 1. Classification of waste treatment channels.

A) Valorisation énergétique	D) Valorisation en agriculture et agro-alimentaire
1- Combustion avec récupération d'énergie	12- Amendement organique
2- Élaboration de combustibles dérivés par des procédés mécaniques	13- Amendement minéral
3- Élaboration de combustibles dérivés par des procédés thermiques	14- Alimentation pour animaux
4- Élaboration de combustibles dérivés par des procédés biologiques	
	E) Valorisation en science de l'environnement
B) Valorisation matière première	15- Traitement des effluents pollués liquides ou gazeux
5- Matières premières organiques naturelles ou artificielles	16- Solidification ou stabilisation des déchets toxiques
6- Matières premières minérales métalliques ou non métalliques	
	F) Élimination
C) Valorisation en science des matériaux	17- Incinération
7- Liants hydrauliques et matériaux de structure	18- Traitement biologique des déchets
8- Verres et céramiques	19- Traitements physico-chimiques
9- Plastiques et caoutchouc	20- Mise en décharge
10- Fibres cellulosiques de récupération	
11- Autres	

CHAPTER VI

IMPACT OF POLLUTION ON HEALTH AND THE ENVIRONMENT 6.1

1. Introduction

Environmental degradation affects ecosystems and human health. Impacts depend on pollutant type, concentration, exposure duration, and vulnerability. Policies therefore rely on both scientific evidence and precaution, setting standards and triggering action during pollution episodes.

2. Exposure and vulnerability — expanded

Exposure is the contact between a person (or ecosystem) and a pollutant. It depends on concentration, time, and pathway (inhalation, ingestion, skin contact). Vulnerability varies with age, health status, pregnancy, occupation, and pre-existing conditions.

- Children: developing lungs and immune systems.
- Elderly: reduced physiological reserves.
- People with asthma/COPD or cardiovascular disease.
- Pregnant women: potential fetal impacts.

3. Ecosystem impacts and biodiversity

Pollution can reduce biodiversity and disrupt ecosystem functions such as water purification, soil stability, and pollination. Acidification, eutrophication, habitat fragmentation, and toxic contamination can combine to weaken resilience.

4. Major health impacts

4.1. Cardiovascular diseases

Risk factors include hypertension, cholesterol, and smoking, but environmental stressors (air pollution, noise) can aggravate conditions. Carbon monoxide exposure can trigger arrhythmias and worsen angina by reducing oxygen delivery in blood.

4.2. Cancers

Cancer risk is influenced by lifestyle and genetics, but environmental exposures (certain pesticides, PAHs, benzene, asbestos, ionizing radiation) contribute, especially in high-exposure workplaces or polluted areas.

4.3. Respiratory diseases

Particles, ozone, NO_2 and SO_2 can irritate airways, worsen asthma, and increase infections. Chronic exposure is associated with reduced lung function and increased mortality.

4.4. Allergies

Pollens, molds, dust mites, and animal allergens can trigger allergic responses. Air pollution can interact with allergens by irritating airways and potentially enhancing sensitivity.

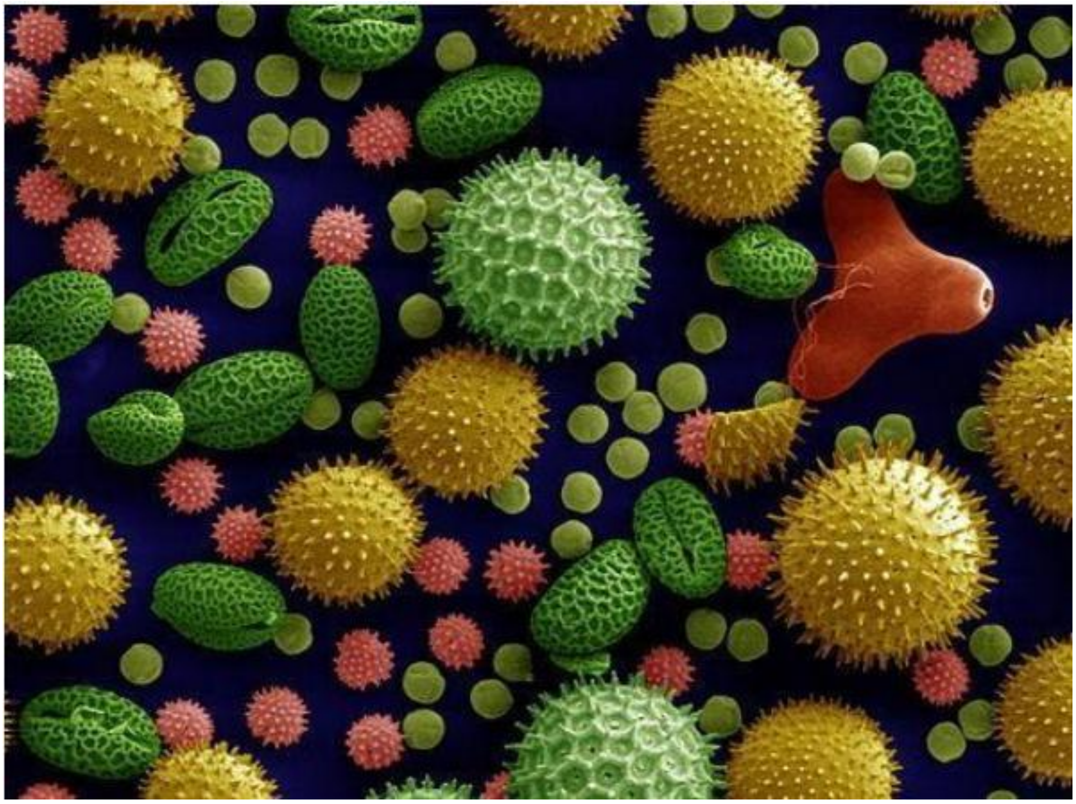

Figure 12: Pollen of various plants.

Figure 13: Dust mite photo.

5. Quantification (key figures)

Reported figures for premature deaths (excess mortality) highlight the scale of air pollution impacts:

- 3.7 million premature deaths worldwide in 2012 due to ambient outdoor air pollution (WHO).
- 420,000 premature deaths in 2010 caused by air pollution in the EU (European Commission).
- 21,400 premature deaths in EU-25 in 2000 caused by tropospheric ozone.

6. Prevention and mitigation — expanded

Mitigation operates at multiple levels:

- At source: cleaner fuels, efficiency, electrification, emission controls.
- Along pathways: urban planning, green buffers, ventilation, wastewater treatment.
- At receptor: health advisories, protective equipment for workers, indoor air improvements.

Co-benefits

Policies that reduce fossil fuel combustion often reduce CO_2 and also local pollutants (PM, NOx, SO_2), delivering climate and health benefits simultaneously.

Appendix A: Quick unit conversions

- 1 kWh = 3.6 MJ
- 1 MWh = 3.6 GJ
- 1 GJ ≈ 277.8 kWh
- Power × time = energy (e.g., kW × h = kWh)

Appendix B: Typical orders of magnitude (indicative)

Values vary by technology and context; these are indicative ranges used for intuition.

- Household electric kettle: ~1–2 kW
- Small room heater: ~1–2 kW
- Car engine (mechanical output): tens of kW
- Wind turbine: 1–6 MW (utility scale)
- Large power plant: hundreds of MW to >1 GW

Appendix C: Glossary (selected terms)

Primary energy: Energy found in nature before conversion (coal, oil, sunlight).

Secondary energy: Energy carrier after conversion (electricity, gasoline).

Final energy: Energy delivered to end users (electricity at socket).

Useful energy: Energy actually providing the service (light, motion, heat).

Efficiency: Ratio of useful output to input energy.

Greenhouse gas (GHG): Gas that absorbs infrared radiation (CO_2, CH_4, N_2O).

VOCs: Volatile organic compounds; can form ozone and smog.

NOx: Nitrogen oxides; contribute to ozone and acid rain.

SOx: Sulfur oxides; contribute to acid rain.

PM2.5: Fine particles <2.5 µm affecting health.

Acid rain: Precipitation with low pH due to sulfuric/nitric acids.

Pumped hydro: Mechanical storage using elevated water reservoirs.

Round-trip efficiency: Energy out divided by energy in for storage.

Circular economy: System aiming to keep materials in use and minimize waste.

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