Energy Resources and Consumption

AP Environmental Science

Renewable and Nonrenewable Resources

A **renewable resource** 可再生资源 replenishes on a human timescale (sun, wind, water, biomass); a **nonrenewable resource** 不可再生资源 exists in fixed amounts that take millions of years to form (fossil fuels, nuclear fuel). Nonrenewables will eventually run out and often pollute more.

Wind turbines: renewable sources replenish on human timescales; fossil fuels do not

Global Energy Consumption

Global energy use is rising, especially in developing nations. Most energy still comes from **fossil fuels** 化石燃料. Wealthy nations consume the most per person; access to energy shapes economic development.

Fuel Types and Uses

Different fuels suit different needs: coal and natural gas for **electricity**, oil for **transportation**, and biomass for heating and cooking in many regions. Each has trade-offs in cost, availability, and pollution.

Distribution of Natural Energy Resources

Energy resources are **unevenly** distributed – oil is concentrated in some regions, coal in others, and renewables depend on local sun, wind, or rivers. This uneven distribution drives trade, economics, and geopolitics.

Fossil Fuels

Fossil fuels (coal, oil, natural gas) formed from ancient organisms. They are energy-dense and reliable but **nonrenewable** and the main source of $\mathbf{CO_2}$ and air pollution. Coal is the dirtiest; natural gas burns cleaner but leaks **methane** 甲烷.

*An open-pit **lignite** 褐煤 (brown coal) mine feeding the power station 发电站 behind it — the fuel is dug from the ground and burned on the spot*

Coal forms in stages, and its **rank** climbs with the heat, pressure, and depth of burial it has endured. Partly decomposed plant matter first becomes **peat** 泥炭 (which can itself be dried and burned), then soft brown lignite, then **bituminous** 烟煤 coal, and finally hard **anthracite** 无烟煤 – each step is drier, more carbon-rich, and higher in energy, so anthracite burns hottest and cleanest.

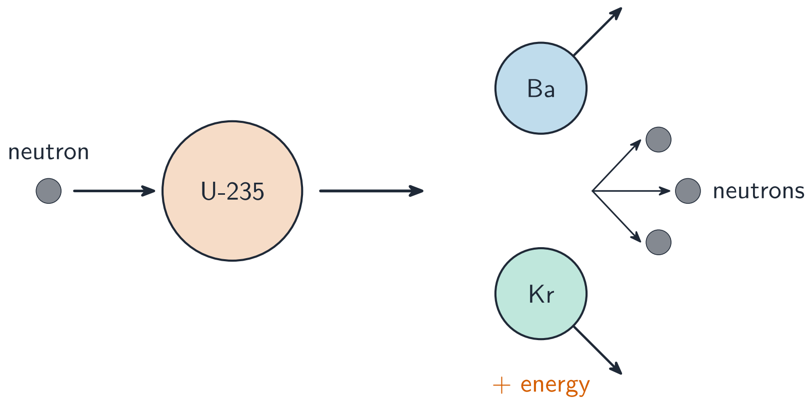
Oil and natural gas are increasingly reached by **hydraulic fracturing** 水力压裂 ("fracking"): a high-pressure fluid is pumped into shale rock to crack it open and release the trapped fuel. It has unlocked huge reserves, but it can **contaminate groundwater** (methane and chemicals reaching drinking-water wells), release **volatile organic compounds** 挥发性有机化合物 into the air, and trigger minor earthquakes.

Crude oil can also be recovered from **tar sands** 油砂 – a mix of clay, sand, water, and thick **bitumen** 沥青. Separating the oil is energy- and water-intensive and clears large areas of land, so its environmental cost per barrel of oil is high.

Nuclear Power

Nuclear power 核能 splits uranium (**fission** 裂变) to boil water and drive turbines. It produces **no** $\mathbf{CO_2}$ and lots of energy from little fuel, but risks include radioactive **waste** 核废料 (long-lived), the danger of meltdowns, and high cost.

Worked example. Radioactive waste decays by its **half-life** – the time for half of it to decay. Suppose an isotope has a half-life of 30 years and a reactor leaves 100 g of it. After 30 years 50 g remains; after 60 years 25 g; after 90 years (three half-lives) $100 \times \left(\frac{1}{2}\right)^3 = 12.5$ g. Because the drop is halving, not linear, the waste stays hazardous for many half-lives – the core reason it must be stored safely for centuries.



Nuclear fission of a uranium-235 nucleus releases energy

A nuclear power station 核电站. The reactor buildings hold the fuel; the sea supplies cooling water. Notice there is no smoke — fission releases no CO_2

Energy from Biomass

Biomass 生物质 (wood, crops, waste, biofuels like ethanol) is renewable and can be carbon-neutral if replanted, but burning it causes air pollution, and growing fuel crops competes with food and habitat.

Ethanol 乙醇, made from crops such as corn or sugarcane, can substitute for gasoline and adds no *new* carbon when burned (the plant absorbed that CO_2 as it grew). Its drawback is a low **energy return on energy investment (EROEI) 能量投资回报率**: growing, harvesting, and distilling the crop uses nearly as much energy as the fuel finally delivers.

Solar Energy

Solar 太阳能 converts sunlight to electricity (photovoltaic panels) or heat. It is renewable and clean during use, but **intermittent** (no sun at night), needs space, and has manufacturing impacts.

*A solar farm. Rows of **photovoltaic** 光伏 panels are tilted toward the sun; a big output needs a large area of land*

Hydroelectric Power

Hydroelectric 水电 power uses flowing water (dams) to spin turbines – renewable and low-emission, but dams flood habitat, block fish migration, trap sediment, and displace people.

A hydroelectric dam 大坝. The ***reservoir*** *水库 is held back behind the wall; water falls through the dam to spin turbines in the power house at its base*

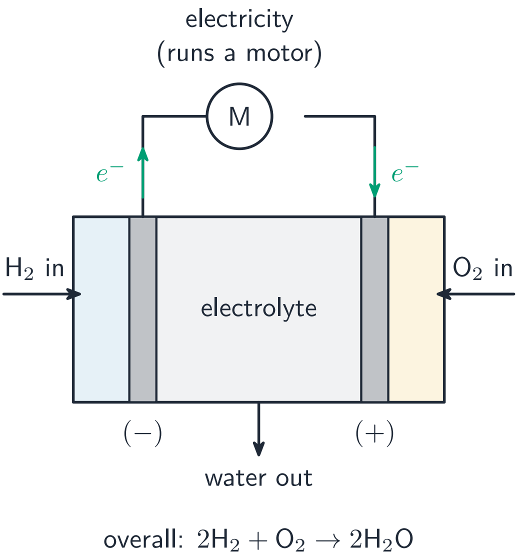
Geothermal Energy

Geothermal 地热能 taps Earth's internal heat for electricity and heating. It is renewable and reliable, but only practical where hot rock is near the surface (volcanic regions) and can release underground gases.

A geothermal power station in Iceland, a volcanic region. ***Steam*** *蒸汽 from hot rock below is piped up to drive the turbines*

Hydrogen Fuel Cell

A **hydrogen fuel cell** 氢燃料电池 combines hydrogen and oxygen to make electricity, with **water** as the only emission at use. But producing hydrogen usually requires energy (often from fossil fuels), and storage is difficult.



A hydrogen-oxygen fuel cell makes electricity, with water as the only product

Wind Energy

Wind 风能 turbines convert moving air to electricity – renewable, clean, and low-operating-cost, but intermittent, land- or sea-intensive, and a hazard to birds and bats. Best where winds are strong and steady.

Wind turbines 风力涡轮机 on farmland. They take little ground, so the land between them can still be farmed

Energy Conservation

Energy conservation 节能 reduces demand through efficiency (LED lighting, insulation, efficient appliances, public transport) and behavior. Saving energy is often the cheapest and cleanest option – the energy you do not use needs no fuel and makes no pollution.

A related efficiency gain is **cogeneration** 热电联产 (combined heat and power): a single fuel burn is used to make **both** electricity **and** useful heat, capturing the waste heat that an ordinary power plant simply dumps – so far more of the fuel's energy ends up doing useful work.

Worked example. Replacing a 60 W incandescent bulb with a 10 W LED that gives the same light saves 50 W. Running it 5 hours a day saves $50\text{ W} \times 5\text{ h} = 250\text{ Wh} = 0.25\text{ kWh}$ per day, or about $0.25 \times 365 \approx 91$ kWh per year. Multiply that by every bulb in a city and conservation rivals a new power plant – at far lower cost.

A solar farm: generating more renewable energy and cutting demand are both energy-conservation strategies

Exam tips

- Separate **renewable** (sun, wind, water) from **non-renewable** (fossil fuels, nuclear) and weigh each source's trade-offs.
- Fossil fuels are energy-dense but emit CO_2; **nuclear** emits no CO_2 but leaves long-lived waste.
- Do **half-life** math: after n half-lives a fraction $(\frac{1}{2})^n$ remains.
- Note that solar and wind are **intermittent** and need storage or backup.
- **Conservation** (efficiency) is often the cheapest, cleanest option — the energy not used needs no fuel.
- Know the **coal ranks** (peat → lignite → bituminous → anthracite; more heat/pressure/burial → higher energy) and the unconventional fuels **fracking** (shale oil/gas; groundwater + VOC pollution) and **tar sands** (bitumen, energy-intensive).
- **Ethanol** adds no net CO_2 but has a **low EROEI**; **cogeneration** (combined heat and power) captures waste heat so one fuel gives both electricity and heat.