Cambridge AS & A Level · Geography 9696 · Notes

# Environmental management A2

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Read first: **Population**, **Settlement dynamics**

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## What you need to know

By the end of this topic you should be able to:

1. **Tell renewable from non-renewable energy resources**, with examples of each.
2. **Explain the factors at the national scale** that affect the **demand for** and **supply of** energy and the **balance between sources** (the energy mix): **sustainability**, **level of development**, **resource endowment**, **climate**, **income**, **technology**, **pollution**, **energy policy** and **energy security**.
3. **Describe and explain trends in the consumption** of fossil fuels, nuclear power and renewables (HEP, wind, biofuels) in **LICs, MICs and HICs**.
4. **Explain the environmental impacts** of energy **production**, **transport** and **usage**, at **local** and **global** scales.
5. **Know a case study of one country's overall electrical energy strategy**: the issues of changing demand and supply, of power production and of where it is located, and an **evaluation** of how successful the strategy has been.
6. **Know a case study of one named, located scheme that produces electricity**, with the same issues and an **evaluation** of its success.
7. **Explain pollution of land, air and water**: its nature, causes and solutions.
8. **Explain the demand for and supply of water**, and **issues of water quality**.
9. **Explain the factors that degrade rural environments** (such as overpopulation, poor farming practices and deforestation) and **urban environments** (such as urbanisation, industrial development and inadequate waste management).
10. **Explain the constraints** that hold back improving the quality of degraded environments.
11. **Explain how environments at risk are protected** at the local or regional scale: the **needs**, the **measures** and the **outcomes**.
12. **Know a case study of one degraded environment**: the causes of its degradation, the problems, the issues met in trying to improve it, and an **evaluation** of the attempted solutions.

It is one of the options in Paper 4 (Advanced human geography options), where you answer two options. For this option you answer Question 4 (10 marks: a data part (a) and an explain part (b), built on a figure) and one essay, Question 5 or Question 6 (20 marks). Question 5 has always been about **energy and electricity**;

Question 6 about **degradation, pollution, water or environments at risk**. Read the notes on population (carrying capacity, overpopulation) and settlement dynamics (urbanisation) first.

## Understand it

### Energy resources: renewable and non-renewable

**Non-renewable** (stock) resources form over millions of years, so using them **uses them up**: **coal**, **oil**, **natural gas** (the **fossil fuels**) and **uranium** for nuclear power. **Renewable** (flow) resources are **replaced naturally** as fast as we use them: **HEP** (falling water), **wind**, **solar**, **geothermal** (heat from inside the Earth), **tidal** and **wave** power, and **biofuels** and **biomass** (wood, crop waste, ethanol from sugar cane or maize, biodiesel from palm or soy oil).

Two points that win marks:

- **Renewable is not the same as sustainable.** Fuelwood is renewable, but cut faster than it regrows it causes deforestation; a geothermal field cools if it is over-used; a biofuel that replaces rainforest releases more carbon than it saves. A **sustainable** energy supply meets today's needs **without** harming the ability of future generations to meet theirs: economically affordable, socially acceptable and environmentally sound.
- **Nuclear** is non-renewable (uranium is mined) but **low-carbon**, so it is often grouped with renewables as "clean" energy. Be precise.

Most questions are about **electricity** (secondary energy, made from primary sources such as coal or wind), so keep answers on how it is generated, moved and used.

**Power and energy.** A power station's **capacity** is its power, in **megawatts (MW)**; energy is power over time, in **kWh**, **MWh** or **TWh**. A 100 MW plant running at full power for an hour makes 100 MWh. Few plants run flat out all the time, so their **capacity factor** (Key facts) matters: wind farms often reach 25–45%, solar 10–25%, nuclear and geothermal 80–90%.

### Factors affecting demand, supply and the energy mix

**Demand** depends on how many people use energy and how much each uses; **supply** depends on what a country has, can buy and can build. The **energy mix** is the share of each source.

| Factor | How it affects demand, supply or the mix | Example |
|---|---|---|
| **Level of development** | Industrialising MICs need fast, cheap, large supplies, so they build coal; HICs have flat demand and can afford to switch; LICs use little electricity and much **fuelwood and charcoal** | China and India built coal fast in the 2000s and 2010s |

| Factor | How it affects demand, supply or the mix | Example |
|---|---|---|
| **Income** (of people and governments) | Richer households buy air conditioners, cars and appliances, so demand per person rises; poorer countries cannot afford the high **up-front cost** of nuclear or large renewables, or the interest on loans | Electricity per person in the USA is many times that in Nigeria |
| **Resource endowment** | Countries use what they have: it is cheap, creates jobs and avoids imports | Coal in South Africa (about 80% of its electricity); hydro in Norway (about 90%); geothermal in Iceland and Kenya; gas in Qatar |
| **Climate** | **Demand**: heating in cold winters, cooling in hot summers (air conditioning peaks); **supply**: rain and snowmelt for HEP, sunshine for solar, wind; droughts cut HEP | Hot-season demand peaks in the Gulf states; HEP falls in drought years in Zambia and Zimbabwe (Kariba) |
| **Technology** | New technology lowers costs and opens new sources: fracking, cheaper solar panels and batteries, smart grids | The US shale gas boom after about 2008 let gas replace much coal |
| **Pollution** | Smog, acid rain and climate change push countries to cleaner sources, and public opinion follows | UK Clean Air Act (1956) after the London smog; China's coal limits around Beijing in the 2010s |
| **Energy policy** | Governments set targets, taxes, subsidies, bans and prices | Germany closed its last nuclear reactors in April 2023 |
| **Energy security** | Countries want a reliable, affordable supply they control, so they diversify and avoid dependence on one supplier | Europe cut Russian gas after Russia's invasion of Ukraine in 2022 |
| **Sustainability** | Long-term thinking favours renewables and efficiency; international agreements set targets | The Paris Agreement (2015) and net-zero targets |

**Population**, **economic structure** (heavy industry uses far more than services) and **urbanisation** also drive demand. Demand **changes** over the **day** (an evening peak), the **week**, the **season** (heating or cooling) and the **years** (population, growth, efficiency).

**The factors interact**, and that is where the essay marks are: **development** decides **income**, which decides whether a country can afford **technology**; **resource endowment** often decides **policy**; **energy security** may push a country towards local coal **or** local renewables. Climate affects both **demand** (heating and cooling peaks) and **supply** (HEP, solar, wind), so keep the two apart: examiners report answers that write about supply when the question asks about demand.

**Energy security** means having **enough** energy, **reliably**, at an **affordable price**, from sources that are **not at risk** of being cut off. A country improves it by:

1. **Diversifying** its mix (no single fuel or supplier dominates);

2. **Using domestic sources** (renewables, local coal or gas) instead of imports;
3. **Securing imports** by long-term contracts, pipelines and cooperation with neighbours, and **interconnectors** to trade electricity;
4. **Storing** energy (oil reserves, gas storage, pumped storage, batteries);
5. **Cutting demand** by efficiency and conservation.

Meeting demand is only one part of energy security: reliability, price and control of supply count too.

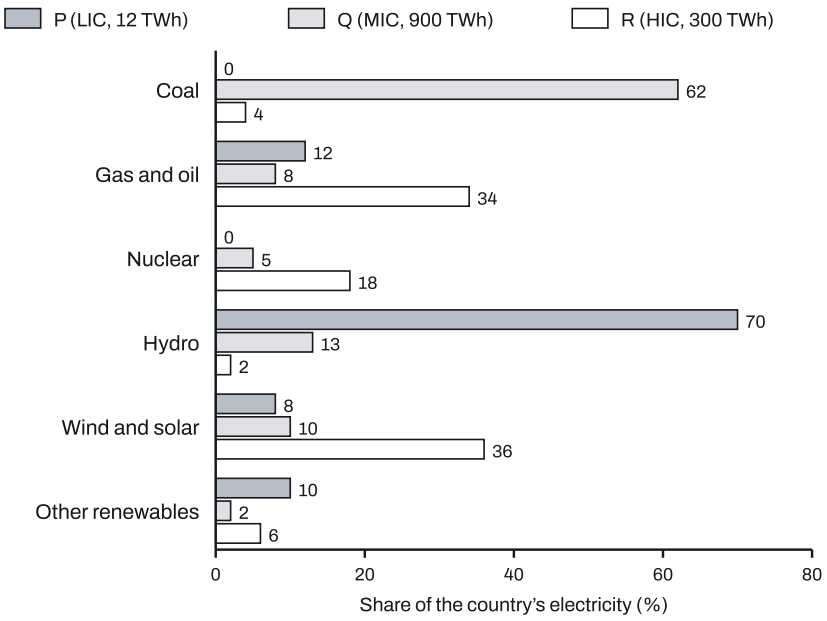
## Trends in energy consumption

World energy use keeps rising, driven by **population growth** and **rising incomes in MICs**. In **2023**, fossil fuels still produced about **60%** of the world's electricity (coal about a third, gas about a fifth); **hydro** about 14%, **nuclear** about 9%, **wind** about 8% and **solar** about 5%. About three-quarters of the world's greenhouse gas emissions come from energy.

| | HICs | MICs | LICs |
|---|---|---|---|
| **Total demand** | Flat or falling (efficiency, deindustrialisation) | Rising fastest (industry, cities, a growing middle class) | Low but rising; much energy is fuelwood and charcoal for cooking |
| **Fossil fuels** | **Coal falling fast** (the UK's last coal power station closed in September 2024); gas often rising as a bridge fuel | Coal still the base of electricity (about 60% in China, about 75% in India) and still growing in total | Diesel generators and imported oil, expensive and unreliable |
| **Nuclear** | Stable or falling (Germany's exit; Japan's reactors shut after Fukushima in 2011, some restarted); a few new plants (Hinkley Point C, UK) | Most new reactors are being built in China | Almost none |
| **Renewables** | Fast growth of **wind** and **solar**; **HEP** mostly fully developed | Fastest installation in the world: in 2023 China added about as much solar as the whole world had added in 2022; big **HEP** schemes | **HEP** often the main grid source (Ethiopia, DR Congo); **off-grid solar** spreading fast; **biomass** dominant |
| **Biofuels** | Ethanol from maize (USA), biodiesel blends (EU) | Ethanol from sugar cane (Brazil, since the 1970s); palm-oil biodiesel (Indonesia) | Little modern biofuel; traditional biomass |

**Reasons for the trends**: falling costs of solar, wind and batteries; climate targets; air pollution; energy security after 2022; and fast-rising demand in MICs, which build **everything** (coal and renewables together). About **685 million people** still had **no electricity** in 2022, most of them in sub-Saharan Africa: this is **energy poverty**.

**Diagram 1. Share of electricity by source (%)**




## Environmental impacts of energy: production, transport and usage

Organise answers by **stage** and by **scale**: **local** impacts are felt near the mine, plant or pipeline; **global** impacts (climate change) are felt everywhere.

| Source | Production | Transport | Usage |
|---|---|---|---|
| **Coal** | Open-cast mines scar land and remove soil; spoil heaps; acid mine drainage into rivers; burning releases **$CO_2$** (global), **sulfur dioxide** (acid rain), **nitrogen oxides**, **particulates** and mercury (local and regional); ash ponds | Dust from trains and stockpiles | Smog in cities with coal power or home heating |
| **Oil** | Drilling spills (Deepwater Horizon, Gulf of Mexico, 2010); gas flaring (Niger Delta) | **Tanker spills** (Exxon Valdez, Alaska, 1989); pipeline leaks | **Vehicle exhausts**: $NO_2$, particulates and $CO_2$; urban smog |
| **Natural gas** | Lower $CO_2$ than coal when burnt (about half per kWh); but **methane leaks** (a powerful greenhouse gas); **fracking** can contaminate groundwater and trigger small earthquakes (fracking in England was halted in 2019 after tremors) | Pipeline construction through forests and permafrost | Cleaner than coal locally |
| **Nuclear** | Uranium mining waste; **radioactive waste** lasting thousands of years (Finland is building the first deep geological store, at Onkalo); accidents (Chernobyl 1986, Fukushima 2011); warm water returned to rivers and seas | Transport of waste and fuel | Almost no air pollution or $CO_2$ |

| Source | Production | Transport | Usage |
|---|---|---|---|
| **HEP** | **Flooding** of valleys, forests and farmland; **displacement** of people (Three Gorges, China: about 1.3 million); reservoirs **trap sediment**, so deltas and farmland downstream lose silt; **barriers to fish** migration; changed flow and temperature downstream; rotting vegetation in tropical reservoirs releases **methane**; can trigger earthquakes | Long power lines | None |
| **Wind and solar** | Bird and bat deaths (wind); noise and **visual impact**; large areas of land (solar); mining for metals; blades and panels hard to **recycle** | Power lines from remote sites | None |
| **Biofuels** | **Deforestation** for plantations (palm oil in Indonesia and Malaysia), **monoculture** and **loss of biodiversity**, **fertiliser** runoff (eutrophication), pesticides, heavy **irrigation**; but **carbon-neutral in theory**, since the crops absorb the $CO_2$ they later release, and using **waste** (crop residues, used cooking oil) avoids landfill | Road and ship transport | Burning releases particulates, but less than fossil fuels |
| **Geothermal** | Releases **hydrogen sulfide** and some $CO_2$; toxic, salty **wastewater**; land can sink; plants in protected areas | Pipelines across the landscape | None |

**Positive impacts** count too (renewables replacing fossil fuels cut $CO_2$ and air pollution; reservoirs control floods). For "environmental" impacts, keep to air, water, land, wildlife and climate, not cost.

## Case study: an overall electrical energy strategy, Kenya

An **overall electrical energy strategy (OEES)** is the whole plan a country follows for electricity: **supply** (the energy mix, where power stations are built, the grid, off-grid supply, imports) and **demand** (prices, efficiency, conservation, connecting new users). It is **more than the energy mix**, and more than one scheme.

**The issues Kenya faced:**

- **Over-dependence on HEP**: in the 1990s most of Kenya's electricity came from dams on the **Tana River** (the Seven Forks scheme). The **drought of 1999–2000** drew the reservoirs down to very low levels and led to **power rationing**, which cost the economy heavily.
- **Expensive emergency supply**: the gap was filled with **diesel and fuel-oil** power stations, using imported fuel, which raised prices and emissions.
- **Low access**: in the early 2010s only about **a third** of Kenyans had electricity, mostly in towns; rural areas used kerosene lamps and fuelwood.
- **Rising demand**: population growth (over 50 million people), urbanisation (Nairobi) and plans for industry under **Vision 2030**; peak demand passed **2000 MW** in 2023.

- **Location**: the best resources are **far from the users**: geothermal heat in the **Rift Valley**, wind in the remote north, while demand is in Nairobi and Mombasa.

**The strategy:**

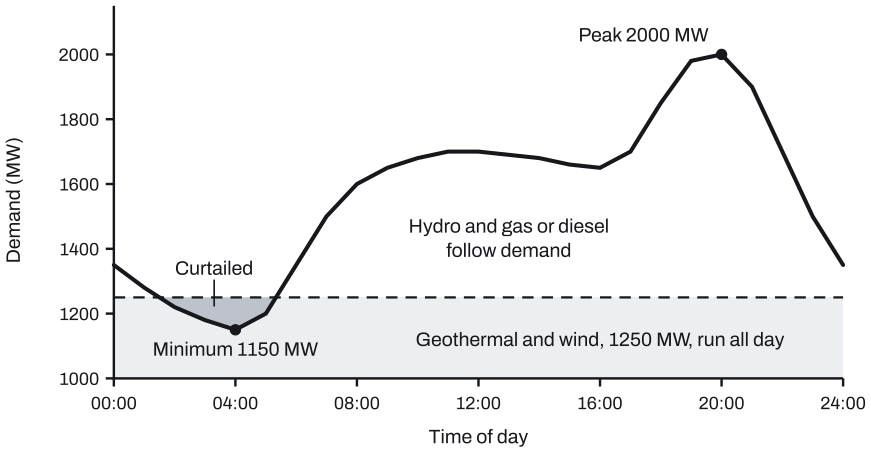
1. **Geothermal power**: from the first plant at **Olkaria**, in Hell's Gate National Park near Lake Naivasha (1981), to **about 950 MW** by 2023, one of the world's largest. It supplies **around 45%** of Kenya's electricity as reliable **baseload** that does not depend on rain.
2. **Wind and solar**: **Lake Turkana Wind Power** (below), Kipeto wind farm, and the **Garissa** solar plant (50 MW, 2018).
3. **Keeping HEP** for flexible supply and **cutting thermal** (diesel) power.
4. **Rejecting coal**: a 1050 MW coal plant planned at **Lamu**, on the coast near a World Heritage town, lost its environmental licence in **2019** after local protests and a tribunal ruling.
5. **Access**: the **Last Mile Connectivity Project** (from 2015) cut connection fees for homes near the grid; **off-grid solar**, sold by firms such as M-KOPA (from 2012) on **pay-as-you-go** terms using mobile money, reached remote areas.
6. **Targets**: a goal of **100% clean electricity by 2030**.

**Evaluation:**

| Successes | Problems |
|---|---|
| About **90%** of Kenya's grid electricity is renewable, among the highest shares in the world | **Reliability**: national **blackouts** in 2023, when single faults tripped the grid; old, overloaded lines and transformers |
| **Diversified** away from HEP, so droughts no longer cause rationing: better **energy security** | **High prices** for consumers and industry, partly from expensive contracts with private producers |
| Access rose from about a third of people to **about three-quarters** by the early 2020s | Many new connections use **very little** electricity, as poor households cannot afford more; the grid company lost money |
| Low emissions: Kenya avoided building coal | **Night-time demand** is low, so geothermal and wind sometimes have to be **cut back** (curtailed) while being paid for (see Diagram 2) |
| Off-grid solar reached people the grid could not | **Displacement**: Maasai families were moved for an Olkaria plant (2014), and a World Bank review found failings in how it was done |

**Judgement**: Kenya's strategy has been successful in **diversifying** supply and making it **clean**, and good at **widening access**, but less successful in **reliability** and **affordability**, which matter most to users. Supply has grown faster than the ability of people and industry to use it.

**Diagram 2. Electricity demand over one day**




## Case study: a named located scheme, Lake Turkana Wind Power, Kenya

**Location**: near **Loiyangalani**, in **Marsabit County**, northern Kenya, on the south-east shore of Lake Turkana. A remote, semi-arid area of pastoral herders (Turkana, Samburu, Rendille), far from roads and the grid.

**Why there**: strong, steady winds are **funnelled** through the gap between **Mount Kulal and Mount Nyiru**, so average wind speeds are among the highest of any wind farm, and they blow day and night much of the year, giving a high capacity factor. Land was cheap and thinly populated.

**The scheme**: **365 turbines** of 850 kW, **310 MW** in total, built 2015–2017; at the time the largest wind farm in Africa and the largest private investment in Kenya's history (about 620 million euros, mostly loans from European and African development banks). A **428 km** power line south to Suswa, near Nairobi, was built by the government to carry the power to users.

**Success**:

- It supplies about **a tenth or more** of Kenya's electricity, cheaply once built, with **no fuel imports** and no emissions, and, since it does not depend on rain, it **diversifies** the mix away from drought-prone HEP and costly diesel.
- Local benefits: about 200 km of road was rebuilt, and there were construction jobs, a few hundred permanent jobs, and spending on schools, water and health.

**Issues of supply, demand and location**:

- **Location far from demand**: the power line was **delayed** after its contractor went bankrupt, so the finished turbines stood idle for about a year. Under its **take-or-pay** contract, Kenya Power had to pay billions of shillings for power it could not take.
- **Demand did not keep up**: the contract requires the grid to buy all its output, and the winds here are often strongest at night, when demand is lowest. Geothermal or wind must then be curtailed (Diagram 2), and the scheme added to the problem of **surplus supply** and high prices.
- **Supply varies** with the wind, so backup from hydro is needed.

- **Land and environment**: in 2021 a Kenyan court ruled that the community land had been acquired irregularly (the farm kept operating); herders lost grazing; the site lies on a bird migration route.

**Judgement**: technically and environmentally a **success** (reliable, clean power from a good site), but **economically** less so for Kenya, because **location** issues (the delayed line) and **demand** that grew more slowly than supply turned its contract into a cost. It shows that a scheme's success depends on the **whole strategy** (grid, demand, contracts), not just the site.

## Pollution: land, air and water

**Pollution** is the release of substances or energy (heat, noise, light) into the environment in amounts that **harm** living things or human health. **Point sources** are single, identifiable places (a factory pipe, a power station chimney); **non-point (diffuse) sources** are spread out (fertiliser runoff from thousands of farms, vehicle exhausts), and are harder to control.

| | Nature | Causes | Solutions |
|---|---|---|---|
| **Air** | **Particulates** (PM2.5 and PM10), **nitrogen dioxide**, **sulfur dioxide**, ground-level **ozone**, carbon monoxide; smog | Vehicles, power stations, industry, burning of waste, crops and fuelwood, dust; worse in basins and valleys where **temperature inversions** trap air, and in calm winter weather | Clean air laws and emission limits; low-emission zones and congestion charges; public transport; cleaner fuels (unleaded petrol, gas); catalytic converters; **scrubbers** on chimneys; moving industry; monitoring and warnings |
| **Water** | Sewage and pathogens; **nutrients** (nitrate, phosphate) causing **eutrophication**; industrial chemicals and heavy metals; oil; plastics; warm water; sediment; natural arsenic and fluoride | Untreated sewage; fertiliser runoff; factories discharging waste; mining (tailings dam collapses at Mariana in 2015 and Brumadinho in 2019, Brazil); landfill leachate | Sewage treatment; laws and fines; buffer strips by rivers; less fertiliser; treating industrial waste; clean-up of rivers |
| **Land** | Solid waste, contaminated soil, plastics, e-waste, mine spoil | Open dumps and landfill; industry; mining; pesticides; the world produced about **62 million tonnes of e-waste** in 2022, and less than a quarter was formally recycled | Waste collection and recycling; sanitary landfill; laws on dumping and export of waste; cleaning contaminated land |

Air pollution kills about **4 million people a year** outdoors (WHO), and almost everyone breathes air above WHO's guideline for PM2.5 (an annual mean of 5 $\mu g/m^3$). Pollution crosses borders: **acid rain** from British and German power stations damaged Scandinavian lakes; **haze** from forest fires in Indonesia reaches Singapore and Malaysia; climate change is global.

**Example of air quality improvement: Mexico City.** The city lies in a **high basin** (about 2240 m) ringed by mountains, so inversions trap pollution, and in 1992 the UN called it the most polluted city in the world. Measures: **Hoy No Circula** (from 1989: each car kept off the roads one weekday, by its number plate), closing an oil refinery (1991), **unleaded petrol** (lead removed by 1997), catalytic converters, the **Metrobús** rapid bus network (from 2005) and air quality plans (**ProAire**). Outcome: lead, sulfur dioxide and carbon monoxide fell sharply, but **ozone** and particulates still often exceed guidelines, because car numbers kept rising and many people bought second cars to get round the driving ban.

**Example of water quality improvement: the River Thames, London.** Declared biologically dead in the late 1950s, it recovered with modern sewage works and now has over 100 fish species; to stop Victorian sewers overflowing into it after heavy rain, the 25 km **Thames Tideway Tunnel** was brought into use in 2024–2025.

## Water: demand, supply and quality

**Demand** for water is rising with **population growth**, **economic development**, **urbanisation**, **industrialisation**, **irrigation** and **changing diets** (meat and dairy need far more water per calorie than grains). Across the world, about **70%** of the fresh water taken is used for **agriculture**, about **20% by industry** (including cooling power stations) and about **10%** for **domestic** use; in HICs industry's share is higher, in LICs agriculture's is.

**Supply** depends on **climate** (rainfall, evaporation, seasonality), **rivers and groundwater** (aquifers), **storage**, and the **money and technology** to collect, treat and deliver it. Water stress is measured by the water available **per person** (Key facts).

- **Physical water scarcity**: there is not enough water to meet demand (the Middle East, North Africa, parts of India and northern China).
- **Economic water scarcity**: there is water, but not the money, infrastructure or institutions to deliver it (much of sub-Saharan Africa).

**Ways to increase supply**: **dams and reservoirs**; **groundwater** (but many aquifers are **over-pumped**, as under the Indian Punjab and the US Great Plains); **water transfers** (China's **South–North Water Transfer Project**, central route opened 2014); **desalination** (the Gulf states, Israel); **recycling** wastewater (Singapore's **NEWater**, from 2003); **rainwater harvesting** (Rajasthan, India). **Managing demand**: metering and pricing, fixing **leaks**, **drip irrigation**, restrictions in droughts (**Cape Town**, 2018, cut use to 50 litres per person per day and avoided "Day Zero").

**Water quality issues**: about **2.2 billion people** lacked **safely managed drinking water** in 2022, and about 3.5 billion lacked safely managed **sanitation**. Unsafe water spreads **cholera**, **typhoid** and **diarrhoeal disease**, which kills hundreds of thousands of young children a year. Causes:

- **Lack of sanitation**: sewage gets into rivers and shallow wells, especially in fast-growing **informal settlements**;
- **Agriculture**: fertiliser (nitrates, eutrophication), pesticides, animal waste;
- **Industry and mining**: heavy metals and chemicals, often from factories that are cheaper to run if waste is dumped;

- **Natural contamination**: **arsenic** in groundwater in Bangladesh and West Bengal, where tube wells dug from the 1970s to avoid polluted surface water exposed tens of millions of people; fluoride in parts of India and East Africa;
- **Over-pumping** that draws salt water into coastal aquifers;
- **Floods and droughts** (floods spread sewage; low river flows concentrate pollution).

**Is rising demand the main cause of water quality problems?** It is an **indirect** cause: more people, more irrigation and more industry produce more sewage, fertiliser and waste, and lower river flows dilute them less. But the **direct** causes are how waste is **managed**: whether sewage is treated, whether factories are regulated and fined, whether farms use less fertiliser. That depends on **money**, **governance** and **technology**. HICs with high demand (the Netherlands, Singapore) have clean water because they treat it; LICs with low demand per person may have dirty water because they cannot. Natural causes (arsenic) have nothing to do with demand.

**Safe and affordable drinking water for all** (UN goal 6, by 2030) is possible **technically** (filters, chlorination, boreholes, piped schemes), and access has improved in most regions since 2000, but too slowly: the barriers are **cost**, **poverty** (the poorest pay most per litre, to water sellers), **conflict**, **rapid urban growth**, **climate change** and **competition** with farming and industry.

## Degradation of rural and urban environments

**Environmental degradation** is the decline in the quality of an environment (its soil, water, air, vegetation, wildlife or built environment), so it becomes less able to support life and human activity.

**Rural environments** are degraded by:

- **Overpopulation**: more people than the land can support with the available technology (the **carrying capacity** is exceeded), so fallow periods shorten, marginal land is farmed and fuelwood is cut faster than it grows (see the population note).
- **Poor agricultural practices**: **overgrazing** (vegetation stripped, soil trampled), **overcultivation** and **monoculture** (soil exhausted, erosion), ploughing **up and down slopes**, too much **fertiliser and pesticide** (water pollution), and **irrigation without drainage** (waterlogging and **salinisation**).
- **Deforestation**: for farming, ranching, logging, fuelwood and plantations. Without tree cover, interception falls, so **runoff** and **soil erosion** rise, rivers **silt up** and flood more, nutrient cycles break, habitats are lost and local rainfall may fall.
- Also **mining** and quarrying (spoil, toxic runoff), **dams** and **climate change** (drought, extreme rain).

**Urban environments** are degraded by:

- **Urbanisation**: rapid growth outruns planning, so **informal settlements** grow on unsafe land without sewers; **sprawl** covers farmland and wetlands; traffic grows.
- **Industrial development**: factories, power stations and brick kilns pollute air and water, especially where regulation is weak. The **Pearl River Delta** in southern China grew into one of the world's largest manufacturing regions from the 1980s, with severe air and water pollution, which tighter laws and moving heavy industry out have since reduced.

- **Inadequate waste management**: open dumps, burning of waste, blocked drains that cause flooding, leachate polluting groundwater. Delhi's **Ghazipur** landfill grew to about 65 m high; part of it collapsed in 2017, killing two people.

## Constraints on improving degraded environments

A **constraint** is anything that **holds back** improvement. It is **not the same** as a **cause** of degradation: examiners report many answers that list causes when the question asks about constraints. A cause can **also** be a constraint when it **cannot be removed** (population growth keeps adding pressure while you are trying to fix the damage).

| Type | Constraints |
|---|---|
| **Physical (environmental)** | The **scale** of the damage; **remoteness** and access; climate (drought slows regrowth); slow natural recovery (soil forms over centuries); pollutants that persist (heavy metals, radioactivity); natural hazards |
| **Economic** | **Lack of capital** for clean-up and new technology; the cost of **maintenance** and monitoring; livelihoods that **depend** on the damaging activity (cotton farming, charcoal selling); poverty, so short-term survival comes first |
| **Social** | **Population growth**; low awareness and education; attitudes and traditions; lack of trust in authorities; unwillingness to change |
| **Political** | Weak **enforcement** of laws; **corruption**; other priorities (economic growth first); **instability** and conflict; **transboundary** causes, where the source is in another country or region; many agencies with unclear responsibility |
| **Technological** | Lack of expertise or suitable technology; solutions that work in one place but not another |

**Issues created by the attempts themselves**: schemes can **displace** people, **move** pollution elsewhere (dirty industry moved to poorer regions), create **conflict** between stakeholders, or have **side effects** (a dam built to supply irrigation water may waterlog and salinise land). Solutions often need to be **sustainable**: affordable to maintain, supported by local people, and addressing the **source**, not just the symptoms.

## Protecting environments at risk

An **environment at risk** is one whose ecosystems or resources are likely to be damaged by human activity or natural change unless they are protected: coral reefs, rainforests, wetlands, islands, mountains, polar regions. Questions use **needs** (why protect it), **measures** (how) and **outcomes** (with what result).

- **Needs**: high **biodiversity** and **endemic** species; **ecosystem services** (water supply, flood control, carbon storage, fisheries); livelihoods (tourism, fishing); cultural value; damage that would be **irreversible**.

- **Measures**: **protected areas** (national parks, marine reserves) with **zoning**; **laws** (hunting bans, fishing quotas); **limits on access** (permits, visitor caps, fees); **removing invasive species** and restoring habitats; **education**; **community-based management** that gives local people a share of the benefits; **international agreements** (World Heritage sites, the Ramsar Convention on wetlands of 1971, CITES on trade in endangered species).
- **Outcomes**: judged by the state of the environment (species numbers, habitat area), by **who gains and loses**, and by whether protection **lasts** when money or attention runs out.

**Example: the Galápagos Islands, Ecuador.** Volcanic islands about 1000 km off the coast of Ecuador, with many **endemic** species (giant tortoises, marine iguanas). **Needs**: tourism and a growing population (about 30 000 residents) brought **invasive species** (goats, rats, blackberry) and illegal fishing; visitor numbers rose from about 40 000 in 1990 to about 270 000 in 2019. **Measures**: a **national park** (1959) covering about 97% of the land, and a **marine reserve** (1998), later enlarged; visits only with licensed guides at fixed sites; limits on cruise ship size; checks on goods brought in (**biosecurity**); a visitor **entry fee**, doubled to 200 US dollars in 2024; **eradication** of goats from several islands by 2006 and of rats from Pinzón Island (2012), after which young tortoises survived there in the wild for the first time in over a century. **Outcomes**: UNESCO placed the islands on its list of World Heritage **in danger** in 2007 and removed them in 2010 after improvements; tortoise numbers are recovering. But invasive species keep arriving, tourism and population keep growing, and foreign fishing fleets work just outside the reserve. Management has prevented the worst, but only by constant effort and money, much of it from tourism, itself a threat.

## Case study: a degraded environment, the Aral Sea, Kazakhstan and Uzbekistan

**The environment.** In 1960 the Aral Sea in Central Asia was the world's **fourth largest lake**, about **68 000 km²**, fed by two rivers from the mountains, the **Amu Darya** and the **Syr Darya**. It supported a large fishing industry, based at **Muynak** (Uzbekistan) and **Aralsk** (Kazakhstan).

**Causes of degradation.** From the 1960s the Soviet government expanded **irrigation** in the deserts of Uzbekistan and Turkmenistan to grow **cotton** (and rice in Kazakhstan), taking water from both rivers through thousands of kilometres of canals, such as the **Karakum Canal**. Most canals were **unlined**, so much water leaked or evaporated. With little river water reaching it, the sea **shrank**: it split into a northern part (in Kazakhstan) and a southern part by about 1990, and by the 2010s held only about a tenth of its former volume; the eastern basin of the South Aral **dried out completely in 2014**.

**Problems.**

- **Environmental**: the water became **saltier** (over 100 grams per litre in the South Aral, saltier than the ocean), so most fish species died; a new desert, the **Aralkum**, formed on the dry sea bed; **dust storms** carry salt and pesticide residues hundreds of kilometres; the **climate** became more extreme (hotter summers, colder winters, a shorter growing season); river deltas and wetlands dried; irrigated land became **salinised** and waterlogged.
- **Economic**: the fishing industry **collapsed**; Muynak is now over 100 km from the water, with ships left on the sand; farmland yields fell with salinity.
- **Social**: high rates of **respiratory disease**, anaemia and other illness in Karakalpakstan (north-west Uzbekistan), linked to dust and polluted water; out-migration.

**Attempts to improve it and their evaluation:**

1. **The Kok-Aral Dam (Kazakhstan, 2005).** A **13 km dyke**, funded mainly by a World Bank loan and the Kazakh government, separates the **North Aral** from the south, so the Syr Darya's water is kept in the north. Together with repairs to the river's channels, it raised the North Aral to its target level of **42 m above sea level** within months, far sooner than expected, lowered its salinity and brought the shore much closer to Aralsk. **Fish returned**, commercial fishing restarted and local incomes and climate improved. It was **cheap** (under 100 million US dollars), **quick** and supported locally. But it **sacrificed** the South Aral, which now gets even less water, and only one country controlled the river at that point. A second phase to raise the level further is planned.
2. **Restoring the South Aral**: given up. Saving it would need much more river water, which would mean **cutting irrigation** upstream, the base of Uzbekistan's and Turkmenistan's farm economies.
3. **Planting on the dry sea bed (Uzbekistan, especially since 2018)**: drought-tolerant **saxaul** shrubs were planted to fix the dust; by Uzbekistan's own figures, well over a million hectares. This reduces dust and salt storms, but survival rates are uncertain, and it treats the **symptom**, not the cause.
4. **Better irrigation**: lining canals, drip irrigation and switching some land from cotton to less thirsty crops (Uzbekistan has reduced its cotton area). Slow and costly for poor farmers.
5. **Cooperation**: the **International Fund for Saving the Aral Sea** (1993) brought together the five Central Asian states, but they disagree over water (upstream countries want it for HEP in winter, downstream ones for irrigation in summer), and a new canal in **Afghanistan** (the Qosh Tepa, begun in 2022) will take more water from the Amu Darya.

**Constraints**: the **scale** of the damage; the **transboundary** rivers shared by several countries; **economic dependence** on irrigated cotton; **population growth** in Central Asia raising water demand; the **cost**; and **climate change** shrinking the mountain glaciers that feed the rivers.

**Judgement.** Improvement has been **real but partial**: the **North Aral** shows that a degraded environment can recover quickly when the **cause** is removed at a **small scale** by **one government** with a clear plan; the **South Aral** shows that when the cause is the economy of several countries, **political and economic constraints** outweigh the technical ones. The solution (more water) is simple to state but very hard to achieve.

## Key facts and formulas

There is no formula list in Paper 4, so learn all of these.

| Formula | Status |
|---|---|
| Share of a source $= \dfrac{\text{output from the source}}{\text{total output}} \times 100$ | Learn it |
| Percentage change $= \dfrac{\text{new} - \text{old}}{\text{old}} \times 100$ (negative for a fall) | Learn it |
| Amount per person = total ÷ population (electricity in kWh per person; water in m³ per person per year) | Learn it |

| Formula | Status |
|---|---|
| Capacity factor $= \frac{\text{energy generated in a year (MWh)}}{\text{capacity (MW)} \times 8760} \times 100$ (there are 8760 hours in a year) | Learn it |
| Units: 1 TWh = 1000 GWh = 1 000 000 MWh; power is measured in MW, energy in MWh | Learn it |
| Water available per person per year: over 1700 $m^3$ no stress; 1000–1700 $m^3$ **water stress**; 500–1000 $m^3$ **water scarcity**; under 500 $m^3$ **absolute scarcity** | Learn it |
| World freshwater withdrawals: about 70% agriculture, 20% industry, 10% domestic | Learn it |
| World electricity, 2023: fossil fuels about 60% (coal about a third); hydro about 14%; nuclear about 9%; wind about 8%; solar about 5% | Learn it |

| Term and meaning | Status |
|---|---|
| **Non-renewable resource**: a stock used up as it is used (coal, oil, gas, uranium) | Learn it |
| **Renewable resource**: a flow replaced naturally as it is used (HEP, wind, solar, geothermal, biofuels) | Learn it |
| **Energy mix**: the share of each source in a country's energy or electricity supply | Learn it |
| **Energy security**: a reliable, affordable supply of energy that is not at risk of being cut off | Learn it |
| **Sustainable energy supply**: one that meets today's needs without harming future generations' ability to meet theirs, affordably and with little environmental damage | Learn it |
| **Overall electrical energy strategy (OEES)**: a country's whole plan for electricity supply and demand | Learn it |
| **Baseload**: the minimum demand, met by plants that run all the time; **peak load**: the highest demand, met by plants that can start quickly | Learn it |
| **Curtailment**: cutting back output from a power station because demand or the grid cannot take it | Learn it |
| **Pollution**: the release of substances or energy into the environment in amounts that harm living things | Learn it |
| **Point source**: pollution from one identifiable place; **non-point (diffuse) source**: pollution spread over a wide area | Learn it |
| **Eutrophication**: nutrient enrichment of water, causing algal blooms and loss of oxygen | Learn it |
| **Temperature inversion**: a layer of warm air above cooler air, which traps pollution near the ground | Learn it |

| Term and meaning | Status |
|---|---|
| **Physical water scarcity**: not enough water to meet demand; **economic water scarcity**: water exists but cannot be delivered for lack of money or infrastructure | Learn it |
| **Environmental degradation**: a decline in the quality of an environment, so it supports life and people less well | Learn it |
| **Carrying capacity**: the largest population an area can support without being degraded | Learn it |
| **Constraint**: something that holds back the improvement of an environment | Learn it |

## How to do it

We have tagged 87 questions for this topic (2021–2025, all Paper 4), 60 different (the variants 41, 42 and 43 often share questions). Every Question 4 (29 of them) has a data part (a) and an explain part (b), so it counts under two types and the counts add up to 116. For essays, the count in brackets is of different questions.

| Question type | Questions |
|---|---|
| **Describe or compare data in a graph, map or table** | 27 |
| Essay: constraints and problems in improving degraded environments | 11 (7 different) |
| **Explain why energy use or choice varies, or how energy security is achieved** | 10 |
| Essay: how far one factor decides energy mix or electricity demand | 9 (6 different) |
| Essay: one country's overall electrical energy strategy | 7 (5 different) |
| Essay: is an energy source or approach a sustainable solution? | 7 (5 different) |
| **Explain environmental impacts or problems of energy sources** | 7 |
| Essay: success of one named located electricity scheme | 6 (4 different) |
| **Explain causes of degradation, water pollution or lack of safe water** | 6 |
| **Explain ways to protect, improve or supply, or constraints on doing so** | 6 |
| Essay: success of attempts to improve degraded environments | 5 (3 different) |
| Essay: water quality, water supply and safe drinking water | 5 (4 different) |
| Essay: protecting environments at risk | 4 (3 different) |
| Essay: causes and scale of pollution or urban degradation | 4 (3 different) |
| **Use a photograph to suggest reasons for a location** | 2 |

Marking: Question 4(a) gives **1 mark for each accurate point** (3 or 4 marks), often with a mark kept for the **overall change or relationship** and a cap (2 or 3) without **data**; one point may be developed for a second mark. Question 4(b) (6 or 7 marks) is marked in **three levels** (Level 3, 5–6 marks: two reasons, ways or

impacts, each **clearly explained**, with examples; one reason alone earns at most 4). The 20-mark essays are marked in **four levels** (Level 4, 16–20 marks: sustained evaluation and a sound conclusion, detailed examples integrated), with a **maximum of 8 without examples**.

## 1. Describe or compare data in a graph, map or table (27 questions)

Figures: **line or stacked graphs** (renewables' share of world electricity, people without basic drinking water, fine particulates), **maps** (solar generation, e-waste per person, gas pipelines, lead pollution), **bar charts and tables** (biofuel growth, carbon capture capacity, HEP output in two years, water use by sector).

1. **The main change or overall pattern first**: rising or falling overall, how far, the **direction** of a relationship (falls with distance: a negative relationship). Many schemes keep a mark for this.
2. **Then detail**: the largest and smallest, the fastest change, changes of rank, with **values and units** ("solar rose from 2% to 9%", "about 350 million fewer people"). Manipulate the data: differences, totals, "almost doubled".
3. **Anomalies**: the one region or source that moves the other way.
4. **Don't list**: going through every country, region or source one by one, or copying numbers off the graph, earns 1–2 marks at most.

Variants:

- **"Compare"**: every point links both sets ("North America has the most capacity under construction, **whereas** Europe has the most planned"); describing one set then the other earns little. Similarities count too.
- **"Distribution"** (maps): **clustered** or **dispersed**, which continents and hemispheres, **between the tropics** or not, isolated examples; counting countries needs a comment ("most of the cluster is in Africa").
- **"Regional variations"**: group by **regions** (continents, parts of continents, hemispheres), not individual countries, and not HICs and LICs (those are categories, not regions).
- **"Main changes"**: the big picture (total, the main source overtaking another), not each line in turn.
- **"Relationship"**: state it (negative or positive), back it with two or three values, then the **exception**.
- **Read the axes and key carefully**: a bar may show a **range** (lowest to highest), not a total; a year may start in October; the units may be per person or a percentage.

## 2. Essay: constraints and problems in improving degraded environments (11 (7 different) questions)

Statements: "there are always solutions to the problems", "overpopulation is the most important constraint", "problems are caused by a lack of capital", "physical factors are the greatest constraint", "removing the constraints is important for success", "the causes are complex but the solutions simple", "overcoming issues created by the attempts is important".

1. **Introduction**: define **degraded environment** and **constraint** (what holds back improvement, not what caused the damage), and name your environment(s).

2. **Set the context**: one or two clearly **located** degraded environments, with the type of degradation (land, air, water) and what has been tried (the Aral Sea; Mexico City's air; the Thames).
3. **The named factor first, in depth**: for overpopulation, how continued growth adds pressure faster than repairs can keep up (Central Asia's growing demand for irrigation water); for capital, the cost of the Kok-Aral Dam compared with the far larger cost of saving the South Aral; for physical factors, scale, climate and remoteness (the Aralkum's size and dryness).
4. **Other constraints, sorted**: physical, economic, social, political (the table in "Understand it"), each linked to **your example**.
5. **Weigh them**: which is the **root** constraint (often political or economic: water stays in cotton fields because the economy depends on it); how they **interact** (poverty makes population pressure worse); how the answer **varies** by place, scale, LIC or HIC, and type of degradation.
6. **Conclude**: answer the statement directly ("always"? "the most important"?).

Variants:

- **"Always solutions"**: solutions exist **technically**, but are they affordable, accepted, lasting? Some damage is **irreversible** (lost species, the South Aral).
- **"Causes complex, solutions simple"**: causes often interact (circular causation: poverty → overuse → more poverty); the solution may be simple **to state** (stop the source) but hard to **carry out** because of profit, tradition and politics.
- **"Issues created by the attempts"**: displacement, cost, pollution moved elsewhere, losers (the South Aral after the Kok-Aral Dam), conflict; and whether overcoming them decides success.

## 3. Explain why energy use or choice varies, or how energy security is achieved (10 questions)

Asked: two reasons countries **rely** on fossil fuels; reasons for high renewable output in some countries; why HEP use varies between countries; why HEP output varies through the year; why carbon dioxide emissions vary; factors in an HIC's choice of energy source; why off-grid sources help LICs and MICs; three ways to achieve energy security.

1. **Pick two (or the number asked) reasons and develop each**: the reason → how it works → an example with a detail. One reason alone earns at most 4.
2. **Answer the context word**: "**rely**" (why they can't easily switch: existing plants, jobs, cheap local supply, exports funding the economy); "**between countries**"; "**HICs**" (they can afford to choose, public opinion); "**seasonally**".
3. **Use the factor list**: resource endowment, climate and physical geography, affluence and cost, demand and stage of development, policy and targets, technology.

Variants:

- **HEP between countries**: rivers with **high, reliable flow** (high rainfall all year, or snow and glacier melt from mountains) and **relief** (steep gradients, large falls in height, **narrow gorges** easy to dam); plus capital (or aid, and small schemes, so poorer countries do use HEP) and demand. Not just "rainy and

mountainous".

- **HEP through the year**: rainfall seasons, snowmelt in spring, freezing in winter, evaporation in summer, and **demand** (reservoirs store water, so output may follow demand, not river flow).
- **Off-grid in LICs and MICs**: extending the grid to remote villages is very expensive; solar home systems and mini-grids are cheap, quick and local, and pay-as-you-go makes them affordable (Kenya; micro-hydro in Nepal).
- **Energy security**: diversify, domestic sources, secure imports and pipelines, storage, cut demand; more than "produce more".

## 4. Essay: how far one factor decides energy mix or electricity demand (9 (6 different) questions)

Factors named: level of development (the energy mix), why fossil fuels stay important, sustainability (supply), climate (demand at the national scale, the type of energy used, trends in demand for renewables).

1. **Define** the key terms: energy mix, demand or supply, and the named factor.
2. **The named factor in depth**, with **country examples**: for climate, HEP needs rain and relief, solar needs sunshine, and **climate change** drives policy; for development, the coal of industrialising India against the renewables of Germany.
3. **Other factors**: resource endowment, income, technology, pollution, policy, energy security, international targets (the table in "Understand it").
4. **Show interaction** (examiners reward this from mid-Level 3): a country's level of development shapes the money for technology; resource endowment shapes policy.
5. **Conclude**: which factor matters **most**, for **which kind** of country.

Variants:

- **Climate and demand**: keep to **demand** (heating and cooling, seasonal peaks, air conditioning in hot countries); examiners report answers that write only about supply.
- **Why fossil fuels stay important**: large **reserves** and cheap local supply (South Africa's coal); **existing plants and grids** built for them; **reliable** baseload and backup when wind and solar vary; rapid demand growth in industrialising MICs (China, India); the high cost of switching; nuclear not an option for many; jobs and exports. Evaluate with countries **trying** to move away.
- **Sustainability and supply**: weigh it all through the essay, not in one paragraph; countries that set out to be sustainable but fell back (Germany burning more coal briefly in 2022).

## 5. Essay: one country's overall electrical energy strategy (7 (5 different) questions)

Asked: how far environmental impacts are the most important consideration; how far changes in the location of power production led to issues; success in overcoming issues in power production; how far environmental impacts were overcome; reducing environmental impacts as a factor.

1. **Name one country and outline its OEES**: supply (mix, where power stations are, the grid, off-grid, imports) **and** demand (prices, efficiency, conservation, access). A single scheme or the energy mix alone keeps the answer in Level 2.
2. **The issues it tackled**, with dates and figures (Kenya: drought rationing, diesel, low access, rising demand, distant resources).
3. **Address the named idea**: environmental impacts (Kenya rejected coal at Lamu; but geothermal displaced people); **location changes** (new power far from demand needs long lines, as at Lake Turkana; local opposition).
4. **Evaluate**: success against **criteria** (reliability, cost, access, emissions, energy security), for different **groups**.
5. **Conclude**.

## 6. Essay: is an energy source or approach a sustainable solution? (7 (5 different) questions)

Asked: nuclear power, or HEP, "offers a sustainable solution for issues in energy production"; renewables are the best way to energy security for LICs and MICs; technology can reduce the impacts of energy production, transport and usage; MICs' energy consumption has become a global issue.

1. **Define sustainable** (economic, social, environmental), and say what the **issues in energy production** are (meeting demand, cost, emissions, security, access).
2. **For** the source, against each issue, with **scheme or country examples** (HEP: Norway's 90% hydro, cheap, clean, flexible; nuclear: France's low-carbon supply; small imports of uranium give a lot of energy).
3. **Against**: HEP's displacement, sediment loss, methane, droughts cutting output (Zambia and Zimbabwe), transboundary conflict over rivers (Ethiopia's Grand Renaissance Dam on the Nile); nuclear's waste, accidents, cost and delays (Hinkley Point C), weapons risk.
4. **Compare** with other sources, and vary by **scale** (micro-hydro in Nepal against giant dams), **place** and **stakeholder**. A list of pros and cons is not an evaluation.
5. **Conclude**: sustainable **where** and **when**? (HEP: sustainable at a good site with care; fusion maybe in the future.)

Variants:

- **Technology**: cover **production** (carbon capture, cleaner plants), **transport** (better pipelines, high-voltage lines, electric vehicles) and **usage** (efficient appliances, smart meters); against: cost, slow uptake, the poorest left out.
- **MICs as a global issue**: China and India's growing coal use and emissions (China is now the largest emitter); but their emissions per person are lower than many HICs, and they install the most renewables.

## 7. Explain environmental impacts or problems of energy sources (7 questions)

Asked: two environmental impacts of biofuels (positive or negative); two environmental problems of using renewables for electricity; problems of renewables other than carbon dioxide; three negative impacts of wind turbines.

1. **Choose two impacts and explain the mechanism**: what happens, why, and the effect on air, water, land or wildlife, with a place (palm oil plantations replacing rainforest in Indonesia → loss of habitat for orangutans and release of carbon from peat soils).
2. Use **any stage**: growing the crop, building the plant, running it, disposing of it (blade and panel waste).
3. Keep to **environmental** impacts when asked (not cost), and develop each; one impact alone earns at most 4.

## 8. Essay: success of one named located electricity scheme (6 (4 different) questions)

Asked: success overall; in overcoming changes in demand and supply; in meeting changes in demand; how far the issues of its location affected its success.

1. **Name and locate** one scheme (Lake Turkana Wind Power, Loiyangalani, northern Kenya), with its size, date, cost and purpose. A country's strategy without a named scheme scores very little.
2. **Criteria** for success: output and reliability; meeting demand (and **changes** in demand over the day, the season and the years); cost and value; environmental and social impacts; who benefits.
3. **Issues**: of **location** (distance from users, land rights, wildlife, access for building), of **supply** (wind varies, droughts for HEP, fuel for thermal), of **demand** (whether it grew as expected; night-time surplus).
4. **Balance**: choose a scheme that has run for some years (one still being built, such as Hinkley Point C, gives little evidence), and know its problems too.
5. **Conclude** on how far it succeeded and why.

"Changes in demand" means **changes**: daily peaks, seasons, growth over time, not demand in general (the examiners reward this).

## 9. Explain causes of degradation, water pollution or lack of safe water (6 questions)

Asked: two factors that degrade rural environments; two causes of water pollution; reasons why more people in a region may lack basic drinking water.

1. **Two causes, each developed**: the source → how it reaches or damages the environment → the result, with an example.
2. For **water pollution**, explain **where** the pollutant comes from and **how** it gets into the water (fertiliser washed off fields by rain into rivers); the effects are not needed. Naming two sources earns 1 mark.
3. For **lack of drinking water**: population growth faster than new supply, poverty, the cost of infrastructure, poor management, pollution, drought and climate change, conflict forcing people to move (Sudan), competition from farms and industry.

## 10. Explain ways to protect, improve or supply, or constraints on doing so (6 questions)

Asked: two ways environments at risk are protected; two methods to improve air quality; how countries increase water supply; two constraints on improving degraded environments.

1. **Two ways, each with how it works and an example**: low-emission zones (London's **ULEZ**, from 2019, extended across all of London in 2023, charging older, more polluting vehicles); clean air laws; public transport; cleaner fuels; scrubbers.
2. **Link to the target**: for air quality, explain how the method **reduces the pollutants people breathe**, not greenhouse gases in general; tree planting needs its local effect (trapping particulates, shade), not just "absorbs $CO_2$".
3. **Water supply "for countries"**: national-scale schemes (desalination, transfers, large reservoirs, recycling) or extending supply to areas without it.

## 11. Essay: success of attempts to improve degraded environments (5 (3 different) questions)

Asked: the success of attempts to improve **one** degraded environment; whether urban environments are easier to improve than rural ones; whether future generations pay for unsustainable management now.

1. **One clearly located environment** degraded by mismanagement (the Aral Sea, the Pearl River Delta). Cover land and water quality too, not only air. Examiners warn against case studies about abandonment and new buildings (London's Docklands) or taught as all success.
2. **At least two attempts**, each judged by **criteria**: cause removed, damage reversed, slowed or only managed? Who gained and lost? Cost? Lasting?
3. **Balance** successes against failures (North against South Aral) and conclude.

Variants:

- **Urban against rural**: urban areas have **money, institutions and attention** (Mexico City, the Thames), but also **density**, many polluters, fast growth and many stakeholders; rural areas are **large, remote** and poor, with fewer sources (the Aral Sea). Use both; judge by type of degradation and HIC or LIC.
- **Future generations**: show what sustainable management looks like and give examples of costs passed on (the South Aral, depleted aquifers).

## 12. Essay: water quality, water supply and safe drinking water (5 (4 different) questions)

Asked: rising demand as the main cause of water quality issues; whether safe and affordable drinking water can be provided for all; whether water quality is more of an issue than water supply for many countries; the role of economic factors in water pollution in LICs and MICs.

1. **Define** the key terms (water quality, supply, safe, affordable) and give the context: use by sector (about 70% farming), numbers without safe water.

2. **The named factor**: rising demand (population, industry, diet, irrigation) and **how** it affects quality (more waste, less dilution).
3. **Other factors**: sanitation and treatment, poverty and governance, natural contamination, climate change, transboundary pollution.
4. **Vary it**: LIC against HIC, rural against urban, named countries (Bangladesh's arsenic, Singapore's recycling, Cape Town's drought).
5. **"For all"**: cover **safe**, **affordable** and **for all**; show what makes it possible (boreholes, filters, desalination, NEWater) as well as the difficulties.
6. **Conclude**.

For **economic factors in LICs and MICs**: firms dump waste because treatment costs money; governments put growth first; poverty means no sewers; but **political** factors (weak enforcement, corruption) let it happen.

## 13. Essay: protecting environments at risk (4 (3 different) questions)

Asked: "environments at risk can be protected by effective management"; protection depends on overcoming constraints; education is the most important factor.

1. **Identify** the environment and its **risks** (the Galápagos: invasive species, tourism, fishing).
2. **Management** at each **scale**: international (World Heritage, CITES), national (parks, laws), local (guides, community schemes).
3. **What makes it effective** (tackling the **source**, restoring damage, money, enforcement, local support) and what **hinders** it (cost, opposition, risks from outside the area, slow results).
4. For **education**: weigh it against laws, money and enforcement (education changes behaviour slowly; laws act faster but need enforcing).
5. **Conclude**: can management protect, or only slow the damage?

## 14. Essay: causes and scale of pollution or urban degradation (4 (3 different) questions)

Asked: whether urbanisation is the main factor in degrading urban environments; whether a global view is needed to solve pollution; whether high economic development always means good air quality.

1. **Define** the terms and set up the factors.
2. **Urban degradation**: urbanisation against industrial development, waste, poor planning, poverty, and sources outside the city (crop burning upwind of Delhi); how they **interact**.
3. **A global view**: some pollution is **global or transboundary** (greenhouse gases, acid rain, ocean plastics) and needs agreements; much is **local** (a city's smog, a river) and is solved by local action (Mexico City, the Thames); HICs' responsibility for climate change and its effects on LICs.
4. **Development and air quality**: HICs usually cleaned up (London after 1952, Clean Air Act 1956), but development **not always** means good air (traffic in HIC cities, ozone, wildfire smoke; MICs at the polluting stage); keep greenhouse gases out unless linked to air quality.
5. **Conclude**.

### 15. Use a photograph to suggest reasons for a location (2 questions)

Asked once: why wind turbines were sited where a photograph shows them.

1. **One reason per mark, each backed by something you can see**: an **exposed ridge** or hilltop (high, steady winds), open land with **no trees or buildings** to slow the wind, **no settlements** nearby (noise, visual impact), low-value land (rough grazing), access roads, a flat top for building.
2. **Suggest** means apply knowledge to the photograph; don't describe things that are not shown.

## Worked examples

### Example 1

Diagram 1 (in "Understand it") shows the share of electricity generated by each source in three model countries. Country P generates 12 TWh a year for 50 million people, Q 900 TWh for 400 million and R 300 TWh for 60 million.

(a) Compare the electricity mixes of countries P, Q and R. **[4]**

(b) Explain two difficulties a country faces in increasing the share of wind and solar power in its electricity mix. **[6]**

**(a)** One mark for each comparison; data needed for full marks.

- Fossil fuels dominate in Q (70%: coal 62% and gas and oil 8%), whereas they are a minority in R (38%) and small in P (12%) **(1)**.
- P relies on hydro (70%), whereas hydro is only 13% in Q and 2% in R **(1)**.
- R has the largest share of wind and solar, 36%, more than three times the shares in Q (10%) and P (8%) **(1)**.
- Only Q and R use nuclear power, R much more (18% against 5%) **(1)**.
- Development: R generates 5000 kWh per person, about 21 times P's 240 kWh; Q's coal alone (558 TWh) is more than R's whole output **(1, if a point above is missing)**.

**(b)** A model answer.

The first difficulty is that wind and solar output **varies** and cannot be switched on when needed. Solar produces nothing at night, and wind output rises and falls with the weather, but demand has its own pattern, with an evening **peak** after sunset (as in Diagram 2, where demand peaks at 2000 MW at 20:00). So a country needs **backup** from plants that can start quickly, such as hydro or gas, or **storage** in batteries or pumped-storage reservoirs, which adds cost. Germany kept coal and gas plants open as backup while renewables grew to more than half its electricity. Without this, a high share of wind and solar risks blackouts.

The second difficulty is **the grid and the money to build it**. The best wind and solar sites are often **far from cities**, so long new power lines are needed: Lake Turkana Wind Power in northern Kenya needed a 428 km line, and when the line was delayed, the turbines stood idle for about a year while Kenya paid for power it could

not use. Wind and solar also have high **up-front costs**, even if their running costs are low, so MICs and LICs with little capital and high interest rates find them hard to finance, and countries with coal plants already built (country Q's 62% coal) face lost jobs and unused plants if they switch.

**Level 3 (5–6 marks)**: two difficulties, each clearly explained with how it arises and its effect, supported by located examples.

## Example 2

Explain two causes of poor air quality in large cities in LICs and MICs. **[6]**

The first cause is **road traffic**. As incomes rise, car and motorbike ownership in cities grows much faster than roads and public transport, so congestion is severe and engines idle in queues. Many vehicles are **old**, poorly maintained and run on low-quality diesel, so they release large amounts of **nitrogen dioxide** and fine **particulates** (PM2.5), which get deep into people's lungs. In Mexico City, rising car numbers kept ozone and particulates above guidelines even after a ban kept each car off the road one day a week, because many families bought a second car.

The second cause is **industry and burning**, made worse by weak regulation. Factories, small workshops, brick kilns and coal power stations on the edge of growing cities often burn coal or waste without filters, because cleaner technology costs money and laws are poorly **enforced**. Households without electricity or gas cook with wood or charcoal, and rubbish is burnt in the open where collection services cannot keep up. In Delhi, these local sources combine with smoke from crop burning upwind in October and November; calm, cold winter air and **temperature inversions** then trap the pollution near the ground, so PM2.5 levels reach many times the WHO guideline.

**Level 3 (5–6 marks)**: two causes clearly explained, each with how the pollutants are produced and why they build up in LIC and MIC cities, with located examples.

## Example 3

'The main constraint on improving a degraded environment is that the causes of its degradation lie outside the area being managed.' With reference to one or more examples, how far do you agree? **[20]**

**Introduction.** A degraded environment is one whose soil, water, air or ecosystems have declined in quality so that it supports life and people less well. A constraint is anything that holds back its improvement. The statement claims that the main constraint is **distance from the cause**: the damage is in one place, but its cause is somewhere else, beyond the control of those managing it. I will test this against the Aral Sea in Central Asia, and Mexico City's air, and weigh it against economic, political and physical constraints.

**The case for: the Aral Sea.** The Aral Sea shrank from about 68 000 km² in 1960 to a fraction of that because its two feeding rivers were diverted for cotton irrigation **hundreds of kilometres upstream**, in Uzbekistan and Turkmenistan. The damage (salty water, dust storms from the dry bed, a collapsed fishing industry at Muynak and Aralsk) is at the sea, but the cause is in the irrigated fields. Kazakhstan, at the northern end, could not stop that. What it **could** do was keep the Syr Darya's water, which flows through its own territory, in the North Aral: the Kok-Aral Dam (2005) raised the level to 42 m within months, brought fish back and revived the fishing

industry. The South Aral could not be saved because its cause, irrigation along the Amu Darya, lies in other countries, and a new Afghan canal taking yet more water makes it worse. This strongly supports the statement: **where the cause was within reach, improvement followed; where it was outside, it did not.**

**Other support.** Delhi's worst smog in October and November is partly smoke from crop burning in neighbouring states, beyond the city's control; acid rain in Scandinavia fell after British and German power stations fitted scrubbers and switched fuels, under international agreements.

**The case against: causes inside the area.** Mexico City's air pollution comes mainly from its own vehicles and industry, and the city acted: driving restrictions from 1989, unleaded petrol, closing a refinery, the Metrobús. Lead and sulfur dioxide fell sharply, but ozone and particulates remain high because car numbers kept growing with population and incomes. The constraint here was **economic and social** (growth and dependence on cars), not distance.

**Other constraints. Economic**: even at the Aral Sea, the deeper reason the rivers stay diverted is that cotton earns income and employs millions; Uzbekistan would have to sacrifice its farm economy to refill the sea. **Political**: the five states have cooperated through the International Fund for Saving the Aral Sea since 1993, but disagree over water, so a **transboundary** cause is really a political constraint. **Physical**: the South Aral's scale and the desert climate mean that even with water, recovery would take decades; planting saxaul on the dry bed fixes dust but cannot restore a sea. **Capital**: the Kok-Aral Dam cost under 100 million US dollars, affordable with a World Bank loan, but replacing irrigation across Central Asia would cost vastly more.

**Evaluation.** Distance from the cause matters because it makes the problem **political**: those suffering the damage cannot control those causing it. So it is less a separate constraint than a **form** of political and economic constraint: the causes lie outside because someone else profits from them. Its importance varies by **type**: greatest for **water** (rivers carry pollution and water use downstream) and **air** (winds carry pollution), smallest for **land** degradation, whose cause is usually on the land itself.

**Conclusion.** I agree only in part. External causes are a major constraint where rivers or winds link places, as the contrast between the North and South Aral shows clearly. But the **main** constraint is usually **economic and political**: whether those who cause the damage have reasons and power to stop. Even causes inside the area, as in Mexico City, are hard to remove when livelihoods and growth depend on them.

**Level 4 (16–20 marks)**: the named constraint discussed in depth with detailed, located evidence; weighed against other constraints and linked to them; the variation by type of degradation; and a conclusion that answers "how far".

## Common mistakes

- **Writing about causes when the question asks about constraints.** A constraint holds back improvement; say why the cause **cannot be removed** if you use it.
- **Reading "physical factors" as human strength or buildings**: they are natural conditions (climate, relief, scale, remoteness).
- **Confusing an OEES with one scheme**, or with the energy mix: the strategy covers supply, demand, the grid and access; the scheme is one named, located power station.

- **Writing about supply when the question asks about demand** (climate and demand essays), and about demand in general when it asks about **changes** in demand.
- **Describing each energy source in its own paragraph** without evaluating.
- **Region-by-region or country-by-country lists** in Question 4(a), copying data without manipulation, misreading what bars show (a range, not a total), or treating HICs and LICs as "regions".
- **Generic answers** that ignore the context word ("HICs", "LICs/MICs", "rely", "for countries").
- **Simple HEP reasons** ("lots of rain and mountains"), and claiming LICs have no HEP because of cost (many do, often with aid).
- **Answering about greenhouse gases** in air quality questions, or saying energy security is just "producing more".
- **Using a degraded environment that is not really degraded by mismanagement** (London's Docklands), or a case study taught as all success, which leaves nothing to evaluate; or writing only about the air when the question is about the whole environment (cover land and water quality too).
- **Mixing up the chronology** of a country's energy policy, confusing gas with oil, or using a scheme still being built as evidence of success.

## How to get the marks

- **Command words. Describe** = what the figure shows, with data, no reasons. **Compare** = linked similarities and differences ("whereas", "both"). **Explain** = reasons and processes, cause and effect. **Suggest** = apply what you know to the figure or place. **Assess**, **evaluate**, **how far**, **to what extent** = weigh both sides and reach a judgement.
- **Question 4(a)**: main change or pattern first; then the extremes and changes, with values and units; manipulate the data; never list.
- **Question 4(b)**: Level 3 needs **two** reasons, ways or impacts, **each developed** with how it works and a **located example**; one reason caps the answer at 4; naming without explaining earns 1.
- **Essays**: define the terms; deal with the **named factor** in depth first; bring in the **other factors** and show how they **interact**; vary the answer by **place**, **scale**, **level of development** and **time**; use **detailed, located examples** (names, dates, numbers); end with a conclusion that answers "how far". Without examples the maximum is 8.
- **Case studies**: one named country (Kenya) for strategy essays, one named scheme (Lake Turkana Wind Power) for scheme essays, one named degraded environment (the Aral Sea) for degradation essays; each with balanced successes and problems.
- **Time**: Question 4 is 10 marks and the essay 20, so spend about twice as long on the essay, and leave time for its conclusion.

## Quick check

1. From Diagram 2, how much higher is the peak demand than the minimum, in MW and as a percentage of the minimum? For about how many hours is demand below the 1250 MW of geothermal and wind output?

2. A country's electricity comes from coal (150 TWh), gas (60 TWh), hydro (45 TWh), wind (30 TWh) and solar (15 TWh). What percentage comes from fossil fuels? If solar output grows to 45 TWh, what is the percentage increase in solar output?
3. A country has 42 $km^3$ of renewable fresh water a year and 28 million people. Calculate the water available per person and classify it. Above what population would it face water scarcity?
4. A 50 MW solar farm generates 105 GWh in a year. Calculate its capacity factor.
5. Explain why population growth can be both a cause of degradation and a constraint on improving it.

## Answers

1. Peak minus minimum $= 2000 - 1150 = 850$ MW, which is $\frac{850}{1150} \times 100 = 73.9\%$ of the minimum. Demand is below 1250 MW from about 01:30 to about 05:20, so for about 3.8 hours: that is when some geothermal and wind output must be curtailed.
2. Total $= 150 + 60 + 45 + 30 + 15 = 300$ TWh. Fossil fuels $= \frac{150 + 60}{300} \times 100 = 70\%$. Solar increase $= \frac{45 - 15}{15} \times 100 = 200\%$ (it trebles).
3. $42$ km³ $= 42\,000\,000\,000$ m³, so per person $= \frac{42\,000\,000\,000}{28\,000\,000} = 1500$ m³ a year: between 1000 and 1700, so **water stress**. Scarcity begins below 1000 m³ per person, which happens when the population passes $\frac{42\,000\,000\,000}{1000} = 42$ million.
4. Maximum possible output $= 50 \times 8760 = 438\,000$ MWh. Actual output $= 105$ GWh $= 105\,000$ MWh. Capacity factor $= \frac{105\,000}{438\,000} \times 100 = 24.0\%$, typical of solar, since there is no output at night.
5. As a **cause**, a growing population needs more food, water and fuel, so it farms marginal land, overgrazes and cuts trees faster than they regrow, beyond the carrying capacity. As a **constraint**, it keeps adding that pressure **while** the land is being restored: terraces or replanted trees must support more people every year, and demand for water (as in Central Asia) rises just as managers try to return water to the environment. The cause cannot simply be removed, so improvement must outpace it.

## Past questions to try

- **9696/43/O/N/24 Q5**: essay evaluating a named scheme's success with changes in demand and supply.
- **9696/42/O/N/24 Q5**: essay on whether environmental impacts are the most important consideration in a country's electrical energy strategy.
- **9696/43/M/J/24 Q4**: graph of people without basic drinking water, then reasons why the number may rise in a region.
- **9696/43/M/J/23 Q6**: essay assessing the success of attempts to improve one degraded environment.