Hydroelectric power: moving water

Moving or falling water can drive a turbine connected to a generator. River hydropower depends on the water cycle; tidal power uses the regular movement of ocean water.

THE ENERGY PATHWAY IN A RESERVOIR SYSTEM

Stored water (potential energy) → **Flowing water** (kinetic energy) → **Turbine shaft** (mechanical energy) → **Generator** (electrical energy)

Water passes through a penstock (pipe), turns the turbine and returns downstream. The generator converts shaft rotation into electricity; no fuel needs to burn.

1. DAM AND RESERVOIR: CONTROL THE RELEASE

An impoundment stores river water behind a dam. Releasing water through turbines generates electricity. Higher head (vertical drop) and greater flow generally allow more power, subject to equipment limits. Stored water can help operators adjust output, but water supply is finite.

2. RUN-OF-RIVER: USE THE AVAILABLE RIVER FLOW

A diversion system channels some river water through a canal or penstock to a turbine. Small in-stream turbines can also use flowing water. A large reservoir is not always needed, so there may be less inundation. Output still depends on river flow, and diversions can affect river habitats.

3. TIDAL POWER: USE OCEAN TIDAL FLOWS

The Moon and Sun, together with Earth's rotation, drive tides. Tidal-stream turbines harness currents; a barrage uses water-level differences across a basin. Tides are predictable but output varies through the cycle. Barrages can alter estuary habitats and water movement.

River flow, head and the energy pathway: US EIA, Hydropower Explained.
Impoundment and diversion systems: US DOE, Types of Hydropower Plants.
Tidal currents, barrages and estuaries: US EIA, Tidal Power.

Scope: College Board AP Environmental Science CED, Topic 6.9, p. 129.

Storage is not a new energy source

Extension: pumped-storage hydropower shifts energy from one time to another. Distinguish electricity used to lift water from electricity recovered when it flows back down.

PUMPED STORAGE: TWO DIRECTIONS, TWO ENERGY FLOWS

A. Charging: use electricity to raise water

Electricity input (from the grid) → **Motor + pump** (moves water uphill) → **Upper reservoir** (stores potential energy)

B. Discharging: release water to recover electricity

Water falls (to lower reservoir) → **Turbine** (drives the generator) → **Electricity output** (back to the grid)

The cycle can help meet later demand. Pumping and generating both involve losses, so the electricity recovered is less than the electricity used for pumping.

WORKED EXAMPLE: ROUND-TRIP EFFICIENCY

Illustrative cycle: 100 MWh in, 80 MWh returned



80 MWh recovered — 20 MWh lost

Efficiency = (electricity out ÷ electricity in) × 100%
= (80 MWh ÷ 100 MWh) × 100% = 80%.
Loss = 100 - 80 = 20 MWh. These are invented values, not a rating for every plant.

RENEWABLE DOES NOT MEAN UNLIMITED OR CONSTANT

Precipitation and runoff replenish river water, so conventional hydropower is renewable. Drought can reduce flow and reservoir levels, limiting generation. Pumped storage does not fix a long-term energy shortage: it must first receive energy to pump the water uphill.

Charging and discharging: US DOE, Types of Hydropower Plants.
Pumping losses, water cycle and drought: US EIA, Hydropower Explained.
Grid flexibility and renewable supply: US DOE, Benefits of Hydropower.

Scope: College Board AP Environmental Science CED, Topic 6.9, p. 129.

Renewable power, changed rivers

Evaluate the whole project: electricity benefits, construction costs, reservoir flooding and downstream effects. The best choice depends on the site, design and operation.

1. BENEFITS: FUEL-FREE GENERATION AND FLEXIBILITY

Generating electricity requires no fuel combustion, so there is no direct combustion smoke or ash. Reservoir plants can vary water release to help meet demand. A project may also support water supply, irrigation, flood management and recreation. Building dams is expensive, and these uses can compete for the same water.

2. TRACE THE ECOLOGICAL AND SOCIAL CHANGES

Flooding land can remove terrestrial habitat and displace communities. A barrier can block fish migration, while turbines may injure fish. Trapped sediment reduces its delivery downstream. Altered flow, temperature and dissolved oxygen can change aquatic habitats. These effects extend beyond the dam itself.

3. NO COMBUSTION DOES NOT MEAN ZERO EMISSIONS

Producing concrete and steel and constructing a dam can release greenhouse gases. Decomposing organic matter in reservoirs can release CO_2. Without oxygen, microbes can produce methane (CH_4). Reservoir emissions vary with local conditions; do not assume every project has the same footprint.

4. MATCH A RESPONSE TO THE SPECIFIC IMPACT

Fish ladders or bypass routes may help fish move around a barrier, but they do not restore flooded land or guarantee passage for every species. A useful evaluation asks what the response improves and what remains unresolved. Compare electricity benefits with habitat changes and community impacts before recommending a project.

Flexibility and other services: US DOE, Benefits of Hydropower.
Habitats, emissions and fish passage: US EIA, Hydropower and the Environment.
Scope and evaluating solutions: College Board, Topic 6.9.

Scope: College Board AP Environmental Science CED, Topic 6.9, p. 129.