

REIES – Lesson 3: Energy Transfer & Conversion

Answer Key

You have worked through the exercises — well done! Use this document to check your answers and deepen your understanding. Pay particular attention to the conversion chain exercises: being able to trace energy from source to delivery is a core skill for this entire course.

Section A – Knowledge Questions

Answer – Exercise 1

Knowledge

Input → Output	Technology	Module
Radiant → Thermal	Solar thermal collector	4a
Chemical → Thermal (combustion)	Combustion boiler	4a
Nuclear → Thermal	Fission reactor	4a
Thermal → Thermal (transfer)	Heat exchanger / Phase change material / Heat pump	4a
Electrical → Thermal	Electric boiler	4a
Chemical → Motion	Combustion engine	4b
Chemical → Motion (aircraft)	Gas turbine	4b
Thermal → Motion	Steam turbine	4b
Motion → Motion (wind/water)	Wind turbine / Water turbine	4b
Motion → Electrical	Electric generator	4c
Radiant → Electrical	Photovoltaic panel	4c
Electrical → Electrical (transfer)	Transformer / Converter	4c
Chemical ↔ Electrical (storage)	Electric battery	4d
Electrical ↔ Chemical (H ₂)	Fuel cell / Electrolyser	4d

Note on 'Thermal → Thermal': the heat exchanger and phase change material are pure transfer technologies (no conversion). The heat pump is slightly different — it transfers heat but requires electrical input to do so. All three are classified in Module 4a in the lesson.

Note on 'Motion → Motion': wind and water turbines transfer the kinetic energy of a moving fluid into rotational motion of a shaft. The energy form does not change (it remains motion/kinetic energy), so this is a transfer, not a conversion.

Answer – Exercise 2

Knowledge

The three main energy delivery forms: Heat (e.g. warm water from a radiator), Electricity (e.g. current from a wall socket), Motion (e.g. rotation of a car's drive shaft).

Solar energy to electricity — full chain from the lesson:

- Solar energy (radiant) → Solar thermal collector → Thermal energy (hot steam)
- Thermal energy → Steam turbine → Motion energy (shaft rotation)
- Motion energy → Electric generator → Electrical energy

That is three conversion steps involving three separate technologies.

Solar energy to heat — shortest chain:

- Solar energy (radiant) → Solar thermal collector → Thermal energy (hot water)

Just one step and one technology. Direct solar heating is two conversion steps fewer than solar electricity, which is why solar thermal collectors are among the most efficient ways to use sunlight for domestic hot water.

Answer – Exercise 3

Knowledge

A reversible converter can operate in both directions: it can convert energy form A to form B, and also form B back to form A. Two examples from the lesson:

- Fuel cell / Electrolyser: fuel cell mode converts hydrogen (chemical) to electricity; electrolyser mode uses electricity to split water into hydrogen (chemical energy stored as a gas).
- Electric motor / Generator: motor mode converts electricity to rotation (motion); generator mode converts rotation to electricity.

Fuel cell / Electrolyser value for renewable integration: when renewable electricity generation exceeds demand (e.g. a very windy day), the surplus electricity can run the electrolyser to produce and store hydrogen. When generation falls short (a calm night), the stored hydrogen feeds the fuel cell to produce electricity again. This reversibility makes hydrogen a form of seasonal or long-duration energy storage — something batteries struggle with at large scale.

Electric motor / Generator — real-world bidirectional example: regenerative braking in electric vehicles. When the car accelerates, the motor converts electrical energy (from the battery) into motion. When the car brakes or goes downhill, the same machine operates as a generator, converting the vehicle's kinetic energy back into electricity and recharging the battery. This recovers energy that would otherwise be wasted as heat in conventional brake pads.

Answer – Exercise 4

Knowledge

Energy transfer: energy moves from one location or system to another without changing its form. A heat exchanger is a pure transfer technology — it moves thermal energy from one fluid to another without converting it into a different form.

Energy conversion: energy changes from one form to another. A combustion boiler converts chemical energy into thermal energy — the form changes.

Two examples of electricity as an intermediate step:

- Battery charging: electricity is converted into chemical energy stored in the battery. Later, the battery discharges and the chemical energy converts back to electricity. Electricity was intermediate — it existed temporarily before becoming chemical storage.
- Pumped hydro: electricity drives a water pump, which lifts water to a higher elevation. The electrical energy is converted to gravitational potential energy for later use. Again, electricity was the intermediate carrier.

Phase change materials (PCMs): a PCM absorbs thermal energy from its surroundings when it melts (solid → liquid), storing it as chemical potential energy in the changed molecular arrangement. When the surroundings cool, the PCM solidifies again, releasing that stored energy as thermal energy. The two conversion directions are: Thermal → Chemical (charging, during melting) and Chemical → Thermal (discharging, during solidification). The key feature is that this happens at a nearly constant temperature — the melting point — which makes PCMs very useful for temperature-stable thermal storage.

Section B – Calculation Questions

Answer – Exercise 5

Calculation

Gas power plant chain efficiency

Overall efficiency:

$$\eta_{total} = \eta_{boiler} \times \eta_{turbine+generator} = 0.90 \times 0.40 = 0.36 = 36 \%$$

Electricity from 1000 GJ gas input:

$$E_{elec} = 1000 \times 0.36 = 360 \text{ GJ}$$

Energy wasted as heat:

$$E_{waste} = 1000 - 360 = 640 \text{ GJ}$$

$$\text{Convert to MWh: } 640 \text{ GJ} \times 0.2778 \text{ MWh/GJ} = 177.8 \text{ MWh} \approx 178 \text{ MWh}$$

This means 64 % of the original gas energy is discharged as waste heat — mostly from the steam turbine exhaust. This is why combined heat and power (CHP) plants, which capture and use this waste heat, can reach overall efficiencies of 80–90 %. The lesson's lesson here is that multi-step conversion chains multiply inefficiencies, and reducing the number of steps always helps.

Answer – Exercise 6

Calculation

Pumped hydro gravitational storage

Gravitational PE stored:

$$E = m \cdot g \cdot H = 5 \times 10^8 \text{ kg} \times 9.81 \text{ m/s}^2 \times 200 \text{ m}$$

$$E = 9.81 \times 10^{11} \text{ J} = 981 \times 10^9 \text{ J} = 981 \text{ GJ}$$

$$\text{Convert to kWh: } 981 \times 10^9 \text{ J} / 3\,600\,000 \text{ J/kWh} = 272\,500 \text{ kWh} \approx 272.5 \text{ MWh}$$

Recoverable electricity at 80 % efficiency:

$$E_{\text{recovered}} = 272.5 \text{ MWh} \times 0.80 = 218 \text{ MWh}$$

218 MWh of recoverable electricity from 500 million kg of water raised 200 m. For context, a medium-sized town of 10 000 households using 3.5 MWh/day each would need about 35 000 MWh/day — so this storage would supply roughly 9 hours. Pumped hydro is the world's dominant large-scale electricity storage technology (about 90 % of global storage capacity) precisely because it can store very large amounts of energy at relatively low cost per kWh, even if the energy density is low.