

REIES – Lesson 1: What is Energy?

Answer Key

You are reading this after attempting the exercises yourself — well done for completing them! Use this document to check your work, understand where you went wrong, and deepen your knowledge. For each exercise you will find the complete answer, a short explanation of why it is correct, and links to go further if you are curious.

Section A – Knowledge Questions

Answer – Exercise 1

Knowledge

Energy Form	Real-life Example
Chemical energy	Food / petrol / batteries
Mechanical energy	Compressed spring / stretched elastic band
Nuclear energy	Uranium fuel rods in a nuclear power plant
Gravitational energy	Water held in a reservoir behind a dam
Radiant energy	Sunlight / microwave oven
Thermal energy	Hot water / geothermal steam
Motion (kinetic) energy	Moving car / spinning wind turbine blade
Sound energy	Music from a speaker / thunder
Electrical energy	Electric current in a wire / lightning

The lesson groups these into potential energy (chemical, mechanical, nuclear, gravitational — stored energy) and kinetic energy (radiant, thermal, motion, sound, electrical — energy in action). Any reasonable real-life example is correct.

Answer – Exercise 2

Knowledge

The Law of Conservation of Energy in plain language: energy cannot be created from nothing, and it cannot simply disappear. Whatever total energy exists in a closed system stays the same; it can only move from place to place or change from one form to another.

Energy transfer versus energy conversion:

- Energy transfer: energy moves from one location to another without changing form. Example — the Sun radiates energy across space and delivers it to the Earth's surface as radiant energy. The form does not change; only the location does.

- Energy conversion: energy changes from one form to another. Example — when you eat food and go for a run, your body converts the chemical energy stored in the food into motion (kinetic) energy. The location may stay roughly the same, but the form changes.

A good way to remember the difference: transfer = same form, new place; conversion = new form, possibly same place.

Answer – Exercise 3

Knowledge

Energy Converter	Input → Output (Efficiency)
Human Body	Chemical → Motion (25 %)
Combustion Engine	Chemical → Motion (20 %)
Gas Boiler	Chemical → Thermal (92 %)
Electric Boiler	Electrical → Thermal (99 %)
Wind Turbine	Motion (wind) → Electrical (30 %)
PV Panel	Radiant → Electrical (18 %)

Notice the pattern: converters that produce heat tend to be very efficient (gas boiler 92 %, electric boiler 99 %) because heat is easy to capture. Converters that produce electricity or mechanical motion from a different form (combustion engine 20 %, PV panel 18 %) lose a large fraction to their surroundings. This has important implications for the energy system.

Answer – Exercise 4

Knowledge

The four primary energy sources on Earth:

- Geothermal heat — originates from radioactive decay and residual primordial heat deep inside the Earth. It has nothing to do with the Sun.
- Tidal movement — driven by the gravitational pull of the Moon (and to a lesser extent the Sun). Again, independent of solar radiation.
- Sunlight — nuclear fusion reactions inside the Sun release vast amounts of energy as electromagnetic radiation, which reaches Earth as light and heat.
- Atom nucleus splitting heat (nuclear fission) — the heat released when heavy atomic nuclei such as uranium-235 are split. The uranium itself was formed in ancient stellar explosions, not by the Sun.

Why wind, biomass and fossil fuels are all solar-derived:

- Wind — the Sun heats the Earth's surface and atmosphere unevenly. Warmer air rises, cooler air flows in to replace it. Those air movements are what we call wind.
- Biomass — plants absorb sunlight and use it to convert CO₂ and water into organic matter through photosynthesis. All biomass is essentially captured solar energy.

- Fossil fuels — coal, oil and natural gas formed over millions of years from ancient organic matter (plants and marine organisms) that originally captured solar energy. They are, in effect, very old, very concentrated biomass.

This means that when you fill up a car with petrol, you are releasing solar energy that was stored roughly 300 million years ago!

Section B – Calculation Questions

Answer – Exercise 5

Calculation

Given: 800 kcal | 1 cal = 4.184 J | 1 kWh = 3 600 000 J | body efficiency η = 25 %

Step 1 – Convert kcal to J: $800 \text{ kcal} = 800\,000 \text{ cal} \times 4.184 \text{ J/cal} = 3\,347\,200 \text{ J} \approx 3.35 \text{ MJ}$

Step 2 – Convert J to kWh: $3\,347\,200 \text{ J} \div 3\,600\,000 \text{ J/kWh} \approx 0.930 \text{ kWh}$

Step 3 – Useful mechanical work: $E_{\text{useful}} = 3\,347\,200 \text{ J} \times 0.25 = 836\,800 \text{ J} \approx 837 \text{ kJ}$

To put this in perspective: 800 kcal is roughly the energy in a generous lunch. Your body can convert only about a quarter of it into movement — the rest becomes body heat. This is why you feel warm after exercise.

Answer – Exercise 6

Calculation

Given: $P = 2000 \text{ W}$ | $t = 5 \text{ min} = 300 \text{ s}$ | $\eta = 99 \%$

Step 1 – Energy consumed: $E = P \times t = 2000 \text{ W} \times 300 \text{ s} = 600\,000 \text{ J} = 600 \text{ kJ}$

Step 2 – Convert to kWh: $E = 600\,000 \text{ J} \div 3\,600\,000 \text{ J/kWh} \approx 0.167 \text{ kWh}$

Step 3 – Useful heat delivered: $E_{\text{heat}} = 600\,000 \text{ J} \times 0.99 = 594\,000 \text{ J} = 594 \text{ kJ}$

The electric boiler / kettle is nearly perfect at converting electricity into heat — almost nothing is wasted. Compare this to a combustion engine at 20 % efficiency and you begin to see why electrification of heating makes a lot of sense from an energy perspective.

Answer – Exercise 7

Calculation

Given: useful output power $P_{\text{out}} = 75 \text{ kW}$ | $\eta = 20 \%$ | $t = 30 \text{ min} = 1800 \text{ s}$

Step 1 – Useful output energy: $E_{out} = 75\,000\text{ W} \times 1800\text{ s} = 135\,000\,000\text{ J} = 135\,000\text{ kJ} = 135\text{ MJ}$
 Step 2 – Total chemical energy input: $E_{in} = E_{out} / \eta = 135\,000\text{ kJ} / 0.20 = 675\,000\text{ kJ} = 675\text{ MJ}$
 Step 3 – Energy wasted as heat: $E_{waste} = E_{in} - E_{out} = 675\,000 - 135\,000 = 540\,000\text{ kJ} = 540\text{ MJ}$

80 % of the fuel energy is wasted as heat in a conventional car engine. This is one of the strongest arguments for electric vehicles, which convert electrical energy to motion at around 85–90 % efficiency.

Answer – Exercise 8

Calculation

Given: $120\text{ m}^3\text{ gas} \mid 1\text{ m}^3\text{ gas} = 35.17\text{ MJ} \mid \eta_{\text{gas}} = 92\% \mid \eta_{\text{electric}} = 99\%$

Step 1 – Energy in $120\text{ m}^3\text{ gas}$: $E = 120 \times 35.17\text{ MJ} = 4\,220.4\text{ MJ}$ In kWh: $4\,220.4\text{ MJ} \div 3.6\text{ MJ/kWh} = 1\,172.3\text{ kWh}$

Step 2 – Useful heat from gas boiler (92 %): $E_{\text{gas_heat}} = 1\,172.3\text{ kWh} \times 0.92 = 1\,078.5\text{ kWh}$

Step 3 – Useful heat from electric boiler (99 %) with same input: $E_{\text{elec_heat}} = 1\,172.3\text{ kWh} \times 0.99 = 1\,160.6\text{ kWh}$ Difference = $1\,160.6 - 1\,078.5 = 82.1\text{ kWh}$ more useful heat

The electric boiler delivers about 82 kWh more useful heat from the same energy input — roughly a 7.6 % improvement. Of course, this comparison only makes sense if the electricity itself was generated cleanly; if it came from a gas power plant at 40–50 % efficiency, the overall chain efficiency would be much lower. This is the broader energy system thinking you will explore in later lessons.

Section C – Internet Exploration

Answer – Exercise 9

Internet Exploration

Reference: <https://www.eia.gov/energyexplained/>

Sample correct answers:

- Three additional energy units not in the lesson: BTU (British Thermal Unit), therm, quad (quadrillion BTU), barrel of oil equivalent, cord of wood — any three of these (or others you found on the site) are correct.

Section D – Home Experiment

Answer – Exercise 10

Home Experiment – Your Own Power Output

How to check your results:

Example for a person of 70 kg climbing 10 steps of 0.18 m each: $H = 10 \times 0.18 \text{ m} = 1.80 \text{ m}$ $E = m \cdot g \cdot H = 70 \times 9.81 \times 1.80 = 1\,234 \text{ J}$

Walking ($t_1 = 6 \text{ s}$): $P_{\text{walk}} = 1\,234 / 6 = 206 \text{ W}$

Running ($t_2 = 2.5 \text{ s}$): $P_{\text{run}} = 1\,234 / 2.5 = 494 \text{ W}$

In horsepower: $494 / 745.7 = 0.66 \text{ hp}$

Reflection answers:

- Comparison with a light bulb (100 W): your walking power (~200 W) is roughly twice a light bulb; your running power (~500 W) is five times a light bulb. A car engine (75–150 kW) is 150–300 times more powerful than you at full sprint. This is why we rely on machines for most of our energy needs.
- Total chemical energy burned ($\eta = 25 \%$): if your mechanical output was 494 W, your body actually consumed $E_{\text{chemical}} = 494 / 0.25 = 1976 \text{ W}$. The remaining 1482 W was released as body heat — which is why you get warm when you exercise hard.
- Energy produced at max power for 1 hour: $E = 494 \text{ W} \times 3600 \text{ s} = 1\,778\,400 \text{ J} \approx 0.49 \text{ kWh}$. A typical banana provides about 90 kcal $\approx 0.10 \text{ kWh}$ of chemical energy. So if your body were 100 % efficient, you could sustain maximum power for only about 12 minutes on one banana — and at 25 % efficiency, even less of that becomes useful work.

The broader lesson: human bodies are remarkable machines, but our power output is tiny compared to modern energy systems. A single wind turbine (3 MW) is equivalent to roughly 6000 humans sprinting simultaneously, non-stop.

Go deeper: <https://www.khanacademy.org/science/physics/work-and-energy> | <https://www.physicsclassroom.com/class/energy/Lesson-1/Power>