Science 7–8

Chapter 13 — Earth and space sciences B: rocks, minerals and Earth's resources

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Contents

The rock cycle: sedimentary, igneous and metamorphic rocks, the processes that make each, and the very different timescales they take

What we teach here — `VC2S8U11` (Victorian Curriculum F–10 Version 2.0, Science, Levels 7 and 8): *“key processes of the rock cycle occur over different timescales; the properties of sedimentary, igneous and metamorphic rocks not only reflect their formation but also impact their usefulness and determine the methods used when mined.”*

This subtopic is the accountable owner of `VC2S8U11`. It teaches the rock-cycle clause: the processes of the rock cycle and the very different timescales they take. The partner subtopic **13B** teaches the other clause — how the properties of rocks reflect their formation, and how those properties decide what a rock is useful for and how it is mined. This section does not repeat that material.

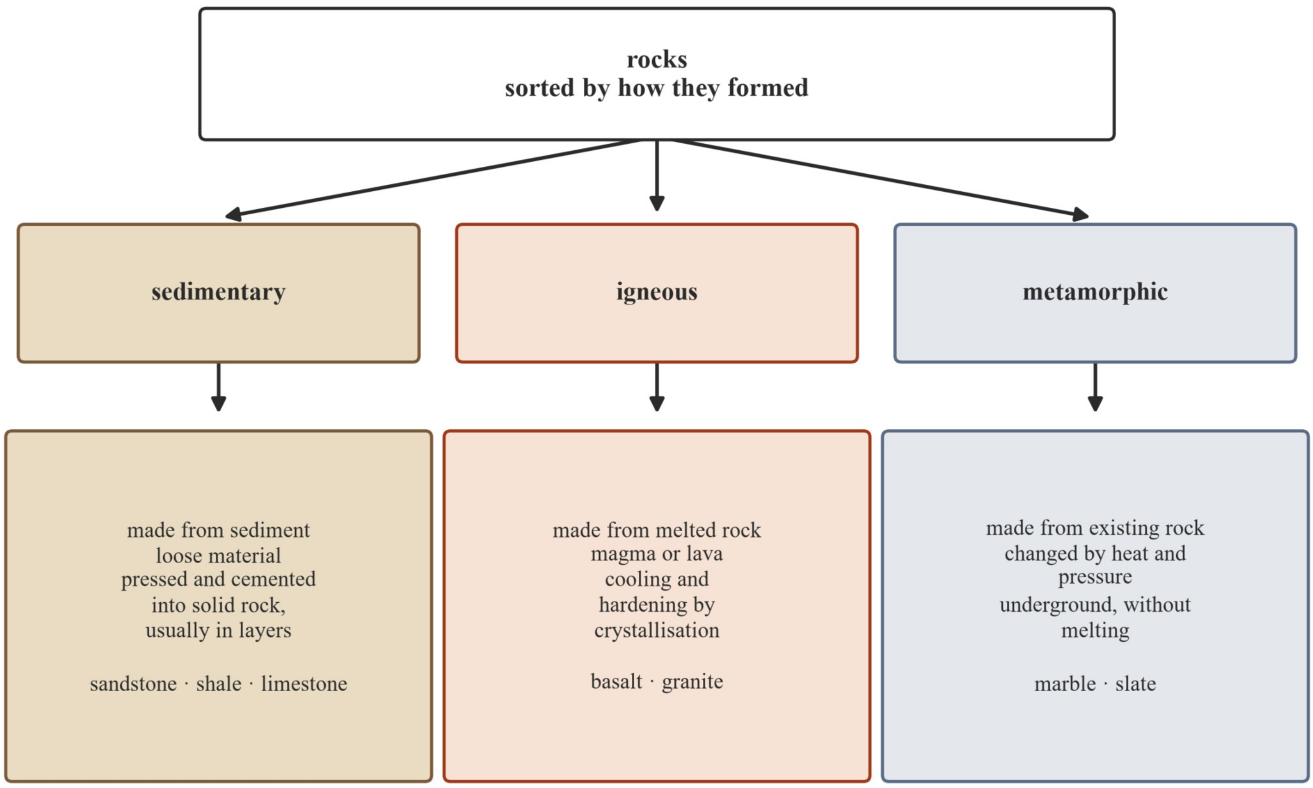
Achievement standard served (quoted exactly): *“They explain how the properties of rocks relate to their formation and influence their use.”*

Elaborations drawn on (a context bank, not a delivery checklist): `VC2S8U11.E02` — the major processes of the rock cycle, including weathering, erosion, deposition, melting, crystallisation, uplift, heat and pressure; `VC2S8U11.E03` — the role of forces and heat energy in the formation of different types of rocks, and how quickly or slowly different processes can occur; `VC2S8U11.E04` — examining fossil evidence, including body, trace and opalised fossils, to predict how and when a rock was formed.

Theory

Stand on any rocky hillside and the rock under your feet feels permanent — hard, still and unchanging. In one human lifetime it is. But rocks are not permanent. They are being made, changed, broken down and made again, all the time, by processes that have been running for the whole history of the Earth. The model that ties all of this together is called the **rock cycle**, and it is the subject of this subtopic: the three great groups of rocks, the processes that make each one, and — the point this subtopic keeps returning to — the **very different timescales** those processes take.

Rocks and minerals. A **mineral** is a substance found in nature with a fixed makeup. Rocks are usually made of one or more minerals packed together — minerals are the ingredients of rocks, and different mixtures of minerals give different rocks their different look and feel (Geoscience Australia, “Australian mineral facts”, n.d., ga.gov.au — retrieved 2026-08-19). Geologists sort rocks into three groups by **how they formed**: **sedimentary**, **igneous** and **metamorphic**. Every rock you will ever hold belongs to one of the three — and every one of them has a formation story.



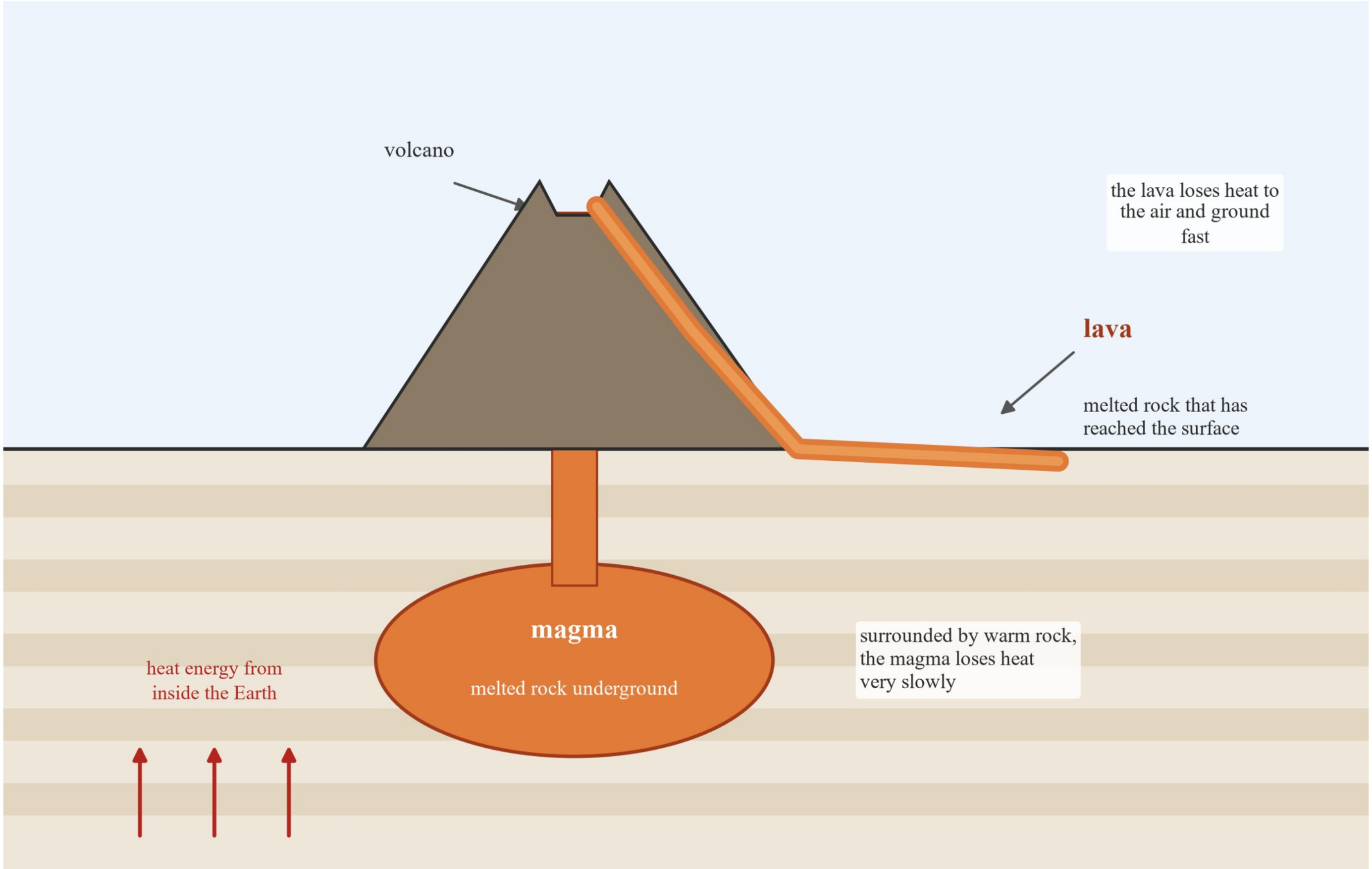
every rock you will ever hold belongs to one of the three groups — and every one of them has a formation story

ClassBasics Science 7–8 · 13A · the three rock groups, sorted by how they formed

A chart that shows rocks sorted into three groups by how they formed. A box at the top reads 'rocks sorted by how they formed', with three arrows leading down to three boxes labelled 'sedimentary', 'igneous' and 'metamorphic'. Under the sedimentary box, a panel reads 'made from sediment — loose material pressed and cemented into solid rock, usually in layers' with the examples 'sandstone, shale, limestone'. Under the igneous box, a panel reads 'made from melted rock — magma or lava cooling and hardening by crystallisation' with the examples 'basalt, granite'. Under the metamorphic box, a panel reads 'made from existing rock — changed by heat and pressure underground, without melting' with the examples 'marble, slate'. A line under the chart reads 'every rock you will ever hold belongs to one of the three groups — and every one of them has a formation story', and the footer line reads 'ClassBasics Science 7–8 · 13A · the three rock groups, sorted by how they formed'.

Igneous rocks — made from melted rock

Deep underground, it is hot enough for rock to melt. Melted rock that is still underground is called **magma**. When magma reaches the surface through a volcano, it is called **lava**. Igneous rocks form when magma or lava cools and **hardens** back into solid rock.



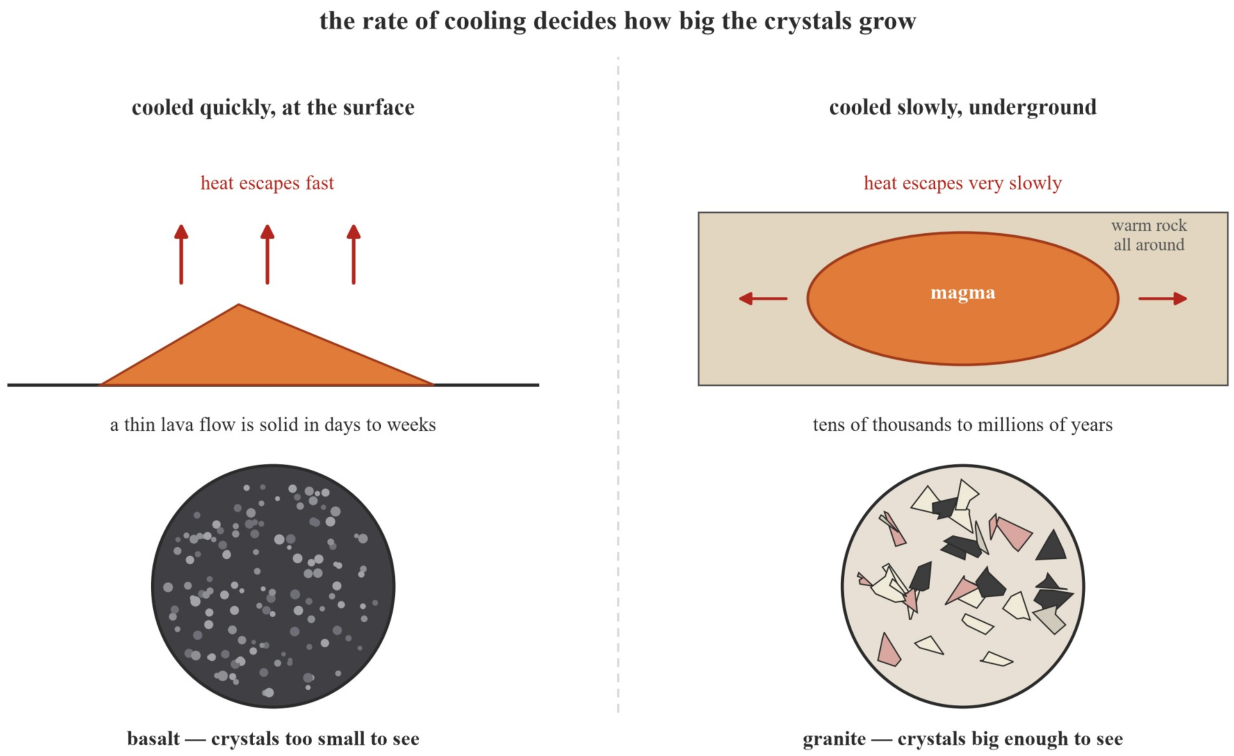
igneous rocks form when magma or lava cools and hardens back into solid rock

A labelled cross-section of a volcano that shows the difference between magma and lava. Below the ground line, red arrows rising from the deep ground are labelled 'heat energy from inside the Earth', and an orange pocket of melted rock is labelled 'magma — melted rock underground'. A pipe of melted rock leads up from the magma to a volcano cone at the surface, and melted rock flowing out along the ground is labelled 'lava — melted rock that has reached the surface'. A note beside the magma reads 'surrounded by warm rock, the magma loses heat very slowly', and a note beside the lava reads 'the lava loses heat to the air and ground fast'. The footer line reads 'igneous rocks form when magma or lava cools and hardens back into solid rock'.

The cooling happens by **crystallisation**: as the melt loses heat energy, the material in it starts to form tiny solid grains called **crystals**, and the crystals grow and lock together into solid rock. (Here *crystallisation* means crystals forming out of a cooling melt — the same word is also used when crystals form out of a solution, as in 10D.)

The rate of cooling decides how big the crystals grow, and this gives igneous rocks two very different looks:

- **Cooled quickly, at the surface.** A lava flow loses its heat to the air and to the ground fast — a thin flow can be solid in days to weeks. Crystals have almost no time to grow, so they stay too small to see without magnifying. **Basalt**, the dark rock that makes up much of the volcanic plains of western Victoria and Melbourne's west, formed this way.
- **Cooled slowly, underground.** A body of magma surrounded by warm rock loses its heat very slowly — over tens of thousands to millions of years. Crystals have a long time to grow, so they end up big enough to see with your eyes. **Granite**, with its speckled pattern of visible crystals, formed this way.



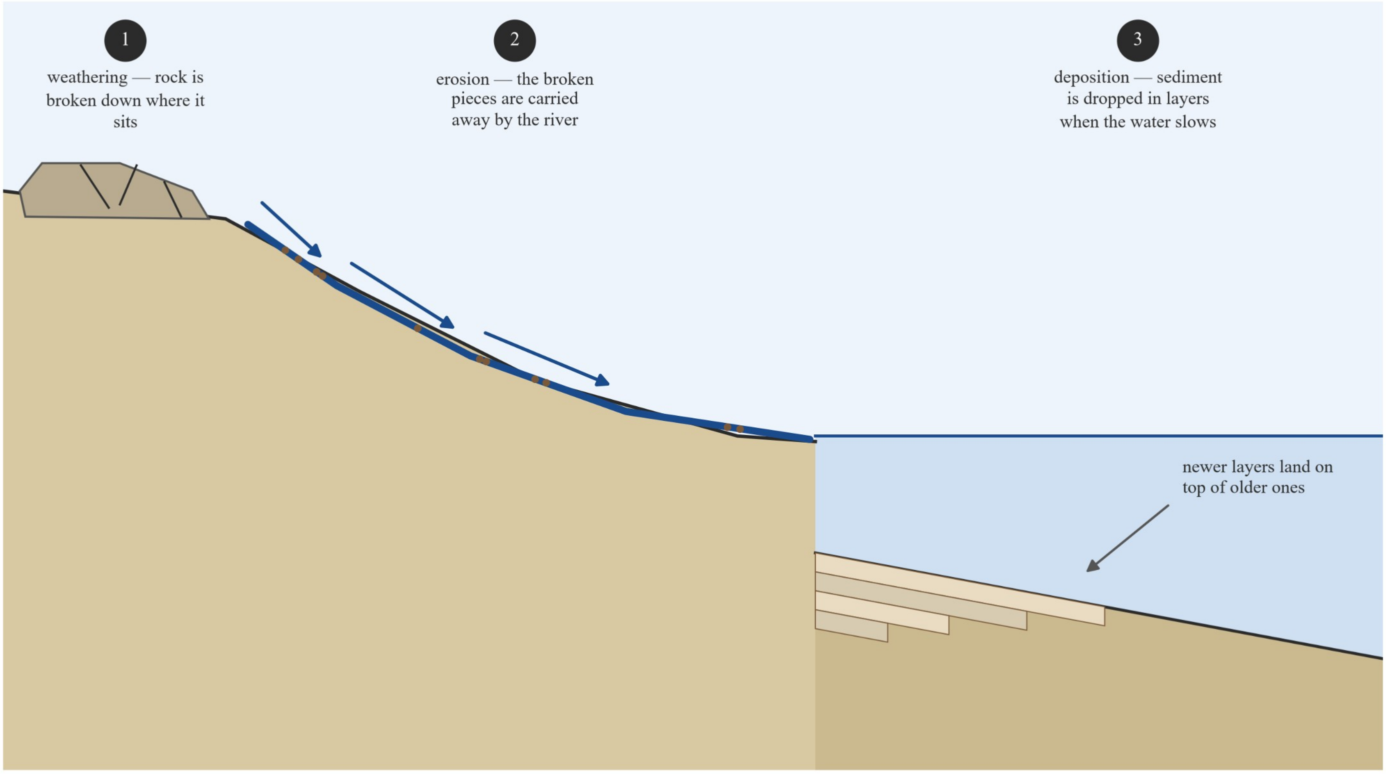
the same process — crystallisation — but the slower the cooling, the bigger the crystals grow

A two-panel diagram titled 'the rate of cooling decides how big the crystals grow'. The left panel, 'cooled quickly, at the surface', shows a thin lava flow on the ground with red arrows pointing up, labelled 'heat escapes fast', and a note 'a thin lava flow is solid in days to weeks'; below it a round close-up of dark rock full of tiny dots is labelled 'basalt — crystals too small to see'. The right panel, 'cooled slowly, underground', shows an orange magma body inside a block of warm rock labelled 'warm rock all around', with red arrows pointing outward, labelled 'heat escapes very slowly', and a note 'tens of thousands to millions of years'; below it a round close-up of pale rock with large coloured crystals is labelled 'granite — crystals big enough to see'. The footer line reads 'the same process — crystallisation — but the slower the cooling, the bigger the crystals grow'.

The heat energy involved in making igneous rocks is Earth's own internal heat. Where that heat finds a way to the surface, you get a volcano (you met where volcanoes form in Chapter 12).

Sedimentary rocks — made from sediment

Sediment is loose material: grains of rock, mud, sand, pebbles, and the shells and bones of living things. Sedimentary rocks form when sediment is laid down in layers and then pressed and glued into solid rock. Four processes do the work — weathering, erosion, deposition, and then compaction and cementation.

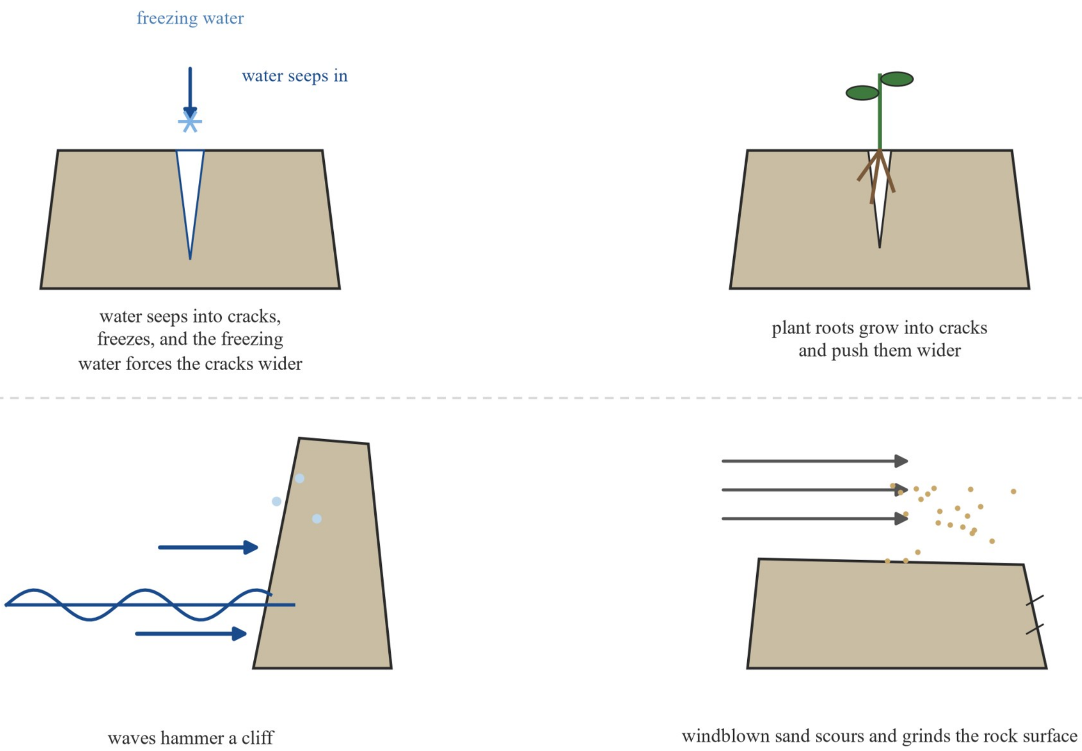


weathering breaks rock down, erosion carries the pieces away, deposition drops them in layers — the surface journey of sediment

A labelled cross-section from a rocky hillside down to the sea that shows the surface journey of sediment in three numbered stages. Stage 1, 'weathering — rock is broken down where it sits', shows a cracked rocky outcrop on the hilltop. Stage 2, 'erosion — the broken pieces are carried away by the river', shows a river running down the slope, with blue arrows and small grains of sediment carried in the water. Stage 3, 'deposition — sediment is dropped in layers when the water slows', shows the river meeting the sea, with flat layers of sediment lying on the sea floor and a note 'newer layers land on top of older ones'. The footer line reads 'weathering breaks rock down, erosion carries the pieces away, deposition drops them in layers — the surface journey of sediment'.

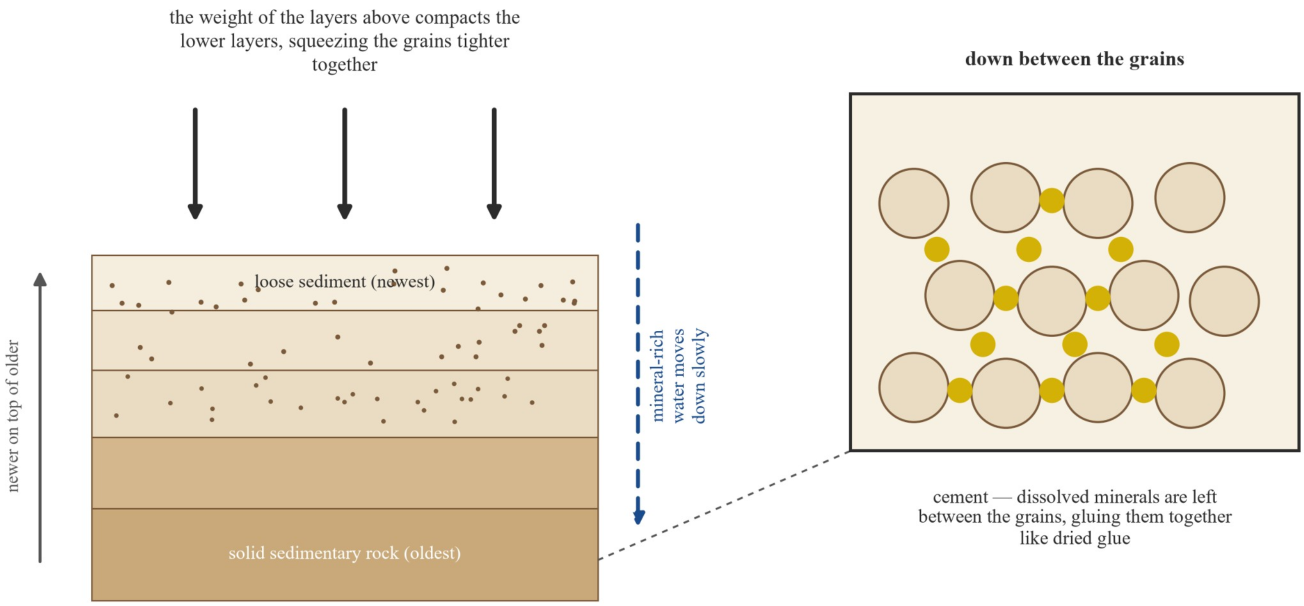
- **Weathering** is the breaking down of rock **where it sits**, with no movement. Water seeps into cracks, freezes, and the freezing water forces the cracks wider. Plant roots grow into cracks and push them wider. Waves hammer a cliff. Windblown sand scours a rock surface. All of these break rock into smaller pieces without carrying the pieces away.

weathering — rock is broken down where it sits



all of these break rock into smaller pieces without carrying the pieces away — that carrying away is erosion

* **Erosion** is the **carrying away** of the broken pieces. Running water in rivers and streams, waves along a coast, wind across dry ground, and moving ice all pick sediment up and transport it. The further a grain is carried, the more it is knocked and rubbed, so grains that have travelled a long way end up rounded and smooth. * **Deposition** is the **dropping** of sediment when its carrier slows down. A river entering flat ground or the sea slows and drops its sand and mud. Wind drops dust when it dies down. Waves drop sand along a beach. Sediment settles in **layers**, with newer layers landing on top of older ones. * **Compaction and cementation** turn loose layers into rock. As more and more layers pile up, the weight of the layers above **compacts** the lower ones, squeezing the grains tighter together. Water moving slowly through the layers carries dissolved minerals, and those minerals are left behind between the grains, **cementing** them together like dried glue. Pressed and glued, the sediment becomes solid sedimentary rock.



pressed and glued, loose layers of sediment become solid sedimentary rock

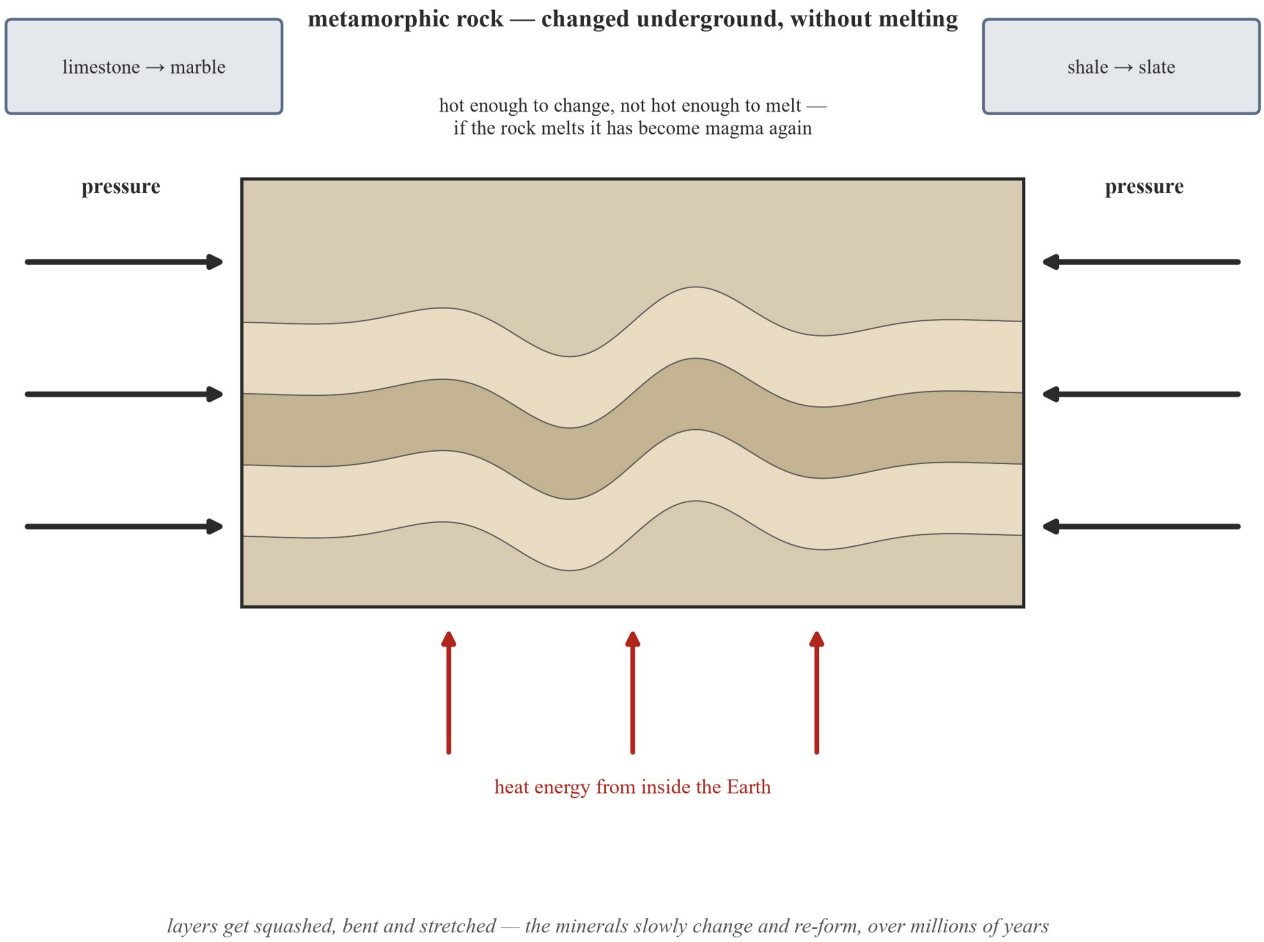
A diagram of compaction and cementation. On the left, a stack of sediment layers is labelled 'loose sediment (newest)' at the top and 'solid sedimentary rock (oldest)' at the bottom, with a side arrow reading 'newer on top of older'; black arrows press down on the stack, labelled 'the weight of the layers above compacts the lower layers, squeezing the grains tighter together', and a dashed blue arrow moving down through the layers is labelled 'mineral-rich water moves down slowly'. On the right, a zoomed inset titled 'down between the grains' shows round sand grains with cement between them, and a caption reads 'cement — dissolved minerals are left between the grains, gluing them together like dried glue'. The footer line reads 'pressed and glued, loose layers of sediment become solid sedimentary rock'.

Well-known sedimentary rocks: **sandstone** (compacted and cemented sand grains), **shale** (hardened mud), and **limestone**, which is built mostly from the shells and skeletons of sea creatures. The famous limestone stacks of the Twelve Apostles on Victoria's Great Ocean Road were once sediment on an ancient sea floor; forces inside the Earth later lifted that rock above sea level, and the waves of the Southern Ocean are now eroding it back into sand and pebbles — the cycle, running in front of you.

Metamorphic rocks — changed by heat and pressure

Metamorphic rocks form when an existing rock — sedimentary, igneous or even older metamorphic rock — is changed by **heat and pressure** underground, **without melting**. If the rock melts, it has left the metamorphic story and become magma again.

Deep underground, rocks are squeezed by the weight of everything above them and pushed by the forces that move and fold the Earth's crust — the same forces you met in Chapter 12, where plates push together, fold rock into mountain ranges and lift whole regions upward. Down where the heat and pressure are great, minerals in the rock slowly change and re-form. Layers get squashed, bent and stretched. The result is a new rock with a new look.



A diagram titled 'metamorphic rock — changed underground, without melting'. A block of rock layers bent into folds sits at the centre, with large black arrows pressing in from both sides, labelled 'pressure', and red arrows rising from below, labelled 'heat energy from inside the Earth'. A note above the block reads 'hot enough to change, not hot enough to melt — if the rock melts it has become magma again', and two small boxes read 'limestone → marble' and 'shale → slate'. The footer line reads 'layers get squashed, bent and stretched — the minerals slowly change and re-form, over millions of years'.

Two familiar changes:

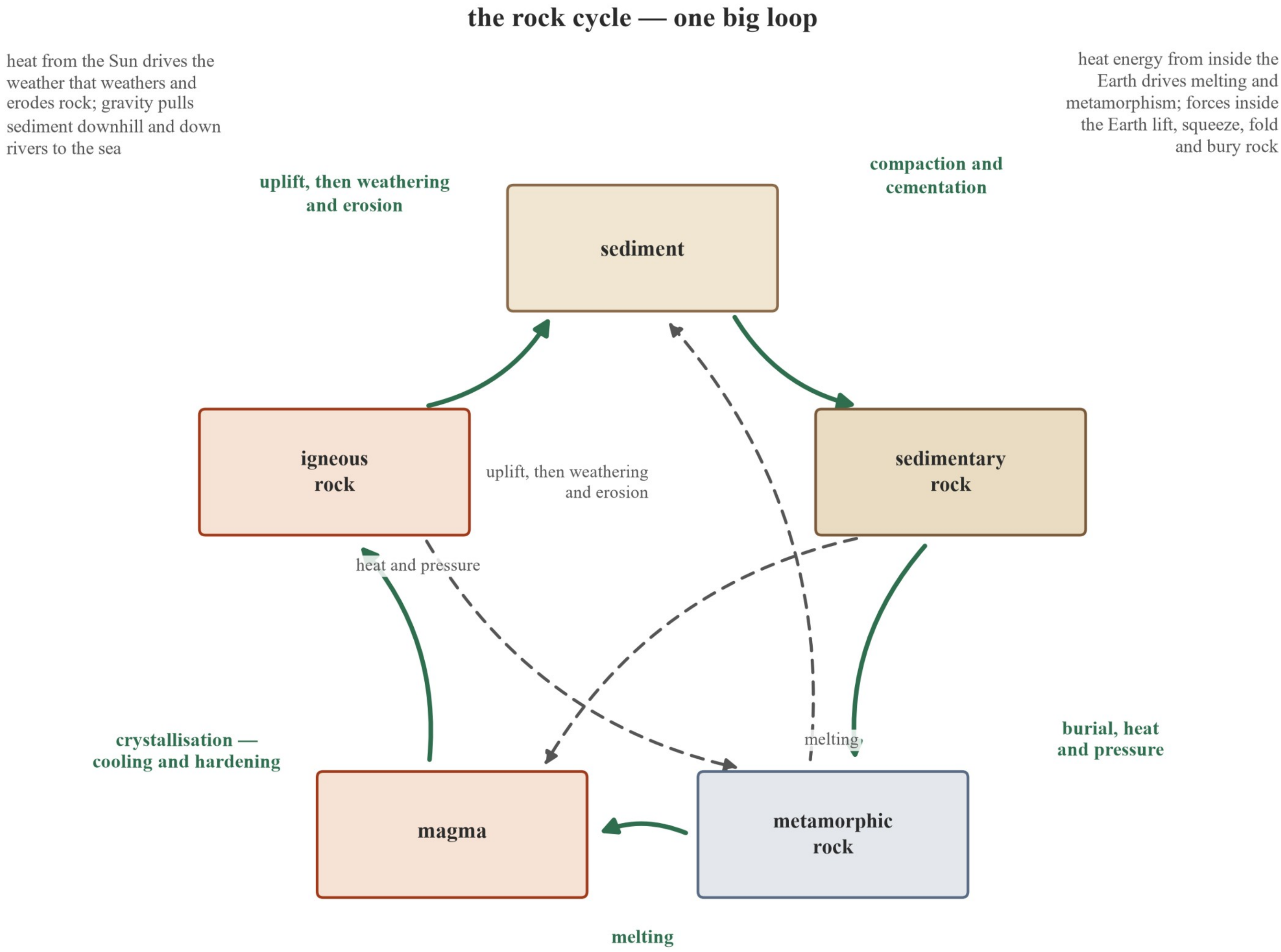
- limestone → **marble**, in which the crystals have re-formed into a sugary, interlocking pattern;
- shale → **slate**, in which the squashed mud layers split into flat, hard sheets.

Any fossil that was in the original rock is usually squashed out of shape or destroyed — the heat and pressure that make metamorphic rock are exactly the things fossils cannot survive. The changing of rock into metamorphic rock is called **metamorphism**, and it is a slow business: millions of years.

The rock cycle — one big loop

Put the three groups together and you get a loop with no beginning and no end:

> sediment → (compaction and cementation) → sedimentary rock → (burial, heat and pressure) → metamorphic rock → (melting) → magma → (crystallisation) → igneous rock → (uplift, then weathering and erosion) → sediment → …



no beginning and no end — the same material goes round and round; dashed arrows are the shortcuts between the groups

A loop diagram titled 'the rock cycle — one big loop'. Five boxes — 'sediment', 'sedimentary rock', 'metamorphic rock', 'magma' and 'igneous rock' — are joined in a ring by green arrows labelled, in order around the loop, 'compaction and cementation', 'burial, heat and pressure', 'melting', 'crystallisation — cooling and hardening' and 'uplift, then weathering and erosion'. Dashed grey shortcut arrows cross the ring, labelled 'melting', 'heat and pressure' and 'uplift, then weathering and erosion'. Notes at the top corners read 'heat from the Sun drives the weather that weathers and erodes rock; gravity pulls sediment downhill and down rivers to the sea' and 'heat energy from inside the Earth drives melting and metamorphism; forces inside the Earth lift, squeeze, fold and bury rock'. The footer line reads 'no beginning and no end — the same material goes round and round; dashed arrows are the shortcuts between the groups'.

Two extra arrows complete the picture: any rock buried hot and far enough underground can **melt** and become magma again, and any rock lifted back to the surface can be **weathered and eroded** into sediment. **Uplift** is the process that brings deep rock back toward the surface, where weathering can get to work on it again. No rock is finished. The same material goes round and round — the sand on a beach today may once have been part of a mountain, a mud layer on an ancient sea floor, or a flow of lava.

Different things power different parts of the loop (this is `VC2S8U11.E03` in action):

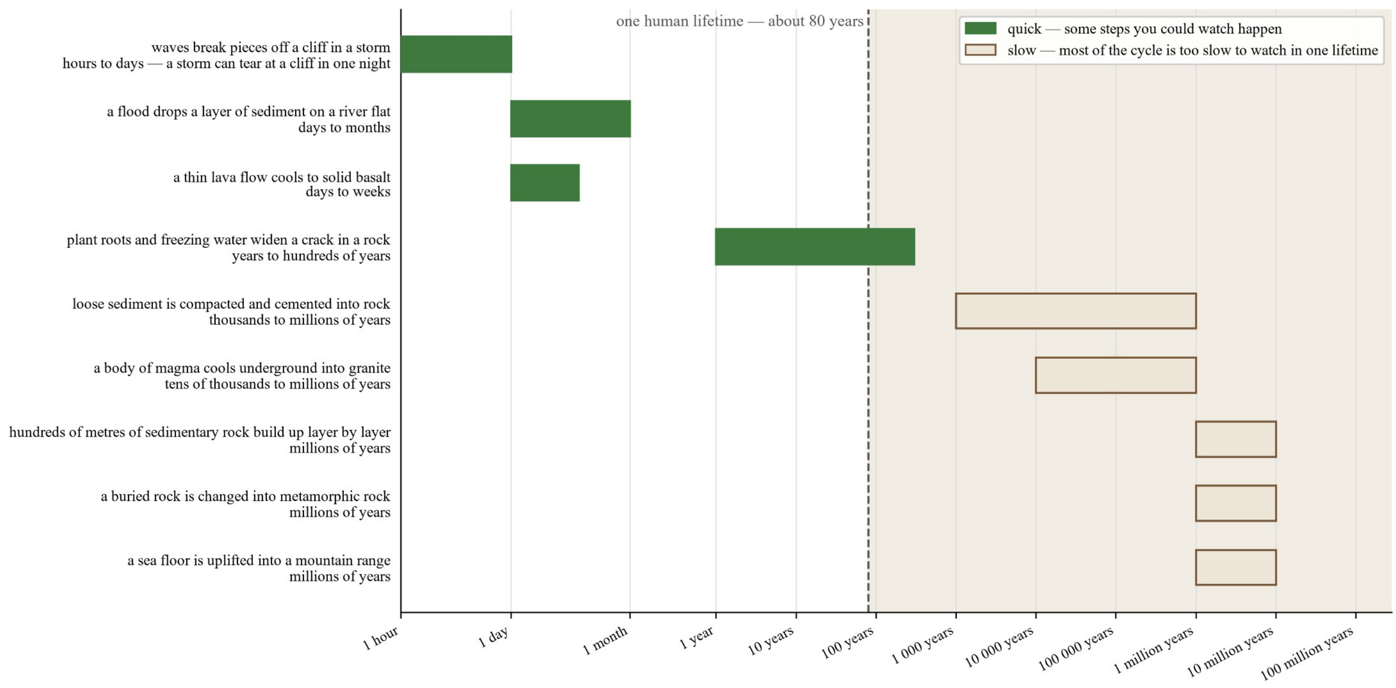
- **Heat energy from inside the Earth** drives melting and metamorphism.
- **Heat from the Sun** drives the weather — wind, rain and waves — that weathers and erodes rock at the surface.
- **Gravity** pulls sediment downhill and carries it down rivers to the sea.

- **Forces inside the Earth** push rock upward (uplift), squeeze it, fold it and bury it.

Timescales — the heart of this subtopic

The rock cycle never stops, but its parts run at very different speeds. Some steps you could watch happen; others take longer than the whole history of human civilisation.

Process	How long it can take
Waves break pieces off a cliff in a storm	hours to days
A flood drops a layer of sediment on a river flat	days to months
A thin lava flow cools to solid basalt	days to weeks
Plant roots and freezing water widen a crack in a rock	years to hundreds of years
Loose sediment is compacted and cemented into rock	thousands to millions of years
A body of magma cools underground into granite	tens of thousands to millions of years
Hundreds of metres of sedimentary rock build up layer by layer	millions of years
A buried rock is changed into metamorphic rock	millions of years
A sea floor is uplifted into a mountain range	millions of years



the same cycle holds steps of hours and steps of millions of years — the ranges shown are the ones named in the table above

A horizontal bar chart titled 'how long does each step of the rock cycle take? (log time scale)'. Nine bars show the time each process takes, on a time axis from 1 hour to 100 million years: green bars for the quick steps (waves breaking a cliff in a storm, a flood dropping a layer of sediment, a thin lava flow cooling, plant roots and freezing water widening a crack) and pale bars for the slow steps (compaction and cementation, magma cooling into granite, thick layers of rock building up, a rock changed into metamorphic rock, and a sea floor uplifted into a mountain range). A dashed vertical line at about 80 years is labelled 'one human lifetime', and the shaded region beyond it holds all five slow bars. A key reads 'quick — some steps you could watch happen' and 'slow — most of the cycle is too slow to watch in one lifetime'. The footer line reads 'the same cycle holds steps of hours and steps of millions of years — the ranges shown are the ones named in the table above'.

Three things to notice about the table:

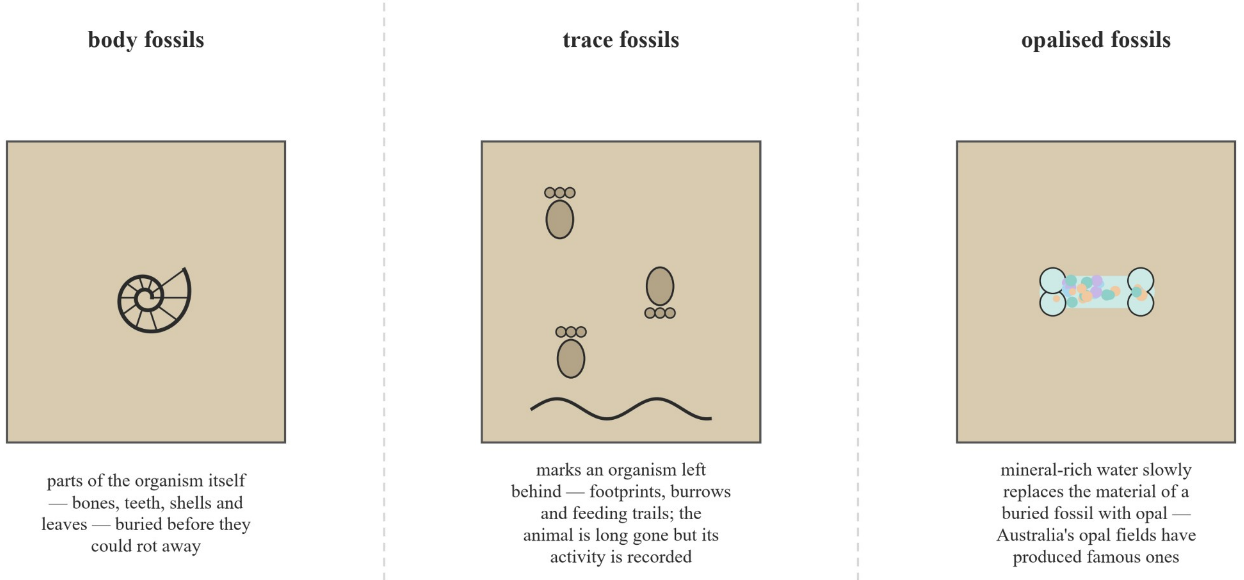
1. **The same rock cycle contains steps of hours and steps of millions of years.** Destruction can be quick — a storm can tear at a cliff in one night — while construction is almost always slow.

2. **Rates change with conditions.** More heat, more pressure, faster water or stronger waves make a process faster; less of each makes it slower. That is why a soft mud layer weathers quickly while a hard basalt cliff resists for far longer.
3. **Most of the cycle is too slow to watch in one lifetime.** Geologists work out the slow steps by studying the evidence left behind — the layers, the crystals and the fossils — and by measuring the slow changes they *can* see now, such as the thin layer of sediment settling in a lake each year.

Reading fossils: how and when a rock formed

A **fossil** is the preserved remains or traces of a living thing from long ago. Nearly all fossils are found in **sedimentary rock** — and that makes fossils powerful evidence for how and when a rock formed (`VC2S8U11.E04`). Fossils come in three main kinds:

- **Body fossils** are parts of the organism itself — bones, teeth, shells or leaves — buried in sediment before they could rot away.
- **Trace fossils** are marks an organism left behind — footprints, burrows or feeding trails. The animal is long gone, but its activity is recorded in the rock.
- **Opalised fossils** form when mineral-rich water slowly replaces the material of a buried fossil with opal, the gemstone. Australia's opal fields have produced some of the most famous opalised fossils in the world.



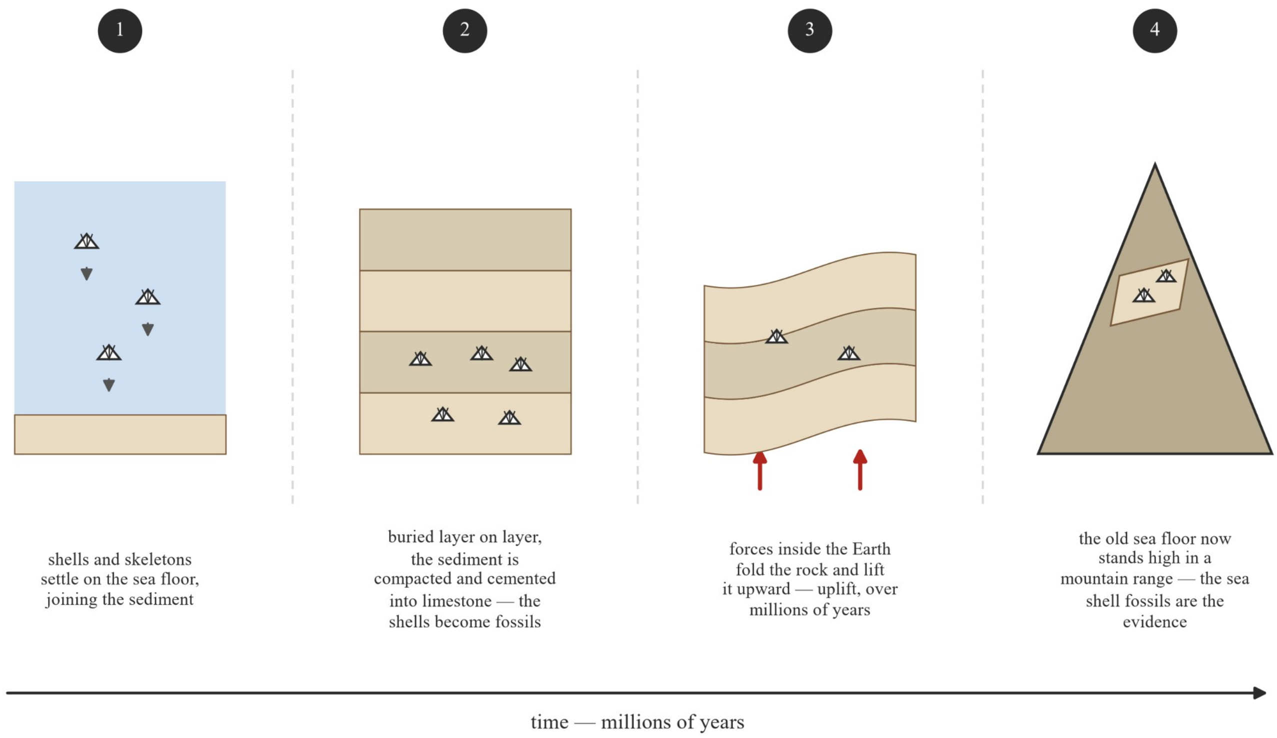
nearly all fossils are found in sedimentary rock — gentle formation preserves what a hot melt would destroy

A three-panel diagram that shows the three main kinds of fossils, each drawn as a slab of rock. The left panel, 'body fossils', shows a coiled shell in the stone; its caption reads 'parts of the organism itself — bones, teeth, shells and leaves — buried before they could rot away'. The middle panel, 'trace fossils', shows footprints and a wavy burrow; its caption reads 'marks an organism left behind — footprints, burrows and feeding trails; the animal is long gone but its activity is recorded'. The right panel, 'opalised fossils', shows a bone shape in speckled opal colours; its caption reads 'mineral-rich water slowly replaces the material of a buried fossil with opal — Australia's opal fields have produced famous ones'. The footer line reads 'nearly all fossils are found in sedimentary rock — gentle formation preserves what a hot melt would destroy'.

What do fossils tell us?

- **How the rock formed.** Sea shells in a rock mean the rock formed from sediment laid down on an ancient sea floor. Fern leaves mean the sediment was laid down on land, near swampy forest. Dinosaur footprints mean an animal walked across soft, wet sediment that was later buried and hardened.

- **When the rock formed.** Different kinds of organisms have lived on Earth at different times. A rock holding a certain set of fossils formed in the age when those organisms were alive — so fossils let geologists say whether one rock formed before or after another. The fossil record is one of the main tools geologists use to place rocks in order through time (Geoscience Australia, “Algae to Zooxanthellae: Life in the rock record”, n.d., ga.gov.au — retrieved 2026-08-19).
- **What did *not* happen to the rock.** Because heat and pressure destroy fossils, a rock that still holds undamaged fossils can never have been buried hot enough or squeezed hard enough to become metamorphic rock. The fossils themselves are evidence that the rock stayed sedimentary.



sea shells on a mountain read as a story: deposition, hardening, then uplift — each step over millions of years

A four-scene story diagram read from left to right along a long arrow labelled ‘time — millions of years’. Scene 1 shows shells settling onto the sea floor, joining the sediment. Scene 2 shows the sediment buried layer on layer and hardened into limestone that holds the shell fossils. Scene 3 shows red arrows lifting the folded layers, with a caption ‘forces inside the Earth fold the rock and lift it upward — uplift, over millions of years’. Scene 4 shows a mountain with a patch of layered rock and shell fossils high on its slope, captioned ‘the old sea floor now stands high in a mountain range — the sea shell fossils are the evidence’. The footer line reads ‘sea shells on a mountain read as a story: deposition, hardening, then uplift — each step over millions of years’.

Words to know in 13A

Word	What it means here
mineral	a substance found in nature; the ingredients that rocks are made of
sediment	loose material — sand, mud, pebbles, shells — that can be pressed and cemented into rock
weathering	the breaking down of rock where it sits, with no movement
erosion	the carrying away of broken rock by water, wind, ice or waves
deposition	the dropping of sediment when its carrier slows down
compaction	the squeezing of sediment layers together by the weight

Word	What it means here
	of layers above
cementation	dissolved minerals left between grains, gluing sediment into solid rock
crystallisation	crystals forming and growing as a melt cools and becomes solid
magma	melted rock underground
lava	magma that has reached the surface
uplift	forces inside the Earth pushing rock back up toward the surface
metamorphic rock	rock changed by heat and pressure underground, without melting
metamorphism	the changing of rock into metamorphic rock by heat and pressure, without melting
fossil	the preserved remains or traces of a living thing from long ago
rock cycle	the model in which rocks are continually made, changed, broken down and made again

Worked examples

Example 1 — scaffolded

A student is given a piece of **sandstone**. Every grain in it is rounded, like a tiny pebble. Reconstruct the formation story of this rock, naming the rock-cycle processes in the order they must have happened. *(Draws on `VC2S8U11.E02`.)*

Working	Comment
1. **Weathering** broke a larger rock (perhaps granite in a mountain range) into small grains, where it sat.	Weathering breaks rock down in place — water in cracks, freezing, plant roots. No movement yet.
2. **Erosion** carried the grains away — most likely down rivers toward the sea.	The rounded shape of the grains is the evidence here: grains only become rounded by being knocked and rubbed during a long journey.
3. **Deposition** dropped the grains in layers when the water slowed — for example where a river met the sea.	Sediment is dropped when its carrier slows. Layers build up, newer on top of older.
4. **Burial, compaction and cementation** turned the loose sand into solid sandstone.	More layers piled on top; the weight squeezed the grains together, and minerals left by water cemented them.
Timescale check: the whole journey — from mountain rock to a piece of sandstone — takes millions of years, even though each single step is small.	This is the pattern of the rock cycle: small steps, enormous time.

Example 2 — scaffolded

Basalt and **granite** are both igneous rocks, made by crystallisation from a melt. But basalt's crystals are too small to see, while granite's are clearly visible. Use heat energy to explain the difference, and compare how long each rock took to form. *(Draws on `VC2S8U11.E03`.)*

Working	Comment
Both rocks formed when a melt lost **heat energy** and hardened by crystallisation.	Start from what the two rocks share: the same process, cooling from a melt.
Basalt forms from **lava** at the surface, where heat escapes quickly into the cooler air and ground. A thin	Fast cooling = crystals have almost no time to grow, so they stay too small to see.

Working	Comment
flow can solidify in days to weeks.	
Granite forms from **magma** underground, surrounded by warm rock, so its heat escapes very slowly — over tens of thousands to millions of years.	Slow cooling = crystals have a long time to grow, so they end up visible.
The difference in heat energy — how fast it left — explains the difference in crystal size, and the two rocks record very different timescales of the same process.	Cooling rate links heat energy, crystal size and timescale in one explanation.

Example 3 — unscaffolded

A geologist finds a rock high up in a mountain range, far from any sea. The rock is in layers and is packed with fossils of sea shells. Explain what kind of rock it is, how it formed, and how it came to be sitting high in a mountain. Give the timescales involved. *(Draws on `VC2S8U11.E04` and `VC2S8U11.E03`.)*

The rock is **sedimentary** — almost certainly **limestone** — because it is in layers and full of sea shell fossils, and fossils survive in sedimentary rock. It formed when the shells and skeletons of sea creatures settled on an ancient **sea floor**, were buried layer on layer, and were slowly compacted and cemented into rock. The rock is now high in a mountain because of **uplift**: the forces inside the Earth that fold and lift crust pushed that old sea floor upward over millions of years — the same forces that build mountain ranges at plate boundaries (Chapter 12). The fossils are the evidence: sea creatures cannot be buried on a mountainside, so the rock must have formed in the sea and moved later. Both parts of the story are slow — the deposition and hardening of the limestone took millions of years, and the uplift that raised it took millions more. ∴ the rock formed on an ancient sea floor, and uplift carried it into the mountains — two rock-cycle processes, each over millions of years, read from one set of fossils.

Example 4 — unscaffolded

A student looks at a hard basalt headland being attacked by the sea and says: *"Basalt is one of the hardest rocks there is, so the sea will never wear it away."* Evaluate this claim using the rock cycle and what you know about timescales. *(Draws on `VC2S8U11.E03` and `VC2S8U11.E02`; evaluating a claim against evidence is the skill taught in subtopic 5A.)*

The claim confuses *how fast* with *whether*. Hardness affects the **rate** of weathering and erosion — basalt resists longer than soft shale would — but it does not stop the processes. Waves hammer the headland, water is forced into cracks, and freezing and the grinding of sand and pebbles all break pieces off. The basalt headland **is** being worn away; the change is just slow, usually only a little in any one year. Over millions of years, even the hardest rock at the coast is cut back, and the material is carried away as sediment to be deposited in a new place — ready to begin the sedimentary half of the rock cycle. Evidence that the claim is wrong can be seen at any rocky coast: caves, arches and stacks cut into hard rock, like the limestone stacks of the Twelve Apostles, which the sea is still eroding today. ∴ the sea *will* wear the basalt away — not never, but slowly; hardness sets the timescale, it does not stop the cycle.

Practice questions

Scaffolded

Q1. Define each of the following, as the words are used in this subtopic: (a) weathering; (b) erosion; (c) deposition; (d) crystallisation.

Q2. Rocks are sorted into three groups by how they formed. (a) Name the three groups. (b) For each group, state what it forms from. (c) Give one example rock for each group.

Q3. Igneous rocks form when a melt cools. (a) What is the difference between magma and lava? (b) Name one igneous rock that cools quickly, and state where it cools. (c) Name one igneous rock that cools slowly, and explain why its crystals are large enough to see.

Q4. Sedimentary rocks form from loose sediment. (a) Name the two processes that turn loose sediment into solid rock. (b) Explain how each of the two processes works. (c) Explain why fossils are found in sedimentary rocks but almost never in igneous rocks.

Q5. Metamorphic rocks form when existing rocks are changed underground. (a) Name the two things that change an existing rock into a metamorphic rock. (b) What must *not* happen to the rock while this is going on, or it stops being a metamorphic story? (c) Complete each change: limestone → ______; shale → ______.

Q6. The rock cycle runs at different speeds. Sort these five events into the two groups of the table below: **fast events**, taking hours to months, and **slow events**, taking thousands to millions of years.

A. A flood drops a fresh layer of sediment on a river flat. **B.** A thin lava flow cools to solid basalt. **C.** Layers of sediment are compacted and cemented into sandstone. **D.** A sea floor is uplifted into a mountain range. **E.** Waves break pieces off a cliff during a storm.

Fast: hours to months	Slow: thousands to millions of years

Unscaffolded

Q7. Follow one grain of sand through the rock cycle. Starting with a piece of granite in a mountain range, describe the sequence of processes that could turn it into a grain of sandstone, and then into a grain inside a metamorphic rock. Name at least five processes in your answer. *(4 marks)*

Q8. Forces and heat energy drive the rock cycle. For each of the three rock groups, state the main source of energy or force that makes it, and choose from: the Sun, gravity, Earth's internal heat, and forces inside the Earth that squeeze and lift rock. *(3 marks)*

Q9. *(Novel scenario.)* A student finds a rock made of rounded pebbles, all cemented together in layers. (a) State which rock group it belongs to, and give the reason. (b) Explain what the rounded shape of the pebbles tells you about the rock's history. *(3 marks)*

Q10. Fossils come in different kinds. (a) Distinguish between a body fossil and a trace fossil, giving one example of each. (b) State one thing a trace fossil can tell you that a body fossil cannot. *(3 marks)*

Q11. *(Novel scenario.)* An opalised dinosaur bone is found at an opal field in central Australia. (a) Explain what must have happened to the bone, long after the dinosaur was buried. (b) Explain why this fossil was found in sedimentary rock, and not in marble. *(3 marks)*

Q12. *"The rock cycle is far too slow for anyone to ever see any of it happening."* Evaluate this claim. In your answer, give one part of the claim that is correct and one part that is wrong, with an example for each. *(3 marks)*

Q13. *(Novel scenario.)* A rock sample contains fossils of sea shells, but the shells are squashed and stretched, and the rock itself is in bent, wavy layers. (a) State which rock group the sample now belongs to. (b) Reconstruct the rock's history in three steps, from loose sediment to the rock in the student's hand. *(4 marks)*

Q14. *(Data interpretation — simulated data for practice.)* Four rock samples are tested, with the results below. Classify each sample as sedimentary, igneous or metamorphic, and give the evidence you used. (Reading a table for patterns and using them to classify is also practice for subtopic 4C.)

Sample	Layers?	Crystals visible?	Fossils?	Other observations
1	Yes	No	Yes — sea shells	Rubs away easily; grains feel gritty
2	No	Yes — large, speckled	None	Very hard; crystals lock together
3	No	No — crystals too small to see	None	Dark; hard; some tiny holes
4	Bent, wavy layers	Crystals re-formed and interlocking	Squashed shell shapes	Hard; splits along shiny surfaces

(4 marks)

Answers

Q1. (a) The breaking down of rock where it sits, with no movement. (b) The carrying away of broken rock by water, wind, ice or waves. (c) The dropping of sediment when its carrier slows down. (d) Crystals forming and growing as a melt cools and becomes solid. **Q2.** (a) Sedimentary, igneous, metamorphic. (b) Sedimentary: from sediment pressed and cemented together. Igneous: from magma or lava cooling and solidifying. Metamorphic: from existing rock changed by heat and pressure without melting. (c) E.g. sandstone / basalt or granite / marble or slate. **Q3.** (a) Magma is melted rock underground; lava is magma that has reached the surface. (b) Basalt; it cools at the surface from a lava flow. (c) Granite; it cools underground surrounded by warm rock, so heat escapes slowly and crystals have a long time to grow. **Q4.** (a) Compaction and cementation. (b) Compaction: the weight of layers above squeezes the grains together. Cementation: dissolved minerals left by water glue the grains together. (c) Sedimentary rocks form at low temperatures from buried sediment, so remains can be preserved; igneous rocks form from melts hot enough to destroy any remains. **Q5.** (a) Heat and pressure. (b) It must not melt — if it melts it becomes magma. (c) Limestone → marble; shale → slate. **Q6.** Fast: A, B, E. Slow: C, D. **Q7.** A sequence such as: weathering breaks the granite apart → erosion carries the grain downhill and down rivers → deposition drops it in a layer of sediment → compaction and cementation turn the sediment into sandstone → burial plus heat and pressure change the sandstone into metamorphic rock (the grain survives inside it). Any correct chain naming at least five processes. **Q8.** Igneous: Earth's internal heat (melts rock; the melt then cools). Metamorphic: Earth's internal heat plus forces inside the Earth (heat and pressure). Sedimentary: the Sun (drives the weather that weathers and erodes) and gravity (carries sediment downhill); forces inside the Earth bury and lift it. **Q9.** (a) Sedimentary — it is in layers and its pieces are cemented together. (b) The pebbles were rounded by being knocked and rubbed while they were carried — a long journey by water before they were deposited. **Q10.** (a) A body fossil is part of the organism itself (e.g. a bone, tooth, shell or leaf); a trace fossil is a mark the organism left behind (e.g. a footprint or burrow). (b) Behaviour — how the organism moved or lived, e.g. that it walked on that spot. **Q11.** (a) Mineral-rich water slowly replaced the material of the bone with opal. (b) The bone was buried in sediment that became sedimentary rock; marble forms by heat and pressure, which would have destroyed the fossil. **Q12.** Correct part: the slow steps — compaction and cementation, uplift, metamorphism — take thousands to millions of years, far longer than a human lifetime. Wrong part: some steps are quick and can be seen — a storm breaking rock off a cliff, or a flood depositing a layer of sediment. **Q13.** (a) Metamorphic. (b) Step 1: shells and sediment were deposited in layers on a sea floor and compacted and cemented into sedimentary rock. Step 2: the rock was buried, and heat and pressure squashed the layers and the fossils, changing it into metamorphic rock. Step 3: uplift brought it back toward the surface, where it was exposed — ready to be found (and, in time, weathered again). **Q14.** Sample 1: sedimentary — layers, fossils, grains cemented together. Sample 2: igneous — large interlocking crystals, no layers, no fossils (slow-cooled underground). Sample 3: igneous — no visible crystals, no layers, tiny holes from gas (fast-cooled lava). Sample 4: metamorphic — bent wavy layers, re-formed crystals, squashed fossils.

Fully-worked solutions

Q1. (a) **Weathering** is the **breaking down of rock where it sits**, with no movement — by freezing water in cracks, plant roots, waves or wind-blown sand. (b) **Erosion** is the **carrying away** of the broken pieces by moving water, wind, ice or waves. (c) **Deposition** is the **dropping** of sediment when its carrier slows down — layers settle out of the moving water, wind or ice. (d) **Crystallisation** is **crystals forming and growing as a melt cools and becomes solid**; in igneous rocks the crystals lock together to make solid rock. *(1 mark each.)*

Q2. (a) **Sedimentary, igneous and metamorphic.** (b) **Sedimentary rocks form from sediment** — loose grains, mud, shells and bones — pressed and cemented together. **Igneous rocks form from melted rock** (magma or lava) cooling and solidifying by crystallisation. **Metamorphic rocks form from existing rock changed by heat and pressure** underground, without melting. (c) Sedimentary: **sandstone** (or shale, limestone). Igneous: **basalt** (or granite). Metamorphic: **marble** (or slate). *(a: 1 mark; b: 1 mark; c: 1 mark.)*

Q3. (a) **Magma** is melted rock **underground**; **lava** is magma that has **reached the surface** through a volcano. (b) **Basalt** cools quickly: it forms from a **lava flow at the surface**, where heat escapes fast into the cooler air and ground, so a thin flow can be solid in days to weeks. (c) **Granite** cools slowly **underground**, surrounded by warm rock, so its **heat escapes very slowly** — over tens of thousands to millions of years — and its **crystals have a long time to grow**, which is why they are large enough to see. *(a: 1 mark; b: 1 mark; c: 2 marks — one for cooling slowly underground, one for crystals having time to grow.)*

Q4. (a) **Compaction** and **cementation**. (b) **Compaction:** as more layers of sediment pile up, the **weight of the layers above squeezes the lower layers**, pressing the grains tighter together. **Cementation:** water moving slowly through the sediment carries **dissolved minerals**, which are left behind **between the grains and glue them together** like dried glue. (c) Sedimentary rocks form from buried sediment **at low temperatures**, so shells, bones and leaves can be preserved before they rot away. Igneous rocks form from **melts hot enough to destroy** any remains — nothing buried in a melt could survive as a fossil. *(a: 1 mark; b: 2 marks; c: 2 marks — one for the gentle formation of sedimentary rock, one for the heat of a melt destroying remains.)*

Q5. (a) **Heat and pressure.** (b) The rock must **not melt** — once it melts it is magma, and when it cools it will be **igneous**, not metamorphic. (c) Limestone → **marble**; shale → **slate**. *(a: 1 mark; b: 1 mark; c: 1 mark.)*

Q6. Fast (hours to months): **A** (a flood depositing a layer), **B** (a thin lava flow cooling), **E** (storm waves breaking rock off a cliff) — all single events you could see in a season or less. Slow (thousands to millions of years): **C** (compaction and cementation into sandstone) and **D** (a sea floor uplifted into a mountain range) — both need burial, weight or Earth's internal forces acting over geological time. *(1 mark per correct group.)*

Q7. One correct chain, with the processes named: **(1) Weathering** breaks the granite apart where it sits in the mountain. **(2) Erosion** carries the loose grain downhill and down rivers. **(3) Deposition** drops the grain in a layer of sediment — for instance where a river meets the sea. **(4) Compaction and (5) cementation** press and glue the sediment into sandstone, with the grain now inside it. **(6) Burial, heat and pressure** then change the sandstone into metamorphic rock, with the grain still inside. Any answer that names at least five of these processes in a workable order — for example, going through uplift before weathering — earns full marks. *(4 marks: 1 for weathering + erosion + deposition as the surface journey; 1 for compaction and cementation making sandstone; 1 for heat and pressure changing it to metamorphic rock; 1 for the whole chain being in a workable order.)*

Q8. Igneous rocks owe their making to **Earth's internal heat**, which melts rock into magma; the melt then loses that heat and hardens by crystallisation. **Metamorphic** rocks need both **Earth's internal heat and the forces inside the Earth** — the heat and the pressure that change a buried rock without melting it. **Sedimentary** rocks are built at the surface: **the Sun** drives the wind, rain and waves that weather and erode rock, and **gravity** carries the sediment downhill and down rivers until it is deposited. *(3 marks: 1 per rock group correctly matched.)*

Q9. (a) It is **sedimentary**: it is built in **layers** and its pieces are **cemented together**, which is how sedimentary rock forms — from loose material deposited, compacted and cemented. (b) The pebbles were **rounded by being knocked and rubbed during transport** — probably carried a long way by running water — before they were deposited. Pebbles do not start out rounded; their shape is a record of the journey. *(a: 1 mark for the group with the layers/cementation reason; b: 2 marks — rounding came from transport, and that means a journey before deposition.)*

Q10. (a) A **body fossil** is the preserved **part of the organism itself —** for example a bone, tooth, shell or leaf. A **trace fossil** is a **mark the organism left behind** — for example a footprint, burrow or feeding trail. (b) A trace fossil records **behaviour —** it can show that the animal walked across that exact spot, or dug into the sediment, which a body fossil alone cannot. *(a: 2 marks — 1 per kind with a correct example; b: 1 mark.)*

Q11. (a) After the bone was buried, **mineral-rich water moved through the sediment and slowly replaced the material of the bone with opal** — the bone's shape was kept while its material changed to the gemstone. (b) The bone was buried in **loose sediment that was compacted and cemented into sedimentary rock**; fossils survive that gentle history. **Marble forms by heat and pressure**, which would have squashed the fossil and destroyed it — so an intact opalised fossil tells you its host rock stayed sedimentary. *(a: 1 mark; b: 2 marks — one for burial in sediment becoming sedimentary rock, one for heat and pressure of marble-making destroying fossils.)*

Q12. The claim is **right in one part and wrong in another**. **Right part:** the slow steps of the rock cycle really are beyond watching — **compaction and cementation, uplift and metamorphism take thousands to millions of years**, far longer than any human lifetime, so nobody sees a limestone turn into a marble. **Wrong part:** some steps of the cycle are quick and can be seen directly — **waves breaking pieces off a cliff in a storm**, or **a flood depositing a fresh layer of sediment** on a river flat, both happen within hours to days. The claim mistakes the slowest steps for the whole cycle. *(1 mark: correct part with a slow example; 1 mark: wrong part with a fast example; 1 mark: a clear overall judgement that separates the two.)*

Q13. (a) The sample is **metamorphic** rock: bent, wavy layers and squashed fossils mean it has been changed by heat and pressure. (b) **Step 1 — deposition to sedimentary rock:** shells and sediment were **deposited in layers on a sea**

floor, buried, and compacted and cemented into a sedimentary rock holding the shell fossils. **Step 2 — metamorphism:** the rock was **buried deeper, where heat and pressure squashed and bent the layers** and stretched the fossils, changing the rock into a metamorphic rock. **Step 3 — uplift and exposure:** forces inside the Earth **uplifted** the rock back toward the surface, where erosion exposed it — and where, given time, weathering will break it down into sediment again. *(a: 1 mark; b: 3 marks — 1 per step, each naming the right process.)*

Q14. Sample 1 — sedimentary: it has **layers**, **no visible crystals**, and it holds **sea shell fossils**; gritty grains cemented together are sediment grains. *(Evidence: layers + fossils + grains.)* **Sample 2 — igneous:** it has **large, interlocking, visible crystals** with no layers and no fossils — crystals that size grow only in a melt that **cooled slowly underground**. **Sample 3 — igneous:** it has **no visible crystals and no layers**, and the **tiny holes** are where gas was trapped in a **lava that cooled quickly at the surface**. **Sample 4 — metamorphic:** its **bent, wavy layers**, **re-formed interlocking crystals** and **squashed fossils** are the marks of a rock changed by **heat and pressure** — the fossils show it began as a sedimentary rock. *(4 marks: 1 per sample correctly classified with its evidence.)*

Rock properties in use: identifying a rock, what its properties make it good for, and the methods used to quarry or mine it

Book: Science, Levels 7 and 8 (VC2) — one banded volume · **Chapter 13 — Earth and space sciences B: rocks, minerals and Earth's resources** · **Subtopic 13B**

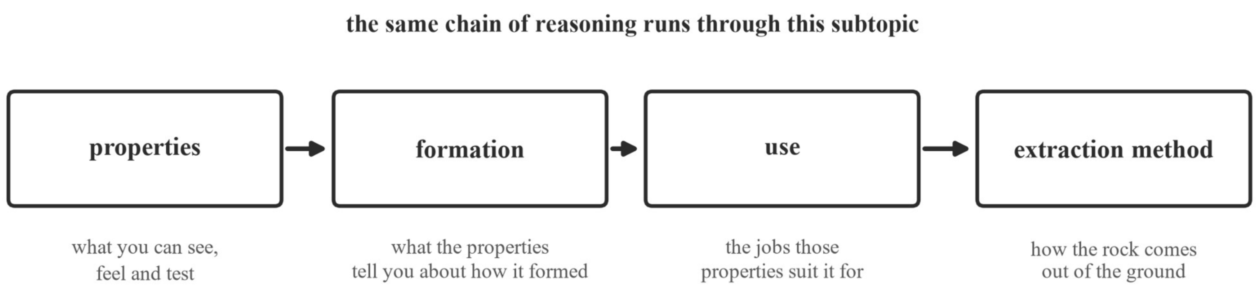
CD: `VC2S8U11` (split delivery, D6) — **13B is the partner; 13A is the accountable owner.** Clause delivered here: *the properties of sedimentary, igneous and metamorphic rocks not only reflect their formation but also impact their usefulness and determine the methods used when mined.* Full CD text (verbatim): *"key processes of the rock cycle occur over different timescales; the properties of sedimentary, igneous and metamorphic rocks not only reflect their formation but also impact their usefulness and determine the methods used when mined."* **Achievement-standard extract:** reproduced verbatim in 13A's header block, as D13 requires for a split CD; the partner cites it by reference. This subtopic serves that extract's requirement that students explain how the properties of rocks relate to their formation and influence their use. **Elaboration ids drawn on:** `VC2S8U11.E01` (identifying rocks by observable properties with a provided dichotomous key), `VC2S8U11.E05` (Aboriginal quarrying, Mount William Stone Hatchet Quarry), `VC2S8U11.E06` (mining impacts and restoring the land). These are a context bank, not a checklist (D12). **Maths interlock (D11):** none listed for 13B; no calculation beyond earlier-band skills is required here.

Theory

In 13A you followed the rock cycle — the slow set of processes that makes, changes and remakes the three families of rock. This subtopic puts those rocks to work. It answers four questions, in order:

1. **How do you identify a rock** when you pick one up?
2. **Why does it have those properties** — what does each property tell you about how the rock formed?
3. **What is the rock good for** — which jobs do its properties suit it for?
4. **How do you get it out of the ground** — and why does the rock itself help decide the method?

The same chain of reasoning — **properties → formation → use → extraction method** — runs through the whole subtopic.



Flow diagram of four boxes joined by arrows, read left to right, titled the chain of reasoning in this subtopic. Box 1: properties — what you can see, feel and test. Box 2: formation — what those properties tell you about how the rock formed. Box 3: use — the jobs those properties suit the rock for. Box 4: extraction method — how the rock comes out of the ground. A line above the boxes reads: the same chain of reasoning runs through the whole subtopic.

1. The properties you look at when identifying a rock

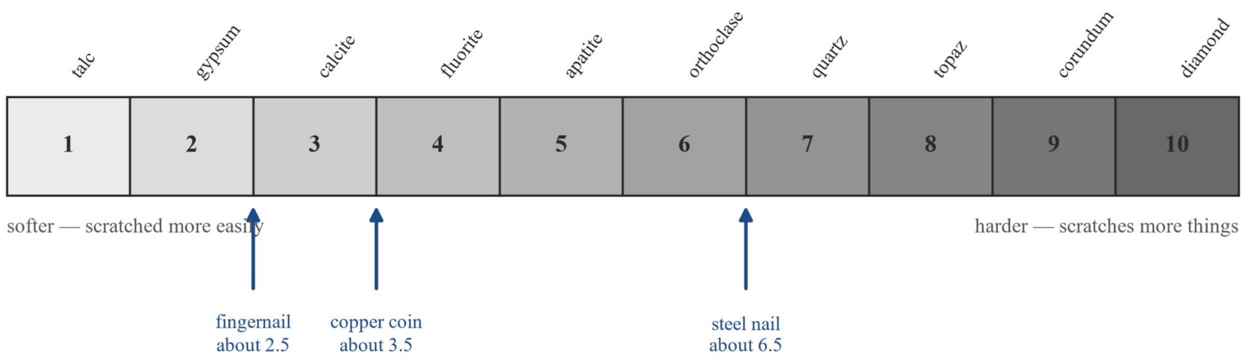
A rock's **properties** are its observable features: what you can see, feel and test without breaking it apart. Six properties do most of the identifying work (VC2S8U11.E01).

Property	What you do	What it tells you
Colour	Look at a fresh, clean surface.	A first clue only — many rocks share colours, and weathering changes the outside.

Property	What you do	What it tells you
Texture	Look closely (a hand lens helps) and rub with a finger. Are the bits large or small, rounded or interlocking? Gritty or smooth?	How the rock was put together — from grains, from crystals, or from fine mud.
Layering	Look for flat layers, stripes or bands.	Layering is typical of rocks formed from sediment settling out.
Hardness	Try to scratch the rock, and try to scratch other things with it (the scratch test, below).	How strongly the rock resists being scratched.
Acid test	Put one drop of dilute acid on the rock and watch for fizzing.	Fizzing (bubbles of gas) shows the rock contains the mineral calcite.
Fossils	Look for shapes of shells, bones or traces.	Fossils are found in rocks formed from sediment, never in rocks that cooled from melted rock.

Hardness and the scratch test. Hardness is how well a material resists being scratched. In 1812 the German geologist Friedrich Mohs introduced a scale that ranks minerals by scratch resistance, from **1** (talc, the softest) to **10** (diamond, the hardest) [S1]. The Mohs numbers are **ranks, not measurements**: they tell you the *order* of hardness, not *how much* harder one mineral is than another [S1]. You do not need laboratory minerals to use the scale. A fingernail has a hardness of about 2.5, a copper coin about 3.5 and a steel nail about 6.5, all as rough guides against the Mohs scale. A rock that your fingernail cannot scratch, but a steel nail can, sits between those two numbers. Two rocks of the same size can also feel different in the hand — one may be clearly heavier — which is a further clue to what it is made of.

Mohs hardness scale — ten minerals ranked by scratch resistance

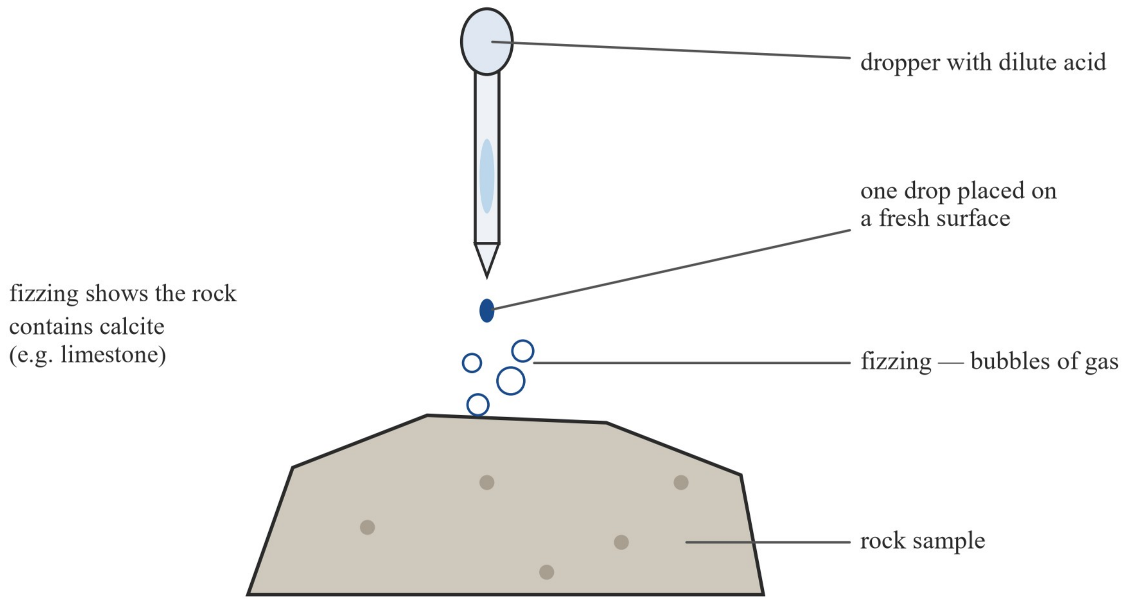


the numbers are ranks, not measurements — they give the order of hardness, not how much harder one mineral is

The Mohs hardness scale drawn as a row of ten boxes ranked 1 to 10, from talc the softest to diamond the hardest, coloured from light for soft to dark for hard. The numbers are ranks, not measurements — they give the order of hardness, not how much harder one mineral is than another. Three blue arrows below the row mark everyday guides: a fingernail at about 2.5, a copper coin at about 3.5, and a steel nail at about 6.5. A footer line reads: a rock your fingernail cannot scratch but a steel nail can sits between those two numbers.

The acid test. Rocks built mostly of the mineral **calcite** — limestone is the common example — **fizz** when a drop of dilute acid is placed on them: bubbles of gas are released [S5]. Even weak household acids such as vinegar can show a slow reaction on a fresh surface. No other common rock does this, so the acid test is a quick way to spot limestone and rocks made from it.

The acid test



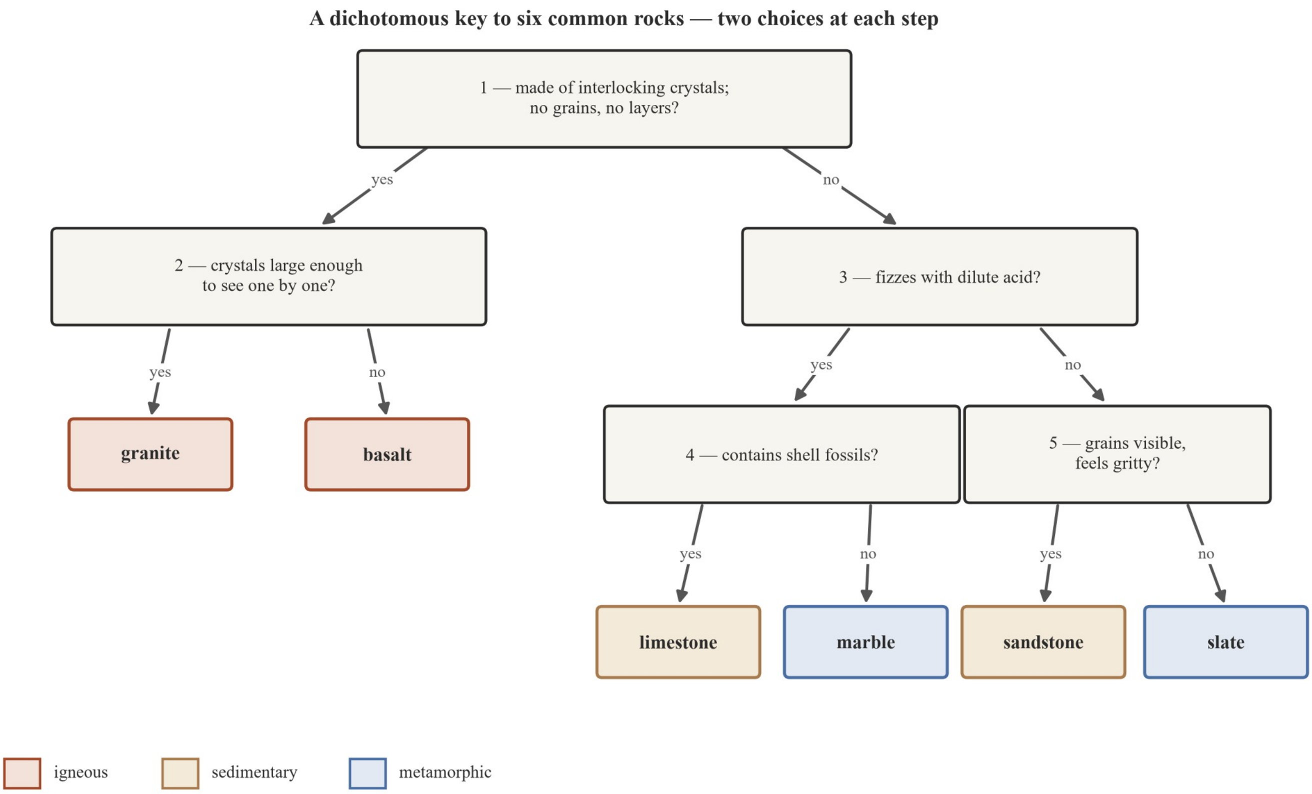
no other common rock fizzes like this — a quick way to spot limestone

Labelled sketch of the acid test. A small tube places one drop of dilute acid onto a fresh surface of a rock sample; the falling drop is shown above the rock, and bubbles of gas rise where it lands, labelled fizzing. A side note reads: fizzing shows the rock contains calcite — limestone is the common example. A footer line reads: no other common rock does this, so the acid test is a quick way to spot limestone.

Using a provided key: the dichotomous key. Identifying a rock from its properties is easiest with a **dichotomous key** — a tool that offers exactly **two choices at each step** and sends you to the next step until you reach a name. (This is VCAA's own term for the tool — `VC2S8U11.E01` asks you to identify rocks *using a provided dichotomous key*.) Here is a key for six common rocks. Keep it nearby: Worked example 1 and Questions 1–3 use it.

A dichotomous key to six common rocks

1a Made of interlocking crystals; no grains, no layers → go to **2** **1b** Made of grains or very fine particles; may show layers → go to **3** **2a** Crystals large enough to see one by one; speckled, often pale with dark flecks → **granite** **2b** Crystals too small to see; dark grey to black → **basalt** **3a** Fizzes with dilute acid → go to **4** **3b** Does not fizz with dilute acid → go to **5** **4a** Often contains shell fossils; cream or grey → **limestone** **4b** No fossils; made of calcite crystals that grew together; takes a polish → **marble** **5a** Grains visible; feels gritty like sandpaper → **sandstone** **5b** No visible grains; splits into thin, flat sheets → **slate**



Flow diagram of the dichotomous key to six common rocks, with two choices at each step. Step 1 asks: is the rock made of interlocking crystals, with no grains and no layers? Yes goes to step 2; no goes to step 3. Step 2 asks: are the crystals large enough to see one by one? Yes gives granite; no gives basalt. Step 3 asks: does the rock fizz with dilute acid? Yes goes to step 4; no goes to step 5. Step 4 asks: does it contain shell fossils? Yes gives limestone; no gives marble. Step 5 asks: are grains visible and gritty? Yes gives sandstone; no gives slate. The six rock boxes are coloured by rock family — igneous, sedimentary, metamorphic — with a legend below.

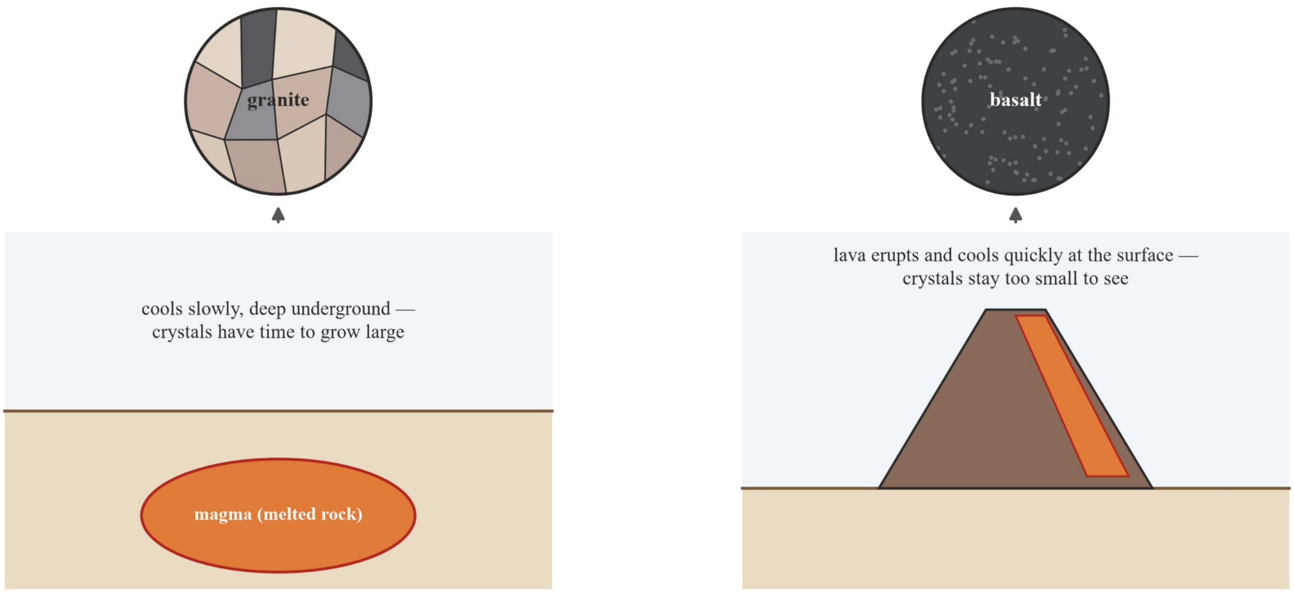
A key works because each step forces a **decision between two observable properties** — colour alone would separate almost none of these rocks, because several of them are grey.

2. Properties reflect formation

Every property above is a clue to how the rock formed. You met the forming processes in 13A; here is what each leaves behind (VC2S8U11).

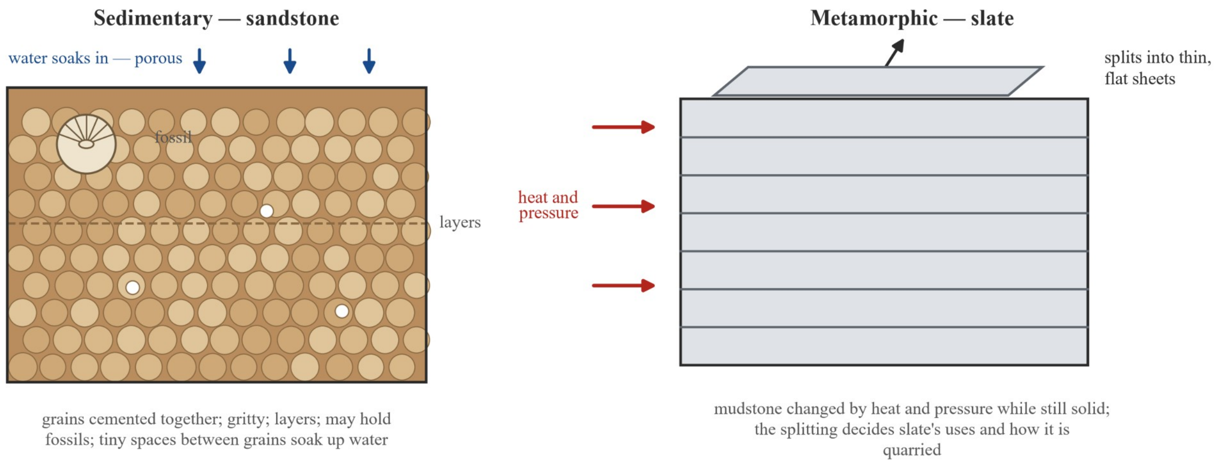
- **Igneous rocks** cooled from melted rock. **Where and how fast they cooled is recorded in their crystal size.** Magma that cools **slowly, deep underground**, has time to grow **large, visible crystals** — granite is the classic example. Lava that erupts and cools **quickly at the surface** gives the crystals no time to grow, so they stay **too small to see** — basalt is the most common rock of this kind [S2]. Both are hard and tough, because their interlocking crystals hold together well.
- **Sedimentary rocks** formed where grains of sand, mud or shell settled, were buried, and were pressed and cemented into rock. Their tell-tale properties follow directly: you can often **see and feel the grains** (sandstone feels gritty), they commonly show **layers**, they may hold **fossils**, and they are usually **softer** than igneous rocks because the cement between the grains is weaker than interlocking crystals. Sandstone is also **porous** — full of tiny spaces between its grains that can soak up water.
- **Metamorphic rocks** are rocks changed by heat and pressure while still solid. The change rearranges the rock: minerals grow into new interlocking crystals (marble is limestone changed this way), or the rock develops a **tendency to split along flat, parallel sheets** (slate is changed mudstone of this kind). That splitting is a property, and — as you will see — it decides both what slate is good for and how it is quarried.

Where and how fast melted rock cooled is recorded in its crystal size



slow cooling underground → large visible crystals; quick cooling at the surface → crystals too small to see

Two-panel diagram titled cooling speed sets crystal size in igneous rocks. Left panel: magma cools slowly, deep underground, so crystals have time to grow large; a close-up circle shows the interlocking crystals of granite, large enough to see one by one. Right panel: lava erupts and cools quickly at the surface, so crystals stay too small to see; a close-up circle shows the fine dark ground of basalt. A footer line reads: slow cooling underground gives large visible crystals; quick cooling at the surface gives crystals too small to see.



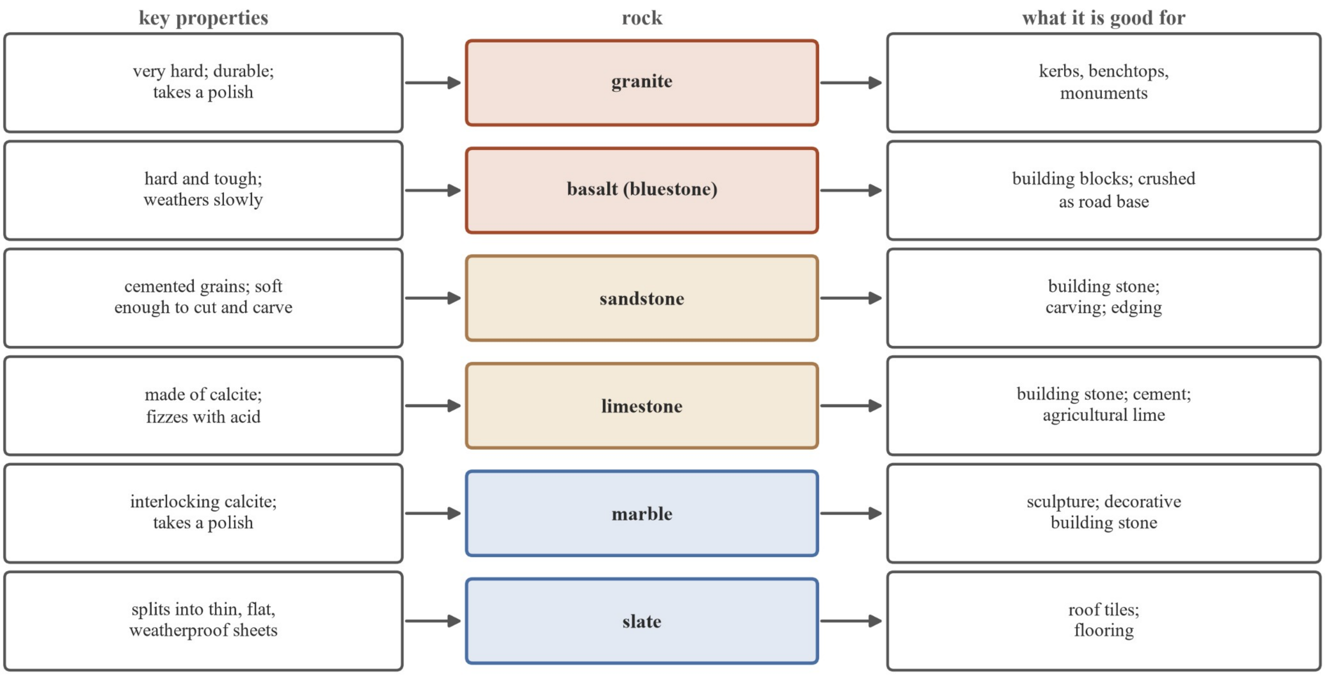
Two-panel diagram of the textures that record how a rock formed. Left panel, sedimentary sandstone: round grains cemented together with tiny spaces between them labelled pores, a line marking layers, a shell fossil, and blue arrows of water soaking in from above, labelled porous. Right panel, metamorphic slate: red arrows of heat and pressure change mudstone while it is still solid, and the rock splits into thin, flat, parallel sheets, with one sheet lifting away. A footer line reads: grains, cement, layers and pores say sedimentary; flat splitting sheets say metamorphic.

3. What the properties make each rock good for

A rock is chosen for a job the way any material is chosen: the **properties must match what the job demands**. The table below is worth learning — it pairs each rock with the properties that suit it to its uses.

Rock	Family	Key properties	What those properties make it good for
Granite	igneous	very hard; extremely	kerbs, benchtops,

Rock	Family	Key properties	What those properties make it good for
		durable; attractive when polished [S3]	monuments, building stone [S3]
Basalt (in Victoria called **bluestone**)	igneous	hard; tough; weathers slowly [S4]	building blocks, kerbs and gutters, cobblestones; crushed as road base, railway ballast and in concrete [S4]
Sandstone	sedimentary	grains cemented together; relatively soft and easy to cut and carve; attractive colours	building stone, carving, garden edging
Limestone	sedimentary	made of calcite; fizzes with dilute acid; often fossil-bearing [S5]	building stone; crushed and heated to make cement; ground as agricultural lime to neutralise acidic soils [S5]
Marble	metamorphic	interlocking calcite crystals; takes a high polish	sculpture, decorative building stone
Slate	metamorphic	splits into thin, flat, weatherproof sheets [S6]	roof tiles [S6], flooring, paving



a rock is chosen for a job the way any material is chosen — the properties must match what the job demands

Diagram in three columns matching properties to rocks to uses, in six rows. Row 1: very hard, durable, takes a polish — granite — kerbs, benchtops, monuments. Row 2: hard and tough, weathers slowly — basalt, called bluestone in Victoria — building blocks, crushed as road base. Row 3: grains cemented together, soft enough to cut and carve — sandstone — building stone, carving, garden edging. Row 4: made of calcite, fizzes with dilute acid — limestone — building stone, cement, agricultural lime. Row 5: interlocking calcite crystals, takes a high polish — marble — sculpture, decorative building stone. Row 6: splits into thin, flat, weatherproof sheets — slate — roof tiles, flooring.

Rock boxes are coloured by rock family as in the key diagram. A footer line reads: a rock is chosen for a job the way any material is chosen — the properties must match what the job demands.

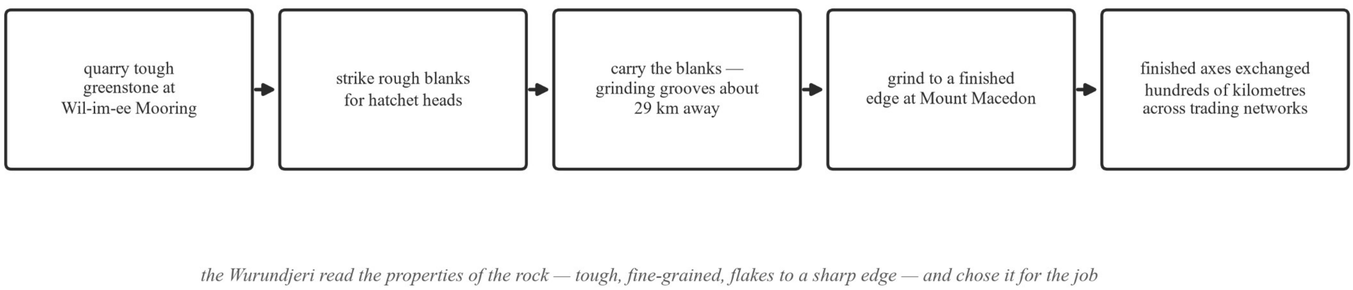
A worked case from Victoria: bluestone. In Victoria the word **bluestone** means the local basalt or olivine basalt [S4]. From the 1850s gold-rush era it was quarried in Melbourne's inner northern suburbs — Clifton Hill, Brunswick and Coburg — and used for warehouses, walls, foundations, cobblestones, and kerbs and gutters [S4]. Buildings such as the Old Melbourne Gaol, St Patrick's Cathedral and Princes Bridge are bluestone [S4]. Crushed bluestone — still sold as **blue metal** — is used as railway ballast, road base and in concrete [S4]. The same two properties, **hardness and toughness**, serve both jobs: a kerb must survive carts and weather for a century, and a road base must carry traffic without crumbling.

4. Quarrying on Country: the Wurundjeri greenstone hatchet quarry at Wil-im-ee Mooring

Long before modern quarries, Aboriginal Peoples in Victoria quarried rock for tools, choosing the rock whose properties suited each job (VC2S8U11.E05). The best-documented example is the **Mount William Stone Hatchet Quarry**, in Central Victoria about 9 km north-east of Lancefield and about 78 km from Melbourne [S7]. The Wurundjeri name for the site is **Wil-im-ee Mooring**, which the Wurundjeri Woi Wurrung Cultural Heritage Aboriginal Corporation gives as "home of many axes" [S9].

- **The People and their custodianship.** The quarry is on the Country of the **Wurundjeri**, and records made by William Barak — a prominent Wurundjeri leader and custodian of the quarry — describe the Kurnung-willam and Kurnaje-berreing clans, two of the three clans that made up the Wurundjeri, as owning and caring for the quarry, with the headman Billi-billeri in charge of the site [S7].
- **The rock and its properties.** The ancestors of the Wurundjeri "quarried superb greenstone" here to make axes [S9]. **Greenstone** is a dark, very tough rock. Being fine-grained and tough, it could be struck so that it flaked into shapes with strong, sharp edges — exactly the properties a hatchet head needs.
- **What was made.** The quarry produced **rough blanks for hatchet heads**, which were then ground to a finished edge in another place [S7]. The closest known grinding grooves are at Mount Macedon, about 29 km away [S7], where a sharpening boulder carries thirty-one grooves [S9]. The Victorian Curriculum asks you to investigate how Aboriginal Peoples used quarrying to access rocks for everyday objects such as grindstones, hammerstones, anvils and cutting tools, and how stone hatchets from this quarry were used for food-gathering, construction, canoe-building and the manufacture of shields, clubs and spears (VC2S8U11.E05).
- **Trade.** Wil-im-ee Mooring was "the centre of an extraordinary trading network" [S9]. Stone from the quarry was traded over a wide area of south-east Australia, and exchange networks extended several hundred kilometres [S7]. Early records describe polished axes being exchanged for possum-skin covers and unpolished ones for bamboo spears [S7].
- **Heritage status today.** The site covers about forty hectares [S9] and was included on the Australian **National Heritage List** on **25 February 2008** [S8]. Ownership of the site was returned to the Wurundjeri in **2012**, and **access to the quarry requires the permission of the Wurundjeri Council** [S9]. That last fact matters for science fieldwork: visiting a cultural site like this one is a matter of permission and respect — part of the fieldwork rules that 3B teaches.

From quarry to trade: the staged making of greenstone hatchets



Five-box flow diagram of the Wurundjeri greenstone hatchet chain, read left to right. Box 1: quarry the tough greenstone at Wil-im-ee Mooring, the Mount William Stone Hatchet Quarry. Box 2: strike rough blanks for hatchet heads. Box 3: carry the blanks to grinding grooves about 29 km away. Box 4: grind the blanks to a finished edge at Mount Macedon. Box 5: finished axes exchanged over several hundred kilometres through trading networks. A footer *line reads: the Wurundjeri read the properties of the rock — tough, fine-grained, flakes to a sharp edge — and chose it for the job.*

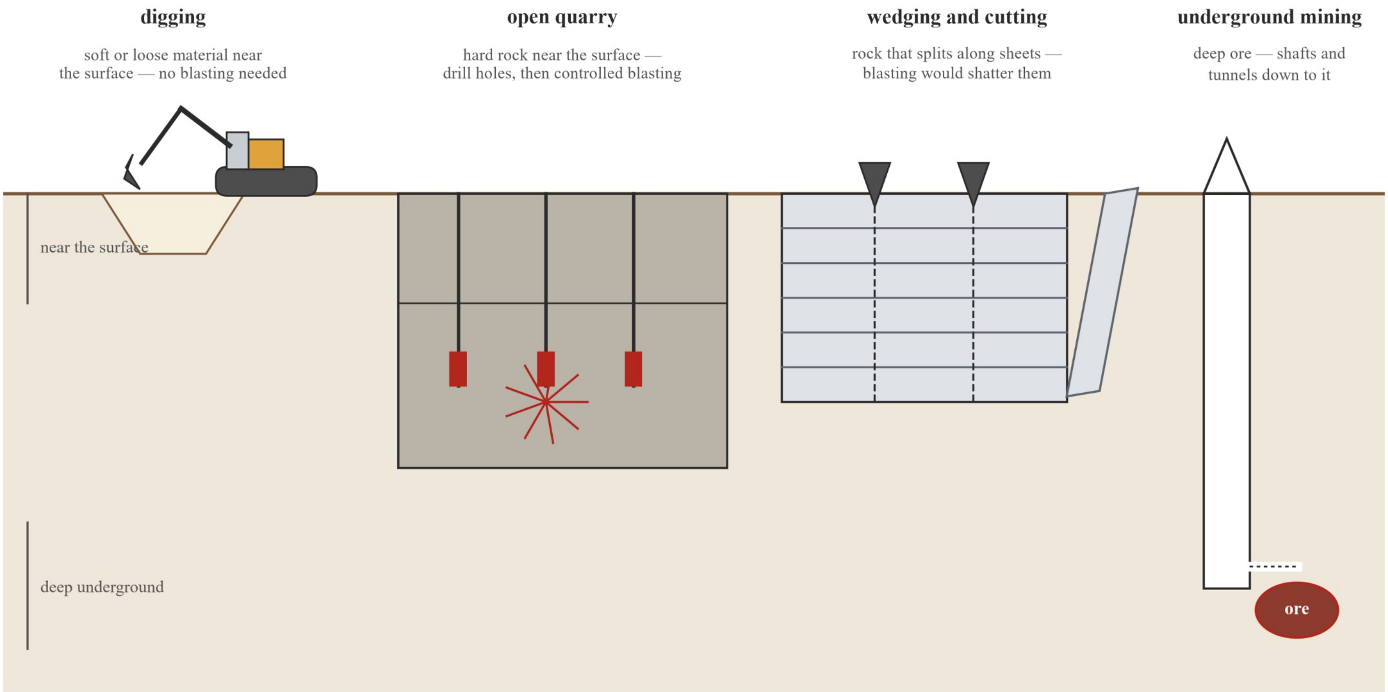
Notice that the reasoning here is identical to a modern quarry engineer's reasoning. The Wurundjeri read the **properties** of the rock — tough, fine-grained, flakes to a sharp edge — and chose it for the job. The properties of the rock decided its use thousands of years ago, exactly as they do today.

5. Getting the rock out: methods follow properties

Rocks useful to people do not come to the surface ready-made. They must be **extracted** — and the way they are extracted depends on their properties and on where they sit.

A **quarry** is a place where rock and earth materials — such as limestone, marble, granite, gravel and sand — are dug out at the surface [S10]. A **mine** may go underground. An **ore** is a rock that contains metals or valuable minerals that can be mined for profit [S11]. Australia produces **19 useful minerals in significant amounts, from over 350 operating mines**, and mining occurs in every state, the Northern Territory and Christmas Island; the Australian Capital Territory has no mining apart from quarries for construction materials [S11].

What the deposit is like	Method used	Why the properties decide it
Soft or loose material near the surface — sand, gravel, soft rock	**Digging** straight out, with no blasting [S10]	Soft rock does not need explosives to break it free.
Hard, solid rock near the surface — granite, basalt	An **open quarry**: holes are drilled, then **controlled blasting** with explosives placed in the drilled holes breaks the rock free [S10]	Hard rock cannot be dug; its hardness forces drilling and blasting.
Rock that splits along sheets or beds — slate, layered sandstone	**Wedging and cutting** along the natural breaks, so blocks and slabs come away in useful shapes [S10]	The rock's own splitting does half the work; blasting would shatter the sheets.
Valuable ore deep underground	**Underground mining** — shafts and tunnels down to the ore [S10]	Depth, not hardness, decides this: an open pit that deep would move too much material.
Hard rock wanted as road base or concrete	Blasted rock is **crushed and sorted by size** afterwards — bluestone sold as blue metal [S4]	Toughness makes it worth crushing; the job wants small, graded pieces, not blocks.



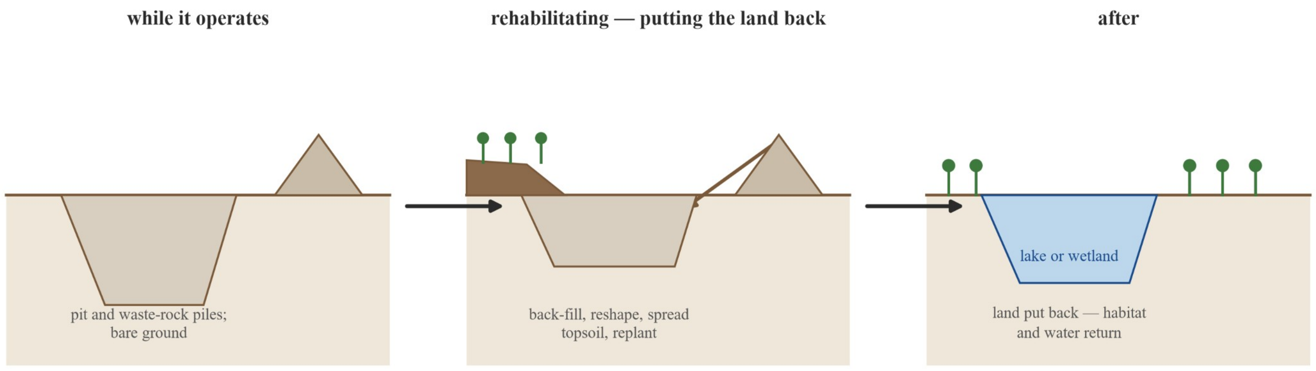
Cross-section of the ground showing four extraction methods side by side. Digging: a digging machine digs soft or loose material near the surface, with no blasting. Open quarry: hard rock near the surface, with holes drilled and explosives placed in the drilled holes, shown with a blast star, labelled controlled blasting. Wedging and cutting: rock that splits along sheets, with wedges driven into the cracks and a slab leaning away, labelled blasting would shatter the sheets. Underground mining: a shaft goes down from the surface with a tunnel across to a deep ore body. Depth marks on the left read near the surface and deep underground. A footer line reads: hardness decides dig or blast; the way the rock breaks decides split or shatter; depth decides open quarry or underground mine.

Three properties dominate the choice of method: **hardness** (dig or blast), **the way the rock breaks** (split or shatter), and **depth** (open quarry or underground mine). A quarry manager reads the rock the same way you do in Question 2 — and then chooses the method to match.

6. Mining changes the local environment — and the land can be put back

Digging rock out of the ground changes the place it comes from (VC2S8U11.E06). Quarrying and mining can **clear land** and **destroy habitat**, which is the main component of losses in the variety of native plants and animals at a site; they can cause **erosion**, and **contaminate soil, groundwater and surface water**; they produce piles of waste rock and fine waste that must be stored; and nearby residents deal with **dust, noise and heavy traffic** [S12].

Rehabilitating a site means restoring mined land so it can be used again [S12]. To do this, operators may **back-fill** worked-out pits with waste rock, reshape the land, control and treat contaminated water, spread saved topsoil, and replant native vegetation — or flood a pit on purpose to form a lake or wetland [S12]. A Victorian example sits in Melbourne’s north: the bluestone quarry that supplied the stone for Pentridge Prison later filled with water and is now **Coburg Lake** [S4]. Rehabilitating the land is now planned into most projects from the start, and regulators can require it [S12].



back-filled, reshaped, topsoiled and replanted — or flooded on purpose as a lake or wetland

Three-panel cross-section of a quarry site over time, with arrows joining the panels in order. Panel 1, while it operates: an open pit with waste-rock piles and bare ground. Panel 2, rehabilitating: waste rock tipped back into the pit, the land reshaped, contaminated water treated, saved topsoil spread, and native plants replanted. Panel 3, after: the pit holds a lake or wetland, and plants cover the ground again. A footer line reads: back-filled, reshaped, topsoiled and replanted — or flooded on purpose as a lake or wetland, as the bluestone quarry that became Coburg Lake.

How much benefit a community gets from extraction, set against these impacts — the weighing of benefits against risks — is the job of **13D**, where Earth's resources and energy production are treated under `VC2S8U09`.

Worked examples

Example 1 — scaffolded

Four labelled samples, A to D, are part of a classroom rock kit. Their observed properties are below. Use the dichotomous key from the Theory section to identify **samples A and B**, writing the steps you take through the key.

Sample	Observed properties
A	interlocking crystals 2–4 mm across, visible one by one; speckled pale grey with dark flecks; hard — a steel nail does not scratch it; no fizzing with dilute acid
B	cream-coloured; very fine, smooth surface; fizzes with dilute acid; several small shell fossils visible
C	grains visible and gritty to the finger; pale orange; shows flat layers; no fizzing with dilute acid
D	dark grey, almost black; crystals too small to see; hard; no fizzing with dilute acid

Working	Comment
Sample A, step 1: the rock is made of interlocking crystals, with no grains and no layers → go to 2.	Read the key from step 1 every time. The first choice is crystals against grains.
Step 2: the crystals are large enough to see one by one, and the rock is speckled and pale with dark flecks → **granite**.	Large visible crystals say it cooled slowly, deep underground.
Sample B, step 1: very fine with no interlocking crystals; may show layers → go to 3.	Fossils are already a hint of a rock formed from sediment, but follow the key.
Step 3: it fizzes with dilute acid → go to 4.	Fizzing shows calcite.
Step 4: it contains shell fossils → **limestone**.	Marble also fizzes, so the fossil test is the step that

Working	Comment
	separates the two.

Example 2 — scaffolded

(a) Explain why slate, and not granite, is used for roof tiles. (b) Explain why crushed bluestone, and not sandstone, is used as road base under heavy traffic.

Working	Comment
(a) Slate is a metamorphic rock that **splits into thin, flat sheets**.	Name the property first.
Thin sheets are light enough to lift onto a roof, flat enough to overlap and shed rain, and weatherproof, so slate is suited to roofing [S6].	Then say why that property fits the job.
Granite is hard and durable [S3], but it breaks across its crystals into rough blocks, not sheets, so it cannot be split into flat tiles.	A comparison earns its place only if it uses a property.
(b) Bluestone is basalt: **hard and tough**, so it does not crumble under load [S4].	Road base must carry traffic without breaking down.
Crushed and sorted by size, it locks together into a firm base [S4].	Crushing gives graded pieces that lock together.
Sandstone is softer and porous, so it would soak up water and wear away under heavy traffic.	The wrong rock fails because of its properties, not by bad luck.

Example 3 — unscaffolded

The Wurundjeri quarried greenstone at Wil-im-ee Mooring (Mount William) for hatchet heads, but the finished, polished axes are found far from the quarry, and the grinding grooves used to sharpen them sit about 29 km away at Mount Macedon. Explain (a) why greenstone was chosen for hatchet heads rather than any convenient rock, (b) what the grinding grooves at Mount Macedon show about how the work was organised, and (c) what the wide spread of the finished axes shows.

Model answer. (a) Greenstone is fine-grained and very tough, so when it is struck it flakes into shapes with strong, sharp edges — the exact properties a cutting hatchet head needs. A soft rock would blunt and crumble, and a rock that shatters would not hold an edge, so the choice was made on properties, not convenience. (b) The grooves at Mount Macedon show that the quarry produced **rough blanks**, which were then carried to another place to be ground and finished. The work happened in stages, in different places. (c) Finished axes from this quarry are found over a wide area of south-east Australia, through exchange networks that extended several hundred kilometres [S7][S9]. The quarry was therefore not only a workshop but **the centre of a trading network**, with hatchet heads exchanged for other goods such as possum-skin covers [S7].

Example 4 — unscaffolded

A company wants to extract rock from two sites. **Site X** is a near-surface deposit of soft, crumbly sandstone under a thin cover of soil. **Site Y** is a near-surface body of hard granite that the company wants to sell as polished benchtops. State the extraction method you would use at each site and explain why the rock's properties decide the method in each case.

Model answer. At **Site X** the sandstone is soft and near the surface, so it can be **dug out directly, without blasting** [S10]: soft rock does not need explosives to break it free, and a shallow deposit does not need a deep pit. At **Site Y** the granite is hard, so it cannot be dug; the method is an **open quarry with drilling and controlled blasting** to break the rock free [S10]. But the product must be large, unbroken slabs for benchtops — and blasting shatters rock, so the granite would be **cut from the quarry face** rather than blasted, because its value depends on keeping large pieces intact [S3][S10]. The same deposit can therefore be worked two ways: blasting for crushed rock, cutting for dimension stone. The properties of the rock and the needs of the product decide which.

Practice questions

Scaffolded

Q1. Define each of the following terms: (a) quarry; (b) hardness; (c) ore.

Q2. Samples C and D from Worked example 1 are still unidentified, and a fifth sample E has been added: **E — no visible grains; splits into thin, flat sheets; no fizzing with dilute acid.** (a) Use the provided key to identify samples C, D and E, writing the step numbers you pass through for each. (b) Explain why a dichotomous key gives more reliable identifications than colour alone.

Q3. Match each property below to the rock family (igneous, sedimentary, metamorphic) it most strongly indicates, and say why: (a) large, visible, interlocking crystals; (b) gritty grains held together by cement, with layers; (c) a tendency to split into flat, parallel sheets after being changed by heat and pressure.

Q4. The table below lists four jobs. For each job, choose the better rock from the pair given and state the property that decides your choice.

Job	Pair of rocks
(a) roof tiles	slate or granite
(b) a kerb along a busy street	basalt or sandstone
(c) a statue meant to be polished	marble or shale
(d) a stone to grind seeds on	sandstone or slate

Q5. Match each deposit to the most sensible extraction method, from: digging; drilling and blasting; wedging and cutting along sheets; underground mining. (a) a flat-lying bed of slate on a hillside; (b) gravel in a shallow pit; (c) a hard basalt flow at the surface, wanted as crushed road base; (d) a gold-bearing ore body 400 m below the surface.

Q6. A new open quarry is proposed next to farmland. (a) List three ways the quarry could affect the local environment while it operates. (b) List three things the operator could do when rehabilitating the site after extraction ends.

Unscaffolded

Q7. Granite and basalt are both igneous rocks, but granite’s crystals are large enough to see while basalt’s are too small to see. Explain how the same family of rock can end up with such different textures, and state one use suited to granite’s hardness. *(3 marks)*

Q8. A limestone building carved with fine detail slowly loses its sharp edges over many decades, especially in a city where rainwater is slightly acidic. Use the acid-test property of limestone to explain this observation. *(3 marks)*

Q9. Read the extract below, then answer the questions.

> *Wil-im-ee Mooring, the Mount William Stone Hatchet Quarry, was included on the Australian National Heritage List on 25 February 2008. The Wurundjeri quarried greenstone there for hatchet-head blanks; the closest grinding grooves are at Mount Macedon, about 29 km away, and finished axes have been found hundreds of kilometres from the quarry.* (Compiled from [S7][S8][S9].)

(a) State two properties of greenstone that made it suitable for hatchet heads.
(b) Explain what the distance between the quarry and the grinding grooves tells you about how the tools were made.
(c) Explain what the finished axes found hundreds of kilometres away tell you about the people who used the quarry. *(4 marks)*

Q10. Two quarries operate side by side. One digs soft sandstone; the other works hard basalt. Explain why the two quarries need different extraction methods, naming the method used at each. *(3 marks)*

Q11. *(Simulated data for practice.)* A council is choosing rock for two jobs: garden edging along a school path, and the base layer under a new car park. Three local rocks are offered, with their tested properties:

Rock	Hardness (Mohs)	Soaks up water?	Crumbles under a heavy load?
Rock P	3	yes	yes
Rock Q	7	no	no
Rock R	2	yes	no

Choose the better rock for each job and justify each choice using the data in the table. *(4 marks)*

Q12. A disused sandstone quarry near a town has steep bare walls, a deep pit that fills with water, and piles of waste rock. Propose three actions to rehabilitate the site, and for each one state which impact from the Theory section it addresses. *(3 marks)*

Q13. A student claims: "Igneous rocks are always better for building than sedimentary rocks, because they are harder." Evaluate this claim. Your answer should state what is correct in it, give at least one reason it is too broad, and use named rocks from this subtopic. *(4 marks)*

Q14. Access to Wil-im-ee Mooring (the Mount William Stone Hatchet Quarry) requires the permission of the Wurundjeri Council. Using what this subtopic says about the site, give two reasons why a science fieldwork group must treat a visit to such a site as a matter of permission and respect, not just as a trip to a rock outcrop. *(3 marks)*

Answers

Q1. (a) A place where rock and earth materials are dug out at the surface. (b) How well a material resists being scratched. (c) A rock that contains metals or valuable minerals that can be mined for profit. **Q2.** (a) C: sandstone (1b, 3b, 5a); D: basalt (1a, 2b); E: slate (1b, 3b, 5b). (b) Many rocks share colours; the key forces decisions between observable properties instead. **Q3.** (a) Igneous — crystals grow as melted rock cools. (b) Sedimentary — grains settle, are buried and cemented, often in layers. (c) Metamorphic — heat and pressure change the rock so it splits along sheets. **Q4.** (a) Slate — splits into flat, weatherproof sheets. (b) Basalt — hard and tough; wears slowly. (c) Marble — interlocking calcite crystals; takes a polish. (d) Sandstone — gritty surface grinds seeds. **Q5.** (a) Wedging and cutting along sheets. (b) Digging. (c) Drilling and blasting. (d) Underground mining. **Q6.** (a) Any three: habitat loss; erosion; contamination of soil or water; dust; noise; heavy traffic. (b) Any three: back-filling the pit; reshaping the land; treating contaminated water; spreading topsoil and replanting native vegetation; flooding the pit as a lake or wetland. **Q7.** Cooling rate: slow cooling underground grows large crystals (granite); fast cooling at the surface gives crystals too small to see (basalt). Use: kerbs, benchtops or monuments. **Q8.** Limestone is made of calcite, which reacts with acid, releasing gas (fizzing); slightly acidic rainwater slowly dissolves the surface, wearing detail away. **Q9.** (a) Tough; fine-grained; flakes to a strong sharp edge (any two). (b) Rough blanks were made at the quarry and carried to another place to be ground and finished — the work happened in stages in different places. (c) The quarry was the centre of a trading network; axes were exchanged over long distances. **Q10.** Sandstone is soft, so it can be dug out without blasting; basalt is hard, so it must be broken free by drilling and controlled blasting. **Q11.** Edging: Rock R is soft enough to shape, and edging carries no load. Car-park base: Rock Q — hardest, does not soak up water, does not crumble under load. **Q12.** For example: reshape and vegetate the walls (habitat loss, erosion); turn the flooded pit into a wetland or lake (the pit itself); spread topsoil and replant over the waste-rock piles (waste rock, habitat). **Q13.** Correct that hardness matters and that many igneous rocks are hard and durable (granite, bluestone). Too broad: sedimentary rocks have uses hardness alone cannot judge — sandstone carves easily and limestone makes cement; "better" depends on the job. **Q14.** It is a cultural site of the Wurundjeri with custodians recorded for it, now returned to their ownership; and it is heritage-listed. Permission from the Wurundjeri Council is required for access.

Fully-worked solutions

Q1. (a) A **quarry** is a place where rock and earth materials — such as limestone, marble, granite, gravel and sand — are dug out at the surface [S10]. (b) **Hardness** is how well a material resists being scratched; on the Mohs scale minerals are ranked from 1 (talc) to 10 (diamond) by scratch resistance [S1]. (c) An **ore** is a rock that contains metals or valuable minerals that can be mined for profit [S11].

Q2. (a) **Sample C:** step 1b (made of grains, shows layers) → step 3b (does not fizz with dilute acid) → step 5a (grains visible, gritty) → **sandstone**. **Sample D:** step 1a (interlocking crystals, no grains or layers) → step 2b (crystals too small to see; dark) → **basalt**. **Sample E:** step 1b → step 3b (does not fizz) → step 5b (no visible grains; splits into thin flat sheets) → **slate**. (b) Colour is a weak clue because several different rocks are grey or cream, and weathering changes a rock's outside. A dichotomous key is more reliable because each step forces a **decision between two observable properties** — texture, hardness, fizzing, splitting — so two rocks that look alike are separated by a test they cannot both pass.

Q3. (a) **Igneous.** Interlocking crystals grow as melted rock cools, and large visible crystals mean the magma cooled slowly, deep underground [S2]. (b) **Sedimentary.** Gritty grains held together by cement, in layers, are the signature of grains that settled, were buried and were pressed and cemented into rock. (c) **Metamorphic.** A rock changed by heat and pressure while still solid can develop a tendency to split along flat, parallel sheets, as slate does [S6].

Q4. (a) **Slate**, because it splits into thin, flat, weatherproof sheets [S6]; granite breaks across its crystals into rough blocks, not sheets. (b) **Basalt**, because it is hard and tough and wears slowly under traffic and weather [S4]; sandstone is softer and porous, so it would soak up water and wear away. (c) **Marble**, because its interlocking calcite crystals take a high polish; shale is soft and splits into flakes. (d) **Sandstone**, because its gritty surface of cemented grains grinds seeds; slate's smooth sheets would not grip.

Q5. (a) **Wedging and cutting along sheets** — slate's splitting does half the work, and blasting would shatter the sheets. (b) **Digging** — gravel is loose and near the surface, so no blasting is needed. (c) **Drilling and blasting** — basalt is too hard to dig; holes are drilled and controlled explosives break the rock free, which is then crushed and sorted for road base [S4][S10]. (d) **Underground mining** — at 400 m depth, shafts and tunnels reach the ore; an open pit that deep would move too much material.

Q6. (a) Any **three**: clearing land and destroying habitat; erosion of exposed ground; contamination of soil, groundwater or surface water; dust; noise from blasting and machinery; heavy vehicle traffic [S12]. (b) Any **three**: back-filling worked-out pits with waste rock; reshaping the land; controlling and treating contaminated water; spreading saved topsoil; replanting native vegetation; flooding a pit on purpose to form a lake or wetland, as happened when the Pentridge quarry filled with water and became Coburg Lake [S4][S12].

Q7. Both rocks cooled from melted rock, but they cooled in different places and at different rates. Granite's magma cooled **slowly, deep underground**, so its crystals had time to grow large enough to see; basalt erupted as lava and cooled **quickly at the surface**, so its crystals stayed too small to see [S2]. Texture therefore records cooling history. One use suited to granite's hardness: **kerbs, benchtops or monuments** — jobs where the surface must resist scratching and wear [S3]. *(1 mark: slow underground cooling → large crystals; 1 mark: rapid surface cooling → crystals too small to see; 1 mark: a hardness-matched use.)*

Q8. Limestone is made mostly of **calcite**, and calcite **reacts with acids**: a drop of dilute acid makes it fizz as bubbles of gas are released [S5]. Rainwater in a city is slightly acidic, so every rainfall runs a very weak version of the acid test over the building's surface. Over many decades the reaction slowly eats the surface away — a little at a time — and the carved detail loses its sharp edges. The same property that lets you identify limestone in the field is what makes it vulnerable to acidic water. *(1 mark: limestone is calcite and calcite reacts with acid; 1 mark: slightly acidic rainwater runs that reaction on the building; 1 mark: slow, repeated loss of surface wears detail away.)*

Q9. (a) Any **two**: greenstone is **tough**; it is **fine-grained**; struck, it **flakes into shapes with strong, sharp edges**. These are the properties a cutting hatchet head must have [S7][S9]. (b) The grinding grooves at Mount Macedon, about 29 km from the quarry, show that the quarry produced **rough blanks**, which were then **carried to another place to be ground to a finished edge**. The making of a hatchet was organised in **stages, in different places** — quarrying here, grinding there [S7]. (c) Finished axes found hundreds of kilometres from the quarry show that the site was **the centre of a trading network**: hatchet heads moved through exchange across a wide area of south-east Australia, bartered for other goods such as possum-skin covers [S7][S9]. The quarry served many groups of people, not only those who lived beside it. *(a: 1 mark for two correct properties; b: 1 mark for blanks transported and finished in another place / staged work; c: 2 marks — 1 for the trading network, 1 for exchange over long distances or for other goods.)*

Q10. The two rocks differ in **hardness**, and hardness decides whether rock can simply be dug or must be broken with explosives. **Sandstone is relatively soft** — its grains are held together by cement weaker than interlocking crystals — so the quarry can **dig it out directly, without blasting** [S10]. **Basalt is hard and tough**, so it cannot be dug; the quarry must **drill holes and use controlled blasting** to break the rock free [S10]. The same difference explains the noise and shaking near one quarry and not the other. *(1 mark: sandstone soft → digging; 1 mark: basalt hard → drilling and blasting; 1 mark: hardness named as the deciding property.)*

Q11. Garden edging: Rock R. Edging carries no traffic load, so "crumbles under load" does not matter; Rock R is the **softest** of the three (Mohs 2), so it is the easiest to cut and shape into edging pieces by hand. **Car-park base: Rock Q.** A base layer must carry vehicles without breaking down, and Rock Q is the only rock that satisfies all three demands in the table: it is the **hardest** (Mohs 7), it **does not soak up water**, and it **does not crumble under a heavy load**. Rock P fails two of the three tests, and Rock R is too soft and soaks up water. (Rock P would also be a poor edging next to a wet garden path, because it soaks up water.) *(2 marks per choice: 1 for the correct rock, 1 for a justification that uses the table's data.)*

Q12. Any three actions, each correctly paired with an impact, for example: **(1) reshape the steep walls and plant native vegetation on them** — addresses **habitat loss and erosion**, because bare steep ground erodes and supports little life; **(2) manage the flooded pit as a lake or wetland**, with safe edges — addresses the **open pit** left behind, turning it into habitat or recreation, as flooded quarries have become lakes [S4][S12]; **(3) spread saved topsoil over the waste-rock piles and replant them** — addresses the **waste rock** and the loss of land, restoring soil so plants can grow again [S12]. *(1 mark each for a valid action paired with the impact it addresses.)*

Q13. The claim contains something correct and something too broad. **What is correct:** hardness is a real property that matters in building, and many igneous rocks are hard and durable — granite is very hard and extremely durable [S3], and bluestone (basalt) served for kerbs, gutters and heavy-use buildings precisely because it is hard and tough [S4]. **Why it is too broad:** "better for building" depends on the **job**, and hardness is not the only property that matters. Sandstone, a sedimentary rock, is softer — and that is exactly what makes it **easy to cut and carve**, a valued property in building stone. Limestone, also sedimentary, is the raw material for **cement** and for agricultural lime [S5]: without it, there would be little to build with at all. And slate, a metamorphic rock, is the best roof-tile rock of the three families because of its splitting, not its hardness [S6]. The correct statement is therefore: **the right rock is the one whose properties match the job**, whatever its family. *(1 mark: hardness genuinely matters, with a named hard igneous use; 1 mark: a sedimentary counter-example whose softness is an advantage; 1 mark: limestone's role in cement or another use beyond hardness; 1 mark: the corrected "match property to job" conclusion.)*

Q14. First, the site is **a cultural place of the Wurundjeri**, not an abandoned hole in the ground: the Kurnung-willam and Kurnaje-berreing clans owned and cared for it, it was the centre of a trading network, and ownership was returned to the Wurundjeri in 2012 [S7][S9]. A visit therefore involves the living custodians of a place that matters to them. Second, the site is on the **National Heritage List**, included on 25 February 2008 as a place of outstanding significance to Australia [S8], and **access requires the permission of the Wurundjeri Council** [S9] — the same expectation of permission and respect for cultural sites on Country that fieldwork rules in 3B teach. A science group that takes rock samples or wanders off marked paths without permission would be damaging exactly the evidence — the quarry pits, the flakes, the landscape — that makes the site significant. *(1 mark: the site's cultural significance and custodianship; 1 mark: heritage listing and/or the permission requirement; 1 mark: why a fieldwork group in particular cannot treat the site like an ordinary rock outcrop — the site's evidence and meaning are fragile.)*

Sources

All retrieved 2026-08-19. The government heritage-listing page for the quarry (dcceew.gov.au) was attempted as the primary source for the National Heritage listing but returned connection errors on retrieval; the listing date was verified against the table in S8, and the site's attribution to the Wurundjeri against S7 (drawing on A. W. Howitt's 1904 records of William Barak's accounts) and S9, the Wurundjeri Woi Wurrung Cultural Heritage Aboriginal Corporation's own page.

- **[S1]** Wikipedia, "Mohs scale of mineral hardness", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S2]** Wikipedia, "Igneous rock", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S3]** Wikipedia, "Granite", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S4]** Wikipedia, "Bluestone", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S5]** Wikipedia, "Limestone", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S6]** Wikipedia, "Slate", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S7]** Wikipedia, "Mount William stone axe quarry", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S8]** Wikipedia, "National Heritage List (Australia)", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S9]** Wurundjeri Woi Wurrung Cultural Heritage Aboriginal Corporation, "Management of Wurundjeri Properties — Significant Places", 2026. www.wurundjeri.com.au — retrieved 2026-08-19.
- **[S10]** Wikipedia, "Quarry", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **[S11]** Geoscience Australia, "Australian mineral facts", 2026. www.ga.gov.au — retrieved 2026-08-19.
- **[S12]** Wikipedia, "Environmental impact of mining", 2026. en.wikipedia.org — retrieved 2026-08-19.
- **Elaboration uses:** VCAA, Victorian Curriculum F–10 Version 2.0, Science Levels 7 and 8, elaborations `VC2S8U11.E01`, `VC2S8U11.E05`, `VC2S8U11.E06`, as recorded in `S:\Files\projects\mcq-system\data\vc2_books\science_7-8.json` (the operative authority file, D15).

Renewable and non-renewable resources: regeneration timescales, and what “sustainable use” actually commits you to

Book: Science, Levels 7 and 8 (VC2) — one banded volume · **Chapter 13 — Earth and space sciences B: rocks, minerals and Earth’s resources** · **Subtopic 13C**

CD: `VC2S8U09` (split delivery, D6) — **13C is the accountable owner; 13D is the partner.** Clause delivered here: *renewable and non-renewable resources and sustainable use.* Full CD text (verbatim): *“the sustainable use of Earth’s resources is influenced by whether the resources are renewable or non-renewable; the processes involved in resource extraction and energy production come with both benefits and risks to sustainability”* **Achievement-standard extract (quoted exactly, D13):** *“They distinguish between renewable and non-renewable resources, evaluate the sustainable use of different resources, and compare the benefits and risks of resource extraction and energy production.”* This subtopic teaches and assesses the first two clauses — distinguishing renewable from non-renewable resources, and evaluating sustainable use. The third clause (comparing benefits and risks of extraction and energy production) is delivered by the partner subtopic 13D. **Elaboration ids drawn on (a context bank, not a delivery checklist — D12):** `VC2S8U09.E01` — considering what is meant by the term ‘renewable’ in relation to Earth’s resources; `VC2S8U09.E02` — considering timescales for regeneration of resources. **Relationship to the other subtopics of Chapter 13:** 13A’s rock-cycle timescales (hours to millions of years) are the template for the timescale thinking here — the same spread of speeds appears when we ask how fast resources re-form. 13B teaches how rocks and minerals are quarried and mined; this subtopic does not repeat mining methods. **13D assumes this subtopic** — it takes the classification and the definition of sustainable use taught here and applies them, weighing the benefits and risks of extraction and energy production (its `VC2S8U09.E03`–`E06` contexts). This subtopic does not repeat that weighing. **Maths interlock (D11):** none required. The arithmetic here is comparison of two rates (e.g. use of water against refill of water), which stays within operations the band already carries.

Theory

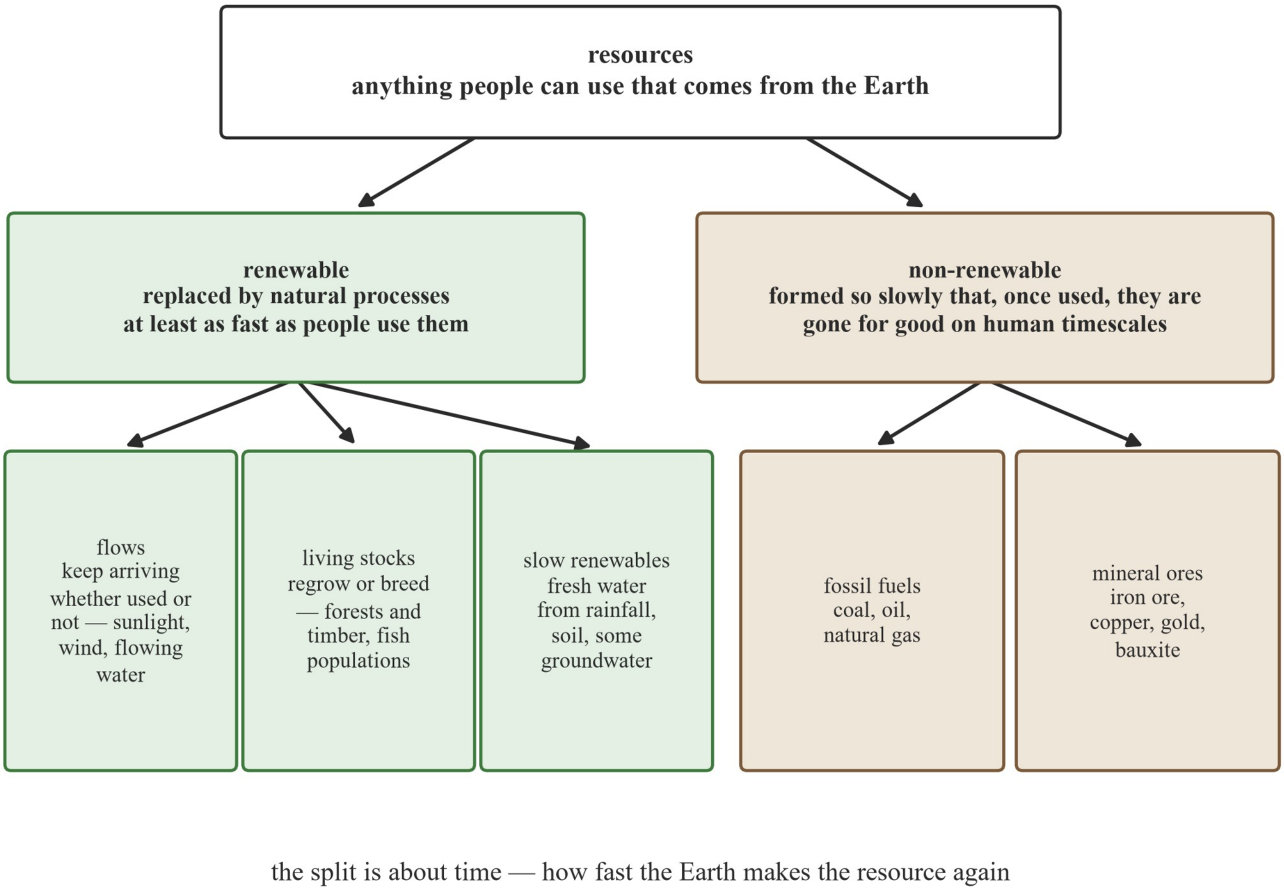
Everything you had to eat this morning, every wall around you, every wire in the building and every litre of fuel in any vehicle came from somewhere. Ultimately it came from the Earth — from the ground, the sea, the air, and the energy that reaches us from the Sun. This subtopic is about those starting points: the things the Earth supplies that people use, **how fast the Earth makes them again**, and what we commit ourselves to when we call a use of them *sustainable*.

1. What counts as a resource

A **resource** is anything people can use that comes from the Earth or from the energy that reaches it. That is the only definition this subtopic needs, and it is wide on purpose:

- **Material resources** — things you can hold: fresh water, timber, fish, soil, and the minerals and rocks mined from the ground (you met rocks and minerals in 13A and 13B).
- **Energy resources** — things that supply energy: coal, oil and natural gas that are burned for heat and electricity; flowing water, wind and sunlight that are captured without burning anything.

Resources are not evenly spread, and they are not all alike in one crucial way: **how fast the Earth makes them again once we have taken them.** That difference is the whole subject of this subtopic.



ClassBasics Science 7–8 · 13C · Earth's resources sorted by regeneration timescale

Classification tree diagram titled Earth’s resources. The top box reads resources — anything people can use that comes from the Earth. It branches into two boxes. The left box, green, reads renewable — replaced by natural processes at least as fast as people use them, and branches into three: flows that keep arriving — sunlight, wind, flowing water; living stocks that regrow or breed — forests and timber, fish populations; and slow renewables — fresh water from rainfall, soil, some groundwater. The right box, grey-brown, reads non-renewable — formed so slowly that, once used, they are gone for good on human timescales, and branches into two: fossil fuels — coal, oil, natural gas; and mineral ores — iron ore, copper, gold, bauxite. A footer line reads: the split is about time — how fast the Earth makes the resource again.

Sort the resources of the world by **how fast they re-form**, and two great groups appear. **Renewable resources** are replaced by natural processes at least as fast as people use them. **Non-renewable resources** are formed so slowly that, on the timescale of human lives and human societies, they do not come back once they are used. The rest of this subtopic unpacks that one sentence, because almost everything about sustainable use follows from it.

2. What “renewable” means — and it is about time (VC2S8U09.E01)

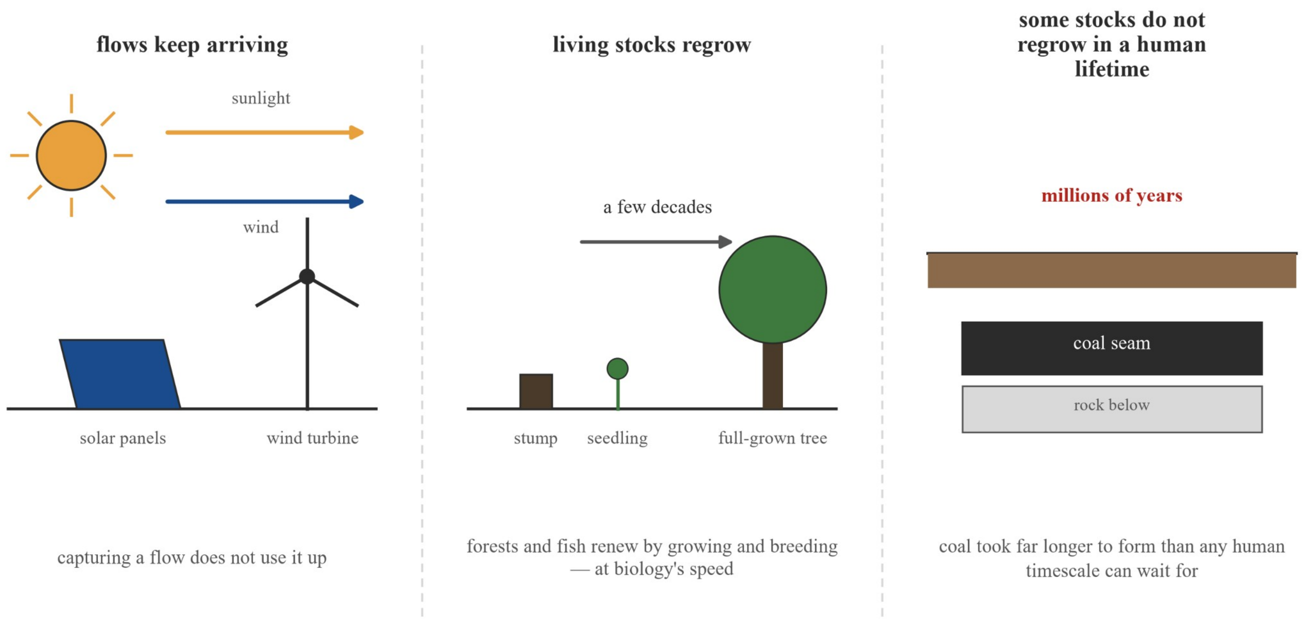
The word *renewable* sounds simple, but it hides a frame. Whether a resource counts as renewable depends on **the timescale you are looking along** — a bit like “down” depends on where you are standing. Look along a human lifetime, and a forest is renewable: cut a tree, and a new one can grow to replace it within a few decades. Look along the same lifetime at a seam of coal, and the coal is not renewable at all: it took far longer than any human lifetime to form, and no amount of waiting within a human life will make more of it.

So in this subtopic, *renewable* is used in a precise, frame-stated sense:

A resource is **renewable** if natural processes replace it, or remake it, **at least as fast as people use it** — so the supply can keep going, in principle, without running out.

Three kinds of renewable resource are worth separating, because they renew in different ways:

- **Flows.** Sunlight and wind keep arriving whether we use them or not. Capturing a flow does not reduce the flow available to the next person — tomorrow's sunlight arrives regardless of today's solar panels. Flowing water (in rivers kept flowing by rainfall) works the same way, as long as the rainfall keeps up.
- **Living stocks.** Forests, fish populations and other living things renew by **growing and breeding**. A harvested forest can regrow; a fished population can breed back. But — the key point of section 4 — they renew only at the speed biology allows.
- **Slow renewables.** Fresh water from rainfall, soil, and some groundwater do renew, but slowly — over years, decades, centuries or longer. They are renewable in principle and exhaustible in practice, because it is easy to use them faster than they renew.

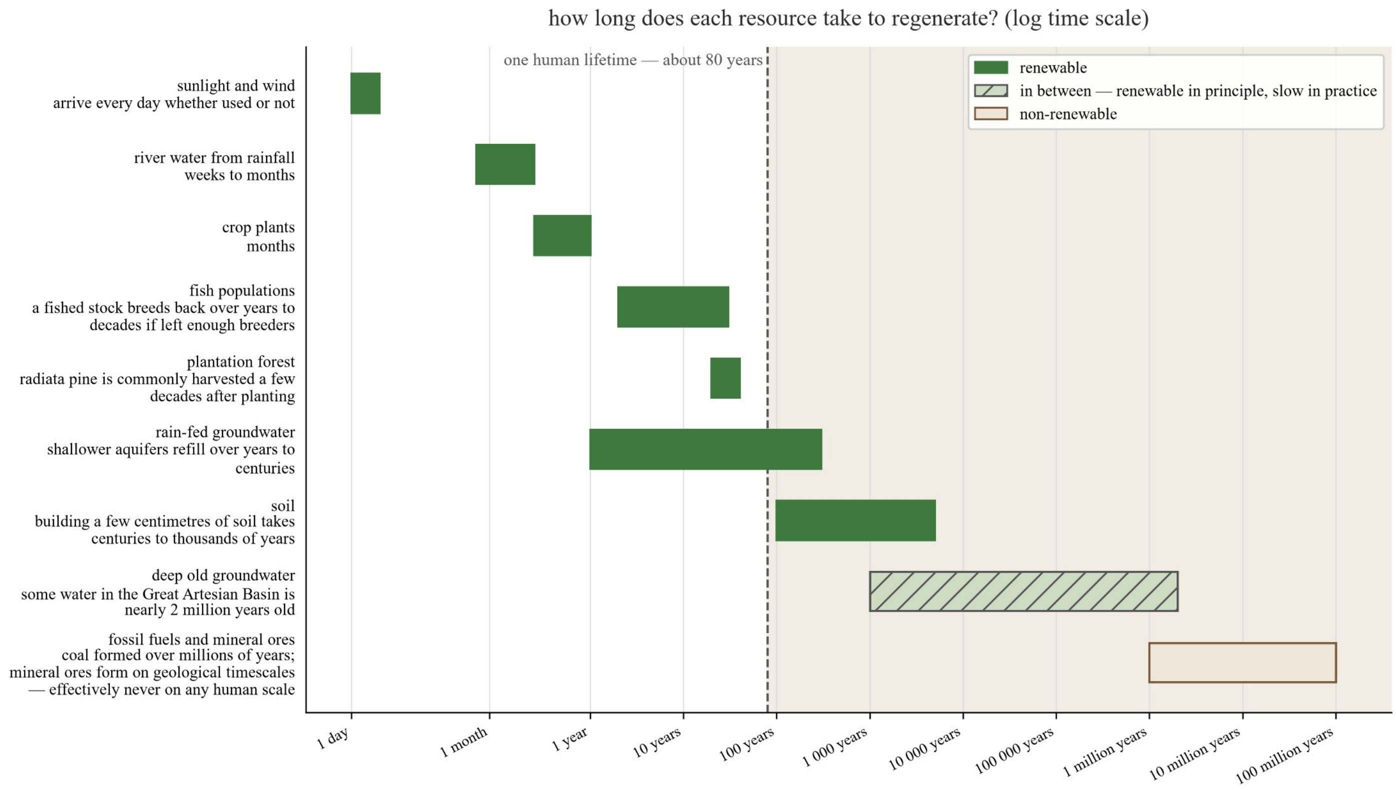


renewable means replaced at least as fast as used — the frame is the timescale

Three-panel diagram titled what renewable means. Panel 1, labelled flows keep arriving, shows a sun and wind over a landscape with a row of solar panels and a wind turbine; an arrow of sunlight and an arrow of wind arrive whether or not the panels and turbine are there; caption: capturing a flow does not use it up. Panel 2, labelled living stocks regrow, shows a harvested tree stump with a new seedling beside it and an arrow of a few decades from stump to full-grown tree; caption: forests and fish renew by growing and breeding — at biology's speed. Panel 3, labelled some stocks do not regrow in a human lifetime, shows a cross-section of a coal seam underground with a miner's pick beside it and a caption of millions of years above the seam; caption: coal took far longer to form than any human timescale can wait for. A footer line reads: renewable means replaced at least as fast as used — the frame is the timescale.

3. Regeneration timescales — the heart of this subtopic (VC2S8U09.E02)

The clearest way to sort resources is to line up **how long each one takes to regenerate** — to be remade or refilled by natural processes. The spread is enormous: from daily to longer than the history of complex life on Earth.



the renewable–non-renewable split is a line drawn on this axis — resources that regenerate inside a human timescale, and resources that do not

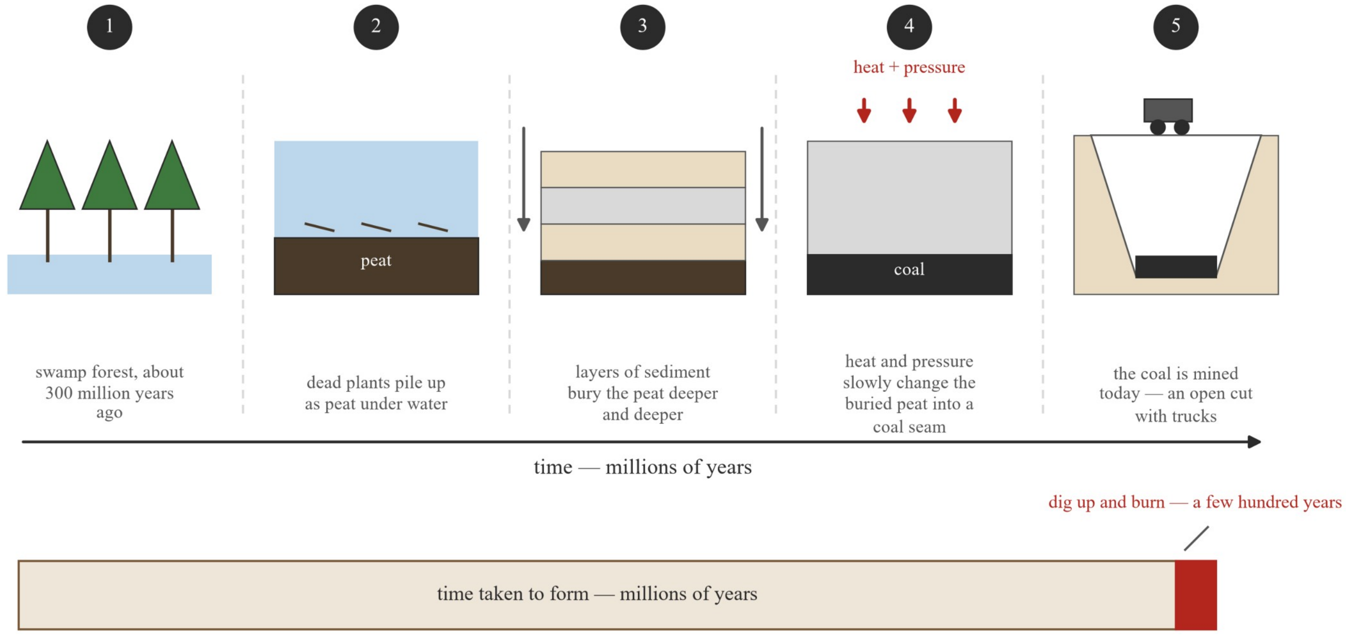
Horizontal bar chart titled how long does each resource take to regenerate, on a time axis running from 1 day to 100 million years, drawn on a scale where each step is ten times longer than the one before. Nine horizontal bars, coloured green for renewable and grey-brown for non-renewable, each spanning its regeneration range. Sunlight and wind: a green marker at 1 day, labelled arrive every day whether used or not. River water from rainfall: green, weeks to months. Crop plants: green, months. Fish populations: green, years to decades, labelled a fished stock breeds back over years to decades if left enough breeders. Plantation forest: green, decades, labelled radiata pine is commonly harvested a few decades after planting. Rain-fed groundwater: green, years to centuries, labelled shallower aquifers refill over years to centuries. Soil: green, centuries to millennia, labelled building a few centimetres of soil takes centuries to thousands of years. Deep old groundwater: grey-green hatched, thousands to millions of years, labelled some water in the Great Artesian Basin is nearly 2 million years old. Fossil fuels and mineral ores: grey-brown, millions of years and beyond, labelled coal formed over millions of years; mineral ores form on geological timescales — effectively never on any human scale. A vertical dashed line marks one human lifetime at about 80 years. A footer line reads: the renewable–non-renewable split is a line drawn on this axis — resources that regenerate inside a human timescale, and resources that do not.

Read the figure along the dashed line of one human lifetime:

- **To the left of the line** — sunlight, wind, river water, crops, fish, plantation forests — regeneration fits comfortably inside a human lifetime, often inside a year. These are renewable without strain.
- **Near the line** — soil, rain-fed groundwater, slow-growing native forests — regeneration still happens, but slowly enough that a careless rate of use can outrun it within a lifetime.
- **Far to the right of the line** — coal, oil, natural gas and mineral ores — regeneration takes millions of years or more. No human lifetime, and no run of human lifetimes, brings them back. These are non-renewable.

Notice what the figure also shows: **the renewable–non-renewable split is not a wall, it is a region of the timescale.** Resources like soil and deep groundwater sit near the boundary, and whether they behave as renewable depends on how fast we use them. That is why timescales, not labels, are the real content of this subtopic.

Where fossil fuels come from — and why they do not come back. Coal formed from forests that died and piled up in swamps about 300 to 360 million years ago; most of the world's coal comes from that ancient age of swamp forests [S1]. The dead plants first became **peat** — the soft, wet material formed when dead plants only half break down, still found in wet ground today. Buried deeper and deeper under sediment, and squeezed and heated over millions of years, the peat slowly changed into coal [S1]. Oil and natural gas formed the same way in principle but from different starting material: the remains of tiny sea organisms (tiny plant-like drift and animal drift) that settled on sea and lake floors in oxygen-poor water, were buried, and were cooked by heat and pressure into liquid and gaseous fuels over millions of years [S3].



the formation of coal is real rock-cycle slowness (13A); the use of it is a blink beside it — the red sliver is drawn large so it can be seen

Formation story diagram with two rows. The upper row is a horizontal timeline labelled millions of years, running left to right through five scenes: 1, a swamp forest about 300 million years ago, drawn as trees and ferns in dark water; 2, dead plants pile up as peat under water; 3, layers of sediment bury the peat deeper and deeper; 4, heat and pressure underground slowly change the buried peat into a coal seam; 5, the coal is mined today, drawn as an open cut with a truck. The lower row is a single thin bar drawn to the same time axis, shaded almost fully, labelled time taken to form — millions of years, with only a tiny sliver at the right-hand end unshaded and labelled time taken to dig up and burn — a few hundred years. A footer line reads: the formation of coal is real rock-cycle slowness (13A); the use of it is a blink beside it.

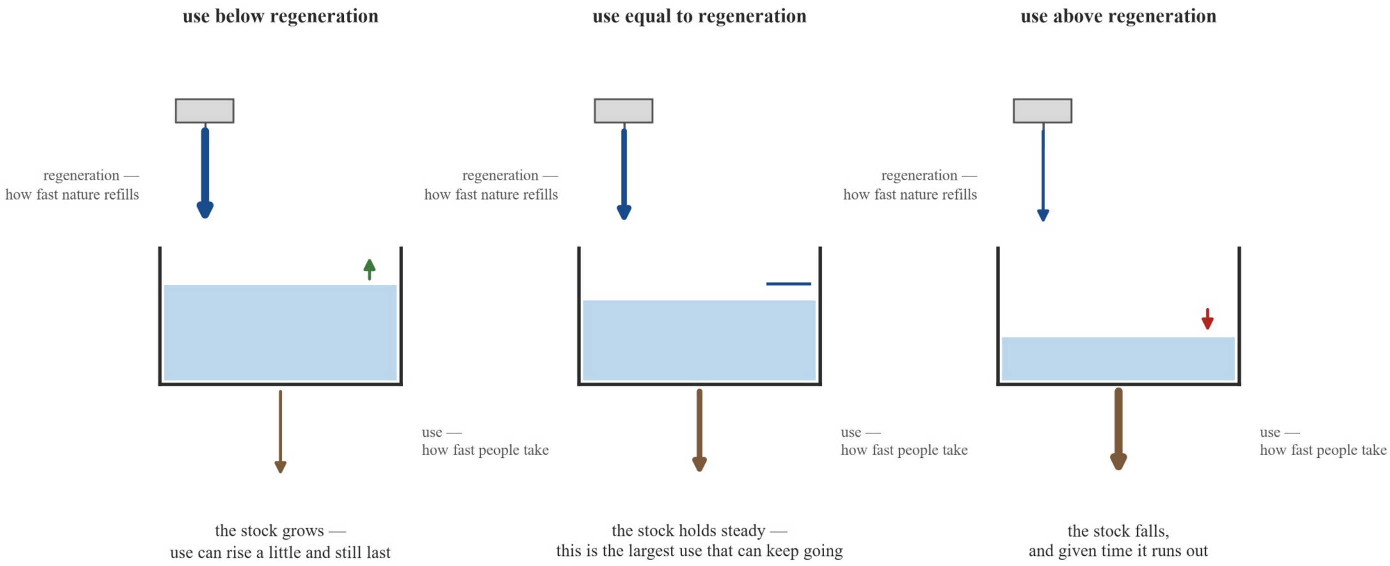
Victoria’s own example is brown coal in the Latrobe Valley. The deposits are enormous — an estimated **65 billion tonnes**, about a quarter of the world’s known brown-coal reserves, in seams up to **98 metres** thick [S2] — and they formed from forests that grew and died tens of millions of years ago. Whatever else is true of that coal, the timescale is not: even a resource as vast as the Latrobe Valley brown coal is a one-time stock on any human timescale, because nothing living now will have become replacement coal within any future we can plan for. (How Victoria weighs the benefits and risks of burning and replacing that coal is the work of 13D.)

Mineral ores — the rocks we mine for iron, copper, gold and the rest (13B) — sit furthest to the right of the timescale axis. New ore forms by geological processes inside the Earth over millions of years and more; for every purpose people can plan around, a mined mineral deposit is **finite**: once extracted and scattered into products, landfills and the environment, the concentrated deposit is gone.

4. Renewable is a rate, not a guarantee

Here is the move that turns the classification into real understanding. A renewable resource renews **at a certain rate** — tonnes of timber grown per year, new fish bred per year, millimetres of soil built per year, litres of water refilled per year. Whether the resource actually lasts is then decided by a second rate: **how fast we take it**.

The model is a simple one — a stock with an inflow and an outflow, like a bath with the tap running and the drain open:



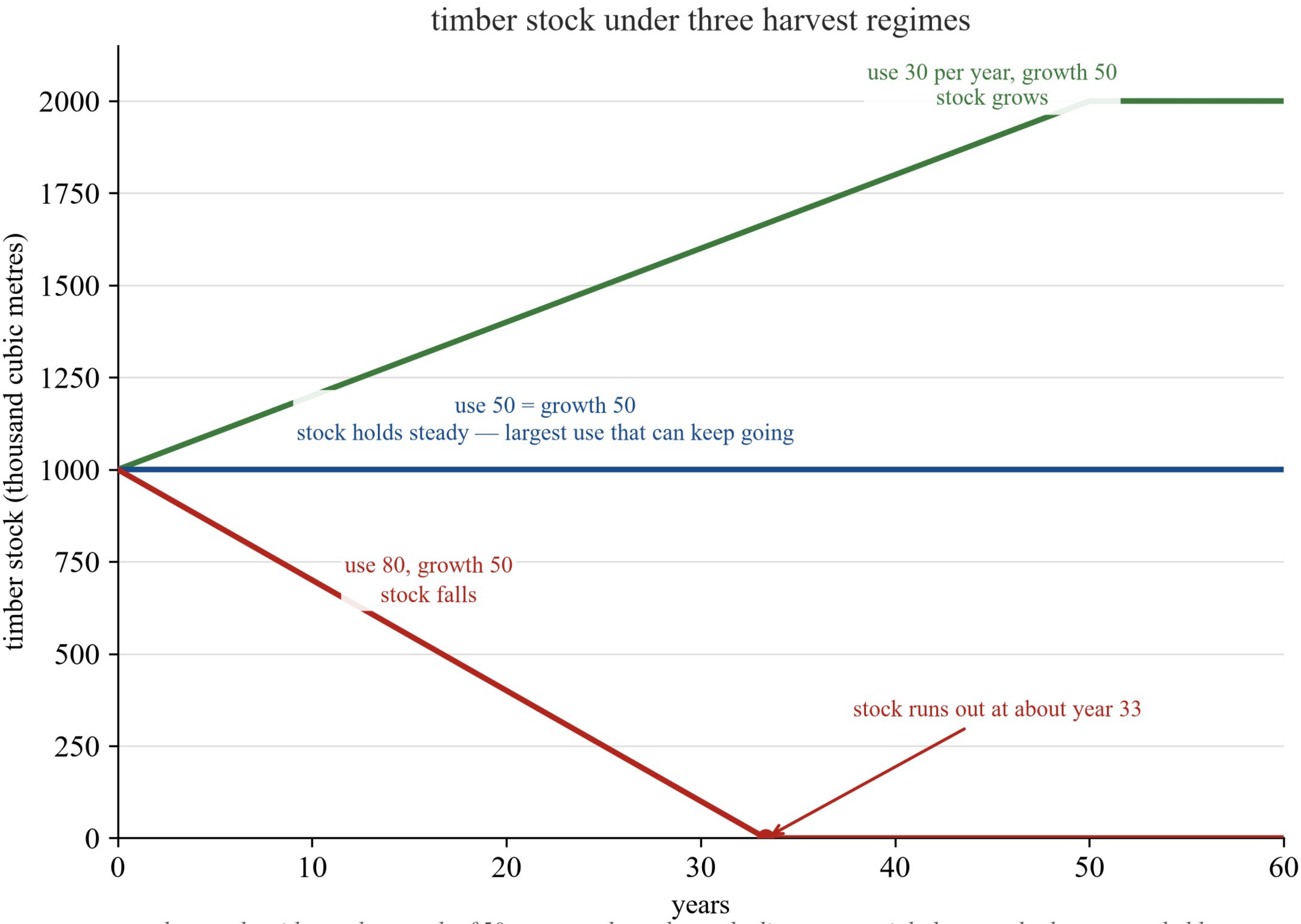
the same resource, three futures — the difference is only the rate of use against the rate of regeneration

Three-panel bathtub model titled the stock, the inflow, the outflow. Each panel shows a bath of water labelled the stock — the amount of the resource in store, with a tap above labelled regeneration — how fast nature refills, and a drain below labelled use — how fast people take. Panel 1: the tap runs faster than the drain; the water level is drawn rising; caption: use below regeneration — the stock grows; use can rise a little and still last. Panel 2: tap and drain run evenly; the water level is drawn steady; caption: use equal to regeneration — the stock holds steady; this is the largest use that can keep going. Panel 3: the drain runs faster than the tap; the water level is drawn falling toward empty; caption: use above regeneration — the stock falls, and given time it runs out. A footer line reads: the same resource, three futures — the difference is only the rate of use against the rate of regeneration.

Three cases, and only three:

1. **Use below regeneration** — the stock grows. There is room for use to rise a little and still keep going.
2. **Use equal to regeneration** — the stock holds steady. This is the **largest rate of use that can keep going**, and any talk of sustainable use of that resource must land here or below it.
3. **Use above regeneration** — the stock falls. While the stock lasts, everything looks fine; then, sooner or later, it runs out.

Case 3 is the trap: **a renewable resource used faster than it regenerates behaves, in practice, like a non-renewable one.** The label “renewable” describes what nature does; whether the resource lasts is decided by what we do.



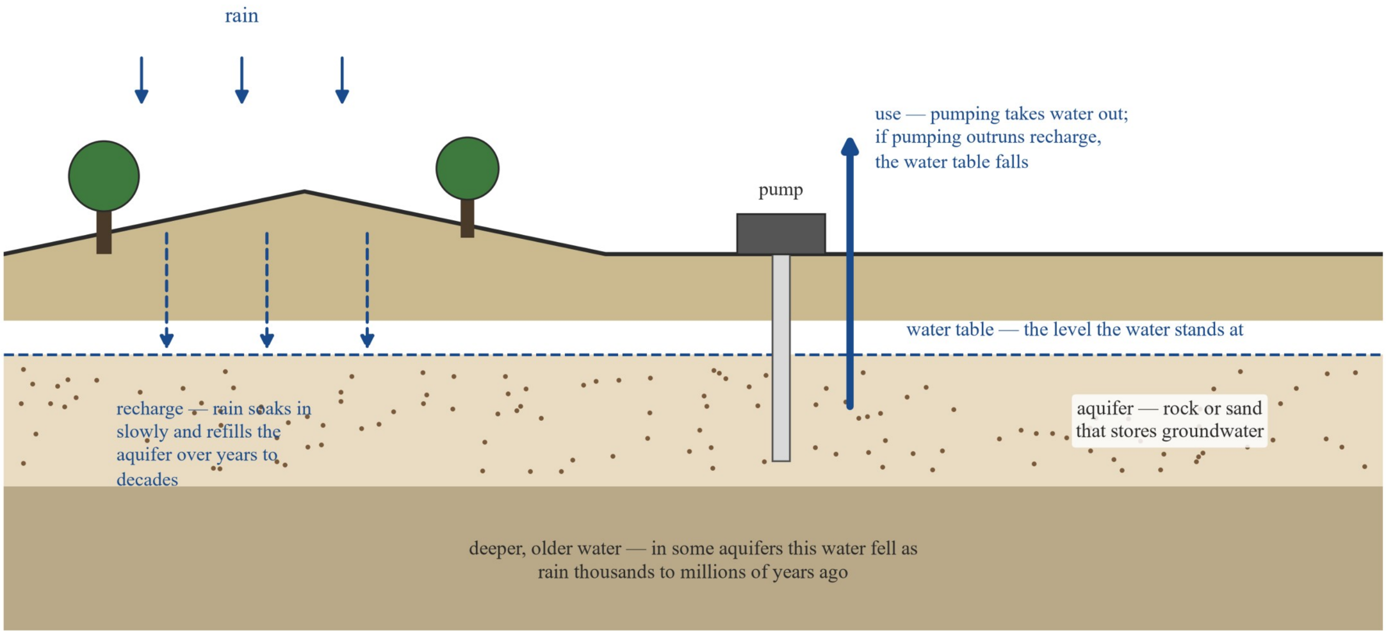
computed example with steady growth of 50 per year throughout; the lines are straight because both rates are held constant

Line graph of timber stock against time, years 0 to 60, vertical axis labelled timber stock in thousand cubic metres from 0 to 2 000. Three straight computed lines all start at 1 000 in year 0. Line A, green, labelled use 30 per year against growth of 50 per year, rises steadily to 2 000 by year 50 and the caption reads the stock grows — use is below regeneration. Line B, blue, labelled use 50 per year against growth of 50 per year, runs flat at 1 000, captioned the stock holds steady — use equals regeneration; this is the largest use that can keep going. Line C, red, labelled use 80 per year against growth of 50 per year, falls steadily, reaching zero at about year 33, captioned the stock runs out at about year 33 — use is above regeneration, even though the resource is renewable. A footer line reads: computed example with steady growth of 50 per year throughout; the lines are straight because both rates are held constant.

The worked numbers in the figure are invented to make the point cleanly, but the shape is real. It is the same shape as the history of one of the world's most famous fisheries — you will meet it in section 5.

5. Three resources that test the rule

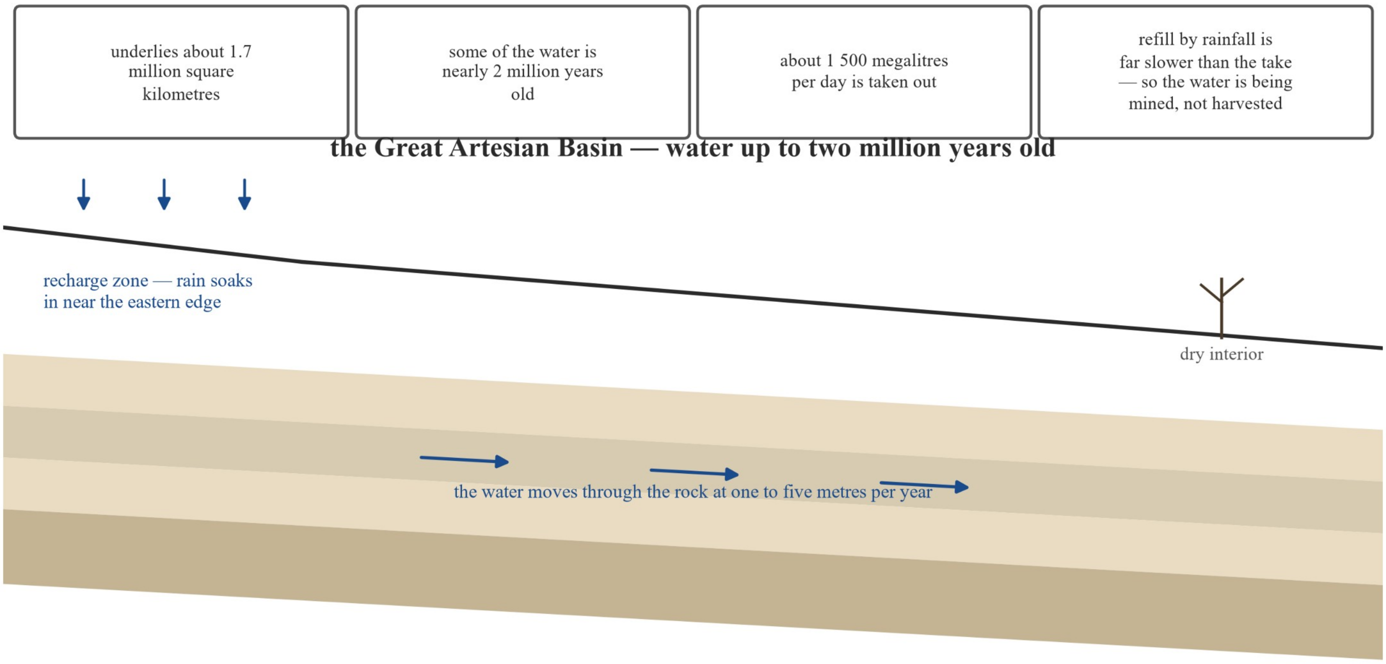
Groundwater — water that can be older than our species. Rain that soaks into the ground collects in **aquifers** — layers of rock or sand underground that hold water. The water in an aquifer is called **groundwater**, and it is pumped to the surface through **bores** (deep holes). Whether groundwater is renewable depends on which aquifer you mean. Shallow aquifers near the surface can refill from rainfall over years to decades — genuinely renewable, if the pumping stays below the refill. But deep, old aquifers are a different story.



groundwater renews only as fast as recharge replaces what pumping removes

Cross-section diagram of an aquifer. The surface shows rain falling on a hillside with trees; arrows of water soak down through the soil layer labelled recharge — rain soaks in slowly and refills the aquifer over years to decades. Below the soil, a porous rock layer labelled aquifer — rock or sand that stores groundwater, with a dashed line across it labelled water table — the level the water stands at. A bore pipe goes down into the aquifer with a pump at the top and a larger upward arrow of water labelled use — pumping takes water out; if pumping outruns recharge, the water table falls. A second, deeper layer is labelled deeper, older water — in some aquifers this water fell as rain thousands to millions of years ago. A footer line reads: groundwater renews only as fast as recharge replaces what pumping removes.

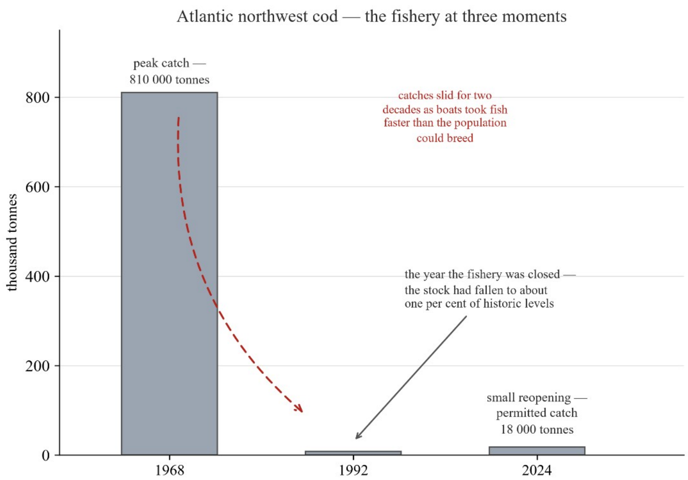
Australia's clearest example is the **Great Artesian Basin**, the largest underground water store in Australia, underlying about **1.7 million square kilometres** of the inland east [S4]. The water in it moves through the rock at only **one to five metres per year**, and some of it fell as rain **nearly two million years ago** [S4]. Today the basin supplies about **1 500 megalitres of water per day**, and the water taken out is refilled by rainfall far more slowly than it is pumped — so much so that taking water from the basin has been described as a **mining operation** rather than a harvest [S4]. That is the bathtub model in a real landscape: the stock is huge but the inflow is tiny, and use above the inflow draws the level down. Water that took two million years to arrive is, for any human planning, a one-time supply.



when the inflow is a trickle and the outflow is a flood of use, even a gigantic stock runs down · source: Wikipedia, Great Artesian Basin, 2026

Case-study panel titled the Great Artesian Basin — water up to two million years old. A sloping cross-section runs left to right: high country on the left labelled recharge zone — rain soaks in near the eastern edge, and the water then moves through the tilted rock layers at one to five metres per year toward the dry interior on the right. Four fact boxes sit along the panel: the basin underlies about 1.7 million square kilometres; some of the water is nearly two million years old; about 1 500 megalitres per day is taken out; and refill by rainfall is far slower than the take — so the water is being mined, not harvested. A footer line reads: when the inflow is a trickle and the outflow is a flood of use, even a gigantic stock runs down. Source: Wikipedia, Great Artesian Basin, 2026.

Fish — a living stock that can crash. Atlantic cod off the coast of Canada were once so plentiful the fishery seemed endless. It was not. Catches rose through the 1950s and 1960s to a peak of **810 000 tonnes in 1968**, then slid downward as bigger boats and better technology took fish faster than the population could breed them back. By 1992 the stock had fallen to about **one per cent of its historic level**, and Canada closed the fishery — a sudden stop after hundreds of years of fishing [S5]. More than thirty years later the cod had still not fully returned; when a small reopening was allowed in 2024, the permitted catch was a sliver of the old peak [S5].

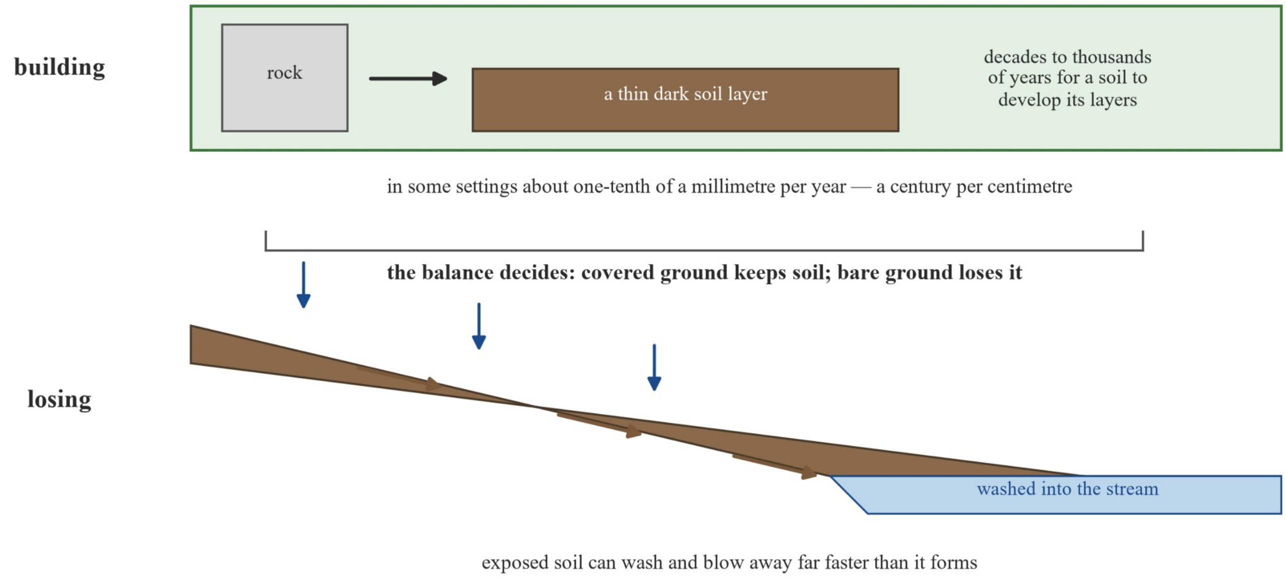


a renewable resource, used above its rate of regeneration, behaving like a non-renewable one · the 1992 bar shows the breeding stock relative to historic levels (about 1%), not a catch figure · source: Wikipedia, Collapse of the Atlantic northwest cod fishery, 2026

Bar chart titled Atlantic northwest cod — catch at three moments, vertical axis in thousand tonnes from 0 to 800, three grey bars with year labels. Bar 1, 1968, height 810, labelled peak catch — 810 000 tonnes. Bar 2, 1992, height *about 8, labelled the year the fishery was closed — the stock had fallen to about one per cent of historic levels. Bar 3, 2024, height 18, labelled small reopening — permitted catch of 18 000 tonnes, a sliver of the 1968 peak. A dashed line at the left connects bars 1 and 2 with a downward arrow labelled catches slid for two decades as boats took fish faster than the population could breed. A footer line reads: a renewable resource, used above its rate of regeneration, behaving like a non-renewable one — the 1992 bar shows the breeding stock relative to historic levels, not a catch figure. Source: Wikipedia, Collapse of the Atlantic northwest cod fishery, 2026.*

The cod were renewable — fish breed. The *fishery* was destroyed anyway, because the catch outran the breeding. Renewable, here as everywhere, is a statement about nature's rate, not a promise to us.

Soil — the slowest renewable most of us stand on. Soil forms when rock is broken down by weather (13A) and mixed with the remains of living things. The timescale is long: a soil can take decades to thousands of years just to develop its natural layers, depending on climate and rock [S6], and in some settings rock weathers into soil at about one-tenth of a millimetre per year — a century to build a single centimetre [S6]. At the same time, exposed soil can be washed and blown away much faster than it forms. Soil sits right on the renewable–non-renewable boundary: renewed in principle, exhaustible in any field where erosion outruns formation.



soil is renewable only while formation keeps pace with erosion · source: Wikipedia, Pedogenesis, 2026

Comparison diagram titled soil — slow to build, quick to lose, drawn as two horizontal process strips. The upper strip, green, is labelled building and shows rock slowly weathering into a thin dark soil layer; along it, markers read decades to thousands of years for a soil to develop its layers, and in some settings about one-tenth of a millimetre per year — a century per centimetre. The lower strip, brown, is labelled losing and shows bare soil on a slope with rain washing it into a stream; along it, a marker reads exposed soil can wash and blow away far faster than it forms. Between the two strips a bracket reads the balance decides: covered ground keeps soil; bare ground loses it. A footer line reads: soil is renewable only while formation keeps pace with erosion. Source: Wikipedia, Pedogenesis, 2026.

6. What "sustainable use" actually commits you to

The curriculum uses the words *sustainable* and *sustainability* but does not define them, and outside this book the words are used in several different senses. So, before we use the word, we fix the frame (this is the same definition 13D uses when it weighs benefits and risks):

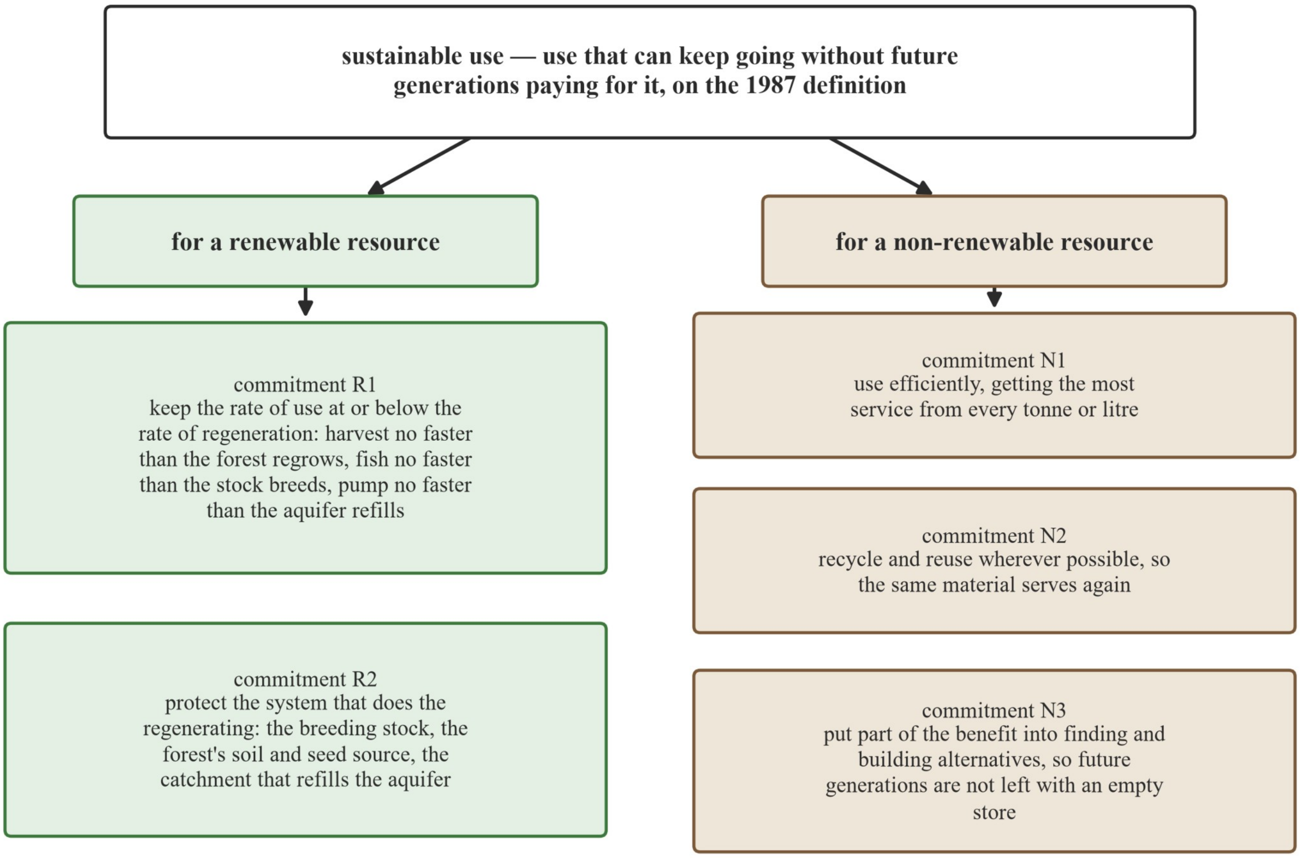
> **Defining a contested term — *sustainable use*.** The Victorian Curriculum uses *sustainable* without defining it. This subtopic therefore uses it in the sense given by the World Commission on Environment and Development, *Our Common Future* (1987): development that *"meets the needs of the present without*

compromising the ability of future generations to meet their own needs" [S7]. Other definitions exist and are not interchangeable with this one; every question in this subtopic is answerable on this definition alone.

Notice the two halves of that definition, because they pull in two directions and an honest answer keeps both:

- **The needs of the present** — sustainable use is not the same as no use. People alive now need water, food, timber, energy and materials, and a definition that ignored them would be useless.
- **The ability of future generations** — use must not burn the base those people will stand on. The resource, or a way of getting what it gave, must still be there for them.

Pulling the definition down to the ground, sustainable use commits you to different things depending on which side of the timescale line the resource sits:



renewable means it can keep going; sustainable means you have done the things that make it keep going

Commitment diagram titled what sustainable use commits you to. A top box reads sustainable use — use that can keep going without future generations paying for it, on the 1987 definition. Two branches run down from it. The left branch, green, reads for a renewable resource and carries two commitment boxes: commitment R1 — keep the rate of use at or below the rate of regeneration: harvest no faster than the forest regrows, fish no faster than the stock breeds, pump no faster than the aquifer refills; and commitment R2 — protect the system that does the regenerating: the breeding stock, the forest's soil and seed source, the catchment that refills the aquifer. The right branch, grey-brown, reads for a non-renewable resource and carries three commitment boxes: commitment N1 — use efficiently, getting the most service from every tonne or litre; commitment N2 — recycle and reuse wherever possible, so the same material serves again; commitment N3 — put part of the benefit into finding and building alternatives, so future generations are not left with an empty store. A footer line reads: renewable means it can keep going; sustainable means you have done the things that make it keep going.

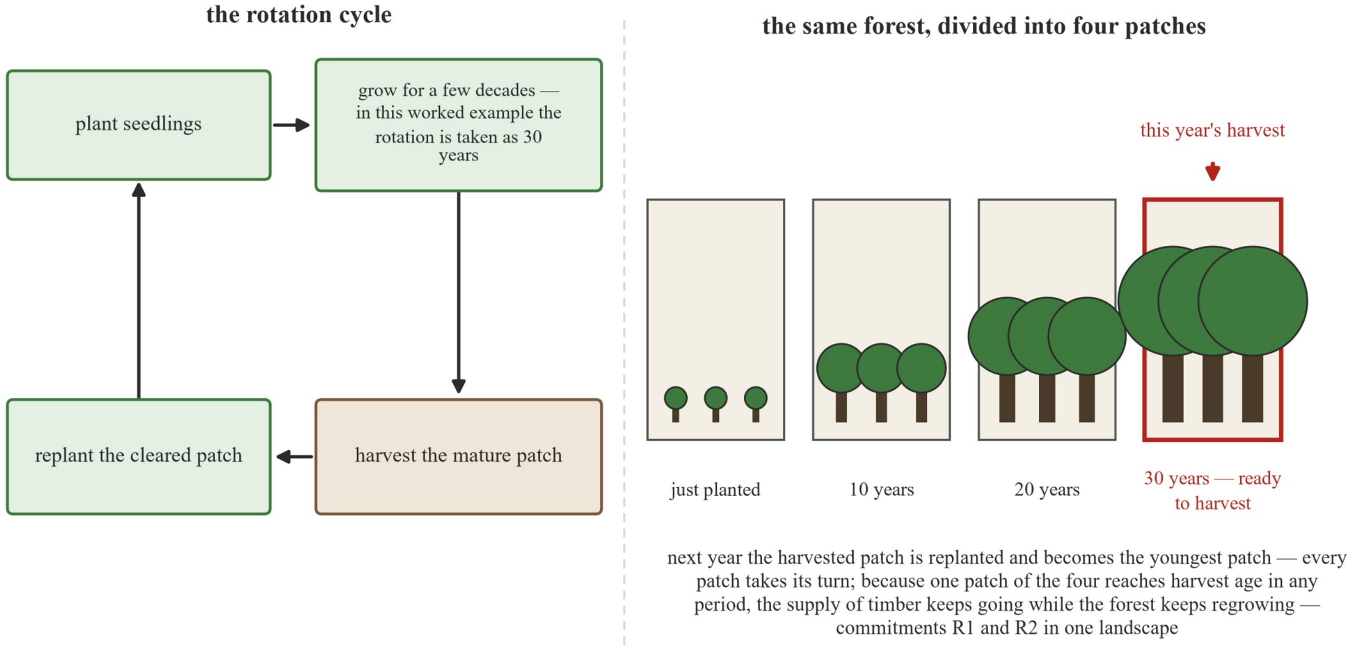
For a **renewable** resource, two commitments:

- **R1 — use at or below regeneration.** Harvest no faster than the forest regrows, take no more fish than the stock breeds back, pump no more water than the aquifer refills. This is case 2 of the bathtub, and it is a number, not a mood: it can be measured and checked.
- **R2 — protect the system that does the regenerating.** A forest is not just its trees; it is also its soil, its seed source and the water cycle around it. A fishery is not just the fish caught; it is the breeding population left behind. Renewable systems renew only while the machinery of renewal is intact.

For a **non-renewable** resource, three commitments:

- **N1 — use efficiently,** so the most service is got from every tonne or litre of a stock that will not be replaced.
- **N2 — recycle and reuse** where possible, so the same material serves again instead of being scattered and lost (sorting and separating materials is 10D's business).
- **N3 — invest the benefit in alternatives,** so that when the stock runs down, future generations inherit a way to meet the same need — not just the memory of it. A society that burns its coal and leaves nothing behind has met its own needs by borrowing from the future.

The commitments in practice — a plantation that keeps going. Radiata pine is the dominant species in Australia's plantation forests [S8]; plantations such as Kuitpo Forest in South Australia, first planted in 1898 on about 3 600 hectares, are managed specifically to keep a timber supply going over the long term [S9]. The method is the rotation cycle: the forest is divided into patches of different ages; each patch is planted, grown for a few decades, harvested, and replanted — so that at any moment some patches are young, some are mid-grown and some are ready for harvest, and the supply of timber never depends on one patch or one year.



the 30-year rotation and the four patches are a worked example chosen for clean numbers

Rotation cycle diagram in two parts. Part 1, left, is a loop of four stage boxes joined by arrows: plant seedlings, then grow for a few decades — in this worked example the rotation is taken as 30 years, then harvest the mature patch, then replant the cleared patch, and the loop returns to plant seedlings. Part 2, right, shows the same forest divided into four equal patches side by side, drawn as squares of trees at different heights and labelled with their age class: patch 1 — just planted, patch 2 — 10 years, patch 3 — 20 years, patch 4 — 30 years, ready to harvest, with an arrow marking patch 4 as this year's harvest and a note reading next year the harvested patch is replanted and becomes the youngest patch, and every patch takes its turn. A footer line reads: because one patch of the four reaches harvest age *in any period, the supply of timber keeps going while the forest keeps regrowing — commitments R1 and R2 in one landscape. Note: the 30-year rotation and the four patches are a worked example chosen for clean numbers.*

Two closing points. First, the commitments can be checked against evidence — rates can be measured, stocks can be counted, and a claim of sustainable use is a claim about numbers, not a badge. Second, the frame is set by the 1987 definition: when you read or write *sustainable*, ask at once — *use that keeps going for whom, over what timescale, and measured against what rate?* That question is the difference between using the word and understanding it.

Words to know in 13C

Word	What it means here
resource	anything people can use that comes from the Earth or from the energy that reaches it
renewable resource	a resource replaced by natural processes at least as fast as people use it
non-renewable resource	a resource formed so slowly that it does not come back on any human timescale once used
regeneration	the natural replacement or re-forming of a resource — regrowth, breeding, refilling
regeneration timescale	how long regeneration takes — from daily (sunlight) to millions of years (coal)
fossil fuel	coal, oil or natural gas — fuel formed from long-dead organisms over millions of years
peat	soft, wet plant material formed when dead plants only half break down; the first stage on the way to coal
ore	rock mined because it holds enough of a useful mineral to be worth extracting
finite	present in a fixed amount that runs down as it is used
stock	the amount of a resource in store at a given time
flow (of a resource)	a supply that keeps arriving whether used or not — sunlight, wind
aquifer	a layer of rock or sand underground that holds groundwater
groundwater	water stored underground in aquifers, reached by bores
recharge	the refilling of an aquifer, mostly by rain soaking in
bore	a deep hole drilled or dug to reach groundwater
overfishing	taking fish faster than the population can breed them back
rotation cycle	the plantation pattern of planting, growing, harvesting and replanting patches in turn
sustainable use	use of a resource in the 1987 sense: meeting the needs of the present without compromising the ability of future generations to meet their own needs

Activity — the regeneration card sort (VC2S8U09.E02)

Work in small groups. Your teacher will give you a set of resource cards — or make your own from the list below. Each card names a resource.

Card	Resource
1	sunlight

Card	Resource
2	wind
3	river water (rain-fed)
4	a crop of wheat
5	a fish population
6	a plantation pine forest
7	a slow-growing native forest
8	fresh water in a shallow aquifer
9	soil
10	water in the Great Artesian Basin
11	a seam of brown coal
12	a deposit of copper ore

1. **Sort by timescale.** Draw a line across a sheet of paper with *days* at one end and *millions of years* at the other. Place each card where its regeneration timescale belongs. Where you cannot place a card exactly, place it where you think it goes and mark it with a question mark.
2. **Draw the line.** Mark on your timescale where you think "renewable" ends and "non-renewable" begins. Different groups will draw the line in different places — be ready to defend yours.
3. **Answer the boundary questions.** (a) Is soil renewable? (b) Is shallow groundwater renewable, and does your answer depend on where the aquifer is? (c) Could any use of the Great Artesian Basin ever be called sustainable, on the 1987 definition?
4. **Add the rate.** For three of your cards, write the two rates that decide whether use can keep going: the rate of regeneration, and the rate of use that would match it.

Compare your sorted line with Figure `13c_timescales.png`, and revise any card you placed wrongly.

Worked examples

Example 1 — scaffolded

Classify each of these resources as **renewable** or **non-renewable**, and give the regeneration timescale that decides your answer: (a) wind; (b) a forest of radiata pine grown for timber; (c) natural gas; (d) copper ore. *(Draws on `VC2S8U09.E01` and `VC2S8U09.E02`.)*

Working	Comment
(a) Wind is **renewable**. Wind is a **flow**: it keeps arriving whether we capture it or not, on a timescale of days at most.	Flows renew regardless of use — capturing wind does not use it up.
(b) A radiata pine plantation is **renewable**. Harvested patches are replanted, and the trees regrow over **decades** — inside a human lifetime.	A living stock that regrows on a human timescale, as long as replanting keeps up (commitment R1).
(c) Natural gas is **non-renewable**. It formed from the buried remains of tiny sea organisms, changed by heat and pressure over **millions of years**.	Millions of years of formation means no replacement on any human timescale [S3].
(d) Copper ore is **non-renewable**. Ore deposits form by geological processes over **millions of years and more** — effectively never, on any timescale people can plan around.	Once a concentrated deposit is mined, it is gone; recycling can return the metal, but not the deposit (commitment N2).

Example 2 — scaffolded

A fishery is managed using the bathtub model. The fish population holds a steady stock, and in a good year the population breeds new fish equal to **1 000 tonnes**. Boats want to catch **1 200 tonnes** this year. (a) Use the model to predict what happens to the stock. (b) State the largest catch that could keep going year after year. (c) Name the commitment this fishery is breaking. *(Draws on `VC2S8U09.E02`; arithmetic kept to comparisons of two rates.)*

Working	Comment
(a) The inflow (regeneration) is 1 000 tonnes; the outflow (catch) is 1 200 tonnes. Outflow exceeds inflow by 1 200 − 1 000 = **200 tonnes**.	Set the two rates side by side; the difference is what the stock loses in the year.
The stock therefore **falls by about 200 tonnes** over the year. Repeated, the stock keeps falling and can eventually crash, as the cod did [S5].	Case 3 of the bathtub model — use above regeneration.
(b) The largest catch that can keep going is **1 000 tonnes per year** — catch equal to the breeding rate, leaving the stock steady.	Case 2: use equal to regeneration is the largest use that can keep going.
(c) Commitment **R1** — keep the rate of use at or below the rate of regeneration.	R1 is a number that can be measured and checked, not a mood.

Example 3 — unscaffolded

A student argues: *"Radiata pine is a renewable resource, so logging a pine plantation is always sustainable."* Evaluate this claim. *(Draws on `VC2S8U09.E01` and the commitments of section 6; evaluating a claim against evidence is the skill taught in subtopic 5A.)*

The claim gets the classification right and the conclusion wrong. Radiata pine **is** renewable: harvested patches regrow over decades because the trees are replanted and grow back [S8]. But "renewable" describes what nature does at a certain rate — it does not, by itself, say anything about the rate of **use**. If patches were harvested faster than they were replanted and regrown — taking two patches a year while only one grows back — the stock of standing trees would fall year after year, exactly like the bathtub with the drain outrunning the tap, and the timber supply would eventually fail. The claim also ignores commitment R2: a plantation keeps regrowing only while its soil, its water and its replanting are looked after. What is true in the claim is the conditional version: logging a pine plantation **can** keep going, *provided* the harvest stays at or below the regrowth and the replanting is done — which is precisely the rotation-cycle method, and what the word *sustainable* commits the manager to. The label "renewable" is the starting point of the argument, never the end of it.

Example 4 — unscaffolded

Water taken from the Great Artesian Basin has been described as a **mining operation** rather than a harvest [S4]. Using this subtopic's ideas about regeneration timescales, explain why that description is fair, and state what would have to change for the basin's use to move toward sustainability on the 1987 definition. *(Draws on `VC2S8U09.E02`.)*

The description is fair because the classification of the water depends on the timescale, and the basin's timescale is not human. Some of the basin's water fell as rain nearly **two million years ago**, and the water still moves through the rock at only **one to five metres a year** [S4] — so the inflow (recharge) is a tiny trickle against the outflow of about 1 500 megalitres a day. Taking out water far faster than it is replaced is the same shape as digging out coal: a one-time stock being drawn down, not a flow being used as it arrives. That is mining, in everything but the material. For the use to move toward sustainability, the take would need to fall to at or below the recharge rate (commitment R1), or the water saved and used in other places so the need for the basin's old water falls — and either way, the needs the water now meets would have to be met for future generations too, which is exactly what the 1987 definition asks.

Practice questions

Scaffolded

Q1. Define each of the following, as the words are used in this subtopic: (a) resource; (b) renewable resource; (c) non-renewable resource; (d) regeneration.

Q2. Classify each resource below as renewable or non-renewable, and give the regeneration timescale behind your answer. (a) sunlight; (b) brown coal in the Latrobe Valley; (c) radiata pine timber from a replanted plantation; (d) a deposit of copper ore.

Q3. Put these five resources in order of regeneration timescale, from shortest to longest: **A** rain-fed river water; **B** a replanted pine forest; **C** a few centimetres of soil; **D** water in the deepest, oldest part of the Great Artesian Basin; **E** a seam of coal.

Q4. Complete the table below for each resource. One row has been done for you.

Resource	Renewable or non-renewable?	Regeneration timescale	Why
Wind	Renewable	days — arrives whether used or not	a flow; capturing it does not reduce what arrives
Oil			
A fish population			
Iron ore			

Q5. A farm dam collects rainwater from the paddocks around it. In most years the winter rains refill the dam fully; in a dry year it does not. (a) Is the dam's water a flow, a living stock, or a slow renewable? Choose and explain. (b) State the condition under which taking water from the dam can keep going year after year. (c) State what happens, over a run of dry years, if use stays the same while refill falls.

Q6. The bathtub model has three cases. For each case below, name the case (use below regeneration / use equal to regeneration / use above regeneration) and state what happens to the stock. (a) pumping 400 ML per year from an aquifer that refills with 400 ML per year; (b) catching 700 tonnes per year from a stock that breeds 1 000 tonnes per year; (c) clearing 50 hectares of forest per year when regrowth and replanting replace 20 hectares per year.

Unscaffolded

Q7. *"Coal is made from ancient plants, and plants are renewable — so coal must be renewable."* Evaluate this claim. In your answer, say what is right in it, what is wrong in it, and give the timescales that decide the matter. *(3 marks)*

Q8. *(Novel scenario.)* A town draws **600 megalitres per year** of groundwater from a shallow aquifer. Rainfall recharges the aquifer with **400 megalitres per year**. The aquifer currently stores **10 000 megalitres**. (a) Find how much the store falls by each year at current use. (b) At that rate of fall, estimate how many years the store would last. (c) Explain why calling this groundwater "renewable" without more information could mislead the town. (d) Give one change that would move the town's use toward sustainability. *(4 marks)*

Q9. Use the cod fishery bar chart (Figure `13c_cod_bars.png`). (a) Describe the change in the fishery between 1968 and 1992. (b) Cod breed — the stock is renewable. Explain, using rates, how the fishery still collapsed. (c) State the commitment (by its label) that sustainable fishing must keep, and put it into one sentence for this fishery. *(4 marks)*

Q10. Soil forms at about one-tenth of a millimetre per year in some settings — a century per centimetre [S6]. (a) Explain why soil is still classified as renewable, in principle. (b) State the condition under which soil use stops being sustainable. (c) Name one way land managers can keep formation and erosion in balance. *(3 marks)*

Q11. A pine plantation is managed on a rotation cycle: four equal patches, one harvested and replanted each period, so that the timber supply never stops (Figure `13c_plantation_cycle.png`). (a) Explain how the cycle keeps a continuous supply of timber. (b) State what the managers would have to check, as numbers, to know the harvest is sustainable. (c) State which commitment, R1 or R2, is served by replanting the harvested patch, and why. *(3 marks)*

Q12. *"If a resource is renewable, its use is automatically sustainable."* Evaluate this claim. Give an example from this subtopic that shows the claim is false, and rewrite the claim so that it is correct. *(3 marks)*

Q13. *(Novel scenario.)* A new town is planned beside three resources: a wind plain, a native forest that grows back very slowly, and a deposit of natural gas. For each resource, state (i) whether it is renewable or non-renewable, with the timescale that decides it, and (ii) which commitment or commitments (R1, R2, N1, N2, N3) the town should apply to it. *(6 marks)*

Q14. *(Data interpretation — simulated data for practice.)* Four resources are studied, with the results below. For each, classify it as renewable or non-renewable **as it is being used**, and give the evidence you used. (Reading a table for patterns and using them to classify is also practice for subtopic 4C.)

Resource	How fast nature replaces it	How fast it is being used
1	refills fully every rainy season	less than the seasonal refill
2	regrows over about 40 years	one patch of ten is harvested every 4 years
3	refills over thousands of years	pumped down every decade
4	forms over millions of years	burned as fuel, year after year

(4 marks)

Answers

Q1. (a) Anything people can use that comes from the Earth or from the energy that reaches it. (b) A resource replaced by natural processes at least as fast as people use it. (c) A resource formed so slowly that it does not come back on any human timescale once used. (d) The natural replacement or re-forming of a resource — regrowth, breeding, refilling. **Q2.** (a) Renewable — arrives daily, whether used or not. (b) Non-renewable — formed tens of millions of years ago from buried forests; no replacement on a human timescale [S2]. (c) Renewable — replanted patches regrow over decades. (d) Non-renewable — ore deposits form over millions of years and more. **Q3.** A, B, C, D, E. **Q4.** Oil — non-renewable; millions of years; formed from buried sea organisms changed by heat and pressure [S3]. A fish population — renewable; years to decades; the stock breeds back if enough breeders are left. Iron ore — non-renewable; millions of years and more; ore forms by geological processes, effectively never on a human scale. **Q5.** (a) A slow renewable — the water is replaced by rainfall over a season to a year, not continuously like wind, and not by living things. (b) Use over the year must stay at or below the refill the rains bring. (c) The stock falls each dry year; after several dry years the dam can run short or run dry even with unchanged use. **Q6.** (a) Use equal to regeneration — the stock holds steady. (b) Use below regeneration — the stock grows. (c) Use above regeneration — the stock falls. **Q7.** Right part: coal did form from ancient plants. Wrong part: the plants became coal only over millions of years of burial, heat and pressure — far outside any human timescale, so coal is non-renewable even though its starting material was alive. **Q8.** (a) 200 ML per year. (b) 50 years. (c) The groundwater renews, but over a much longer time than the town's use — at current rates the store behaves like a finite stock being drawn down. (d) Any one, e.g. cut use to at or below 400 ML per year, add a second source, or store wet-season water. **Q9.** (a) Catches fell from the 1968 peak of 810 000 tonnes to about one per cent of historic levels by 1992, when the fishery was closed [S5]. (b) The catch ran faster than the breeding: use above regeneration draws the stock down until it collapses. (c) R1 — for this fishery: take no more cod per year than the population breeds back. **Q10.** (a) Soil is continually being made by weathering and the breakdown of living material — formation does not stop, so renewal happens in principle. (b) When erosion removes soil faster than formation builds it. (c) Any one, e.g. keeping ground covered with plants, windbreaks, or contour ploughing. **Q11.** (a) Because the patches are different ages, one patch is always ready to harvest while the others grow — the harvest never waits on a whole forest regrowing at once. (b) That the area harvested and the area regrown replace each other — harvest at or below regrowth (R1), measured in area or timber volume per year. (c) R1 — replanting is what keeps the regrowth rate up to the harvest rate; R2 would cover the soil, water and seed supply behind the regrowth. **Q12.** Wrong as written. Example that shows it is false: the cod fishery was renewable and still collapsed, because the catch outran the breeding [S5]. Corrected: if a resource is renewable, its use can be sustainable — but only if the rate of use is kept at or below the rate of regeneration and the renewing system is protected. **Q13.** Wind — renewable (daily flow); commitments R1/R2 apply weakly since a flow is not drawn down — the town's task is not to depend on the wind beyond what it supplies. Native forest — renewable only over a very long timescale; R1 (harvest far below the slow regrowth) and R2 (protect soil, seed and water). Natural gas — non-renewable (millions of years); N1, N2 and N3. **Q14.** 1 — renewable and sustainably used: use is below the refill. 2 — renewable and sustainably used: one patch of ten every 4 years means each patch is harvested every 40 years, matching the 40-year regrowth. 3 — renewable in principle but not sustainable as used: pumping outruns the very slow refill — the store is being mined. 4 — non-renewable: formation takes millions of years, so ongoing burning draws down a finite stock.

Fully-worked solutions

Q1. (a) A **resource** is anything people can use that comes from the Earth or from the energy that reaches it — materials (water, timber, minerals) and energy sources (coal, wind, sunlight). (b) A **renewable resource** is replaced by natural processes **at least as fast as people use it**, so the supply can keep going in principle. (c) A **non-renewable resource** is formed so slowly that, on any human timescale, it **does not come back once used**. (d) **Regeneration** is the natural replacement or re-forming of a resource — a forest regrowing, a fish stock breeding back, an aquifer refilling. *(1 mark each.)*

Q2. (a) Sunlight is **renewable**: it is a **flow** that arrives daily whether used or not — capturing it does not reduce what arrives tomorrow. (b) Latrobe Valley brown coal is **non-renewable**: the deposits formed from forests that grew and died **tens of millions of years ago** [S2]; no coal forming now will be available within any human timescale. (c) Radiata pine timber from a replanted plantation is **renewable**: harvested patches are **replanted and regrow over decades**, inside a human lifetime [S8]. (d) A copper ore deposit is **non-renewable**: ore deposits form by geological processes over **millions of years and more** — effectively never on any timescale people can plan around. *(1 mark each: classification + timescale.)*

Q3. A rain-fed river water (weeks to months) → **B** a replanted pine forest (decades) → **C** a few centimetres of soil (centuries to millennia [S6]) → **D** the oldest Great Artesian Basin water (up to nearly two million years [S4]) → **E** a seam of coal (millions of years [S1]). So the order is **A, B, C, D, E**. *(1 mark for the correct order.)*

Q4. Oil — non-renewable; formed from the buried remains of tiny sea organisms changed by heat and pressure over **millions of years** [S3]; once burned it is gone for good on a human timescale. **A fish population** — renewable; the stock **breeds back over years to decades** provided enough breeders are left (if the catch outruns the breeding, the classification holds but the use fails — see Q9). **Iron ore** — non-renewable; ore forms by geological processes over **millions of years and more**, effectively never on a human scale. *(1 mark per completed row.)*

Q5. (a) The dam's water is a **slow renewable**: it is replaced by **rainfall over a season to a year** — not continuously like wind (a flow), and not by living things. (b) Taking water can keep going year after year **provided use over the year stays at or below the refill the rains bring** — case 2 of the bathtub model. (c) In a run of dry years the refill falls while use stays the same, so **use sits above regeneration and the stock falls each year**; after several dry years the dam can run short or run dry even though nothing about the town's use changed. *(a: 1 mark; b: 1 mark; c: 1 mark.)*

Q6. (a) Pumping 400 against a refill of 400: **use equal to regeneration** — the stock **holds steady**; this is the largest use that can keep going. (b) Catching 700 against breeding of 1 000: **use below regeneration** — the stock **grows** (by about 300 tonnes in the year). (c) Clearing 50 hectares against 20 hectares of regrowth: **use above regeneration** — the stock **falls**, and if continued the forest cover runs down. *(1 mark each.)*

Q7. What is right: coal really did form from ancient plants — dead swamp forest piled up as peat [S1]. **What is wrong:** those plants became coal only through **burial, heat and pressure acting over millions of years** [S1] — the replacement timescale of coal is millions of years, which is far outside any human timescale. Whether a resource is renewable is decided by **how fast it is replaced**, not by what it started as. **Verdict:** the claim is false — coal is non-renewable. *(1 mark each part.)*

Q8. (a) The store falls by use − recharge = 600 − 400 = **200 ML per year**. (b) 10 000 ÷ 200 = **50 years**. (c) The water does renew — but the recharge (400 ML per year) is far below the use (600 ML per year), so **on the town's timescale the aquifer behaves like a finite stock being drawn down**, not a flow being used as it arrives; the label "renewable" without the rates hides the coming shortage. (d) Any one: **cut use to at or below 400 ML per year** (commitment R1); add a second water source; store wet-season water for dry years. *(1 mark each.)*

Q9. (a) Catches **fell from the peak of 810 000 tonnes in 1968 to about one per cent of historic levels by 1992**, when Canada closed the fishery [S5]. (b) Cod breed, so the stock renews — but only at the breeding rate. The catch was **held above the breeding rate for years**, so the outflow outran the inflow and the stock was drawn down until it collapsed: a renewable resource used faster than it regenerates, behaving like a non-renewable one. (c) Commitment **R1** — keep use at or below regeneration: for this fishery, *take no more cod per year than the population breeds back. (a: 1 mark; b: 2 marks — one for the rate comparison, one for the draw-down conclusion; c: 1 mark.)*

Q10. (a) Soil is being made **continuously** — rock weathers and living material breaks down all the time, so formation never stops; that makes soil renewable **in principle**, however slowly [S6]. (b) Soil use stops being sustainable **when erosion removes soil faster than formation builds it** — use above regeneration. (c) Any one: keeping the ground **covered with plants**, planting windbreaks, contour ploughing — anything that slows erosion to at or below the formation rate. *(1 mark each.)*

Q11. (a) The four patches are different ages, so **one patch is always at harvest age while the other three grow** — the mill never has to wait for a whole forest to regrow at once, and every harvested patch is replanted to become the youngest patch. (b) The managers must check the **harvest rate against the regrowth rate** — hectares (or timber volume) cut per year against hectares (or volume) reaching maturity per year — and keep the first at or below the second (commitment R1). (c) Replanting serves **R1**: it is what keeps the regrowth coming so the harvest rate can be matched. (R2 would instead cover the soil, water and seed supply that the regrowth depends on.) *(a: 1 mark; b: 1 mark; c: 1 mark.)*

Q12. The claim is **wrong as written**: being renewable is a statement about nature's rate, not a guarantee about our use. **Example that shows it is false:** the Atlantic northwest cod were renewable — fish breed — yet the fishery collapsed because the catch outran the breeding [S5]. **Corrected claim:** if a resource is renewable, its use **can** be sustainable — but only **provided the rate of use is kept at or below the rate of regeneration** (R1) and the system that does the regenerating is protected (R2). *(1 mark each part.)*

Q13. Wind — renewable; a **flow arriving daily**, so nothing is drawn down; the town's commitments are weak versions of R1/R2: do not build dependence on more wind power than the wind actually supplies, and maintain the turbines and land that capture it. **Native forest** — renewable only over a **very long timescale** (slow regrowth); commitment **R1** — harvest far below the slow regrowth — and commitment **R2** — protect the soil, seed source and water the slow regrowth depends on. **Natural gas** — non-renewable; formed over **millions of years** [S3]; commitments **N1** (use efficiently), **N2** (capture and reuse the material where possible) and **N3** (put part of the benefit into alternatives before the deposit runs down). *(1 mark per resource for classification with timescale; 1 mark per resource for the correct commitment(s).)*

Q14. Resource 1 — renewable and sustainably used: it refills fully each rainy season and use stays **below** the refill (bathtub case 2 or better). **Resource 2 — renewable and sustainably used:** harvesting one patch of ten every 4 years means each patch is harvested every **40 years**, which matches the **40-year regrowth** exactly — use equal to regeneration. **Resource 3 — renewable in principle but not sustainable as used:** the refill takes thousands of years while pumping draws the store down every decade — **use above regeneration; the store is being mined**, like the oldest Great Artesian Basin water [S4]. **Resource 4 — non-renewable:** formation over millions of years [S1] means ongoing burning draws down a **finite** stock. *(1 mark per resource: classification + evidence.)*

Sources

All retrieved 2026-08-21.

- **[S1]** Wikipedia, "Coal", 2026 — retrieved 2026-08-21. (Formation from swamp-forest plant matter via peat, burial, heat and pressure over millions of years; about 90% of coal beds accumulated in the coal-forming age about 300 to 360 million years ago.)
- **[S2]** Wikipedia, "Lignite", 2026 — retrieved 2026-08-21. (Latrobe Valley brown-coal deposits: estimated reserves of some 65 billion tonnes, about 25 per cent of known world reserves; seams up to 98 metres thick.)
- **[S3]** Wikipedia, "Petroleum", 2026 — retrieved 2026-08-21. (Formation from the remains of tiny sea organisms settled on sea and lake floors, buried in oxygen-poor conditions and changed by heat and pressure over thousands to millions of years.)
- **[S4]** Wikipedia, "Great Artesian Basin", 2026 — retrieved 2026-08-21. (Area about 1 700 000 square kilometres; oldest water nearly two million years; water moves one to five metres per year; total output about 1 500 megalitres per day; extraction described as a mining operation because recharge is far below extraction.)
- **[S5]** Wikipedia, "Collapse of the Atlantic northwest cod fishery", 2026 — retrieved 2026-08-21. (Peak catch 810 000 tonnes in 1968; closure in 1992 with the stock at about one per cent of historic levels; incomplete recovery; 2024 reopening with an 18 000-tonne limit.)
- **[S6]** Wikipedia, "Pedogenesis", 2026 — retrieved 2026-08-21. (Decades to several thousand years for a soil to develop a profile; weathering-based soil production of about one-tenth of a millimetre per year in the cited Mediterranean setting.)
- **[S7]** Wikipedia, "Sustainable development", 2026 — quoting World Commission on Environment and Development, *Our Common Future*, 1987 — retrieved 2026-08-21.
- **[S8]** Wikipedia, "Pinus radiata", 2026 — retrieved 2026-08-21. (The dominant tree species in the Australian plantation estate.)
- **[S9]** Wikipedia, "Kuitpo Forest", 2026 — retrieved 2026-08-21. (Radiata pine plantation established in 1898, about 3 600 hectares, managed for a sustainable timber supply.)
- **Elaboration uses:** VCAA, Victorian Curriculum F–10 Version 2.0, Science Levels 7 and 8, elaborations `VC2S8U09.E01`, `VC2S8U09.E02`, as recorded in `S:\Files\projects\mcq-system\data\vc2_books\science_7-8.json` (the operative authority file, D15).

Extraction and energy production: weighing the benefits against the risks, from mine rehabilitation to desalination to the vehicle fleet

Book: Science, Levels 7 and 8 (VC2) — one banded volume · **Chapter 13 — Earth and space sciences B: rocks, minerals and Earth's resources** · **Subtopic 13D**

CD: `VC2S8U09` (split delivery, D6) — **13D is the partner; 13C is the accountable owner.** Clause delivered here: *the benefits and risks of resource extraction and energy production.* Full CD text (verbatim): *"the sustainable use of Earth's resources is influenced by whether the resources are renewable or non-renewable; the processes involved in resource extraction and energy production come with both benefits and risks to sustainability"* **Achievement-standard extract:** reproduced verbatim in 13C's header block, as D13 requires for a split CD; the partner cites it by reference. This subtopic serves that extract's requirement that students *compare the benefits and risks of resource extraction and energy production*. **Elaboration ids drawn on:** `VC2S8U09.E03` (creating an infographic to illustrate the risks and benefits of different forms of energy production), `VC2S8U09.E04` (preparing a case study for the regeneration of an old mine), `VC2S8U09.E05` (examining how the use of desalination plants to produce fresh water has impacted marine ecosystems at desalination plant sites), `VC2S8U09.E06` (examining hybrid and solar, electric and hydrogen-powered vehicles as applications of contemporary science responses to the depletion of fossil fuels). These are a context bank, not a checklist (D12). **Maths interlock (D11):** `VC2M8M05` — rates comparing two quantities of different units (fuel use in L/100 km, brine in litres per litre of fresh water); `VC2M7N06` — four operations with positive rational numbers, used here for an energy-and-resource audit (Worked examples 1–3). **Relationship to 13C:** 13C teaches what makes a resource renewable or non-renewable, and what "sustainable use" commits you to. This subtopic assumes those ideas and applies them — it weighs the benefits and risks of actually getting resources out of the ground and turning them into energy.

Theory

In 13C you sorted Earth's resources into renewable and non-renewable, and you met the idea of sustainable use. In 13B you saw how rocks are quarried and mined, and how mined land can be put back. This subtopic takes the next step: every one of those activities brings **benefits** and brings **risks**, and the job here is to learn to **weigh** them honestly. The subtopic answers four questions, in order:

1. **Where does Victoria's energy come from** — and how is that changing?
2. **What are the benefits and risks of each way of producing energy?**
3. **What are the benefits and risks of extracting resources** — and how does rehabilitation fit in?
4. **How do new responses — desalination and new vehicle types — weigh up?**

The same move runs through all four: name the benefits, name the risks, then weigh them on the evidence.

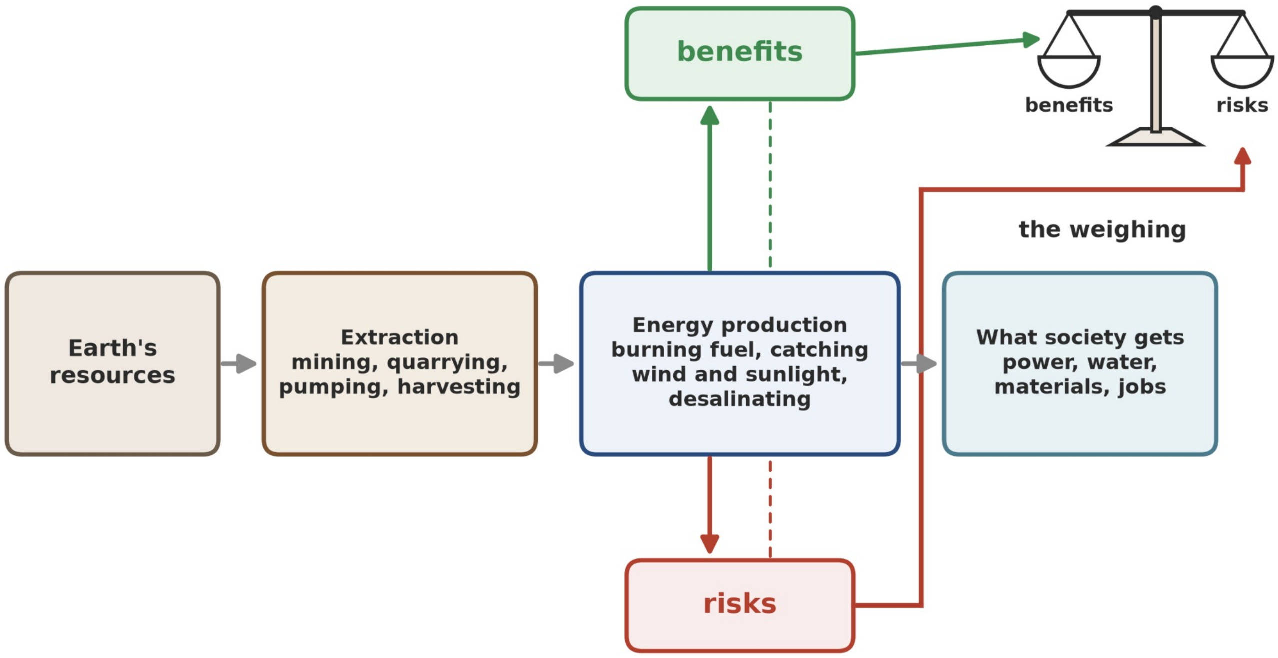
Defining the terms before we use them

Two words in this subtopic need care, because people use them in different ways.

Defining a contested term — *sustainable*. The Victorian Curriculum uses the words *sustainable* and *sustainability* but does not define them. This subtopic therefore uses them in the sense given by the World Commission on Environment and Development, *Our Common Future* (1987): development that *"meets the needs of the present without compromising the ability of future generations to meet their own needs"* [S9]. Other definitions exist and are not interchangeable with this one. Every question in this subtopic is answerable on that definition alone.

Defining *benefit* and *risk* as used here. A **benefit** is anything an activity gives that people have reason to value — electricity, jobs, water, materials, money. A **risk** is the **chance** that an activity causes harm, combined with **how serious** that harm would be. A harm that is very serious but very unlikely, and a harm that is minor but happens all the time, are both risks — the weighing has to say which it is talking about.

Notice the two kinds of statement you will meet. Some parts can be **measured** — litres, dollars, kilograms of carbon dioxide, megawatts. Other parts depend on **whose view you ask** — whether a wind farm spoils a view, or whether a town wants a mine next to it. Both parts matter in a weighing. Confusing the two — treating a measured fact as an opinion, or an opinion as a measured fact — is where most bad weighings go wrong.



This subtopic weighs the benefits against the risks, for sustainability as defined in 1987 — meeting today's needs without compromising future generations.

Overview diagram. A central flow runs left to right through four boxes: Earth's resources; extraction — mining, quarrying, pumping, harvesting; energy production — burning fuel, catching wind and sunlight, desalinating water; and what society gets — power, water, materials, jobs. From the middle of the flow, one arrow points up to a green box labelled benefits, and one arrow points down to a red box labelled risks. Both arrows then feed into a pair of balance scales at the right, labelled the weighing. A footer line reads: this subtopic weighs the benefits against the risks, for sustainability as defined in 1987 — meeting today's needs without compromising future generations.

1. Where Victoria's electricity comes from — and how that is changing

Most of the energy discussion in Australia is about **electricity**, because almost everything modern runs on it. Australia's main electricity grid — the network that supplies the eastern and southern states, including Victoria — is called the **National Electricity Market**. In 2022 it generated **208.4 TWh** of electricity [S1]. A **TWh** (terawatt-hour) is a unit for very large amounts of energy: 1 TWh is one million million watt-hours. Here is where it came from [S1].

Source	Generation in 2022 (TWh)	Share
Black coal	89.5	43%
Brown coal	32.0	15%
Gas	13.2	6%
Hydro	16.6	8%
Wind	25.9	12%
Solar	30.1	14%
Other sources	1.1	1%
Total	**208.4**	

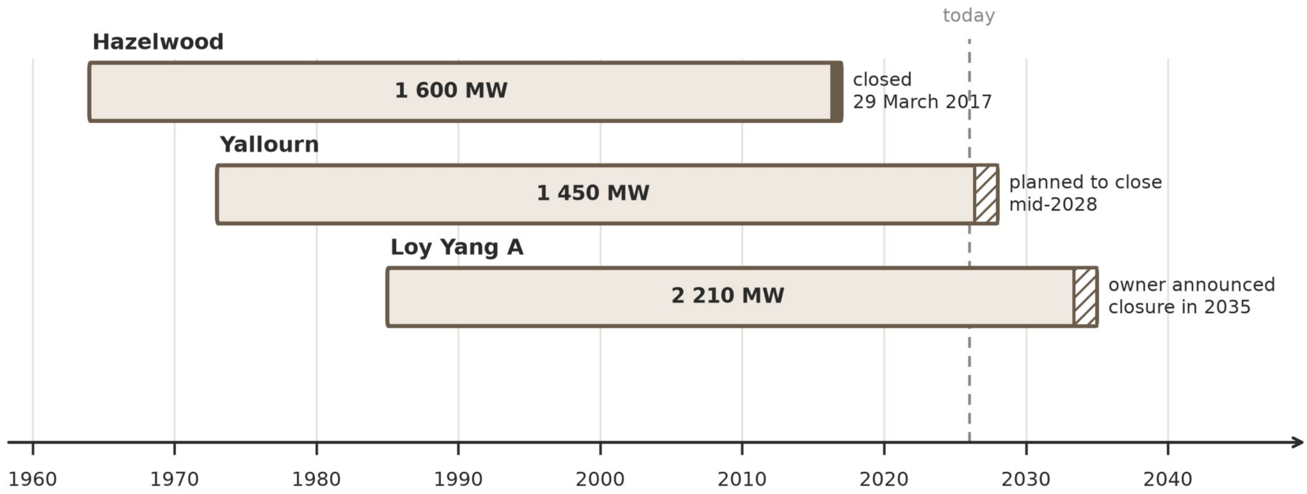
Shares are rounded to the nearest whole per cent, so they do not add exactly to 100%. Two things stand out:

- **Coal still supplied most of it.** Black coal and brown coal together supplied **121.5 TWh** — more than all the other sources combined.

- **The mix is changing.** Wind and solar together supplied 56.0 TWh — more than brown coal alone.

Victoria's own story is built on **brown coal**, also called lignite. Huge deposits of it sit in the **Latrobe Valley**, about 150 km east of Melbourne, and for decades Victoria's biggest power stations have burned it. The three names to know:

- **Hazelwood** — 1 600 MW, in service from 1964, **closed 29 March 2017** [S2].
- **Yallourn** — 1 450 MW, four units, fed by the largest open-cut coal mine in Australia; **planned to close in mid-2028** [S3].
- **Loy Yang A and Loy Yang B** — 2 210 MW and 953 MW; counted together they are the largest power station in Australia; the owner of Loy Yang A has announced it will **close in 2035** [S4].



Victoria's biggest brown-coal power stations, and when they leave the grid. As these stations retire, Victoria's electricity mix shifts — the mix table in this subtopic shows what is filling the gap.

Timeline diagram with a horizontal axis of years, 1960 to 2040. Three horizontal bars show the working lives of three Latrobe Valley brown-coal power stations. Hazelwood: bar from 1964 to 2017, labelled 1 600 MW, closed 29 March 2017. Yallourn: bar from 1973 to 2028, labelled 1 450 MW, planned to close mid-2028. Loy Yang A: bar from 1985 to 2035, labelled 2 210 MW, owner announced closure in 2035. A dashed line marks today (2026). A note below the axis reads: as these stations retire, Victoria's electricity mix shifts — the mix table in this subtopic shows what is filling the gap.

The change is not only about coal retiring. New sources are being built. The **Macarthur Wind Farm**, near Hamilton in western Victoria, was completed in **January 2013**: **140 turbines** with a combined capacity of **420 MW**, reported at the time as Australia's biggest wind farm [S5]. Solar panels are going onto roofs across the state. The weighing question of this subtopic is not *"coal or renewables?"* as a slogan — it is *"for each source, what exactly do we get, what exactly do we risk, and what does the evidence say?"*

2. Benefits and risks of each way of producing energy

Every way of producing electricity has benefits and risks. Read the table below row by row — each row is a **steelman**: the benefits and the risks are both stated at full strength, the way their own advocates would put them (the rule matters: a position shown only in its weakest form has not really been examined).

Source	Benefits	Risks
Brown/black coal	Victoria has huge brown-coal deposits, so the fuel is local and cheap; coal stations can run day and night, in any weather, so the supply is steady; the stations and mines employ people in the Latrobe Valley	Burning coal releases carbon dioxide, a greenhouse gas, and other gases and particles that can affect health; mining the coal clears land and changes the landscape (13B); ash waste is left behind; coal is non-

Source	Benefits	Risks
	[S2][S3].	renewable (13C), and the mines carry risks such as the 2014 Hazelwood mine fire [S2].
Gas	Burns with less carbon dioxide per unit of energy than coal; gas stations can start and stop quickly, filling gaps when wind and solar drop [S1].	Still a fossil fuel, so burning it releases carbon dioxide; drilling and extracting it can disturb land and groundwater; prices can rise and fall sharply.
Wind	No fuel to burn and no carbon dioxide while generating; the land under a wind farm can still be farmed — at Macarthur, sheep graze between the turbines [S5]; once built, running costs are low.	The wind does not blow all the time, so output goes up and down; turbines are large and visible, and some nearby residents object to how they look and sound; building turbines takes steel and concrete, and birds and bats can collide with the blades.
Solar	No carbon dioxide while generating; Australia has abundant sunlight; panels can go on existing roofs, using no extra land; small systems work for a single house.	No output at night and less on cloudy days; making panels takes energy and materials; old panels become waste that must be dealt with; large solar farms need land.
Hydro	Reliable, and water can be stored behind the dam and released when needed — a kind of stored energy; stations last a very long time.	Building a dam floods a valley and changes the river ecosystem downstream; in drought there is less water to generate with.

source	benefits	risks
Coal (brown and black)	huge local brown-coal deposits — cheap fuel steady supply day and night, in any weather jobs for the Latrobe Valley	releases carbon dioxide and other emissions mining clears land; ash waste left behind non-renewable; mine fires (Hazelwood 2014)
Gas	less carbon dioxide than coal per unit of energy quick to start and stop — fills gaps	still a fossil fuel drilling disturbs land and groundwater prices can rise and fall sharply
Wind	no emissions while generating land under turbines can still be farmed low running costs once built	output varies with the wind large and visible; some residents object blades can strike birds and bats
Solar	no emissions while generating abundant sunlight; panels fit on roofs	no output at night; less on cloudy days making panels takes energy; old panels are waste large solar farms need land
Hydro	reliable; water stored behind the dam released when needed — stored energy	a dam floods a valley and changes the river less water to generate with in drought

Every source has both columns — the weighing is the point. Each row is a steelman: both sides stated as strongly and fairly as their own advocates would put them.

Summary table as a diagram, with one row per energy source and two columns — benefits and risks. Coal row: benefits — local cheap fuel, steady day-and-night supply, Latrobe Valley jobs; risks — carbon dioxide and other emissions, mine impacts, ash waste, non-renewable. Gas row: benefits — less carbon dioxide than coal per unit of energy, quick to start and stop; risks — still a fossil fuel, drilling disturbs land, prices swing. Wind row: benefits — no emissions while generating, land can still be farmed, low running costs; risks — output varies with wind, visible and audible to nearby residents, blades can strike birds and bats. Solar row: benefits — no emissions while generating, abundant sunlight, panels fit on roofs; risks — none at night, panel manufacture and waste, large farms need land. Hydro row: benefits — reliable, water can be stored for when it is needed; risks — dams flood valleys and change rivers, less water in drought. A footer line reads: every source has both columns — the weighing is the point.

Two habits keep this table honest.

> **Word watch — "no emissions" means *while generating*.** Wind and solar produce no carbon dioxide while they make electricity. But their towers, panels and batteries had to be made, transported and installed, which used energy. The fair statement is *"no emissions while generating"*, not *"no emissions at all, ever"*. The same care applies the other way: a coal station's risks include mining and ash, not only the smoke from its chimneys.
>
> **Word watch — variable, not unreliable.** Wind and solar are **variable**: their output changes with the weather. That is a real problem for a grid, but it is not the same as being unreliable by accident. The responses — storing energy, connecting the grid over wider areas, keeping quick-start gas stations as back-up — are engineering questions with engineering answers, and they belong to the weighing.

3. Extracting resources: benefits and risks

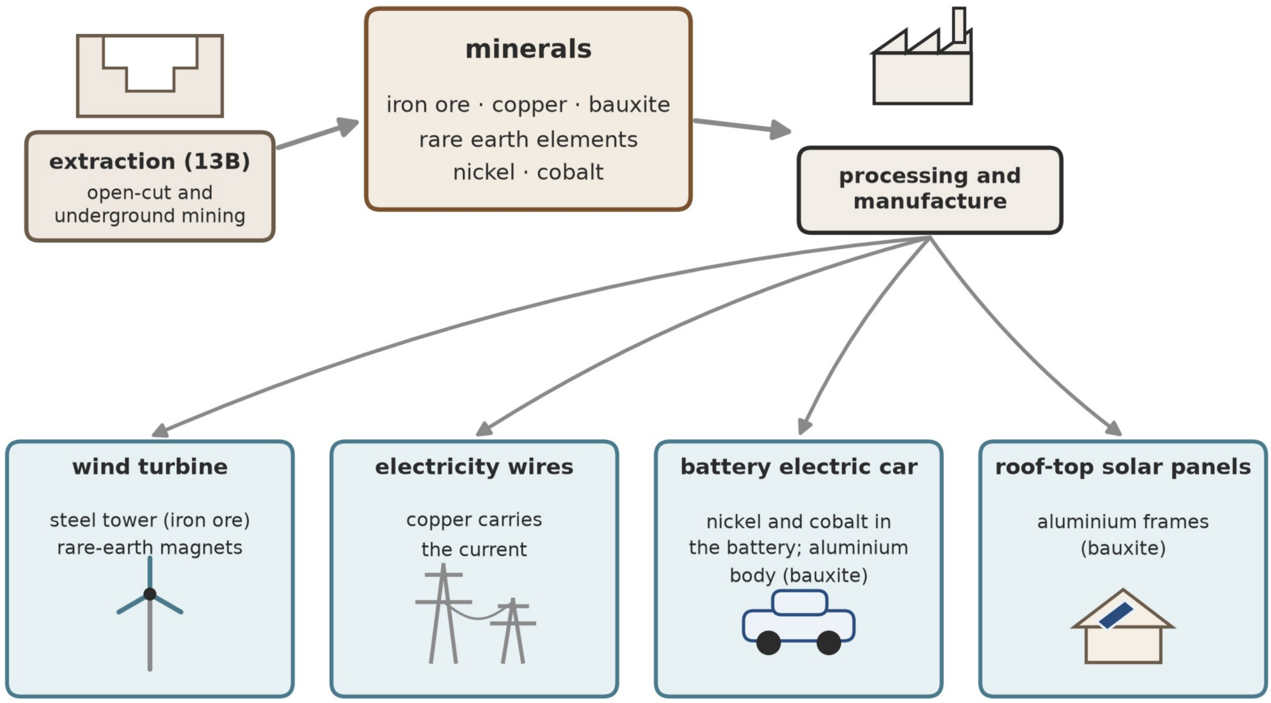
Energy is only half of the clause. The other half is **resource extraction** — getting minerals and other resources out of the ground. In 13B you met the methods: digging, drilling and blasting, wedging and cutting, underground mining. Here is the weighing.

The benefits. Australia produces **19 useful minerals in significant amounts, from over 350 operating mines**, and is one of the world's leading producers of bauxite (aluminium ore), iron ore, gold, lead, rare earth elements and zinc

[S7]. These are not just export numbers. The minerals go into things you use every day — and into the new energy technologies themselves:

- **iron ore** becomes the steel in wind-turbine towers, roofs and cars;
- **copper** becomes the wire that carries electricity;
- **bauxite** becomes the aluminium in frames, panels and cans;
- **rare earth elements** go into the magnets in some turbine generators and car motors;
- **nickel and cobalt** go into many batteries.

So the energy transition itself — moving from fossil fuels toward wind, solar, batteries and new vehicles — **depends on mining**. That connection matters: someone weighing a new mine has to hold both facts at once — the mine changes a local place, and the minerals it produces may be part of a cleaner energy system.



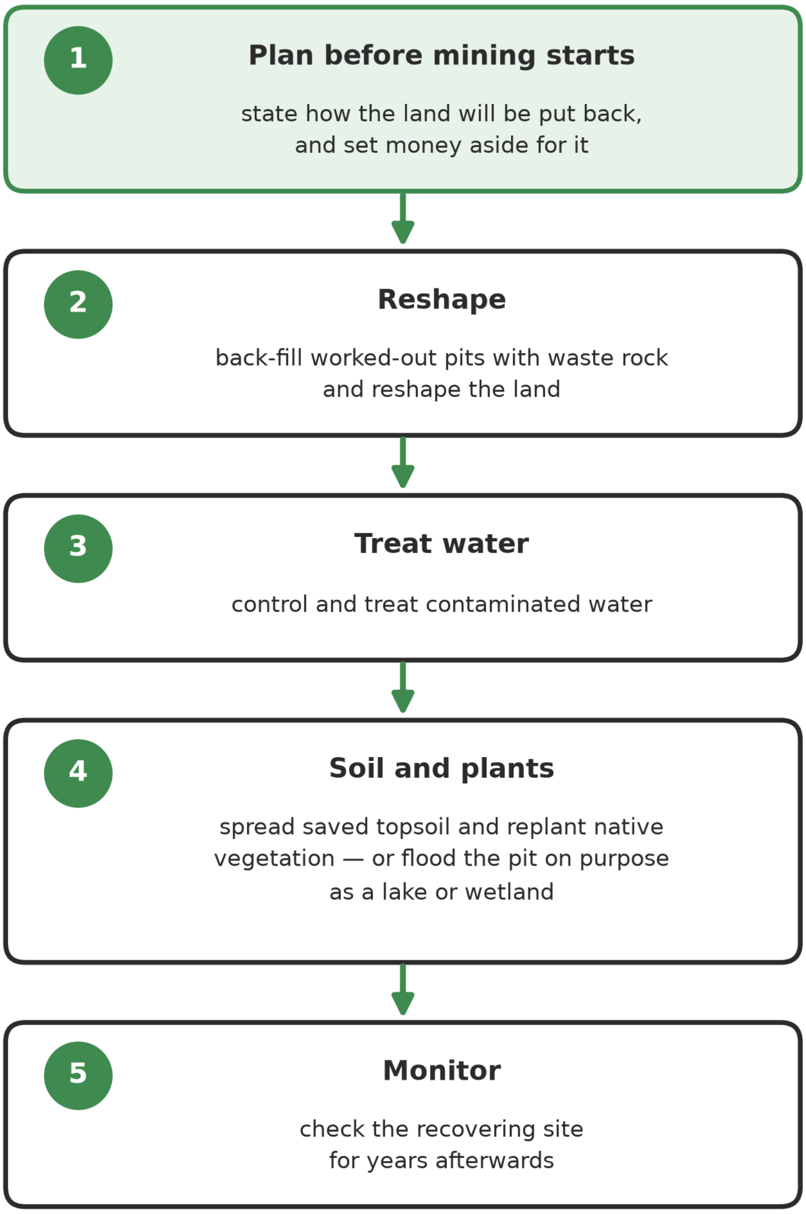
The energy transition runs through mines — Australia produces 19 useful minerals in significant amounts, from over 350 operating mines (Geoscience Australia).

Flow diagram in two rows. The top row runs left to right: an open-cut mine labelled extraction (13B), an arrow to a box labelled minerals — iron ore, copper, bauxite, rare earth elements, nickel, cobalt, an arrow to a factory labelled processing and manufacture. The bottom row shows four end products fed from the factory: a wind turbine (steel tower, rare-earth magnets); electricity wires (copper); a battery electric car (nickel and cobalt in the battery, aluminium body); and solar panels on a roof (aluminium frames). A footer line reads: the energy transition runs through mines — Australia produces 19 useful minerals from over 350 operating mines.

The risks. You met these in 13B and they are worth repeating, because the weighing needs them: clearing land and destroying habitat; erosion; contamination of soil, groundwater and surface water; waste-rock piles; and dust, noise and heavy traffic for nearby residents [S8]. The benefits of a mine are often spread widely — jobs, exports, materials for everyone — while the risks land hardest on the **local** community and environment. Noticing *who gets the benefit and who carries the risk* is part of every honest weighing.

Rehabilitation is risk management. In 13B you saw what rehabilitation involves: back-filling pits, reshaping the land, treating contaminated water, spreading saved topsoil, replanting native vegetation — or flooding a pit on purpose as a lake or wetland. The key idea here: **rehabilitation is planned before mining starts, not invented after it ends**

[S8]. A mining company that must state, in advance, how the land will be put back, and set money aside for it, is a company whose risks are being managed rather than ignored. The next section is a real case study of exactly that (VC2S8U09.E04).



Rehabilitation planned from the start turns a risk into a managed task.

Flow diagram of five rehabilitation steps in rounded boxes with arrows between them. Box 1: plan before mining starts — state how the land will be put back and set money aside. Box 2: reshape — back-fill worked-out pits with waste rock and reshape the land. Box 3: treat water — control and treat contaminated water. Box 4: soil and plants — spread saved topsoil and replant native vegetation, or flood the pit as a lake or wetland. Box 5: monitor — check the recovering site for years afterwards. A footer line reads: rehabilitation planned from the start turns a risk into a managed task.

4. Case study — Hazelwood: a mine that must be put back (VC2S8U09.E04)

The Hazelwood Power Station, in the Latrobe Valley, burned brown coal from its own open-cut mine. Its story shows both sides of the clause at once [S2].

- **The benefit, first.** From 1964, Hazelwood generated up to **1 600 MW** of electricity — cheap power from local coal, with jobs for the Latrobe Valley.
- **The risk, made real.** On **9 February 2014**, a fire in the mine's exposed coal faces and worked-out areas burned for weeks — until 10 March 2014 — becoming one of the largest, longest-running and most complex fires in Victoria's history. Smoke and ash affected nearby residents, and the subsequent inquiry found the fire had adverse health effects [S2].
- **The closure.** The station's owner closed Hazelwood on **29 March 2017**, saying it had reached the end of its productive life [S2].
- **The put-back.** Closing the station did not end the responsibility. Estimated decommissioning and rehabilitation costs were at least **$743 million** — about **$439 million** for the mine rehabilitation itself and about **$304 million** for demolishing the plant and restoring the site [S2]. The eight chimneys came down in May 2020 [S2].

February 2014

A mine fire burns at the Hazelwood open-cut coal mine — one of the largest, longest-running and most complex fires in Victoria's history. It burned from 9 February until 10 March 2014; the inquiry found adverse health effects from smoke and ash.

March 2017

The 1 600 MW power station closes at the end of its productive life, on 29 March 2017, after generating cheap electricity from local brown coal since 1964.

May 2020

The station's eight chimneys are demolished (25 May 2020).

Ongoing

Rehabilitation of the mine and site — estimated at least $743 million in total: about $439 million for the mine itself and about $304 million for demolishing the plant and restoring the site.

The benefits arrived while the station ran; the risks and the put-back outlasted it.

Case-study panel in four dated blocks down the page. Block 1, February 2014: a mine fire burns at the Hazelwood open-cut coal mine — one of the largest and longest-running fires in Victoria's history; an inquiry later found adverse *health effects. Block 2, March 2017: the 1 600 MW power station closes at the end of its productive life. Block 3, May 2020: the eight chimneys are demolished. Block 4, ongoing: rehabilitation of the mine and site — estimated at least $743 million in total, about $439 million for the mine and $304 million for plant demolition and site restoration. A footer line reads: the benefits arrived while the station ran; the risks and the put-back outlasted it.*

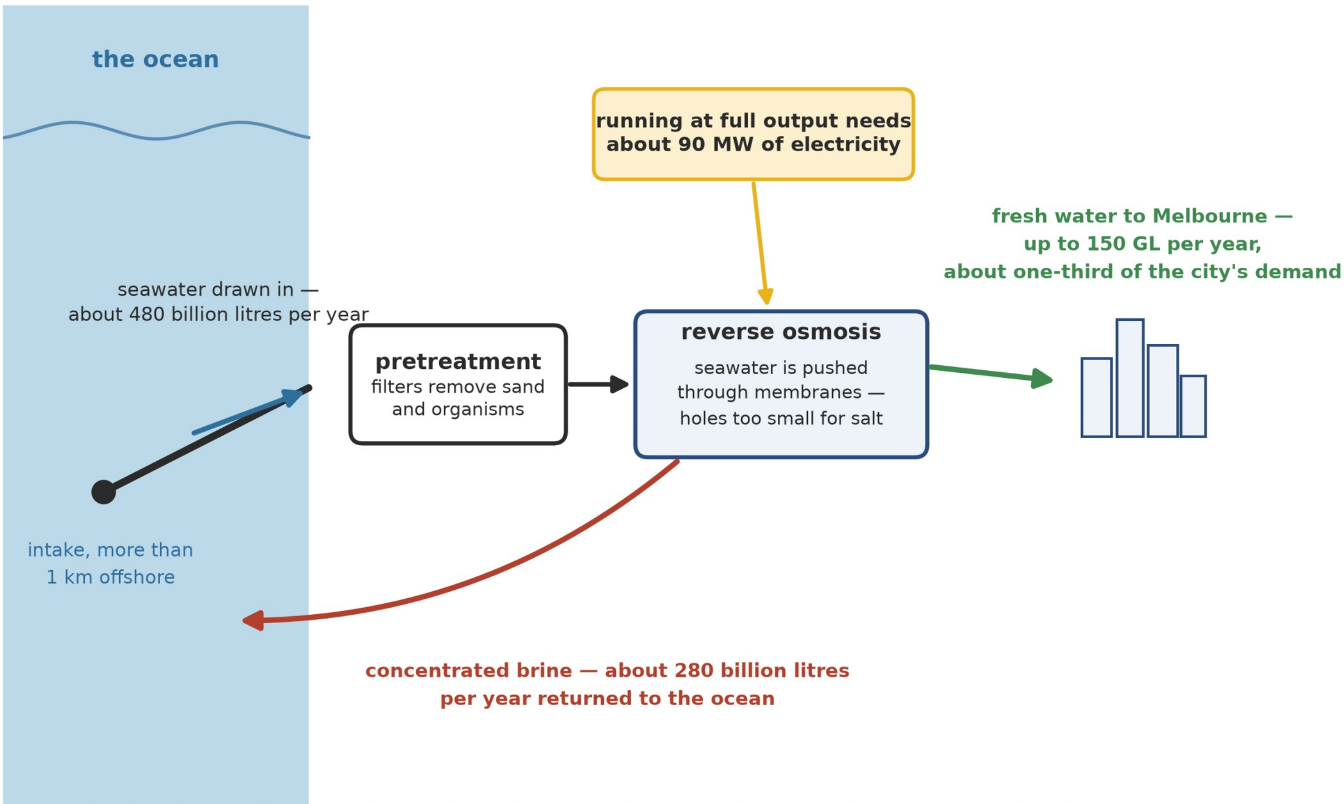
Notice the timescale. The station generated electricity for **53 years**; the fire ran for weeks but its effects were studied for years; the rehabilitation will run for decades after closure. **Benefits and risks can sit on very different clocks**, and a weighing that only looks at one timescale is incomplete. The Hazelwood case is a good template for any mine-regeneration case study you prepare: what was taken out, what went wrong, who is responsible for the put-back, and what the land will become.

5. Desalination: fresh water without rain (VC2S8U09.E05)

Energy is not the only resource with a benefit-and-risk story. Water is another. Melbourne's water has long come from rainfall filling reservoirs — which means supply depends on the weather. During the long drought of the 2000s, that dependence looked risky, and Victoria built a second source that does not care whether it rains: a **desalination plant**, which makes fresh water from seawater.

The **Victorian Desalination Project** sits at Dalyston on the Bass Coast, near Wonthaggi. It was completed in **December 2012**, and its first water entered Melbourne's supply in March 2017 through Cardinia Reservoir [S6]. Its key numbers [S6]:

- It can make up to **150 GL** of drinking water a year — about **one-third of the water Melbourne uses in a year** — with the ability to expand to 200 GL. (1 GL, one gigalitre, is one billion litres.)
- It can run at about **410 ML** per day. (1 ML, one megalitre, is one million litres.)
- To make that fresh water, it draws about **480 billion litres** of seawater a year through an intake **more than 1 km offshore**, and returns about **280 billion litres** of concentrated saltwater — **brine** — to the ocean.
- Running at full output needs about **90 MW** of electricity — a large, steady demand.



The Victorian Desalination Project, Dalyston (near Wonthaggi): fresh water without rain — completed December 2012.

Process diagram of a desalination plant, drawn as a cross-section from left to right. Left: the ocean, with an intake pipe reaching more than 1 km offshore, labelled seawater drawn in — about 480 billion litres per year. The pipe leads to a box labelled pretreatment — filters remove sand and organisms. Then a box labelled reverse osmosis — seawater is pushed under pressure through membranes with holes too small for salt; two arrows leave it. The upper arrow, *labelled fresh water — up to 150 GL per year, about one-third of Melbourne's demand, runs to a city skyline. The lower arrow, labelled concentrated brine — about 280 billion litres per year returned to the ocean, runs back to the sea. A small box above reads: running at full output needs about 90 MW of electricity.*

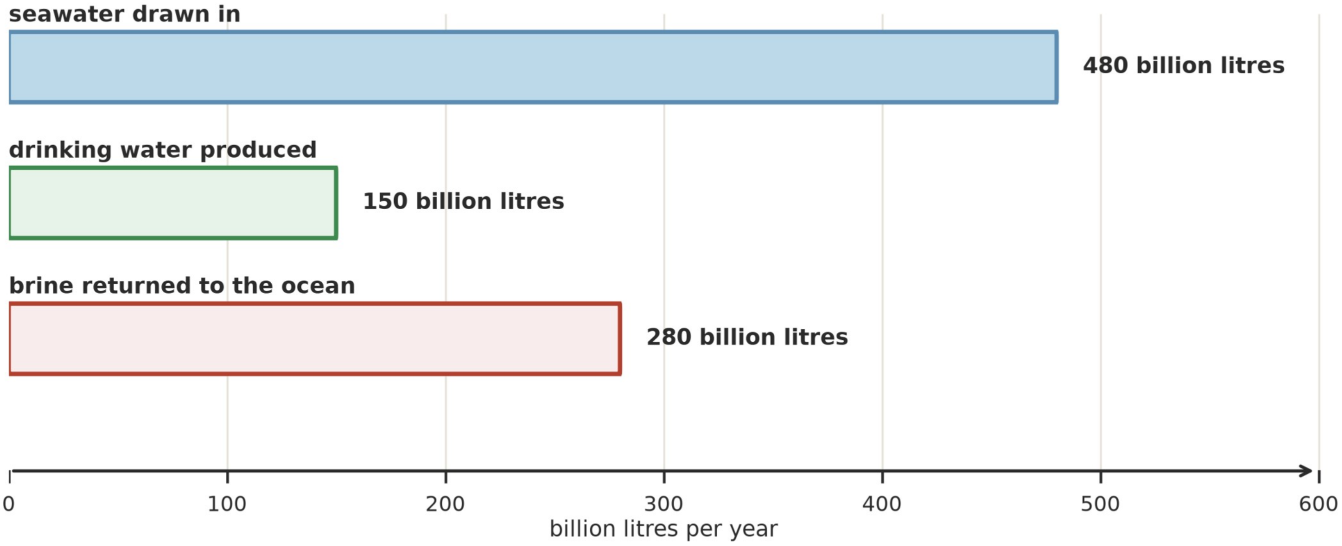
How it works. The heart of the plant is **reverse osmosis**. Seawater is pushed, under pressure, through **membranes** — sheets of material with holes small enough to let water through but too small for salt. Fresh water comes through one side; salt stays behind. What is left is water with even more salt than seawater: the brine.

The benefit. A source of drinking water that does not depend on rain. In a dry year, when reservoirs fall, the plant can keep supplying about one-third of the city [S6]. For a city that remembers the drought, that security is the whole point.

The risks — to the marine ecosystem at the plant site. This is what `VC2S8U09.E05` asks you to examine [S6].

- **The intake.** Drawing 480 billion litres of seawater a year through an intake means small marine organisms — eggs, larvae and small creatures — can be drawn in with the water.
- **The brine.** The returned water is saltier and denser than normal seawater. If it did not mix with the ocean quickly, it could sink along the sea floor and stress seagrass, kelp and the animals that live there.
- **The energy.** Running the plant at about 90 MW means its benefits come with a large electricity demand — which carries the benefits and risks of whatever generates that electricity.

The plant's environmental effects report predicted some impacts on protected species but no major worsening [S6], and the plant's design — an offshore intake, and an outlet that mixes the brine into moving ocean water — is how those risks are managed. Monitoring continues. The honest summary is: **the plant solves one problem (rainfall-dependent water) and creates others (intake, brine, energy), and the design and the monitoring are how Victoria keeps the second set small.**



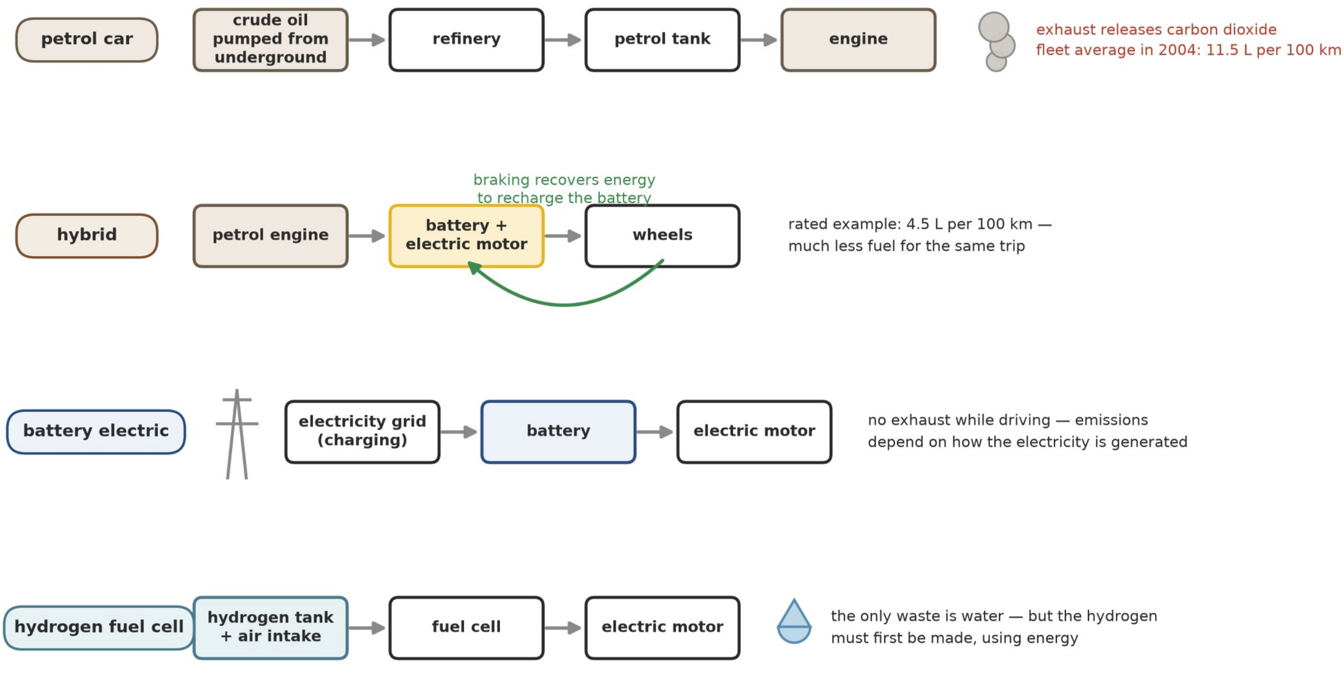
For every litre of drinking water made, about 1.9 litres of concentrated brine go back to sea — Worked example 2 shows where that number comes from.

Two-bar comparison drawn as horizontal bars to scale. Top bar, labelled seawater drawn in — about 480 billion litres per year, is drawn full width. Middle bar, labelled drinking water produced — up to 150 billion litres per year, is drawn about one-third of full width. Bottom bar, labelled brine returned to the ocean — about 280 billion litres per year, is drawn a little more than half of full width. A note reads: for every litre of drinking water made, about 1.9 litres of concentrated brine go back to sea — Worked example 2 shows where that number comes from.

6. The vehicle fleet: responses to the depletion of fossil fuels (VC2S8U09.E06)

The last context is transport. Almost all of Australia's cars, trucks and buses still burn petrol or diesel — **fossil fuels**, which are non-renewable (13C) and whose burning releases carbon dioxide. Two problems push the change: the fuels are being **depleted** — used up faster than they can ever be replaced — and burning them changes the climate. Contemporary science has produced four responses, and each one is a weighing of its own.

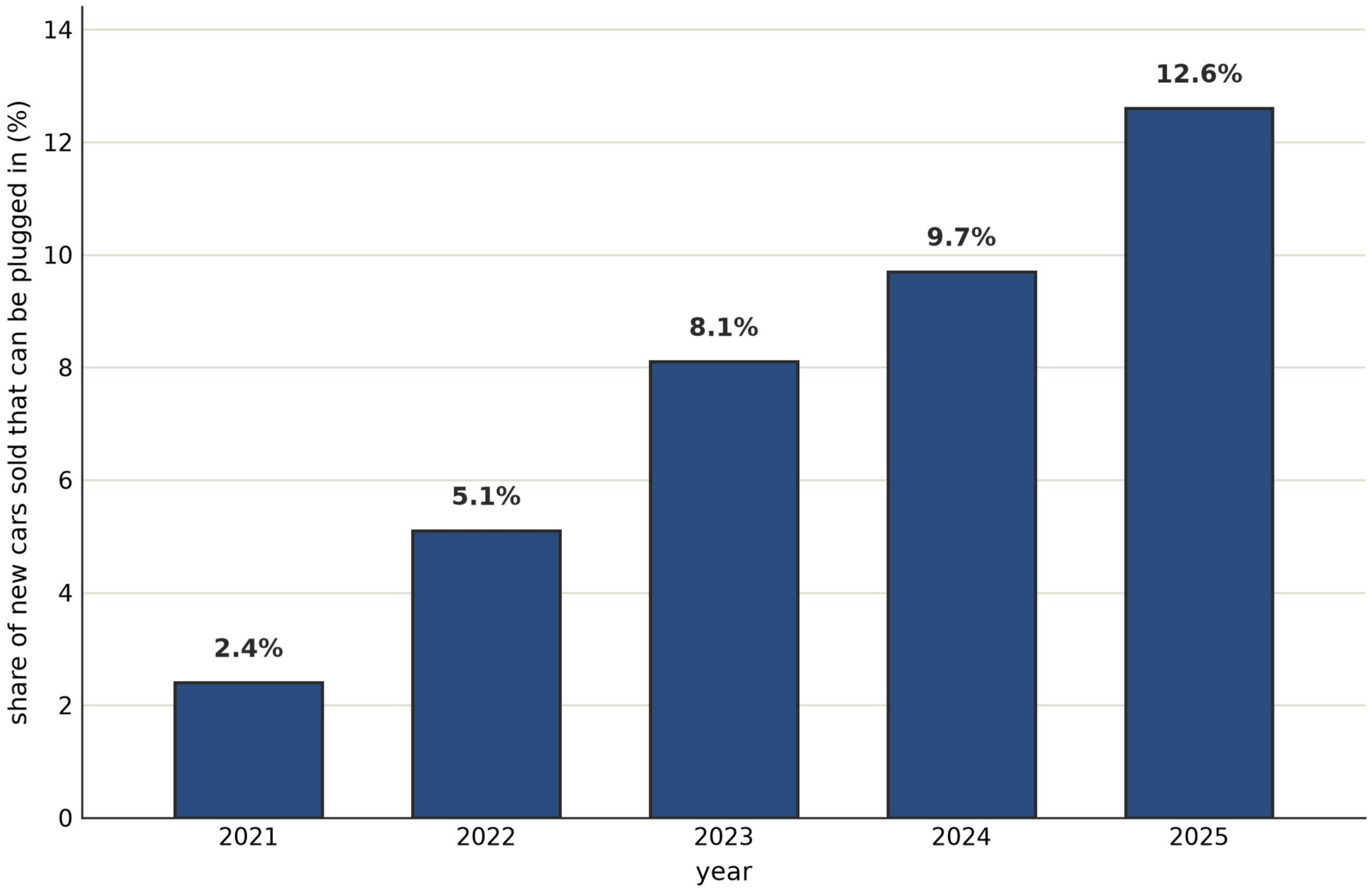
- **Hybrid vehicles** carry a petrol engine **and** a battery with an electric motor. The two work together: the electric motor helps at low speeds, and the car recovers some energy every time it slows, using it to recharge the battery. Benefit: much less fuel for the same trip. Risk or limit: it still burns petrol, so the problem is reduced, not removed. A Toyota Corolla hybrid is rated at **4.5 L/100 km** [S11] — compare the Australian car fleet average in 2004 of **11.5 L/100 km** [S10]. Worked example 1 does the arithmetic of what that saves.
- **Battery electric vehicles** have no engine at all: electricity from the grid charges a battery, and the battery drives an electric motor. Benefit: no exhaust gases while driving, and lower running cost per kilometre. Risk or limit: the electricity has to be generated somewhere — if it comes from coal, some of the emissions have moved, not disappeared — and making the battery takes minerals and energy.
- **Hydrogen-powered vehicles** carry hydrogen gas. In a **fuel cell**, the hydrogen combines with oxygen from the air, releasing energy as electricity to drive the motor; the only waste is water. Benefit: no exhaust gases, and refuelling is quick. Risk or limit: hydrogen is not found free in useful amounts — it must be made, using energy, so its cleanness depends on how it was made.
- **Solar-powered vehicles** use solar panels to make electricity from sunlight. Panels on the vehicle itself can add some charge; more often, rooftop panels at home charge an electric car with sunlight. Benefit: fuel from sunlight. Risk or limit: the amount of sunlight a car's surface can catch is small, so solar alone cannot power a whole fleet — it works as a helper.



Four contemporary responses to the depletion of fossil fuels (VC2S8U09.E06) — each is an energy chain with its own weighing.

Four energy chains in horizontal rows, one per vehicle type, each chain read left to right. Row 1, petrol car: crude oil pumped from underground, arrow to refinery, arrow to petrol tank, arrow to engine — with a tag below reading exhaust releases carbon dioxide; fleet average in 2004 was 11.5 L per 100 km. Row 2, hybrid: the same petrol chain plus a battery-and-motor box joined to the engine, with a loop arrow from the wheels back to the battery labelled braking recovers energy to recharge the battery; rated example 4.5 L per 100 km. Row 3, battery electric: power grid arrow to battery arrow to motor; tag reads no exhaust while driving — emissions depend on how the electricity is generated. Row 4, hydrogen fuel cell: hydrogen tank and air intake arrow to fuel cell arrow to motor; tag reads the only waste is water — but the hydrogen must first be made, using energy.

The change is visible in the sales figures. The share of new cars sold in Australia that can be plugged in — battery electric or plug-in hybrid — rose from **2.4% in 2021** to **8.1% in 2023** and **12.6% in 2025** [S13].



A growing share of new cars can be plugged in — the fleet is changing.
Battery electric and plug-in hybrid sales, Australia. Source: Wikipedia, “Electric vehicle use by country”, 2026, retrieved 2026-08-21.

Bar chart of five bars on labelled axes. Horizontal axis: year, with bars at 2021, 2022, 2023, 2024 and 2025. Vertical axis: share of new cars sold in Australia that were plug-in vehicles, in per cent, from 0 to 14. Bar heights, in per cent: 2021 is 2.4, 2022 is 5.1, 2023 is 8.1, 2024 is 9.7, 2025 is 12.6. The bars rise steadily. A footer line reads: a growing share of new cars can be plugged in — the fleet is changing. Source line: Wikipedia, Electric vehicle use by country, 2026.

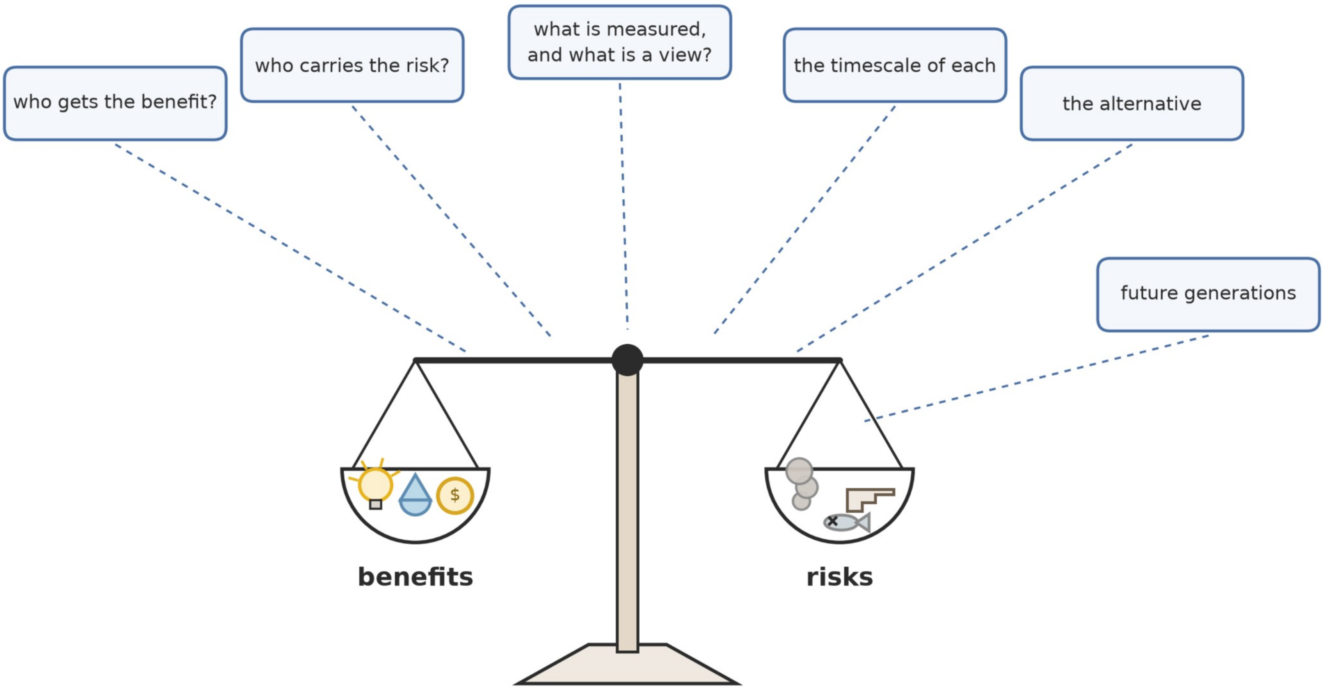
7. How to weigh — the method this subtopic uses

The content description says the processes *“come with both benefits and risks to sustainability”* — it does not tell you the answer to any particular weighing, and neither does this book. Different people, reasoning well from the same facts, can reach different conclusions. That is not a flaw in the topic; it is the topic. Marks in the questions below are awarded for the **quality of the reasoning**, not for the conclusion reached.

Use this checklist every time:

1. **Name the benefits** — what do we get, and who gets it?
2. **Name the risks** — what could go wrong, how serious would it be, how likely, and who carries it?
3. **Separate the measurable from the view-dependent.** Litres, dollars and kilograms are measured; views about landscape and fairness are views — report both, and say which is which.
4. **Check the timescale.** A benefit now and a risk in thirty years are still a benefit and a risk (Hazelwood).
5. **Ask about the alternative.** Every “no” to one option is a “yes” to another — doing nothing is itself an option with benefits and risks.
6. **Decide what “sustainable use” requires** — using the 1987 definition: are future generations left able to meet their needs?

The full treatment of socio-scientific issues like these — ethical, environmental, social and economic considerations, argued well — is the business of **18A**. What you build here is the habit: both sides at full strength, evidence cited, timescales named.



The weighing is the skill — the same facts can support different conclusions when reasoned well.

A pair of balance scales at the centre. The left pan is labelled benefits and holds small icons: a light bulb for power, a water drop, a coin for jobs and money. The right pan is labelled risks and holds small icons: a smoke plume, a dead-fish symbol for marine impacts, a landscape scar. Around the scales, six small labels point in: who gets the benefit; who carries the risk; what is measured and what is a view; the timescale of each; the alternative; and future generations. A footer line reads: the weighing is the skill — the same facts can support different conclusions when reasoned well.

Activity — build an infographic (VC2S8U09.E03)

Choose **one** way of producing energy or obtaining a resource from this subtopic — coal, gas, wind, solar, hydro, a mined mineral, desalination, or one of the new vehicle types. Make a one-page **infographic** — a visual summary that teaches its topic at a glance — that illustrates its benefits **and** its risks.

Plan it like this:

1. **Title and definition** — name your source and say in one sentence what it is.
2. **Benefits** — at least two, each with a fact, figure or named example from this subtopic (with its source).
3. **Risks** — at least two, same standard of evidence.
4. **One worked number** — a rate or comparison calculated from the data here (Worked examples 1–3 show the style).
5. **A one-line weighing** — your bottom line, phrased so someone who disagrees with you would still call it fair.

Choose your format for your audience and purpose — that is the skill 6B teaches (choosing the format for the purpose and the audience). A good test: could a student who missed this subtopic read your infographic and pass a short quiz on it?

Worked examples

Example 1 — scaffolded

The average fuel use of Australia's car fleet in 2004 was **11.5 L per 100 km** [S10]. A car of that kind travels **15 000 km** in a year. (a) How many litres of petrol does it use in the year? (b) If the car is replaced by a hybrid rated at **4.5 L per 100 km** [S11], how many litres are saved in the year? (c) Burning one litre of petrol releases about **2.3 kg** of carbon dioxide [S12]. About how many kilograms of carbon dioxide are avoided in the year?

Working	Comment
(a) Fuel rate = 11.5 L per 100 km. Number of "100 km blocks" in 15 000 km: 15 000 ÷ 100 = 150.	A rate in L/100 km means you count the 100 km blocks first.
Fuel used = 150 × 11.5 = **1 725 L**.	Multiply blocks by litres per block.
(b) Hybrid: fuel used = 150 × 4.5 = **675 L**.	Same distance, lower rate.
Saved = 1 725 − 675 = **1 050 L per year**.	The saving is the difference.
(c) CO_2 avoided = 1 050 × 2.3 = **2 415 kg**, about **2 400 kg** per year.	Rounded to two significant figures, since 2.3 kg has two.

Example 2 — scaffolded

The Victorian Desalination Project can make up to **150 GL** of drinking water a year [S6]. (1 GL = one billion litres = 1 000 ML.) (a) Show that the output of a full year works out at about **410 ML per day**, matching the plant's stated daily figure. (b) The plant returns about **280 billion litres** of brine a year [S6]. For every 1 litre of drinking water made, about how many litres of brine go back to sea? Round to one decimal place.

Working	Comment
(a) 150 GL = 150 × 1 000 ML = 150 000 ML per year.	Convert GL to ML first (×1 000).
Per day: 150 000 ÷ 365 = 410.958… ≈ **411 ML per day**, i.e. about **410 ML per day**.	Divide by the days in a year; round to match the stated figure.
(b) Brine per litre of fresh water = 280 ÷ 150 = 1.866…	Both figures are in billions of litres, so the units cancel — the answer is a plain number.
≈ **1.9 L of brine per litre of drinking water** (one decimal place).	A rate comparing two volumes — the same idea as L per 100 km.

Example 3 — unscaffolded

In 2022, Australia's main electricity grid generated **208.4 TWh**, broken down as follows [S1]: black coal 89.5 TWh, brown coal 32.0 TWh, gas 13.2 TWh, hydro 16.6 TWh, wind 25.9 TWh, solar 30.1 TWh, and other sources 1.1 TWh. (a) How much came from coal altogether? (b) How much came from renewable sources (hydro, wind and solar) altogether? (c) How much more did renewables generate than gas?

Model answer. (a) Coal = black coal + brown coal = 89.5 + 32.0 = **121.5 TWh**. (Check against the share in the table: coal supplied 58.3% of 208.4 TWh, and 0.583 × 208.4 = 121.497… ≈ 121.5 TWh — the two agree.) (b) Renewables = hydro + wind + solar = 16.6 + 25.9 + 30.1 = **72.6 TWh**. (c) More than gas: 72.6 − 13.2 = **59.4 TWh**.

Example 4 — unscaffolded

A coastal town is short of drinking water in dry years. Two proposals are on the table: **Proposal A** — a small desalination plant like the Victorian Desalination Project; **Proposal B** — a new dam on a nearby river, filled in wet years. Weigh the two proposals using the checklist from section 7, and give a reasoned recommendation. (There is no single correct conclusion — the marks are for the weighing.)

Model answer. *Benefits:* Proposal A supplies water that does not depend on rain — exactly the benefit Victoria built its plant for, worth about one-third of Melbourne's demand at full output [S6]. Proposal B stores water in wet years for use in dry years, and hydro-style storage can last a long time. *Risks:* Proposal A draws seawater through an intake (small organisms can be drawn in) and returns concentrated brine to the ocean, and it needs a large, steady electricity supply — at the Victorian plant, about 90 MW at full output [S6]. Proposal B floods a valley, changes the river ecosystem downstream, and in drought may simply be empty — the risk it is meant to manage. *Timescale:* both are built once and run for decades; the dam's risk arrives on the day it fills, the desalination plant's risks arrive every day it runs. *Alternatives:* doing nothing leaves the town dependent on rain — itself a risk. *Recommendation (one defensible line):* if the town is on the coast and dry years are its main problem, Proposal A's rain-independent supply outweighs its managed marine risks, provided the intake and brine outlet are designed and monitored as in the Victorian case [S6]. A student who recommends Proposal B — reasoning that a dam avoids daily energy demand and marine impacts, and serves a town with a suitable river — is equally creditable if the reasoning covers both sides.

Practice questions

Scaffolded

Q1. Define each term as it is used in this subtopic: (a) benefit; (b) risk; (c) sustainable use (name the definition used here and its source); (d) rehabilitation.

Q2. Use the National Electricity Market table from section 1 (2022 figures [S1]). (a) Which single source generated the most electricity? (b) Calculate the total generation from coal (black and brown together). (c) Calculate the total generation from renewable sources (hydro, wind and solar). (d) How much more did renewables generate than gas?

Q3. Match each statement to the energy source it most strongly describes: coal, gas, wind, solar, hydro. (a) Can start and stop quickly to fill gaps when wind and solar drop, but is still a fossil fuel. (b) Can store water and release it when needed, but changes the river ecosystem. (c) Makes no emissions while generating, but its output varies with the weather and its towers are large and visible. (d) Runs day and night in any weather, but releases carbon dioxide and leaves ash behind. (e) Can go on existing roofs, but makes no power at night.

Q4. The Hazelwood case study (section 4) is a mine-regeneration case study in miniature [S2]. (a) State one benefit the Hazelwood station provided while it ran. (b) State what happened on 9 February 2014. (c) State two figures from the case study that show the scale of the put-back after closure. (d) Why is rehabilitation planned before mining starts, rather than after it ends?

Q5. The Victorian Desalination Project [S6]. (a) State the problem the plant was built to solve. (b) State two risks to the marine ecosystem at the plant site. (c) The plant can make up to 150 GL of drinking water a year. About how many megalitres is that per day? (1 GL = 1 000 ML; use 365 days.) (d) If 150 GL is about one-third of what Melbourne uses in a year, about how much water does the city use in a whole year?

Q6. Put these rehabilitation steps in the order they would usually happen, starting from the planning stage: spreading saved topsoil and replanting; planning how the land will be put back; back-filling worked-out pits with waste rock and reshaping the land; monitoring the recovering site; treating contaminated water.

Unscaffolded

Q7. A family drives **12 000 km** a year in a car that uses **9.0 L per 100 km**. They replace it with a hybrid that uses **4.5 L per 100 km**. Fuel costs **$1.90 per litre**. (a) Calculate the fuel used per year by each car. (b) Calculate the money saved per year. (c) Calculate the kilograms of carbon dioxide avoided per year, using 2.3 kg per litre [S12]. *(4 marks)*

Q8. A student claims: *"Renewable energy has no risks — only fossil fuels do."* Evaluate this claim. Your answer should state what is correct in it, give at least one reason it is too broad (using named examples from this subtopic), and restate the claim in a correct form. *(3 marks)*

Q9. Read the extract below, then answer the questions.

> *The Victorian Desalination Project draws about 480 billion litres of seawater a year through an intake more than 1 km offshore, makes up to 150 GL of drinking water, and returns about 280 billion litres of concentrated saltwater to the ocean. Running at full output needs about 90 MW of electricity.* (Compiled from [S6].)

(a) Explain why the intake being more than 1 km offshore matters for the marine ecosystem.
(b) Explain one risk the brine could pose if it did not mix quickly with the ocean water.
(c) The energy demand is itself part of the weighing. Explain why. *(4 marks)*

Q10. Hydrogen-powered vehicles are one of the responses named in `VC2S8U09.E06`. (a) State what a fuel cell does in a hydrogen-powered vehicle, and what the only waste is. (b) State one benefit of hydrogen-powered vehicles. (c) State one challenge, and explain why it matters for the weighing. *(3 marks)*

Q11. Australia is one of the world's leading producers of bauxite, iron ore, gold, rare earth elements and zinc, from over 350 operating mines [S7]. (a) Give two examples of new energy technologies that depend on mined minerals, naming the mineral in each. (b) Explain the tension this creates for someone weighing a proposal for a new mine. *(4 marks)*

Q12. Plan the infographic from the Activity for **wind power**. List the four content pieces you would include (two benefits, two risks — each with the evidence you would print under it), and state one audience decision that would change how you present it. *(3 marks)*

Q13. The share of new cars sold in Australia that can be plugged in rose from **2.4% in 2021** to **12.6% in 2025** [S13]. (a) Describe the trend shown by these figures. (b) Give two reasons, from this subtopic, why the fleet is changing. (c) Give one challenge the change brings. *(3 marks)*

Q14. A student says: *"If an activity has any risk at all, it should not be done."* Evaluate this claim using the method of section 7. Your answer should say what the claim gets right, why it cannot work as a rule (use one named example from this subtopic), and what should be asked instead. *(3 marks)*

Answers

Q1. (a) Anything an activity gives that people have reason to value. (b) The chance that an activity causes harm, combined with how serious that harm would be. (c) Use in the sense of the World Commission on Environment and Development, *Our Common Future* (1987): meeting the needs of the present without compromising the ability of future generations to meet their own needs [S9]. (d) Restoring mined land so it can be used again. **Q2.** (a) Black coal (89.5 TWh). (b) 121.5 TWh. (c) 72.6 TWh. (d) 59.4 TWh. **Q3.** (a) gas; (b) hydro; (c) wind; (d) coal; (e) solar. **Q4.** (a) Up to 1 600 MW of cheap electricity from local coal; jobs. (b) A mine fire began that burned for weeks. (c) Any two: at least $743 million total; about $439 million for mine rehabilitation; about $304 million for demolition and site restoration. (d) So the risks are managed, and the company is committed (with money set aside) before the land is disturbed. **Q5.** (a) Melbourne's water depended on rainfall; in drought, supply was at risk. (b) Any two: small marine organisms drawn into the intake; concentrated brine returned to the ocean; large energy demand. (c) About 410–411 ML per day. (d) About 450 GL. **Q6.** Planning → back-filling and reshaping → treating contaminated water → spreading topsoil and replanting → monitoring. **Q7.** (a) 1 080 L and 540 L; (b) $1 026; (c) 1 242 kg. **Q8.** Correct: renewables make no emissions while generating; fossil fuels release carbon dioxide and carry mining risks. Too broad: renewables have risks of their kind — variability, panel waste, turbine blades striking birds and bats, dams flooding valleys. Corrected: renewable energy has *different and often smaller* risks, not none. **Q9.** (a) Deep, moving ocean water is drawn in rather than shallow coastal water where many organisms live and breed. (b) Saltier, denser water could sit along the sea floor and stress seagrass, kelp and bottom-dwelling animals. (c) About 90 MW must be generated somewhere; the plant's benefit therefore inherits the benefits and risks of that generation. **Q10.** (a) Combines hydrogen with oxygen to release energy as electricity; the only waste is water. (b) No exhaust gases; quick refuelling. (c) Hydrogen must be made using energy — if that energy comes from fossil fuels, the benefit is reduced. **Q11.** (a) For example: copper for electricity wires; iron ore (steel) for wind-turbine towers; nickel and cobalt for batteries; rare earth elements for magnets in motors and generators. (b) The mine disturbs a local place now, while its minerals may serve a cleaner energy system later — both facts must be held at once. **Q12.** Benefits and risks as in the source table, each with its cited evidence; audience decision, for example: younger readers → more pictures, fewer words; council decision-makers → include the worked number and costs. **Q13.** (a) Rising fast — more than fivefold in four years. (b) Any two: depletion of fossil fuels; reducing carbon dioxide emissions; improving technology and choice. (c) Any one: electricity demand rises; batteries need mined minerals; charging must be available. **Q14.** It gets right that risks must be named, not ignored. It cannot work: every option, including doing nothing, carries risk — e.g. Melbourne doing nothing about drought kept a real risk of running short of water. Ask instead: which option's benefits outweigh its managed risks, on the evidence, over the timescale that matters.

Fully-worked solutions

Q1. (a) A **benefit**, as used in this subtopic, is anything an activity gives that people have reason to value — electricity, jobs, water, materials, money. (b) A **risk** is the **chance** that an activity causes harm, combined with **how serious** that harm would be — a very serious but unlikely harm and a minor but constant one are both risks, and a weighing must say which it means. (c) **Sustainable use** is used here in the sense given by the World Commission on Environment and Development, *Our Common Future* (1987): development that *"meets the needs of the present without compromising the ability of future generations to meet their own needs"* [S9]. Other definitions exist; this subtopic is answerable on this one alone. (d) **Rehabilitation** is restoring mined land so it can be used again — back-filling, reshaping, treating water, replacing soil and replanting, or flooding a pit as a lake or wetland (13B).

Q2. (a) **Black coal**, at 89.5 TWh, is the largest single source [S1]. (b) Coal total = black coal + brown coal = 89.5 + 32.0 = **121.5 TWh**. (c) Renewables = hydro + wind + solar = 16.6 + 25.9 + 30.1 = **72.6 TWh**. (d) Renewables − gas = 72.6 − 13.2 = **59.4 TWh** more. *(All figures from the 2022 National Electricity Market table [S1].)*

Q3. (a) **Gas** — quick to start and stop, filling gaps, but still a fossil fuel. (b) **Hydro** — stored water can be released when needed, but the dam changes the river. (c) **Wind** — no emissions while generating; output varies; towers are large and visible. (d) **Coal** — steady in any weather, but releases carbon dioxide and leaves ash. (e) **Solar** — fits on roofs, but no output at night.

Q4. (a) While it ran, Hazelwood generated up to **1 600 MW** of electricity from cheap local brown coal, with jobs for the Latrobe Valley [S2]. (b) On **9 February 2014** a fire began in the open-cut mine and burned until 10 March 2014 — one of the largest, longest-running and most complex fires in Victoria's history; the inquiry found adverse health effects [S2]. (c) Any **two** of: total decommissioning and rehabilitation estimated at **at least $743 million**; about **$439 million** for the mine rehabilitation itself; about **$304 million** for demolishing the plant and restoring the site [S2]. (d) Planning rehabilitation **before** mining starts means the put-back is designed and paid for while the ground is still intact — the risks are managed rather than discovered. A company that must state its rehabilitation plan and set money aside in advance cannot simply walk away from the land it has disturbed [S8].

Q5. (a) Melbourne's water supply depended on rainfall filling reservoirs; the drought of the 2000s showed how risky that dependence was, so Victoria built a source that does not care whether it rains [S6]. (b) Any **two**: small marine organisms can be drawn into the intake with the seawater; concentrated brine is returned to the ocean and could stress sea-floor life if it did not mix; the plant's large energy demand (about 90 MW at full output) [S6]. (c) 150 GL = 150 × 1 000 = 150 000 ML per year; per day: 150 000 ÷ 365 = 410.958… ≈ **411 ML per day** — that is, about **410 ML per day**, matching the plant's stated daily figure [S6]. (d) If 150 GL is one-third, the water Melbourne uses in a year is about 150 × 3 = **450 GL**.

Q6. The usual order is: **(1)** planning how the land will be put back (before mining starts); **(2)** back-filling worked-out pits with waste rock and reshaping the land; **(3)** controlling and treating contaminated water; **(4)** spreading saved topsoil and replanting native vegetation (or flooding the pit as a lake or wetland); **(5)** monitoring the recovering site afterwards (13B) [S8].

Q7. (a) Number of 100 km blocks: 12 000 ÷ 100 = 120. Old car: 120 × 9.0 = **1 080 L** per year. Hybrid: 120 × 4.5 = **540 L** per year. (b) Fuel saved: 1 080 − 540 = 540 L; money saved: 540 × $1.90 = **$1 026** per year. (c) CO_2 avoided: 540 × 2.3 = **1 242 kg** per year. *(Marks: 1 for both fuel figures; 1 for the saved fuel; 1 for the money; 1 for the CO_2.)*

Q8. What is correct: renewable sources make no carbon dioxide *while generating*, and fossil fuels genuinely carry the risks of burning (carbon dioxide, other emissions) and of mining (habitat loss, waste, fires — Hazelwood) [S2] [S8]. **Why it is too broad:** every source has risks of its own kind — wind output varies and its blades can strike birds and bats; solar makes none at night and old panels become waste; hydro dams flood valleys and change rivers [S1]. Saying renewables have *no* risks would also make it impossible to explain why a community might weigh a proposal carefully. **Corrected claim:** renewable energy usually carries *different and often smaller* risks than fossil fuels — not none — and each still has to be weighed. *(1 mark each for the three parts.)*

Q9. (a) An intake more than 1 km offshore draws deep, moving ocean water rather than shallow coastal water, where more organisms feed and breed — so fewer of them are drawn in [S6]. (b) Brine is saltier and denser than seawater; if it did not mix quickly, it could sink and sit along the sea floor, stressing seagrass, kelp and bottom-dwelling animals [S6]. (c) The 90 MW must be generated somewhere. If that electricity comes from coal, part of the desalination plant's benefit is bought with coal's risks; if it comes from wind or solar, the weighing improves. The energy demand means the plant's benefits and risks cannot be judged on the plant alone — they inherit those of whatever generates its power [S6]. *(Marks: 1, 1, 2 — the last for connecting the plant's demand to the source of the electricity.)*

Q10. (a) A **fuel cell** combines hydrogen with oxygen from the air, releasing energy as electricity to drive the motor; the only waste is **water**. (b) Any **one**: no exhaust gases while driving; refuelling is quick. (c) Hydrogen is not found free in useful amounts — it must be **made**, using energy. If that energy comes from fossil fuels, some of the vehicle's benefit is cancelled where the hydrogen is made; if it comes from renewables, the benefit holds. That is why the weighing must include how the hydrogen is made, not only what happens in the car. *(1 mark each.)*

Q11. (a) Any **two**, mineral paired with technology: **copper** — electricity wires; **iron ore** (steel) — wind-turbine towers; **nickel and cobalt** — batteries for electric cars; **rare earth elements** — magnets in some turbine generators and car motors; **bauxite** (aluminium) — solar-panel frames. (b) The tension is that the mine's **risks are local and arrive first** — cleared land, habitat loss, waste, dust and traffic for nearby residents [S8] — while its **benefits are spread widely and arrive through time**, including the minerals a cleaner energy system needs [S7]. An honest weighing holds both at once: neither "the minerals are needed, so the local risks do not count" nor "the local risks are real, so the minerals do not matter" is a complete argument. *(2 marks for two correct mineral–technology pairs; 2 marks for the tension, with both sides named.)*

Q12. Content pieces (each needs its printed evidence): **Benefit 1** — no emissions while generating; **Benefit 2** — land under turbines can still be farmed, as at Macarthur (140 turbines, 420 MW) [S5]; **Risk 1** — output varies with the wind; **Risk 2** — turbines are large and visible, and blades can strike birds and bats. **Audience decision (one):** for younger readers, use more pictures and fewer words and define every unit; for a council deciding a proposal, lead with the worked number and the evidence lines. *(1 mark for two benefits with evidence; 1 mark for two risks with evidence; 1 mark for the audience decision.)*

Q13. (a) The share is **rising**, and fast: from 2.4% to 12.6% in four years — more than five times as high (12.6 ÷ 2.4 = 5.25) [S13]. (b) Any **two**: fossil fuels are being depleted (13C); burning them releases carbon dioxide, and electric and hybrid vehicles avoid exhaust emissions while driving; technology is improving and more models are offered (E06). (c) Any **one**: more electricity is needed to charge the fleet, which inherits the benefits and risks of generation; batteries need mined minerals (nickel, cobalt); charging must be available where people live and travel. *(1 mark each.)*

Q14. What it gets right: risks must be *named and weighed*, never ignored — that is the whole method of section 7. **Why it cannot work as a rule:** every option carries some risk, including doing nothing. Melbourne before the desalination plant depended on rain; doing nothing kept the real risk of running short of water in drought [S6]. If "any risk means no", then no option can ever be chosen — the rule defeats itself. **What to ask instead:** for each option — including doing nothing — what are the benefits and risks, who carries them, on what timescale, and which option's benefits outweigh its *managed* risks, on the evidence, using the 1987 definition of sustainability. *(1 mark each part.)*

Sources

All retrieved 2026-08-21. The DEECA page for the Victorian Desalination Project (deeca.vic.gov.au) and the Victorian Earth Resources Regulation pages (earthresources.vic.gov.au) were attempted as primary sources and returned access errors on retrieval; the plant's facts were verified against S6 instead, in line with house practice for unreachable primary sources.

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- **Elaboration uses:** VCAA, Victorian Curriculum F–10 Version 2.0, Science Levels 7 and 8, elaborations `VC2S8U09.E03`, `VC2S8U09.E04`, `VC2S8U09.E05`, `VC2S8U09.E06`, as recorded in `S:`

`\Files\projects\mcq-system\data\vc2_books\science_7-8.json` (the operative authority file, D15).