Environmental Science Units 3 & 4

Chapter 11 — Managing climate change

Aboriginal and Torres Strait Islander content has been excluded as accuracy cannot be guaranteed, and it is better to be respectful than cover the entire curriculum inaccurately.

Significant effort has been made to ensure this content is legal. Please send any areas of concern to admin@vwx.au with appropriate document/legal references so errors can be verified and changes be made.

Contents

Chapter 11 Managing climate change — 11A Risks and opportunities at a selected region or location

Theory

A dot point with a place in it. Almost every key knowledge statement in this study asks you to learn a concept. This one asks you to learn a concept *somewhere*. The wording is *"the risks and opportunities associated with climate change for humans and ecological systems* ***at a selected region or location****"*, and it then names five specific things to examine: increase in range of exotic species; changes in length of plant growing seasons and animal breeding cycles; phenological changes for plant–pollinator interactions; increasing risks to coastal infrastructure from continuing sea level rise; and reduction in agricultural production due to warmer and drier conditions.

Three consequences follow, and each one is worth marks.

First, a general answer is an incomplete answer. "Sea levels will rise and damage infrastructure" states a global fact. "Mean sea level rise adds to the tide and storm surge that already reach the seawall at Lakes Entrance, and the assets exposed there are a navigable artificial entrance, a fishing fleet berth and a foreshore town built on a sand barrier" states a regional risk. The second answer is what the dot point asks for.

Second, the word **opportunities** is in the dot point and carries marks of its own. The easy failure is to treat the dot point as a list of damages, which answers only half of it. An **opportunity** is a beneficial outcome made possible by the changed climate that can be realised if there is the capacity to act on it. It is not the absence of a risk, it is not the same thing as a response to a risk, and — as you will see — almost every one of them carries a catch.

Third, "for humans **and** ecological systems" is a two-part requirement. A risk to a dairy business and a risk to an alpine frog are different in kind: one is mediated by markets, insurance and infrastructure, the other by physiology, habitat and the timing of other species. Answers that cover only one half of the pair cap out.

What this subtopic does not cover. Keep to your own ground, because the neighbouring dot points are marked separately.

Question	Subtopic that owns it
What are the risks and opportunities here, and for whom?	**11A**
How confident are we in the projections, and how is that confidence expressed?	10D
How do we reduce net greenhouse gas emissions to slow the change?	11B
How do we build resilience to change we cannot now avoid, at this same region?	11C
Whose values, which regulations and what data pull against each other in deciding?	11D

The boundary between 11A and 11B is worth pinning down, because **mitigation** (reducing net emissions to limit the change) and **adaptation** (adjusting to the change that arrives) are routinely confused — the assessors reported it on the 2024 paper and again on the 2025 multiple-choice section. Gippsland is Australia's first declared offshore wind area and hosts a proposed offshore carbon storage project; both are real and both are *mitigation*, so they belong to 11B and are not opportunities under this dot point. The opportunities here arise from the changed climate itself — a longer frost-free window, a new fishery, a wine region shifting varieties — not from the economics of decarbonising.

The selected region: Gippsland, Victoria. This series uses the Gippsland region as the Victorian Government defines it for climate reporting and adaptation planning: the six local government areas of **Bass Coast, Baw Baw, East Gippsland, Latrobe, South Gippsland and Wellington**. It runs from Western Port east to the New South Wales border, and from the alpine Baw Baw Plateau and the Victorian Alps in the north to a long, mostly sandy and highly dynamic coast in the south.

Gippsland was chosen because it puts all five of the dot point's named risks inside one set of boundaries, and because the projections and the adaptation planning for it are published, current and free to reach.

Feature of the region	Why it matters to this dot point
An alpine zone at its northern edge, including the **Baw Baw Plateau** about 120 km east of Melbourne	Species at the top of a mountain cannot move further up. Alpine systems supply the clearest breeding-cycle and range-limit examples in Victoria
A large coastal barrier and lagoon system — the **Gippsland Lakes**, Ramsar-listed in 1982, and the Ninety Mile Beach	Low-lying, already salinising, and carrying towns, roads and a navigable entrance. The sea level rise limb lives here
An eroding open coast in the west, at **Inverloch** and along the Bass Coast	Measured, documented, contested shoreline retreat with public assets in the retreat path
A major dairy and irrigated agriculture zone, including the **Macalister Irrigation District** — about 53,000 ha, the largest irrigation area south of the Great Dividing Range, supplied from Lake Glenmaggie	The agricultural production limb has real water accounting behind it
Cool-climate horticulture and the Gippsland wine zone	Growing-season and pollination examples with a commercial edge
Marine waters at the western end of the strengthening **East Australian Current**	The marine range-shift examples, including one that is now a fishery

The published projections for the region. These are the numbers the risk statements in this subtopic are built on. They come from *Victorian Climate Projections 2019* (VCP19), the state projections produced with CSIRO, and its Gippsland regional report; the sea level rise figure is the planning benchmark set in Victorian policy rather than a projection of the most likely rise. VCP19 is not the newest generation — *Victorian Climate Projections 2024* (VCP24), built on CMIP6 models and the SSP scenarios, now supersedes it — but VCP19 is the generation Gippsland's current adaptation plans were written against, and it publishes locality-level figures VCP24 reports differently. Where a figure below is VCP19, the scenario names are the older RCPs, and they cannot be swapped for SSP labels.

Variable	Observed	Projected for Gippsland
Average temperature	Victoria has warmed by just over 1 °C since 1910, most of it since 1950	Annual daily maximum temperature a median **+1.2 °C (1.0 to 1.8) by the 2030s**, **+2.0 °C (1.5 to 2.9) by the 2050s** and **+4.3 °C (2.9 to 6.0) by the 2090s** under a high-emissions scenario (RCP8.5), against a 1986–2005 baseline. Minimum temperatures rise less: **+1.4 °C (1.4 to 2.0) by the 2050s**
Very hot days	About **6.2 days a year** above 35 °C at Bairnsdale, averaged over 1981–2010	At Bairnsdale, a median **11.1 days a year (6.6 to 17.2)** for 2040–2059 under RCP8.5, and 10.8 (5.9 to 12.5) under RCP4.5
Rainfall	Cool-season, and particularly autumn and spring, rainfall has declined	Continued decline, sharpest in **winter and spring**; small summer increases are possible
Rainfall intensity	Rising	Heavy rainfall events become **more intense**, even where annual totals fall
Drought	Recent decades drier than the long-term average	Increased frequency and duration of extreme drought
Snow	Declining	Continued decline in snowfall and

Variable	Observed	Projected for Gippsland
		maximum snow depth; the snowline rises
Fire weather	Longer, harsher seasons	Continued increase in dangerous fire weather and a longer fire season
Sea level	Global mean sea level has risen through the twentieth and twenty-first centuries	Victorian planning must allow for a rise of **not less than 0.8 m by 2100**

Sources: Victorian Climate Projections 2019 (Clarke et al. 2019) and the Gippsland regional report; Victoria's Climate Science Report 2019; Marine and Coastal Policy 2020 and Clause 13.01-2S of the Victoria Planning Provisions. Retrieved July 2026. **Teacher note:** projections are reissued as new model generations and emissions scenarios are published, and the temperature figures above are the VCP19 generation. For comparison, *Gippsland Climate Projections 2024* gives average annual temperature a median **+1.5 °C (0.9 to 1.8) by 2050** and **+3.2 °C (2.2 to 3.7) by 2090** under its high-emissions scenario **SSP3-7.0**, against the same 1986–2005 baseline. Note the two things that change together: the model generation *and* the scenario names. VCP24 does not run RCP4.5 or RCP8.5 at all, so an SSP figure can never be reported under an RCP label. Note the baseline period as well whenever you quote a temperature change — a rise "of 1.8 °C" means nothing until you say what it is measured from.

One further reading trap sits in the table above. Observed and projected values in a report need not share a baseline period: VCP19's observed count of days above 35 °C is averaged over **1981–2010**, while its projected changes are measured against **1986–2005**. Quote each with the period that belongs to it, and never take a number from one scenario's column as the baseline for another's.

Two habits go with quoting projections. Always name the **scenario**, because a projection is conditional on an emissions pathway and is not a forecast. Always keep the **range**, because the range is the projection; reporting the midpoint alone throws away the information that makes it usable. How that uncertainty is expressed and rated is 10D's work, and you should not spend marks on it here — but you must not misreport it either.

Risk is not the same as a hazard, an impact or a consequence. This is the analytical core of the subtopic, and the distinction is straightforward once you see that risk has three ingredients.

Term	Definition	Gippsland example
Hazard	The physical event or trend with the potential to cause harm	A 0.8 m rise in mean sea level by 2100; a run of days above 35 °C
Exposure	The people, assets, species or systems located where the hazard occurs	The Esplanade and foreshore assets at Lakes Entrance; 53,000 ha of irrigated farmland
Vulnerability	The propensity of what is exposed to be harmed — sensitivity to the hazard, and lack of capacity to cope	A road built at its current level with a 50-year design life; a frog whose entire world is one plateau
Risk	The potential for harm arising from the **interaction** of hazard, exposure and vulnerability, described by its **likelihood** and its **consequence**	*Likely* inundation of low-lying Esplanade assets at Lakes Entrance during storm surge events by mid-century, with consequences for road access, drainage and property
Impact	A change that has actually occurred	33.5 m of shoreline retreat measured at Inverloch since 2012

Three things follow, and each is examinable.

A hazard on its own is not a risk. A one-in-a-century storm surge over open ocean harms nobody. Risk appears only when the hazard meets something exposed and vulnerable, which is why the same hazard produces very different risks at Seaspray and on the Baw Baw Plateau.

Risk can be reduced without touching the hazard. Moving an asset reduces exposure. Raising it reduces vulnerability. Neither changes the sea level. This is why adaptation works at all, and it is 11C's material.

An impact is evidence; a risk is a projection. Do not write a risk statement in the past tense, and do not offer a measured impact when a question asks for a risk. Conversely, if a question asks what has already happened, projections earn nothing.

How to write a risk statement that scores. Assemble four parts, in this order: the hazard with its magnitude and timeframe; what is exposed; why it is vulnerable; and the consequence with a likelihood word. The four-part shape is what turns "sea level rise threatens the coast" into an answer.

> *By 2100, mean sea level along the Gippsland coast is expected to be at least 0.8 m higher than at present (hazard). Roads, drainage, jetties and buildings on the low-lying margins of the Gippsland Lakes are exposed. They are vulnerable because they were designed to today's water levels and cannot be relocated cheaply, and because the lakes are already connected permanently to the sea. The consequence is that flooding that is currently rare becomes frequent, and permanent inundation of the lowest land becomes likely (consequence and likelihood).*

Now take the dot point's five named risks in turn.

1. Increase in range of exotic species. An **exotic species** is a species occurring outside its natural range as a result of human activity. Climate change increases the range of exotic species through several distinct mechanisms, and naming the mechanism is what separates a 3-mark answer from a 1-mark one.

Mechanism	How it works	Gippsland example
Climatic envelope shift	The area that meets a species' temperature and moisture requirements moves poleward and upslope. Ground that was climatically unsuitable becomes suitable	Weeds of pasture and bushland moving to higher elevation in the Strzelecki Ranges and onto the alpine fringe
Improved overwinter survival	Fewer frosts and warmer minimum temperatures raise survival of adults, eggs, nests or seed, so each season starts from a larger population	**European wasp** (*Vespula germanica*) nests surviving mild winters, so colonies begin the season already large
More generations per year	Development rate in ectotherms depends on accumulated warmth, so a longer warm season allows more complete generations (higher **voltinism**)	Insect pests of horticulture completing an extra generation, raising damage and the number of sprays needed
Changed dispersal pathways	Currents, floods and storms carry propagules further and to new places	Strengthening of the **East Australian Current** carrying marine larvae further south along the eastern Victorian coast
Disturbance opening niches	Fire, drought and flood create bare ground and light gaps. Fast-growing, well-dispersed exotics colonise them faster than slow-growing natives, and the natives are simultaneously stressed	**Blackberry** (*Rubus fruticosus* aggregate), a Weed of National Significance, thickening after fire in Gippsland gullies
Grazing pressure released or added	A herbivore's own range expansion adds pressure that favours weeds	**Sambar deer** (*Cervus unicolor*), exotic and expanding through Gippsland and into alpine peatlands

Two refinements matter, and both are easy to get wrong.

Exotic is not the same as range-extending native. The **long-spined sea urchin** (*Centrostephanus rodgersii*) is native to south-eastern Australia. Warming waters and a strengthening East Australian Current have carried its larvae south, and it is now abundant in eastern Victorian waters and has reached Tasmania. Where it reaches high density it grazes kelp to bare rock, creating **urchin barrens** and displacing the algae that abalone and rock lobster depend on. The ecological damage is severe — and the species is not exotic. It is a native undergoing a climate-driven **range extension**. If a question specifies *exotic species*, this is the wrong example; if it asks about range shifts and ecological risk, it is one of the best in the state.

The exotic organism need not be visible. **Amphibian chytrid fungus** (*Batrachochytrium dendrobatidis*) is an introduced pathogen, and its activity is temperature-dependent. Where warming moves the thermal conditions of a mountaintop into or out of the fungus's optimum, the disease risk to the frogs living there changes without any new species arriving.

2. Changes in length of plant growing seasons and animal breeding cycles. The **growing season** is the part of the year in which conditions allow net plant growth. In Gippsland it is bounded at the cold end by temperature and frost, and at the dry end by soil moisture. Two measures do most of the work:

- **Growing degree days (GDD)** — accumulated warmth above a base temperature below which the species does not develop. For each day, GDD = mean daily temperature − base temperature, counted only when positive, then summed. Warming raises the annual GDD total, so a developmental stage that needs a fixed GDD sum is reached earlier in the year.
- **Frost-free period** — the number of days between the last frost of spring and the first of autumn. Warming lengthens it at both ends.

Warming therefore lengthens the temperature-limited part of the growing season. But in a drying region it *shortens* the moisture-limited part, because higher temperatures raise **evapotranspiration** — the water returned to the atmosphere by evaporation and by transpiration through plants — so soil moisture is drawn down faster after each rainfall event. Gippsland is projected to warm in every season while losing winter and spring rainfall, which is exactly the combination that lengthens the season at the cold end and closes it earlier at the dry end.

Where the limit is	Effect of warming	Gippsland consequence
Cold-limited (winter, high elevation)	Season lengthens; growth starts earlier and continues later	Earlier spring pasture growth in South Gippsland and the Strzeleckis; earlier budburst in the Gippsland wine zone
Moisture-limited (late spring to autumn, lowlands)	Season shortens as soil moisture is exhausted earlier	Earlier and longer summer feed gap on dryland dairy pasture
Chill-requiring crops	Winter chill accumulation falls	Reduced or unreliable flowering and fruit set in apples, pears and cherries

Animal breeding cycles respond to cues, and *which* cue an animal uses determines whether warming shifts its breeding. Temperature-cued and rainfall-cued breeders shift; **photoperiod**-cued breeders — those triggered by day length — largely do not, because day length does not change. That difference is the engine of the next limb.

The Gippsland case worth knowing is the **Baw Baw frog** (*Philoria frosti*), endemic to the Baw Baw Plateau and its escarpment and found nowhere else on Earth. It breeds in wet seepages, soaks and moss beds, and its eggs and tadpoles develop in that saturated ground rather than in open water, so the timing and persistence of plateau wetness set its breeding success. It is listed as **critically endangered** on the IUCN Red List **and** under the *Environment Protection and Biodiversity Conservation Act 1999* (Cth) — the Commonwealth transferred it from endangered to critically endangered in 2019 — and it has declined by around 98% since 1985. Check each register separately for each species rather than assuming they agree: for *Burramys parvus*, the mountain pygmy-possum, they do not.

Handle its attribution precisely, because this is where answers go wrong in both directions. Amphibian chytrid fungus is the leading explanation and the highest-ranked current threat in the Commonwealth conservation advice — but the same advice states that the cause of the decline that began in the early 1980s **is unclear**, and that it has not been determined whether the fungus triggered that initial collapse. Climate change is listed as a threat in its own right, with the finding that a warming and drying climate **may be a major factor** in the decline and in the shift in the species'

distribution. Warming and drying also act as an *interacting* stressor: they reduce the duration of saturation in the breeding seepages, they cannot be escaped by moving uphill because the plateau is already the top, and they alter conditions for the pathogen. So the defensible statement has three parts — disease is the leading explanation, climate is implicated as an interacting and possibly major factor, and the trigger of the 1980s decline remains formally unresolved. What is *not* defensible is the flat claim that climate change drove the decline: that concludes causation from co-occurrence, and the statutory assessment does not support it.

3. Phenological changes for plant–pollinator interactions. Phenology is the timing of recurring biological events — budburst, flowering, leaf fall, emergence, migration, breeding. Almost all of these events have shifted earlier in temperate regions as spring temperatures have risen.

The risk is not the shift. The risk is that two interacting species shift by **different amounts**, so an interaction that depended on their overlap is degraded. That is a **phenological mismatch**.

Why partners shift unequally	Consequence
They use different **cues** — a plant may respond to accumulated warmth while an insect responds to soil temperature, or a bird to day length	The shifts differ in size and direction, so the overlap window narrows
They have different **sensitivities** to the same cue — the number of days earlier per degree of warming differs	A small difference compounds over decades into a missed window
The plant's flowering is compressed by heat while the pollinator's emergence is not	Flowering finishes before peak pollinator abundance arrives
Extreme events hit one partner and not the other	A heat spell that aborts flowers, or a wet cold snap that grounds foraging bees, removes overlap in a single season

For a flowering plant that depends on animal **pollination** — the transfer of pollen from anther to stigma — the consequences run in both directions. Reduced pollinator visitation during the receptive window means less pollen transfer, so less fruit and seed set, smaller and more misshapen fruit, and lower seed production for the next generation. For the pollinator, flowers that open before it emerges mean less nectar and pollen at the point in its life cycle when it needs them, so fewer offspring are provisioned and the population entering the next season is smaller. The interaction can decay from both ends at once.

In Gippsland this reaches humans through pollination-dependent horticulture — berries, orchard fruit, vegetable seed crops — which relies on managed **European honey bee** (*Apis mellifera*) hives supplemented by wild native bees, flies, beetles and birds. Two points are worth carrying into an answer. Managed hives give growers a partial buffer, because hives can be moved to match a shifted flowering date in a way that wild pollinators cannot be, but the buffer is limited: hive strength depends on the earlier flowering of other plants, and moving hives cannot manufacture pollinators that failed to emerge. And a diverse pollinator assemblage is itself insurance, because species with different cues are unlikely to all mismatch in the same year — which is why the loss of wild pollinator diversity raises the risk from the mismatch rather than merely adding to it.

4. Increasing risks to coastal infrastructure from continuing sea level rise. Sea level rise has two dominant causes: **thermal expansion**, because seawater expands as it warms, and the addition of water from melting glaciers and ice sheets. Both continue for centuries after emissions stabilise, because the deep ocean and the ice sheets respond slowly — which is why the dot point says *continuing*, and why this risk cannot be removed by mitigation alone within any student's lifetime.

The critical insight is that a rise in **mean sea level** does not act alone. It is a new baseline on which every other water-level process now sits.

Component	What it adds
Mean sea level rise	A permanent increase in the still-water baseline
Astronomical tide	The predictable daily and monthly range, now starting higher
Storm surge	Water piled onshore by low atmospheric pressure and

Component	What it adds
	onshore wind during a storm
Wave setup and run-up	Additional elevation from breaking waves at the shoreline
Catchment flood	Rainfall runoff meeting a raised sea, so floodwater drains more slowly

Because these components add, a modest rise in the baseline produces a large rise in the *frequency* of the combined level exceeding a threshold. A flood level that is currently reached once a century is reached far more often once the baseline lifts, and the increase in frequency is much greater in proportion than the increase in height. This is why Victorian planning policy requires more than a sea level number: Clause 13.01-2S of the Victoria Planning Provisions directs that planning allow for sea level rise of **not less than 0.8 m by 2100** *and* for "the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology". The same clause also requires that land subject to coastal hazard be identified and managed, and that use and development be avoided in areas vulnerable to coastal inundation and erosion — so the benchmark is a floor under a wider hazard test, not a design number standing on its own. Note the single horizon: state planning policy carried a shorter 2040 horizon until **2021**, when it was removed on the reasoning that land-use decisions and buildings outlive it. Everything now answers to 2100.

The words *not less than* do real work. They set a floor, not a ceiling, and the policy expressly allows planning for more. In 2024 the Minister approved a planning scheme amendment for Port Fairy in western Victoria using a **1.2 m by 2100** scenario — the first time a Victorian scheme had gone above the statewide figure — rejecting a panel recommendation to hold at 0.8 m. If you are asked what benchmark applies in Victoria, the accurate answer names the 0.8 m floor, notes that it is a minimum, and can cite that a higher figure has been applied where local evidence supported it.

Sea level rise also produces risks that are not inundation at all.

Process	Mechanism	Gippsland example
Coastal erosion	A higher sea moves wave attack landward and up the beach profile, and a sediment budget in deficit cannot replace what is removed	**Inverloch**: Bass Coast Shire Council reports 33.5 m of shoreline retreat since 2012 at the surf life saving club and 35.6 m near the Surf Parade intersection on Bunurong Road. The Cape to Cape Resilience Plan covers this coast from Cape Paterson to Cape Liptrap
Saline intrusion	Higher sea level pushes salt water further into estuaries, lakes and coastal groundwater	The **Gippsland Lakes** have salinised chronically since an artificial entrance to Bass Strait was cut at Lakes Entrance in **1889**, with a marked decline in *Phragmites australis* reed beds. Sea level rise and larger storm surges will exacerbate that salinisation
Coastal squeeze	Wetlands would migrate landward as the sea rises, but a road, levee or town blocks the retreat path, so the habitat is compressed against the barrier and lost	Saltmarsh and reed bed on the developed margins of the Gippsland Lakes and Corner Inlet
Groundwater and drainage failure	Raised water tables reduce the head available to drain stormwater, and outfalls submerge	Low-lying drainage on the lakes' town margins
Loss of buffer	Dunes and beaches that absorb storm energy are the first thing lost, so the	The Bass Coast dune system

Process	Mechanism	Gippsland example
	assets behind them face the next storm undefended	fronting roads and a caravan park

Two features of infrastructure make this risk distinctive. **Asset lifetimes are long** — a road, bridge, outfall or seawall built now is expected to serve for decades, so a decision made today commits to sea levels not yet reached, and choosing to build to today's levels is itself a decision about risk. And **infrastructure is immobile and networked**: a single inundated road segment removes access to everything beyond it, so the consequence of a local hazard is not local.

5. Reduction in agricultural production due to warmer and drier conditions. Note the causal claim in the dot point — *warmer* and *drier*, and each acts through its own mechanisms.

Mechanism	Process	Gippsland consequence
Higher evapotranspiration	Warmer air holds more moisture and drives faster transpiration, so more water is needed for the same growth	More irrigation water required per tonne of pasture dry matter
Lower soil moisture	Reduced winter and spring rainfall, plus faster drawdown, shortens the moisture-available window	Longer summer–autumn feed gap; more bought-in fodder
Reduced runoff and storage inflow	Runoff falls proportionally more than rainfall, because dry catchments absorb the first rain	Lower and less reliable inflow to Lake Glenmaggie, so lower seasonal allocations to the **Macalister Irrigation District**
Plant heat stress	Above a species' threshold, photosynthesis falls and pollen viability drops; heat during flowering causes yield loss disproportionate to the number of hot days	Perennial ryegrass pasture stalling in summer heat; poor fruit set in a heatwave that coincides with flowering
Shortened grain and fruit filling	Development is faster when warm, so the filling period is shorter and less dry matter is accumulated	Smaller grain and fruit size even where total rainfall is unchanged
Livestock heat stress	Above the thermoneutral zone, cattle reduce feed intake and divert energy to cooling	Measurable falls in milk yield and conception rates during hot spells; higher demand for shade and cooling
Compound and extreme events	Drought, heatwave, fire and post-fire flood arriving together, or in sequence, prevent recovery	Consecutive dry years with no rebuilding season between them

Two accuracy points. Falling *annual* rainfall is not the whole story: **when** the rain falls matters more than how much, because a wet summer cannot substitute for the lost spring rain that fills a soil profile and a storage. And more intense heavy rainfall is projected *alongside* drying, which sounds contradictory but is not — a drier region with more intense downpours loses more water to runoff and erosion and stores less of it, so the two projections compound rather than cancel.

The opportunities, and the catch attached to each. This is the half of the dot point that is easiest to leave thin. An honest treatment names the opportunity, the mechanism that creates it, and the condition or trade-off that limits it.

Opportunity	Mechanism	Gippsland example	The catch
Longer frost-free growing season	Fewer frosts and more accumulated warmth at the cold end of the year	Earlier and later pasture growth in cool, wet South Gippsland; a wider planting window	Only realisable where water is available. A longer season without soil moisture is a longer dormant season, not more

Opportunity	Mechanism	Gippsland example	The catch
			production
CO_2 fertilisation	Higher atmospheric CO_2 raises photosynthesis in C3 plants and lets them partly close stomata, improving water-use efficiency	Pasture ryegrass, clover and most crops and trees in the region are C3	The protein and mineral concentration of the tissue falls, so feed and food quality drop even as bulk rises; the gain saturates, is cancelled by heat and water stress, and shifts pasture composition because C4 summer grasses and weeds respond differently
Reduced frost damage	Fewer damaging frost events in spring	Lower frost loss in horticulture and early pasture	Some crops need winter **chill accumulation** to flower and fruit, and fewer cold nights reduce it; fewer frosts also raise overwinter survival of pests and weeds
New varieties and crops become viable	Warmer season sums allow varieties currently grown further north	Gippsland wine zone growers able to ripen later-maturing varieties	Vines and trees are decade-scale investments made against an uncertain future climate; harvests come earlier and more compressed; and a region's price premium is often tied to the style its old climate produced
A range-shifting species becomes a resource	Warming brings a harvestable species into reach	The Victorian sea urchin fishery harvests the range-extending long-spined sea urchin	The fishery exists because kelp is being lost. Harvest is an opportunity only while coupled to reef recovery, and it does not restore what has already gone
Longer warm-weather tourism season	More warm days at beaches, lakes and rivers	Gippsland Lakes and coastal tourism extending either side of summer	Offset by a shorter and less reliable snow season in the Baw Baw alpine area and by more extreme fire days closing parks in peak season
Lower winter heating demand	Fewer cold days	Reduced winter energy use in buildings	Offset, and in Victoria likely more than offset, by rising summer cooling demand and heat-related illness

Three principles hold this together.

An opportunity is conditional, not automatic. Every row above needs capital, water, knowledge, market access or a licence to be realised. Two neighbouring farms facing the identical climate signal will realise different amounts of it, and that difference is **adaptive capacity**, not climate.

Opportunities and risks are usually the same process seen from two positions. Warmer water is an opportunity for an urchin diver and a risk for an abalone diver. A longer growing season is an opportunity for a grower with irrigation and a risk for the neighbour without it. Saying whose position you are reasoning from is part of a complete answer.

Ecological systems do not have opportunities in the human sense. An ecosystem has no preferences and cannot bank a benefit. What happens is that some species gain range or productivity while others lose, changing community composition and function — and where the gaining species is exotic or a high-impact range extender, the "gain" is an ecological risk.

Where students lose marks.

- **Answering globally when the question says *at a selected region*.** Name the place, the asset, the species, the figure. Generic climate impacts earn generic marks.
- **Leaving out opportunities.** They are half the dot point's wording, so an answer that names only damage has answered half the dot point.
- **Confusing hazard with risk.** A hazard is the event; a risk needs exposure, vulnerability, a likelihood and a consequence.
- **Confusing mitigation with adaptation** — a reported error on both the 2024 and the 2025 paper. Reducing emissions is mitigation; adjusting to the change is adaptation; neither is a risk or an opportunity.
- **Calling a range-extending native an exotic species.** The long-spined sea urchin is native to south-eastern Australia.
- **Attributing every decline to climate change.** For the Baw Baw frog, chytrid fungus is the leading explanation and the top-ranked current threat, the trigger of the 1980s collapse is formally unresolved, and climate is an interacting and possibly major factor. Co-occurrence is not causation — in either direction.
- **Treating sea level rise as a still-water problem.** Damage arrives when a raised baseline is combined with tide, surge, waves and catchment flood.
- **Quoting a temperature or sea level change with no baseline, scenario or timeframe.** "+1.8 °C" is not a projection until you state what it is measured from, under which pathway, and by when.
- **Describing a shift in timing as a mismatch.** A mismatch requires two partners shifting *differently*.
- **Assuming a longer growing season means more production.** In a drying region the moisture-limited end closes earlier, and CO_2 fertilisation dilutes quality.

Worked examples

Example 1 — scaffolded

A student researching Gippsland has recorded five statements.

#	Statement
I	Mean sea level along the Victorian coast is expected to be at least 0.8 m higher by 2100
II	About 53,000 ha of irrigated farmland lies in the Macalister Irrigation District
III	Bass Coast Shire Council reports 33.5 m of shoreline retreat at Inverloch since 2012
IV	Dairy sheds and laneways built to current levels cannot be relocated cheaply
V	Warmer coastal water has brought a harvestable urchin population within reach of Victorian divers

a. Classify statements I, II and IV as a hazard, an exposure or a vulnerability. (3 marks)

b. Explain why statement III is an impact rather than a risk. (2 marks)

c. Statement V describes an opportunity. Explain the catch attached to it. (2 marks)

Step 1 — sort by the three ingredients of risk. A hazard is the physical event or trend. Exposure is what sits in its path. Vulnerability is why what is exposed would be harmed.

Step 2 — answer a. I is a **hazard** — a physical trend with the potential to cause harm, quantified and dated. II is an **exposure** — an asset located where the hazard acts. IV is a **vulnerability** — it explains why the exposed asset would be harmed, combining sensitivity (built to today's levels) with a lack of capacity to cope (relocation is not affordable).

Step 3 — answer b. An impact is a change that has already occurred and been measured; a risk is potential harm that has not yet occurred, and it must carry a likelihood. Statement III is a measurement of retreat that has already happened, expressed in metres over a stated period, so it is an impact — it is evidence, not a projection.

Step 4 — answer c. The urchin fishery exists because the long-spined sea urchin is overgrazing kelp and creating barrens, so the same warming that supplies the harvest is destroying the algal habitat that abalone and rock lobster depend on. The opportunity is therefore conditional: it is a genuine benefit only while harvest is coupled to reef recovery, and harvesting urchins does not restore kelp that has already been lost.

Example 2 — scaffolded

Fennimore Berry Farm Pty Ltd grows raspberries in West Gippsland and depends on insect pollination. The grower has kept records for two decades.

Measure	2006–2010 mean	2021–2025 mean
Date of first open flower	2 October	19 September
Peak abundance of the main wild pollinator (day of year)	Day 285	Day 281
Days from last spring frost to first flower	21	34
Marketable fruit per cane (g)	640	578

a. Calculate the change in the number of days between first flower and peak wild pollinator abundance. Day 285 is 12 October and day 281 is 8 October. (2 marks)

b. Explain, using the data, why this is a phenological mismatch and not simply a phenological shift. (3 marks)

c. The grower proposes to explain the fall in marketable fruit entirely by the mismatch. Give one reason this conclusion is not yet justified. (2 marks)

Step 1 — put both events on the same scale. First flower moved from 2 October to 19 September, which is 13 days earlier. Peak pollinator abundance moved from 12 October to 8 October, which is 4 days earlier.

Step 2 — answer a. In the earlier period the gap from first flower to peak pollinator abundance was 2 October to 12 October = 10 days. In the later period it is 19 September to 8 October = 19 days. The gap has increased by **9 days** — which is also the difference between the two shifts, 13 − 4 = 9 days.

Step 3 — answer b. Both events shifted earlier, so a shift alone is not the issue. The plant advanced by 13 days and the pollinator by only 4, so the two partners moved by different amounts and the interval between them widened by 9 days. That unequal movement is what defines a **phenological mismatch**: the plant now begins flowering well before the pollinator reaches peak abundance, so a larger share of the flowering period occurs when few pollinators are foraging, reducing pollen transfer during the receptive window.

Step 4 — answer c. The data are correlational, and other explanations are available and untested. Marketable fruit per cane could have fallen because of heat during flowering or fruit filling, water availability, changed cane management or cultivar, or reduced abundance of the pollinator rather than its timing. The records show an association between a widening gap and a lower yield across two five-year means; they do not isolate pollination as the cause. Attributing the whole 62 g fall to the mismatch concludes causation from an association.

Example 3 — unscaffolded

Hollingcott Coastal Engineering Pty Ltd is advising on the replacement of a public boat ramp, its access road and a stormwater outfall on the low-lying margin of a Gippsland coastal lake. The client asks the consultants to design to present-day water levels, on the grounds that the structures can be rebuilt later if needed.

Explain the risk this creates, and identify the sea level rise allowance that Victorian planning policy requires. (6 marks)

Solution. The risk is created by the mismatch between the design life of the assets and the timeframe over which the hazard grows.

The hazard is a rise in mean sea level of not less than 0.8 m by 2100, which does not act alone. It raises the baseline on which the astronomical tide, storm surge, wave setup and catchment flood all sit, so the combined water level reached in any given storm is higher than it is today. Because these components add, the *frequency* with which a given level is exceeded rises far more steeply than the level itself: a water level currently reached rarely becomes a regular event. The exposure is the ramp, the access road and the outfall. Their vulnerability lies in being fixed in place, being designed to a water level that is already being left behind, and — for the outfall in particular — depending on a head difference to discharge, which a raised receiving water reduces or removes, so stormwater backs up behind it during exactly the events when drainage matters most.

The client's reasoning fails on two counts. Public infrastructure of this kind is built for decades of service, so designing to today's levels commits the asset to conditions that will not persist for most of its life. And "rebuild later" is not the cheap option it sounds like: the asset would be replaced early, under pressure, probably after a damaging event, and the road and outfall are networked — losing the road removes access to everything beyond it, and losing drainage floods land that the ramp does not even touch.

On the allowance, Clause 13.01-2S of the Victoria Planning Provisions, reflecting the Marine and Coastal Policy 2020, directs that planning allow for sea level rise of **not less than 0.8 m by 2100**, and additionally allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology. There is no shorter-horizon allowance to fall back on: state planning policy removed its 2040 planning horizon in 2021, precisely because buildings and land-use decisions outlive it, so 2100 is the horizon this design must answer to. The phrase *not less than* sets a floor rather than a ceiling: the policy permits planning for more, and in 2024 a Victorian planning scheme amendment for Port Fairy was approved using a 1.2 m by 2100 scenario. So 0.8 m is the minimum the consultants must design to, not the answer to what they should design to.

Example 4 — unscaffolded

Two Gippsland businesses describe changes they have observed.

Coldwarren Dairy Pty Ltd, a dryland dairy farm in South Gippsland, reports that spring pasture growth now begins about two weeks earlier than in the 1990s, that its summer feed gap has lengthened, and that blackberry has thickened in its gullies since a fire.

Tregonning Dive Harvest Pty Ltd, based in far East Gippsland, reports that it has moved from abalone to harvesting long-spined sea urchins from reefs where kelp has been lost.

For each business, identify one risk and one opportunity arising from climate change, and state whether the species each has named is exotic. (8 marks)

Solution. Both businesses are describing the same regional climate signal from two positions.

Coldwarren Dairy. The **opportunity** is the earlier start to spring pasture growth. Fewer frosts and more accumulated warmth extend the cold-limited end of the growing season, so the farm can grow feed earlier in the year and reduce the fodder it buys in late winter. The catch is that this opportunity is realisable only while soil moisture lasts, and on a dryland farm it is not purchasable.

The **risk** is the lengthening summer feed gap. Higher temperatures raise evapotranspiration and reduced winter and spring rainfall leaves a drier soil profile, so soil moisture is exhausted earlier and perennial ryegrass pasture stalls sooner and for longer. The consequence is more purchased fodder at the time of year when it is dearest, lower stocking

capacity, and reduced milk production. Note the structure of the change: the season lengthens at the cold end and closes earlier at the dry end, so a longer growing season and less total feed are entirely compatible.

Blackberry (*Rubus fruticosus* aggregate) **is exotic** — introduced from Europe and a Weed of National Significance. Its thickening after fire illustrates the disturbance mechanism: fire opens bare ground and light gaps that a fast-growing, bird-dispersed exotic colonises faster than the slower native species it replaces, and those natives are simultaneously stressed by heat and drought while the blackberry, with deep root reserves and vigorous resprouting, is not.

Tregonning Dive Harvest. The **risk** is the loss of the abalone fishery. Warming water and a strengthening East Australian Current have carried long-spined sea urchin larvae south into eastern Victorian waters, and at high density the urchins graze kelp to bare rock, creating barrens. Abalone depend on that algal habitat for food and shelter, so the business's original resource has been reduced by a climate-driven ecological change it cannot influence.

The **opportunity** is the urchin harvest itself: a species newly abundant in reach of the divers has a market, and harvesting it can also relieve grazing pressure on remaining kelp. The catch is that this opportunity is a symptom of the loss — it exists because the reef has degraded, it is worth calling an opportunity only while it is coupled to reef recovery, and it does not restore kelp already gone.

The long-spined sea urchin (*Centrostephanus rodgersii*) is **not exotic**. It is native to south-eastern Australia and is undergoing a climate-driven range extension. The ecological damage it causes is severe and the distinction still matters: a question about exotic species is not answered by this example, and management of a protected native range extender raises different legal questions from control of an introduced pest.

Practice questions

Scaffolded

Q1. Define the term *risk* as it is used in this area of study. (1 mark)

Q2. Distinguish between a *hazard* and a *risk*, using a Gippsland example. (2 marks)

Q3. Define *phenology* and *phenological mismatch*. (2 marks)

Q4. Complete the table. For each risk named in the study design, identify the main physical driver and whether that risk falls on a human system, an ecological system, or both. (5 marks)

Named risk	Main physical driver	Human, ecological or both
Increase in range of exotic species		
Changes in length of plant growing seasons and animal breeding cycles		
Phenological changes for plant–pollinator interactions		
Increasing risks to coastal infrastructure from continuing sea level rise		
Reduction in agricultural production due to warmer and drier conditions		

Q5. State and explain three mechanisms by which a warming climate increases the range of exotic species. (3 marks)

Q6. At Bairnsdale in East Gippsland, the observed average number of days above 35 °C each year was 6.2 over 1981–2010. For 2040–2059 under a high-emissions scenario the projected median is 11.1 days a year.

a. Calculate the percentage increase. Show your working. (2 marks)

b. State one reason this figure should not be quoted as a prediction. (1 mark)

Q7. The long-spined sea urchin is expanding its range into eastern Victorian waters and is destroying kelp habitat. Explain why it is not an example of an exotic species, and why the distinction matters in an examination answer. (3 marks)

Q8. Explain why a rise in mean sea level of 0.8 m creates a risk to coastal infrastructure that is greater than a 0.8 m rise in still water would suggest. (4 marks)

Q9. Bass Coast Shire Council reports 33.5 m of shoreline retreat at the Inverloch surf life saving club since 2012.

a. Assuming this retreat occurred over 11 years, calculate the mean annual rate of retreat. (1 mark)

b. Explain why the mean annual rate is a poor basis for predicting the position of the shoreline in any individual future year. (2 marks)

Q10. Explain four mechanisms by which warmer and drier conditions reduce agricultural production in Gippsland. (4 marks)

Q11. Elevated atmospheric carbon dioxide raises photosynthesis and water-use efficiency in C3 plants such as perennial ryegrass. Explain why this is described as an opportunity with a catch. (3 marks)

Unscaffolded

Q12. Gippsland hosts Australia's first declared offshore wind area. Explain why this is not an *opportunity* under this dot point, and identify which part of this area of study it belongs to. (2 marks)

Q13. The Baw Baw frog has declined by about 98% since 1985 and lives only on the Baw Baw Plateau and its escarpment. A student writes: *"This shows that climate change has driven the Baw Baw frog to the edge of extinction."* Evaluate this statement. (3 marks)

Q14. Compare a risk that climate change poses to a human system in Gippsland with a risk it poses to an ecological system there. Refer to what is exposed, why it is vulnerable, and what capacity each has to respond. (4 marks)

Q15. Write a complete risk statement for saline intrusion in the Gippsland Lakes. Include the hazard, the exposure, the vulnerability and the consequence with a likelihood. (4 marks)

Q16. Oatmill Ridge Vineyard Pty Ltd grows cool-climate pinot noir in the Gippsland wine zone. Over twenty years the grower has recorded budburst advancing by 11 days and harvest by 16 days, and is considering planting a later-maturing variety currently grown in warmer parts of Victoria.

Identify one risk and one opportunity in this situation, and explain why the decision to replant is difficult. (5 marks)

Q17. Braysmoor Pastoral Pty Ltd farms 400 ha of dryland pasture in West Gippsland. The table shows each season's share of the farm's current annual pasture growth, and the modelled change in that season's growth for the 2050s under a high-emissions scenario, against a 1986–2005 baseline.

Season	Share of current annual growth	Modelled change in seasonal growth
Winter	15%	+14%
Spring	40%	+6%
Summer	20%	−23%
Autumn	25%	−11%

Using the data, explain how the annual growing season can lengthen while total annual production falls, and identify one opportunity and one risk the pattern creates for this business. (6 marks)

Q18. Discuss the risks that continuing sea level rise poses to a low-lying settlement on the Gippsland Lakes. Refer to at least three distinct processes, to what makes infrastructure particularly vulnerable, and to the sea level rise allowance required under Victorian planning policy. (8 marks)

Q19. *"Climate change presents Gippsland with as many opportunities as risks."*

Evaluate this statement. In your answer, analyse at least three of the risks named in the study design at this region, identify at least two genuine opportunities and the conditions on which each depends, and address both human and ecological systems. (10 marks)

Answers

Q1. The potential for harm arising from the interaction of a hazard with exposure and vulnerability, described by its likelihood and its consequence. (1)

Q2. A hazard is the physical event or trend with the potential to cause harm — for example a rise in mean sea level of at least 0.8 m by 2100 (1). A risk requires that hazard to meet something exposed and vulnerable, and carries a likelihood and a consequence — for example the likely inundation of low-lying road and drainage assets on the Gippsland Lakes margin by mid-century (1).

Q3. Phenology is the timing of recurring biological events such as budburst, flowering, emergence, migration or breeding (1). A phenological mismatch occurs when two interacting species shift their timing by different amounts, so the overlap the interaction depended on is reduced (1).

Q4. Exotic species range — warming (with disturbance and changed dispersal); both (1). Growing seasons and breeding cycles — warming, plus reduced rainfall and higher evapotranspiration, acting on temperature- and rainfall-cued organisms; both (1). Plant–pollinator phenology — warming, acting on different cues in each partner; both (1). Coastal infrastructure — sea level rise combined with tide, surge and waves; primarily human, though coastal squeeze also makes it ecological (1). Agricultural production — warming and drying, acting through higher evapotranspiration, lower soil moisture and heat stress; primarily human, though reduced runoff and storage inflow also affect the ecological condition of rivers and wetlands (1).

Q5. Any three, each with its mechanism: climatic envelope shift — the climatically suitable area moves poleward and upslope (1); improved overwinter survival — fewer frosts and warmer minima raise survival of adults, eggs or seed, so each season starts from a larger population (1); more generations per year — ectotherm development depends on accumulated warmth, so a longer warm season allows higher voltinism (1); changed dispersal — strengthening currents, floods and storms carry propagules further (1); disturbance opening niches — fire and drought create bare ground that fast-growing exotics colonise while natives are stressed (1).

Q6. a. (11.1 − 6.2) / 6.2 × 100 = 4.9 / 6.2 × 100 = 79.0%, about a **79% increase** (2 — 1 for working, 1 for the value). **b.** It is a projection conditional on a high-emissions scenario, not a forecast; it also carries a range and a stated baseline period, and quoting the single figure discards both. (1)

Q7. It is native to south-eastern Australia, so it is not occurring outside its natural range as a result of human activity — it is undergoing a climate-driven range extension (1). An exotic species is one introduced beyond its natural range by human activity, which this is not (1). The distinction matters because a question specifying exotic species is not answered by this example, and because managing a protected native raises different legal questions from controlling an introduced pest (1).

Q8. Mean sea level rise raises the baseline on which every other water-level process sits (1). Tide, storm surge, wave setup and catchment flood are all added to that raised baseline (1). Because the components add, the frequency with which a damaging threshold is exceeded rises far more steeply than the height itself, so a level currently rare becomes common (1). Higher water also drives erosion, saline intrusion and drainage failure, which cause damage without any inundation of the asset (1).

Q9. a. 33.5 / 11 = 3.0 m per year (1). **b.** Shoreline retreat is episodic, not steady — most of it occurs during a small number of storm events, with partial recovery between them (1). A mean rate therefore describes the trend over the whole period but predicts no individual year, and it also assumes a constant process when sea level rise and sediment supply are both changing (1).

Q10. Any four: higher evapotranspiration raises water requirement per unit of growth (1); reduced winter and spring rainfall plus faster drawdown lowers soil moisture and shortens the moisture-available window (1); reduced runoff lowers storage inflow and irrigation allocations (1); heat above a plant's threshold reduces photosynthesis and pollen viability, cutting yield disproportionately when it coincides with flowering (1); faster development shortens the grain or fruit filling period so less dry matter accumulates (1); livestock above the thermoneutral zone reduce feed intake, cutting milk yield and conception (1); compound drought, heat, fire and flood events prevent recovery between seasons (1).

Q11. Opportunity — higher CO_2 raises photosynthesis in C3 plants and allows partial stomatal closure, so more growth is achieved per unit of water (1). Catch — the protein and mineral concentration of the tissue falls, so feed and food quality decline even as bulk rises (1). The gain also saturates, is cancelled by heat and water stress, and shifts pasture composition because C4 grasses and weeds respond differently (1).

Q12. Offshore wind reduces net greenhouse gas emissions, so it is a **mitigation** option, not a consequence of the changed climate (1). It belongs to the mitigation dot point, taught in 11B (1).

Q13. The statement claims more than the evidence supports. Amphibian chytrid fungus, an introduced pathogen, is the leading explanation and the top-ranked current threat, and the Commonwealth conservation advice records that the cause of the decline beginning in the early 1980s is unclear (1). Climate change is nonetheless implicated as an interacting and possibly major factor in the decline and distribution shift — a warmer, drier plateau shortens saturation of the breeding seepages, and the species cannot retreat upslope because the plateau is already the top of its range (1). Asserting that climate change *drove* the decline infers causation from an association, which the evidence does not establish (1).

Q14. See fully-worked solutions. Both sides required on all three criteria: exposure, vulnerability, and capacity to respond. (4)

Q15. Hazard — mean sea level at least 0.8 m higher by 2100, with larger storm surges, pushing salt water further through the permanent artificial entrance at Lakes Entrance (1). Exposure — the brackish lake system, its *Phragmites australis* reed beds, saltmarsh, fringing wetlands and the Ramsar values they support, plus coastal groundwater (1). Vulnerability — the lakes have salinised chronically since the entrance was cut in 1889, reed beds have already declined, and wetlands cannot migrate landward where roads and settlements block the retreat path (1). Consequence and likelihood — further loss of reed bed and freshwater-dependent vegetation is likely, with change in the lakes' ecological character and in the fish and bird communities that depend on it (1).

Q16. Risk — earlier and compressed ripening in a warmer season shifts sugar, acid and flavour development out of balance, changing the wine style on which a cool-climate region's price premium depends (2). Opportunity — a warmer season sum makes later-maturing varieties viable, opening new products and markets (1). The decision is difficult because vines are a decade-scale investment made against a projection with a range and a scenario attached, so the grower must commit capital now to a climate that is not yet observed, and replanting forfeits mature vine yield and an established regional identity in the meantime (2).

Q17. See fully-worked solutions. (6)

Q18. See fully-worked solutions. (8)

Q19. See fully-worked solutions. (10)

Fully-worked solutions

Q1. The mark is for the three ingredients plus the two descriptors. "Something bad that might happen" is not enough: risk arises from the *interaction* of hazard, exposure and vulnerability, and it is described by likelihood and consequence. A definition that omits likelihood cannot distinguish a risk from an impact.

Q2. The discriminator is what has to be present. A hazard is purely physical and exists whether or not anything is in its way; a risk requires something exposed, a reason it would be harmed, and a statement of how likely and how bad. A useful check: the same hazard produces very different risks at Seaspray and on the Baw Baw Plateau, which is only possible because exposure and vulnerability differ.

Q3. Two separate definitions. The commonest error is to define mismatch as "timing changing", which is just a phenological shift. A mismatch needs *two* partners and *unequal* movement, and the harm is the loss of overlap, not the change of date.

Q4. Five rows, because the dot point names five risks, and one mark each. The physical driver column must name the process, not restate the risk. Note the coastal infrastructure row: it is primarily a human-system risk, but coastal squeeze — wetland unable to migrate landward because a road or town blocks the retreat path — makes the same hazard an ecological risk as well. The agricultural production row runs the other way: primarily human, but the

reduced runoff behind it is also what strips flow from rivers and wetlands. Answers that assign every row to one system only are missing the dot point's "humans **and** ecological systems" requirement.

Q5. Three mechanisms, one mark each, and each must be a mechanism rather than a restatement of "it gets warmer so they spread". The two that most need spelling out are voltinism — because development in ectotherms depends on accumulated warmth above a base temperature, a longer warm season permits an additional complete generation, which multiplies the population rather than merely extending it — and disturbance, which works by changing the *competitive* balance rather than the climate envelope: fire and drought open bare ground and stress the slow-growing natives at exactly the moment a fast-growing, well-dispersed exotic can occupy it.

Q6. a. Percentage increase uses the change over the original value, not the new value over the old: (11.1 − 6.2) / 6.2 × 100 = 79.0%. Dividing 11.1 by 6.2 gives 1.79 and reporting "179%" confuses a ratio with an increase. **b.** Two acceptable answers: it is conditional on RCP8.5, so it is a projection under a scenario rather than a forecast; or it is a median drawn from a range — 6.6 to 17.2 days for this projection — and quoting one number discards the range that makes it usable. Note also that both figures are annual means for one locality — a projection for Bairnsdale is not a projection for the Baw Baw Plateau — and that the two numbers do not share a period: 6.2 is an observed average for 1981–2010, while the projection is for 2040–2059 against a 1986–2005 baseline. Take the baseline from the same scenario and table as the projection; the low end of a *different* scenario's range is not an observation.

Q7. Work from the definition. Exotic means outside the natural range *as a result of human activity*. *Centrostephanus rodgersii* is native to south-eastern Australia and has moved south under a changed current and warmer water — the movement is human-caused only in the indirect sense that the climate change driving it is. That is a range extension, and the accepted term for such a species is a range extender, not an exotic. The distinction is not pedantry: it changes which dot point the example answers, and it changes the management question, because a native species has legal protections that an introduced pest does not, so "control it" is not automatically available.

Q8. Four marks means four distinct points, and the key one is the frequency argument. Mean sea level rise is a new baseline, and the tide, storm surge, wave setup and catchment flood that already produce damaging water levels are all measured from it. Because these add, lifting the baseline by 0.8 m does not simply make each flood 0.8 m deeper: it converts the water levels that are currently rare into levels reached routinely, and the proportional increase in *frequency* is much larger than the proportional increase in *height*. Victorian planning policy recognises this directly by requiring that the 0.8 m allowance be combined with tides, storm surges, coastal processes and local conditions. The fourth mark is for recognising that inundation is not the only damage pathway: erosion moves wave attack landward, saline intrusion pushes salt water into estuaries and groundwater, and a raised receiving water removes the head that stormwater outfalls need in order to drain.

Q9. a. 33.5 / 11 = 3.045, so about 3.0 m per year. **b.** The mean is a description of the period, not a model of the process. Sandy shorelines retreat episodically: a single storm sequence can remove several metres in days, and the beach may partly rebuild in the following calm years. A constant 3.0 m per year would also assume that sea level, sediment supply and storm climate are unchanging, and none of them is. The practical implication is that a planning decision cannot rely on a linear projection of a mean rate; it needs the distribution of storm events, which is why coastal hazard assessments model event-based scenarios rather than trend lines.

Q10. Four mechanisms, and each must connect the physical change to the production loss. Two distinctions are worth making explicitly. Warmer and drier act through *different* pathways — heat damages the plant and the animal directly, while drying works through the water balance — so an answer built only on "less water" is half an answer. And the timing of rainfall matters more than the total: a wet summer does not substitute for lost spring rain, because spring rain is what fills the soil profile and the storage that carry production through the dry months. The apparent contradiction in the projections — drier overall, but heavier downpours — resolves the same way: more of the rain arrives too fast to infiltrate, so it leaves as runoff and erosion rather than as stored soil water.

Q11. The opportunity is real and is worth stating mechanistically: elevated CO_2 raises the rate of carbon fixation in C3 plants and allows them to achieve the same fixation with stomata less open, which reduces transpiration per unit of growth — genuinely valuable in a drying region. The catch has three parts, and any one earns the third mark. Quality: the extra carbon dilutes nitrogen and minerals, so protein concentration in pasture and grain falls, which matters to a dairy farm because milk production depends on feed quality and not merely on tonnes of dry matter. Saturation and cancellation: the response flattens at higher concentrations and is overridden when heat or water stress is limiting, and heat and water stress are exactly what the same climate change delivers. Composition: C4 species respond much less

to CO_2 than C3 species, so the balance of a mixed pasture and its weed flora shifts, which changes management rather than simply adding growth.

Q12. Two marks, two ideas. First, the classification: offshore wind displaces fossil-fuelled generation and so reduces net emissions, which is mitigation — a response intended to limit the change, not a consequence of the changed climate. Second, the placement: mitigation options are their own dot point, taught in 11B. This dot point deals in risks and opportunities *arising from* the changed climate. Mitigation and adaptation are reliably confused — the assessors reported it on the 2024 paper and again on the 2025 multiple-choice section — and the safe test is to ask whether the thing acts on the *cause* (mitigation) or on the *consequences* (adaptation) — and if it does neither, whether it is a risk or an opportunity at all.

Q13. The statement overreaches on attribution while pointing at something real, and the mark scheme rewards students who say exactly how far the evidence goes. Amphibian chytrid fungus, an introduced pathogen, is the leading explanation and the highest-ranked current threat in the Commonwealth conservation advice — but that advice is careful, and so should the answer be: it records that the cause of the decline beginning in the early 1980s **is unclear**, and that it has not been determined whether the fungus triggered that initial collapse. Climate change is nonetheless a serious *interacting* stressor for this species, and the same advice finds that a warming and drying climate **may be a major factor** in the decline and in the observed shift in distribution. The reasons are specific to it: it breeds in wet seepages and moss beds on a plateau, so its reproductive success depends on how long that ground stays saturated, and a warmer, drier climate shortens that window; and it is an alpine endemic at the top of its own mountain, so the standard escape route of moving upslope does not exist. The reasoning error to name is concluding causation from co-occurrence — the decline happened while the climate warmed, which is not evidence that the warming caused it. Note the symmetry, because it is the harder half of the mark: naming disease as *the* cause of the 1980s collapse overreaches in the same way, and the accurate position is that disease leads, climate is implicated, and the trigger is unresolved.

Q14. *Model response (4 marks).* Take the Macalister Irrigation District as the human system and the Baw Baw Plateau as the ecological one.

What is exposed. In the irrigation district, about 53,000 ha of irrigated farmland, the dairy and fodder businesses on it, and the water entitlements supplied from Lake Glenmaggie. On the plateau, an endemic amphibian, its breeding seepages and the alpine vegetation that holds moisture in them.

Why each is vulnerable. The district is vulnerable because production depends on a seasonal allocation determined by storage inflow, and reduced winter and spring rainfall plus higher evapotranspiration lowers both inflow and the reliability of the allocation, while raising the water needed per tonne of dry matter. The plateau population is vulnerable because it occupies a single small area at the top of a mountain, is already reduced to a fraction of its former abundance with disease the leading explanation, and depends on ground staying saturated through its breeding period.

Capacity to respond. This is the sharpest contrast. The irrigation district has options: modernised delivery, trade in water, changed crops and cultivars, bought-in fodder, shade and cooling for stock, insurance and credit. Its risk is severe and unevenly distributed, but it is manageable, and the damage is mostly financial and reversible. The frog has none of these. It cannot move upslope, its range cannot be enlarged, and it cannot be compensated. Any capacity to respond has to be supplied from outside, through captive breeding and habitat management, and the loss, if it occurs, is irreversible. The general point is that human systems typically have substitutes and can convert a physical loss into a financial one, whereas ecological systems facing a habitat limit often have no substitute at all.

Q15. The four parts must all be present and must all be about salinity, not about inundation generally. The hazard is a higher mean sea level driving salt water further through the permanent artificial entrance and further up the lakes and their tributaries, with larger surges pushing it further still on individual events. The exposure is the lake system's brackish and freshwater-dependent vegetation — the *Phragmites* reed beds in particular — its saltmarsh and fringing wetlands, the Ramsar values they support, and coastal groundwater. The vulnerability has a history: the lakes were a largely fresh-to-brackish system before the entrance was cut in 1889, they have salinised chronically since, and reed beds have already declined markedly, so the system is being pushed further along a change it has been undergoing for well over a century. Wetlands would ordinarily migrate landward as salinity moves, but roads, levees and settlement block the retreat path, which is coastal squeeze. The consequence, stated with a likelihood, is that further loss of reed bed and freshwater-dependent vegetation is likely, changing the lakes' ecological character and the fish and waterbird communities that depend on it.

Q16. The risk and the opportunity are two readings of the same signal, and the third element — why the decision is hard — is where the marks concentrate. Earlier budburst and a 16-day advance in harvest mean the fruit now ripens in warmer conditions, so sugar accumulates faster relative to acid and flavour development, and the resulting wine style drifts away from the cool-climate profile that carries the region's premium. The opportunity is that the same added warmth makes later-maturing varieties viable, which could open new products. The difficulty is structural: a vineyard is a decade-scale capital commitment, the projection the grower must plant against has a scenario and a range attached rather than a single value, and replanting sacrifices the yield of mature vines and an established regional identity during the years before the new planting produces. The grower is being asked to convert an uncertain projection into an irreversible investment — and note that the timing evidence here is observed data, so it can support a claim about what has happened, while the replanting decision necessarily rests on projection.

Q17. *Model response (6 marks).* The two questions in the data are answered by *when* the growth changes occur, and by how much of the year's growth sits in each of those seasons.

The positive changes fall in winter (+14%) and spring (+6%), which are the seasons where pasture growth is limited by temperature. Warming relieves that limit: fewer frosts and more accumulated warmth allow growth to begin earlier and continue later, so the temperature-limited end of the growing season lengthens and produces more. The negative changes fall in summer (−23%) and autumn (−11%), which are the seasons where growth is limited by soil moisture. Here warming makes things worse rather than better, because higher temperatures raise evapotranspiration and draw the soil profile down faster, and reduced winter and spring rainfall means it was filled less in the first place. So the season starts earlier *and* shuts down earlier and harder.

The annual direction then has to be worked out, not assumed, and this is where the share column earns its place. A seasonal percentage change cannot be added to another seasonal percentage change; each must first be weighted by that season's share of annual growth. Winter contributes 0.15 × (+14) = **+2.1** percentage points of the annual total and spring 0.40 × (+6) = **+2.4**, while summer contributes 0.20 × (−23) = **−4.6** and autumn 0.25 × (−11) = **−2.75**. The four sum to **−2.85%**, so total annual production falls by about **3%** even though the period in which some growth occurs has lengthened. Growing-season *length* and growing-season *yield* are different quantities, and this data set separates them.

Two things to notice about that calculation, because both are where marks go. Summer's −23% is the largest *percentage* change, but that alone is not why the annual total falls: spring's far smaller +6% sits on twice summer's share of the year. On a farm with a bigger spring and a smaller summer — 45% and 12%, with winter 20% and autumn 23% — those same four seasonal changes give **+0.2%**, an annual *rise*. Magnitude of change is not magnitude of contribution. And that is the second point: without the share column the annual direction could not be derived from the seasonal percentages at all, because four percentage changes with no weights are consistent with either sign.

The **opportunity** is the winter and early-spring gain. On a dryland farm the late-winter feed gap is expensive, and 14% more winter growth reduces the fodder that must be bought at that time of year. Realising it requires management change — earlier grazing rotations, and pasture species or cultivars that respond to the warmer winter — so it is conditional on the business acting, not automatic.

The **risk** is the summer and autumn loss. A 23% fall in summer growth on 400 ha of dryland pasture lengthens and deepens the summer feed gap, forcing more purchased fodder or reduced stocking, and it arrives at the time of year when fodder is dearest and when heat is simultaneously reducing feed intake and milk yield in the stock. Two further points sharpen the answer: the annual figures conceal a shift in *when* the farm can carry animals, so the risk is to the shape of the production system and not only to its total; and the gains and losses are not interchangeable, because winter growth cannot be stored as standing feed for summer without conserving it as silage or hay, which costs money and requires the surplus to be large enough to cut.

Q18. *Model response (8 marks).* A settlement on the low-lying margin of the Gippsland Lakes faces not one risk from sea level rise but a set of distinct processes, each with a different mechanism, and the infrastructure exposed has features that make it unusually poorly suited to a moving hazard.

Inundation, permanent and episodic. Mean sea level along this coast is expected to be at least 0.8 m higher by 2100. The lowest land is at risk of permanent inundation, but the more immediate risk is episodic: because the raised mean sea level is the baseline on which the astronomical tide, storm surge from low pressure and onshore wind, and wave setup all sit, the combined water level reached during a storm is higher than today's. The components add, so the

frequency with which a damaging threshold is exceeded rises far more steeply than the height does — flooding that is presently rare becomes a regular event, which is a different management problem from a one-off relocation.

Erosion and loss of buffer. A higher sea level moves wave attack landward and up the beach and bank profile. Where the sediment budget is already in deficit, the shoreline retreats, and the dune or bank that absorbs storm energy is the first thing lost — so each subsequent storm reaches further with less resistance. The measured retreat on the Bass Coast at Inverloch, reported at 33.5 m at the surf life saving club since 2012, shows the scale such retreat can reach on a Gippsland coast within a decade.

Saline intrusion and drainage failure. Higher sea level pushes salt water further through the permanent artificial entrance cut at Lakes Entrance in 1889 and further into the lakes, their tributaries and coastal groundwater, adding to a chronic salinisation that has already reduced *Phragmites* reed beds. For the settlement itself the practical failure is drainage: a stormwater outfall discharges on a head difference, and a raised receiving water reduces or removes it, so runoff backs up during precisely the storms when drainage matters most. Rainfall flooding and marine flooding therefore combine, and the projected increase in rainfall intensity makes that coincidence worse.

Coastal squeeze. Saltmarsh and reed bed would ordinarily migrate landward as water levels rise. Where a road, levee or the settlement itself blocks that path, the habitat is compressed against the barrier and lost — so protecting the settlement can extinguish the wetland, which is the ecological limb of the same hazard.

Why infrastructure is particularly vulnerable. Three features. It is **long-lived**: a road, bridge, outfall or seawall is built for decades of service, so a design decision made today commits the asset to sea levels it will meet later in its life, and building to present levels is itself a choice about risk. It is **immobile**: relocation is expensive and often impossible where the settlement is fixed around it. And it is **networked**: a single inundated road segment removes access to everything beyond it, and one failed outfall floods land it does not touch, so the consequence of a local hazard propagates.

The policy allowance. Clause 13.01-2S of the Victoria Planning Provisions, reflecting the Marine and Coastal Policy 2020, requires planning to allow for sea level rise of **not less than 0.8 m by 2100** and to allow for the combined effects of tides, storm surges, coastal processes and local conditions such as topography and geology. There is one planning horizon, not two: the 2040 horizon that state planning policy once carried was removed in 2021, because buildings and land-use decisions outlive it — which is the same argument as the long-lived-asset point above. The phrase *not less than* matters: it is a floor, the policy permits more, and in 2024 a Victorian scheme amendment for Port Fairy was approved using 1.2 m by 2100. What to do about all this — protect, accommodate or retreat — is the adaptation question, and it belongs to 11C.

Q19. *Model response (10 marks).* The statement is false as an accounting claim and useful as a provocation. Gippsland does face genuine opportunities, but they are fewer, smaller, conditional on capacity that not everyone has, and — crucially — they are almost entirely confined to human systems, while the risks fall on human and ecological systems alike. The two sides are not commensurable, and treating them as a balance sheet obscures the reason.

The risks. Take three of the study design's five, at this region.

Reduction in agricultural production due to warmer and drier conditions. Gippsland is projected to warm in every season — annual daily maxima higher by a median 1.2 °C (1.0 to 1.8) by the 2030s and 2.0 °C (1.5 to 2.9) by the 2050s under RCP8.5, against a 1986–2005 baseline — while losing winter and spring rainfall. Higher temperatures raise evapotranspiration, so more water is needed per tonne of dry matter and the soil profile is drawn down faster; reduced cool-season rainfall means it was filled less to begin with; and runoff falls proportionally more than rainfall, so inflow to Lake Glenmaggie and the allocation to the 53,000 ha Macalister Irrigation District become lower and less reliable. Heat adds a separate pathway: above their thresholds, pasture photosynthesis falls and dairy cattle reduce feed intake, cutting milk yield and conception. The consequence is a longer, deeper summer feed gap, more purchased fodder at its dearest, and reduced carrying capacity.

Increasing risks to coastal infrastructure from continuing sea level rise. Mean sea level is expected to be at least 0.8 m higher by 2100, and because tide, storm surge and wave setup are all measured from that raised baseline, water levels that are presently rare become common. On the Gippsland Lakes this means episodic and then permanent inundation of low-lying assets, drainage that cannot discharge against a raised receiving water, and saline intrusion driven further through the artificial entrance cut in 1889 — a system already chronically salinising, with reed beds already reduced.

On the open Bass Coast it means erosion: 33.5 m of retreat at Inverloch since 2012. Infrastructure is particularly exposed because it is long-lived, immobile and networked.

Increase in range of exotic species. Warming shifts climatic envelopes poleward and upslope, raises overwinter survival, permits additional generations in ectotherms, and — with more fire and drought — opens disturbed ground that fast-growing exotics such as blackberry occupy while native competitors are stressed; sambar deer continue to expand through Gippsland and into alpine peatlands. The ecological consequence is displacement of natives and altered community composition; the human consequence is higher control costs and lost production.

Two of the region's ecological risks show a feature no opportunity offsets. The Baw Baw frog, endemic to a single plateau and already reduced by about 98% since 1985 — an introduced pathogen the leading explanation, climate implicated as an interacting factor — is warming and drying at the top of its own mountain: it has no upslope refuge and no substitute habitat. And in the water, a climate-driven range extension by the native long-spined sea urchin is converting eastern Victorian kelp reef to barrens, removing the habitat abalone depend on. These losses are irreversible on any human timescale.

The opportunities. Two are genuine.

A longer cold-limited growing season. Fewer frosts and more accumulated warmth allow pasture growth to begin earlier and continue later, which in cool, wet South Gippsland reduces the expensive late-winter feed gap. The condition is water and management: the gain is confined to the temperature-limited end of the year, it is cancelled at the moisture-limited end, and realising it requires changed grazing rotations and pasture species. Modelled seasonal changes for the 2050s show the pattern plainly — gains in winter and spring, larger losses in summer and autumn — so a longer season and lower annual production are entirely compatible.

A new fishery from a range-shifting species. Warming water has brought harvestable long-spined sea urchins within reach, and a Victorian fishery now takes them. The conditions are severe: the resource exists because the reef is degrading, the opportunity is only defensible while harvest is coupled to reef recovery, and it does not restore lost kelp. It is a salvage opportunity, not a gain.

Two more are real but heavily qualified. Higher CO_2 raises photosynthesis and water-use efficiency in C3 pasture and crops, but dilutes protein and mineral concentration, saturates, is cancelled by heat and water stress, and shifts pasture composition — so it delivers more bulk of poorer feed. And warmer seasons make later-maturing wine varieties viable in the Gippsland zone, but require a decade-scale investment against a projection with a range, and put at risk the cool-climate style the region's premium depends on.

Evaluation. Three asymmetries defeat the statement. First, **conditionality**: every opportunity requires capital, water, knowledge or market access to realise, so adaptive capacity determines who gets it, while the risks arrive regardless — two neighbouring farms facing the same signal will not receive the same benefit. Second, **reversibility**: the human risks are largely financial and, though severe, are substitutable — fodder can be bought, varieties changed, assets raised or moved — whereas an endemic alpine amphibian with no upslope refuge, a Ramsar reed bed squeezed against a road, and a kelp reef converted to barrens are losses with no substitute. Third, **distribution**: opportunities are concentrated in human systems and in the parts of them best resourced to act, while the risks fall across human *and* ecological systems, which is exactly the pairing the study design requires an answer to address.

The defensible position is therefore that Gippsland faces real and specific opportunities that should be identified, quantified and acted on, and that they do not balance the risks — because a benefit that must be purchased is not equivalent to a loss that cannot be undone. What follows from that judgement is the design of mitigation and adaptation responses, which are the next dot points; identifying the risks and opportunities accurately, at this region, is the work this one requires.

Theory

The study design gives this subtopic eleven words: **"mitigation options for reducing net greenhouse emissions to slow climate change"**. Three of them are load-bearing, and almost every mark available in this dot point is won or lost on whether you have read them properly. **Mitigation** fixes *what kind* of response is being asked for. **Net** fixes *what quantity* is being reduced. **Slow** fixes *what the response can honestly claim to achieve*. Work through those three, then the option space, then how an option is judged — that is the whole subtopic.

Where this sits. Chapter 09 built the physics: the energy balance (9A, 9B), the natural-versus-enhanced distinction (9C), warming potential and the CO_2-e currency (9D), and the carbon cycle with its short-term and long-term sequestration bands (9E). Chapter 10 built the measurement and projection machinery. In this chapter, **11A** owns the risks and opportunities at a selected region, **11C** owns adaptation at that region, and **11D** owns the stakeholder, regulatory, data and technology tensions that arise when a society has to choose. This subtopic owns the option space itself, and the test that puts a proposed measure on the mitigation side of the line rather than the adaptation side. Two adjacent boundaries are worth naming now: 9E already established *how long a carbon store holds its carbon*, so that physics is used here and not re-taught; and **13C** owns the specifically energy-sector question of "options for building a sustainable energy future", so the energy options below are treated as members of the wider mitigation set, not surveyed source by source — that is 12A, 12B and 13C's work.

A word with two jobs. In climate science, *mitigation* means reducing net greenhouse gas emissions. In biodiversity and development assessment, the **mitigation hierarchy** taught in 8C means something different — avoid, then minimise, then offset a *biodiversity* impact. Same word, two jobs. A question about mitigation in Unit 4 Area of Study 1 is asking about greenhouse gases; check which sense the stem is in before you answer.

Mitigation, and the test that separates it from adaptation

Mitigation is action that reduces net greenhouse gas emissions, and so acts on the **cause** of climate change. **Adaptation**, which 11C treats in full, is action that reduces harm from climate change that is going to happen anyway, and so acts on the **consequence**. Confusing the two is the most frequently reported error in this part of the study — examiners have flagged it in more than one year — and it is entirely avoidable, because there is a mechanical test.

Test	Question to ask	Mitigation	Adaptation
The atmosphere test	Does the measure change the quantity of greenhouse gas in the atmosphere?	Yes — fewer tonnes go in, or more tonnes come out	No — the atmosphere is unchanged; what changes is the damage it does
The where-does-the-benefit-land test	Who benefits from the measure?	Everyone, everywhere — a tonne avoided at Traralgon has exactly the same effect as a tonne avoided in Toronto	Only the place, asset or population that was adapted
The when test	How soon does the benefit appear?	Decades — the emission must work through concentration, forcing and temperature before an impact changes	Immediately, or at the next event of the kind adapted for

Those three properties are why the two responses are not interchangeable, and why a serious strategy needs both. Mitigation is a **shared, delayed, global** benefit, which makes it easy for any one party to leave to somebody else. Adaptation is a **private, prompt, local** benefit, which makes it easy to fund and easy to prefer. Neither substitutes for the other: adaptation does nothing about the cause, and mitigation does nothing about the warming already committed.

Borderline cases are where the marks are, so work them explicitly.

Measure	Classification	Reasoning
A wind farm displacing brown coal generation	Mitigation	Fewer tonnes of CO_2 enter the atmosphere per megawatt hour delivered
Raising a coastal road above the projected still-water level	Adaptation	The atmosphere is unaffected; exposure of the asset is reduced
Restoring tidal saltmarsh	**Both**	The sediment accumulates carbon (mitigation, via the removal term) *and* the vegetated flat absorbs wave energy and provides habitat refuge (adaptation)
Planting street trees	**Both, for different reasons**	Shade lowers surface and air temperature on hot days (adaptation); the wood is a carbon store (mitigation, small)
Installing air conditioning in a school hall	Adaptation — and possibly counter-productive	It reduces heat harm, but on a fossil-heavy grid it raises emissions, so it worsens the cause while treating the symptom
Breeding a heat-tolerant pasture cultivar	Adaptation	Production is protected under warmer conditions; no emission changes
Injecting reflective aerosol into the stratosphere	**Neither**	It would alter the energy balance without changing net emissions at all, so it is not mitigation; and it treats the global temperature rather than a local exposure, so it is not adaptation either. It is a third category, and it is not in this dot point

The air-conditioning row deserves its own name. A measure that reduces harm from climate change while increasing net emissions, or while shifting harm onto someone else, is **maladaptation**. It is worth a sentence in an evaluation whenever it appears, because a proposal that mixes mitigation and maladaptation can look coherent while pulling in two directions.

"Net" — the emissions ledger

Net greenhouse emissions are what is left after removals are subtracted from emissions:

> **net emissions = gross emissions (sources) − removals (sinks)**

Both terms are measured in **tonnes of carbon dioxide equivalent (t CO_2-e)** or, at national scale, **megatonnes (Mt CO_2-e)** — one megatonne is one million tonnes. The CO_2-e currency and the global warming potential factors that convert each gas into it were established in 9D; use its AR6 values (methane 27.0 non-fossil and 29.8 fossil, nitrous oxide 273, HFC-134a 1 526, all on a 100-year horizon) and always state the horizon, because the same gas has a different number on a different one.

The single word *net* therefore hands you **two levers, not one**:

Lever	What it does to the ledger	Examples
Reduce the source term	Fewer tonnes enter the atmosphere	Efficiency, fuel switching, electrification, process change, leak repair, refrigerant substitution
Increase the removal term	More tonnes leave the atmosphere	Reforestation, soil carbon, blue

Lever	What it does to the ledger	Examples
	and are retained	carbon restoration, biochar, direct air capture with storage

Two consequences follow, and both are examinable.

"Net zero" is not "zero emissions". Net zero is the state in which remaining emissions — the **residual emissions** that cannot yet be eliminated — are balanced by an equal quantity of durable removals. A net zero economy still emits; it just removes as much as it emits. Writing "net zero means we stop emitting" throws away the whole point of the word.

Avoiding an emission is not the same as removing carbon. 9E made this distinction on the physics: sequestration requires carbon actually to *leave* the atmosphere and be retained. So **carbon capture and storage (CCS)**, which intercepts CO_2 in a flue or process stream before it is released and injects it into deep porous rock, is an **avoided emission** — it reduces the source term. **Carbon dioxide removal (CDR)** takes CO_2 that is already in the air, whether biologically or chemically, and stores it — it increases the removal term. Both reduce net emissions; they are not the same entry in the ledger, and a question that asks which term a measure acts on is asking exactly this.

Because the two levers are not equally reliable, mitigation options are ordered. The **abatement hierarchy** — distinct from 8C's biodiversity mitigation hierarchy — runs:

> **avoid** the activity or demand → **improve efficiency** so less energy or material delivers the same service → **substitute** a lower-emission input or process → **sequester** what remains → **offset** only the residual

Offsetting is last for reasons, not by convention. An offset relies on a physical process somewhere else staying intact for decades; it must be bought again every year the emission recurs; and it does nothing to the emitting activity itself, so the emission is still there the day the offset budget is cut.

Reported emissions and net emissions are different quantities. A ledger is drawn around a boundary, and moving an activity across the boundary changes the report without changing the atmosphere. A manufacturer that sells its truck fleet and contracts an external carrier to drive the same routes in the same trucks reports a large fall; global net emissions are unchanged. This is **relocation**, not abatement, and it is the first thing to check when a reported reduction looks too easy. The same logic applies to **leakage** — the term 8D uses for pollution that moves rather than stops — where restraining an activity in one place causes it to expand somewhere else, so the tonnes reappear outside the boundary. The companion test, **additionality**, is the one 7F applies to biodiversity offsets: securing a site that was never going to be cleared creates nothing new, just as crediting abatement that would have happened anyway reduces nothing.

"Slow" — why the study design does not say "stop"

Peak warming is closely proportional to the **cumulative** quantity of CO_2 emitted, not to the rate in any one year. That single fact explains the dot point's verb. Reducing the annual emission rate slows the rate at which the total accumulates; it does not undo the accumulation already there, because CO_2 persists in the atmosphere for centuries to millennia (9E). There is also a chain of lags between an emission and an impact —

> emission → atmospheric concentration → radiative forcing → surface temperature → physical impact

— with the ocean's thermal inertia dominating the last two steps. Warming is therefore **committed** before it is felt, which is precisely why 11C exists: a perfect mitigation strategy starting today still leaves change that has to be adapted to.

The corollary is the most useful piece of physics in this subtopic. **Not all tonnes act on the same timescale.** Methane's atmospheric lifetime is about 11.8 years, against a CO_2-e conversion factor of 27 to 30 on a 100-year horizon (9D). Cut methane emissions and its atmospheric concentration falls within a couple of decades, so the temperature response arrives quickly. Cut CO_2 emissions and the concentration merely stops rising as fast. This is why enteric methane from ruminants, fugitive methane from coal and gas, and landfill methane attract attention out of proportion to their share of the CO_2-e total: they are the fastest available brake. It is not an argument for neglecting CO_2, because CO_2 sets where warming finally settles — but it is the reason "slow climate change" and "reduce net emissions" are the same sentence.

The option space

Sort options by **where in the chain they act**. A list sorted this way is far easier to recall under examination conditions than an alphabet of technologies, and it makes the mechanism obvious — which is what the marks are for.

Where it acts	Mechanism	Options, with the gas and source each engages
Demand	Deliver the same service with less energy or material, so the emission is never created	Building thermal performance (insulation, glazing, draught sealing); industrial energy management; freight load factors and route optimisation; mode shift from road to rail; compact urban form and public transport; reducing food waste (avoids both production emissions and landfill CH_4)
Conversion efficiency	Get more useful output per unit of fuel or electricity	Heat pumps in place of resistive or gas heating; high-efficiency motors and drives; waste-heat recovery; combined heat and power
Supply substitution	Same energy service, lower-emission source	Wind, solar, hydro and other non-combustion generation displacing coal and gas; storage and transmission that let them do so reliably (12B, 13B, 13C own the sources)
End-use electrification	Move an end use off direct combustion onto an electricity supply that is itself decarbonising	Electric vehicles; induction cooking; electric process heat. **Conditional**: the abatement equals the difference between the two, so it grows as grid emissions intensity falls
Agricultural non-CO_2	Suppress the biological processes that make CH_4 and N_2O	Feed additives that inhibit rumen methanogens, including the red seaweed *Asparagopsis* developed from Australian research; herd productivity and turn-off management; nitrification inhibitors and matched fertiliser rate, timing and placement to cut N_2O; anaerobic digestion of effluent with gas capture
Industrial process emissions	Change the chemistry, because these emissions are not from burning fuel	Cement: about 60% of a clinker plant's CO_2 comes from calcining limestone ($CaCO_3 \rightarrow CaO + CO_2$), so fuel switching cannot touch it — clinker substitution with slag or fly ash, and lower-clinker cements, can. Iron and steel: replacing coke as the reductant. Aluminium: suppressing PFC-generating anode effects
Fugitive emissions	Stop gas escaping unburnt	Leak detection and repair on gas networks; capture instead of venting; pre-drainage of coal seam methane; reduced flaring

Where it acts	Mechanism	Options, with the gas and source each engages
Waste	Stop putting degradable carbon where it will decompose anaerobically	Diverting organics to composting or digestion; landfill gas capture. Note that **flaring** captured landfill gas is real mitigation: oxidising CH_4 (GWP-100 27.0) to CO_2 removes almost all of the CO_2-e those molecules carried. Landfill methane is biogenic, so inventory practice does not add the flare's CO_2 to the CO_2-e total; counted as though it were fossil, a tonne of CH_4 yields only 44 ÷ 16 = 2.75 t CO_2 against 27.0 t CO_2-e, still a cut of about 90% (9D)
Synthetic gases	Substitute a lower-GWP working fluid, and stop losing it	Low-GWP refrigerants replacing HFCs; leak-tight design and end-of-life recovery; SF_6-free switchgear
Avoided emissions at the stack	Capture before release	CCS on a process or flue stream — reduces the source term, not a removal
Removals	Take CO_2 out of the air and retain it	Reforestation and revegetation; avoided deforestation; human-induced regeneration; soil carbon; blue carbon restoration; biochar; bioenergy with CCS; direct air capture with storage. Durability is 9E's question, and it decides how much a removal is worth
Enabling instruments	Change the incentive, the rule or the information, so the physical options above actually happen	Carbon pricing and baseline-and-credit schemes; standards and mandates; disclosure; public investment. **These do not abate anything by themselves** — an instrument that no one responds to reduces nothing

That last row is a trap in its own right. "Australia has legislated net zero by 2050" is not a mitigation option; it is a target. "The Safeguard Mechanism requires covered facilities to reduce emissions" is not an option either; it is the pressure that makes a facility choose one. When a question asks for a mitigation option, name the physical change and the gas it engages.

The instruments that operate in Australia and Victoria

Named accurately, because these are the frameworks a Victorian student is expected to know, and because 11D's tensions cannot be discussed without them. Here they are the scaffold; 11D works the conflicts.

Instrument	What it does
Paris Agreement (2015)	Parties submit successive **nationally determined contributions (NDCs)**. Australia's NDC commits to 43% below 2005 levels by 2030 and net zero by 2050; a 2035 target of **62–70% below 2005 levels** was submitted in September 2025
Climate Change Act 2022 **(Cth)**	Legislates the 43%-by-2030 and net-zero-by-2050

Instrument	What it does
	targets, requires an annual climate change statement to Parliament, and requires the Climate Change Authority to advise on targets
***National Greenhouse and Energy Reporting Act 2007* (Cth)**	The measurement and reporting backbone, and the home of the **Safeguard Mechanism**, which covers facilities whose covered **scope 1 (direct) emissions** exceed **100 000 t CO_2-e a year** — purchased electricity is scope 2 and does not count towards the threshold. Reformed from 1 July 2023, it sets each facility a baseline that declines at a default rate of **4.9% each year to 2030**; facilities that go below their baseline can be issued **Safeguard Mechanism Credits**
***Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth)**	The **ACCU Scheme**, administered by the **Clean Energy Regulator**. One **Australian Carbon Credit Unit (ACCU)** represents one tonne of CO_2-e avoided or sequestered. Sequestration projects nominate a permanence period of **25 or 100 years**, with a 20% discount on units issued for the 25-year option — see 9E. The 2022 independent review chaired by Professor Ian Chubb assessed the scheme's integrity and recommended changes
***Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth)**	Implements the **Kigali Amendment** to the Montreal Protocol. Australian HFC imports have been phased down under an annual quota since 1 January 2018, reaching 15% of the baseline — an **85% reduction** — on 1 January 2036
***Climate Action Act 2017* (Vic)**	Originally the *Climate Change Act 2017*, renamed and amended by the *Climate Change and Energy Legislation Amendment (Renewable Energy and Storage Targets) Act 2024* (Vic), which received Royal Assent on 26 March 2024 — older sources cite the former name. Sets **net zero by 2045** and five-yearly interim targets: 28–33% below 2005 by 2025, **45–50% by 2030**, **75–80% by 2035**
Victorian renewable energy, storage and offshore wind targets	Legislated targets of **65% renewable electricity by 2030** and **95% by 2035**; energy storage of at least 2.6 GW by 2030 and 6.3 GW by 2035; offshore wind of at least 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040
***Victorian Energy Efficiency Target Act 2007* (Vic)**	The **Victorian Energy Upgrades** program, administered by the Essential Services Commission. Accredited providers create **Victorian Energy Efficiency Certificates (VEECs)**, each representing one tonne of CO_2-e abated, which energy retailers must surrender against an annual target

Where Australia's abatement task actually sits

Real data, because an option is only worth discussing against the emissions it could engage. 9F treats how and why concentrations have altered; this table is about *where the tonnes are* for a country choosing options.

Australia's net greenhouse gas emissions	Value
Year to December 2025	**458.9 Mt CO_2-e**
Change on the previous year	**−9.7 Mt CO_2-e (−2.1%)**

Australia's net greenhouse gas emissions	Value
Electricity	−5.7 Mt (−3.8%), on record renewables generation displacing coal and gas
Fugitive emissions	−2.5 Mt (−5.2%), partly reduced natural gas venting and new CCS activity
Agriculture	−0.1 Mt (−0.1%): lower grazing cattle and sheep numbers almost exactly offset by increased feedlot cattle and cropping emissions
Transport	The **largest-growing sector** since June 2005: **+19.0 Mt (+23.3%)**

Source: Department of Climate Change, Energy, the Environment and Water, National Greenhouse Gas Inventory Quarterly Update: December 2025. Retrieved 31 July 2026. Teacher note: replace with the most recent quarterly update before use.

Read the pattern, not just the numbers. Electricity fell because a substitute was available, cheap and scalable. Transport rose because activity growth outran efficiency gains, and because until recently no substitute for liquid fuel was available at fleet scale. Agriculture barely moved at all, and the composition of that non-movement is the lesson: fewer grazing cattle and sheep pulled emissions down, more feedlot cattle and cropping pushed them back up, and the two nearly cancelled. There is no substitute for the rumen, so the sector's emissions track livestock numbers and land use rather than the adoption of any abatement measure. Two lessons for evaluation follow. First, **abatement is measured against a counterfactual, not against last year** — the question is always "what would have been emitted without this measure?". Second, an option's value depends on whether a substitute for the emitting activity exists at all; that is why process emissions from cement and steel, and agricultural methane, are called **hard-to-abate**, and why residual emissions are expected to persist even at net zero.

Evaluating and ranking mitigation options

A question that says *evaluate*, *justify*, *compare* or *discuss* wants criteria applied, not a list. Six criteria cover the ground.

Criterion	Question it answers	Unit or form
Abatement potential	How many tonnes, against a stated counterfactual, and cumulatively by when?	t CO_2-e yr^{-1}; t CO_2-e to a date
Cost of abatement	What does each tonne cost, so that unlike options can be compared?	$ per t CO_2-e avoided. Some options are negative-cost — the efficiency saving exceeds the outlay
Time to effect	How long from decision to tonnes?	Months for a feed additive or a leak repair; years for plant; decades for a forest sink to accumulate
Permanence and reversal risk	Will it stay abated?	Removals only. Fire, drought, harvest, land-use change, or seal failure. 9E supplies the physics; the ACCU permanence periods put a legal number on it
Additionality and leakage	Would it have happened anyway, and did the emission simply move?	Offsets and boundary-limited measures. A credit for something already occurring reduces nothing
Co-benefits and trade-offs	What else changes?	Air quality, biodiversity, water, soil, land competition with food production, energy reliability, employment and regional transition

Two of the six deserve emphasis because they are where confident answers separate from adequate ones. **Cost per tonne** is what makes a seaweed feed additive and an offshore wind farm commensurable at all, and it is why the cheapest tonnes are not automatically the first tonnes: the cheapest option is often an offset, and the hierarchy puts offsets last. **Time to effect** matters because the target is cumulative; an option that abates a small amount from next month can beat a larger one that starts in eight years.

Applying the six sustainability principles taught in 3B to mitigation specifically:

Principle	How it bites on a mitigation option
Intergenerational equity	Cumulative emissions are the mechanism by which today's choices bind future generations. Asset lock-in is the concrete form: a plant or vehicle bought today fixes decades of emissions
Intragenerational equity	Who bears the cost now — a household that cannot fund an upgrade, a region whose employment sits in the emitting industry, a country that emitted little and is warming fast
Precautionary principle	Act on serious or irreversible risk without waiting for certainty about the exact damage. It is *not* an instruction to be generally cautious, and it is not cost–benefit analysis
Efficiency of resource use	The demand and efficiency rungs of the abatement hierarchy are this principle in operation — the same service from fewer resources
User pays	The emitter, not the atmosphere or a later generation, bears the cost of abatement. Baseline-and-credit schemes and certificate schemes are attempts to make this operational
Conservation of biodiversity and ecological integrity	Land-based removals compete for land and can be done well or badly: mixed local-provenance revegetation builds habitat, a single-species block plantation may not

Where students lose marks.

- **Answering with adaptation when mitigation was asked**, or the reverse. Apply the atmosphere test in writing: does the measure change what is *in* the air?
- **Naming an option without a mechanism.** "Use renewables" earns little. "Wind generation displaces brown coal, so the CO_2 from combusting that coal is never emitted" earns the mark.
- **Ignoring the removal term.** The dot point says *net*. An answer that never mentions sinks has covered half of it.
- **Treating an offset as equivalent to abatement.** It sits last in the hierarchy, and it depends on another party's project holding for decades.
- **Writing "net zero" as though it means no emissions.**
- **Confusing CCS with carbon dioxide removal.** CCS avoids an emission; CDR removes CO_2 already in the air.
- **Claiming renewables have "no emissions".** The accurate claim is no combustion emissions at generation; construction and materials carry embodied emissions.
- **Linking the ozone hole to global warming.** They are different problems with different mechanisms. HFCs are the honest exception and must be stated precisely: they were introduced *because* they do not deplete ozone, and they are being phased down *because* they are potent greenhouse gases. That is a climate measure carried inside an ozone treaty, not evidence that the two problems are one.
- **Offering solar radiation modification as mitigation.** It changes no emissions.

- **Confusing energy efficiency with emissions intensity.** Efficiency is energy per unit of service; emissions intensity is CO_2-e per unit of energy. A factory can improve one and not the other.
- **Unit slips.** t CO_2-e is not t CO_2; Mt is a million tonnes; a change of 5 percentage points is not a 5% change.

Worked examples

Example 1 — scaffolded

A regional council's draft climate strategy lists four measures.

#	Measure
I	Contracting output from a new 250 MW wind farm that displaces brown coal generation in the Victorian grid
II	Raising the deck of a municipal pier by 0.6 m to allow for projected sea level rise
III	Restoring 40 ha of tidal saltmarsh on a former grazed flat behind a breached levee
IV	Installing evaporative cooling in a community hall for use on heatwave days

a. Classify each measure as mitigation, adaptation, both, or neither. (4 marks)

b. State the test you used, and apply it to measure III. (3 marks)

c. For each measure with a mitigation component, state which term of the net-emissions ledger it changes and name the gas. (3 marks)

Step 1 — set up the test before looking at the measures. Ask of each: does it change the quantity of greenhouse gas in the atmosphere? If yes, it is mitigation. Does it reduce harm from a change that will occur anyway? If yes, it is adaptation. Both answers can be yes.

Step 2 — answer a. I is **mitigation**. II is **adaptation**. III is **both**. IV is **adaptation**.

Step 3 — answer b. The atmosphere test, supported by the where-does-the-benefit-land test. Measure III passes the atmosphere test because waterlogged, largely anoxic saltmarsh sediment accumulates organic carbon and retains it, so CO_2 leaves the atmosphere — a mitigation effect whose benefit is global. It is *also* adaptation, because a vegetated tidal flat dissipates wave energy and provides habitat that can migrate landward, reducing local harm from sea level rise and storm surge — a benefit that lands only on that coast.

Step 4 — answer c. Measure I changes the **source term**: electricity generated without combustion displaces brown coal generation, so the CO_2 that burning that coal would have released is never emitted. Measure III changes the **removal term**: CO_2 is taken from the atmosphere by photosynthesis and retained in sediment. Measure IV has no mitigation component and, on a fossil-heavy grid, works against mitigation, because the electricity it consumes carries CO_2 emissions — it is a candidate for maladaptation.

Example 2 — scaffolded

Ockendale Cement Pty Ltd operates a single clinker plant in western Victoria. Its reported annual greenhouse gas inventory is:

Source	t CO_2-e yr^{-1}
Calcination of limestone in the kiln (process emissions)	210 000
Combustion of kiln fuel	95 000
Purchased electricity	40 000
Site vehicles and transport	15 000
Sequestration by a registered revegetation project on company land	−1 200

Three options are costed:

Option	Description	Abatement (t CO_2-e yr^{-1})	Annual cost
A	Substitute 20% of clinker with blast-furnace slag, cutting process emissions by 20%	42 000	$2 100 000
B	Replace 30% of kiln fuel with a lower-carbon alternative fuel	28 500	$2 280 000
C	Purchase and surrender 42 000 ACCUs	42 000	$1 470 000

a. Calculate the plant's gross and net annual emissions, and state whether the facility is covered by the Safeguard Mechanism. (3 marks)

b. Calculate the cost of abatement per tonne of CO_2-e for each option, and rank them from cheapest to dearest. (3 marks)

c. Explain why the cheapest option per tonne is not the option to implement first. (4 marks)

Step 1 — answer a. Gross emissions are the sum of the sources: 210 000 + 95 000 + 40 000 + 15 000 = **360 000 t CO_2-e**. Net emissions subtract the removal: 360 000 − 1 200 = **358 800 t CO_2-e**. The Safeguard Mechanism test is applied to neither of those totals. It is applied to the facility's covered **scope 1** emissions — the ones released directly on site — and purchased electricity is **scope 2**, emitted at the power station rather than at the plant, so the 40 000 t line is excluded: 210 000 + 95 000 + 15 000 = **320 000 t CO_2-e**. That is well above the 100 000 t CO_2-e threshold, so the facility is covered. The distinction is not academic: a facility with 90 000 t of scope 1 and 40 000 t of purchased electricity has a 130 000 t inventory and is **not** covered.

Step 2 — answer b. Cost per tonne is annual cost divided by annual abatement. Option A: $2 100 000 ÷ 42 000 = **$50.00 per t CO_2-e**. Option B: $2 280 000 ÷ 28 500 = **$80.00 per t CO_2-e**. Option C: $1 470 000 ÷ 42 000 = **$35.00 per t CO_2-e**. Ranking, cheapest first: **C, then A, then B**.

Step 3 — answer c. Four reasons, and they compound. First, the abatement hierarchy puts offsets last: Option C leaves every tonne the plant emits exactly where it was, so the facility's own emissions are unchanged and the plant is no closer to being able to operate at low emissions. Second, C's abatement depends on somebody else's project holding its carbon for the length of its permanence period, and it must be repurchased every year the emission recurs, whereas A eliminates 42 000 t of *process* emissions permanently once the batch is reformulated. Third, the Safeguard Mechanism baseline declines by 4.9% a year to 2030, so the abatement task grows annually; buying an increasing quantity of credits each year carries an escalating and open-ended cost, and exposes the business to the credit price. Fourth, process emissions are hard-to-abate — they come from decomposing limestone, not from burning fuel — so an opportunity to cut them directly is scarce and worth taking while it exists. The correct reading of the ranking is that C is the cheapest *this year*, and A is the cheapest *tonne actually removed from the plant*.

Example 3 — unscaffolded

A generator announces: *"Our new gas-fired peaking plant is a climate mitigation measure, because gas emits about half the carbon dioxide of coal per unit of electricity generated."*

Evaluate this claim. (6 marks)

Solution. The claim contains a true fact and three unstated assumptions, and the assumptions decide whether the fact makes the plant a mitigation measure.

The fact is right: combusting natural gas releases roughly half the CO_2 of black coal per unit of electricity, because more of the energy comes from oxidising hydrogen rather than carbon and because gas turbines convert at higher efficiency. But mitigation is measured against a **counterfactual**, and the claim never states one. If the plant displaces coal generation that would otherwise have run, it abates. If it displaces wind and solar generation, or occupies the role

that storage would have taken, it *increases* emissions relative to what would otherwise have happened. “Half of coal” is a comparison with the wrong alternative unless coal is the alternative.

Second, the claim counts only CO_2 at the stack. The gas supply chain releases **fugitive methane** during extraction, processing and transmission, and methane’s global warming potential is 29.8 on a 100-year horizon and 82.5 on a 20-year horizon for fossil-origin methane (9D). A loss rate of only a few per cent of throughput erodes a substantial part of the advantage, and on the shorter horizon it can erase it. A complete claim must be made in CO_2-e across the supply chain, not in stack CO_2.

Third, the claim is about **intensity**, not **quantity**. Emissions equal intensity multiplied by output. A peaking plant that runs 200 hours a year emits little; the same plant run as mid-merit generation emits a great deal. Half the emissions per megawatt hour is not half the emissions.

Fourth, and most importantly for this dot point, warming responds to **cumulative** emissions. A plant commissioned now has an operating life of decades, so approving it commits a stream of emissions across the period in which the ledger has to reach net zero — **asset lock-in**, and a direct intergenerational equity issue. A measure that lowers emissions relative to the worst available option while adding to the cumulative total is better described as a **lower-emission alternative** than as mitigation.

The defensible version of the claim is conditional: the plant is a mitigation measure to the extent that it demonstrably displaces higher-emitting generation, that its supply-chain methane is measured and controlled, that it runs only as firming capacity, and that its retirement date is consistent with the net zero target. Stated unconditionally, it is not supportable.

Example 4 — unscaffolded

Drayfen Glassworks Pty Ltd melts container glass in a single gas-fired furnace. Its annual inventory is 86 000 t CO_2-e: 61 000 t from furnace gas combustion, 14 000 t from decomposition of carbonates in the raw batch, 9 000 t from purchased electricity and 2 000 t from site transport. It has no removals.

Option	Description	Abatement (t CO_2-e yr^{-1})	Annual cost	Lead time
W	Raise recycled glass (cullet) in the batch from 25% to 60%	9 800	$300 000	6 months
X	Waste-heat recovery to preheat the incoming batch	4 200	$210 000	18 months
Y	Convert 60% of furnace firing to electric boost, on a grid at 0.30 kg CO_2-e kWh^{-1}	21 000	$2 940 000	4 years
Z	Purchase 20 000 ACCUs each year	20 000	$840 000	Immediate

Recommend an implementation sequence, justify it against three criteria, and identify one criterion the data does not allow you to assess. (8 marks)

Solution. Cost per tonne first, since it makes the four commensurable: W $300 000 ÷ 9 800 = **$30.61**; X $210 000 ÷ 4 200 = **$50.00**; Y $2 940 000 ÷ 21 000 = **$140.00**; Z $840 000 ÷ 20 000 = **$42.00**.

The recommended sequence is **W, then X, then Y, with Z used only for the residual and only while the others are being built**.

Abatement potential and mechanism. W is first on every criterion that matters. It is the cheapest per tonne, it is fastest, and it acts on **both** emission sources at once: cullet melts at a lower temperature than virgin batch, so less gas is burnt, and cullet contains no carbonates to decompose, so part of the 14 000 t of process emissions disappears as well. That

double action is why it out-performs its modest headline tonnage. X is next: it is cheap, quick and reduces the same furnace gas demand. Y delivers by far the largest single reduction — 21 000 t, a quarter of the site's total — but at four and a half times W's cost per tonne and with a four-year lead time, so it belongs in the sequence, not at the front of it. Together W, X and Y abate 35 000 t yr^{-1}, which is 35 000 ÷ 86 000 × 100 = **40.7%** of the current inventory.

Time to effect. Because warming responds to cumulative emissions, the tonnes abated in the years before Y is commissioned are real and are lost if the sequence waits for the big option. Starting with the six-month measure and the eighteen-month measure captures roughly 14 000 t yr^{-1} during Y's construction period that a "wait for the big project" strategy forgoes.

Position in the abatement hierarchy. Z is cheaper per tonne than X and Y, and it must still come last. It leaves all 86 000 t of the site's emissions in place, must be renewed annually, and shifts the physical abatement onto a third party. It is defensible as a bridge for emissions that cannot yet be eliminated; it is not defensible as a substitute for W, X or Y.

Two conditions worth naming. Y's 21 000 t is calculated at a grid intensity of 0.30 kg CO_2-e kWh^{-1}. Electrification abatement is the *difference* between the two supplies, so that figure is a forecast, not a measurement: on a more emissions-intensive grid the abatement is smaller, and it improves as Victoria's renewable share rises toward its legislated 65% by 2030 and 95% by 2035. And W's ceiling is set by cullet supply — a 60% batch requires a reliable stream of clean, colour-sorted glass, which depends on a collection system the company does not control.

The criterion the data does not support. **Permanence and reversal risk**, together with **additionality**, cannot be assessed, because the table does not say what kind of ACCU project Z buys from. A 100-year permanence sequestration project, a 25-year one and an avoided-emissions credit are materially different products, and none can be judged without knowing which it is. **Co-benefits and trade-offs** are similarly unassessable — furnace electrification would also remove local combustion pollutants, which is not in the table.

Practice questions

Scaffolded

Q1. Define *mitigation* as the term is used in relation to climate change. (1 mark)

Q2. Distinguish mitigation from adaptation, and state the test used to tell them apart. (2 marks)

Q3. Explain what the word *net* adds to the phrase "reducing net greenhouse emissions", and name the two levers it makes available. (3 marks)

Q4. Complete the table. Classify each measure as mitigation, adaptation, both or neither. (4 marks)

Measure	Classification
Capturing methane from a closed landfill and flaring it	
Building a levee to protect a sewage pump station from storm surge	
Replacing HFC-134a in a refrigerated fleet with a low-GWP refrigerant	
Injecting reflective aerosol into the stratosphere to reduce incoming solar radiation	

Q5. Explain why reducing methane emissions slows warming faster than reducing carbon dioxide emissions, even though carbon dioxide sets where warming eventually settles. (2 marks)

Q6. State the annual emissions threshold at which a facility becomes covered by the Safeguard Mechanism, and the default rate at which its baseline declines to 2030. (2 marks)

Q7. Distinguish carbon capture and storage from carbon dioxide removal, state which term of the net-emissions ledger each acts on, and give one example of each. (3 marks)

Q8. Classify each option by where in the chain it acts — demand, conversion efficiency, supply substitution, agricultural non-CO_2, or removals. (4 marks)

Option	Where it acts
Feeding an *Asparagopsis* additive to lot-fed cattle	
Insulating the ceilings of 3 000 social housing dwellings	
Replacing a resistive electric hot water unit with a heat pump	
Registering 80 ha of mixed local-provenance revegetation as a sequestration project	

Q9. Explain why an offset must be *additional* and *permanent* if it is to reduce net greenhouse emissions, and define *leakage* in this context. (3 marks)

Q10. Pellowbridge Foods Pty Ltd reports gross emissions of 48 000 t CO_2-e in year 1, of which 12 000 t comes from its own truck fleet, offset against 800 t CO_2-e sequestered by a registered revegetation project on company land. In year 2 the company sells the fleet and contracts an external carrier, which drives the same routes in the same trucks. Reported gross emissions fall to 36 000 t CO_2-e; the revegetation project is unchanged.

a. Calculate the reported net emissions in each year. (2 marks)

b. Calculate the apparent percentage reduction in reported net emissions. (1 mark)

c. Explain whether this constitutes mitigation. (2 marks)

Q11. Explain why the phase-down of hydrofluorocarbons is a climate change mitigation measure even though it is administered under ozone protection legislation, and state why it is wrong to say that the ozone hole causes global warming. (3 marks)

Unscaffolded

Q12. State two reasons why "net zero emissions" does not mean "no emissions". (2 marks)

Q13. A student writes that installing air conditioning in a school is a mitigation option because it protects students from heatwaves. Explain why this is incorrect, and rewrite it as a correctly classified pair of measures. (3 marks)

Q14. Compare *energy efficiency* and *emissions intensity* as mitigation levers. Refer to what each measures, its units, and one situation in which one improves while the other does not. (4 marks)

Q15. Thistlebourne Pastoral Pty Ltd runs 900 lot-fed steers and applies urea to 400 ha of improved pasture. It is considering three measures: an *Asparagopsis* feed additive for the lot-fed animals; a nitrification-inhibitor-coated fertiliser in place of urea; and planting 60 ha of unproductive land with mixed native woodland.

Identify the principal greenhouse gas and biological source engaged by each measure, state which term of the net-emissions ledger each acts on, and rank the three by time to effect. (5 marks)

Q16. A Victorian household replaces a 90% efficient natural gas heater with a reverse-cycle heat pump with a coefficient of performance of 4.0. Natural gas releases 0.185 kg CO_2-e per kWh of gas consumed. Explain, using calculations, why this replacement delivers almost no abatement at a grid emissions intensity of 0.85 kg CO_2-e kWh^{-1} but substantial abatement at 0.30 kg CO_2-e kWh^{-1}, and state what this means for the sequencing of electrification. (5 marks)

Q17. Wintlebury Shire Council publishes a five-point "climate mitigation program":

1. Replacing 4 200 mercury-vapour streetlights with LED luminaires.
2. Installing shade sails and drinking fountains in three playgrounds ahead of hotter summers.
3. Upgrading the gas collection system at the closed municipal landfill and flaring the captured gas.
4. Raising the minimum floor level required for new buildings in the flood overlay.
5. Purchasing ACCUs to "neutralise" the emissions of the council vehicle fleet.

Identify which measures are correctly described as mitigation and which are not, name the gas and source engaged by each mitigation measure, and state one significant gap in the program. (6 marks)

Q18. Discuss why a credible mitigation strategy requires both reduction of the source term and increase of the removal term, and why removals cannot be substituted freely for source reduction. Refer to permanence, scale and the cumulative nature of warming. (8 marks)

Q19. Cobblewick Freight Pty Ltd operates 140 prime movers on regional Victorian distribution routes. Its annual inventory is 62 000 t CO_2-e: 58 000 t from diesel combustion, 2 400 t from HFC-134a losses from refrigerated trailer units, and 1 600 t from depot electricity. It has no removals. Its sustainability report states: *"Cobblewick is carbon neutral. We purchase Australian Carbon Credit Units equal to our full footprint every year."*

Evaluate Cobblewick's position as a mitigation strategy. State its net emissions; identify four mitigation options of different types, each traced to a specific gas and source; evaluate them against at least three criteria; apply two sustainability principles; and explain the difference between an option that reduces net greenhouse emissions and one that only reduces reported emissions. (10 marks)

Answers

Q1. Action that reduces net greenhouse gas emissions, and so addresses the cause of climate change. (1)

Q2. Mitigation reduces net greenhouse gas emissions and so acts on the cause; adaptation reduces harm from climate change that will occur anyway and so acts on the consequence (1). The test: does the measure change the quantity of greenhouse gas in the atmosphere? If it does, it is mitigation; if it only changes the damage the atmosphere does, it is adaptation (1).

Q3. *Net* means gross emissions from sources minus removals by sinks (1). It therefore makes two levers available: reducing the source term, so fewer tonnes enter the atmosphere (1); and increasing the removal term, so more tonnes leave it and are retained (1).

Q4. Landfill gas capture and flaring — **mitigation** (1). Levee protecting a pump station — **adaptation** (1). Low-GWP refrigerant substitution — **mitigation** (1). Stratospheric aerosol injection — **neither** (1).

Q5. Methane's atmospheric lifetime is about 11.8 years, so cutting methane emissions lowers its atmospheric concentration within about two decades and the temperature response follows quickly (1). CO_2 persists for centuries to millennia, so cutting CO_2 emissions slows the rise in concentration rather than lowering it, making the temperature response much slower (1).

Q6. More than 100 000 t CO_2-e a year of covered scope 1 (direct) emissions (1); the default baseline decline rate is 4.9% each year to 2030 (1).

Q7. CCS intercepts CO_2 in a flue or process stream before release and stores it, so it is an avoided emission acting on the **source** term — example: capture on a gas processing plant (1). CDR takes CO_2 already in the atmosphere and retains it, acting on the **removal** term — example: reforestation, or direct air capture with geological storage (1). The discriminator is whether the carbon was ever in the atmosphere (1).

Q8. *Asparagopsis* additive — **agricultural non-CO_2** (1). Ceiling insulation — **demand** (1). Heat pump replacing resistive element — **conversion efficiency** (1). Registered revegetation — **removals** (1).

Q9. Additional — the abatement must not have happened anyway; crediting an activity that would have occurred regardless issues a unit against no real reduction, so the emission it offsets is uncompensated (1). **Permanent** — sequestered carbon must be retained, because carbon returned to the atmosphere by fire, clearing or drought cancels the abatement the unit represented (1). **Leakage** is where restraining an emitting activity in one place causes it to expand elsewhere, so the tonnes reappear outside the accounting boundary (1).

Q10. a. Year 1: 48 000 − 800 = **47 200 t CO_2-e**; year 2: 36 000 − 800 = **35 200 t CO_2-e** (2). **b.** (47 200 − 35 200) ÷ 47 200 × 100 = 12 000 ÷ 47 200 × 100 = **25.4%** (1). **c.** No (1). The same trucks drive the same routes and burn the same diesel, so the quantity of CO_2 entering the atmosphere is unchanged; the emissions have moved across a reporting boundary to the contractor. This is relocation, not abatement — reported emissions fell, net emissions did not (1).

Q11. HFCs do not deplete stratospheric ozone, but they are potent greenhouse gases — HFC-134a has a GWP-100 of 1 526 — so phasing them down reduces net CO_2-e emissions and is a mitigation measure (1). It is administered under the *Ozone Protection and Synthetic Greenhouse Gas Management Act 1989* (Cth) because HFCs were introduced as substitutes for ozone-depleting substances, and the Kigali Amendment added them to the Montreal Protocol's existing machinery (1). The ozone hole does not cause global warming: ozone depletion is caused by halogen-catalysed destruction of stratospheric ozone and increases surface UV, while warming is caused by greenhouse gases absorbing and re-emitting infrared radiation — different mechanisms and different gases, with HFCs the coincidence that links the two policy regimes (1).

Q12. Any two of: net zero means residual emissions are balanced by an equal quantity of removals, so emission continues (1); some emissions are hard-to-abate — process emissions from cement and steel and agricultural methane — and are expected to persist, which is precisely why removals are needed (1); the word *net* is a statement about a balance between two terms, not about one of them being zero (1).

Q13. Air conditioning reduces harm from heat that will occur regardless; it changes nothing about the quantity of greenhouse gas in the atmosphere, so it is **adaptation** (1). It may also increase emissions if the electricity is fossil-generated, making it potentially maladaptation (1). Correct pair: air conditioning, or better a heat pump plus shading

and insulation, is the **adaptation** measure; supplying it from renewable generation, and insulating the building so less cooling energy is needed, are the **mitigation** measures (1).

Q14. Energy efficiency is the energy required per unit of service delivered — MJ or kWh per unit of output, lumen, tonne-kilometre or square metre heated (1). Emissions intensity is the CO_2-e released per unit of energy or output — kg CO_2-e per kWh, or t CO_2-e per tonne of product (1). They act on different factors of the same product: emissions = service × efficiency × intensity (1). A plant that halves its electricity use per tonne while its grid supply stays unchanged improves efficiency but not intensity; a plant that switches to renewable supply without changing its equipment improves intensity but not efficiency (1).

Q15. Feed additive — **methane (CH_4)** from enteric fermentation by methanogens in the rumen; **source** term (1). Nitrification-inhibitor fertiliser — **nitrous oxide (N_2O)** from microbial nitrification and denitrification of applied nitrogen in soil; **source** term (1). Native woodland planting — **carbon dioxide (CO_2)** taken up by photosynthesis and held in woody biomass and soil; **removal** term (1). Ranking by time to effect: feed additive is fastest, taking effect within days of being fed; the fertiliser substitution follows within the first application season; the woodland is slowest, accumulating appreciable carbon only over decades (2).

Q16. Per kWh of delivered heat — gas: $1 \div 0.90 \times 0.185 =$ **0.206 kg CO_2-e**; heat pump at 0.85: $1 \div 4.0 \times 0.85 =$ **0.213 kg CO_2-e**, marginally worse; heat pump at 0.30: $1 \div 4.0 \times 0.30 =$ **0.075 kg CO_2-e**, a reduction of about 64%. Electrification abatement is the *difference* between the two supplies, so it is created by grid decarbonisation as much as by the appliance — which is why electrification and renewable supply must be sequenced together. See fully-worked solutions. (5)

Q17. Mitigation: 1 (CO_2 from grid electricity generation, via reduced streetlight demand); 3 (CH_4 generated by anaerobic decomposition of landfill waste, oxidised to biogenic CO_2 by flaring, which removes almost all of the CO_2-e that gas carried); 5 (an offset, so mitigation in the ledger sense only — it changes no council emission). Not mitigation: 2 and 4 are **adaptation**. Gap: no measure reduces the fleet's own diesel emissions or the gas use of council buildings — the largest controllable sources are offset rather than abated, which inverts the abatement hierarchy. (6)

Q18. See fully-worked solutions. (8)

Q19. See fully-worked solutions. (10)

Fully-worked solutions

Q1. One mark, one idea, and the idea is *net emissions*. "Reducing climate change" is circular; "reducing emissions" omits the removal side that the dot point's word *net* puts in. The safest single sentence names both the action and what it acts on: reducing net greenhouse gas emissions, thereby addressing the cause.

Q2. Two marks: the distinction, then the test. The distinction must be *cause versus consequence*, not "prevention versus coping", which is vaguer and does not discriminate the both-categories. State the test as a question you can apply, because that is what makes the answer usable on an unfamiliar measure.

Q3. Three marks and three separate ideas. Do not stop at defining *net* — the question asks what the word *adds*, and what it adds is the second lever. A very common one-of-three answer defines the equation and never names sinks as an option class.

Q4. Each row turns on the atmosphere test. Landfill gas capture and flaring converts CH_4 to CO_2 and so removes almost all of the CO_2-e that gas carried — students often mark this "neither" because flaring still emits CO_2, which mistakes an emission for a net effect. Be careful with the size of the effect, because it is not simply methane's GWP of 27: carbon is conserved but oxygen is added, so a tonne of CH_4 (16 g mol^{-1}) burns to $44 \div 16 = 2.75$ t of CO_2. Landfill methane is biogenic, so inventory practice reports that CO_2 separately rather than adding it to the CO_2-e total and the abatement is the full 27.0 t CO_2-e per tonne destroyed; counted as though it were fossil, 27.0 t CO_2-e becomes 2.75 t CO_2-e, which is still a cut of about 90%. State which convention you are using (9D). The levee protects an asset and changes nothing in the air. Refrigerant substitution reduces CO_2-e because the working fluid released on leakage has a far lower GWP. Stratospheric aerosol injection is the discriminating row: it alters the energy balance without altering net emissions, so it is not mitigation, and it is not local exposure-reduction either, so it is not adaptation.

Q5. The mark is for **lifetime**, not for GWP. A frequent wrong answer says methane matters more "because its GWP is 27", which explains why a tonne of methane counts as 27 t CO_2-e — not why the *response is faster*. The mechanism is

that a short-lived gas has its concentration set mainly by recent emissions, so cutting emissions lowers the concentration within a couple of decades, whereas CO_2 accumulates and cutting emissions only slows the accumulation.

Q6. Both figures, exactly: more than 100 000 t CO_2-e a year, and 4.9% a year to 2030. The threshold is a facility-level test, not a company-level one, and it is a test on covered **scope 1** emissions — what the facility releases directly. Purchased electricity is scope 2 and does not count towards it, which is why a site can report a six-figure inventory and still sit outside the scheme. The decline rate is the default — trade-exposed baseline-adjusted facilities may be approved for a different rate.

Q7. The discriminator is where the CO_2 was immediately before it was captured. CCS takes it from a concentrated stream on its way out, so the atmosphere never receives it: an avoided emission on the source side. CDR takes it from the air, at about 424 parts per million (9A), which is why removal technologies cost more per tonne than capture at a stack. Both reduce net emissions, and calling CCS a "removal" is one of the commonest errors in this dot point.

Q8. Sort by *what changes*, not by who does it. The additive changes rumen biology, so it is agricultural non-CO_2. Insulation reduces the heating and cooling service required, so it is demand. The heat pump delivers the same hot water from about a quarter of the electricity by moving heat rather than generating it, so it is conversion efficiency — not demand, because the service is unchanged. Revegetation adds to the removal term.

Q9. Three distinct ideas, and the third is a defined term. Additionality is a counterfactual test — would the abatement have occurred without the credit? Permanence is a durability test on the store, and 9E's permanence periods of 25 or 100 years put a legal figure on it, with the 20% discount on units for the shorter period an explicit price on the higher reversal risk. Leakage is neither: it is the displacement of the emitting activity beyond the boundary, so the ledger improves while the atmosphere does not.

Q10. The arithmetic is straightforward; the third part is the point of the question. Subtract the removal in *both* years — a common slip is to subtract it once. The percentage is calculated on the year 1 net figure, so 12 000 ÷ 47 200, not 12 000 ÷ 48 000. Part **c** is the discriminator between reported and net emissions: the trucks, the routes and the diesel are identical, so the atmosphere sees exactly the same tonnes. Note the honest qualification — outsourcing *could* eventually lead to abatement if the contractor operated newer or better-loaded vehicles, but nothing in the scenario says so, and the reduction as reported is entirely a boundary effect.

Q11. Three marks, and the third is the anti-trap. Do not write that HFCs "damage the ozone layer and cause warming" — they do not deplete ozone, and that is exactly why they were adopted. The regimes are linked by substitution history, not by mechanism: ozone depletion is halogen-catalysed destruction of stratospheric O_3 that raises surface UV; the enhanced greenhouse effect is infrared radiation absorbed and re-emitted by greenhouse gases (9C). Getting this separation right is worth practising, because examiners have reported it as a recurring error.

Q12. Two reasons, and they must be reasons rather than restatements. The definitional one: net zero is a balance between residual emissions and equal removals. The physical one: some emissions are hard-to-abate — the calcination CO_2 in cement, the reduction chemistry of primary steel, enteric methane from ruminants — so residual emissions are expected to persist, which is why the removal term is structurally necessary rather than a convenience.

Q13. The error is a category error, not a factual one: the measure is real and useful, and it is adaptation. The second mark rewards seeing that on a fossil-heavy grid it also raises emissions, so it can be maladaptation — a measure that treats the symptom while worsening the cause. The rewrite must keep the adaptation and add the mitigation, because the point of the question is that a strategy needs both and must label each correctly.

Q14. Four marks means both concepts on all three requirements. The clean way to hold them apart is the identity **emissions = service × energy per unit of service × emissions per unit of energy**: efficiency is the middle factor, intensity the last. The contrasting case must be genuinely one-way — halving energy use per tonne on an unchanged supply improves efficiency alone; switching to renewable supply with unchanged equipment improves intensity alone. Both cut emissions, and neither implies the other.

Q15. Five marks: three gas-and-source-and-term identifications, then the ranking, worth two. Precision matters in the sources — CH_4 from *enteric fermentation by rumen methanogens*, not "from cows"; N_2O from *nitrification and denitrification of applied nitrogen*, not "from fertiliser". Two observations lift the answer. Only the woodland acts on the removal term, and it is the only one of the three carrying reversal risk, because fire or clearing returns the carbon.

And the feed additive is limited by feeding system, not by chemistry: it works where the ration is controlled, which is why it is proposed for the 900 lot-fed steers and not for pasture-grazed stock.

Q16. *Model response (5 marks).* Electrification does not abate by itself. What it does is replace one emissions pathway with another, and the abatement is the difference between them — which means it can be zero, or even negative, depending on the electricity supply.

Work in emissions per kWh of *delivered heat*, because that is the service the household actually buys. The gas heater is 90% efficient, so delivering 1 kWh of heat requires 1 ÷ 0.90 = 1.111 kWh of gas, and at 0.185 kg CO_2-e per kWh of gas that is 1.111 × 0.185 = **0.206 kg CO_2-e per kWh of heat**.

The heat pump has a coefficient of performance of 4.0, so it delivers 4 kWh of heat per kWh of electricity — it moves heat rather than generating it, which is why the figure can exceed 1. Delivering 1 kWh of heat therefore requires 0.25 kWh of electricity. At a grid intensity of 0.85 kg CO_2-e kWh^{-1} that is 0.25 × 0.85 = **0.213 kg CO_2-e per kWh of heat** — marginally *higher* than the gas heater it replaced. At 0.30 kg CO_2-e kWh^{-1} it is 0.25 × 0.30 = **0.075 kg CO_2-e per kWh of heat**, a reduction of (0.206 − 0.075) ÷ 0.206 × 100 = **63.6%**.

The same appliance, the same house and the same physics therefore produce almost no abatement on a brown-coal-dominated grid and roughly a two-thirds cut on a largely renewable one. Victoria matters here because its grid has been the most emissions-intensive in the National Electricity Market, and its legislated targets of 65% renewable electricity by 2030 and 95% by 2035 are what convert electrification from a neutral swap into a large abatement.

Two conclusions for sequencing. First, end-use electrification and supply decarbonisation are a single strategy, not two independent ones; a program that electrifies without a decarbonising grid buys little, and a decarbonised grid with unchanged gas appliances leaves the household's largest emission untouched. Second, timing is not a reason to defer, because appliances are replaced on 10-to-20-year cycles: a heat pump installed today is still in place through the years in which the grid intensity falls, so it captures the improvement, whereas a gas heater installed today locks the household into 0.206 kg CO_2-e per kWh of heat for the whole of its life regardless of what the grid does. Asset lifetimes, not this year's grid intensity, decide the right sequence.

Q17. *Model response (6 marks).* Two of the five measures are misclassified, and one is classified correctly only in a weak sense.

Measure 1 is mitigation. LED luminaires deliver the same lighting service for a fraction of the electrical energy, so less electricity is generated and the CO_2 released by generating it is not emitted. The gas is carbon dioxide and the source is fossil-fuelled electricity generation; on Victoria's grid, at 4 200 luminaires, the saving is material. This is the demand-and-efficiency rung of the abatement hierarchy.

Measure 3 is mitigation, and probably the largest single item. Waste in a closed landfill decomposes anaerobically to produce methane. Captured methane that is flared is oxidised to carbon dioxide, and because non-fossil methane has a GWP-100 of 27.0 against carbon dioxide's 1, almost all of the CO_2-e those molecules carried is removed. The size of that cut has to be worked from the chemistry rather than from the GWP alone: carbon is conserved in combustion but oxygen is added, so each tonne of CH_4 (16 g mol^{-1}) yields 44 ÷ 16 = 2.75 t of CO_2. Landfill methane is biogenic — its carbon was taken from the air by photosynthesis within the last few decades — so inventory practice reports the flare's CO_2 separately rather than adding it to the CO_2-e total, and on that convention the abatement is the whole 27.0 t CO_2-e for every tonne of methane destroyed. If it were counted as though it were fossil carbon, 27.0 t CO_2-e would fall to 2.75 t CO_2-e, a cut of about 90%. Either way the measure is strong mitigation, but the convention used has to be stated (9D). Students often reject this measure because flaring still releases CO_2, which confuses an emission with a net effect. If the gas were used to generate electricity instead of flared, it would abate twice — once by conversion and again by displacing grid generation.

Measure 5 is mitigation only in the ledger. Purchasing ACCUs changes no council emission. It is an offset, it must be repurchased every year, and it depends on a third party's project holding its carbon. Describing the fleet as "neutralised" invites the reader to believe the diesel is no longer being burnt.

Measures 2 and 4 are adaptation, not mitigation. Shade sails and drinking fountains reduce heat harm to people using playgrounds on hot days; raised floor levels reduce flood damage to new buildings. Both are worthwhile and both belong in a climate strategy — under the adaptation heading, which is 11C's territory. Neither changes the

quantity of greenhouse gas in the atmosphere. Publishing them under "mitigation" overstates what the program does about the cause.

The gap. The council's own controllable emissions are its fleet, its buildings and its waste. The program abates lighting and landfill gas, and *offsets* the fleet, but proposes nothing that reduces the diesel the fleet burns — no route optimisation, no vehicle replacement, no mode or fuel change — and nothing at all about gas use in council buildings such as aquatic centres, which is typically among the largest single line items. The program therefore inverts the abatement hierarchy on its second-largest source, reaching for the offset rung before the avoid, efficiency and substitute rungs have been tried. A secondary gap is that no measure carries a quantity: without tonnes of CO_2-e attached to each item the program cannot be ranked, costed or evaluated later.

Q18. *Model response (8 marks).* Both terms of the ledger are needed, and they are needed for different reasons. Source reduction is what stops the problem getting worse; removals are what deal with the part of the problem that source reduction cannot reach. Neither substitutes for the other, and the asymmetry between them is what the question is really about.

Why the removal term is necessary. Some emissions are hard-to-abate with any technology now available. About 60% of the CO_2 from a cement plant comes from calcining limestone, which is the chemistry of making cement rather than a fuel choice, so no amount of fuel switching removes it. Enteric methane is produced by methanogens in the rumen of every ruminant animal, and feed additives suppress it rather than eliminating it. Primary steelmaking uses carbon as a chemical reductant. Because these **residual emissions** are expected to persist, a target of net zero can only be reached if an equal quantity of carbon is being removed. That is the definitional reason the dot point says *net*.

Why the source term cannot be replaced by removals. Three arguments, each independent.

Permanence. A source reduction is permanent by construction — a tonne not emitted cannot be un-not-emitted. A removal is a stock held in a store that has to keep holding it, and the land-based stores that supply most removals today are the reversible ones (9E). Fire, drought, harvest, disease, clearing or a change of land manager returns the carbon to the atmosphere. The ACCU Scheme prices this asymmetry explicitly: sequestration projects nominate a permanence period of 25 or 100 years, and the 25-year option carries a 20% discount on the units issued. A ledger balanced by reversible removals is balanced conditionally.

Scale. The removal term is limited by land, water, nutrients and time in a way the source term is not. Land-based sequestration competes with food production and with biodiversity objectives, accumulates slowly, and saturates as a planting matures — 9E's distinction between a store and a sink matters here, because a mature forest holds a great deal of carbon while removing very little each year. Engineered removals such as direct air capture are not land-limited but are energy-intensive and currently far more expensive per tonne than most source reductions, because they extract CO_2 from air at about 424 parts per million rather than from a concentrated stack stream. Arithmetically, the removals available cannot cover today's gross emissions, so relying on them is a plan that does not close.

The cumulative argument. Peak warming is closely proportional to cumulative CO_2 emissions. A source reduction lowers the cumulative total from the moment it takes effect. A removal that arrives decades later — a planting takes decades to accumulate appreciable carbon — lowers the total eventually, but the emissions in the interim have already occurred, and the warming they cause is committed for centuries because of CO_2's atmospheric lifetime and the ocean's thermal inertia. Delay is therefore not neutral: "emit now, remove later" and "do not emit" are not equivalent even when the tonnages match, and the difference is borne by whoever lives through the interval. That is the intergenerational equity objection to treating removals as interchangeable with abatement.

How the two fit together. This is why the abatement hierarchy is an order and not a menu: avoid, improve efficiency, substitute, then sequester, and offset only the residual. Removals are the last line, sized to what genuinely cannot be eliminated, and the strategy has to be explicit about which emissions it has placed in that category. The honest qualification is that removals are not a lesser option — at net zero and beyond they are indispensable, and well-designed land-based removals deliver biodiversity and soil co-benefits that no emission reduction does. The error is not using them; it is using them instead.

Q19. *Model response (10 marks).* Cobblewick's claim describes a balanced ledger, not a mitigation strategy. Its net emissions are 58 000 + 2 400 + 1 600 = **62 000 t CO_2-e**, with no removals on the company's own account. Purchasing 62 000 ACCUs a year does not change that figure; it acquires units representing abatement carried out by other parties.

Four mitigation options of different types, each traced to a gas and a source.

Demand and efficiency. Route and load optimisation, driver training, aerodynamic fairings and low-rolling-resistance tyres reduce the diesel burnt per tonne-kilometre carried. Gas: CO_2 from diesel combustion, the 58 000 t line. This rung typically returns fuel savings that exceed its cost, so its abatement cost can be negative.

Mode substitution. Containerising the long linehaul leg onto rail moves freight to a mode that uses substantially less energy per tonne-kilometre. Same gas and source, engaged by removing the tonne-kilometres from the road fleet rather than by improving it.

Fuel and drivetrain substitution. Battery-electric prime movers on short metropolitan runs replace diesel combustion with grid electricity; renewable diesel replaces fossil carbon in the fuel itself. The abatement from electrification is the *difference* between diesel emissions and grid emissions, so it grows as Victoria moves toward its legislated 65% renewable electricity by 2030 and 95% by 2035.

Non-CO_2 abatement. Replacing HFC-134a in the refrigerated trailer units with a lower-GWP refrigerant, together with a leak detection and repair program and end-of-life recovery, engages the 2 400 t line directly. HFC-134a has a GWP-100 of 1 526 (9D), so a small mass of refrigerant carries a large CO_2-e; and because refrigerant loss is a leak rather than a combustion product, it is abated by containment and substitution rather than by using less energy.

Evaluation against criteria. On **abatement potential**, the diesel line is 93.5% of the inventory, so any credible strategy has to engage it — the refrigerant line is only 3.9%, which caps what refrigerant work can deliver however cheap it is. On **cost of abatement**, the ranking is likely to run efficiency first (often negative-cost), then refrigerant containment, then mode shift, with electric prime movers dearest per tonne today. On **time to effect**, efficiency and leak repair deliver within months, mode shift within a year or two subject to terminal access, and fleet replacement over a 10-to-15-year turnover cycle. On **co-benefits and trade-offs**, electrification and mode shift also cut particulate and NO_x emissions along freight corridors, while mode shift depends on infrastructure Cobblewick does not control and may lengthen transit times for customers. **Permanence** does not arise for any of the four, because a tonne of diesel not burnt cannot revert — it arises only for the ACCUs, and it cannot be assessed without knowing what project types they come from and on what permanence period.

Two sustainability principles. Intergenerational equity bites through asset lock-in: a diesel prime mover bought today commits 10 to 15 years of emissions, and because warming responds to cumulative emissions, that commitment transfers a cost to people not party to the decision. It follows that fleet replacement timing is the highest-leverage decision the company makes, and offsetting does not touch it. **User pays** bites on the offset strategy itself: the principle requires the emitter to bear the cost of its emissions, and buying credits does discharge a cost. But it discharges it by paying a third party to abate, leaving Cobblewick's own emissions and its own transition cost untouched, so the principle is satisfied only in the narrowest financial sense. **Efficiency of resource use** and the **precautionary principle** could each be applied instead, the latter supporting action on fleet replacement now despite uncertainty about future fuel and credit prices.

Reducing net emissions versus reducing reported emissions. An option reduces **net** greenhouse emissions when fewer tonnes physically enter the atmosphere, or more tonnes leave it and stay out — tested by the atmosphere test, and independent of who reports what. An option reduces **reported** emissions when the accounting boundary moves or a unit is acquired against the total. The two diverge in three ways visible here. Contracting the linehaul to an external carrier that drives the same routes in the same trucks would cut the reported figure and change nothing in the air — relocation, not abatement. Purchasing ACCUs reduces the reported net position while the trucks burn exactly as much diesel; it may represent real abatement elsewhere, but not by Cobblewick, and it must be bought again every year. Genuine abatement changes the physical activity, and it shows up as a lower gross figure, not as a larger offset line.

The verdict. Cobblewick's position is not a mitigation strategy; it is an annual purchase that leaves the company's emissions, its exposure to fuel and credit prices, and its transition task exactly where they were. Offsets are defensible as a bridge for residual emissions while physical abatement is being built, and the word *residual* is doing the work — 62 000 t of untouched diesel and refrigerant emissions is not a residual. A credible strategy would state a quantity and a date for each of the four options above, keep the offsets only for what remains after them, and stop calling the result carbon neutral until the abatement is in the inventory rather than in the credit register.

Chapter 11 Managing climate change — 11C Adaptation options at a selected region or location

Theory

One word in this dot point does all the work, and it is *unavoidable*. The study design asks for "adaptation options for building resilience to the effects of **unavoidable** climate change at a selected region or location". That word concedes something before the question even starts: some climate change is already locked in, no mitigation policy can now prevent it, and therefore a management response built only on reducing emissions is incomplete. **Mitigation** is the attempt to limit how much climate change happens. **Adaptation** is the attempt to limit how much damage the climate change that happens actually does. This subtopic is about the second.

Get the sequence of ideas right and the rest of the subtopic follows. Because greenhouse gases persist and because the ocean warms slowly, warming and sea level rise continue for decades to centuries after emissions fall — this is **committed warming**, sometimes called locked-in change. Global average temperature has already risen by roughly 1.1 to 1.2 °C above pre-industrial levels, and Victoria's average annual temperature has increased by about **1.2 °C since 1910**. None of that is recoverable on a human planning horizon. So there is a quantity of change that will arrive regardless of what is decided about emissions, and every asset, ecosystem, farm and town in the state will meet it. Adaptation is the management response to that quantity.

The discriminator that separates adaptation from mitigation. This is the most reliably examined relationship in the chapter, and the test is mechanical once you see it. Climate risk arises from the **interaction** of three ingredients — hazard, exposure and vulnerability — and is described by its likelihood and its consequence, which is how 11A defines it. Note that this is an interaction and not a multiplication: none of the three carries a unit or a numerical scale, so writing risk as a product of three numbers implies a calculation that cannot actually be performed.

A **hazard** is the physical climate event or trend itself — a heatwave, a storm surge, a rainfall deficit, a rising mean sea level. **Exposure** is the presence of people, assets, species or activities in the place the hazard reaches. **Vulnerability** is how badly the exposed thing is harmed when the hazard arrives, which depends on its sensitivity and on its capacity to cope.

Now the test. **Mitigation reduces the hazard. Adaptation reduces the exposure or the vulnerability.** Ask of any measure: *does this change the climate, or does it change what the climate does to us?* Nothing else is needed. Figure 11C.1 draws the three ingredients and the two levers together. Note what it deliberately does not do: the three circles overlap rather than multiply, because none of hazard, exposure or vulnerability carries a unit or a numerical scale.

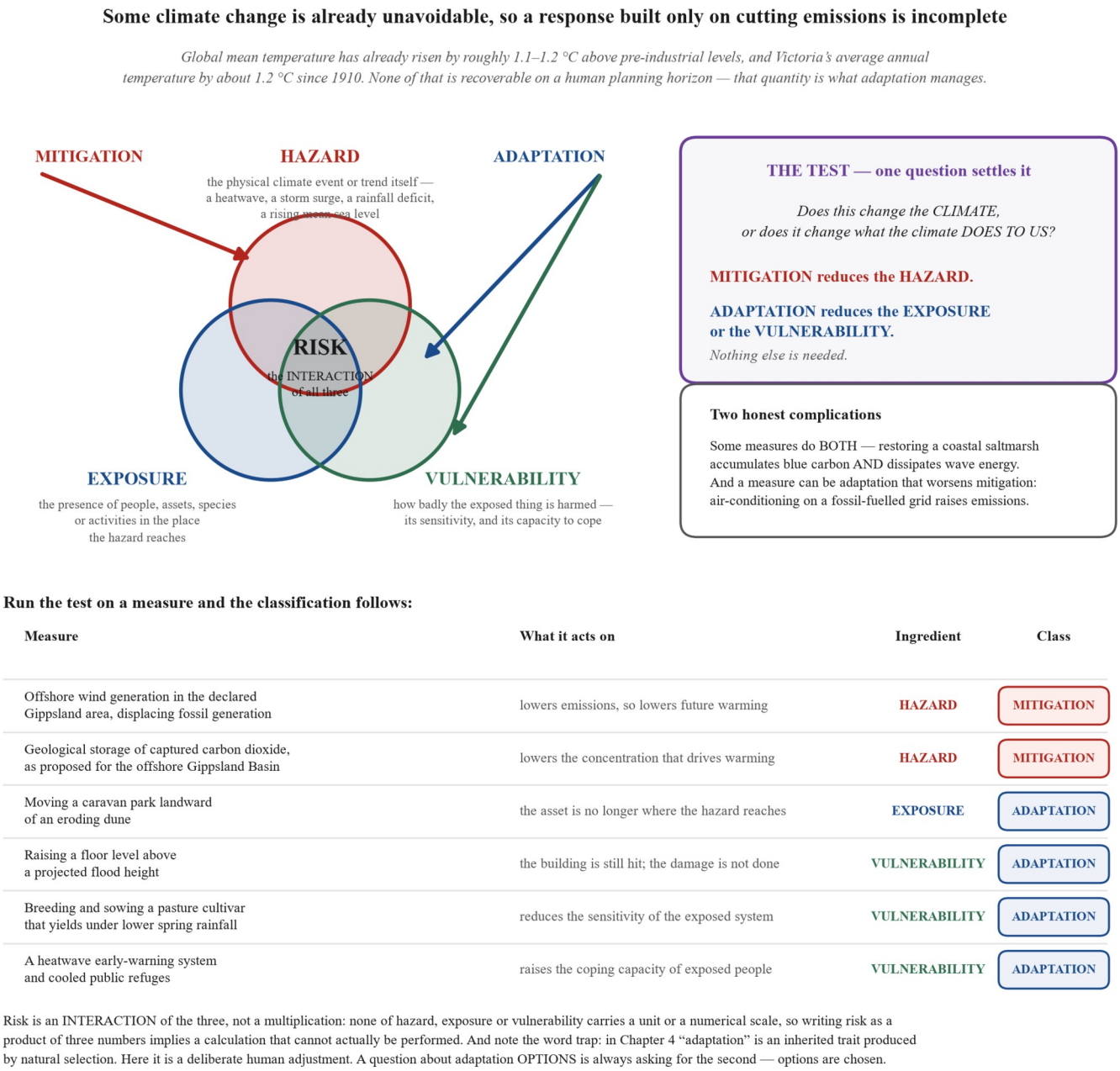

Figure 11C.1 Risk arises where the three ingredients interact. Mitigation acts on one of them and adaptation on the other two, so classifying any measure is a matter of asking which circle it reaches. The table beneath runs the test on six of the measures listed above and lets the classification fall out of the answer rather than being asserted alongside it.

Measure	What it acts on	Classification
Offshore wind generation in the declared Gippsland area, displacing fossil generation	Lowers emissions, so lowers future warming — the hazard	**Mitigation** (developed at 11B)
Geological storage of captured carbon dioxide, as proposed for the offshore Gippsland Basin	The hazard	**Mitigation** (11B)
Raising a floor level above a projected flood height	The building is still hit; the damage is not done — vulnerability	**Adaptation**
Moving a caravan park landward of an eroding dune	The asset is no longer where the hazard reaches — exposure	**Adaptation**
Breeding and sowing a pasture cultivar that yields under lower spring rainfall	Sensitivity of the exposed system — vulnerability	**Adaptation**

Measure	What it acts on	Classification
A heatwave early-warning system and cooled public refuges	Coping capacity of exposed people — vulnerability	**Adaptation**
Piping an open irrigation channel to cut evaporation and seepage losses	Water available per hectare under a drier climate — vulnerability	**Adaptation**

Two honest complications. First, some measures do both, and saying so earns marks rather than losing them. Restoring a coastal saltmarsh accumulates carbon in waterlogged sediment — **blue carbon**, which is mitigation — while also dissipating wave energy in front of a shoreline, which is adaptation. Expanding urban tree canopy sequesters a little carbon and substantially reduces surface and air temperatures in the streets beneath it. Second, a measure can be adaptation that *worsens* mitigation: air-conditioning is a genuine adaptation to heat, and on a fossil-fuelled grid it raises emissions. Naming that trade-off is a higher-order skill, and the chapter returns to how such tensions are resolved at 11D.

A term this course uses in two different senses — check which one is being asked. In Chapter 4, *adaptation* is the biological sense: an inherited trait that improves survival and reproduction, produced over generations by natural selection. In this chapter *adaptation* is a management sense: a deliberate human adjustment to actual or expected climate and its effects. A population evolving heat tolerance is biological adaptation; a water corporation piping a channel is management adaptation. A question about "adaptation options" is always asking for the second, because options are chosen and biological adaptation is not.

Resilience, and what it is made of. Resilience is the capacity of a system — ecological, social, economic or engineered — to absorb a disturbance, continue to function, and reorganise while retaining its essential identity and function. The dot point says adaptation is for "**building resilience**", so resilience is the stated *purpose* and the options are the means. Three capacities make it up, and a strong answer names which one an option is building.

Capacity	What it means	Gippsland illustration
Absorptive	Taking the hit without failing	A levee or a raised floor level that keeps a flood out of a building
Adaptive	Adjusting how the system works so the same hazard causes less harm next time	Shifting calving to a season with more reliable pasture growth; changing the crop
Transformative	Changing what the system fundamentally is, when adjustment is no longer enough	Converting flood-prone dairy land to wetland and carbon farming; relocating a settlement

Adaptive capacity is the underlying ability to do any of this — the money, information, skills, institutions, entitlements and social networks a community can draw on. It is unevenly distributed, which is why two towns facing an identical hazard do not face identical risk, and why adaptation planning that ignores capacity delivers plans nobody can implement.

The four families of adaptation option. For any hazard that arrives at a place, there are only so many things that can be done. The coastal literature names four, and they generalise well beyond the coast. They are the teaching scheme, and they are not the only scheme: the statutory list set out below them has six options, and where a Victorian planning decision is involved it is the statutory one that binds.

Family	What it does	Coastal example	Non-coastal example
Protect	Keep the hazard away from the asset	Seawall, rock revetment, groyne, beach renourishment, restored dune or saltmarsh	Levee; fire-resistant buffer; farm dam
Accommodate	Let the hazard arrive, but reduce the harm it does	Raise floor levels; use salt-tolerant materials; flood-proof services	Heat-refuge buildings; shade for stock; drought-tolerant cultivars
Retreat	Move the asset out of the	Relocate a road, a caravan	Move irrigation to a more

Family	What it does	Coastal example	Non-coastal example
	hazard's reach	park, a surf club; buy back land	reliable district
Avoid	Never put the asset there in the first place	Overlay controls; setback lines; refusing subdivision in a hazard zone	Zoning that keeps new housing out of the fire and flood interface

Two structural points about this table are worth more than the table itself. **Avoid is nearly always the cheapest option and it is only available before development occurs** — which is why planning controls are adaptation instruments even though they build nothing. And **protect defends everything behind it at once, which makes it attractive and makes its failure catastrophic**: a wall that is overtopped delivers the full hazard to a community that has stopped expecting it.

The order Victorian planning law actually requires. Clause 13.01-2S of every Victorian planning scheme requires a decision-maker to assess the effectiveness, costs, benefits, impacts and **path dependency** of the available adaptation options **in a set order**. It names six options, not four, and the order is part of the requirement.

#	Option in the statutory order	Relation to the four families
1	**Non-intervention**	Not one of the four. Accepting the change and its consequences — appraised on the record, and costed, rather than assumed away
2	**Avoid**	Avoid
3	**Nature-based methods**	A family in its own right here, *not* a kind of protection — dune, saltmarsh, wetland and vegetation doing the work
4	**Accommodate**	Accommodate
5	**Retreat**	Retreat
6	**Protect**	Protect — assessed **last**, not first

Three things follow, and each is examinable. Hard **protection is the last option the clause reaches**, not the default the engineering instinct suggests. **Nature-based methods are ranked three places ahead of protection**, so calling a restored marsh "a soft kind of seawall" gets the policy backwards: a marsh that is the thing being saved is not protecting anything. And **non-intervention is not neglect** — it is the option of doing nothing, put on the list precisely so that its consequences are costed against the others instead of arrived at by default.

A fuller classification, for options that are not about a shoreline. Cutting the same field a second way, by *what kind of thing the option is*, catches options the four families can hide.

Type	Mechanism	Real Victorian examples
Structural / engineered	Build or modify physical infrastructure	Piped irrigation distribution; rock revetment; upgraded stormwater capacity; raised bridge approaches
Technological	Apply a technique or system	Seasonal climate forecasting for on-farm decisions; remote soil-moisture monitoring; heat-health alert systems
Ecosystem-based (nature-based)	Use a functioning ecosystem to deliver the protective service	Dune revegetation; saltmarsh and mangrove restoration; riparian shading to hold stream temperature; wildlife corridors that let species shift range
Institutional / regulatory	Change the rules, entitlements or plans	Coastal hazard overlays and setbacks in a planning scheme; water

Type	Mechanism	Real Victorian examples
		entitlement and trading rules; building standards
Economic / financial	Change the price, the risk transfer or the funding	Insurance and reinsurance pricing; adaptation grant programs; land purchase and buy-back
Informational / social	Change what people know and do	Community coastal hazard engagement; farm business risk planning; Landcare and Coastcare volunteer networks that move practice between landholders

Options also differ in ambition. **Incremental adaptation** maintains the existing system and its purposes — a higher levee, a better cultivar, a bigger culvert. **Transformational adaptation** changes the system's fundamental attributes — a different land use, a different location, a different industry. Incremental options are cheaper, faster and politically easier, and they are the right answer for most of this century in most places. They are the wrong answer when the hazard eventually exceeds what adjustment can absorb, and the standard failure of real adaptation plans is to keep buying increments past the point where transformation was the cheaper choice.

The related distinction is **hard** against **soft**. Hard options are engineered, capital-intensive, long-lived and difficult to reverse; soft options are flexible, cheaper to change and often ecological or institutional. Hard options deliver certainty and remove future choices; soft options preserve choices and deliver less certainty. Which is preferable depends on how confident the projections are — and that is why the confidence ratings taught at 10D feed directly into this subtopic.

Why the dot point says "at a selected region or location". Adaptation, unlike mitigation, is irreducibly local. A tonne of carbon dioxide has the same effect on the hazard wherever it is avoided, so mitigation can be planned globally and nationally. Adaptation cannot, because exposure and vulnerability are properties of particular places: the same 0.8 m of sea level rise floods a low sandy barrier and does nothing to a basalt cliff twenty kilometres away. So the examinable skill is not "list adaptation options" — it is **match options to the hazards, assets, ecosystems, economy and capacity of one named place, using that place's own published projections and plan**. An answer that would read identically for any coastline in Australia has missed the dot point.

The selected region: Gippsland, Victoria

This series uses **Gippsland** as its selected region, for both this subtopic and the risks and opportunities at 11A. It is a defensible choice because it carries every kind of exposure the study design names, in one region, with published regional projections and a published adaptation strategy.

Feature	Detail
Extent	South-eastern Victoria, from Western Port and the Strzelecki Ranges east to the New South Wales border; about 41,500 km², roughly a fifth of Victoria
Coast	Around 700 km, including the **Ninety Mile Beach**, one of the longest uninterrupted sand barriers in the world, and the artificially maintained entrance at **Lakes Entrance**
Wetlands	The **Gippsland Lakes**, a Ramsar-listed coastal lagoon system, plus Corner Inlet and the Heart and Dowd Morasses
Agriculture	Victoria's principal dairy region, with irrigated dairy concentrated in the **Macalister Irrigation District**, the largest irrigation district in southern Victoria; also beef, horticulture, vegetables and plantation forestry
Energy and industry	The Latrobe Valley brown coal basin and its power

Feature	Detail
	generation; offshore oil and gas in the Gippsland Basin; a declared offshore wind area
Uplands	The Victorian Alps, with alpine and sub-alpine ecosystems and a snow-dependent visitor economy
Regulators and managers	DEECA; Southern Rural Water and Gippsland Water; the West and East Gippsland Catchment Management Authorities; six local councils

The published projections. Adaptation options must be chosen against numbers, and the numbers must be cited with their scenario, their time horizon and their baseline — a projection quoted without those three things cannot be checked, cannot be compared with another projection, and cannot be used to size anything. That is a scientific requirement rather than a matter of style: "+1.8 °C by 2050 against 1986–2005" and "+1.8 °C by 2090 against pre-industrial" are different statements about the world, and one of them may be the wrong number for the decision in front of you.

Victoria's current generation of regional projections is **Victorian Climate Projections 2024 (VCP24)**, summarised in **Victoria's Climate Science Report 2024** with a regional report for each of Victoria's regional partnership areas, Gippsland among them. VCP24 is built on **CMIP6** global models and the SSP emissions scenarios, with 32 regionally downscaled simulations per scenario. It supersedes **Victorian Climate Projections 2019 (VCP19)**, which used CMIP5 and the older RCP scenarios — but VCP19 is still worth knowing, because most adaptation plans currently in force were written against it, including Gippsland's. Reading a plan therefore means reading the projection generation it was built on.

Variable	Projected change	Scenario, horizon, baseline and source
Annual daily **maximum** temperature, Gippsland	**+2.0 °C** median, model range 1.5 to 2.9	RCP8.5, 2040–2059 against 1986–2005 (VCP19 Gippsland report); +1.8 °C median under RCP4.5
Annual daily **minimum** temperature, Gippsland	**+1.4 °C** median, range 1.4 to 2.0	RCP8.5, 2040–2059 against 1986–2005 (VCP19 Gippsland report)
Annual average temperature, Victoria	**+1.3 to 2.0 °C**, central estimate 1.6 °C; 1.4 to 2.4 °C from downscaled models	RCP8.5, 2040–2059 against 1986–2005
Days above 35 °C, Bairnsdale	From **6.2** a year to a median **11.1** (6.6 to 17.2)	RCP8.5, 2040–2059 against the 1981–2010 average (VCP19 Gippsland report)
Days below 0 °C, Bairnsdale and Traralgon	Bairnsdale from **2.3** a year to **0.6** (0.3 to 1.0); Traralgon from **3.6** to **1.2** (0.7 to 1.8)	RCP8.5, 2040–2059 against 1981–2010 (VCP19 Gippsland report)
Days below 0 °C, Alpine Peaks	From over **45** a year to **26 to 28** — a fall of about **40%**	East Gippsland Regional Catchment Strategy 2021–2027, which publishes **no scenario and no baseline** for it
Cool-season rainfall	Continued decline in **winter and spring** (*medium to high* confidence); autumn decline at *low to medium* confidence, with some chance of little change	VCP19 Gippsland report, both scenarios
Rainfall intensity	1-in-20-year daily rainfall up **3 to 17%**, so heavy events intensify even as totals fall	2040–2059 against 1986–2005, across seasons and both scenarios (VCP19 Gippsland report)
Sea level, Gippsland coast at	About **24 cm** higher — a median 4	RCP8.5, 2050s against the 1990s

Variable	Projected change	Scenario, horizon, baseline and source
Inverloch	mm/yr	(VCP19 Gippsland report)
Very high fire danger days, Bairnsdale	**+5.8 days** a year, about **32%** more, counting days above the 1986–2005 95th percentile of the Forest Fire Danger Index	RCP8.5, 2050s (VCP19 Gippsland report; *high confidence*)
Very high fire danger days, **Victoria**	About **40%** more	CSIRO and Bureau of Meteorology, *Climate Change in Australia* Victoria state climate statement

Read the last two rows together before going further, because they are the trap this table exists to set. The regional number is **32%** and the statewide number is **40%**; both are real, and an answer that attaches the statewide figure to Gippsland has quoted a correct number about the wrong place. The Alpine Peaks row is in the table for the same reason — it is a genuine published projection from a genuine regional strategy, and it arrives with no scenario and no baseline attached, so it cannot be compared with the VCP19 rows above it. Notice also that the strategy summarises that fall as "a halving" while its own figures give about 40%; do the percentage change yourself rather than trusting a source's adjective.

Three further features of that table drive everything that follows. Temperature change is projected with high confidence and a narrow range, so options addressing heat can be sized now. Rainfall is projected with much lower confidence and the *direction* of change differs by season, so options addressing water must work across a range of futures rather than a single number. And the combination of falling cool-season totals with rising rainfall intensity means the same region must adapt to **less water and worse floods at the same time** — which sounds contradictory and is not, and which no single option can address.

The published plans, and the instruments that make them binding. Adaptation in Victoria is not discretionary goodwill; it sits in a legislated structure, and questions frequently turn on knowing which instrument does what.

Instrument	What it actually does
Climate Action Act 2017 (Vic) — renamed from the *Climate Change Act 2017* (Vic) by amendments made in 2024	Sets the long-term target of net zero emissions by 2045 and interim targets, and requires a Climate Change Strategy every five years. For adaptation, it requires an **Adaptation Action Plan** every five years for each of seven prescribed **systems**: built environment, education and training, health and human services, natural environment, primary production, transport, and the water cycle
Adaptation Action Plans 2022–2026	The first generation of those plans, one per system. The second generation, for **2027–31**, is in preparation and adds **energy** as an eighth system
Gippsland Regional Climate Change Adaptation Strategy 2021–2026	The region's own five-year strategy, one of six Regional Adaptation Strategies, funded through the Sustainability Fund's *Supporting Our Regions to Adapt* program. It works on regional adaptive capacity and place-based priorities rather than issuing directions
Marine and Coastal Act 2018 (Vic)	The head of power for coastal management, including the making of statutory guidelines under s 41
Marine and Coastal Policy 2020	Requires planning for sea level rise of **not less than 0.8 m by 2100**, and allows planning for more
Victoria's Resilient Coast — Adapting for 2100+ (DEECA, 2023)	The guidelines made under s 41, which **must** be followed when planning for, assessing or managing coastal hazard risk under the Policy. Sets a seven-stage process from scoping to implementation, and supplies an

Instrument	What it actually does
	Adaptation Actions Compendium and an adaptation pathways template
Planning scheme clause 13.01-2S (coastal inundation and erosion)	Carries the Policy's benchmark into every Victorian planning scheme, so it binds decisions on individual permits and rezonings. It also requires land subject to the hazard to be identified and managed, requires that adaptation options be assessed **in the six-option order set out above**, and requires that works responding to coastal hazard avoid detrimental impacts on coastal processes
Local Coastal Hazard Assessments	Place-specific technical studies of inundation and erosion hazard. Ones covering the **Gippsland Lakes and Ninety Mile Beach** are published, and they are the evidence base a council's adaptation plan is built on

Note carefully what the 0.8 m benchmark is: a **floor, not a ceiling**. The Policy expressly enables planning for higher values where local conditions justify it, and in October 2024 the Minister set a scenario of **1.2 m by 2100** for Port Fairy — a different Victorian coastal town — over a planning panel recommendation to hold to the statewide figure. A student who writes that Victoria "plans for 0.8 m" is right; one who writes that Victoria "may not plan for more than 0.8 m" is wrong.

Real adaptation options at Gippsland, traced to the risk each addresses. This is the table the dot point is really asking for. Each row names the projected change, the option, its family and type, and the mechanism by which it reduces harm. The mechanism is where the marks are.

Projected change	Adaptation option	Family / type	Mechanism
Sea level rise plus more intense storms on a sandy barrier coast	Dune revegetation and fenced access paths along the Ninety Mile Beach	Protect / ecosystem-based	Vegetation traps windblown sand and binds the dune face, rebuilding the sediment buffer that absorbs storm wave energy before it reaches assets
Sea level rise threatening a fixed entrance and its township	Continued dredging and structural maintenance at Lakes Entrance, with hazard mapping under the Local Coastal Hazard Assessment	Protect / structural	Maintains navigable depth and entrance stability as the tidal prism and wave climate change; the assessment sets the levels other decisions are sized against
Rising inundation risk behind the barrier	Coastal hazard overlays and setback controls under clause 13.01-2S	Avoid / institutional	Prevents new assets being placed where they will need defending, so the exposed value stops growing
Inundation of existing low-lying assets	Raising road and bridge approaches, floor levels and switchgear above projected levels	Accommodate / structural	The hazard still arrives; the asset keeps functioning through it
Assets that cannot be defended economically	Planned relocation of foreshore facilities landward, sequenced by trigger point	Retreat / institutional and economic	Removes exposure permanently rather than paying to defend it repeatedly
Lower cool-season rainfall	**Macalister Irrigation**	Protect / structural and	Evaporation and seepage

Projected change	Adaptation option	Family / type	Mechanism
and higher evaporative demand on irrigated dairy	**District Modernisation** — open channels replaced by pipeline, outlets automated; begun 2013, completed February 2024, delivering about **20,800 ML** of water savings across its three phases, with measured district distribution system efficiency reaching **87%** in 2023-24	technological	losses that occur between the storage and the farm gate are eliminated, so more of each entitlement reaches pasture; the saved water is available in drier years
Same, on-farm	On-farm efficiency investment, effluent reuse for nutrients, and pasture species suited to a shorter reliable growing season	Accommodate / technological	Raises production per megalitre and per millimetre, lowering sensitivity to the same rainfall deficit
Heat stress on dairy cattle	Shade, sprinklers and shifted milking and calving times	Accommodate / structural and technological	Reduces the physiological heat load, protecting milk yield and fertility at unchanged air temperature
More intense rainfall on a drying catchment	Riparian revegetation, wetland reinstatement and stormwater retention	Protect / ecosystem-based	Slows and stores runoff, cutting peak flows, nutrient pulses to the Lakes and bank erosion
Ramsar wetland squeezed between rising water and fixed land use	Securing landward migration space for saltmarsh, and blue carbon restoration	**Retreat** (managed realignment) / ecosystem-based and institutional — a *nature-based method* in the clause's order	The habitat is the asset here, and giving it land to move into takes it out of the water's reach rather than defending it in place; the same sediment stores carbon, so the option is also mitigation
More very high fire danger days	Fuel management, refuge and warning arrangements, and building standards at the interface	Accommodate and avoid / mixed	Reduces both fire intensity at the interface and the vulnerability of the people and buildings exposed to it
Species ranges shifting under a warming climate	Corridor and remnant connectivity across the Strzelecki and alpine gradients	Protect / ecosystem-based	Gives populations a physical route to track their climatic niche instead of being stranded in an unsuitable remnant
Declining snow reliability	Diversifying the alpine visitor economy towards year-round activity	Transformational / economic	Removes the economic dependence on a variable that is projected to keep declining

Adaptation pathways: the method that makes these choices defensible. The obvious way to plan is to pick the best option and build it. Under climate uncertainty this is close to the worst way, because the "best" option depends on how much change arrives and by when — and that is exactly what is not known. If a council sizes a wall for 0.8 m and 1.2 m arrives, the wall fails; if it sizes for 1.2 m and 0.5 m arrives, it has spent decades of rates on defending against a hazard that did not come.

An **adaptation pathway** solves this by sequencing options over time and attaching each to a **trigger point** — an observed, measurable threshold that starts the next action. The pathway commits to the *decision rule*, not to the whole build. Victoria's Resilient Coast supplies a template for exactly this, which is a strong hint about what a good answer looks like.

Pathway stage	Action	Trigger to move to the next stage
Now	Monitor beach profiles and water levels; apply overlays to stop new exposure; revegetate dunes	Dune toe retreats past a surveyed marker in three consecutive annual surveys
Next	Beach renourishment and access management	Renourishment interval falls below a defined number of years, or cost per year exceeds a set threshold
Later	Raise or protect the specific assets still worth defending	Design flood level exceeded more than once a decade; protection cost exceeds asset value
Eventually	Planned retreat of remaining assets, land use converted	Defence no longer economic or physically feasible

The strengths are worth stating explicitly, because they are the answer to "why not just build the wall". The pathway is **robust** — it performs acceptably across the whole range of projections instead of optimally in one. It **preserves flexibility**, keeping later options open rather than committing capital that constrains successors. It **matches spending to evidence**, so money is committed when monitoring shows it is needed. And it **makes the retreat decision in advance and in public**, at a calm moment, rather than in the week after a storm — which is both fairer and cheaper.

Criteria for appraising options. When a question asks you to *evaluate* or *justify* an option, these are the grounds available.

Criterion	The question it asks
Effectiveness	Does it actually reduce harm, and by a mechanism you can state?
Robustness	Does it still work if the projection turns out at the high or low end?
Flexibility and reversibility	Can it be adjusted, extended or abandoned later without stranding the investment?
Lead time against design life	Can it be delivered before the hazard arrives, and will it last as long as the asset it protects?
Cost and who bears it	Capital and ongoing cost, and whether the beneficiary pays
Equity	Who is protected, who is not, and who is asked to move
Co-benefits and trade-offs	Does it also deliver mitigation, habitat or amenity — or undercut them?
Acceptability and feasibility	Is it lawful, resourced, and supported by the community that must live with it?

Maladaptation. Maladaptation is an adaptation action that increases the risk of adverse outcomes — either now, or for someone else, or later. It is not merely an option that fails; it is one that makes things worse, and it is the discriminator that separates a strong answer from a list. Five recognisable signatures:

Signature	Mechanism	Example
Transfers the harm	The hazard is redirected rather than reduced	A groyne or seawall interrupts longshore sediment transport, starving the beach downdrift and accelerating erosion on the next

Signature	Mechanism	Example
		property
Removes the buffer	Hard armour on a rising sea leaves the intertidal habitat nowhere to go — **coastal squeeze**	Saltmarsh in front of a wall drowns, so wave energy reaching the wall increases and the habitat is lost too
Induces new exposure	Protection makes a hazardous place feel safe, so more is built there — the **safe development paradox**	A levee triggers subdivision behind it; when it is overtopped, the loss is larger than before it was built
Locks in a path	A long-lived, costly asset removes future options	A pipeline sized for today's irrigated area makes reducing that area politically and financially very hard, even if the water is no longer there
Shifts the burden in time or sector	Reduces one risk by increasing another	Fossil-fuelled air-conditioning adapts to heat while adding emissions; deeper bores adapt to drought while depleting the aquifer that made the region resilient

The test for maladaptation is to ask three questions of any option: *who else is affected, what happens at the high end of the projection, and what does this stop us doing in 2060?* An option that survives all three is a good option. Notice that **doing nothing is not automatically the safe choice either** — allowing exposure to accumulate in a hazard zone is itself a decision with consequences. That is why *non-intervention* is the first option on the clause's list rather than absent from it: it is assessed on the same terms as the others, so its consequences are costed rather than inherited by default.

Limits to adaptation. Adaptation is not unbounded, and pretending otherwise is a marked error.

- A **soft limit** is one where options exist but are not currently accessible — no money, no legal power, no social acceptance, no skilled workforce. Soft limits can be moved, and much adaptation policy exists to move them.
- A **hard limit** is one where no adaptive action can avoid intolerable risk. An alpine ecosystem whose climatic envelope has moved off the top of the mountain has nowhere to go; a sand barrier cannot be defended indefinitely against a sea that keeps rising.

Whatever is left after every feasible option has been taken is **residual risk**, and it must be managed by other means — insurance, emergency response, or accepting the loss. This is the strongest argument for the pairing the study design insists on: because adaptation has limits, mitigation is the only thing that keeps the hazard inside the range adaptation can handle. Neither substitutes for the other.

What this subtopic hands to the rest of the chapter. Stay on your own ground.

Question being asked	Subtopic that owns it
What are the risks and opportunities of climate change at the region?	11A
What options reduce net greenhouse emissions?	11B
What options build resilience to unavoidable change at the region?	**11C**
How do stakeholder values, regulation, data and new technology pull against each other in deciding?	11D
How confident are the projections, and what do the IPCC confidence terms mean?	10D

Where students lose marks.

- **Answering with mitigation.** The commonest error in the whole chapter. Solar panels, electric vehicles and tree planting for carbon are mitigation. Apply the test: does it change the hazard, or what the hazard does to us?
- **Listing options with no place attached.** "Build seawalls, plant trees, use less water" would answer a question about anywhere. The dot point says *at a selected region or location*; name the region, its projected change, and the asset or ecosystem at risk.
- **Naming an option without its mechanism.** "Pipe the channel" earns little; "pipe the channel so the evaporation and seepage losses between storage and farm gate are eliminated, delivering more of each entitlement to pasture in a drier year" earns the mark.
- **Quoting a projection without scenario, horizon and baseline.** "It will be 1.8 degrees warmer" is not a projection. Under which scenario, by when, relative to what?
- **Attaching a statewide number to the region.** Victoria's 40% more very high fire danger days is not Gippsland's 32%. A correct number about the wrong place is a wrong answer to a question about a *selected* region — check the geography a figure is scoped to before you quote it.
- **Confusing the family with the type, or the ambition level with either.** *Protect, accommodate, retreat and avoid* are families; *structural, technological, ecosystem-based, institutional, economic and informational* are types; *incremental* and *transformational* are ambition levels. A question that asks for three different types is not answered by three options from three different families.
- **Treating 0.8 m as a maximum.** It is a statutory minimum that the Policy permits exceeding, and has been exceeded.
- **Confusing the biological and management senses of *adaptation*.** Options are chosen; traits are inherited.
- **Assuming protection is always best.** Protect defends everything behind it and fails all at once, transfers erosion downdrift, and induces the development that raises the eventual loss. It is also the *last* option clause 13.01-2S reaches, behind non-intervention, avoid, nature-based methods, accommodate and retreat.
- **Ignoring maladaptation and limits.** An evaluation that finds no downside and no limit has not evaluated anything.

Worked examples

Example 1 — scaffolded

A regional planning workshop lists five proposed measures for a Gippsland coastal shire.

#	Measure
I	Replace the shire's diesel plant fleet with electric equipment charged from a solar array
II	Apply a coastal inundation overlay preventing new dwellings below a mapped level
III	Revegetate 4 km of frontal dune with local provenance species
IV	Raise the switchgear of a low-lying pump station 1.2 m above the projected flood level
V	Restore 30 ha of saltmarsh landward of an existing rock wall

a. Classify each measure as mitigation, adaptation, or both. (5 marks)

b. For each measure you classified as adaptation **only** — not for the one classified as both — name the family it belongs to: protect, accommodate, retreat or avoid. (3 marks)

c. Explain the test you applied in part **a**. (2 marks)

Step 1 — set up the test. Mitigation reduces the hazard by lowering emissions and therefore future warming. Adaptation reduces exposure or vulnerability, leaving the hazard unchanged.

Step 2 — answer a. I is **mitigation** — it displaces diesel combustion, lowering emissions; it does nothing about any climate impact on the shire. II is **adaptation** — the hazard is unchanged, but assets are kept out of its reach. III is **adaptation** — a rebuilt dune absorbs storm wave energy. IV is **adaptation** — the flood still arrives, and the station keeps working through it. V is **both** — waterlogged saltmarsh sediment accumulates blue carbon, which is mitigation, while restoring the marsh on the landward side of the wall gives the intertidal habitat somewhere to move into as sea level rises, instead of it drowning against the structure, which is adaptation. Note that the marsh is *behind* the wall, so it cannot be dissipating wave energy in front of it; the adaptation mechanism here is migration space, not wave attenuation.

Step 3 — answer b. Three measures were classified as adaptation only, so three families are wanted. II is **avoid** — it stops exposure being created. III is **protect** — it keeps the hazard away from what is behind it. IV is **accommodate** — the hazard arrives and the harm is reduced. (V, on its adaptation limb, is **retreat** — managed realignment, in which the habitat rather than a building is the thing moved out of the hazard's reach. Naming it here earns nothing, because the stem asked only for the measures classified as adaptation alone; offering four families where three were asked for is a reported examiner complaint.)

Step 4 — answer c. Ask what each measure acts on. If it changes the quantity of greenhouse gas in the atmosphere, and therefore the hazard itself, it is mitigation. If it changes what or who is in the hazard's path, or how badly they are harmed when it arrives, it is adaptation. Measures acting on both limbs are classified as both, and saying so is not a hedge — it is the accurate answer.

Example 2 — scaffolded

A council is deciding how to respond to erosion threatening a foreshore car park and surf club. Two options are on the table.

Option	Description	Cost
A	Build a 300 m rock revetment now, designed for 0.8 m of sea level rise	\$6.4 million capital, \$40,000 a year maintenance
B	Revegetate the dune and begin annual beach profile surveys now; renourish when the dune toe passes a surveyed marker in three consecutive years; relocate the car park and club landward when renourishment is needed more often than every four years	\$0.9 million over five years, later stages costed when triggered

a. Identify which option is an adaptation pathway, and state the two features that make it one. (3 marks)

b. Give two reasons Option B is more robust than Option A under uncertain projections. (2 marks)

c. Identify one way Option A could prove maladaptive. (2 marks)

d. State one circumstance in which Option A would nonetheless be the better choice. (1 mark)

Step 1 — answer a. Option **B**. It sequences several options over time rather than choosing one, and each stage is attached to an observed, measurable trigger — a surveyed dune-toe marker, then a renourishment interval — so the decision rule is committed to now and the capital is not.

Step 2 — answer b. First, it performs acceptably across the range of projections: if sea level rise tracks low, the later stages are never triggered and the money is never spent; if it tracks high, the triggers fire earlier and the response escalates. Option A is sized to one number, and is either overbuilt or overtopped if that number is wrong. Second, it preserves flexibility — nothing in the early stages prevents the later ones, whereas a \$6.4 million structure creates a strong financial and political commitment to keep defending that line.

Step 3 — answer c. A revetment fixes the shoreline while the sea keeps rising, so the beach and any intertidal habitat in front of it are progressively drowned against the structure — coastal squeeze. The recreational beach that the surf club exists for is lost, and as the buffer disappears, wave energy reaching the wall increases and maintenance cost

rises. A second route is downdrift: by interrupting longshore sediment transport it can starve the beach beyond its northern end, exporting the erosion problem to a neighbour.

Step 4 — answer d. If the assets behind the line cannot be relocated — a hospital, a major road with no alternative alignment, a treatment plant — then retreat is unavailable, the lead time for protection is long, and building the structure is justified despite its costs.

Example 3 — unscaffolded

Explain why adaptation is necessary even under the most ambitious mitigation scenario, and why mitigation remains necessary despite the availability of adaptation. (6 marks)

Solution. The two halves rest on different arguments, and both must be made.

Adaptation is necessary because a quantity of climate change is already unavoidable. Greenhouse gases already emitted persist in the atmosphere for a long time, and the ocean's thermal inertia means it continues to take up heat and expand for centuries after atmospheric concentrations stabilise. Global average temperature has already risen by about 1.1 to 1.2 °C above pre-industrial levels, and Victoria's average annual temperature by about 1.2 °C since 1910. Sea level rise in particular continues well beyond the point at which emissions stop, because deep-ocean warming and ice sheet response operate on much longer timescales than emissions policy. Even on the most ambitious mitigation path, then, the hazard already in the system will reach existing coastlines, farms and ecosystems, and the only management response available for that increment is to reduce the exposure and vulnerability of what it reaches. This is precisely why the study design specifies adaptation to the effects of *unavoidable* change.

Mitigation remains necessary because adaptation has limits, and the limits are reached at levels of change that mitigation determines. Some limits are soft — an option exists but there is no funding, legal power or social licence for it — and can be shifted. Others are hard: an alpine ecosystem whose climatic envelope has moved above the summit has nowhere to migrate to, and a low sandy barrier cannot be defended indefinitely against a sea that continues to rise. Beyond those limits there is residual risk that no adaptation removes. Adaptation is also costly, and its cost rises non-linearly with the amount of change, so an unmitigated trajectory eventually presents a bill that cannot be paid, unevenly distributed towards those with the least adaptive capacity.

The relationship is therefore complementary and not substitutable: mitigation determines how much has to be adapted to, adaptation determines how much damage that quantity causes, and each becomes more expensive as the other is neglected.

Example 4 — unscaffolded

Morrindah Shire, on a low-lying stretch of the Gippsland coast, has commissioned a local coastal hazard assessment. It maps a 1.9 km frontage where a sealed road, 40 dwellings, the Wingerra Point Caravan Park and 60 ha of saltmarsh behind a degraded dune are exposed to inundation and erosion. The dune is retreating at about 0.6 m a year. The council's engineers propose a rock wall along the full frontage. The saltmarsh is a feeding area for migratory shorebirds.

Evaluate the proposal and recommend an alternative approach. (8 marks)

Solution. The proposal would work as engineering and fails as adaptation, for four reasons, and the alternative follows from them.

The first problem is coastal squeeze. Fixing the shoreline with a wall while mean sea level continues to rise removes the space the intertidal zone needs to migrate landward. The 60 ha of saltmarsh behind the dune would be progressively drowned against the structure rather than moving inland, so an option adopted to protect assets would destroy the habitat and the migratory shorebird feeding area it supports. Because that habitat also dissipates wave energy, its loss raises the wave energy reaching the wall, increasing maintenance costs over the structure's life — the option undermines itself.

The second is the transfer of harm. A continuous 1.9 km structure interrupts longshore sediment transport, so the shoreline beyond each end is starved of sand and erodes faster. The problem is exported to neighbouring land rather than solved, which is a defining signature of maladaptation.

The third is scope. The wall is proposed for the full frontage, which means the shire pays to defend the saltmarsh and the caravan park at the same standard as the road and dwellings, although their values, relocatability and design lives differ enormously. A caravan park is among the most relocatable land uses on any coast; a saltmarsh does not need protection from the sea at all, it needs somewhere to move to.

The fourth is the commitment the wall creates. It is a hard, capital-intensive and effectively irreversible option sized against a single sea level rise figure. If change tracks above that figure the structure is overtopped, with the loss made larger by whatever has been built behind it in the meantime — the safe development paradox. If change tracks below, decades of rates have been spent on a hazard that did not arrive. Either way the shire has removed its own future options.

The alternative is a differentiated adaptation pathway, applying a different family of option to each asset — and taking the options in the order clause 13.01-2S requires them to be assessed. **Avoid**: apply hazard overlays and setbacks immediately, so no further exposure is created behind the frontage — the cheapest action available and only available now. **Nature-based, protecting**: revegetate and fence the dune to rebuild the sediment buffer in front of the road and dwellings. **Accommodate**: raise the road pavement and services where realignment is impractical, and require flood-resilient construction for the dwellings. **Retreat**, in two forms: secure a landward migration corridor for the saltmarsh by covenant or acquisition, so the habitat moves inland as the water rises rather than drowning against the frontage; and plan the relocation of the caravan park now, with a trigger point — the dune toe passing a surveyed marker in three consecutive annual surveys, or renourishment becoming necessary more often than a stated interval — so the move is decided in advance and executed calmly rather than after a storm. Retain focused protection only where an asset is both immovable and worth more than its defence.

The pathway should be built on the assessment's own mapped levels, using not less than the 0.8 m by 2100 benchmark required by the Marine and Coastal Policy 2020, and higher if local conditions justify it, since that benchmark is a floor rather than a ceiling. It should follow the seven-stage process in Victoria's Resilient Coast — Adapting for 2100+, which is not merely good practice but the statutory guideline made under s 41 of the *Marine and Coastal Act 2018* (Vic) that must be followed in assessing coastal hazard risk. Because retreat and acquisition affect identified people, the process must also carry genuine community engagement, and consultation with any body holding a statutory heritage interest over the frontage. In this scenario that body is the **Morrindah Coastal Heritage Trust**, which — like Morrindah Shire and Wingerra Point themselves — is invented for this exercise and is not a real organisation. The transferable point survives the invention: a heritage consultation step sits inside the statutory process rather than beside it as a courtesy, so a pathway that schedules works and acquisitions over a registered heritage area without identifying who must be consulted is incomplete as a matter of law, not just of manners.

Practice questions

Scaffolded

Q1. Define **adaptation** as the term is used in managing climate change. (1 mark)

Q2. State the three ingredients of climate risk, and identify which of them adaptation acts on. (2 marks)

Q3. Explain why some climate change is described as *unavoidable*. (2 marks)

Q4. Classify each measure as mitigation or adaptation. (4 marks)

Measure	Classification
Installing shade structures and sprinklers in a dairy holding yard	
Capturing carbon dioxide and storing it in an offshore geological formation	
Applying a coastal inundation overlay to a low-lying subdivision	
Replacing a coal-fired generator with offshore wind capacity	

Q5. Distinguish between the *protect*, *accommodate* and *retreat* families of adaptation option, using a coastal example of each. (3 marks)

Q6. Define **resilience**, and state which of its three capacities a raised floor level builds. (2 marks)

Q7. The table lists four adaptation options at Gippsland. For each, name the family and state the mechanism by which it reduces harm. (4 marks)

Option	Family and mechanism
Replacing open irrigation channels with pipeline in the Macalister Irrigation District	
Securing land for saltmarsh to migrate into as sea level rises	
Setback controls preventing new dwellings below a mapped inundation level	
Relocating a foreshore surf club landward at a defined trigger point	

Q8. A student writes: *"Gippsland will be 1.8 °C warmer."* State three things missing from this statement that a usable projection must include. (3 marks)

Q9. Define **maladaptation**, and describe two of its recognisable signatures with an example of each. (4 marks)

Q10. Victoria's Marine and Coastal Policy 2020 requires planning for sea level rise of not less than 0.8 m by 2100. In October 2024 the Minister set a scenario of 1.2 m by 2100 for the coastal town of Port Fairy.

a. Calculate the percentage increase in the planning benchmark applied at Port Fairy relative to the statewide figure. Show your working. (2 marks)

b. State what this decision demonstrates about the nature of the statewide benchmark. (1 mark)

c. Explain one consequence for a landowner of the benchmark applied to their area being raised. (2 marks)

Q11. Explain why lower cool-season rainfall and more intense rainfall events can both be projected for Gippsland, and state one implication for adaptation planning. (3 marks)

Unscaffolded

Q12. State one reason why the "avoid" family of adaptation options is usually the cheapest, and one limitation on its use. (2 marks)

Q13. Distinguish between a *soft limit* and a *hard limit* to adaptation, and give one example of each from Gippsland. (3 marks)

Q14. Compare hard and soft adaptation options with reference to cost, reversibility and the certainty of the protection they deliver, and state which is preferable when projections carry low confidence. (4 marks)

Q15. Wirrancoort Pastoral Pty Ltd milks 480 cows on 260 ha of irrigated pasture in Gippsland. Its water entitlement has been fully delivered in only six of the last ten seasons, and the business has recorded falling milk yields in February heat.

Recommend three adaptation options for this business, each from a different type in the classification, and state the mechanism by which each reduces harm. (5 marks)

Q16. Explain how the "safe development paradox" can cause a protective structure to increase the total damage eventually suffered by a community, and state one measure that prevents it. (5 marks)

Q17. A council proposes to meet a projected increase in extreme heat days by subsidising domestic air-conditioning units, with no other measures.

Evaluate this as an adaptation option, identifying at least two weaknesses, and propose a stronger set of options. (6 marks)

Q18. Discuss why adaptation options must be selected "at a selected region or location" rather than prescribed nationally, using Gippsland to illustrate. Refer to hazard, exposure, vulnerability and adaptive capacity. (8 marks)

Q19. *"The best adaptation plan is the one that decides least now."*

Discuss this statement with reference to Gippsland. Identify at least three projected changes for the region with their scenario and horizon, describe at least four adaptation options of different families or types and trace each to a projected change, explain the role of trigger points, and identify the limits of the approach the statement recommends. (10 marks)

Answers

Q1. A deliberate adjustment in human or ecological systems to actual or expected climate and its effects, which reduces harm by lowering exposure or vulnerability rather than by reducing the climate hazard itself. (1)

Q2. Hazard, exposure and vulnerability (1). Adaptation acts on exposure and vulnerability; mitigation acts on the hazard (1).

Q3. Greenhouse gases already emitted persist in the atmosphere, and the ocean's thermal inertia means it keeps taking up heat and expanding for centuries after concentrations stabilise (1), so a quantity of warming and sea level rise will arrive regardless of future emissions decisions and can only be managed by adaptation (1).

Q4. Shade and sprinklers — adaptation (1). Carbon capture and geological storage — mitigation (1). Coastal inundation overlay — adaptation (1). Offshore wind replacing coal — mitigation (1).

Q5. *Protect* keeps the hazard away from the asset — a revetment or a restored dune (1). *Accommodate* lets the hazard arrive but reduces the harm — raising a floor level above the projected flood height (1). *Retreat* moves the asset out of the hazard's reach — relocating a foreshore caravan park landward (1).

Q6. Resilience is the capacity of a system to absorb a disturbance, keep functioning and reorganise while retaining its essential function and identity (1). A raised floor level builds **absorptive** capacity (1).

Q7. Pipeline — protect / structural; evaporation and seepage losses between storage and farm gate are eliminated, so more of each entitlement reaches pasture in a drier year (1). Saltmarsh migration land — **retreat**, in its managed-realignment form / ecosystem-based; the marsh is the asset here, and giving it land behind its present position moves it out of the water's reach as sea level rises instead of leaving it to drown against a fixed boundary — a *nature-based method* in the order clause 13.01-2S sets (1). Setback controls — avoid / institutional; no new assets are placed where the hazard will reach, so exposed value stops growing (1). Relocating the surf club at a trigger — retreat; exposure is removed permanently rather than defended repeatedly, and the trigger means the move is decided on observed evidence (1).

Q8. The emissions scenario (1); the time horizon (1); the baseline period the change is measured against (1).

Q9. Maladaptation is an adaptation action that *increases* the risk of adverse outcomes rather than merely failing to reduce it (1), and the increase may fall now, on someone else, or later (1). Any two signatures, each named with its mechanism **and** an example (1 each): *transfers the harm* — a groyne interrupts longshore transport and accelerates erosion downdrift; *removes the buffer* — hard armour causes coastal squeeze, drowning the saltmarsh in front of it; *induces new exposure* — a levee triggers subdivision behind it; *locks in a path* — a pipeline sized to today's irrigated area makes reducing that area very hard; *shifts the burden* — fossil-fuelled air-conditioning adapts to heat while raising emissions.

Q10. a. $(1.2 - 0.8) / 0.8 \times 100 = 0.4 / 0.8 \times 100 = 50\%$ (2 — 1 for working, 1 for the value). **b.** That 0.8 m is a minimum, or floor, which the Policy permits exceeding where local conditions justify it — not a maximum (1). **c.** The mapped hazard area expands, so more land falls within the overlay (1); permits for new development or subdivision may be refused or made conditional, floor levels and construction standards may be raised, and land value and insurance cost may be affected (1).

Q11. A warmer atmosphere holds more water vapour, so when rain falls it can fall harder, while the poleward shift of the westerlies reduces the frequency of the cool-season frontal systems that deliver Gippsland's winter and spring rainfall (2). Implication: the region must adapt to less reliable water supply and to larger flood peaks at the same time, so water security and flood options are both needed and no single option addresses both (1).

Q12. Either reason earns the mark: it prevents exposure being created rather than paying to defend or remove it later; or it is delivered through planning controls rather than capital works, so it costs little to apply (1). Limitation: it is only available before development occurs — it does nothing about assets already in the hazard zone (1).

Q13. A soft limit is one where adaptation options exist but are not currently accessible because of cost, legal power or social acceptance, and can be shifted (1). A hard limit is one where no adaptive action can avoid intolerable risk (1). Examples: soft — planned retreat of foreshore assets is technically possible but lacks funding and community

acceptance; hard — alpine ecosystems whose climatic envelope moves above the summit have nowhere to migrate to (1).

Q14. Hard options are engineered, capital-intensive and long-lived; soft options are ecological, institutional or informational and cheaper to establish (1). Hard options are difficult or impossible to reverse and commit future decisions; soft options can be adjusted, extended or abandoned (1). Hard options deliver a high degree of protection up to their design limit and fail abruptly beyond it; soft options deliver less certain protection but degrade gradually (1). Where confidence in projections is low, soft and flexible options are preferable because they remain appropriate across a range of futures (1).

Q15. Any three, each from a different **type** in the six-type classification (1 each for three correctly distinct types = 3), with a stated mechanism for each (2). One option per type: *structural / engineered* — pipe or line the farm channels and upgrade the on-farm irrigation layout, so evaporation and seepage losses are eliminated and more of the entitlement reaches pasture; *technological* — seasonal forecasting and soil-moisture monitoring to time irrigation and fodder purchase, raising production per megalitre; *ecosystem-based* — shelterbelts and laneway shade trees, cutting radiant heat gain on the cattle in February and wind-driven evaporative loss from pasture; *institutional / regulatory* — carryover and temporary trade on the entitlement, so water can be shifted between seasons rather than lost in a wet one and missing in a dry one; *economic / financial* — forward purchase of temporary water and a fodder budget fixed before the season, moving price risk off the season it lands in; *informational / social* — a farm business risk plan with pre-agreed decision rules for a dry season. Shade and sprinklers in the holding yard are a good option but are **structural and technological**, so they cannot supply a third type alongside the first two.

Q16. See fully-worked solutions. Chain: protection is built → the place is perceived as safe → more development occurs behind it → exposed value rises → the design standard is eventually exceeded → the loss is larger than it would have been without the structure. Prevention: pair any protective works with hazard overlays and setback controls that cap development behind the structure. (5)

Q17. See fully-worked solutions. (6)

Q18. See fully-worked solutions. (8)

Q19. See fully-worked solutions. (10)

Fully-worked solutions

Q1. The definition must contain the *mechanism*, not just the word “adjustment”. Adaptation reduces exposure or vulnerability; it does not reduce the hazard. Answers that say “changing to cope with climate change” are circular and earn nothing. Note also that this is the management sense of the word, not Chapter 4’s biological sense.

Q2. Hazard, exposure and vulnerability — risk arises from the *interaction* of the three, and is not a product of them. The second half of the question is the discriminator the whole subtopic rests on: mitigation lowers emissions and so lowers the hazard; adaptation changes what is in the hazard’s path and how badly it is harmed. If you can state this, every classification question in the chapter becomes mechanical.

Q3. Two distinct sciences, one mark each. Atmospheric persistence: carbon dioxide already emitted stays in the atmosphere for a long time, so concentrations do not fall when emissions do. Ocean thermal inertia: the ocean has enormous heat capacity and mixes slowly, so it continues absorbing heat and thermally expanding for centuries after stabilisation — which is why sea level rise in particular is committed well beyond the emissions decision. Quoting the observed 1.2 °C of Victorian warming since 1910 strengthens the answer but does not by itself explain *why* further change is unavoidable.

Q4. Apply the test once per row. Shade and sprinklers change nothing about the atmosphere; they lower the heat load on exposed animals, so vulnerability — adaptation. Carbon capture and storage keeps carbon dioxide out of the atmosphere — hazard, mitigation. An overlay keeps assets out of the hazard’s reach — exposure, adaptation. Offshore wind displacing coal lowers emissions — mitigation. The trap in this question is the offshore wind row: it is located in Gippsland and is often discussed alongside the region’s climate response, but its mechanism is emissions, so it belongs to 11B.

Q5. Three families, three examples, and the distinction must be the *relationship between hazard and asset* rather than the type of works. Protect: the hazard is stopped before it arrives. Accommodate: the hazard arrives and is tolerated

with reduced harm. Retreat: the asset leaves. A common error is to classify by hardness — dune revegetation is soft *and* protective, and a planning overlay is institutional *and* avoidance.

Q6. The definition needs three elements: absorb the disturbance, continue functioning, and reorganise while keeping essential function and identity. "Bouncing back" is too weak, because it omits reorganisation. A raised floor level builds absorptive capacity: nothing about the system changes, and the flood is simply survived. Contrast with adaptive capacity, which would be changing how the building is used seasonally, and transformative capacity, which would be relocating it.

Q7. One mark per row, and each row needs *both* the family and a stated mechanism — naming the family alone is half an answer. The pipeline row is the one most often written loosely: "saves water" is not a mechanism. The water is saved *because* open channels lose water to evaporation from the surface and seepage through the bed, and a closed pipe eliminates both. Quote the district's numbers carefully if you quote them at all: the three phases of the modernisation are credited with about 4,000 ML, 9,600 ML and 7,200 ML respectively — roughly 20,800 ML in total, though only the first is stated as long-term average annual yield — and measured distribution system efficiency for the district reached 87% in 2023-24, having run at 80%, 79% and 86% in the three preceding years. Figures announced at the start of a component of the works, such as the 4,300 ML and "over 90 per cent" published when the Newry pipeline was launched in January 2023, are forecasts for that component and not achieved results for the district. The saltmarsh row is the one most often mis-classified: because a marsh can also shelter something, students reach for *protect*, but here the marsh is the thing being saved and nothing is being kept away from it — the option moves the asset out of the hazard's reach, which is retreat. On the setback row, note that the option creates no protection at all — its entire effect is on future exposure, which is what makes it cheap.

Q8. All three are needed. Scenario, because the projected change differs substantially between low and high emissions futures. Horizon, because 2050 and 2090 differ by more than the scenarios do. Baseline, because a change of 1.8 °C measured against 1986–2005 is not the same statement as 1.8 °C against pre-industrial. The omission is not hypothetical: the Alpine Peaks frost-day projection in the theory table is published by a real regional strategy with no scenario and no baseline attached, which is exactly why it cannot be set beside the VCP19 rows and compared. A fourth mark-worthy addition, if asked to improve the statement, is the confidence rating, which 10D covers.

Q9. The definition must include that the action *increases* risk, and the three dimensions — now, for others, or later — are what make it more than "an option that did not work". For the signatures, the mechanism matters more than the label. Downdrift erosion works because longshore transport is a conveyor: intercepting sand at one point starves everywhere downstream of it. Coastal squeeze works because intertidal habitat needs to migrate landward as water rises, and a wall denies it the space. The safe development paradox works because protection changes behaviour, not just water levels.

Q10. a. Percentage increase is the change over the original: (1.2 − 0.8) / 0.8 × 100 = 50%. A frequent slip is 1.2 / 0.8 × 100 = 150%, which is the new value as a percentage of the old, not the increase. **b.** The decision demonstrates that the statewide figure is a floor. The Policy expressly enables planning for higher values, and here the Minister adopted a higher scenario over a panel recommendation to retain 0.8 m. **c.** The practical consequences run through the planning scheme: a larger mapped hazard area brings more land within the overlay, so permit applications for new dwellings or subdivision face refusal or conditions, minimum floor levels and construction standards rise, and both insurance cost and land value can move. This is also why the benchmark is contested — it allocates cost between present landowners and future ones.

Q11. The apparent contradiction resolves into two separate mechanisms operating on different quantities. *Totals*: the poleward shift of the mid-latitude westerlies moves the cool-season frontal systems that deliver Gippsland's winter and spring rain further south, so fewer of them cross the region and cool-season totals fall. *Intensity*: a warmer atmosphere holds more water vapour, so the rain that does fall can fall harder. Falling totals and rising intensity are therefore entirely compatible. The adaptation implication is the important mark: the region needs water security options — storage, efficiency, entitlement flexibility — and flood options — capacity, retention, setbacks — simultaneously, and an option chosen for one can worsen the other, which is why pathways are appraised against a range of futures rather than a single design number.

Q12. The reasons are that avoidance prevents exposure from being created rather than paying to defend or relocate it afterwards, and that it is delivered through planning controls rather than capital works. The limitation is temporal and absolute: avoidance is only available before development occurs. Once dwellings, roads and a caravan park are in the

hazard zone, the shire's remaining choices are protect, accommodate or retreat, all of which cost more. This is why applying overlays is almost always the first action in a pathway even though it builds nothing.

Q13. The distinction is about whether options exist at all. Soft limits are constraints on *access* to options — funding, legal power, workforce, social licence — and adaptation policy largely exists to move them; planned retreat of Gippsland foreshore assets is technically straightforward and constrained mainly by cost and acceptance. Hard limits are constraints on *existence* of options: an alpine ecosystem whose climatic envelope has moved above the summit cannot migrate further, and no management action returns it to a tolerable state. The consequence of a hard limit is residual risk that must be managed by insurance, emergency response or accepted loss — and residual risk at hard limits is the strongest argument for mitigation.

Q14. Four marks, and a one-sided answer caps at two. *Cost*: hard options carry high capital cost and ongoing maintenance; soft options are cheaper to establish, though ecological options need time and continuing management. *Reversibility*: a revetment cannot be undone cheaply and creates a financial and political commitment to keep defending that line, so it removes future options; revegetation, overlays and monitoring can each be adjusted or abandoned. *Certainty*: hard options deliver a high standard of protection up to their design limit and fail abruptly and completely beyond it, while soft options deliver less certain protection that degrades gradually — which is often preferable, because a gradual failure is visible in time to respond. Under low confidence, soft and flexible options are preferable, because the value of keeping options open rises with uncertainty; the exception is an immovable, high-consequence asset with a long protection lead time, where hard protection may be justified despite the uncertainty.

Q15. Three options, three different types, three mechanisms — the marks are lost by naming three variants of the same type, most often three engineering fixes. The business has two distinct problems and a good answer addresses both: unreliable water delivery in four of ten seasons, and February heat depressing yield. A structural option addresses delivery losses; a technological option addresses the timing of decisions under variability; an ecosystem-based option — shelterbelts and laneway shade — addresses heat load on the animals. Watch the trap in that third slot. *Accommodate* is a **family**, not a type, so offering "an accommodate option" answers a different question from the one asked; and the obvious accommodate answer for heat, shade and sprinklers in the holding yard, is itself structural and technological, so a student who lists it third has in fact submitted two structural options and is caught by the very rule they were warned about. Institutional, economic and informational options are all available and all unused, and each addresses the water-reliability limb from a different direction. Note the mechanism for shade, whether from trees or a built structure: it does not lower air temperature meaningfully, it reduces radiant heat gain and increases evaporative cooling from the animal, which lowers core heat load and protects milk yield and conception rates. If a transformational option is offered — cutting irrigated area and changing system — remember that transformational is an *ambition level* rather than a type, so it still has to be assigned one, and it should be justified by the entitlement reliability trend rather than asserted.

Q16. *Model response (5 marks).* The paradox is that protection changes behaviour as well as water levels, and the behavioural change can outweigh the hydraulic one.

When a levee or wall is built, the land behind it is protected up to the structure's design standard, and it is also *perceived* as safe. Hazard mapping may be relaxed, planning controls may be eased, insurance may become cheaper and more available, and development follows. Over the following decades the value and population exposed behind the structure grows, often substantially, and grows precisely because the structure exists.

The structure, however, has a finite design standard. It was sized against a particular flood or sea level, and under a changing climate the event that exceeds it becomes more likely over the structure's life. When that event arrives the protection fails, and it fails for everything behind it simultaneously, because a single line of defence has a single point of failure. The community that is flooded is now larger and more valuable than the one that would have been flooded had nothing been built, and it is less prepared, because decades of protection have removed the flood from local memory and from local practice. The total expected damage can therefore be higher with the structure than without it.

The measure that prevents this is to pair protective works with the avoidance family: hazard overlays and setback controls that cap development behind the structure, so that the protected area does not accumulate new exposure. The protection then benefits the assets it was built for without generating the additional exposure that converts an eventual overtopping into a catastrophe. Retaining the hazard mapping and continuing to communicate residual risk to residents does the same work on the behavioural side.

Q17. *Model response (6 marks).* Subsidised air-conditioning is a genuine adaptation option, and as the *only* measure it is a weak plan.

What it does well should be conceded first. Extreme heat is the deadliest climate hazard in Victoria, the projections for more days above 35 °C carry high confidence, and mechanical cooling directly reduces the physiological heat load on exposed people. It acts on vulnerability, it can be delivered quickly, and it reaches individual households.

The weaknesses are structural. First, it is a maladaptive trade-off on a fossil-fuelled grid: cooling demand peaks exactly when the grid is most stressed, so the option raises emissions and therefore the hazard it is responding to, while also increasing the chance of the network failure that would remove the protection at the moment of greatest need. Second, it distributes protection by capacity to use it: a subsidy covers the capital cost but not the running cost, so low-income households, renters whose landlords control the building, and people in poorly insulated housing gain least — and these are the groups with the highest heat vulnerability. Third, it protects only people who are inside a cooled dwelling, and does nothing for outdoor workers, people travelling, or those without secure housing. Fourth, it does nothing about the urban heat island that raises the local temperature in the first place, and running the units discharges waste heat to the street, marginally worsening it. Fifth, it creates a dependency with a single point of failure — a heatwave with a coincident outage removes all of the protection at once.

A stronger set works at several levels at once. Retain subsidised cooling, but tie it to building performance: subsidise insulation, draught sealing, shading and efficient reverse-cycle units together, so that the same comfort is achieved with less energy and the dwelling stays habitable for longer during an outage — an *accommodate* option acting on the building rather than the appliance. Add urban tree canopy and shade along walking routes and at transport stops, an ecosystem-based option that lowers ambient temperature for everyone, including those outdoors, and delivers a small mitigation co-benefit. Add a heat-health warning system with named cooled public refuges and active outreach to people known to be at risk, an informational and institutional option that reaches those the appliance subsidy misses. Add planning and building requirements for thermal performance and shading in new dwellings, an *avoid* option that stops new heat-vulnerable housing being created. Pair the cooling demand with renewable generation and storage so the option does not raise the hazard. And review whether workforce rules for outdoor work address extreme heat. The set costs more than the subsidy alone, reaches the people most at risk, and does not undermine mitigation.

Q18. *Model response (8 marks).* Mitigation can be prescribed nationally because a tonne of carbon dioxide has the same effect on the hazard wherever it is avoided. Adaptation cannot, because all four of the things that determine what a place should do — including the hazard itself — are properties of that place.

Hazard varies by place, even within one region. Gippsland's own VCP19 projections, under RCP8.5 for 2040–2059 against a 1986–2005 baseline, include a median rise of about 2.0 °C in annual daily maximum temperature and 1.4 °C in annual daily minimum, continued cool-season rainfall decline at medium to high confidence, about 32% more very high fire danger days at Bairnsdale, and about 24 cm of sea level rise at Inverloch by the 2050s. But those changes do not arrive uniformly: sea level rise is the operative hazard on the Ninety Mile Beach and irrelevant in the Strzelecki Ranges, while the loss of frost matters most in the uplands — the East Gippsland Regional Catchment Strategy projects the Alpine Peaks local area falling from over 45 frost days a year to 26 to 28, a drop of about 40%, against the 2.3 days a year Bairnsdale records on the lowland. Even the statewide figures do not transfer: Victoria as a whole is projected about 40% more very high fire danger days, which is not Gippsland's 32%. A national prescription must either be so general as to be useless or wrong for most places it applies to.

Exposure varies by place. The same 0.8 m of sea level rise floods a low sandy barrier with a township, a caravan park and a Ramsar-listed lagoon system behind it, and does nothing to a rocky shore. Gippsland's exposure profile is unusually broad — around 700 km of coast including an artificially maintained entrance at Lakes Entrance, the largest irrigation district in southern Victoria, a Ramsar wetland, alpine ecosystems and a snow-dependent visitor economy, and a coal and gas industrial base. The options that follow are correspondingly different: dune revegetation and setbacks on the barrier, piped distribution in the Macalister Irrigation District, migration space for saltmarsh in the Lakes, and economic diversification in the alpine areas. Nothing links these except that they are in one region.

Vulnerability varies by place. Two exposed assets are harmed differently by the same hazard. A dairy business on reliable groundwater and one wholly dependent on surface entitlement face the same rainfall deficit with very different consequences; a modern dwelling with a raised floor and a 1960s beach house on the same street face the same storm surge differently. Vulnerability depends on sensitivity and coping capacity, both of which are local and both of which change what the right option is.

Adaptive capacity varies by place, and this is the limb most often omitted. Capacity is the money, information, skills, institutions, entitlements and social networks available, and it decides which options are actually deliverable rather than merely correct. A shire with rates revenue, technical staff and a completed local coastal hazard assessment can run a pathway with monitoring and staged works; a smaller shire without them cannot, however well the pathway is designed. This is exactly why Victoria's structure has a regional layer as well as a state one: the Adaptation Action Plans required under the *Climate Action Act 2017* (Vic) work system by system, while the Gippsland Regional Climate Change Adaptation Strategy 2021–2026 works on regional adaptive capacity and place-based priorities. Neither replaces the local coastal hazard assessment that supplies the actual mapped levels.

The state's role is therefore to set the framework, the benchmarks and the evidence base — a minimum 0.8 m by 2100 through the Marine and Coastal Policy 2020, carried into every planning scheme by clause 13.01-2S, and a compulsory process through Victoria's Resilient Coast — Adapting for 2100+ — while the selection of options remains local. That is precisely the division the dot point's wording reflects: options are chosen *at a selected region or location*, against that place's own projections, exposure and capacity.

Q19. *Model response (10 marks).* The statement is a sharp and mostly accurate summary of adaptation pathways thinking, and it overstates its case in one important respect: what a good plan decides least of is *capital commitment*, not decisions. A pathway decides a great deal now — it decides the rules, the triggers and the sequence. What it withholds is irreversible spending.

The projected changes for Gippsland must be stated with scenario, horizon and baseline, and with the source they come from. The *Gippsland Climate Projections 2019* report (VCP19), which is the generation the region's current strategy was written against, gives the following for 2040–2059 under RCP8.5 against a 1986–2005 baseline: annual daily maximum temperature up by a median 2.0 °C and annual daily minimum by 1.4 °C; continued cool-season rainfall decline through winter and spring at *medium to high* confidence, with some chance of little change, while 1-in-20-year daily rainfall rises 3 to 17%, so heavy events intensify as totals fall; and, at Bairnsdale, about 5.8 more very high fire danger days a year — a 32% increase — with days below 0 °C falling from 2.3 a year to about 0.6. Sea level at Inverloch is projected a median 24 cm higher by the 2050s under RCP8.5, on a trajectory the Marine and Coastal Policy 2020 requires be planned for at not less than 0.8 m by 2100.

Two figures that are often quoted alongside these belong to other sources and must be labelled as such. The Alpine Peaks fall from over 45 frost days a year to 26 to 28 — about 40%, not the "halving" its source calls it — comes from the East Gippsland Regional Catchment Strategy and carries no scenario or baseline. The "about 40% more very high fire danger days" figure is CSIRO and Bureau of Meteorology's statewide number for Victoria, not Gippsland's 32%. Victoria's observed warming of about 1.2 °C since 1910 is a VCP24-era observation; the VCP19 report itself says just over 1 °C between 1910 and 2018. The current projection generation is VCP24, built on CMIP6 and the SSP scenarios, and a plan being written now should be built on it.

Four adaptation options, of different families and types, each traced to a change. *Nature-based, protecting*: revegetate and fence the frontal dunes of the Ninety Mile Beach, addressing sea level rise and storm intensity by rebuilding the sediment buffer that absorbs wave energy before it reaches assets. *Protect, structural and technological*: the Macalister Irrigation District Modernisation, which replaced open channels with pipeline and automated outlets between 2013 and February 2024, addressing declining cool-season rainfall by eliminating the evaporation and seepage losses between storage and farm gate — about 20,800 ML of savings across its three phases, with the district's measured distribution system efficiency reaching 87% in 2023-24. *Avoid, institutional*: coastal hazard overlays and setback controls under planning scheme clause 13.01-2S, addressing rising inundation risk by preventing new exposure being created behind the barrier. *Accommodate, mixed*: fuel management, refuges, warning arrangements and interface building standards, addressing the projected increase in very high fire danger days by reducing both fire intensity and the vulnerability of exposed people and buildings. A fifth, *transformational*, addresses declining snow reliability by diversifying the alpine visitor economy away from a variable that is projected to keep falling.

Trigger points are what make "deciding least" responsible rather than negligent. A trigger is an observed, measurable threshold that starts the next action — a dune toe passing a surveyed marker in three consecutive annual surveys, a renourishment interval falling below a set number of years, a design flood level exceeded more than once a decade, a protection cost exceeding the value of the asset protected. Attaching options to triggers converts a wish list into a decision rule, and it delivers four things. The plan is robust, performing acceptably whether change tracks high or low, instead of optimally under one number. It preserves flexibility, so later options are not foreclosed by earlier

capital. It matches spending to evidence, committing money when monitoring shows it is needed. And it settles the retreat decision in advance and in public, at a calm moment, rather than in the week after a storm — which is fairer to the people affected and much cheaper. Victoria's Resilient Coast — Adapting for 2100+, the guideline made under s 41 of the *Marine and Coastal Act 2018* (Vic) that must be followed in assessing coastal hazard risk, supplies a seven-stage process and a pathways template for exactly this.

The limits of the approach are real, and a 10-mark answer must name them. First, monitoring is not free, and a pathway without funded surveys, defined markers and someone accountable for reading them is a plan to do nothing with extra steps. Second, some options have lead times longer than the interval between trigger and impact: land acquisition, major realignment and ecological restoration take years to decades, so a trigger that fires too late leaves no time to act, and pathways must therefore use *lead indicators*, not damage. Third, deferral is not available for immovable, high-consequence assets — a hospital or a treatment plant may need protection built before the hazard is observed. Fourth, delay has a political cost: an unfunded future stage is easy for a later council to abandon, so "deciding least" can become deciding nothing. Fifth, pathways manage uncertainty but do not remove hard limits; where the climatic envelope of an alpine ecosystem moves above the summit, no sequencing helps, and the residual risk must be carried. Sixth, staging can be inequitable if the assets defended first belong to those with the most influence.

So the statement is right about capital and wrong about decisions. The best adaptation plan **commits** least irreversibly and **decides** most explicitly: it decides the overlays now, because avoidance is only available before development; it decides the triggers, the monitoring and the accountability now; it decides in advance which assets will eventually be defended and which will be relinquished; and it leaves open only the question of *when*, because that is the only question the projections cannot yet answer. And because adaptation has limits at any level of change, the plan is only half a response — the other half is mitigation, which determines how much has to be adapted to at all.

---

§2A RECORDED SCOPE DECISION

Aboriginal and Torres Strait Islander knowledge — deliberately not covered (ICIP). This workbook does not reproduce Aboriginal and Torres Strait Islander knowledge, cultures or histories. The Study Design's Aboriginal and Torres Strait Islander knowledge and perspectives requirement is therefore not covered here. Real Aboriginal and Torres Strait Islander knowledge must be sourced by teachers directly with the relevant community under the appropriate protocols; any Indigenous-looking example in this book is fictitious and must not be taken as real.

§2A RECORDED SCOPE DECISION

Aboriginal and Torres Strait Islander knowledge — deliberately not covered (ICIP). This workbook does not reproduce Aboriginal and Torres Strait Islander knowledge, cultures or histories. The Study Design's Aboriginal and Torres Strait Islander knowledge and perspectives requirement is therefore not covered here. Real Aboriginal and Torres Strait Islander knowledge must be sourced by teachers directly with the relevant community under the appropriate protocols; any Indigenous-looking example in this book is fictitious and must not be taken as real.

Theory

Chapter 11 has so far produced three things a decision-maker can hold: a list of regional risks and opportunities (**11A**), a set of mitigation options (**11B**) and a set of adaptation options (**11C**). None of them tells anybody what to do. Somebody now has to choose, with a fixed budget, in a real region, against a statute, on evidence that is incomplete and will keep changing, while the people affected disagree about what matters. That choosing is this subtopic's key knowledge: *"interconnections and tensions between factors that influence responsible decision-making around managing climate change: diverse stakeholder values, knowledge and priorities, regulatory frameworks that inform environmental management strategies, use and interpretation of historical and current scientific data, and application of new technologies"*.

Two nouns carry the dot point. An **interconnection** is a relationship in which a change in one factor changes what another factor requires, permits, wants or can see. A **tension** is a structural opposition: moving towards one pole necessarily moves away from another, so someone must choose and be answerable for choosing. The test for a tension is not "do people disagree" but "does satisfying one more fully mean satisfying the other less". **8F** taught those two ideas, the general anatomy of the four factors, and what the word *responsible* demands of any environmental decision. This subtopic does not repeat that. It supplies the part that is specific to climate — and climate decisions have a structure that no other environmental decision in this course shares.

Question	Where it is taught
What the risks and opportunities *are*, at the selected region	11A
What the mitigation options *are*, and what each one abates	11B
What the adaptation options *are*, and what resilience each one builds	11C
How climate data is produced, modelled, and given a confidence rating in IPCC language	10A–10D
The six sustainability principles; the four value systems; how to tell an evidence claim from a value claim	3B, 3C, 3D
The same key knowledge for environmental management generally — the four factors, adaptive management, the five tests of a responsible decision	8F
The same key knowledge for energy futures	13D
Cost–benefit analysis, risk matrices and discounting as tools	8E

Three hand-offs are worth stating precisely, because this subtopic uses them without re-teaching them. **11B** tabulates the mitigation instruments — the Paris Agreement and Australia's nationally determined contribution, the *Climate Change Act 2022* (Cth), the safeguard mechanism, the ACCU scheme, the Victorian targets — and supplies the appraisal tools: cost per tonne abated, the abatement hierarchy, and the six criteria by which a mitigation option is

ranked, among them additionality and leakage, and permanence and reversal risk. **11C** supplies the adaptation taxonomy, the 0.8 m sea level planning benchmark, and adaptation pathways with trigger points. Here those are the scaffold; this subtopic works the conflicts between them, which is what the dot point asks for.

The councils, companies, co-operatives and community groups in the scenarios below are fictional, and are invented for this workbook, as are the Marrowvale Heritage Protection Act 2011 and every body, plan and place named under it — these are marked fictitious wherever they appear, and no real instrument of that name exists. Every other Act, policy, agency, assessment, dataset and projection named is real and is stated as at July 2026; sources and dates are given so a teacher can refresh them. Gippsland in eastern Victoria is used as the running decision context because it is where Victoria's coastal hazard, energy transition and irrigated agriculture decisions actually collide; 11A and 11C treat the region's risks and adaptation options in detail.

Five features that make a climate decision different. Learn these, because almost every tension later in the subtopic is a consequence of one of them.

Feature	Consequence for the decision
The cause is global and the effect is local. Emissions mix through the whole atmosphere within a year or two, so a tonne abated in Gippsland has exactly the same effect as a tonne abated anywhere	The costs of mitigation fall on the party that acts; the benefits are shared with everyone who did not. No region can mitigate its own climate
What matters is the accumulated stock, not this year's flow. Carbon dioxide persists for centuries, so warming tracks cumulative emissions	Delay is not neutral. An emission avoided in 2026 and the same emission avoided in 2046 are not equivalent, because the intervening stock is permanent on any management timescale
The response is lagged and partly committed. Ocean thermal inertia (**9B**) means surface temperature trails the energy imbalance by decades, and sea level keeps rising for centuries after temperature stabilises	Some change must be adapted to whatever is decided about mitigation. Mitigation and adaptation are not alternatives — a strategy needs both
The uncertainty is about the future, not the past. The observed record is strong and the disputed quantities are projections, which depend on choices humans have not yet made	The decision must choose a scenario and a time horizon before the data means anything. That choice is contestable, and it is often made silently
There are two kinds of response with different beneficiaries. Mitigation buys a small share of a global, delayed benefit; adaptation buys a large share of a local, sooner benefit	The two compete for one budget while answering to different constituencies — the defining tension of the dot point

Factor 1 — diverse stakeholder values, knowledge and priorities. The study design defines a **stakeholder** as "an individual, group or organisation involved in decision-making related to an environmental case study, project or issue", and names categories of stakeholder: a local or regional community; media; environmental interest groups; industry representatives; and non-government and government agencies. (One further category named by the study design is outside this workbook's scope — see **§2A**.) It then splits the stakeholder into three separable objects, and collapsing them is the commonest error in this dot point.

- **Stakeholder values** — "the set of principles, standards and/or qualities that a stakeholder holds in high regard and that determines the way the stakeholder chooses actions and evaluates events". What they hold worth having.
- **Stakeholder knowledge** — "the scientific, technical and experiential knowledge held by a stakeholder". What they actually know. Note that the definition puts **experiential** knowledge on the same list as scientific and technical: sixty years of watching a dune line move is knowledge, not opinion.
- **Priorities** — how a stakeholder ranks the things they value when not all of them can be had. Two stakeholders can share every value and still be opposed, because they rank them differently.

Climate widens the stakeholder set in two ways nothing else in this course does. First, the most affected parties **cannot be in the room**: people who will be alive in 2100, and the non-human species that will shift range or fail to. Standing for them has to be built into the procedure deliberately, which is what **intergenerational equity** does when it is

treated as a decision rule rather than a slogan. Second, because emissions mix globally, **other jurisdictions are stakeholders in a local decision** — an argument Australian decisions meet constantly in the form "our share is too small to matter".

The table sets out a real decision context with a fictional cast: a coastal settlement on the Ninety Mile Beach in Kirtlebrae Shire, where 340 dwellings sit on a low sand barrier. The barrier, its dunes and the old fishing village behind them are, in this workbook, a declared heritage landscape called the **Ashlern Commons**. Both the place and the statute that protects it are invented, and are used here so the table can carry a stakeholder whose standing comes from law rather than from opinion.

Stakeholder	Values	Knowledge	Priority when they conflict
Residents of the settlement	Security of home and place; fair treatment; continuity of a community	Experiential — decades of observed storm cut, dune movement, drain performance	Keep the houses where they are, now
Kirtlebrae Shire Council	Public safety; sound use of rates; defensible statutory decisions	Technical — asset condition, the local coastal hazard assessment, its own liability	Avoid committing ratepayers to an asset it cannot maintain for a century
Skellowby Coastal Estates Pty Ltd	Certainty of development rights; return on land already purchased	Technical and legal — planning provisions, engineering options, precedent	Secure a permit before the hazard overlay tightens
Tarrowmede Fishers Co-operative	Continued access to the entrance and the estuary; viable livelihoods	Experiential and technical — channel behaviour, catch records, weather windows	Protect the entrance and the fishery, not the dwellings
Ashlern Commons Trust (fictitious)	The heritage landscape as a whole, and the obligation to hand it on intact	Documentary and experiential — six generations of village, dune and entrance records; the heritage register file	Protect the heritage landscape in place; be a decision-maker, not a consultee
A statewide environmental group	Ecological integrity of the barrier, the dunes and the Ramsar wetland behind them	Scientific — published projections, ecological survey	Let the barrier migrate landward rather than fix it in place
Future residents and the ecosystem of 2100	—	—	Not represented unless the procedure represents them

Two things follow. The **diversity is within categories as well as between them**: two residents of the same street can want opposite outcomes depending on whether their equity is in the house or in the business that needs the entrance open. And **values become power only through procedure** — the Trust's row is different in kind from the others, because the Trust holds recognised rights, not merely a view. In this workbook's invented framework the Trust is the declared heritage landscape body for the Ashlern Commons under the *Marrowvale Heritage Protection Act 2011*: works inside the declared landscape require a **heritage landscape management plan**, the Trust evaluates that plan, and a joint management agreement gives it a share of the management of the reserved land. So the Trust appears twice in the decision — once as a holder of values, and once as a body whose approval is a condition of proceeding — and it is the second appearance that the other stakeholders do not have. *The Trust, the Ashlern Commons, the Marrowvale Heritage Protection Act 2011 and the heritage landscape management plan are invented for this workbook. They stand in for a general structure — a heritage instrument that converts a stakeholder into a decision-maker — and not for any real community, statute or instrument. See* **§2A** *for what this workbook does not cover.*

Factor 2 — regulatory frameworks that inform environmental management strategies. Climate frameworks are built differently from the pollution and biodiversity frameworks in Chapters 7 and 8. Those work mainly by **site permission** — a licence, a permit, a duty attaching to an activity at a place. Climate frameworks work mainly by

target and account: a jurisdiction commits to a number, an accounting system measures progress against it, and only a few instruments reach down to bind an individual decision. Knowing which kind of instrument you are dealing with is usually half the answer.

So the useful question is not "which instruments exist" — **11B** lists the mitigation instruments and **11C** the coastal ones — but **what kind of thing each one is**. Sort them by function and the conflicts become visible.

Function	Instruments that do it	Why the function matters to the decision
Set a target	Paris Agreement and Australia's nationally determined contribution; *Climate Change Act 2022* (Cth); *Climate Action Act 2017* (Vic), which is the *Climate Change Act 2017* renamed and amended when the long-term target was brought forward — net zero by 2045, with five-yearly interim targets; the Victorian renewable energy, storage and offshore wind targets under the *Renewable Energy (Jobs and Investment) Act 2017* (Vic)	A target is an obligation of the **jurisdiction**, not of the organisation in the scenario. It creates political and market pressure, and it is not a duty anybody in a stimulus can breach
Keep the account	*National Greenhouse and Energy Reporting Act 2007* (Cth); the ACCU methods under the *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth); an organisation's chosen inventory boundary	What the rules make countable is what success is measured in. An emission the rules do not count is invisible to the strategy, however real it is
Impose a limit or a duty	The **safeguard mechanism**, the only instrument putting a declining limit on individual Australian facilities — above 100 000 t CO_2-e a year, 219 facilities in 2023–24, about 31% of national emissions; the **general environmental duty** under the *Environment Protection Act 2017* (Vic)	These are the only rows that bind a private decision-maker directly. The safeguard threshold excludes nearly every business a student will meet in a scenario
Compel assessment and disclosure	Chapter 2M of the *Corporations Act 2001* (Cth) as amended in 2024, with **AASB S2** — the largest entities reporting for financial years beginning on or after 1 January 2025, smaller cohorts phased in	It does not require abatement. It requires the organisation to *state* its climate risks, and therefore to have assessed them — which changes behaviour without setting a limit
Create the procedure	*Planning and Environment Act 1987* (Vic) and planning scheme clause 13.01, with Practice Note PPN53; the *Marine and Coastal Act 2018* (Vic), Marine and Coastal Policy 2020 and the **Victoria's Resilient Coast** guidelines made under s 41; *Offshore Electricity Infrastructure Act 2021* (Cth), under which the Gippsland area — about 15 000 km² from off Lakes Entrance to south of Wilsons Promontory — was	Procedure decides **who decides**, who must be consulted, who may object and what must be assessed. This is where values become power, and it is the tier at which contested climate decisions are actually resolved

Function	Instruments that do it	Why the function matters to the decision
	declared on 19 December 2022, the first in Australia, with nine feasibility licences active; and, in this workbook's invented framework, the *Marrowvale Heritage Protection Act 2011* (fictitious)	
Prescribe how to decide	The guiding principles in Division 3 of the *Climate Action Act 2017* (Vic): **informed decision making**, **integrated decision making**, **risk management**, **equity**, **community engagement** and **compatibility**; and the Act's requirement that specified decision-makers **have regard to climate change** in the decisions listed in its own schedule	Unusually, the statute addresses the reasoning rather than the outcome. This is the dot point written into Victorian law, and it is the standard against which a decision's process is judged
Assess, but not regulate	The **IPCC**	Not a regulator. It assesses published science and expresses confidence and likelihood in the language taught at **10D**. Treating an IPCC finding as a rule, or as a policy, is a category error

Three structural points earn marks, and none of them is a list of Acts.

1. **Almost nothing binds an individual emitter.** Most mitigation by most organisations is therefore voluntary, driven by cost, disclosure, customer requirements or reputation rather than by law. A stimulus that says "the company must reduce its emissions" is usually wrong about *must*, and a strategy justified as compliance will be abandoned the moment somebody reads the Act.
2. **A strategy can be designed to satisfy the account rather than the atmosphere.** Two organisations reporting the same net figure — one having rebuilt its plant, one having bought credits — have not done the same thing. Because the accounting rules are what a decision is held to, they are a factor in the decision and not merely a way of describing it.
3. **The number in the rule is usually older than the science behind it.** The 0.8 m sea level planning benchmark taught at **11C** is the clearest Victorian case: a scientific figure fixed into a planning clause, which now sits inside the high-emissions likely range published by IPCC AR6 rather than above it. The point for this subtopic is not the number but the coupling — the data gave the rule its figure once, and the rule now determines which figure a council is obliged to act on, whatever the current assessment says. Rules move only when someone with power moves them, so this lag is a permanent feature of climate decision-making rather than an oversight.

Factor 3 — use and interpretation of historical and current scientific data. Chapter 10 owns how the data is produced, modelled and rated. What 11D owns is what happens when someone has to *decide* with it. Three kinds of evidence come into a climate decision, and they do different jobs.

Evidence	Job in the decision	Characteristic weakness
Historical instrumental records — the observed trend	Establishes that change is occurring, its rate and its direction; supplies the baseline against which a target is set	Short relative to the phenomenon; station moves and instrument changes create breaks that are not changes in climate
Palaeoclimate and long proxy records (10A)	Puts the present rate in a context of millennia and shows how systems	Coarse in time and space; proxies measure climate indirectly

Evidence	Job in the decision	Characteristic weakness
	behaved outside the instrumental range	
Projections from models (10B, 10C)	The only evidence about the future, and therefore the only evidence a hundred-year decision can use	**Conditional.** A projection is not a forecast — it says what follows *if* a given emissions pathway occurs

The conditionality is the heart of this factor. A projection has no meaning until three choices are made, and each is a place where a decision can go quietly wrong.

- **Which scenario.** RCP4.5 or RCP8.5; SSP1-2.6 or SSP5-8.5. The difference between scenarios by 2090 is larger than the difference between models, so the choice of scenario often decides the answer. Choosing a low scenario for a design life that extends to 2100 is a judgement about how the world will behave, not a technical input — and it transfers risk to whoever owns the asset later.
- **Which baseline and horizon.** Percentage reductions are meaningless without the year they are measured from, and a target expressed against a high historical year flatters the effort. Compare like with like, and say what the base year is.
- **Which spatial scale.** Confidence is highest for global means and lowest for local detail, because projecting a change in the atmospheric circulation over one estuary asks more of a model than projecting global temperature. **10D**'s confidence and likelihood language exists precisely so this can be stated rather than glossed. A decision built on a regional number without its confidence qualifier has used the data badly, however good the number is.

Two further traps recur in Victorian material specifically. The first is a live one, and it is a decision problem rather than a technical one: **Victoria has changed projection generations, and most of its in-force plans have not.** The current state projections are **Victorian Climate Projections 2024 (VCP24)**, summarised in Victoria's Climate Science Report 2024 with a regional report for Gippsland, and built on **CMIP6** models and the **SSP** scenarios, accompanied by *Updated Sea-Level Projections for Victoria 2024*. They supersede **VCP19**, which used CMIP5 and the older **RCP** scenarios. But the regional adaptation strategies, council plans and hazard assessments now being implemented were largely written against VCP19 — so a decision-maker is routinely holding a current projection and a strategy built on the previous one. Two rules follow. Never treat an RCP and a similarly-numbered SSP as the same pathway; they come from different model generations, and a table that mixes them without saying so is misleading. And always state which generation a figure comes from, because a difference between two numbers may be a change in the science rather than a change in the climate. The second trap is to **confuse attribution with projection**: showing that a past event was made more likely by warming is a different scientific operation from projecting a future frequency, and the confidence attaching to each is different.

Deciding when the data will not resolve the question. Some climate uncertainty is not going to be reduced in time to help, because it depends on future human choices. The study design's own vocabulary applies here: students should be able to identify **contradictory, provisional and incomplete data**, including possible sources of bias. Four decision rules are used in practice, and naming one is a strong move in an extended response.

- **Precautionary principle** — the study design's definition: it is "triggered when the risk of harm to the environment due to a proposed action is high but the scientific evidence is uncertain, requiring that measures be taken to prevent environmental damage and that the proof of no, or minimal, harm be provided by the proposer". Note where it puts the burden: on the proposer, not the objector. Uncertainty is therefore an argument for acting, not for waiting — the opposite of the way it is usually deployed in a stimulus.
- **Robustness rather than optimality** — choose the option that performs acceptably across the whole range of scenarios, instead of the option that performs best under the single scenario judged most likely.
- **No-regrets and low-regrets actions** — do first the things worth doing even if the projection is wrong: fixing the drain, mapping the hazard, keeping the option open.
- **Adaptation pathways with trigger points** — taught at **11C**. For this subtopic the relevant property is what a pathway does to the *decision*: by fixing the trigger in advance and in public, it settles the contested question while nobody is under pressure, and it names who has the power to move to the next stage. That is why it is the honest answer to a projection that will be revised.

Factor 4 — application of new technologies. In climate decisions technology arrives on both sides of the ledger, and the two sides behave differently.

	Mitigation technologies	Adaptation technologies
Examples	Wind and solar generation, grid-scale storage, electrification of process heat, green hydrogen, carbon capture and storage, soil and vegetation carbon methods	Coastal protection works, managed retreat and relocation, hazard mapping from LiDAR and satellite data, seasonal forecasting, provenance-adjusted revegetation, heat-resilient building design, irrigation modernisation
Who gets the benefit	Everyone, later, in proportion to nothing	The party that installs it, sooner, locally
Characteristic failure	Promised abatement that does not arrive, or arrives somewhere else	Risk moved rather than removed

Six questions test a proposed technology, and the last three are the ones students omit.

1. **Is it demonstrated at this scale?** Working in a pilot is not working in a plant.
2. **What is the life-cycle emission**, not the emission at the point of use? Hydrogen made from unabated fossil fuel is not low-emission because the vehicle using it is clean.
3. **What does it cost per tonne abated**, over what asset life? **11B** supplies the calculation; what matters here is that the cheapest tonne and the tonne the organisation can actually afford this year are often not the same, and that is a tension, not an arithmetic problem.
4. **Does it create lock-in?** A long-lived asset commits a community to one pathway for decades, and can become a **stranded asset** if policy or economics move.
5. **Does it transfer risk instead of removing it?** A rock revetment holding one beach in place commonly starves the beach downdrift of sand, so the erosion reappears next door. Whoever gains protection and whoever loses it are usually different parties.
6. **Does the promise of it change behaviour now?** This is **mitigation deterrence**: if abatement is deferred because a future technology is expected to remove the carbon later, and the technology arrives late, smaller or not at all, the deferred emissions are already in the stock and permanent. The expectation of the technology has then caused harm the technology did not offset.

Two Victorian cases show the questions biting. The Victorian Government's **CarbonNet** project has investigated offshore storage of carbon dioxide in the Gippsland Basin; capture and storage is real engineering, and the questions that decide whether it is a mitigation option here are questions 1, 3, 4 and 6, not question 2. The **Hydrogen Energy Supply Chain** pilot in the Latrobe Valley produced hydrogen from brown coal and shipped liquefied hydrogen to Japan in 2022 aboard the diesel-powered *Suiso Frontier* — the hydrogen was the cargo, not the fuel, so the voyage itself burned marine fuel and emitted carbon dioxide like any other ship. The pilot's climate value turns entirely on question 2, and the answer is on the record: the carbon dioxide released in making the hydrogen was not captured, and offsets were purchased instead, so what the pilot demonstrated was the shipping chain rather than the abatement. Treating technology itself as the answer to a climate problem is **technocentrism** (**3C**): a value position, which may be right, but which is not a finding and does not substitute for one.

Offsets are where the technology limb and the accounting limb meet. An ACCU is worth only what its integrity rules make it worth. Under the ACCU scheme's methods, made under the *Carbon Credits (Carbon Farming Initiative) Act 2011* (Cth), the abatement a unit represents must be **additional** to what would have happened anyway, **measurable and verifiable**, and free of **leakage** to emissions outside the project boundary; and a sequestration project must hold its carbon for a nominated **permanence** period — 25 or 100 years, which **11B** sets out. The decision-making point this subtopic adds is what those tests do to the *choice*: because two options that report the same net figure can differ entirely in permanence and in whether the organisation's own plant changes at all, the accounting rules can make unlike things look alike to a board. That is why regulators have moved against unsubstantiated neutrality claims, and why Australian courts have imposed penalties totalling tens of millions of dollars on financial firms for misleading sustainability claims.

The interconnections. Six couplings, each with a mechanism that is specific to climate.

Coupling	Mechanism	Reinforcing or opposing
Data → Regulation	A projection becomes a design number: AR6 and the coastal hazard assessments are the reason a planning scheme carries a sea level figure at all	Reinforcing, but **slowly** — the rule is revised only when someone with power revises it, so the number lags the science
Regulation → Data	The NGER rules and the ACCU methods define what is counted, by whom, at what accuracy; the state guidelines define which hazard assessment is authoritative	Reinforcing for consistency, but it **bounds what the decision can see** — an emission the rules do not count is invisible to the strategy
Technology → Regulation	Once a technology is available and affordable, "so far as reasonably practicable" tightens under the general environmental duty, and a target that was aspirational becomes achievable and therefore expected	Reinforcing
Regulation → Technology	A declining safeguard baseline, a renewable energy target or a declared offshore wind area creates the market that makes deployment worth financing	Reinforcing, and it is the main mechanism by which climate policy actually changes physical assets
Regulation → Stakeholders	Procedure allocates standing: who must be consulted, who evaluates a heritage landscape management plan, who may object to a permit, who is merely affected. The Act's community engagement principle converts a preference into leverage	Reinforcing for those given standing; opposing for those without
Stakeholders → Data	Stakeholders supply experiential records the instruments never captured, and contest interpretation; who produced a dataset affects whether the community will act on it	Both: it extends the record, and it makes trust a precondition of the evidence being used at all

Two whole-system points follow. The couplings are **not symmetric** — regulation shapes data far more tightly than data shapes regulation. And an intervention aimed at one factor lands on all four: commissioning a new tide gauge network is a data decision, a compliance decision, a technology decision and a community-trust decision at the same time.

The tensions. Each has a sustainability principle on each side, which is how the marks are earned.

Tension	Pole A	Pole B	Principle on each side
Mitigate or adapt	Spend on abatement: a small share of a global, delayed benefit	Spend on resilience: a large share of a local, sooner benefit	A: intergenerational equity, conservation of ecological integrity. B: intragenerational equity
Act now or wait for better projections	Commit while the projection is uncertain, risking over- or under-building	Defer, keep options open, and accept the harm accruing meanwhile	A: precautionary principle. B: efficiency of resource use
Protect, accommodate or	Hold the line with works,	Raise, redesign or relocate,	A: intragenerational equity

Tension	Pole A	Pole B	Principle on each side
retreat	keeping assets and value in place	letting the coast move	for current owners. B: intergenerational equity and conservation of ecological integrity
Who pays for a global benefit	The emitter or the beneficiary pays for abatement directly	The cost is spread across ratepayers, taxpayers or consumers	A: user pays principle. B: intragenerational equity, where the direct payer cannot afford it
Transition speed against transition fairness	Close and replace emitting industry on the fastest technically feasible schedule	Sequence closures to the pace at which workers and towns can be re-employed	A: intergenerational equity. B: intragenerational equity — the "just transition" argument
Green against green	Build the mitigation project: an offshore wind farm, a solar farm, a transmission line	Protect the local ecology or productive land it occupies	Both poles claim **conservation of biodiversity and ecological integrity**, at different scales
Proven technology or new	A known option with known limits	A better-performing option with unquantified reliability and its own risks	A: precautionary principle. B: efficiency of resource use

The **green against green** row is the one students least expect and examiners most like, because it cannot be resolved by deciding that the environment matters — both poles say so. In the Gippsland declared area the same argument runs in both directions: offshore wind is the state's largest single mitigation opportunity, and the Bass Strait waters it occupies carry a commercial fishery, migrating whales and seabird foraging grounds. No further data dissolves that, because nothing is in dispute about the mechanism. Someone has to decide which value the decision is made for, at which scale, and say so.

What "responsible" adds, in a climate decision specifically. 8F's five general tests still apply. Five climate-specific additions are assessable here.

1. **State the scenario and the horizon.** A decision quoting a sea level or a yield change without saying which emissions pathway and which year it comes from cannot be reviewed, because nobody can tell whether it later proved wrong or was merely a different scenario.
2. **Do not let adaptation be counted as mitigation, or the reverse.** A seawall abates nothing; a solar array protects nothing. Strategies that blur the two usually do so to claim credit twice.
3. **Say where the residual risk goes — in space and in time.** Every climate decision moves risk: to the property downdrift, to the ratepayer of 2060, to the worker whose plant closes, to the generation that inherits the stock of carbon. Naming the recipient is the difference between a trade-off and a concealed transfer.
4. **Build the trigger point, not just the plan.** Because projections will be revised, the strategy must state what will be monitored, what observed value triggers the next stage, and who has the power to act on it. A decision designed to be revised is stronger, not weaker.
5. **Be honest about what the decision cannot do.** No Victorian decision changes the global climate. A regional strategy can reduce the region's contribution, reduce the region's exposure and shape who bears the loss; claiming more than that is not a responsible framing, and neither is using it as a reason to do nothing.

A structure for the extended-response items. Six steps, in this order, will answer almost any 8- or 10-mark question on this dot point.

1. Identify the decision and who is making it.
2. Set out the stakeholders, separating **values**, **knowledge** and **priorities** — not a list of names.
3. Name the instruments that actually bind, and say what each one does (target, account, permission or procedure).

4. State what the data does and does not support: the source, the scenario, the horizon, the confidence.
5. Assess any technology on life-cycle emissions, scale, cost per tonne, lock-in and risk transfer.
6. Name the tension explicitly, resolve it, and justify the resolution against sustainability principles — then state the residual risk and the trigger point for review.

Where students lose marks.

- **Listing the four factors instead of connecting them.** The dot point's nouns are *interconnections* and *tensions*. Four paragraphs, one per factor, answers a question that was not asked.
- **Naming stakeholders without separating values, knowledge and priorities.** "Farmers, council and an environment group" is a list of parties, not an analysis of diversity.
- **Calling every disagreement a tension.** If more data or better explanation would dissolve it, it is a dispute, not a tension. A tension survives agreement on the facts.
- **Treating uncertainty as a reason to wait.** The precautionary principle points the other way, and puts the burden of proving minimal harm on the proposer.
- **Quoting a projection without its scenario, horizon or confidence** — and treating a projection as a forecast.
- **Assuming the law requires what the scenario's organisation is being urged to do.** Below the safeguard threshold, an Australian business's abatement is generally voluntary.
- **Confusing mitigation with adaptation**, or awarding a measure credit for both.
- **Treating an offset as physically equivalent to abatement** at the site, and ignoring additionality and permanence.
- **Reciting "technology will solve it"** as though technocentrism were a finding, and missing the mitigation deterrence created by relying on a technology that does not yet exist at scale.
- **Forgetting the parties with no standing** — future generations, other species, and communities the procedure does not reach.

Worked examples

Example 1 — scaffolded

A settlement of 340 dwellings sits on a low sand barrier on the Ninety Mile Beach, in the fictional Kirtlebrae Shire. The Shire must settle a long-term response to coastal erosion and inundation. The local coastal hazard assessment for the Gippsland Lakes and Ninety Mile Beach has been completed. Three submissions are before the council.

Residents' Alliance: "We have watched this dune for forty years. It always comes back after a storm."

Skellowby Coastal Estates Pty Ltd: "A revetment is proven engineering and it protects the rate base."

A statewide environmental group: "The barrier has to be allowed to move landward. Fixing it in place guarantees the loss of the beach in front of it."

a. Classify the residents' statement and Skellowby's statement as stakeholder knowledge or stakeholder values, and justify each classification. (2 marks)

b. Name three instruments engaged by this decision and state what each one contributes, identifying whether it sets a target, keeps an account, creates a procedure or prescribes how to decide. (3 marks)

c. Explain, in both directions, how the regulatory framework and the interpretation of scientific data are coupled in this decision. (3 marks)

d. Name the central tension and state one sustainability principle relied on by each pole. (2 marks)

Step 1 — answer a. The residents' statement is **stakeholder knowledge**, and specifically *experiential* knowledge: it reports forty years of observation of dune recovery, which is a factual claim about how the system has behaved. Skellowby's statement is a **value** claim wearing technical clothing: "proven engineering" is a knowledge claim, but the operative words are *protects the rate base* — what the company holds in high regard, and the ground on which it wants the decision made.

Step 2 — answer b. Any three, with the function named rather than just the instrument. Clause 13.01-2S of the planning scheme under the *Planning and Environment Act 1987* (Vic) — **procedure**, and within it the design threshold the Shire must allow for at any particular permit decision. The *Marine and Coastal Act 2018* (Vic), with the Marine and Coastal Policy 2020 and the Victoria's Resilient Coast guidelines made under s 41 — **procedure**: it fixes how coastal hazard risk must be assessed and adapted to, and makes the local hazard assessment the authoritative dataset. The *Climate Action Act 2017* (Vic) — **prescribes how to decide**: specified decision-makers must have regard to climate change, and the guiding principles of informed decision making, risk management, equity and community engagement govern the process. (The fictitious *Marrowvale Heritage Protection Act 2011* used in this workbook is also engaged — **procedure** — through the Ashlern Commons Trust's role in evaluating a heritage landscape management plan for works inside the declared landscape.)

Step 3 — answer c. Both directions, with a mechanism for each. **Data → Regulation:** the sea level and coastal process science is where the planning benchmark and the hazard overlays got their numbers, and the completed local hazard assessment is what converts a general projection into lines on this Shire's maps. **Regulation → Data:** the framework then determines which dataset the Shire is *obliged* to act on, at which scenario and horizon, and who may contest it — so the rule bounds what the decision is permitted to see, and the residents' forty years of observation counts only to the extent the procedure lets it in. The coupling is asymmetric, which is the examinable part: new science does not update the rule until someone with power updates it, so a decision taken correctly under the current rule can still be designed for a sea level the current science has moved past. (The benchmark itself, and why it is a floor rather than a ceiling, is 11C's.)

Step 4 — answer d. The tension is **protect or retreat** — holding the shoreline in place with works against relocating the assets and allowing the barrier to migrate. Protection relies on **intragenerational equity**: the current residents keep their homes and are not made to carry the loss. Retreat relies on **intergenerational equity**, and on **conservation of biodiversity and ecological integrity**, because a fixed structure will eventually eliminate the beach and the dune system in front of it and commits future ratepayers to maintaining it. (**User pays** also bears on the choice: nourishment and revetment spread the cost across all ratepayers to protect 340 titles.)

Example 2 — scaffolded

Harnsleigh Dairy Processing Pty Ltd operates a milk processing plant in Gippsland. Its scope 1 and 2 emissions are 5 200 t CO_2-e per year, most of it natural gas used for process heat. The plant is well below the safeguard mechanism threshold. Its board is choosing between two ways of meeting a customer's requirement that the site's reported emissions fall.

Option	Capital cost	Annual effect	Life
A Electrify process heat with heat pumps, plus 2.5 MW of on-site solar	\$7 400 000	Abates 4 100 t CO_2-e; saves \$310 000 in energy	20 years
B Continue as now and buy 4 100 ACCUs each year at \$38.00 each	nil	Reported net emissions fall by 4 100 t CO_2-e	—

a. Calculate the percentage of the site's emissions that Option A abates. (1 mark)

b. Calculate the net cost of each option over 20 years, and the cash outlay each requires in year 1. (3 marks)

c. Explain the tension your figures in **b** expose, and state who carries it. (3 marks)

d. The board minutes record that "we are required by law to reduce our emissions". Evaluate that statement. (3 marks)

Step 1 — answer a. 4 100 / 5 200 × 100 = **78.8%**.

Step 2 — answer b. Option A over 20 years: capital \$7 400 000 less energy savings of 310 000 × 20 = \$6 200 000, so a **net cost of \$1 200 000**. Its year 1 cash outlay is 7 400 000 − 310 000 = **\$7 090 000**. Option B over 20 years: 4 100 × 38.00 = \$155 800 a year, × 20 = **\$3 116 000**, and its year 1 cash outlay is **\$155 800**. Both options deliver the same 4 100 × 20 = 82 000 t CO_2-e on paper. (Expressed per tonne by 11B's method, that is \$14.63 against \$38.00.)

Step 3 — answer c. The tension is between **cost over the life** and **cash now**: Option A is less than half the total cost for the same reported abatement, and it requires about 45 times as much money in the first year. A business without access to $7.1 m of capital is not behaving irrationally in choosing the dearer total — which is why abatement that is cheap per tonne so often does not happen.

Who carries it has two answers, and both should be stated. In the short term the board carries it as a financing problem. In the long term, under Option B the plant's gas consumption and therefore its physical emissions are unchanged for twenty years, so the consequence is carried by everyone downstream of those emissions and by the business itself later, which will face the same conversion with twenty years less asset life. Option B also transfers a risk the board does not control: the ACCU price, and the integrity rules that govern what its purchased units are worth (**11B**).

Step 4 — answer d. The statement is wrong as a matter of law and right as a matter of commerce. Australia's targets under the *Climate Change Act 2022* (Cth) and Victoria's under the *Climate Action Act 2017* (Vic) bind the jurisdictions, not this company. The safeguard mechanism is the instrument that imposes a declining limit on individual facilities, and it reaches only those emitting more than 100 000 t CO_2-e a year — twenty times this site. What is real is the **customer requirement**, and, if the company is large enough or is in the supply chain of an entity that is, the pressure created by mandatory climate-related financial disclosure under Chapter 2M of the *Corporations Act 2001* (Cth) and AASB S2. The board should record the driver accurately, because a strategy justified as compliance will be abandoned the moment somebody reads the Act.

Example 3 — unscaffolded

The Gippsland offshore wind area, about 15 000 km² between Lakes Entrance and Wilsons Promontory, was declared on 19 December 2022 under the *Offshore Electricity Infrastructure Act 2021* (Cth), and nine feasibility licences are active. Braithlow Offshore Wind Pty Ltd holds one. Tarrowmede Fishers Co-operative works grounds inside the licence area.

Explain how an interconnection between two of the dot point's factors produced a tension in this decision. Name the two factors coupled by the interconnection, and the two factors on either side of the tension. (6 marks)

Solution. The interconnection is **Regulation → Technology**, and it is the mechanism by which climate policy turns into steel in the water. Offshore wind at this scale was technically possible in Australian waters before 2021 but not financeable, because there was no way to obtain secure tenure over a patch of Commonwealth marine area. The *Offshore Electricity Infrastructure Act 2021* (Cth) created the licensing system; the declaration of the Gippsland area on 19 December 2022 identified where it applied; and Victoria's legislated offshore wind targets of at least 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040 under the *Renewable Energy (Jobs and Investment) Act 2017* (Vic), alongside its 95% renewable electricity target for 2035 in the same Act and its net zero 2045 target under the *Climate Action Act 2017* (Vic), created the demand the projects are built to serve. The regulatory framework did not merely permit the technology — it brought the option into existence.

The tension it produced is between **diverse stakeholder priorities** and the **application of the new technology**, and its shape is *green against green*. Braithlow's project is a mitigation asset: generation that displaces emitting plant, serving a global and intergenerational benefit, and defensible under conservation of biodiversity and ecological integrity at the global scale. Tarrowmede's grounds, the whales that migrate through Bass Strait and the seabirds foraging there are ecological and economic values at the local scale, defensible under exactly the same sustainability principle and under intragenerational equity — the loss falls on identified people now, while the benefit is diffuse and later.

That is a genuine tension rather than a dispute, because it does not dissolve when everyone agrees on the facts. Both parties can accept the same abatement figures, the same survey data and the same migration tracks and still be opposed, because the disagreement is about which scale of ecological value the decision is made for, and about who carries the cost of a benefit shared with everybody. A responsible resolution therefore does not pretend the evidence settles it: it uses the assessment and licensing procedure to give the fishery genuine standing, states which values were preferred and why, and places the residual risk explicitly — by micro-siting and seasonal restrictions where they reduce the ecological cost, and by compensating or relocating effort where they do not.

Example 4 — unscaffolded

Grindlecote Hydrogen Pty Ltd proposes a plant in the Latrobe Valley producing hydrogen from brown coal for export. Its submission states: *"Hydrogen is a zero-emission fuel. Carbon capture and storage will be retrofitted once it is commercially available in the Gippsland Basin. The project secures 400 jobs in a region losing its power stations, and no law prevents it."*

Evaluate the submission. (8 marks)

Solution. Three of the four sentences are true in isolation, and the argument they build does not stand.

The emissions claim confuses the point of use with the life cycle. Burning hydrogen releases water, so a hydrogen-fuelled engine emits no carbon dioxide. That is not the project's emission. Producing hydrogen from brown coal releases carbon dioxide at the plant, and unless it is captured and stored the fuel is not low-emission — it has moved the emission from the vehicle overseas to the Latrobe Valley. The correct test is question 2 of the technology assessment, life-cycle emission, and the submission has answered a different question. Exporting the hydrogen does not change the physics either: the carbon dioxide is released here and mixes globally within a year or two.

The capture-and-storage sentence is mitigation deterrence in its clearest form. Storage in the Gippsland Basin has been investigated — the Victorian Government's CarbonNet project has done exactly that — so this is not fantasy engineering. But "once it is commercially available" makes the abatement conditional on an event outside the proponent's control and after the emissions occur. If capture arrives late, at smaller scale, or not at all, the intervening emissions are already in the atmospheric stock and are permanent on any management timescale, because what drives warming is cumulative emissions, not this year's flow. A retrofit promise is not abatement; and under the **precautionary principle** as the study design defines it, the burden of proving no or minimal harm sits with the proposer, not with the objector. A responsible submission would either abate from commissioning or accept a condition tying operation to demonstrated storage.

The jobs claim is the strongest part of the submission and is being used to answer the wrong question. The Latrobe Valley's transition is real: Hazelwood closed in 2017, and Yallourn and Loy Yang A have announced closures in 2028 and 2035. Employment for a region that carried Victoria's generation for decades is a serious claim under **intragenerational equity**, and the "just transition" tension — transition speed against transition fairness — is genuine. But it is an argument for regional employment, not for this project's emissions profile. It would support an equivalent number of jobs in a lower-emission activity just as well, and using it to justify the emissions treats two separable questions as one.

"No law prevents it" is probably accurate and is not a defence. Australia's target under the *Climate Change Act 2022* (Cth) and Victoria's net zero 2045 target under the *Climate Action Act 2017* (Vic) bind the jurisdictions, not the proponent. If the plant emitted more than 100 000 t CO_2-e a year it would fall under the safeguard mechanism and face a baseline declining at 4.9% a year to 2030 — which is a constraint, but on intensity per facility rather than a prohibition. So the submission may well be lawful. **Lawful is not responsible**: a decision that satisfies every applicable instrument can still transfer risk onto parties with no standing, and the Victorian statute itself directs decision-makers to the principles of informed decision making, risk management and equity, not merely to compliance.

What a responsible version of this proposal would look like. State the life-cycle emission per kilogram of hydrogen, with the scenario and boundary declared. Make capture and storage a condition of operation with a demonstrated storage pathway, not an intention. Cost the abatement per tonne so it can be compared with the alternative uses of the same capital — including renewable hydrogen, which faces question 1 of the technology assessment rather than question 2. Address the region's employment as its own question, on its own evidence. Engage any holder of statutory rights over the site — in this workbook's invented framework, the declared heritage landscape body for the landscape the plant would sit in, under the fictitious *Marrowvale Heritage Protection Act 2011* — through that instrument's own process, rather than as one submission among many. And say who carries the residual risk if the capture never arrives — on the present submission, that is everyone alive in 2100, none of whom is in the room.

Practice questions

Scaffolded

Q1. Define the term *stakeholder* as it is used in environmental decision-making. (1 mark)

Q2. Distinguish between *stakeholder values* and *stakeholder knowledge*, giving one example of each from a climate decision. (2 marks)

Q3. Complete the table with one example of each factor, drawn from climate decision-making in Victoria. (4 marks)

Factor	One example
Diverse stakeholder values, knowledge and priorities	
Regulatory frameworks	
Use and interpretation of scientific data	
Application of new technologies	

Q4. Distinguish between an *interconnection* and a *tension* between two factors. (2 marks)

Q5. For each tier below, name one instrument and state what it does in a climate decision. (4 marks)

Tier	Instrument	What it does
International		
Commonwealth		
Victorian		
Local		

Q6. State the precautionary principle, identify who carries the burden of proof under it, and explain why climate decisions frequently trigger it. (3 marks)

Q7. Explain why mitigation and adaptation compete for the same funding, and why they are not substitutes for one another. (3 marks)

Q8. Kirtlebrae Shire's community greenhouse gas inventory reports 410 kt CO_2-e in 2005, 356 kt in 2019 and 291 kt in 2024.

a. Calculate the percentage reduction from 2005 to 2024. (1 mark)

b. Calculate the percentage reduction from 2019 to 2024. (1 mark)

c. The Shire's media release claims a 29% reduction. Explain what the choice of base year does to the apparent size of the achievement, and state what the release must include for the figure to be interpretable. (2 marks)

Q9. For each statement, identify whether it expresses a stakeholder's **values**, **knowledge** or **priority**. (3 marks)

a. *"The channel has silted at the same rate every year since I started fishing here in 1978."*

b. *"Protecting the wetland matters more to us than protecting the caravan park."*

c. *"Every family in this town has the right to stay in the house they own."*

Q10. State two ways in which the application of a new technology can change a climate decision, and two questions that should be asked before the technology is relied on. (4 marks)

Q11. Wenmarra Berries Pty Ltd farms in Gippsland. Victorian Climate Projections 2024 indicate a hotter and drier cool season for the region, with more days above 35 °C. The company is deciding between installing shade and misting infrastructure, and buying land at a cooler elevation.

a. Identify one value and one priority likely to be held by the company's neighbouring growers, who irrigate from the same system. (2 marks)

b. State one sustainability principle supporting each of the two options. (2 marks)

c. Explain one interconnection between the projection data and the regulatory framework that will apply to either option. (2 marks)

Unscaffolded

Q12. A submission argues: *"Until the projections agree, the responsible course is to gather more data before committing to any adaptation works."* Explain why this reasoning fails. (3 marks)

Q13. Explain how a stakeholder's experiential knowledge can change a decision that instrumental data alone would not, and state one condition that must be met for it to be used properly. (4 marks)

Q14. Planning scheme clause 13.01-2S requires planning for a sea level rise of not less than 0.8 m by 2100. Explain the tension that arises when a regulatory number is older than the science it came from, and state how a decision-maker can resolve it responsibly. (4 marks)

Q15. Kirtlebrae Shire proposes coastal works costing $4 200 000, which protect 340 titles in one settlement. The Shire has 11 500 rateable properties. It may fund the works from general rates, or by a special charge levied on the properties that benefit.

a. Calculate the cost per property under each funding method. (2 marks)

b. State the sustainability principle each funding method relies on, and explain the tension between them. (3 marks)

Q16. Explain how the application of a new technology can itself create a tension with intergenerational equity, using the concept of mitigation deterrence. (5 marks)

Q17. Explain how a climate decision can be responsible even though a major stakeholder opposes it, referring to two of the dot point's factors. (5 marks)

Q18. The Macalister Irrigation District in Gippsland supplies irrigated dairy and horticulture, and its drainage flows towards the Gippsland Lakes, listed under the Ramsar Convention in 1982. Victorian Climate Projections 2024 indicate reduced cool-season rainfall and higher evaporation for the region; the district's current management plan was written against the earlier VCP19 generation. A fictional water co-operative in the district proposes to spend a fixed sum either on modernising channels to reduce losses, or on retiring a share of the district's water entitlement and revegetating the retired land.

Analyse the interconnections and tensions this decision involves, and state what a responsible decision would have to include. (8 marks)

Q19. *"Climate decision-making would be straightforward if people would simply follow the science."*

Discuss this statement. Refer to all four factors named in the key knowledge, to at least one interconnection and one tension, and to what makes a climate decision responsible. (10 marks)

Answers

Q1. An individual, group or organisation involved in decision-making related to an environmental case study, project or issue (1). Categories include a local or regional community, media, environmental interest groups, industry representatives, and non-government and government agencies. (A further category named by the study design is outside this workbook's scope — see **§2A**.)

Q2. Values are the principles, standards or qualities a stakeholder holds in high regard and that determine how they choose actions and evaluate events — e.g. a residents' group holding security of home and place above all else (1). Knowledge is the scientific, technical or experiential knowledge the stakeholder holds — e.g. the same group's forty years of observation of how the dune recovers after storms (1).

Q3. One mark each, any defensible example: stakeholder factor — a heritage landscape trust, a fishing co-operative and a shire council holding different priorities over the same coastline (1); regulatory — the *Climate Action Act 2017* (Vic) legislating net zero by 2045 and requiring specified decision-makers to have regard to climate change (1); data — Victorian Climate Projections 2024 and IPCC AR6 sea level ranges used to set a design level (1); technology — offshore wind under the Gippsland declared area, grid-scale storage, electrification of process heat, or carbon capture and storage (1).

Q4. An interconnection is a relationship in which a change in one factor changes what another requires, permits, wants or can see — e.g. new data prompting revision of a design benchmark (1). A tension is a structural opposition in which moving towards one pole necessarily moves away from another, so a choice must be made and justified — e.g. spending the same dollar on mitigation or on adaptation (1).

Q5. One mark per row, instrument **and** function both required. International — Paris Agreement: sets the well below 2 °C goal and obliges parties to submit and strengthen NDCs; binds states, not businesses (1). Commonwealth — *Climate Change Act 2022* (Cth): legislates 43% below 2005 by 2030 and net zero by 2050; or the safeguard mechanism: declining baselines for facilities above 100 000 t CO_2-e a year (1). Victorian — *Climate Action Act 2017* (Vic): net zero by 2045, interim targets, adaptation action plans, guiding principles for decision-making (1). Local — planning scheme clause 13.01-2S and hazard overlays: apply the 0.8 m by 2100 benchmark to a particular permit decision (1).

Q6. It is triggered when the risk of harm to the environment from a proposed action is high but the scientific evidence is uncertain, requiring that measures be taken to prevent environmental damage (1). The burden of proving no, or minimal, harm rests on the **proposer** (1). Climate decisions trigger it routinely because the harms are potentially severe and partly irreversible while the projections remain uncertain and depend on future human choices, so waiting for certainty guarantees the harm (1).

Q7. They draw on the same finite budget, so a dollar spent abating emissions is not available for resilience works and vice versa (1). They are not substitutes because mitigation reduces the future magnitude of change but cannot remove the change already committed by the existing stock of greenhouse gases and ocean thermal inertia (1); and adaptation reduces local exposure but abates nothing, so it does not slow the driver (1).

Q8. a. (410 − 291) / 410 × 100 = 119 / 410 × 100 = 29.0% (1). **b.** (356 − 291) / 356 × 100 = 65 / 356 × 100 = 18.3% (1). **c.** Measuring from the earlier, higher base year makes the reduction look larger — 29% against 2005 versus 18% against 2019 — although the tonnes avoided since 2019 are the same 65 kt either way (1). The release must state the base year, the boundary of the inventory and the units, or the percentage cannot be interpreted or compared (1).

Q9. a. Knowledge — experiential (1). **b.** Priority — a ranking between two things both valued (1). **c.** Values (1).

Q10. Two ways, any of: it makes a previously impossible option feasible; it changes the cost of an existing option; it changes what can be measured; it raises the standard of what is "reasonably practicable" under the general environmental duty (2). Two questions, any of: is it demonstrated at this scale; what is its life-cycle emission; what is the cost per tonne abated over the asset life; does it create lock-in or a stranded asset; does it transfer risk rather than remove it; does the promise of it defer abatement now (2).

Q11. a. Value: the continued viability of irrigated farming in the district, or fair access to a shared water resource (1). Priority: securing their own water reliability ahead of a neighbour's expansion, or keeping district charges low ahead of new infrastructure (1). **b.** Shade and misting — efficiency of resource use, or intragenerational equity, since the

existing farm and its workforce continue (1). Buying land at elevation — the precautionary principle, or intergenerational equity, since it addresses the change projected for later decades rather than this season's heat (1). **c.** One direction, correctly named (1), with the mechanism that carries it (1). Either direction earns both marks — data → framework: the projections supply the design case that a planning or water authority requires the company to address, so data determines what the framework asks for; or framework → data: the framework determines which projection the company must use — the authoritative dataset, scenario and horizon — so regulation bounds which data counts. A direction named without a mechanism earns 1.

Q12. The reasoning inverts the precautionary principle, which is triggered by exactly this combination of high potential harm and uncertain evidence, and which requires measures to be taken (1). Delay is not neutral: warming tracks cumulative emissions and coastal exposure continues to increase while data is gathered, so waiting imposes a real cost (1). The uncertainty largely concerns future human emissions rather than the observed record, so it will not be resolved by more measurement — which is why no-regrets actions and adaptation pathways with trigger points are used instead of deferral (1).

Q13. Experiential knowledge covers periods, places and variables the instrumental record does not: a long-standing observation of dune recovery, channel silting, flowering times or fish movements may extend decades before the nearest gauge was installed and at the exact site that matters (1). It can therefore reveal a rate, a threshold or a local process that a regional dataset averages away, and can contradict an interpretation drawn from short records (1). It also changes whether a community will act on the decision at all, because evidence that ignores what people have seen is not believed (1). The condition: it must be treated as evidence and tested like evidence — recorded, attributed, checked against other sources and for bias — not accepted or dismissed because of who holds it (1).

Q14. The 0.8 m benchmark derives from Victorian coastal policy of the late 2000s, while IPCC AR6 (2021) gives a likely 2100 range of 0.63–1.01 m under SSP5-8.5 and states that under that same very high emissions scenario a rise approaching 2 m by 2100 cannot be ruled out, with low confidence (1). The tension is between **certainty and currency**: a fixed number gives applicants, councils and financiers a single defensible design level and equal treatment, while a number that lags the science under-designs long-lived assets and transfers the shortfall to future owners and ratepayers (1). It is structural, because updating the rule continuously would destroy the certainty that is its main value (1). Responsible resolution: treat the clause as the floor it is expressed to be — "not less than" — design and sensitivity-test above it for assets with a life to 2100, state the scenario and horizon assumed, and use an adaptation pathway with a monitored trigger point so the design can be escalated on observed sea level rather than on the next policy revision (1).

Q15. a. Special charge on the benefiting properties: 4 200 000 / 340 = **$12 352.94** per title (1). General rates: 4 200 000 / 11 500 = **$365.22** per rateable property (1). **b.** The special charge relies on the **user pays principle** — the user of a service pays directly for the amount they use, rather than the cost being shared equally across the community (1). Funding from general rates relies on **intragenerational equity** — preserving the environment and the assets of the current generation by spreading the cost so that the works are not defeated by the capacity of 340 households to pay (1). The tension is that the allocation which is fairest by benefit is the one most likely to be unaffordable and therefore not to happen, while the affordable allocation charges 11 160 properties for works from which they gain nothing directly (1).

Q16. See fully-worked solutions. Chain: a technology that promises future removal or abatement changes present behaviour → abatement is deferred on the strength of it → the technology arrives late, at smaller scale, or not at all → the deferred emissions are already in the cumulative stock and are permanent on any management timescale → the generation that inherits the stock carries a loss caused by a decision made for them and without them, which is a breach of intergenerational equity. (5)

Q17. See fully-worked solutions. Key points: opposition is not disproof; a tension means a choice must be made against someone's priority; responsibility lies in the *process and the transparency*, not in unanimity — naming the tension, giving the opposing stakeholder standing and a genuine hearing, stating which values were preferred and why against sustainability principles, placing the residual risk explicitly, and building a review trigger. (5)

Q18. See fully-worked solutions. (8)

Q19. See fully-worked solutions. (10)

Fully-worked solutions

Q1. The mark is for the definition, not for a list of examples. Two elements do it: a person, group or organisation, and *involved in the decision-making* about an issue, project or case study. A common loss is answering with a list — "farmers, councils, industry" — which names instances of the category without defining it.

Q2. The discriminator is *is it a claim about what is, or about what matters*. Knowledge can be checked against other evidence; values cannot be checked at all, only stated and weighed. The study design's own wording is worth carrying: knowledge is "scientific, technical and experiential", which is the authority for counting a resident's long observation as knowledge rather than as opinion. The third object, **priorities**, is the ranking that appears only when values conflict — which is why two stakeholders who share every value can still be opposed.

Q3. Marks are for examples that are recognisably of the right kind. The frequent error is putting a technology in the regulatory row ("the government's solar rebate") or a value in the data row ("the community believes the sea is rising"). Test each entry: a regulatory example must name an instrument and its effect; a data example must name a dataset or projection; a technology example must name a physical or measurement capability.

Q4. Both definitions must be relational. An interconnection is a *causal or informational* link — one factor changes what another requires, permits, wants or can see. A tension is an *opposition* — the poles cannot both be fully satisfied. The useful test to state is that a tension survives complete agreement on the facts, while a dispute does not: if better data or clearer explanation would end the argument, it was never a tension.

Q5. The marks are in the *function*, not the name, and the four tiers do genuinely different things. The international tier sets goals and obliges reporting between states. The Commonwealth tier legislates targets and builds the accounting system, and reaches individual facilities only through the safeguard mechanism. The Victorian tier legislates targets and, unusually, prescribes how decisions are to be made — the guiding principles of informed decision making, integrated decision making, risk management, equity, community engagement and compatibility. The local tier applies a number to a title boundary, which is where almost every contested adaptation decision is actually resolved.

Q6. The definition, the burden and the trigger are three separate marks. The burden is the part most often lost: the principle requires "the proof of no, or minimal, harm be provided by the proposer", so a proponent cannot rely on the absence of proof of harm. That is what makes the principle bite in climate decisions, where the harm is severe, partly irreversible and separated from the action by decades, and where the residual uncertainty is about future human choices and so cannot be reduced by further measurement in the time available.

Q7. Three marks, three ideas: the shared budget, then one limitation on each side. The limitation on mitigation is *committed change* — the stock of greenhouse gases already emitted, plus ocean thermal inertia (**9B**), guarantees further change whatever is now abated, so some adaptation is unavoidable. The limitation on adaptation is that it *abates nothing* — it reduces exposure at a place, while the driver continues and the required adaptation grows. A common wrong answer treats them as alternatives and argues for one; the examinable point is that the tension is over the *allocation*, not over which is correct.

Q8. Both calculations are ordinary percentage change, taken on the earlier value. The interpretive mark is the point of the question: the same 65 kt of reduction since 2019 can be presented as 29% or as 18% purely by choosing the base year, and choosing 2005 is not dishonest — it is the base year Victoria's own targets use — but the figure is uninterpretable unless the base year is stated. The transferable rule is the one that governs every emissions claim in the news: *a percentage without a base year, a boundary and a unit is not a number*.

Q9. Run the same three tests. (a) is checkable against records, so it is knowledge — and experiential knowledge, which the study design's definition explicitly includes. (b) contains the word *more than*: it is a ranking of two things both valued, which is a priority. (c) asserts a right, with no evidential content at all, which is a value. Students who answer "values" to all three have not noticed that the study design treats the three as separable objects, and questions of this kind exist to test exactly that.

Q10. The four ways and the six questions are worth learning as lists, because this is a two-plus-two mark question in every form it appears. The most-missed *way* is the fourth: a duty framed as what is "reasonably practicable" tightens automatically once a better technique becomes available and affordable, so a technology can change what the law requires of an operator who has changed nothing. The most-missed *question* is the sixth: whether the promise of the technology is deferring abatement now.

Q11. Part (a) requires one of each object, correctly labelled: a value is a thing held worth having, a priority is a ranking. Part (b) works because the two options are on opposite sides of the *act now or adapt later* axis: on-farm infrastructure serves the present operation and the present workforce, which is intragenerational equity and efficiency of resource use; buying land at elevation is a precautionary, intergenerational move that addresses projected conditions rather than current ones. Part (c) accepts either direction of the coupling, but the answer must state a *mechanism* — data supplying the design case the authority requires, or the framework nominating which dataset, scenario and horizon are authoritative. Saying only that "they are connected" earns nothing.

Q12. Three distinct failures, and a good answer names all three rather than elaborating one. First, the argument inverts the precautionary principle: high potential harm plus uncertain evidence is the trigger for action, and the burden of showing minimal harm sits with the proposer. Second, delay has a cost, because warming tracks *cumulative* emissions and exposure keeps growing while data is collected — the do-nothing option is a decision with consequences, not a neutral holding position. Third, the uncertainty is of a kind that further measurement will not resolve: the projections diverge mainly because future emissions depend on choices not yet made, so "until the projections agree" is a condition that may never be met. The constructive answer is not to commit prematurely but to sequence — take the no-regrets actions now and set trigger points that escalate the response on observed values.

Q13. Four marks: what experiential knowledge adds, why it can change the answer, why it changes whether the decision sticks, and the condition on its use. On the first, be concrete: it covers the period before the instruments were installed and the exact site the regional dataset averages over, and it captures variables nobody thought to measure. On the second, the mechanism is that a local rate or threshold can differ from the regional average, so an interpretation drawn from a short or coarse record can be wrong at the place where the decision applies. On the third, evidence that contradicts what a community has watched for decades is not believed, and an unbelieved strategy is not implemented — trust is a condition of the evidence being used at all. The condition is symmetry of treatment: experiential knowledge is tested like any other evidence, for consistency, corroboration and bias, and is neither privileged nor dismissed because of who holds it.

Q14. The structure of the answer is: where the number came from, what the science now says, why that is a tension rather than an error, and how to resolve it. The tension is between **certainty and currency**, and it is genuine on both sides — a fixed benchmark delivers equal treatment, defensible permits and financeable projects, and a benchmark that moved with every publication would deliver none of those. Note that the clause resolves part of it already, by expressing the figure as a floor rather than a ceiling — the benchmark itself is taught at **11C**, and a student who has it the wrong way round will misread this question. So the responsible course is available inside the rule — design above the floor where the asset's life reaches 2100, state the scenario and horizon assumed, sensitivity-test against the high-end storyline, and set a monitored trigger point that escalates the design on observed sea level instead of waiting for the policy to be rewritten.

Q15. The arithmetic is deliberately simple, because the point of the question is what the two numbers do to the argument. $12 352.94 per protected title against $365.22 per rateable property is a difference of about 34 times, and the whole *who pays* tension is contained in it.

Get the principles the right way round. **User pays** is the study design's principle that calls upon the user of a service or resource to pay directly for the amount they use, "rather than the cost being shared by all the users or a community equally" — which is exactly what a special charge on the 340 benefiting titles does. **Intragenerational equity** — preserving natural resources and the environment for the benefit of the current generation — is what general rates serve, because the works only protect anybody if they are actually built.

Then state the tension, which is structural rather than a matter of preference. Charging by benefit is the defensible allocation in principle and is likely to be unaffordable in practice: $12 353 per household, on titles whose value is itself threatened by the hazard, may simply not be payable, in which case the works do not proceed and the principle has protected nothing. Spreading the cost makes the works happen and charges 11 160 properties for a benefit they do not receive. A responsible decision does not pretend one of these is correct; it chooses, says which principle it preferred and why, and states the residual risk it has left with whoever ends up paying. Two refinements are worth a sentence if there is room: the split can be apportioned rather than all-or-nothing, in the proportion in which benefit is actually received; and if the works only defer the hazard, then a third party — the ratepayer of 2070, who inherits both the asset and the maintenance liability — is paying too, which is an **intergenerational equity** question the two options as framed do not show.

Q16. *Model response (5 marks).* New technology enters a climate decision not only when it is deployed but as soon as it is *expected*, and that is where the tension with intergenerational equity begins.

Mitigation deterrence is the deferral of abatement that is now possible on the strength of abatement that is promised later. A proponent argues that capture and storage, or direct air capture, or a future fuel, will remove the carbon dioxide in due course, so the emissions of the intervening decades need not be avoided. The argument is coherent only if the technology arrives, at the promised scale, at the promised time, and at a cost someone will actually pay.

The asymmetry is what makes it a tension rather than a gamble. Because warming is driven by **cumulative** emissions and carbon dioxide persists for centuries, an emission released while waiting is permanent on any management timescale, whereas the promised removal is contingent. If the technology under-delivers, the shortfall cannot be recovered: there is no mechanism by which a later generation can un-emit the carbon that the deferral produced. The party that benefits from the deferral — the present operator, who avoids capital expenditure now — and the party that carries the consequence of the promise failing are therefore different parties, separated in time.

That is a breach of **intergenerational equity**, which requires preserving natural resources and the environment for the benefit of future generations, because the risk of the technology failing has been transferred to people who have no standing in the decision and no ability to reverse it. It also engages the **precautionary principle**, since the burden of proving no or minimal harm sits with the proposer, not with those who doubt the retrofit.

None of this makes the technology illegitimate. Capture and storage, and removal technologies generally, are necessary for emissions that cannot yet be eliminated, and the Gippsland Basin has been investigated for exactly that purpose. The responsible form of the decision separates the two questions: abate what can be abated now, treat future removal as a supplement rather than a substitute, and make any reliance on it conditional and reviewable — a demonstrated storage pathway and a trigger point, not an intention.

Q17. *Model response (5 marks).* Opposition from a major stakeholder is evidence about the decision's distribution of costs, not evidence that the decision is wrong. A tension, by definition, is a situation in which satisfying one party's priority means not satisfying another's, so a decision that no one opposes is usually a decision in which the tension has been concealed rather than resolved. Responsibility is therefore located in the process and the transparency, not in unanimity.

Take the factors of **diverse stakeholder priorities** and **regulatory frameworks**. A shire that resolves to relocate a small settlement rather than armour its shoreline will be opposed by the residents, whose priority is to remain, and whose experiential knowledge of past dune recovery is real. The decision can still be responsible if four things are true. The opposing stakeholder had genuine standing, not a notification — which is what the *Climate Action Act 2017* (Vic)'s community engagement principle requires, and what the procedural rights in the planning framework supply. The reasoning is stated on the ground it was actually made on: the Shire preferred **intergenerational equity** and the integrity of the barrier system over the **intragenerational equity** of current owners, and said so, rather than presenting the choice as compelled by the data. The residual risk is placed explicitly, including who bears the loss of property value and on what terms it is compensated. And a trigger point is set, so that if observed sea level or storm frequency turns out lower than assumed, the sequence can be revised.

What would make the same decision *irresponsible* is not the opposition. It is presenting a value judgement as a technical necessity, hearing the residents only after the choice was settled, or leaving the loss to fall where it happens to fall. A responsible decision can leave a stakeholder worse off and unpersuaded; what it cannot do is leave them unheard, or leave the judgement hidden.

Q18. *Model response (8 marks).* The decision is a choice about what a fixed sum of money buys in a district facing a drier cool season and higher evaporation: **channel modernisation**, which delivers the same production from less water and keeps the district's current footprint, or **entitlement retirement with revegetation**, which reduces the footprint and returns water and land to the environment.

The interconnections. Data → Regulation is the first: Victorian Climate Projections 2024, built on CMIP6 models and the SSP scenarios and reported for Gippsland in Victoria's Climate Science Report 2024, supply the reduced cool-season rainfall and higher evaporation that any water authority's planning must now address, and they are the reason a decision is being taken at all. Regulation → Data runs the other way and bounds what the district can see: the framework sets which dataset, scenario and horizon are authoritative, and the district's plan is in force against the superseded **VCP19** generation, which used CMIP5 and RCPs. So the co-operative is holding a current projection and

a plan built on the previous one, and a table setting an RCP8.5 figure beside an SSP5-8.5 figure as though they were the same pathway would mislead. Part of the apparent change between the two sets of numbers is a change in the modelling, not in the catchment. Technology → Regulation matters because modernisation is a technology decision that changes what is "reasonably practicable" for water delivery, and because drainage into the Gippsland Lakes engages the general environmental duty under the *Environment Protection Act 2017* (Vic) and, through the Lakes' listing under the Ramsar Convention in 1982, Commonwealth environmental law as well. Regulation → Stakeholders allocates who decides: entitlement holders, the district's co-operative members, the catchment management authority, the declared heritage landscape body for the district under this workbook's fictitious *Marrowvale Heritage Protection Act 2011*, and downstream users of the Lakes each have different standing, and standing is what converts a view into influence.

The tensions. Three are structural. First, **efficiency against ecological outcome**: modernisation serves **efficiency of resource use** directly, but efficiency gains are often taken as expanded production rather than as returned water, in which case the Lakes receive no benefit and the nutrient load may not fall. Second, **who bears the loss**: retirement concentrates the cost on the specific irrigators whose entitlement is retired, while the benefit — a healthier Ramsar wetland — is shared across the region and beyond, so **intragenerational equity** and **user pays** pull against each other. Third, **green against green**: the Lakes' ecological condition and the district's continued agricultural viability are both defensible on sustainability grounds, and the district's drainage is simultaneously the mechanism that sustains production and part of the nutrient pressure on the receiving wetland. None of the three dissolves with more data, because nothing in dispute is a matter of fact.

What a responsible decision must include. It states the scenario and horizon it is designed for, and does not mix RCP- and SSP-based figures without saying so. It separates the mitigation claim from the adaptation claim — revegetation sequesters carbon and is a mitigation measure as well as an adaptation one, while channel modernisation is adaptation and abates little, so neither should be credited twice. It says whether the water saved by modernisation is returned to the environment or made available for production, because that single choice determines whether the project delivers an ecological outcome at all. It places the residual risk: on the retiring irrigators, on the district's remaining members through higher per-megalitre charges, or on the Lakes. It gives the declared heritage landscape body standing as a rights-holder under the instrument that creates that role — here, the fictitious *Marrowvale Heritage Protection Act 2011* — not as one submission among many. And it sets monitored trigger points — inflow, salinity, nutrient load, allocation reliability — with a named decision-maker empowered to move to the next stage of the pathway when a threshold is crossed.

Q19. *Model response (10 marks).* The statement contains a real insight and a serious error. The insight is that decisions which ignore the science are worse decisions, and that a great deal of public argument consists of disputing evidence that is not in fact disputed among those who produce it. The error is the word *simply*. Following the science tells a decision-maker what is happening and what is likely to happen under stated conditions. It does not tell them what to do, because every climate decision requires at least four further things the science cannot supply: a choice of scenario and horizon, a ranking of competing values, a legal instrument through which to act, and a judgement about a technology that does not yet exist at scale.

Scientific data does less than the statement assumes, and it does it conditionally. The observed record is strong: Australia's climate has warmed by 1.51 ± 0.23 °C since 1910, sea surface temperatures around Australia have risen about 1.08 °C since 1900, April to October rainfall in south-eastern Australia has fallen by around 9% since 1994, and global mean sea level has risen more than 22 cm since 1900, half of it since 1970 (CSIRO and the Bureau of Meteorology, *State of the Climate 2024*). But a hundred-year decision needs the future, and the future exists only as **projections**, which are conditional on emissions pathways that depend on human choices not yet made. IPCC AR6 gives a likely global mean sea level rise by 2100 of 0.32–0.62 m under SSP1-2.6 and 0.63–1.01 m under SSP5-8.5, and says that under the very high emissions scenario, SSP5-8.5, a rise approaching 2 m by 2100 cannot be ruled out, with low confidence. "Following the science" does not choose between those, and the choice changes the answer more than any disagreement between models does. Choosing a scenario, a base year and a spatial scale — with the confidence qualifiers of **10D** attached — is a judgement made *with* the science, not read off it.

Values and priorities cannot be derived from data at all. The study design separates a stakeholder's **values**, **knowledge** and **priorities** for this reason. On the Ninety Mile Beach, residents, a shire, a fishing co-operative, a developer, an environmental group and the Ashlern Commons Trust can agree on every number in a coastal hazard assessment and still divide, because they rank security of home, public safety, ecological integrity, livelihood and

continuity of a heritage landscape differently. Two of the most affected constituencies — the people alive in 2100 and the species that will have to shift range — hold no view that can be consulted, so their interests enter only if **intergenerational equity** is treated as a decision rule and the procedure gives them standing.

Regulatory frameworks decide who may act, and on what. Science has no operative force. The Paris Agreement binds states; the *Climate Change Act 2022* (Cth) legislates 43% below 2005 by 2030 and net zero by 2050, with a 2035 target of 62–70% announced in September 2025; the *Climate Action Act 2017* (Vic) legislates net zero by 2045 with five-yearly interim targets, requires adaptation action plans, and prescribes the principles — informed decision making, integrated decision making, risk management, equity, community engagement and compatibility — by which Victorian decisions are to be made. Almost none of that reaches an individual business: the safeguard mechanism, with baselines declining 4.9% a year to 2030, applies only above 100 000 t CO_2-e a year. So most abatement by most organisations is voluntary, and a strategy premised on legal compulsion collapses on inspection.

Technology adds a judgement the science does not settle. Whether to build now or wait for capture and storage, whether hydrogen from brown coal is low-emission, whether an offset is additional and permanent — these turn on life-cycle accounting, scale, cost per tonne, lock-in and risk transfer. Treating technology as the answer is **technocentrism** (**3C**), a value position, not a finding; and the expectation of a future technology can cause harm through **mitigation deterrence**, because deferred emissions enter a cumulative stock that no later technology can be relied upon to remove.

The four factors also act on each other, which is why the decision cannot be decomposed. One coupling makes the point. Data → Regulation gave planning scheme clause 13.01-2S its requirement to allow for a sea level rise of not less than 0.8 m by 2100 — a scientific number frozen into a rule. Regulation → Data then runs back the other way: that clause now determines which sea level a council is obliged to design for, whatever AR6 says. Following the science does not resolve that loop; only a decision-maker can, by treating the figure as the floor it is expressed to be and designing above it.

And the hard cases are tensions, which survive agreement on the facts. Mitigation against adaptation is a contest over one budget between a small share of a global, delayed benefit and a large share of a local, sooner one. Transition speed against transition fairness is why the Latrobe Valley's closures — Hazelwood in 2017, Yallourn and Loy Yang A announced for 2028 and 2035 — are an equity question as well as an emissions question. Green against green is the sharpest: the Gippsland offshore wind area, about 15 000 km² declared on 19 December 2022 under the *Offshore Electricity Infrastructure Act 2021* (Cth), is both the state's largest single mitigation opportunity and a working fishery, a whale migration route and seabird habitat. Both poles invoke **conservation of biodiversity and ecological integrity**, at different scales. No dataset adjudicates between two scales of the same value.

What follows is a better standard than "follow the science". A responsible climate decision states the scenario and horizon it assumes; keeps separate what the data showed, with its confidence, from what was judged acceptable and by whom; does not credit a measure as both mitigation and adaptation; names the tension instead of presenting the choice as compelled; says where the residual risk goes, in space and in time; sets a monitored trigger point and a decision-maker empowered to act on it; and is honest that no Victorian decision changes the global climate — it changes the region's contribution, the region's exposure, and who bears the loss. Science is indispensable and insufficient. It is the input that disciplines the judgement, not a substitute for making one.

Topic 4 Test — Unit 4 Area of Study 1 — Climate change

Total 40 marks. Working time 60 minutes, in class. Answer all questions in the spaces provided. Stationery and one scientific calculator only: no notes, no devices.

What this task is. This is a **practice** task that mirrors the mark total and the shape of the Unit 4 Outcome 1 School-assessed Coursework task. **It is not a SAC.** SACs are set, timed and authenticated by your school, one task type per outcome, and no task type may be used twice across Units 3 and 4. Use this to meet the material under time pressure before the real thing.

What it covers. Chapters **09**, **10** and **11** — Earth's energy balance and the greenhouse effect; measuring, modelling and projecting climate change; and managing climate change. Every one of the thirteen key knowledge dot points in Unit 4 Area of Study 1 is assessed somewhere in this paper.

A note on the region used in Questions 6 to 8. Chapters 11A and 11C build their risk, opportunity and adaptation material at **Gippsland**. This test is set at a **different real Victorian region — the Great South Coast**, so that it tests whether you can apply the method to a place rather than recall the place you were taught. You are **not** expected to have studied the Great South Coast. Every figure you need is printed in the stimulus, with its scenario, its time period and its baseline.

How marks are earned. Every question carries its marks. A 2-mark *explain* wants the definition **and** its application to the stimulus; a 3-mark *explain* wants the mechanism **and** specific data from the stimulus — years, figures and units. Where a question says *use the data provided*, quote the data. Where a calculation is asked for, show working and give the unit.

Q1. *(5 marks)*

Use the information below to answer Question 1.

> **Stimulus — effective radiative forcing, 1750 to 2019.** The table gives the change each factor has made to Earth's energy balance over the industrial era, in watts per square metre.

Factor	Natural or anthropogenic	ERF (W m^{-2})
Carbon dioxide	Anthropogenic	+2.16
Methane	Anthropogenic	+0.54
Ozone, troposphere and stratosphere combined	Anthropogenic	+0.47
Halogenated gases	Anthropogenic	+0.41
Nitrous oxide	Anthropogenic	+0.21
Land-use surface albedo and irrigation	Anthropogenic	−0.20
Aerosols, direct scattering and absorption	Anthropogenic	−0.22
Aerosols, effect on cloud brightness and lifetime	Anthropogenic	−0.84
Total anthropogenic		**+2.72**
Change in solar irradiance	Natural	+0.01
Volcanic stratospheric aerosol, long-term average	Natural	about 0
Total natural		**+0.01**
Net total		**+2.73**

a. Identify the natural factors in the table, and use the values provided to explain why they cannot account for the change in Earth's energy balance since 1750. (2 marks)

b. Explain how an increase in the atmospheric concentration of carbon dioxide raises the temperature of Earth's surface. Trace the radiation from the Sun to the surface and back. (3 marks)

Q2. *(5 marks)*

Use the information below to answer Question 2.

Stimulus — global warming potential over three time horizons. Values are from the Intergovernmental Panel on Climate Change Sixth Assessment Report, Working Group I (2021), Table 7.15.

Gas	Atmospheric lifetime	GWP-20	GWP-100	GWP-500
Carbon dioxide	no single value	1	1	1
Methane (fossil origin)	11.8 y	82.5	29.8	10.0
Nitrous oxide	109 y	273	273	130
Sulfur hexafluoride	3200 y	18 300	25 200	34 100

a. Explain what is meant by the **global warming potential** of a greenhouse gas. (2 marks)

b. A gas network operator reports a fugitive emission of fossil-origin methane. Calculate the percentage by which the reported carbon dioxide equivalent of that emission falls when the reporting horizon is changed from 20 years to 100 years. Show your working. (2 marks)

c. State the property of a gas that determines whether its global warming potential rises or falls as the time horizon lengthens. (1 mark)

Q3. *(4 marks)*

Use the information below to answer Question 3.

Stimulus — atmospheric carbon dioxide, 1750 to 2024.

Interval	CO_2 at the start	CO_2 at the end	Mean growth rate
1750 → 1900	278 ppm	about 296 ppm	about 0.12 ppm per year
1900 → 1960	about 296 ppm	about 317 ppm	about 0.35 ppm per year
1960 → 2024	about 317 ppm	423.9 ppm	about 1.67 ppm per year
2015 → 2024	—	—	about 2.6 ppm per year

a. Referring to the data, describe how the **rate** of increase of atmospheric carbon dioxide has changed between 1750 and 2024. (2 marks)

b. Revegetating cleared farmland is classified as short-term carbon sequestration. The burial of carbonate in deep-sea sediment is classified as long-term. Explain the difference. (2 marks)

Q4. *(6 marks)*

Use the information below to answer Question 4.

Stimulus — three Australian climate records.

Law Dome (DE08), Wilkes Land, Antarctica. An Australian Antarctic Division ice core from a coastal site receiving over a metre of ice-equivalent snowfall a year. Air trapped in the bubbles is extracted and

analysed. Gas smoothing is about a decade, the narrowest of any core. This record fixes the pre-industrial carbon dioxide baseline at about 278 ppm and traces the industrial rise.

Cape Grim Baseline Air Pollution Station, north-west Tasmania. A World Meteorological Organization Global Atmosphere Watch baseline station operated by the Bureau of Meteorology with CSIRO, sampling air arriving on the Roaring Forties after a long ocean fetch. Continuous in-situ measurement since April 1976.

ACORN-SAT. The Bureau of Meteorology's Australian Climate Observations Reference Network – Surface Air Temperature: 112 long-record stations beginning in 1910, homogenised. Built from this network, CSIRO and the Bureau of Meteorology's *State of the Climate 2024* reports that Australia has warmed on average by **1.51 ± 0.23 °C** since 1910.

a. Explain why the Law Dome record and the Cape Grim record must **overlap in time** before they can be joined into a single carbon dioxide series. (2 marks)

b. Explain what homogenisation of ACORN-SAT removes, and why it is not an alteration of data to suit a conclusion. (2 marks)

c. A student writes: *"Cape Grim shows carbon dioxide rising, so global carbon dioxide is rising."* Evaluate this statement. (2 marks)

Q5. *(5 marks)*

Use the information below to answer Question 5.

Stimulus — confidence statements from a regional projection. The following are published findings for the Great South Coast region of Victoria.

- "Maximum and minimum daily temperatures will continue to increase over this century (**very high confidence**)."
- "Rainfall … over the long term it is expected to continue to decline in winter and spring (**medium to high confidence**), and autumn (**low to medium confidence**), but with some chance of little change."
- "Extreme rainfall events are expected to become more intense on average through the century (**high confidence**) but remain very variable in space and time."

a. Explain why the rainfall statements carry lower confidence ratings than the temperature statement. (3 marks)

b. State what a rating of *very high confidence* is built from, and state one thing such a rating does **not** mean. (2 marks)

Q6. *(6 marks)*

Use the information below to answer Questions 6 and 7.

Stimulus — the Great South Coast, Victoria. The region runs from the Otway Ranges west to the South Australian border, taking in Warrnambool, Port Fairy, Portland, Hamilton and Colac. It carries dairy and grazing country inland, a high-energy open coast, and the **Western District Lakes**, a group of nine lakes in the landlocked Lake Corangamite catchment listed under the Ramsar Convention in 1982 and covering about 33 000 ha. Lake Corangamite is Australia's largest permanent saline lake. The lakes have no outlet: their level and their salinity are set by the balance between inflow and evaporation.

Published projections, Great South Coast. All values are for the high-emissions scenario **RCP8.5** and the period **2040–2059**, against a **1986–2005** baseline, unless the table states otherwise. Projected values are the median, with the 10th to 90th percentile range in brackets.

Variable	Observed	Projected
Days a year above 35 °C, Hamilton	8.7 (1981–2010)	17.7 (13.1 to 23.0)
Days a year above 35 °C, Warrnambool	5.8 (1981–2010)	11.6 (8.1 to 13.4)

Variable	Observed	Projected
Days a year below 2 °C, Hamilton	20.4 (1981–2010)	9.1 (8.6 to 10.9)
Annual rainfall, Hamilton Airport	616.6 mm (1986–2005)	−12% (−20 to −2)
Spring rainfall, Hamilton Airport	181.7 mm (1986–2005)	−22% (−23 to +18)
Annual pan evaporation	—	+17.3% (8.6 to 24.6)
Days a year with a Forest Fire Danger Index above the 1986–2005 95th percentile, Hamilton	—	+10.3 days a year, a 56% increase (*high confidence*)
Sea level at Portland, 2050s against the 1990s	—	+24 cm, a median 4 mm per year

a. Use the data provided to calculate the percentage increase in the median number of days a year above 35 °C at Hamilton. Show your working. (2 marks)

b. Referring to the data, explain one risk that the projected changes pose to an **ecological** system in this region. (2 marks)

c. Identify one **opportunity** that these projections create for agriculture in this region, and state the condition on which realising it depends. (2 marks)

Q7. *(4 marks)*

Four measures currently in place or declared in the Great South Coast region are listed below.

> **A** Sand renourishment and geotextile sand containers placed on the eroding shoreline at East Beach, Port Fairy.
>
> **B** The Southern Ocean offshore wind area off Port Fairy and Warrnambool, declared on 6 March 2024 under the *Offshore Electricity Infrastructure Act 2021* (Cth).
>
> **C** Coastal hazard overlays applied to Port Fairy through Moyne Planning Scheme Amendment C69, using a sea level rise benchmark of 1.2 m by 2100.
>
> **D** Replacing gas ducted heating with electric heat pumps in Warrnambool households under the Victorian Energy Upgrades program.

a. Complete the table by classifying each measure as **mitigation** or **adaptation**. (2 marks)

Measure	Mitigation or adaptation
A Sand renourishment at East Beach	
B Southern Ocean offshore wind area	
C Coastal hazard overlays, Amendment C69	
D Heat pumps under Victorian Energy Upgrades	

b. Explain the mechanism by which **one** of the measures you classified as adaptation reduces harm. (2 marks)

Q8. *(5 marks)*

Use the information below to answer Question 8.

> **Stimulus — declaring the Southern Ocean offshore wind area.** On 6 March 2024 the Commonwealth declared an offshore wind area in the Southern Ocean off south-west Victoria, under the *Offshore Electricity Infrastructure Act 2021* (Cth). The proposed area covered about **5100 km²**; the area actually

declared covers about **1030 km²**, confined to waters west of Port Fairy and east of the southern right whale nursery at Logans Beach, Warrnambool. Three proposed projects near Portland, in Discovery Bay and near Port MacDonnell fell outside the declared area. The declaration followed a **64-day public consultation** from 28 June to 31 August 2023. Feasibility licence applications opened on 6 March and closed on 2 July 2024.

Victoria has legislated offshore wind targets of at least **2 GW by 2032, 4 GW by 2035 and 9 GW by 2040**, and a target of **net zero emissions by 2045** under the *Climate Action Act 2017* (Vic).

Discuss the interconnections and tensions between the factors that influenced this decision. In your answer refer to diverse stakeholder values and priorities, the regulatory framework, and the use and interpretation of scientific data. (5 marks)

End of test questions

Topic 4 Test — solutions

Mark allocation and coverage. The paper mirrors the 40-mark Unit 4 Outcome 1 SAC total and covers all thirteen key knowledge dot points of Unit 4 Area of Study 1.

Q	Marks	Subtopic	Key knowledge
1	5	9A, 9B, 9C	U4A1-K1 natural and anthropogenic factors; U4A1-K2 absorbed, re-emitted and reflected solar energy; U4A1-K4 natural versus enhanced greenhouse effect
2	5	9D	U4A1-K6 greenhouse gas warming potential
3	4	9E, 9F	U4A1-K3 short- and long-term carbon sequestration; U4A1-K5 altered concentrations over different time periods
4	6	10A, 10B	U4A1-K7 ice cores, palaeoclimate records, atmospheric and ocean temperature monitoring; U4A1-K8 direct measurement and modelling
5	5	10C, 10D	U4A1-K9 projections and IPCC confidence ratings
6	6	11A	U4A1-K10 risks and opportunities at a selected region
7	4	11B, 11C	U4A1-K11 mitigation options; U4A1-K12 adaptation options at a selected region
8	5	11D	U4A1-K13 interconnections and tensions in responsible decision-making
	40		

Command terms used in this test. Every model response below is built to the depth its term demands.

Term	What it requires	Used at
State	Give the required information briefly, with no elaboration. One clear idea.	Q2c, Q5b, Q6c
Identify	Name or select the thing asked for.	Q1a, Q6c
Describe	Give the characteristics or the pattern accurately, going beyond listing.	Q3a
Explain	Account for how or why — supply the mechanism, plus its application to the stimulus.	Q1a, Q1b, Q2a, Q3b, Q4a, Q4b, Q5a, Q6b, Q7b

Term	What it requires	Used at
Calculate	Work the value, show the working where asked, and give the unit.	Q2b, Q6a
Evaluate	Weigh the statement against the evidence and reach a judgement.	Q4c
Complete the table	Enter the required classification in each cell.	Q7a
Discuss	Develop a considered argument across the named factors, weigh what pulls each way, and reach a position.	Q8

Aboriginal and Torres Strait Islander knowledge — deliberately not covered (ICIP). This workbook does not reproduce Aboriginal and Torres Strait Islander knowledge, cultures or histories. The Study Design's Aboriginal and Torres Strait Islander knowledge and perspectives requirement is therefore not covered here. Real Aboriginal and Torres Strait Islander knowledge must be sourced by teachers directly with the relevant community under the appropriate protocols; any Indigenous-looking example in this book is fictitious and must not be taken as real.

Q1. *(5 marks)*

Command term — identify, then explain. Part **a** wants two things named and then an argument built out of the numbers in the table, not an assertion. Part **b** is the single worst-answered question type in this part of the course: in 2025 only about one student in ten scored full marks on the greenhouse mechanism.

Model response.

a. The natural factors are the **change in solar irradiance**, at +0.01 W m^{-2}, and **volcanic stratospheric aerosol**, whose long-term average is about zero (1). Together they total **+0.01 W m^{-2}** against a net total of +2.73 W m^{-2} — about **0.4%** of the change. The anthropogenic total of +2.72 W m^{-2} is some 270 times larger, so natural forcing is too small by more than two orders of magnitude to account for the change (1).

b. Solar radiation arrives mostly as short-wavelength visible light. The atmosphere is largely transparent to it, so it passes through and is **absorbed at Earth's surface**, warming it (1). The warmed surface re-emits energy at much longer wavelengths, as **infrared radiation**. Carbon dioxide molecules absorb infrared at the frequencies of their vibrational modes (1). The excited molecules then **re-emit infrared in all directions**, so a portion is directed back down and absorbed at the surface. Raising the carbon dioxide concentration increases the fraction of outgoing infrared absorbed and increases the back radiation, so the surface warms until the energy leaving the planet again balances the energy arriving (1).

Marking guide. **a** — 1: both natural factors identified with their values. 1: the comparison made numerically — natural total +0.01 against net +2.73, or against the anthropogenic +2.72 — with the conclusion drawn. **b** — 1: incoming solar is short-wavelength, passes through the atmosphere, is absorbed at the surface. 1: the surface re-emits as infrared, which greenhouse gases absorb. 1: re-emission **in all directions**, so more returns to the surface as the concentration rises.

Common errors. In **a**, saying "the natural factors are small" without quoting a figure — the marks are in the arithmetic. Also, treating volcanic forcing as zero in every year: it was about −3 W m^{-2} in 1992, but it averages to nothing over a century because it is episodic. In **b**, the reported failures are: describing greenhouse gases as acting "like a blanket", which is an analogy and not a mechanism; saying the gases "trap" heat without naming absorption and re-emission; omitting the change of wavelength between the incoming and outgoing streams, which is the whole reason the effect exists; and linking warming to the ozone hole or to ultraviolet radiation, which is a different problem with a different mechanism.

Q2. *(5 marks)*

Command term — explain, calculate, state. Part **a** was answered for zero marks by half the cohort in 2025. The marks are in the four elements of the definition, not in the sentiment.

Model response.

a. The global warming potential of a gas is the **total infrared radiation that a given mass of that gas will absorb over a stated time horizon** (1), expressed **relative to the same mass of carbon dioxide**, which is defined as 1 (1).

b. GWP-20 for fossil-origin methane is 82.5; GWP-100 is 29.8.

$$\frac{82.5 - 29.8}{82.5} \times 100 = \frac{52.7}{82.5} \times 100 = 63.9\,\%$$

The reported carbon dioxide equivalent falls by about **63.9%** (2 — 1 for the working, 1 for the value with its unit).

c. Its **atmospheric lifetime relative to the time horizon**. (1)

Marking guide. **a** — 1: infrared radiation absorbed by a given **mass**, integrated over a **stated time horizon**. 1: expressed **relative to carbon dioxide**, the reference gas at 1. **b** — 1: the change divided by the original value, shown. 1: 63.9% (accept 64%, or 63–64%), with the per-cent sign. **c** — 1: atmospheric lifetime, compared with the horizon.

Common errors. In **a**, the three reported wrong answers are all in the stimulus if you look: global warming potential is **not** the quantity of gas emitted or present in the atmosphere, **not** the gas's atmospheric lifetime, and **not** "how much it warms the Earth" without the comparison to carbon dioxide. An answer that omits the horizon is incomplete, because the same gas has as many potentials as there are horizons — methane is 82.5 at 20 years and 10.0 at 500. In **b**, dividing 29.8 by 82.5 and reporting "36.1%" answers a different question: that is what remains, not the fall. In **c**, "it depends on the gas" restates the stem; the property is the lifetime, and the direction follows from it — methane, far shorter lived than 100 years, stops accumulating absorption while the reference gas continues, so its potential falls; sulfur hexafluoride, at 3200 years, is still absorbing at full strength after the reference gas has been drawn down, so its potential rises.

Q3. *(4 marks)*

Command term — describe, then explain. Part **a** asks about the **rate**, not the concentration. Part **b** turns on the study design's own definition of the two bands.

Model response.

a. The rate of increase has itself **increased** — the concentration is rising, and rising faster with time (1). The mean growth rate goes from about 0.12 ppm per year over 1750–1900, to about 0.35 ppm per year over 1900–1960, to about 1.67 ppm per year over 1960–2024 — roughly fourteen times the first figure — and the most recent decade, 2015–2024, is running faster again at about 2.6 ppm per year (1).

b. The two bands are set by **residence time**: the study design defines short-term sequestration as changes lasting less than 100 years and long-term as more than 1000 years (1). Carbon fixed into woody biomass and soil by revegetation is held for decades to about a century and is returned to the atmosphere by fire, drought, harvest, decay or clearing, so it sits in the fast carbon cycle and its residence time is under 100 years. Carbonate buried in deep-sea sediment is removed from exchange with the atmosphere on a geological time scale of many thousands to millions of years, which places it in the slow carbon cycle (1).

Marking guide. **a** — 1: the rate is increasing, i.e. the rise is accelerating. 1: at least two of the four rates quoted with their intervals and the unit *ppm per year*, supporting the claim. **b** — 1: the 100-year and 1000-year bands named as the criterion, or residence time named as the property that decides. 1: the mechanism for each — biological carbon is returnable on a decadal-to-centennial time scale, buried carbonate is not.

Common errors. In **a**, "carbon dioxide has increased steadily" is the marked error: it describes a straight line, and the data show four different rates. Quoting the concentrations rather than the rates answers a question that was not asked. Omitting the unit *ppm per year* loses the second mark on its own. In **b**, answering with "one is short and one is long"

restates the classification instead of explaining it; and calling revegetation "permanent" ignores the reversal risk that is precisely why it falls in the short-term band.

Q4. *(6 marks)*

Command term — explain, explain, evaluate. Part **c** is deliberately double-edged: the student's **reasoning** is unsound but the **conclusion** happens to be sound, and a full-mark answer separates the two.

Model response.

a. The two records measure the same quantity — the atmospheric carbon dioxide concentration — by **independent methods**, on different material, with unrelated sources of error: air extracted from bubbles in ice, against air drawn directly into an analyser (1). Where the two overlap in the mid-twentieth century they agree within their uncertainties, and that agreement is the **test** that the join is sound. Without an overlap the splice would be assumed rather than demonstrated, and any offset between the methods would be read as a change in the atmosphere (1).

b. Homogenisation removes **step changes in a station's record that have nothing to do with the climate** — a site relocation, a replaced screen, a manual thermometer becoming an automatic weather station, a changed observation hour, a car park built alongside. Each is a **systematic error** introduced at a known moment (1). It is not an alteration to suit a conclusion because the correction is **derived from neighbouring stations**, whose climate moved with the affected station, and it is documented and reproducible by another analyst. Removing a known systematic error is what any measurement discipline requires (1).

c. As reasoning, the statement is incomplete: a single site cannot on its own establish a global trend, and the assessors have reported students drawing global conclusions from one station (1). The conclusion is nonetheless correct, but for reasons the statement does not give — Cape Grim is a **World Meteorological Organization baseline station**, sited to sample air after a long ocean fetch precisely so that it represents the well-mixed background rather than a local source; carbon dioxide is long-lived and globally well mixed; and the same rise appears at Mauna Loa and across the global network (1).

Marking guide. **a** — 1: the two are independent methods measuring the same quantity, with different sources of error. 1: agreement in the overlap is what licenses the splice — reproducibility across methods, tested rather than assumed. **b** — 1: at least two named non-climatic causes of a step change, identified as systematic error. 1: the correction is derived from neighbouring or overlapping observations, documented and reproducible. **c** — 1: identifies the logical weakness — one site does not demonstrate a global trend. 1: identifies why the conclusion nevertheless holds — baseline siting, a long-lived and well-mixed gas, and corroboration by the wider network. An answer that only rejects the statement, or only accepts it, caps at 1.

Common errors. In **a**, describing the overlap as "checking the data" without naming what the check establishes. In **b**, the reported error is describing homogenisation as data being changed to produce a warming trend; the discriminator is that the correction comes from an independent source and can be reproduced. Also confusing an instrument limitation with a coverage limitation — "the thermometer was inaccurate" and "there were no thermometers in the Southern Ocean" are different faults with different remedies. In **c**, the commonest failure is to answer only half: either "correct, carbon dioxide is rising" or "wrong, one site proves nothing". *Evaluate* requires the judgement to be reached on both.

Q5. *(5 marks)*

Command term — explain, then state. Part **a** is a 3-mark explain, so it needs the mechanism plus the specific ratings from the stimulus. Part **b** is the confidence-rating trap reported in 2024 and again in 2025.

Model response.

a. A confidence rating is built from the **evidence** and the **agreement**, so a variable that models handle consistently earns a higher rating than one they handle differently (1). Temperature responds directly and consistently to a change in the energy balance, so the models agree closely on both the direction and the magnitude of the change — robust evidence with high agreement, which supports **very high confidence** (1). Rainfall depends on circulation patterns that

models represent differently, so the simulations disagree on magnitude and, in autumn, on whether there is much change at all — which is why the stimulus rates winter and spring decline at *medium to high confidence* but autumn at *low to medium confidence*, and adds "with some chance of little change". Rainfall in this region is also naturally very variable, so the trend is harder to separate from the year-to-year noise (1).

b. *Very high confidence* is built from the **evidence** — its type, amount, quality and consistency — **and** the degree of **agreement** between independent lines of evidence and among the assessors (1). It does **not** carry a probability: no percentage attaches to any confidence qualifier, and the rating is not a statement of how likely the outcome is — that is the job of a likelihood term such as *very likely*, which does have a published range of 90–100% (1).

Marking guide. **a** — 1: names the two ingredients of a confidence rating. 1: temperature is directly and consistently tied to the energy balance, so models agree — high evidence and high agreement. 1: rainfall depends on circulation, models disagree in magnitude and even direction, and natural variability is large; the stimulus's own graded ratings quoted in support. Credit is also available for the observational-record limb and for model resolution. **b** — 1: evidence **and** agreement, both named. 1: one correct negative — it carries no percentage, or it is not a likelihood, or it is not "how confident the IPCC feels".

Common errors. Writing that "the IPCC is less confident about rainfall" restates the stimulus instead of explaining it. Attaching a number to a confidence qualifier — "high confidence means about 80% sure" — is wrong rather than imprecise. Reading *low confidence* as "it probably will not happen": it means the basis for **that statement, at that scale, for that period** is limited or contested, and where consequences are serious it is the precautionary principle that the decision-maker reaches for, not inaction.

Q6. *(6 marks)*

Command term — calculate, explain, identify and state. All three parts are anchored to the printed table; an answer that does not quote it cannot earn the second mark.

Model response.

a. Hamilton: 8.7 days observed, projected median 17.7 days.

$$\frac{17.7 - 8.7}{8.7} \times 100 = \frac{9.0}{8.7} \times 100 = 103.4\,\%$$

An increase of about **103%** (2 — 1 for the working, 1 for the value with its unit).

b. Annual rainfall at Hamilton is projected to fall by about **12%** from 616.6 mm while annual pan evaporation rises by about **17.3%**, so inflow falls and evaporative loss rises at the same time (1). The Western District Lakes sit in a **landlocked** catchment with no outlet, so their level and their salinity are set by exactly that balance: lower inflow with higher evaporation lowers the water level, concentrates the salt in a lake that is already Australia's largest permanent saline lake, and shrinks the shallow fringing habitat that the waterbird populations for which the site was Ramsar-listed in 1982 depend on (1).

c. Opportunity — frost days at Hamilton are projected to fall from 20.4 to a median 9.1 a year, so the frost-free window lengthens and frost-sensitive pasture species and horticultural crops become viable over a longer season (1). **Condition** — the gain is only realisable where water is not the binding constraint, and the same table projects annual rainfall down about 12%, spring rainfall down about 22% and pan evaporation up about 17.3%; so the longer window is usable only where water can be supplied or where species are matched to a drier spring (1).

Marking guide. **a** — 1: change over the **original** value, shown as working. 1: about 103% (accept 103–104%), with the per-cent sign. **b** — 1: two projected changes quoted from the table with their figures. 1: the mechanism traced to a named ecological system and to what it stands to lose. **c** — 1: a genuine opportunity created by the changed climate, with the figure that supports it. 1: a real condition or catch, supported by a second figure from the table.

Common errors. In **a**, dividing 17.7 by 8.7 and reporting "203%" confuses a ratio with an increase; using the 13.1 or 23.0 figures instead of the median answers a different question; taking the Warrnambool row answers about the wrong town. Note also that the observed figures are averages for **1981–2010** while the projected changes are measured

against **1986–2005** — quote each with the period that belongs to it. In **b**, naming a risk without quoting the data is the reported "rewriting the stem" failure. In **c**, the two standard errors are offering a **mitigation** project as an opportunity — an offshore wind farm reduces emissions, it is not a consequence of the changed climate — and offering an opportunity with no condition attached, when almost every one of them carries a catch.

Q7. *(4 marks)*

Command term — complete the table, then explain. The classification is the discriminator reported on the 2024 paper and again on the 2025 multiple-choice section. Apply the atmosphere test in writing: does the measure change what is **in** the air?

Model response.

a.

Measure	Mitigation or adaptation
A Sand renourishment at East Beach	**Adaptation**
B Southern Ocean offshore wind area	**Mitigation**
C Coastal hazard overlays, Amendment C69	**Adaptation**
D Heat pumps under Victorian Energy Upgrades	**Mitigation**

b. *(Either measure earns full marks.)*

Measure A. Renourishment returns sand to the beach and dune, rebuilding the **sediment volume** that absorbs and dissipates wave energy before it reaches the assets behind it (1). The hazard itself is unchanged, so the protection lasts only as long as the sand does; while the sediment deficit continues, the works must be repeated, which is why renourishment is usually one stage of a sequenced pathway rather than a permanent answer (1).

Measure C. An overlay changes nothing physical. It works by **preventing new assets being placed where they will be exposed**, so the value at risk stops growing (1). That contains the cost of any later defence or retreat, and it is the first option in the order Victorian planning schemes require decision-makers to work through — avoid before protect (1).

Marking guide. **a** — 2 marks for all four correct; 1 mark for three correct; 0 for two or fewer. **b** — 1: the physical or institutional mechanism by which harm is reduced. 1: a further correct consequence — the limit on the measure, its place in the option order, or what it does to the value at risk.

Common errors. Classifying the offshore wind area as adaptation because it is "a response to climate change" — everything in the list is a response to climate change; the question is whether it changes the composition of the atmosphere. Classifying heat pumps as adaptation because they also provide cooling on hot days: the reason they are on this list is that they deliver the same heating service without combustion, and their abatement grows as the grid decarbonises. In **b**, "it protects the beach" is the stem rewritten; name the sediment, the wave energy, or the exposure.

Q8. *(5 marks)*

Command term — discuss. Five marks, three named factors and a required position. Work through the factors in order, then state a tension with a principle on each side, then land the judgement. Answers that describe the decision without naming what pulled against what cannot pass the middle marks.

Model response.

Stakeholder values and priorities. The proponents and the Victorian Government prioritised generation capacity: the state's legislated offshore wind targets of 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040 need declared areas to be built in, and the region's port and workforce make the economic case regionally as well as nationally. Commercial

fishers prioritised continued access to grounds; coastal residents and the tourism economy at Port Fairy, Warrnambool and Portland prioritised amenity and the visual seascape; conservation interests prioritised the ecological values of the waters off Warrnambool, in particular the southern right whale nursery at Logans Beach. These are not all scientific positions — they are economic, aesthetic and ecological, which is exactly why a scientific assessment could not settle the question by itself.

The regulatory framework. The *Offshore Electricity Infrastructure Act 2021* (Cth) is the head of power: without a declared area there is no licensing pathway, so the declaration is the step that converts a target into a buildable project. It also prescribes the consultation the decision must pass through — here 64 days, from 28 June to 31 August 2023 — and it is the statutory mechanism by which those stakeholder positions entered the decision. Behind it stands the demand: the *Climate Action Act 2017* (Vic) net-zero-by-2045 target and the offshore wind targets, which is what makes a *smaller* area a cost rather than a saving.

Use and interpretation of scientific data. The declared area is about **1030 km²** against a proposed **5100 km²** — about **20%** of what was proposed — and it was confined to waters west of Port Fairy and east of the Logans Beach nursery. That boundary was drawn where the ecological and community evidence placed the constraint, not where the wind resource is strongest, and three proposed projects near Portland, in Discovery Bay and near Port MacDonnell fell outside it as a result. The same body of data therefore supported two defensible conclusions — that the resource is large, and that parts of it should not be used — and the decision is the choice between them.

The interconnection. Consultation carried stakeholder values into a statutory decision; the statutory decision redrew the area; the redrawn area determines how much of the mitigation target this zone can deliver, and therefore how much must be found elsewhere or later. A decision taken for ecological and community reasons feeds back onto the emissions pathway — which is the characteristic shape of a climate decision, where the costs fall locally and now and the benefits fall globally and later.

The tension, and a position. Conservation of biodiversity and ecological integrity sits on one side — a nursery for an endangered species, and fishing grounds that support a regional economy. **Intergenerational equity** and **efficiency of resource use** sit on the other: emissions are cumulative, so every year of delay adds permanently to the burden carried by people who had no part in the decision, and a world-class wind resource left unused is a resource cost. The reduction was justified: the ecological constraint is specific, local and irreplaceable, while the generation constraint is general and can be met from other declared areas, and the precautionary principle applies squarely to a whale nursery, where the potential harm is serious and irreversible and full scientific certainty is not available. What the decision does **not** license is treating the target as unaffected — the shortfall is now someone else's tonnes, and a responsible decision names where they will come from.

Marking guide. 1 — diverse stakeholder values and priorities, at least three named with the position each held, and recognition that they are not all scientific. 1 — the regulatory framework named and its function stated: the *Offshore Electricity Infrastructure Act 2021* (Cth) as the head of power and the consultation route, or the Victorian targets as the demand the declaration serves. 1 — use and interpretation of scientific data, with the figures: 5100 km² proposed against 1030 km² declared, and the boundary set by the whale nursery rather than by the wind resource. 1 — an **interconnection** stated with a mechanism — how one factor acted on another, and what followed from it. 1 — a **tension** named with a sustainability principle on each side, and a position reached and justified.

Common errors. Describing the decision at length without ever naming a tension: *discuss* requires two sides and a judgement. Listing stakeholders without saying what each valued. Quoting no figures, when the 5100-to-1030 reduction is the single most informative number in the stimulus. Treating the declaration as adaptation — it reduces net emissions, so it is mitigation, and the fact that it is a response to climate change does not make it adaptation. Asserting that "the government should just build it" or "the whales matter more" without engaging the principle on the other side: a position is required, but so is the acknowledgement of what it costs.

Sources for the real-world material used here

Source: IPCC, Climate Change 2021: The Physical Science Basis, Working Group I contribution to the Sixth Assessment Report — Chapter 7 (Table 7.15, global warming potentials) and the effective radiative forcing assessment for 1750–2019 — https://www.ipcc.ch/report/ar6/wg1/. Accurate as at July 2026. (Source for the radiative forcing table at Question 1 and the global warming potential table at Question 2.)

Source: Clarke JM, Grose M, Thatcher M, Round V & Heady C. 2019. Great South Coast Climate Projections 2019. *CSIRO, Melbourne, Australia. Updated 19 February 2020. ISBN 978-1-76077-724-1 (pdf) — https://www.climatechangeinaustralia.gov.au/media/ccia/2.2/cms_page_media/508/Vic%20Climate%20Projections%202019%20Regional%20Report%20-%20Great%20South%20Coast_20200219.pdf. Retrieved 3 August 2026.* (Source for every projection in Questions 5 and 6: the confidence statements quoted at Question 5; days above 35 °C at Hamilton and Warrnambool and days below 2 °C at Hamilton, Tables 1 and 2; annual and spring rainfall and the 1986–2005 Hamilton Airport baselines, Table 3; annual pan evaporation, Table 4; the Forest Fire Danger Index projection for Hamilton; and the Portland sea level figure. Read in conjunction with Clarke JM et al. 2019, *Victorian Climate Projections 2019 Technical Report*, CSIRO, Melbourne.) **Teacher note:** VCP19 has been superseded by *Victorian Climate Projections 2024*, which is built on CMIP6 models and the SSP scenarios and does not run RCP4.5 or RCP8.5 at all. VCP19 is used here because it publishes the locality-level counts this question type needs and because the adaptation planning currently in force in the region was written against it. An SSP figure can never be reported under an RCP label; refresh both the projection generation and the scenario names together.

Source: CSIRO and Bureau of Meteorology, State of the Climate 2024 — *https://www.csiro.au/en/research/environmental-impacts/climate-change/State-of-the-Climate. Accurate as at July 2026.* (Source for Australia's warming of 1.51 ± 0.23 °C since 1910 at Question 4.)

Source: Bureau of Meteorology, Australian Climate Observations Reference Network – Surface Air Temperature (ACORN-SAT), 112 stations from 1910 — http://www.bom.gov.au/climate/data/acorn-sat/. Accurate as at July 2026. (Source for the ACORN-SAT description and the homogenisation material at Question 4b.)

Source: Cape Grim Baseline Air Pollution Station, operated by the Bureau of Meteorology with data quality and analysis by CSIRO, continuous since April 1976 — https://capegrim.csiro.au. Accurate as at July 2026. (Source for the Cape Grim record at Question 4.)

Source: Australian Antarctic Division, Law Dome ice core program (DE08 and DSS cores, Wilkes Land) — https://www.antarctica.gov.au. Accurate as at July 2026. (Source for the Law Dome record, its decade-scale gas smoothing, and the 278 ppm pre-industrial baseline at Questions 3 and 4.)

Source: Department of Climate Change, Energy, the Environment and Water, Western District Lakes Ramsar Site Ecological Character Description — *https://www.dcceew.gov.au/water/wetlands/publications/western-district-lakes-ramsar-site-ecological-character-description; and Corangamite Catchment Management Authority, Western District Lakes Ramsar Site — https://ccma.vic.gov.au/western-district-lakes-ramsar-site/. Retrieved 3 August 2026.* (Source for the Ramsar listing in 1982, the nine lakes of the landlocked Lake Corangamite catchment, the site area of about 33 000 ha, Lake Corangamite as Australia's largest permanent saline lake, and the waterbird values at Question 6b.)

Source: Moyne Shire Council, Port Fairy coastal hazard assessment — https://www.moyne.vic.gov.au/Our-community/Environment/Port-Fairy-coastal-hazard-assessment; UNSW Water Research Laboratory, Port Fairy coastal hazard assessment — https://www.unsw.edu.au/research/wrl/projects-and-research/port-fairy-coastal-hazard-assessment; and Moyne Planning Scheme Amendment C69. Retrieved 3 August 2026. (Source for the East Beach renourishment and geotextile sand container works, the coastal hazard overlays, and the 1.2 m by 2100 sea level rise benchmark adopted for Port Fairy on advice from the Glenelg Hopkins Catchment Management Authority — a benchmark above the statewide minimum of not less than 0.8 m by 2100 set by the Marine and Coastal Policy 2020 and carried into clause 13.01-2S of every Victorian planning scheme.)

Source: Department of Climate Change, Energy, the Environment and Water, Southern Ocean region off Victoria — declared offshore wind area — https://www.dcceew.gov.au/energy/renewable/offshore-wind/areas/southern-ocean-region; and the joint media release of 6 March 2024. Retrieved 3 August 2026. (Source for the declaration on 6 March 2024 under the *Offshore Electricity Infrastructure Act 2021* (Cth), the reduction from about 5100 km² proposed to about 1030 km² declared, the confinement of the area to waters west of Port Fairy and east of the Logans Beach southern right whale nursery at Warrnambool, the exclusion of the three proposed projects near Portland, in Discovery Bay and near Port MacDonnell, the 64-day consultation from 28 June to 31 August 2023, and the feasibility licence application window of 6 March to 2 July 2024.)

Source: Climate Action Act 2017 *(Vic), as renamed and amended by the* Climate Change and Energy Legislation Amendment (Renewable Energy and Storage Targets) Act 2024 *(Vic); Victorian legislated offshore wind targets of at least 2 GW by 2032, 4 GW by 2035 and 9 GW by 2040 — https://www.energy.vic.gov.au/renewable-energy/offshore-*

wind-energy. Accurate as at July 2026. (Source for the targets quoted at Question 8. Older sources cite the Act under its former name, the *Climate Change Act 2017* (Vic).)

Source: Barwon South West Regional Climate Adaptation Strategy 2020–2025, Victorian Government — https://www.climatechange.vic.gov.au. Retrieved 3 August 2026. (The region's own five-year adaptation strategy, one of six Regional Adaptation Strategies across Victoria, and the plan against which the region-scale adaptation measures in Question 7 sit. Teacher note: check for the successor strategy before use.)

Source: Essential Services Commission, Victorian Energy Upgrades program, made under the Victorian Energy Efficiency Target Act 2007 *(Vic) — https://www.esc.vic.gov.au/victorian-energy-upgrades. Accurate as at July 2026.* (Source for measure D at Question 7.)

Source: Victorian Curriculum and Assessment Authority, VCE Environmental Science Study Design 2022–2026, and the Examination Reports for 2022, 2023, 2024 and 2025 — https://www.vcaa.vic.edu.au/curriculum/vce/vce-study-designs/environmentalscience. Accurate as at July 2026. (Source for the key knowledge wording, the confidence and likelihood language, the 40-mark Unit 4 Outcome 1 School-assessed Coursework total, and the reported student errors named in the *Common errors* notes throughout these solutions.)

AUTHORED: topic4 test — 40 marks, 8 questions