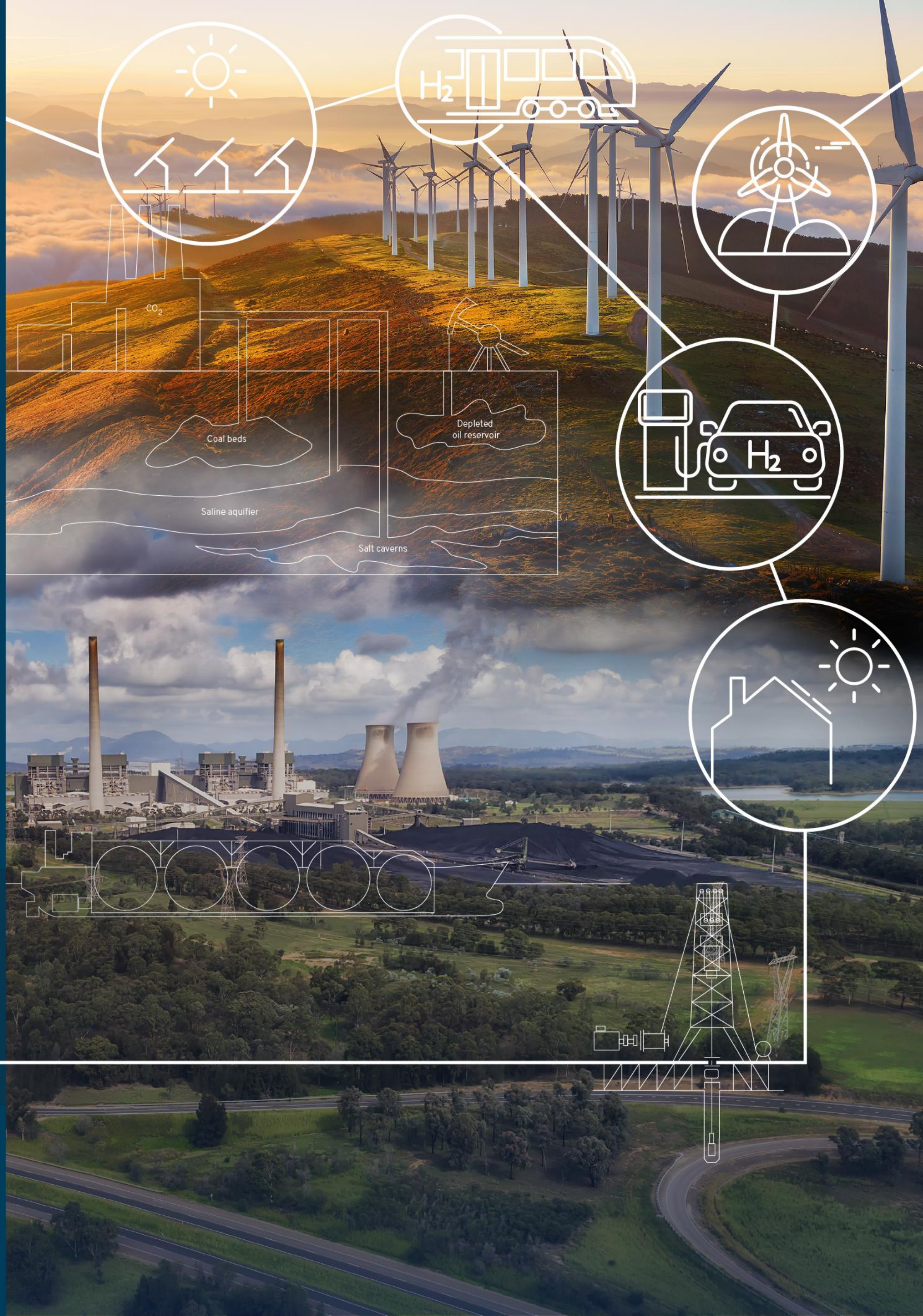
How to make net zero happen

Mobilisation report

July 2023



NET ZERO
AUSTRALIA

THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA
CREATE CHANGE

PRINCETON UNIVERSITY

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1. About the Net Zero Australia study

About Net Zero Australia.

The Net Zero Australia project (NZAu) is analysing net zero pathways that reflect the boundaries of the Australian debate, for both our domestic and export emissions.

The study is:

- **Rigorous** and **granular**
- **Scenario-based** and **evidence-driven**
- **Technology-neutral** and **non-political**

Net Zero Australia is a partnership between the **University of Melbourne,** the **University of Queensland, Princeton University,** and management consultancy **Nous Group.**

NZAu uses the modelling method developed by Princeton University and Evolved Energy Research for its 2020 ***Net-Zero America study.***

NZAu is funded by gifts and grants, and engages broadly.

SPONSORS

Generous financial support has enabled this study

Gift and grant agreements protect the project's independence

ADVISORY GROUP

Crucial input is being provided by diverse advisers

INDEPENDENT MEMBERS

SPONSOR NOMINEES

ENGAGEMENT

Numerous briefings have been provided to:

COMMONWEALTH MINISTERS AND DEPARTMENTS

STATE MINISTERS AND DEPARTMENTS

NON-GOVERNMENT ORGANISATIONS

RESEARCH BODIES

For more, explore the website: netzeroaustralia.net.au

NZAu has consulted widely with the project's sponsors, Advisory Group members and many stakeholders, but is independent of all of them.
NZAu does not purport to represent their positions or imply that they have agreed to our methodologies or results.

The Net Zero Australia team.

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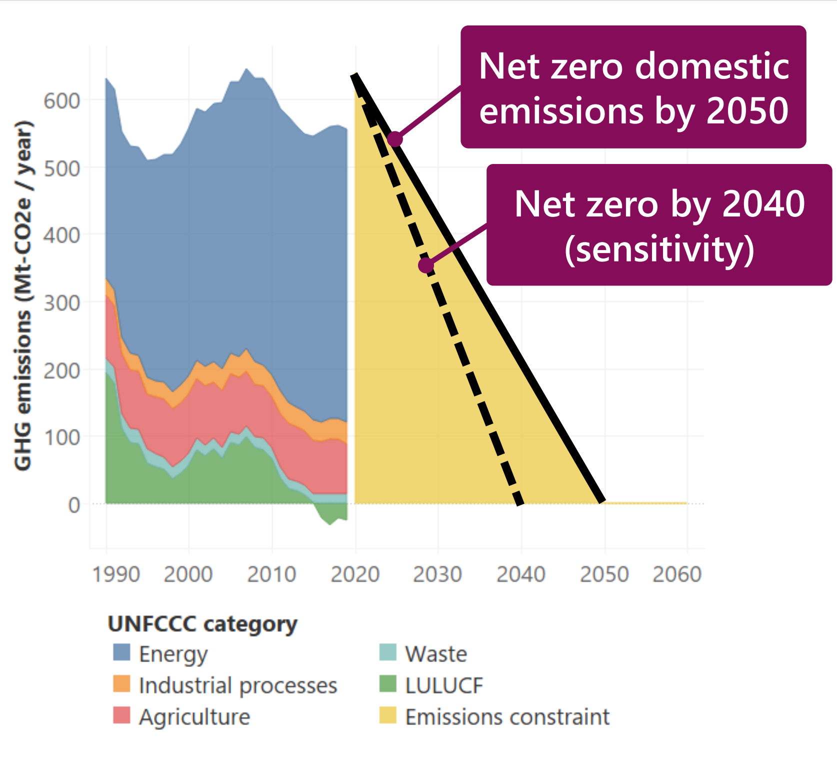
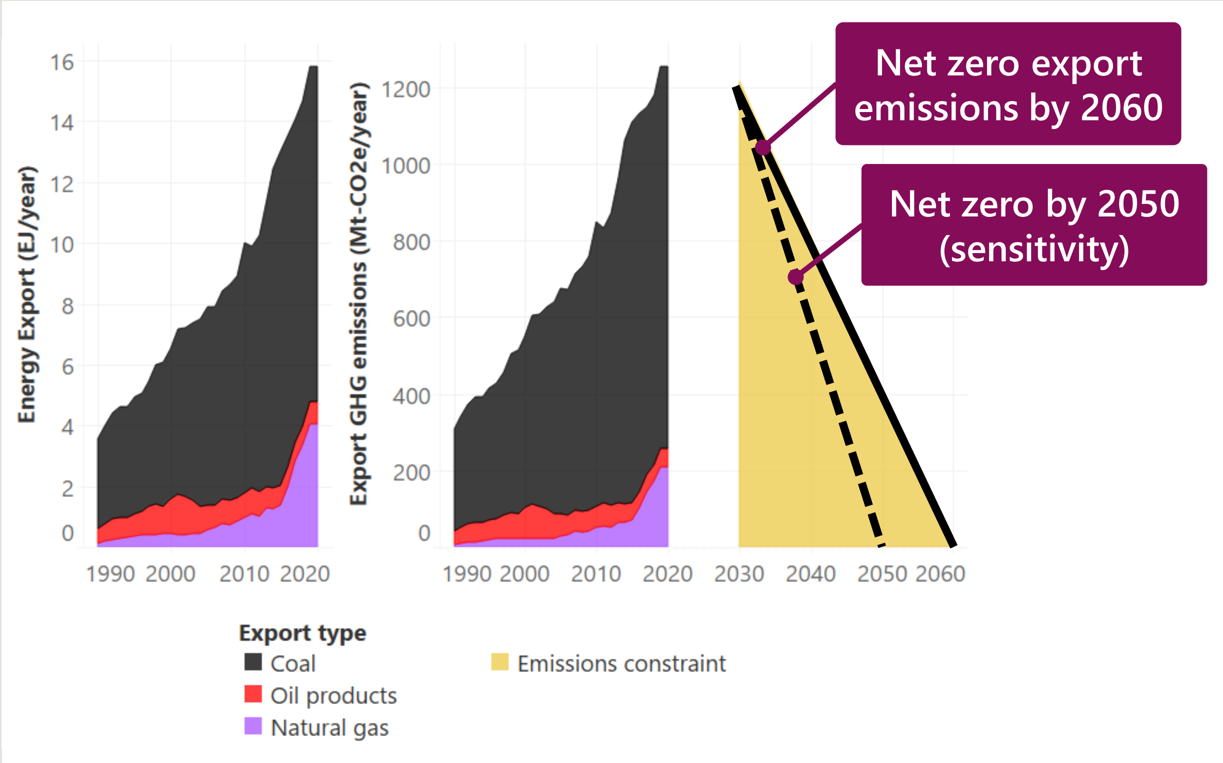
Refresher: we modelled linear reductions to net zero.

Domestic emissions



Fossil fuel energy export emissions



Refresher: we modelled six core Scenarios.

REF

REFERENCE

- Projects historical trends, does not model cost impacts of fossil fuel supply constraints
- No new greenhouse gas emission constraints imposed domestically *or* on exports
- Policy settings frozen from 2020 onwards.

E+

RAPID ELECTRIFICATION

- Nearly full electrification of transport and buildings by 2050
- Renewable rollout rate almost unconstrained
- Lower cap on underground carbon storage rate.

E-

SLOWER ELECTRIFICATION

- Slower electrification of transport and buildings compared to E+
- Renewable rollout rate almost unconstrained
- Lower cap on underground carbon storage rate.

E+ RE+

FULL RENEWABLES ROLLOUT

- No fossil fuel use allowed by 2050
- Renewable rollout rate almost unconstrained
- Lower cap on underground carbon storage rate, which is only used for non-fossil fuel sources post 2050 (e.g. cement production).

E+ RE-

CONSTRAINED RENEWABLES ROLLOUT

- Renewable rollout rate limited to several times historical levels (to examine supply chain and social licence constraints)
- Much higher cap on underground carbon storage (to make net zero achievable).

E+ ONS

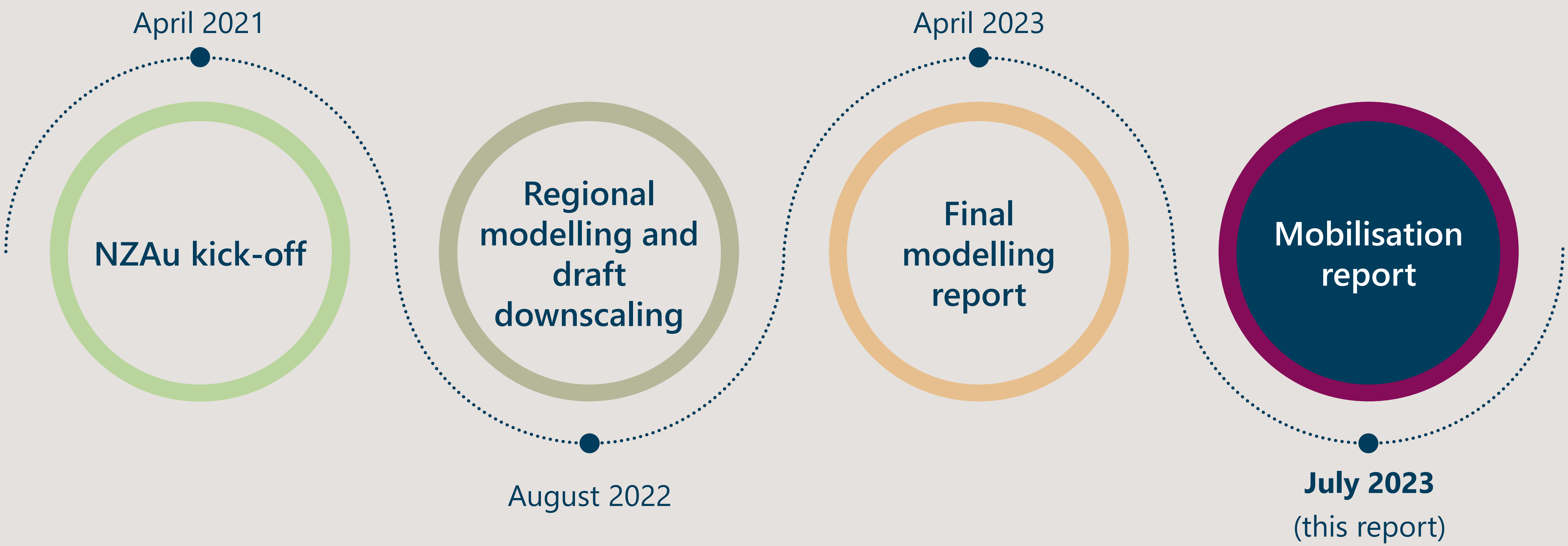
ONSHORING

- Domestic production of iron and aluminum using clean energy
- Progressively displaces exports of iron ore, bauxite, alumina and fossil fuels.

The Reference Scenario has *no emissions objective*. All other Scenarios are 'net zero' for both the domestic and exported emissions separately, and start from current emissions, and track in a line to net zero emissions by 2050 (domestic) and 2060 (export). None of the Scenarios are forecasts.

This is the final report of phase 1 of Net Zero Australia.

NET ZERO AUSTRALIA STUDY TIMELINE



2 – Introduction

How to read this report.

The Net Zero Australia mobilisation report analyses potential methods and strategies to mobilise the transition to net zero, focused on discussing the most challenging elements of the transition, grounded in the modelling.

This report suggests **strategies and actions** for Australia to **mobilise a transition** to net zero emissions – domestically and for our exports**.**

It is a report of the **Net Zero Australia** (NZAu) project – a collaboration of University of Melbourne, The University of Queensland, Princeton University, and management consultancy Nous Group.

NZAu **models Scenarios** under which Australia could reach net zero.

- The Scenarios **reflect the boundaries of the Australian debate** about pathways to net zero.
- The modelling **Illustrates the scale, complexity, and speed** of transitions to net zero.

The final NZAu modelling report was released in April 2023 and is available here.

This mobilisation report is intended to**:**

- **Suggest** what Australia must do, or decide, to reach net zero, where this is supported by evidence**.**
- **Provide** insights and guidance to governments, households, communities, and industries to mobilise and manage the transition.
- **Highlight** the priority actions to be completed by 2030, based on what needs to happen by 2035 and beyond.

However, it does not:

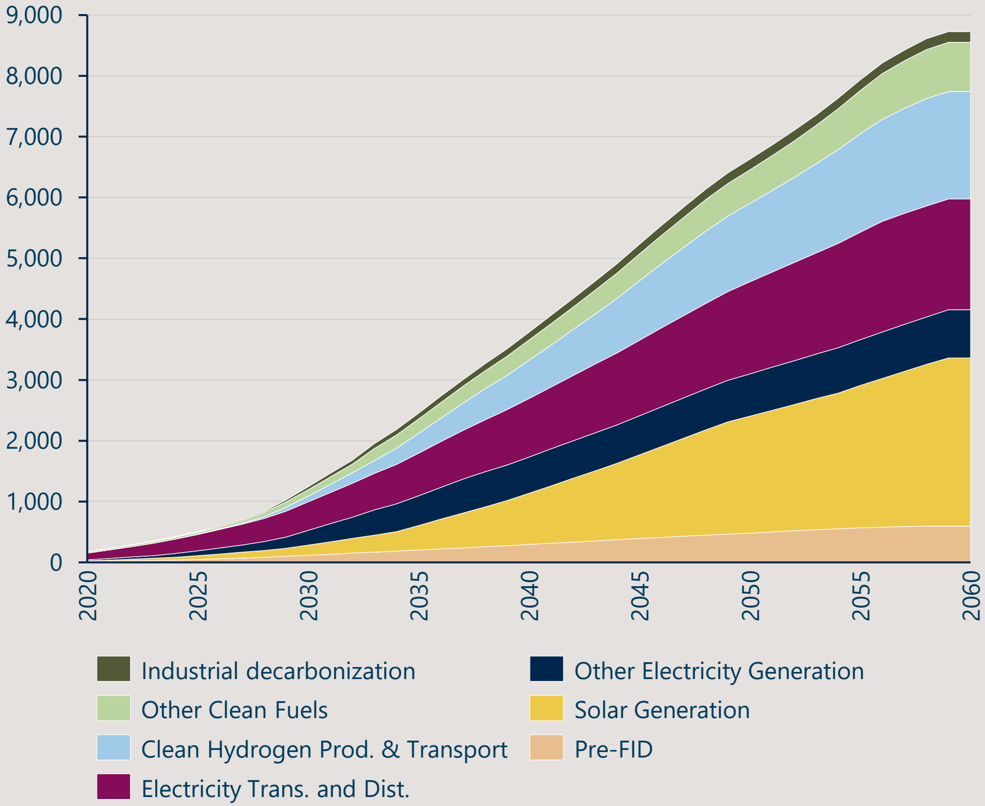
- **Consider** whether we should reach net zero – just how we could.
- **Critique** the past or proposed actions of governments or companies.
- **Express** philosophical preferences.
- Dive deeply into **sectoral** transitions.

The net zero transition will be among the largest and fastest economic transformations in history (1/2).

Our final modelling results, released in April 2023, highlight the immense scale and speed at which a transformation to net zero by 2050 (domestic) and 2060 (export) occurs.

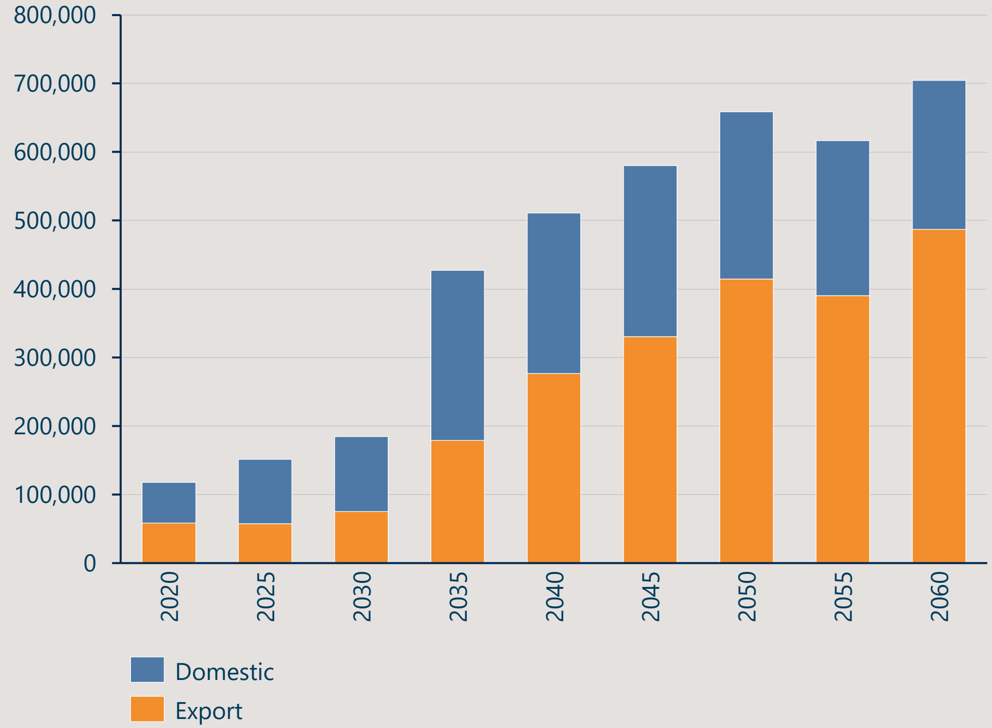
We are predicted to commit up to $9 trillion on the transition in the next 37 years.

Cumulative capital committed over time, by technology, E+ Scenario, AUD$ billion.[1]



Energy sector employment is modelled to increase from less than 1% to 3-4% of the total workforce by 2060.

Gross jobs (E+ Scenario) for the domestic and export energy systems (Full Time Equivalent (FTE) jobs.[2]



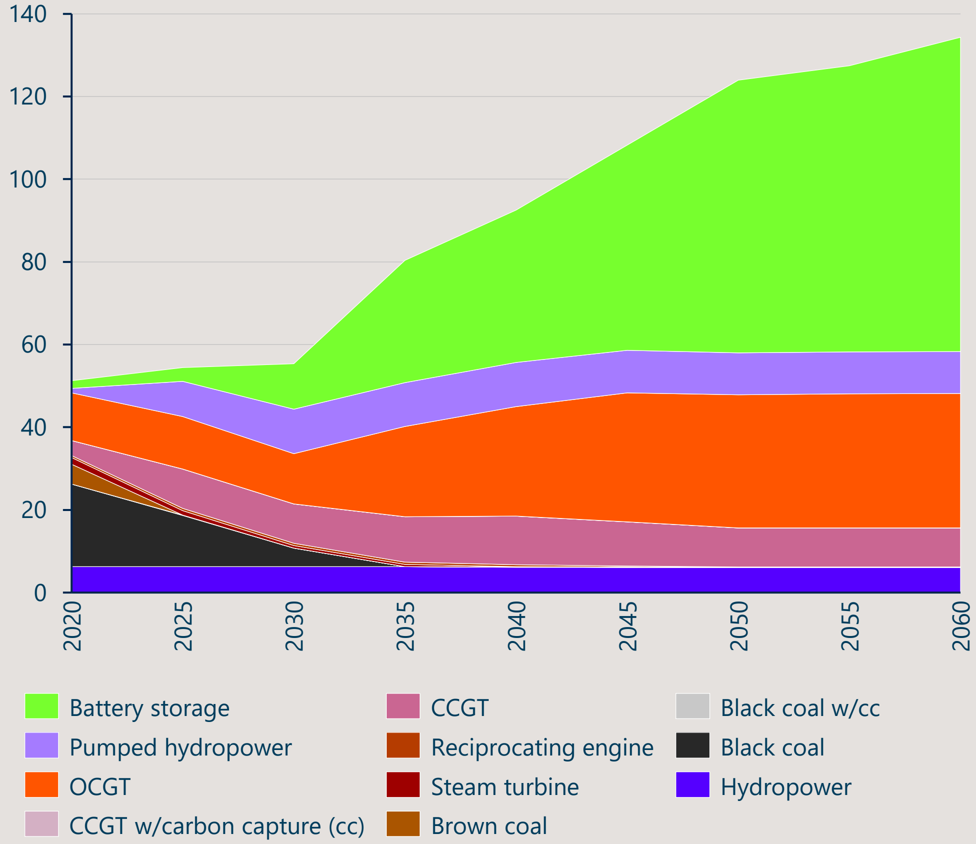
1. Net Zero Australia, 2023, Downscaling – Capital mobilisation.
2. Net Zero Australia, 2023, Downscaling – Employment impacts.

The net zero transition will be among the largest and fastest economic transformations in history (2/2).

Major new infrastructure is required, and we're not accelerating quickly enough, based on current progress.

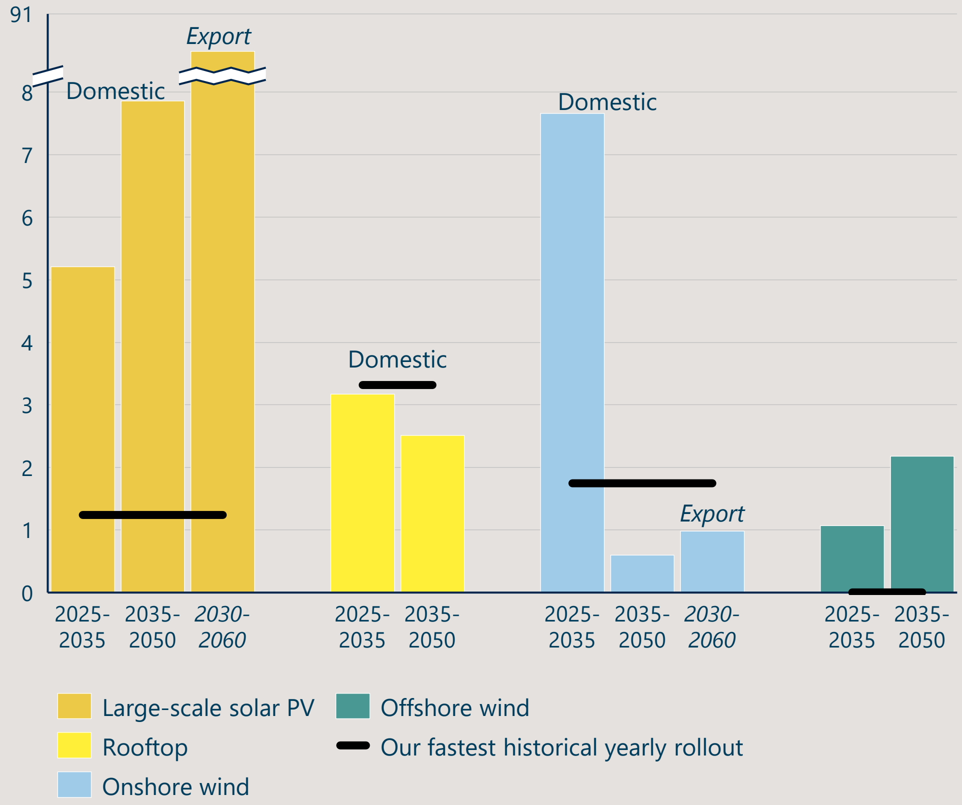
Significant domestic storage and generation capacity is needed to firm renewables.

Projected domestic firm electric & storage capacity by technology (GW, E+ Scenario).[1]



Other than rooftop solar, our progress is slower than the modelled rates. We must accelerate action.

Annual new domestic and export capacity additions, E+ Scenario (GW/year), alongside historical data on Australia's current renewable deployment rates.[2]



1. Net Zero Australia, 2023, Downscaling – Firm generation and pumped hydro energy storage.
2. Clean Energy Council, 2022, Clean Energy Australia Report.

3 – Results summary

Focus of the findings.

Our findings are split into two categories....

STRATEGIC DIRECTIONS	WHAT MUST HAPPEN BY 2030
These are the overall findings of the mobilisation task. They are intended to **frame the priority actions**.	These are the **priority actions** that must be taken in the next seven years to set us on the right path to achieve net zero by 2050.

...and grouped by four areas.

NET ZERO OPTIONS	EXPORTS, INVESTMENT, & JOBS	IMPACT MITIGATION	COORDINATION & ROLES
Which essential net-zero options should we prioritise and accelerate?	What role in global decarbonisation do we want to play? How should we distribute export investment and jobs across the nation?	How should we share net zero's costs and benefits among Australians? How can we roll out renewables while improving the environment?	What more should governments, businesses, communities, and households do?

Summary of strategic directions

OPTIONS	**Accelerate all options** that could make a material contribution to decarbonisation.
EXPORTS	A **clean energy export framework** will be needed to ensure that we phase out fossil fuel exports and grow clean energy exports in an orderly, fair, and net zero-compatible transition. Both **clean energy** and **clean processed minerals** should be pursued as export opportunities. **Industry** strategies and import replacement pathways should be re-oriented towards **comparative advantages.** We should be **early adopters** of export technologies, and **fast followers** of domestic technologies.
IMPACTS	The speed of **land use change** will be essential and requires proactive management, particularly for First Nations communities and farming communities. **Benefit sharing** must be prioritised, proactive, and based on principles of partnership, inclusion, and net gain. Net gain for **environments and biodiversity** should be pursued in parallel with net zero. Minimising public impacts requires **orderly asset closures**, supported by multiple policy mechanisms. **Low-income households** and **fossil fuel regions** will need support to mitigate impacts.
ROLES	**Trust** in government institutions and businesses involved in the transition is essential to its success. **Governments** must stimulate and coordinate **private action**, and decide who pays, and how. Private sector **investment risk** will be too high in many cases, unless mitigated by government. Building net zero workforces and supply chains requires a certain, large, and long **investment pipeline.** Net zero must be a **high national priority** for decades, requiring sustained leadership and collaboration.

What must happen by 2030?

OPTIONS	Clean electricity	• Strengthen deployment drivers of **renewables**, **transmission**, and **electricity storage**, as the most important decarbonisation options. • Plan and build a large fleet of **gas-fired peaking generation** to help accelerate renewable growth, and close coal power on time.
	Zero carbon fuels and feedstocks	• Begin planning and development of **clean hydrogen infrastructure**, including **hydrogen storage**. • Determine whether **bioenergy** has a serious role to play through research, pilots, and demonstrations.
	End use energy efficiency, electrification	• Determine decarbonisation pathways for buildings, including ambitious **energy productivity standards** for new builds, and incentives for retrofits (particularly for lower income households). • Decide and communicate the future of **gas distribution** to household and commercial customers. • Develop plans and mechanisms for **industrial decarbonisation**, through partnerships and accelerating new technologies, prioritised for clean and transitioning industries. • Implement **mandatory emissions standards** for all road vehicles, starting with cars, and support **EV charging infrastructure**, particularly in under-serviced areas.
	CO2 capture, transport, utilisation and storage	• Prepare **carbon capture, utilisation and storage (CCUS)** networks and basins for large-scale use.
	Non-CO2 emissions and enhanced land sinks	• Research, develop, and scale up **land sector abatement** pathways, policies and technologies.
	Nuclear	• Do not factor **nuclear power** into renewable, storage, and firming targets.

What must happen by 2030?

EXPORTS	• Establish a **clean energy export framework** to decarbonise our exports through a transition which is orderly and just, for our fossil fuel regions and trading partners. • Prioritise demonstration of **clean mineral processing** and **plan for onshoring** when commercially viable, including through constructive engagement with trading partners. • Devise a national plan for **locating** clean energy and mineral export hubs and **attracting investment**. • Plan and implement complementary measures to grow sectoral **employment**, **education**, **and immigration**. • Identify opportunities to increase **local industry content** and develop **import replacement** industries. • Take responsibility for **aviation and shipping emissions** through local production of zero carbon fuels. • Enable early voluntary adoption of **new technologies** by reforming regulations.
IMPACTS	• Implement **integrated planning** and **delivery** for renewable energy zones (REZs) and biodiversity zones. • Establish budgets and governance for **benefit sharing** in REZs, including for **community capacity building**. • Further expedite the transition by reforming **planning and environment approvals**. • Establish a policy and mechanism for **orderly asset closures**, initially for coal generators. • Target vulnerable **households** to provide support, alongside regulation for landlords and strata management. • **Refresh our infrastructure priorities** to rebalance national investment towards the transition.
ROLES	• Develop **trust in institutions** while stimulating **business and household action** with information, incentives and regulation. • Strengthen the **role**, capability, and capacity of governments to **coordinate action** and **drive collaboration**. • **Establish mechanisms** to achieve net zero, **including statutory schemes and mechanisms** to drive investment.

4 - Net zero options

Section summary

TOPIC	STRATEGIC MESSAGE	PAGE
Overall	Progress all options that could make a material contribution to decarbonisation.	21
Clean electricity	Accelerate deployment of all renewables, transmission, and electricity storage.	22 – 24
	Drive the establishment of a large fleet of gas-fired peaking generation to support more renewables, and timely coal exits.	25
Zero carbon fuels & feedstocks	Begin planning and development of clean hydrogen infrastructure.	26
	Stimulate exploration and development of hydrogen storage with incentives and regulation.	27
	Develop a realistic bioenergy strategy, establishing pilots and demonstrations where justified.	28
End use energy efficiency, electrification	Significantly increase energy productivity of new and existing buildings.	29
	Decide whether existing gas distribution should be repurposed to a zero-carbon fuel.	30
	Assist existing industries to decarbonise through planning, research and demonstration projects.	31
	Accelerate deployment of decarbonised road transport.	32
CO_2 capture, transport, utilisation & storage	Prepare carbon capture, utilisation and storage (CCUS) networks and basins for commercial use from 2030.	33
	Private investment in a CCUS industry requires targeted government support.	34
Non-CO_2 emissions & enhanced land sinks	Scale up the most prospective land sector abatement pathways, particularly revegetation.	35 – 36
Nuclear	Do not factor nuclear energy into net zero plans, but monitor international developments.	37

Progress all options that could make a material contribution to decarbonisation.

There is considerable uncertainty about the future cost and contribution of all sources, demonstrated by the differences in primary energy and storage between Scenarios. Net Zero Australia's modelling and sensitivities illustrates these uncertainties.

Narrowing options too early would prevent the most cost-effective options being deployed.

The history of solar PV shows how expectations of cost and scale can change greatly as technology and production innovation proceeds.

At this early stage of the transition all options that have the potential to make a material contribution to achieving net zero should be progressed, so that their potential contribution remains viable. How and when this should be done is a judgement to be made for each option, taking into account its maturity, risk, and potential scale and cost.

The cost of enabling options will be a factor in deciding whether they should be kept alive. For example, light and medium road transport using hydrogen is not widely seen as prospective, but high-use back-to-base applications could still be warranted.

As the transition progresses, different options will be given a higher or lower priority, or eliminated altogether, as their relative potential becomes clearer.

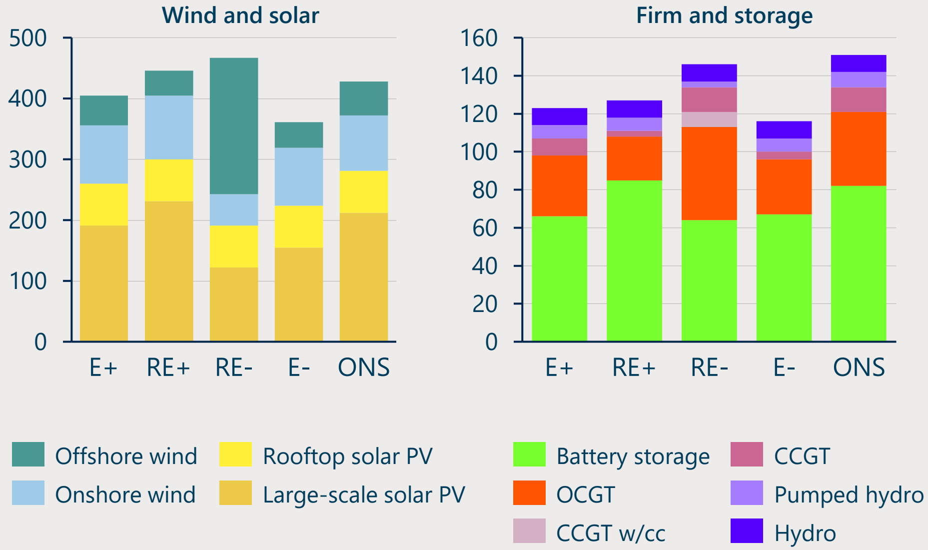
Some options have already been eliminated, in effect. For example, tidal and wave power lack the potential scale and cost-competitiveness of wind and solar power, despite decades of work.[1] Australia lacks the high-grade geothermal resources of countries such as New Zealand and Iceland.[2] Accordingly, these sources are not recommended as options. In contrast, we have no alternatives to CCUS for permanent carbon storage or negative emissions.

Other choices should be made early in the transition. For example, residential use of hydrogen would be costly and complex to implement, warranting an early decision on whether to enable it.

The ultimate mix of technologies will be determined by costs, scale and societal preferences over the transition; today's priority is to progress those which have the potential to make a large contribution.

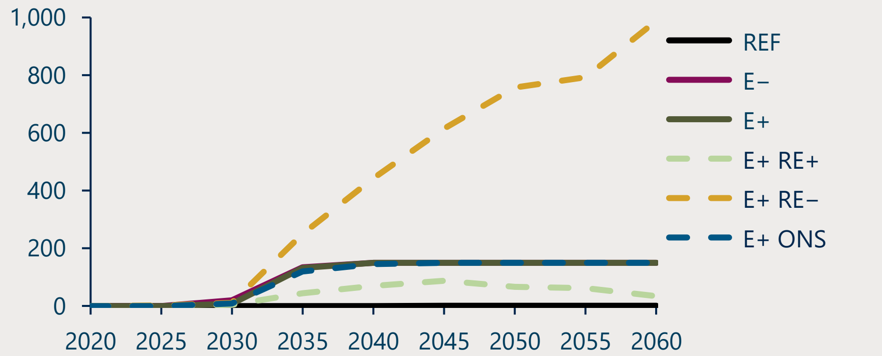
Energy generation and storage differs dramatically between Scenarios – optionality is required.

Projected *domestic* capacity, by technology, 2050 (GW)



Carbon capture and storage differs dramatically between Scenarios.

Geological carbon dioxide (CO_2) sequestration (Mt-CO_2 / year)



1. U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, 2019, Powering the Blue Economy: Exploring Opportunities for Marine Renewable Energy in Maritime Markets.
2. CSIRO, 2014, Geothermal Energy in Australia.

Accelerate large-scale deployment of renewables.

Onshore wind and solar are deployed at scale in *all* Scenarios, but the current pipeline of projects risks falling short of the required build rate.

- From now to 2035, onshore wind is the largest renewable contributor in all Scenarios except E+RE-, in which large scale solar has the highest capacity.
- Deployment of both sources must be accelerated. The large-scale solar in the NEM pipeline[1] falls short of the best-case Scenarios, and onshore wind falls short of all Scenarios except E+RE-. Recent analysis shows that investment has slowed.[3]
- Rooftop solar is rapidly accelerating (see introduction) but is not large or low-cost enough to make up a shortfall in large-scale projects.

Renewable energy investment faces major risks in a period of rapid transition.

- Risks to the rapid transition include the high capital intensity of renewables; a limited supply of long-term purchasing commitments; grid access constraints; global competition for finance, equipment and skills; uncertain closure dates of coal power plants; and competition from government for private sector investment.

Offshore wind has the most uncertain pipeline …

- Offshore wind faces the highest barriers due to the need for large subsidies and long lead times to develop initial projects, establish supply chains, and provide grid access.
- No NZAu Scenarios chose NSW projects because of the high cost of floating platform technologies and moderate winds, an additional risk to pipeline realisation. Despite this, about half of the announced NEM pipeline is off the coast of NSW.[1]

… but is a crucial option that needs to be mobilised as soon as possible.

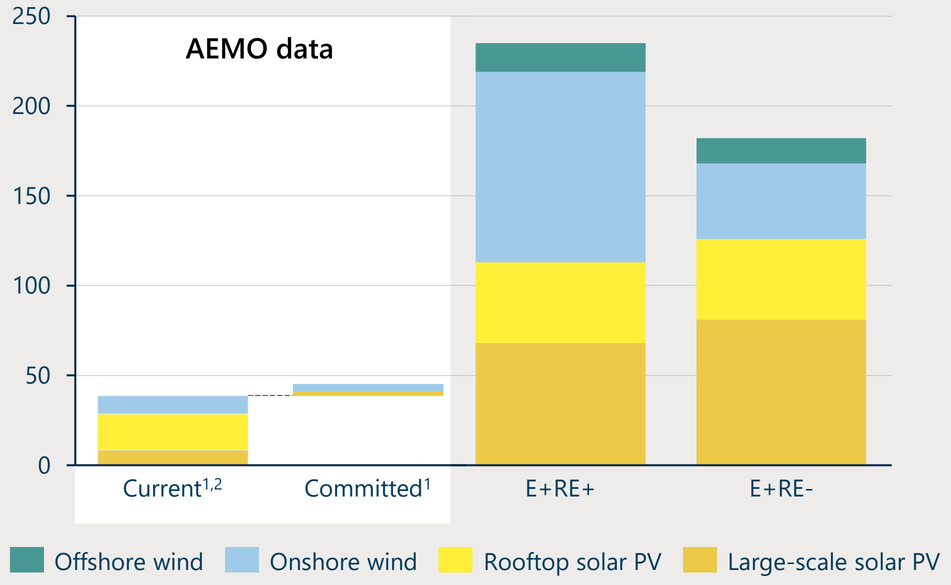
- Our modelling shows that offshore wind is an important future source, particularly if onshore renewables are constrained (e.g. by social licence).
- To preserve this option requires an offshore wind industry to be established as soon as possible, particularly in the Bass Strait. First power from offshore wind should be targeted for 2030.

Government programs are needed to achieve high and sustained investment.

- High, and certain levels of renewable investment, requires government support to mitigate these risks and accelerate measures.

Large quantities of large-scale solar and onshore wind are needed, but the current pipeline falls short.

Current renewable pipeline (NEM) vs modelled *domestic* wind and solar capacity, by technology, 2035 (GW).



WHAT MUST HAPPEN BY 2030?

Accelerate large-scale onshore renewable deployment and achieve first offshore wind power from 2030.

Implement a mix of acceleration measures, legislated where possible. Possible actions include to: designate more renewable energy zones (REZ); mandate renewable energy purchases; subsidise costs; underwrite revenues; coordinate renewable and transmission upgrades; reform planning approvals; and negotiate REZ-wide benefit-sharing agreements.

1. Australian Energy Market Operator, 2023, May 2023 NEM Generation Information – Existing Generation & Devs. Pipeline includes committed and anticipated projects only, it does not account for withdrawals. Given difficulties in reporting, projected new rooftop solar capacity has not been included. New projects do not include 'confidential' projects. Data is based on 'aggregated upper nameplate capacity'.
2. Current rooftop solar generation data: Clean Energy Regulator, 2023, Postcode data for small-scale installations.
3. Clean Energy Council, 2023, Clean energy construction peaks as investment pipeline battles headwinds.

Accelerate deployment of transmission.

A much more rapid growth of electricity transmission is needed.

- Transmission projects may encounter **local community opposition** due to impacts on visual amenity and the operation of intensive and irrigated farms.
- Transmission developments also have impacts on the Indigenous Estate and biodiversity.
- These factors can cause **delays** due to protracted planning approvals. Supply chain constraints may also slow development.[1]

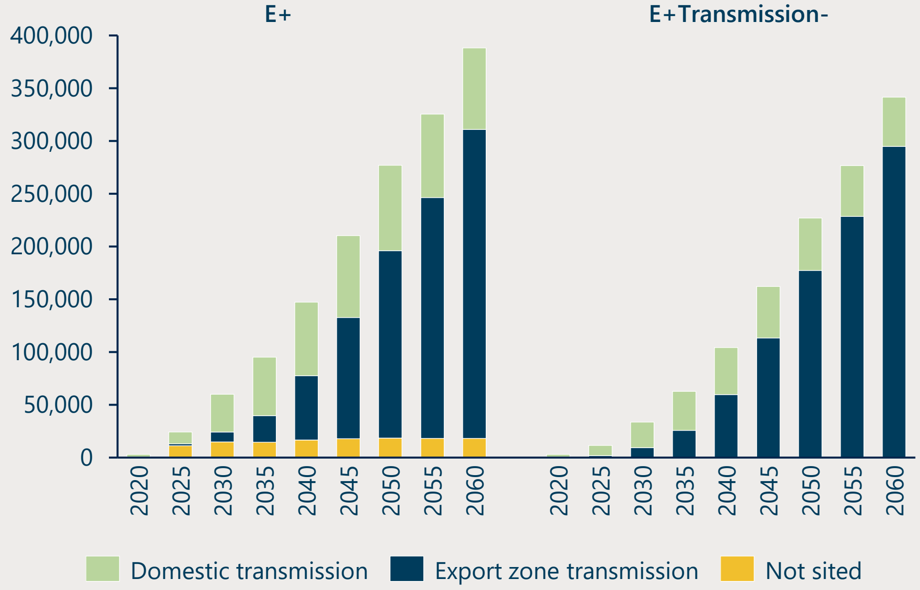
Regulatory change, benefits sharing, and central planning is required to upscale.

Net zero requires rapid and parallel growth of supply (renewables), demand, electrification, and transmission, which raises commercial risk and needs regulatory change, because Australia's **legacy regulatory regimes** are designed for incremental expansions.[2]

- Transmission can also share renewable energy across regions to better match supply and reduce storage needs – under the E+ Scenario in 2060, 45 per cent of domestic transmission capacity (GW) is inter-regional. Such shared infrastructure requires central planning, a benefit-sharing framework, and reformed land and environment planning to expedite transmission project approval and construction.
- There must be network planning reforms, procurement, and economic regulation to accelerate transmission growth in coordination with supply and demand.
- Commitments to build renewables, require prior commitments to build transmission. Concurrent construction will achieve the required deployment pace, therefore, **timing risk** will need to be shared by governments.

A massive scaling up of electricity transmission is required, even when transmission is constrained.

Transmission capacity needing to be added[3] at 5 year intervals (GW-km), E+ and E+Transmission-, compared to Ref Scenario



WHAT MUST HAPPEN BY 2030?
Reform network planning, procurement and economic regulation to accelerate transmission growth.
Coordinate grid upgrades with supply and demand growth, including by sharing timing and grid access risks with renewable developers.
Establish a benefit-sharing framework and reform land and environment planning, to expedite transmission project approval, and construction.

1. Clean Energy Council, 2023, Clean Energy Construction Peaks as Investment Pipeline Battles Headwinds.
2. Australian Energy Market Commission, 2023, Transmission Planning and Investment Review.
3. Spur line transmission is not included in the modelling, more transmission capacity will be required than shown.

Accelerate deployment of electricity storage.

Substantially more battery storage is needed than the current and planned pipeline.

- The capacity of battery storage falls significantly short of modelled capacity, and build rates require acceleration. Despite the economic case for batteries, government support is likely to be needed to address revenue uncertainty.
- The required build rate of batteries is ~17 GWh / year, between now and 2035 (E+ Scenario). Current build rates are far lower and will require acceleration – large-scale battery projects under construction at the end of 2022, only totalled 2 GWh.[1]
- The Scenario with the lowest new battery storage need by 2035 – 134 GWh under E+ONS – is more than double the current pipeline. The Scenario with the highest battery capacity need increases to 325 GWh in E+RE-, six times the current and prospective pipeline.

Support is needed to reduce uncertainty and improve battery innovation.

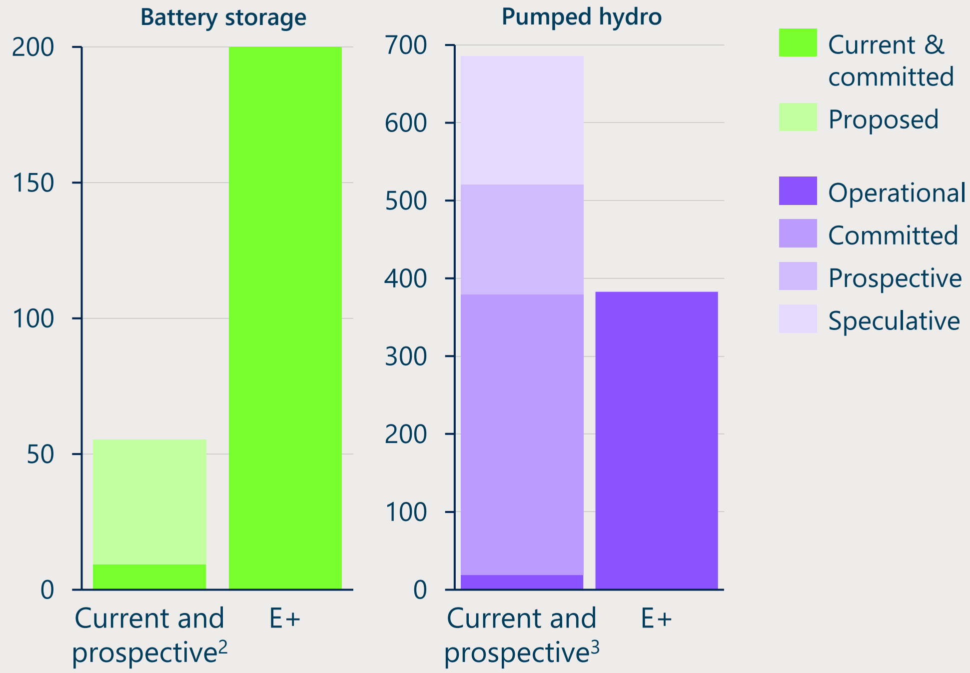
- The growth of renewables and decline of coal power should make commercial investment in batteries more attractive, however, the uncertainties are considerable and government support will be needed.
- Our modelling assumes battery storage duration will grow from current levels of 2 hours to an average of 7 hours by 2050 (and 15 hours for pumped hydro). International innovation will be needed to achieve this.

The pumped hydro pipeline is healthy, but build rates have been low. This creates a risk to delivery of longer-duration storage.

- Rising costs and engineering challenges have constrained the historic pumped hydro build rate. This creates a risk to the provision of longer-duration storage than batteries can provide.
- As with batteries, pumped hydro requires support to mitigate commercial risks, and strategies to manage the risk of late, and costly delivery.

Pumped hydro dominates future storage capacity projects.

Current *domestic* storage capacity, by technology vs modelled 2035 (GWh) – note Y axes.



WHAT MUST HAPPEN BY 2030?
Accelerate storage build rates using a mix of storage purchasing obligations, subsidies, underwriting and shared transmission upgrades.
Seek to accelerate and reduce the commercial risk of pumped hydro projects, while revising capacity forecasts and firming strategies.
Fund prospective battery storage innovations to grow storage duration.

1. Clean Energy Council, 2023, Clean Energy Australia Report 2023.
2. For battery storage: Australian Energy Market Operator, 2023, May 2023 NEM Generation Information.
3. For pumped hydro: this is the aggregation of speculative, prospective, committed, and operational, as defined in the relevant Downscaling report.

Drive the establishment of a large fleet of gas-fired peaking generation to support more renewables, and timely coal exits.

All Scenarios include new gas-fired generation to provide a weather-independent back-up to renewables and storage.

- Gas-fired peaking generation capacity is modelled to rapidly accelerate to support the growth of renewables and maintain a reliable supply as coal power closes to schedule.
- While more peaking capacity ('peakers') is needed, the amount of gas burnt would start low, and become minimal as renewables and storage grows, because the capacity would only be used occasionally – effectively as a strategic reserve.
- Only E+RE- shows an increase in gas use for generation (together with CCS), should renewable build rates be constrained.

Peakers will support renewables, and coal exits by mitigating transitional and 'tail' risks.

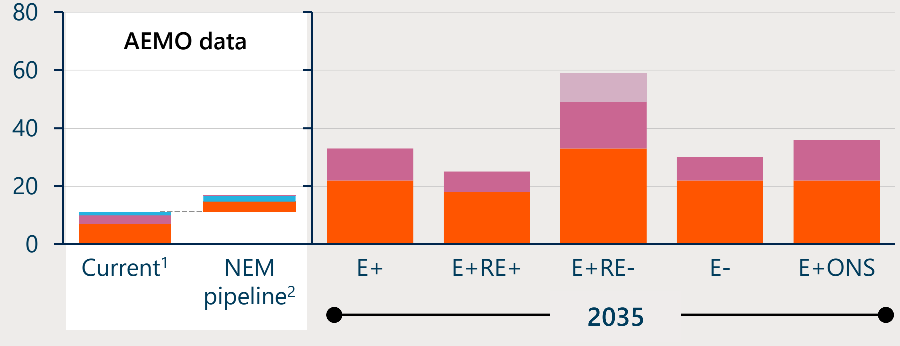
- Peakers would help to meet transitional shortfalls when coal-fired power stations close, while a complex replacement combination of wind and solar farms, transmission and storage, is being made operational. This would avoid the need to extend the life of coal.
- Peakers would also maintain supply during rare, prolonged periods of low wind and sun, high demand, and large supply or network failures with long repair times.

We need a larger pipeline of gas turbines that do not compete with renewables.

- Even in the Scenario with the lowest gas capacity (E+RE+), deployment peaks at ~6 GW per year for OCGTs (open-cycle gas turbines) from 2035-40, compared to a current pipeline of 3.5 GW.
- The role of peakers is to support renewables, not compete with them. Renewables and storage are typically driven by deployment mechanisms such as underwriting contracts (effectively a targeted carbon price).
- The risks associated with the rapid transition may mean that required level of peaking capacity will also require support. This may include network upgrades and complementary forms of support that complement renewable and storage schemes.

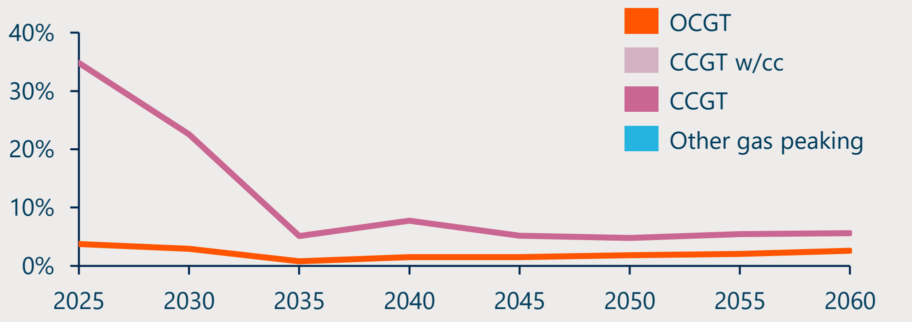
We need to accelerate the deployment of new gas capacity for grid firming.

Current installed gas power capacity vs modelled 2035 (GW)



From 2035, gas is used sparingly.

Average gas capacity factors (% of time running at full capacity), E+ Scenario.



WHAT MUST HAPPEN BY 2030?

Strengthen mechanisms to grow gas-fired capacity which can convert to clean fuel.

1. Australian Energy Market Operator, 2023, May 2023 NEM Generation Information – Existing Generation & Devs. Pipeline includes committed, anticipated, and publicly announced projects, it does not account for withdrawals. New projects do not include 'confidential' projects. Data is based on 'aggregated upper nameplate capacity'.

Begin planning and development of clean hydrogen infrastructure.

Large-scale demonstrations of hydrogen production and use should be supported through the 2020s, prioritising:

- Exports of clean fuel and processed minerals; and
- Replacement of imports of strategic importance (e.g. ammonia and urea for industry and farming).

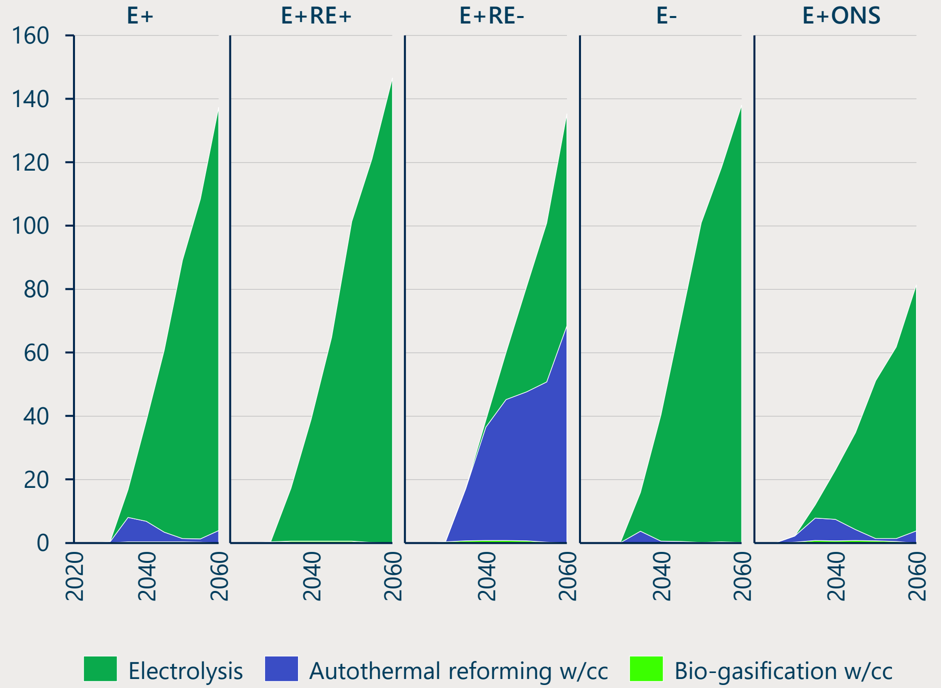
Trading partners with large demand and willingness to invest should be the initial focus for exports (e.g. Japan, South Korea). Clean mineral processing should be prioritised because of its potential scale, relatively low cost of abatement compared to energy export, and competition from green hydrogen exporters in processing Australian ores.

As hydrogen production for export scales up, we should leverage that advantage by building domestic supply and use in industry, heavy transport, and grid firming. This should start in the 2030s.

- Hydrogen production and use should employ common infrastructure where efficient; detailed hydrogen infrastructure planning and development should begin in the 2020s.
- **Blue and green hydrogen projects should both be supported to capture early export opportunities**; green hydrogen should become the major (but not exclusive) focus as renewable capacity grows and costs fall.
- The onshoring of urea is one exception, because rapid expansion for domestic use will reduce reliance on imports made with high emissions.
- **Large-scale hydrogen storage options should be identified** through the 2020s, for development in the 2030s and 2040s.

Significant supplies of both green and blue hydrogen are required in all Scenarios.

Projected hydrogen supply, by technology (Mt-H_2/year)



WHAT MUST HAPPEN BY 2030?
Adopt a policy to support new hydrogen projects based on emissions intensity, not fuel source.
Begin detailed hydrogen infrastructure planning and development, for both blue and green hydrogen projects.

Stimulate exploration and development of hydrogen storage with incentives and regulation.

Our modelling concludes that very large underground hydrogen storage capacity is needed to ensure constant supply for export.

- Major underground hydrogen storage capacity is needed across the country.
- Domestic capacity must rapidly scale up in 2040 in all Scenarios and could comprise 40,000-100,000 tonnes of hydrogen (6 – 14 PJ) energy storage.
- Export zones and ports will require 4–25× the hydrogen storage of the domestic system.
- This export system energy storage ensures that a constant level of energy may be supplied to meet export energy demand in each hour of the year.

The model consistently chooses to build underground engineered storage, the most expensive storage option, as it is still cheaper than increasing the utilisation of electrolysers.

Storage solutions are immature and the site availability, capacity, and costs, are highly uncertain.[1] Potential solutions include natural formations (e.g. salt caverns), existing fossil wells, engineered caverns, and aquifers.

To deliver the modelled storage levels over the 2030s, storage solutions must be investigated and identified, and rights allocated from the mid-2020s, to enable rapid deployment in the following decade.

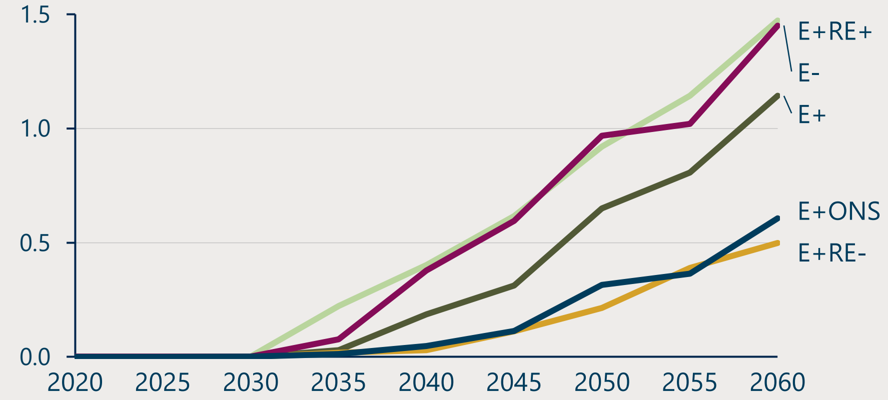
WHAT MUST HAPPEN BY 2030?

Develop regulatory regimes and incentives to identify and develop hydrogen storage, to enable development in the 2030s.

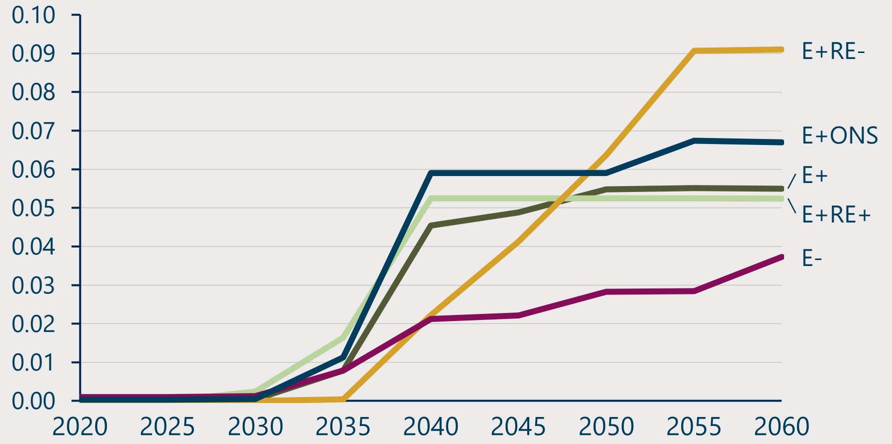
Hydrogen storage must increase rapidly in the 2030s and 2040s, earlier for E+RE+.

Projected capacity of underground hydrogen storage (Mt-H_2). Note varying y-axes.

Export system



Domestic system



1. Wells, C. et al., 2022. Strategies for the Adoption of Hydrogen-Based Energy Storage Systems: An Exploratory Study in Australia.

Develop a realistic bioenergy strategy, establishing pilots and demonstrations where justified.

Australia's limited biomass supply is used, up to sustainable resource availability, in all Scenarios to produce zero-emissions gaseous and liquid fuels (~600 PJ/year), including bio-synthetic natural gas (including biomethane), hydrogen, and bio-oils.[1]

Biomethane and biofuel (from crop residues, wood and animal waste) will need to overcome significant challenges to be implemented at scale:

- Bioenergy resources are limited and distributed, and compete with food and revegetation (for land use), and soil health (for biomass use).
- Limited information on feedstock locations, uses, and supply chains.
- Lack of regulation and standards permitting biomass substitution.

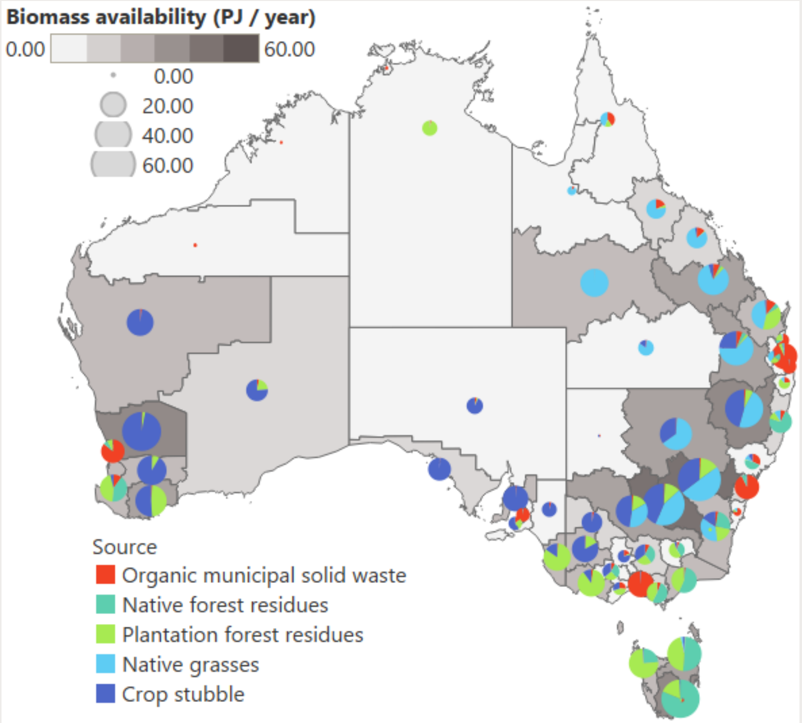
Bioenergy is mostly used to avoid a domestic changeover of gas pipes and in transport.[1] But its necessity for domestic heating is questionable. Prioritising its use here over harder to abate options (e.g. as an input for heavy industry) is questionable.

Australia must plan how it will use bioenergy in the transition. A diverse range of pilots and demonstrations should be funded in the 2020s.

- An initial set of pilots and demonstrations of bioenergy should be funded to test and illustrate the potential of the sector.
- Incentives and improved information may be necessary to create a substantial increase in investor interest in the bioenergy sector, which will be required to enable scaled deployment.
- A net zero bioenergy strategy should be based on demonstrations to identify prospective fuels and technologies, and identify the potential volume of bioenergy that can be injected into current networks. More work is also needed to determine the carbon content of these bioresources and carbon accounting for a bioenergy industry, hence the size of potential emissions abatement.

Biomass distribution, availability and source differs significantly across Australia.

2050 biomass resource availability (PJ/year), aggregated by resource type and ABS statistical division.



WHAT MUST HAPPEN BY 2030?
Develop a realistic bioenergy strategy that considers competition for land and biomass resources, prospective conversion technologies, and the amount of bioenergy that can be injected into current networks.
Fund diverse pilots and demonstrations of bioenergy in the 2020s.

1. Net Zero Australia, 2023, Downscaling – Bioenergy systems.

NET ZERO OPTIONS

End use energy efficiency, electrification

Significantly increase energy productivity of new and existing buildings.

The final consumption of energy in buildings accounted for 18.3% of overall domestic emissions in 2020.[1] **Our modelling reduces these emissions through energy productivity improvements** by assuming faster (E+) and slower (E-) electrification rates. It does not solve for least cost appliance switching.[2]

A high level of electrification is likely to be a least-cost abatement option, because moving from natural gas to zero-carbon fuels is likely to encounter supply constraints (e.g. biomethane) or high costs (e.g. hydrogen), and the cost of electrification should fall as supply chains expand and mature.

Charting the best pathways for decarbonising buildings, requires further analysis and public engagement, that takes into account many factors that will influence the optimal timing, pace and mix of decarbonisation measures such as, electrification, increased appliance efficiency, and insulation. The best pathway varies by building. It will also be influenced by supply considerations: the pace of electrification should be matched to the pace of supply decarbonisation, to achieve abatement at least cost.

Energy productivity standards for new buildings are likely to be the primary driver of building decarbonisation. By mid-century, a significant number of existing buildings will be replaced by new builds where higher energy productivity standards can be imposed with relative low cost.

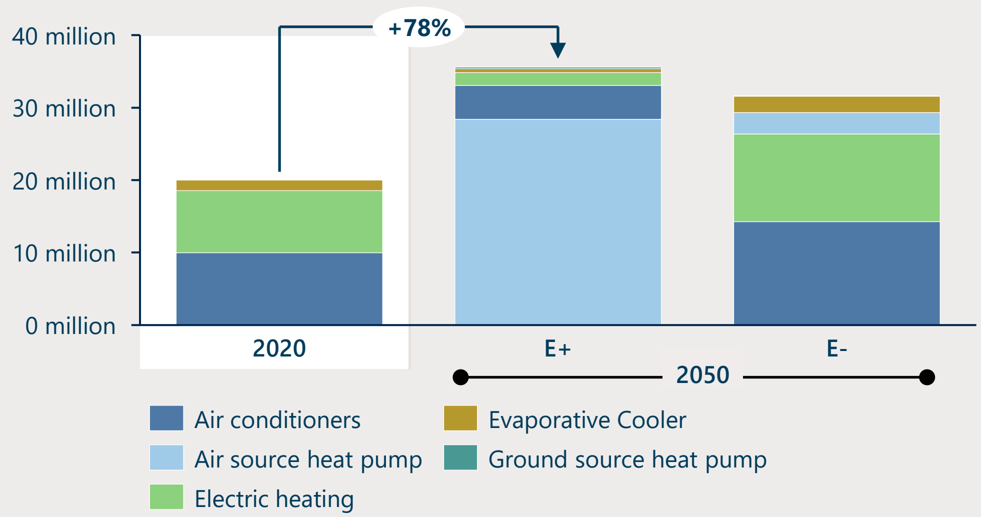
In contrast, **retrofits are best encouraged with incentives.** Mandating increased energy productivity for existing buildings may produce very high costs in some cases (e.g. due to building designs which are incompatible with appliance electrification) that may not be justified by the remaining life of the building.

Electrification and efficiency upgrades come with risks that need to be managed, including: **industry tipping points** (such as the possible closure of gas distribution networks); **social impacts** arising from, for example, higher costs of gas and electricity networks disproportionally impacting non-electrified dwellings; and **increased energy demand** which can slow abatement in energy production if demand growth outstrips the growth of decarbonised power.

The development of electricity and gas distribution networks will be profoundly affected by building decarbonisation. The likely growth of electrification means that power distribution will require considerable investment to increase its capacity. Gas distribution networks to small users, by contrast, are likely to be decreasingly utilised to the point of ultimate closure.

Electrification is the primary means by which household building emissions are reduced in the modelling, however, achieving optimal decarbonisation pathways for housing necessitates more investigation and planning.

Residential HVAC (heating, ventilation and air conditioning) stock (units).



WHAT MUST HAPPEN BY 2030?
Determine optimal decarbonisation pathways for representative types of housing stock across the Nation.
Implement ambitious energy productivity standards for all new buildings and appliances.
Mandate all-electric new build homes if analysis and engagement suggests that is justified.
Design and implement additional measures to stimulate decarbonisation of existing buildings by the most cost-effective method, with lower income households and renters receiving most support.

1. Net Zero Australia, 2023, Downscaling – Buildings, rooftop photovoltaics and batteries.
2. Net Zero Australia, 2023, Methods, Assumptions, Scenarios & Sensitivities.

Decide whether existing gas distribution should be repurposed to a zero-carbon fuel.

By 2030, Australia must determine whether gas distribution to household and commercial customers should be repurposed to a zero-carbon fuel such as biomethane.

Biomethane can largely be used in existing gas pipelines, requiring limited investment in new appliances and infrastructure. Use of biomethane is assumed in E-. However, bioenergy faces possible constraints on biomass supply (given competition from higher-value uses)[1], which is the basis of our recommendation to develop a realistic bioenergy strategy.

Reticulating clean hydrogen through gas distribution pipes is expected to be technically feasible. It is being trialled in the UK and is implied as a possibility by hydrogen blending trials in Australia.

However, it is an expensive decarbonisation approach[2] which requires a high degree of central control, to synchronise the cutover of distribution network segments to hydrogen while simultaneously replacing consumers' burners or appliances. This use of hydrogen is not an input to any Scenario.

The E+ modelling assumes that gas distribution to homes will only cease by 2050, in favour of electrified heating and cooking. If the average life of a gas appliance is 20 years, then a decision on the extent, timing and pace of electrification, and whether any role is envisaged for biomethane, should be made and announced by 2030.

Without a clear and well-communicated roadmap for gas distribution, some consumers risk being stranded with unusable or expensive gas appliances.

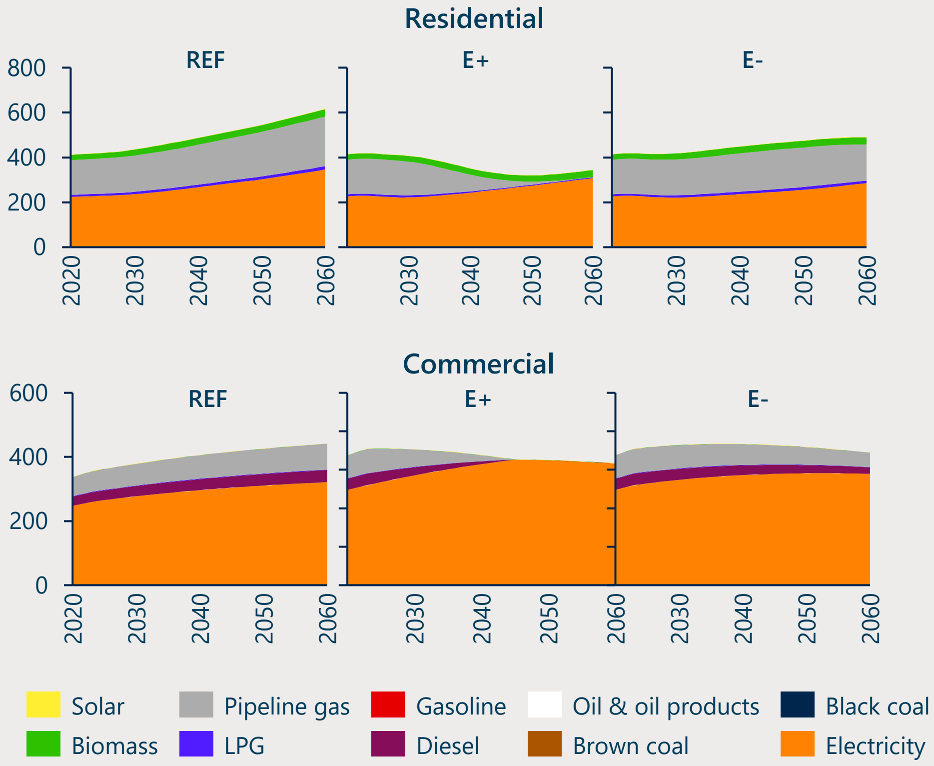
There is a risk that gas demand and network access will decline quickly, driven by: public preference for electrification, caused by concern about carbon emissions from gas, its longer-run availability, and high prices. If the future of gas is uncertain, 'flight from gas' is likely to be encouraged.

However, not all consumers will electrify, due to cost or preference. Without clear communication on the future of gas, consumers risk making ill-informed choices of heating and cooking assets. Assets may be unusable before end of life or have unexpectedly high operating costs.

The question whether the loss of value of gas distribution networks to their owners justifies compensation is addressed in section 6.

The assumed amount of pipeline gas used in the residential and commercial sectors differs greatly between Scenarios

Domestic final energy demand, by sector (PJ/year).



WHAT MUST HAPPEN BY 2030?
Decide the future of gas distribution to household and commercial customers.
Communicate the decision to consumers and explain its implications for their choices.

1. International Energy Agency, 2020, Outlook for biogas and biomethane
2. International Energy Agency, 2022, Global Hydrogen Review

Assist existing industries to decarbonise through planning, research and demonstration projects.

Options for decarbonisation of industry explored in the modelling include:

- **Electrification** that displaces coal, oil products, and gas.
- **Hydrogen** that displaces oil products, and gas.
- **Carbon capture and storage for either:** i) direct use in industrial applications like cement-making; ii) direct air capture to offset the pipeline gas, oil products, and diesel used; or iii) use in the production of biogas and biofuels.

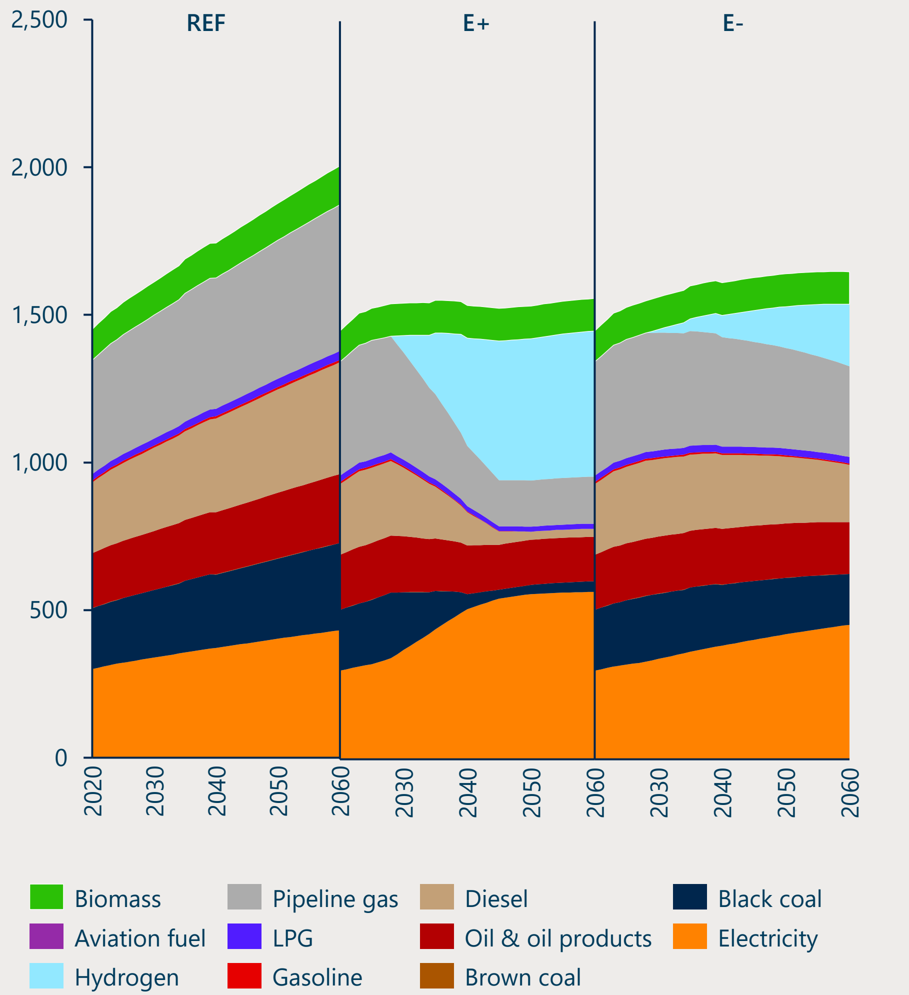
Most abatement options for industry are not yet commercially viable, so it will take time and government support for decarbonisation to achieve scale.

- Today's priority is to establish demonstrations, and plan decarbonisation pathways and mechanisms, with a view to accelerating deployment from 2030.
- Much innovation will occur overseas so accelerating technology transfer should be a priority, with commercial deployment likely to require mandates and/or subsidies. New industrial processes require significant capital investment, estimated at $175b in E+ and $220b in E-, in currently uncertain technologies and markets.[1] A recent study[2] provides a useful roadmap.
- New industrial processes will require some new inputs such as hydrogen, so new supply chains (production, storage, and distribution networks) will need to be planned and established.

WHAT MUST HAPPEN BY 2030?
Develop plans and mechanisms for achieving industrial decarbonisation, through partnerships of industry and government.
Accelerate development and demonstration of prospective technologies.
Prioritise industrial development that is focused on clean exports and helping fossil fuel regions to transition.

The source energy supplied to industry varies significantly depending on decarbonisation pathway.

Domestic final energy demand in the industry sector, 2020 – 2060 (PJ/year).



1. Net Zero Australia, 2023, Methods, Assumptions, Scenarios & Sensitivities.
2. Australian Industry Energy Transitions Initiative, 2023, Pathways to industrial decarbonisation

Accelerate deployment of decarbonised land transport.

The Rapid and Slower electrification Scenarios (E+ and E-) assume a high level of electrification of the land vehicle fleet, but E- assumes a longer transition.[1]

It is generally accepted that moving to battery-electric vehicles (EVs) is the most economic long-run choice for the **light duty land transport fleet**. However, the path to decarbonisation needs to be tailored to maximise abatement at least cost, which should consider other low-emission options, and to progress on the decarbonisation of the power supply.

Voluntary purchases are unlikely to meet the modelled trajectories, **so takeup would need to be stimulated** to the extent that this would lower supply chain constraints. The target takeup rates for low-emission vehicles should be consistent with a net zero target, taking into account prices and progress on the decarbonisation of supply.

More than 80% of all new car sales globally already occur in markets that regulate the fuel economy or GHG emissions from cars[2,3,4] with a maximum fuel economy or emissions intensity. To increase takeup to the desired level, **Australia will need to regulate light duty vehicles, as the Commonwealth is progressing,[5] preferably with a scheme that targets emissions intensity**.

Although EVs will play a major role, they currently have a higher cost of abatement than other options, particularly a larger ICE vehicle is replaced with a similar sized EV. More cost-effective options include downsizing vehicles, hybrid vehicles and using active and public transport, at least while emissions from power generation remain high. Policies should stimulate vehicle purchase in proportion to the abatement that they offer.

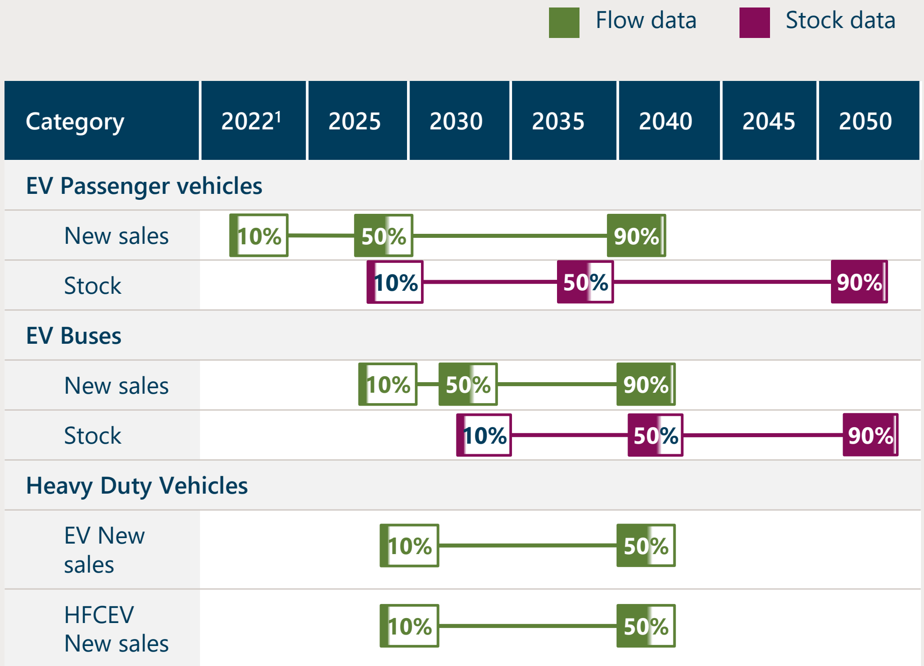
Measures which complement standards will also likely be needed. Examples for the light duty fleet could include:

- Greater support for EV charging infrastructure to poorly served areas.
- Subsidies for low-emission vehicle purchases to those for whom compliance with the standards is otherwise unaffordable, particularly low-income households..
- Investment in active transport, public transport and mode shift.

The optimal choice for ***heavier and higher duty land transport vehicles*** (trucks, trains, vans and fleet cars) is less clear and likely more application dependent. All paths should be kept open, and demonstrations of harder to abate transport tasks should be implemented and learned from before 2030.

TRANSPORT SECTOR TRANSITION TIMELINES (E+ Scenario).

Stock and flow data in the E+ Scenario for EV passenger vehicles (% of vehicles), EV buses (% of buses), heavy duty vehicles (% of HDVs).[6]



WHAT MUST HAPPEN BY 2030?

WHAT MUST HAPPEN BY 2030?
Implement mandatory emissions standards for all road vehicles, starting with cars, using international best practice as a guide.
Plan and implement complementary measures to decarbonise all road transport.
Support EV charging infrastructure, particularly in under-served areas.

1. Net Zero Australia, 2023, Methods, Assumptions, Scenarios & Sensitivities.
2. M. Brear, 2019, The opportunities and risks of decarbonising our transport.
3. International Council on Clean Transportation, 2022, Fuel efficiency standards to decarbonise Australia's light-duty vehicles.
4. Examples of such regulations include the US' Corporate Averaged Fuel Economy (CAFE) standard, and the EU's Regulatory Incentive Mechanism for Zero- and Low-Emission Vehicles (ZLEV).
5. Department of Climate Change, Energy, Environment and Water, 2023, National Electric Vehicle Strategy.
6. Net Zero Australia, 2023, Downscaling – Transport sector energy transition

Prepare carbon capture, utilisation and storage (CCUS) networks and basins for commercial use from 2030.

CCUS grows to high levels in all Scenarios – between 80-1000 Mt/yr of CO_2. Injections are constrained in all but E+RE- to 150 Mt/yr, and this limit is rapidly reached in all but the full renewables case (E+RE+).[1]

Blue hydrogen production is the dominant use of CCUS to 2060 in a constrained renewable build. The extraordinary injection rate of 1000 Mt/year is reached in E+RE-. Without it, decarbonisation of the assumed 15 EJ/year of exports would not be possible.

The dominant use of CCUS across all Scenarios with no renewable constraint is permanently storing CO_2 from direct air capture (DAC) powered with renewables, to offset emissions in the land sector and aviation.

Secondary, but important uses, are to store CO_2 from biofuel production (also for offsets), blue hydrogen production, natural gas purification, and cement manufacturing.

In these Scenarios, blue hydrogen production supports the early establishment of clean hydrogen exports, then diminishes in favour of green hydrogen production through the 2040s as solar costs fall.

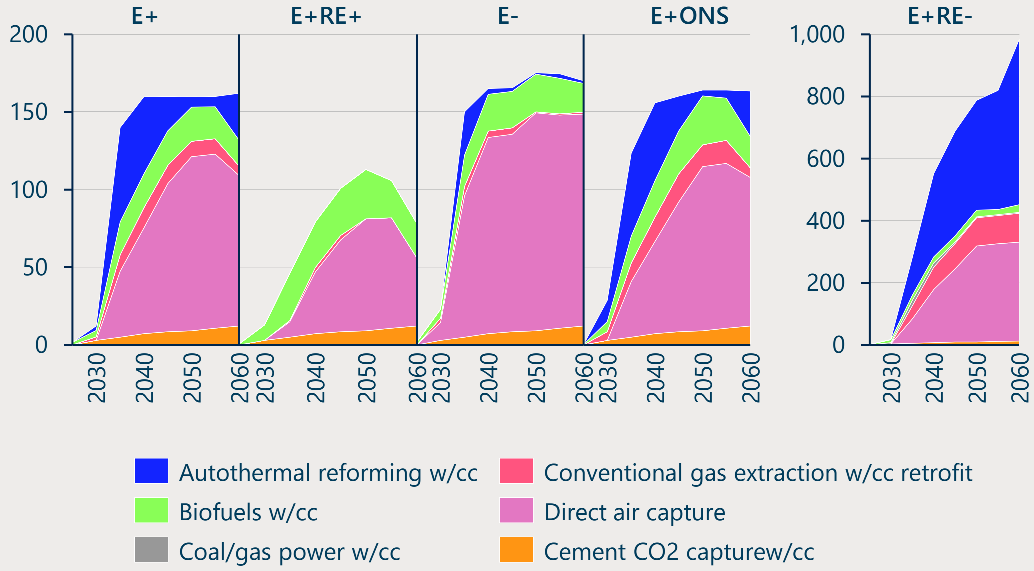
The modelling suggests that Australia should develop and permit CCUS hubs, networks, and basins through the 2020s. **Carbon storage basins should be made ready for large-scale injection from 2030.** This may require geo-technical investigations, coordination of possible injection sources and alignment of feedstock compositions, and possible planning and investment attraction for common use CO_2 pipelines.

CCUS is a crucial component of a net zero strategy, because a core application is to support decarbonisation with renewables (by producing negative emissions though DAC) and to maximise our clean export opportunities.

This means that **public funding and regulatory support should be provided to scale up CCUS to commercial viability,**

CCUS must be rapidly accelerated in all Scenarios.

Projected CO_2 supply, by technology (Mt-CO_2/year), note different axis for E+RE-.



Limitations in Australia's Gorgon LNG field do not mean CCUS is unviable.

The success of carbon capture depends on the industrial process to which it is applied, and the success of carbon storage is specific to the geological formation into which the CO_2 is injected.

Australia's Gorgon field is a site which has not met injectivity expectations.[2] There are many other sites around the world which have not encountered this limitation.

Australia's lack of progress on CCUS is largely due to the lack of a price signal or regulatory obligation to decarbonise the industrial processes to which CCUS could be applied.[3]

1. Net Zero Australia, 2023, Downscaling – CO2 capture, transmission, use & storage.
2. Sydney Morning Herald, 2022, Gas giant's $3.2b effort to bury carbon pollution is failing.
3. Australian Financial Review, 2023, Safeguard changes to kick forward carbon capture.

Private investment in a CCUS industry requires targeted government support.

Targeted government support is needed to attract private investment in large-scale CCUS.

1. **Facilitating commercialisation:** Historically, CCS has been made attractive by revenues obtained from enhanced oil recovery (EOR)[1] but this source is not appropriate for abatement projects. These rely on financial support such as tax credits in the US[2] and carbon taxes in Norway.[3] In Australia, recent changes to the Safeguard Mechanism provide an incentive for some CCUS applications.[4]

   Some applications of CCUS will need support to achieve economies of scale. That may be some form of carbon price, a regulatory requirement, underwriting contracts, or subsidies. Large-scale assistance of these kinds has been routinely used to accelerate the deployment of renewable technologies well past the demonstration phase. The form and level of support should encourage efficient abatement.

2. **Supporting pre-commercial development:** Immature capture technologies will likely require pre-commercial support, such as direct air capture.

3. **Enabling CO_2 transport:** Gaining social licence to build large-scale CO_2 pipelines will prove challenging. Multi-user CCUS networks could lower costs and social opposition. Victoria's CarbonNet and ExxonMobil's SE Australia Carbon Capture Hub both propose this for the Gippsland Basin. In theory, user commitments can attract private investment in a network, however a chicken-and-egg impediment could arise (users need certainty of network investment to develop their projects, and vice-versa). This problem has arisen in the case of transmission upgrades for renewable energy zones, and has resulted in the use of network upgrades being underwritten by statutory schemes.[5]

4. **Defining and regulating storage sites:** CCUS developers need pre-commercial data on storage resources and a clear regulatory framework of rights, obligations and liabilities. Both are core roles of government.

5. **Building public confidence and understanding:** Despite some momentum[1], public support for CCUS remains low.[5] Increasing awareness on the use and importance of CCUS will be critical. This is best done by governments.

WHAT MUST HAPPEN BY 2030?
Make economic applications of CCUS commercially viable with domestic support, where required.
Establish regulatory frameworks, where not yet in place, and release pre-commercial data for storage sites to be identified and developed.
Build public awareness of the efficacy and importance of CCUS.

1. International Energy Agency, 2020, A new era for CCUS.
2. International Energy Agency, 2022, Section 45Q Credit for Carbon Oxide Sequestration.
3. International Energy Agency, 2020, CO2 tax on offshore oil and gas.
4. Australian Financial Review, 2023, Safeguard changes to kick forward carbon capture.
5. Renew Economy, 2021 NSW commits $380m to speed up network upgrades for renewable energy.; NSW Treasury, 2021, The NSW Budget
6. Ashworth et al., 2019, International Journal of Greenhous Gas Control, Comparing how the public perceive CCS across Australia and China.

Scale up the most prospective land sector abatement pathways, particularly revegetation. (1/2)

There is large abatement potential for the land sector by 2050, based on our analysis, including:

- Biosequestration of 51 Mt-CO_2e/year from reforestation of 9 per cent of rainfed cropping and pasture land.[1,2]
- Reduction of ~35 Mt-CO_2e/year from reduced land clearing.[2]
- Reductions in agricultural emissions by 18.2 Mt-CO_2e/year from reduced enteric emissions, manure management, and fertiliser switching.[2]
- Additional sequestration of 50 Mt-CO_2e/year from better management of rangelands and use of nascent technologies (Land+ sensitivity).[1,3]

Some abatement techniques are prospective and could be supported by policy.

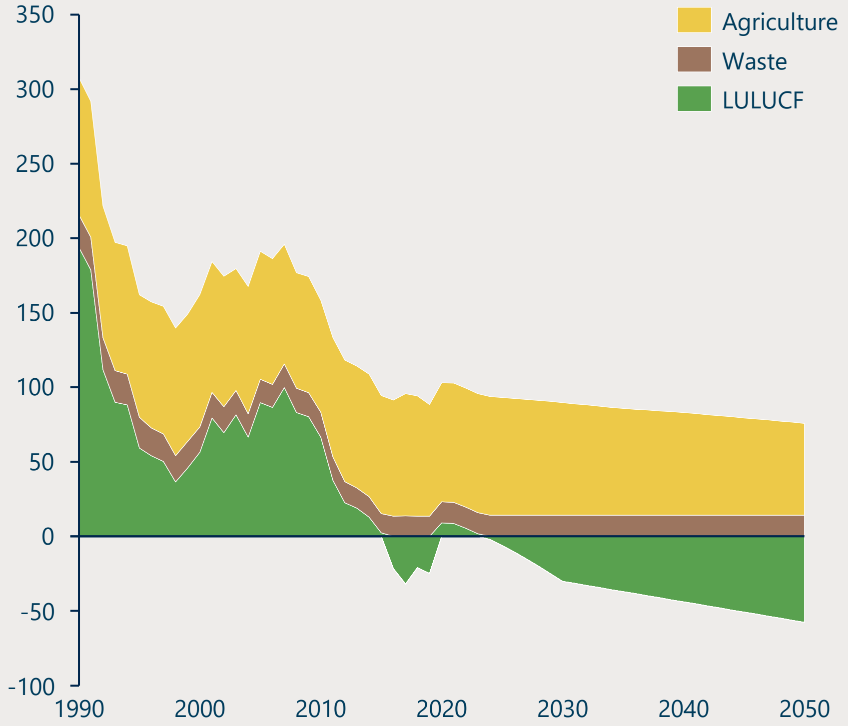
For example, reducing manure emissions through covered anaerobic ponds (CAPs) is proven technology and applicable to dairy, feedlot, swine, and poultry industries.[2] Incentives in the form of subsidies, taxes and/or regulation could improve adoption rates.

But achieving abatement in the land sector is practically challenging, and the efficacy of proposed policies highly uncertain. Revegetation is the most prospective abatement pathway for the land sector.

- **The land sector is not homogenous:** pushing a sector comprising fragmented actors to zero emissions is much more challenging than standardised sectors with relatively large and few companies, like energy production. Different land areas and subsectors will require different approaches, with owners incentivised by varied policies and interests across States and Territories.
- **Reducing enteric fermentation is practically challenging:** although the technology is proven and widely available (3-NOP[4]) and can be applied in non-grazing circumstances to great effect, it requires frequent administration to ruminant animals. This might not be feasible with grazing herds which produce the most methane.[5]
- *Continued on the following page.*

In our modelling, LULUCF delivers the most abatement in the land sector, with modest reductions in agriculture and waste emissions.

Historical and projected Agriculture; Land Use, Land-Use Change and Forestry; and Waste sector GHG emissions (Mt-CO_2e/year)



1. Net Zero Australia, 2023, Downscaling – The role of forestry in enhancing the Australian land CO2 sink.
2. Net Zero Australia, 2023, Methods, Assumptions, Scenarios & Sensitivities.
3. Options include integrated savannah burning, feral animal control, human-inducted regeneration of deep-rooted plant species, early life rumen microbiota engineering, and reductions in overgrazing (reference 1).
4. 3-nitrooxypropanol mixed into the diet of livestock.
5. The pasture-fed beef industry produces 47% of agriculture emissions (reference 1).

Scale up the most prospective land sector abatement pathways, particularly revegetation. (2/2)

Continued from previous page.

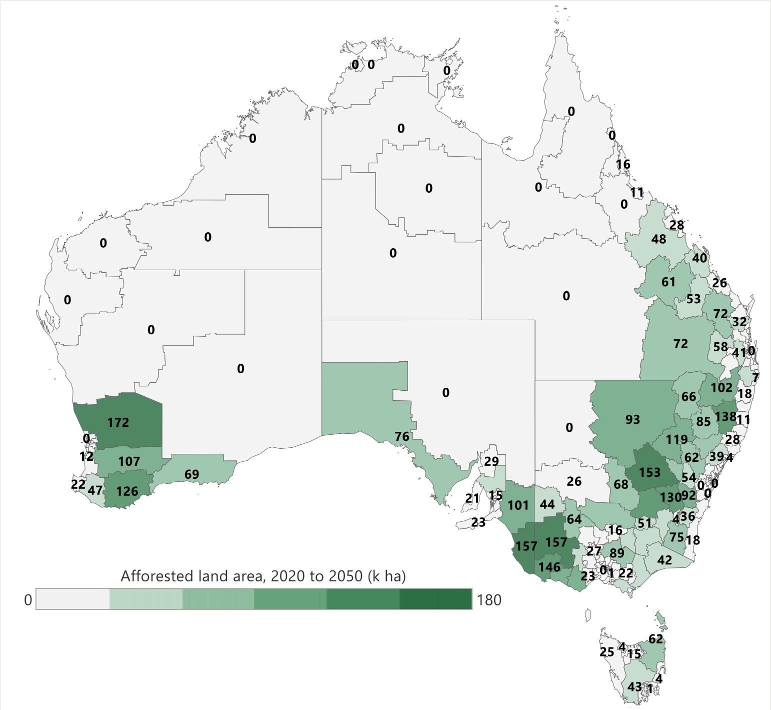
- **Difficulties achieving afforestation of agricultural land:** expanding the forest area by 5.1m hectares will require significant changes to farming practice, new investments and technology development to support more efficient forest establishment and more rapid tree growth. Techniques will need to be specific to the regions of focus (predominantly southern Australia), and agreements will need to be negotiated with landholders. Landowners will need to be helped with planning and establishment of an expanded supply chain.
- **Reliability risks to afforestation, amplified by climate change:** over half the emissions abatement from agriculture and LULUCF relies on afforestation. The reliability of these plantations for abatement is highly uncertain, particularly as the climate continues to change. For example, the frequency of bushfires is expected to increase in southern Australia and may be compounded by changes to agricultural productivity, making regrowth of forest systems less effective.[1]
- **Significant uncertainty in carbon accounting:** unlike industrial and energy production processes, determining emissions from cows or trees is uncertain and variable. If achieving net zero relies on environmental policies on farms, Australia needs to build a better picture of carbon accounting in the sector.

This uncertainty about the land sector's contribution calls for more research. Research into and focus on opportunities to increase abatement in the land sector should be intensified, like we've seen with the electricity sector.

WHAT MUST HAPPEN BY 2030?
Research and develop plans for land sector abatement, including technologies, farm practices, and policy mechanisms.
Begin scaling up prospective abatement pathways, particularly revegetation, by expanding advisory and nursery services to farmers.
Plan net zero transitions for all sectors on the expectation that the land sector will be a net purchaser of offsets

Our modelling sites 5.1 million hectares of new trees on cropland and pasture land. This will be very difficult.

Downscaled farmland afforestation, 5.1 million hectares (thousand ha total).



The above arguments suggest that the land sector would require offsets, not become a source of them. If the land sector cannot decarbonise, we will need more CCUS.

Should the abatement of 100+ $MtCO_2e$/year be unachievable by the land sector, Australia will need to secure abatement from other sources, likely direct air capture (DAC).

1. Reserve Bank of Australia, 2020, Macroeconomic Effects of Drought and Bushfires

Do not factor nuclear energy into net zero plans, but monitor international developments.

In the modelled sensitivity most favourable to nuclear deployment (constrained renewable build rate and low nuclear costs), nuclear produces a small proportion of energy.

- Nuclear energy is currently illegal in Australia. If it were legalised, and the renewable build constrained (E+RE-, Nuclear), it is modelled to produce 2 TWh or 0.1 per cent of domestic energy in 2050.
- If renewables are constrained, and the cost of nuclear is made 30 per cent lower than current international best practice (~A$5,200 / kW; E+RE-, CheapNuclear), it produces 78 TWh, or 4 per cent of domestic energy in 2050.

To reduce renewable targets in the belief that nuclear will be deployed later at scale would create a material risk of not achieving net zero, or doing so at an excessive cost.

Australia has a large renewable energy base and general public acceptance of renewables. If nuclear is factored into the future energy mix, resulting in slower renewable deployment, the modelling suggests that would be a costly error, because it likely to be more expensive than renewables with firming.[1]

It is also likely to take much longer. Nuclear power stations take an average of 9.4 years to build, compared to 1-3 years for a major solar or wind project.[2] Australia's lack of expertise and experience would likely make the lead time much longer.

Nuclear should not be regarded as an alternative to renewables, but the option could be monitored as a hedge against the risks of the transition.

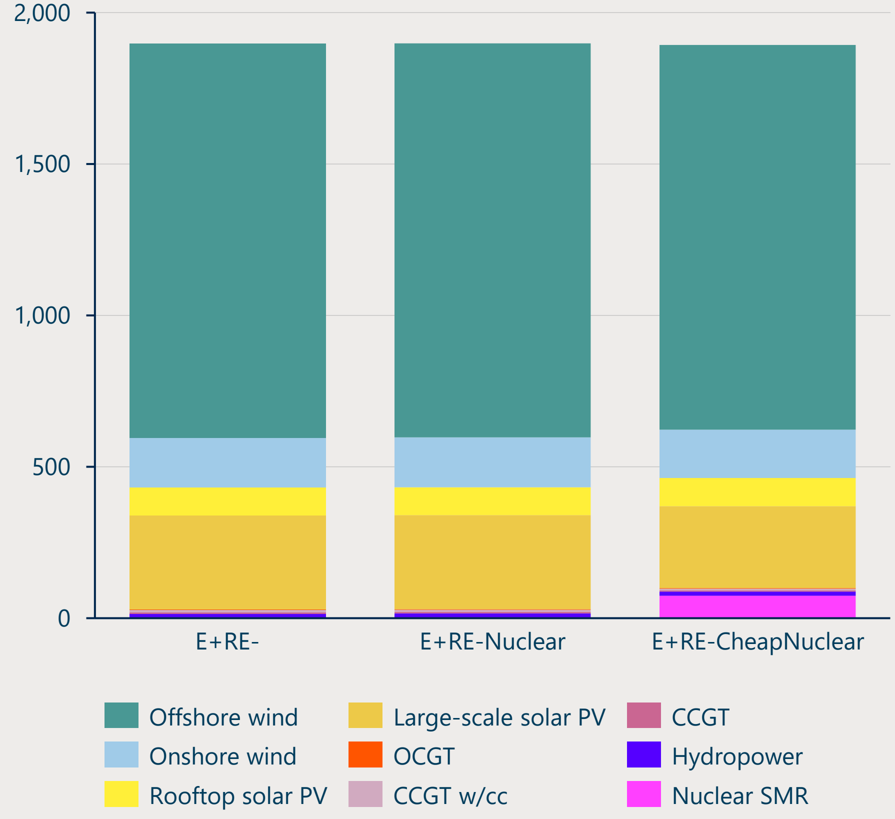
There is considerable uncertainty about future scale and cost of all key sources, as demonstrated by the differences in primary energy between Scenarios. The size of the decarbonisation task means where technologies are competitive and can make a material contribution to decarbonisation, they should be deployed.

We should proceed on the basis of no nuclear contribution.

However, a future combination of renewable cost, integration and/or supply constraints and dramatic nuclear cost reductions overseas may prompt a rethink.

Nuclear makes a modest contribution to domestic energy generation when renewables are constrained and costs are low.

Domestic electricity production by technology, 2050 (TWh/y)



WHAT MUST HAPPEN BY 2030?

Do not factor nuclear power into renewable, storage and firming targets.

1. CSIRO, 2021, GenCost 2021-2022: Consultation Draft.
2. World Nuclear Association, 2022, World Nuclear Performance Report.
3. Lowy Institute, 2022, Nationwide poll: Potential federal government policies on climate change.

5 – Exports, investment, & jobs

Section summary

Develop a clean energy export framework.

A mid-century target for reaching net zero is a long transition period for Australia's energy exports. Clean energy exports will grow over that period as fossil fuel exports decline, and the concurrency of these export streams, together with the duration of the transition, will make it challenging to navigate. Opposition to fossil fuel exports in Australia may intensify, even if clean exports grow, fossil fuel exports fall, and abatement obligations are met,

The sole reason for this export transition is to contribute to global carbon abatement to mitigate climate change. However, other goals – whether related or complementary – will influence how it is implemented.

During the large-scale switch from fossil fuels to clean exports, Australia will seek access to overseas capital, technology and skills to grow our clean exports. A just transition will be important to Australian workers in fossil fuel export industries, a stable business environment will be important to exporters, and energy security will be paramount to our trading partners.

An added complication will arise if Australia seeks to onshore mineral processing using clean energy, as proposed on page 41 of this report. Currently, most Australian ores are processed abroad. Onshoring would transfer some of that processing to Australia, with a resultant loss of jobs in countries to which we aspire to export clean commodities.

This transition would benefit from a strategy and framework to guide our planning and delivery of the transition in collaboration with trading partners. Its objectives would be to optimise the phase down of fossil commodities with the phase up of clean commodities, ensure an adequate supply of capital, technology and skills for export decarbonisation, and provide for the transition to occur in a fair, orderly and net zero-compatible manner.

During the transition, there will be many decisions to make, to build clean exports, and many others that concern exports of coal and LNG.

The implications of a net zero-compatible transition for decisions on individual projects, are well beyond the scope of the Net Zero Australia project. We suggest that a high priority be given to establishing an initial framework, so that these decisions can be taken in a strategic context.

Any conditions attached to future fossil fuel exports must consider the learnings from historic examples.

CASE STUDY 1: Uranium exports in the 1970/80s

In the 1970s, a government push to develop a uranium export industry, faced public opposition based on concerns about nuclear weapons proliferation and nuclear safety. The Ranger Uranium Environmental Inquiry supported uranium exports under strict conditions. The Coalition government allowed exports with strict bilateral safeguards from 1977.[1]

Current obligations on importing countries include: sole use for peaceful non-explosive purposes, coverage by IAEA safeguards and fallback safeguards, and physical security requirements.[2]

The Hawke Government was elected in 1983 with a policy to limit uranium mining to the three already in operation. There was a long debate to remove the 'three mines policy' that was resolved in 1997. Community sentiment had a major bearing on the conditions of exports and volumes of exports.[3]

CASE STUDY 2: Live animal exports

Another example of community values disrupting exports occurred with live cattle exports to Indonesia, which were abruptly banned in 2011 in response to video footage of cruel treatment in Indonesian slaughterhouses.[4] Reviews and government responses including the Exporter Supply Chain Assurance System are continuing to be implemented to improve the regulation and transparency of this industry.[5]

WHAT MUST HAPPEN BY 2030?

Establish a clean energy export framework to decarbonise our exports through a transition which is orderly and just, for our fossil fuel regions and trading partners.

1. Harris, S., 2009, Australia as a supplier of uranium to the Asian region: Implications.
2. Australian Safeguards and Non-proliferation Office, 2023, Australia's Uranium Export Policy.
3. Parliament of Australia, n.d., Chronology of ALP uranium policy 1950 – 1994.
4. The Guardian, 2011, Australia suspends cattle export to Indonesian abattoirs.
5. Inspector-General of Live Animal Exports, 2023, Reviews.

Pursue exports of both clean energy and clean processed minerals.

Australia should prepare to establish all potentially viable export pathways.

Future ***demand*** for clean energy exports is highly uncertain. The volume of demand for minerals is established, though the timing of demand growth for clean minerals is not.

International competition to ***supply*** clean energy and minerals is also uncertain. However, Australia has world-class clean energy resources and is widely cited as a likely clean energy exporter, in competition with other countries (e.g. Saudi Arabia, Chile).

Australia should build on our comparative advantages to onshore clean mineral processing.

Our combination of export-scale clean energy resources and mineral resources is unusual, possibly unique.

The E+ONS Scenario, in which direct reduced iron and aluminium are produced here using Australian ores and clean energy, demonstrates that it is much more economic to use piped hydrogen locally for industrial purposes than to convert it to exportable form for use in mineral processing overseas.[1] Onshoring of mineral production would also enhance our economics security.

Currently, most Australian ores are processed overseas with fossil fuelled energy. If more processing were to be onshored, this could create tensions with trading partners which currently host those industries. However, those industries are vulnerable to losing the processing of Australian ores to other locations with high potential to make green hydrogen, because shipping Australian ores to those destinations is relatively cheap.

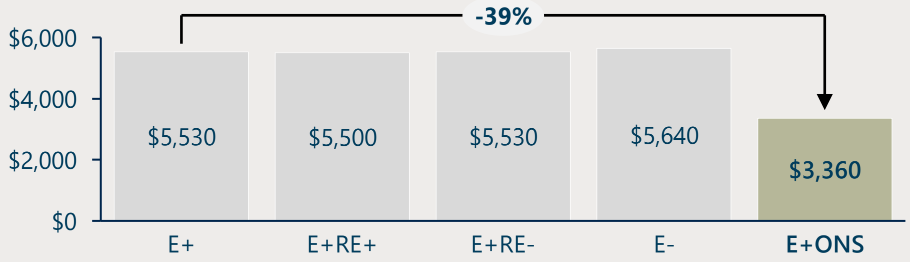
In other words, onshoring of clean mineral processing may compete with other clean energy exporters, not with our current energy and ore importers.

Australia should also seek clean energy export opportunities.

Some importers will need clean energy, because they lack domestic resources with which to be self-sufficient in energy (e.g. Japan and Korea). These opportunities should be pursued as well.

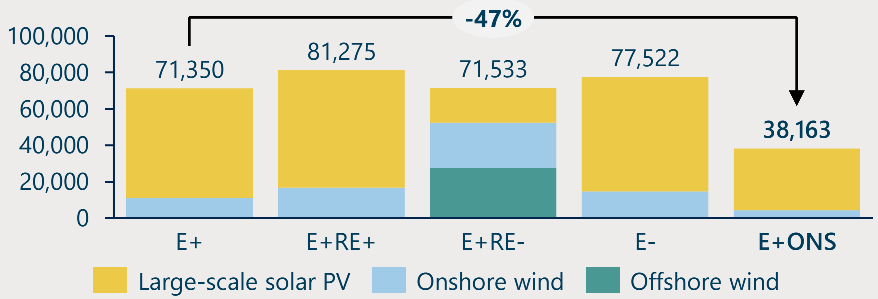
Onshoring production of iron and alumina is ~40% cheaper than exporting primary clean energy…

Levelized export system cost at 2060 by Scenario (2020 $AUD billion)



…and reduces the infrastructure land footprint by ~50% for equal amounts of energy exported.

Energy system land use (domestic and export) at 2060 by Scenario by technology (km^2)



WHAT MUST HAPPEN BY 2030?
Attract investment in production of clean energy for exports.
Prioritise demonstration of clean mineral processing and plan for onshoring when commercially viable, including through constructive engagement with trading partners.

1. Net Zero Australia, 2023, Downscaling – Onshoring of Industry.

Devise a national plan for clean energy and mineral exports.

If construction costs are assumed to be nationally uniform, the modelling places export energy production across northern Australia due to its world-class solar resources. However:

- Our distributed export sensitivity (which places a cap on exports from any region) found only a 3 per cent increase in export costs (NPV).
- Our construction cost sensitivity (which assumes costs are 30 per cent higher in NT and northern WA, and 15 per cent higher in Qld), found substantial energy production in NSW, SA, and Vic, and far less in NT and WA.

Concentrating exports in Northern Australia comes with significant risks including: underdeveloped supply chains[1]; difficulties attracting a skilled workforce due to lack of services and amenities, and a less appealing climate; vulnerability of infrastructure to natural disasters and security threats; and disproportionate impacts on local communities including First Nations.

For example, in E+, employment in the NT energy sector expands 102x by 2060. Combined with associated service jobs, this could triple the NT population.[2,3]

The location of clean energy and mineral processing for export can be flexible, which would avoid remoteness costs and mitigate impacts on fossil fuel regions. However, it would change the risk and value proposition and would need to be managed so that the appetite for foreign investment is not impacted.

Our modelling (E+ONS) locates clean iron production in north-west WA, because 90 per cent of Australia's identified ores are there[4] and the region already has substantial infrastructure.[5] However, this did not consider the cost of attracting 1.7 million workers (direct and indirect) to remote areas and building settlements.

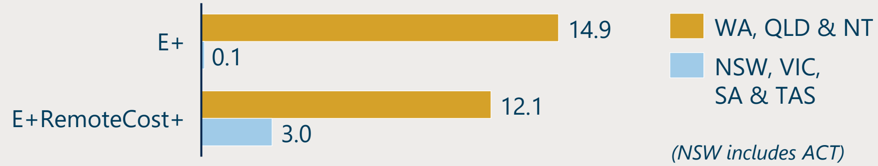
Transporting iron ore to fossil fuel regions to be processed with green hydrogen, made inland from solar, may mitigate impacts of closures (see page 55). This could be a feasible and even cost-effective plan, because it may be cheaper to transport iron ore to eastern Australia and make direct reduced iron there than in the Pilbara[6], due to other cost advantages and good renewable resources.

However, separating processing from mining will increase some supply chain costs, and possibly financing costs and risks. The impact on Indigenous Estate is uncertain but may be lower, depending on where the solar-hydrogen hubs are located.

A national plan for the location of clean energy and mineral export hubs is required.

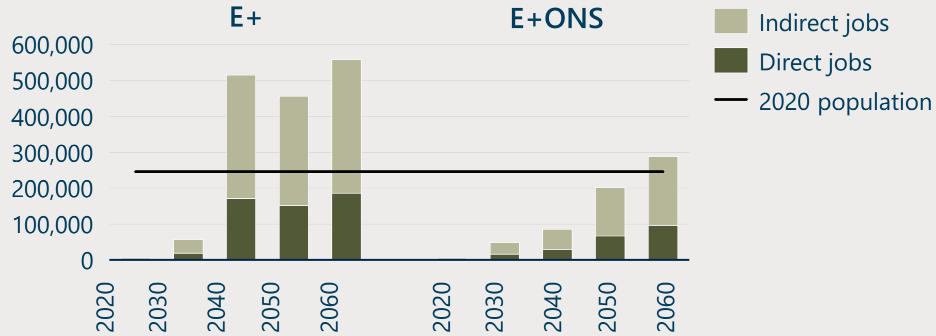
Exports shift south and east if remote costs increase.

Total energy produced for export by state (2060, EJ/y).



The location of exports has major consequences for employment and population changes, and needs careful planning.

Number of direct and indirect[3] energy jobs by Scenario in the Northern Territory.



WHAT MUST HAPPEN BY 2030?
Assess and compare the costs and benefits of northern and distributed locations for clean energy and mineral production.
Investigate the feasibility of clean mineral processing in current fossil fuel regions to minimise local transition costs.
Devise a national plan for locating clean energy and mineral export hubs and attracting investment.

1. H. Babacan & P. Tremblay, 2020, Reframing Smart Supply Chains in Northern Australia.
2. Australian Bureau of Statistics, 2020, National, state and territory population.
3. A ratio of 2 indirect job for every direct job was derived from Department of Industry, Innovation, Science, Research and Tertiary Education, 2013, Lessons learnt from large firm closures.
4. Geoscience Australia, n.d., Iron.
5. Net Zero Australia, 2023, Downscaling – Onshoring of industry.
6. Grattan Institute, 2020, Start with steel: A practical plan to support carbon workers and cut emissions.

Grow sectoral employment and related education and immigration.

The NZAu project has identified that ~650k more jobs will be required in the energy sector by mid-century. The sector currently employs ~100,000 people. Between 2030-2040, Australia is modelled to see significant growth in the domestic energy sector, the remaining job growth will occur primarily in the export sector.[1] We have also found that:

- There is significant uncertainty in the number of export sector jobs. This is because the study has assumed that current energy exports will be maintained, and job productivity (number of workers per task per annum) will continue to evolve significantly;
- The location of these export jobs is uncertain, relatively small changes in project costs shift export sector investments from the North/NW to the South/SE of Australia and thus nearer to current, larger population centres; and
- These projections would make the energy sector a significant sectoral employer by mid-century but still smaller than several other sectors.

Finding, educating, and employing these roughly 7x more workers, is an enabling part of achieving net zero emissions and needs a significant effort on its own. Industry, government and educational institutions (TAFE and universities), must therefore develop and implement complementary measures by which these workers can start to be deployed before 2030. This is an ***urgent*** challenge, as many of these first cohorts will currently be at school, and require ~4 years of tertiary education before qualifying and commencing work in the lead up to 2030.

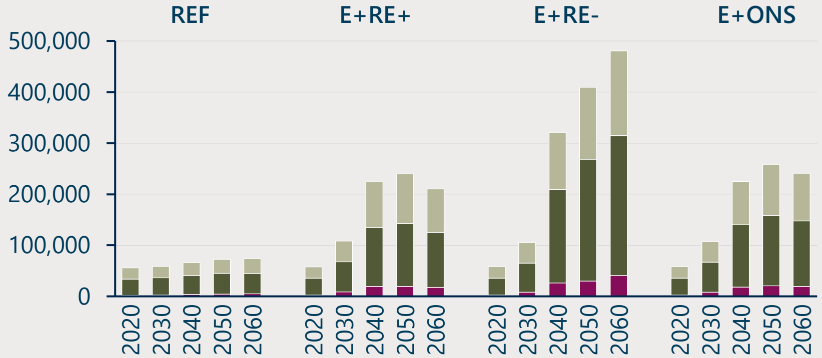
These complementary measures should include:[2]

- Development of new curricula at TAFEs and universities that focus on existing energy technologies and the 'new' energy technologies such as solar, batteries and electrolysis;
- Attraction of students into these courses through paid cadetships[3] and other means (these could also be used to improve diversity in the sector); and
- Immigration programs to attract students and overseas workers with appropriate qualifications,[4] as well as bridging courses that will enable recognition of qualifications locally.

Such measures are likely to have spill-over benefits of enhancing workforce productivity overall given the high skill level of these workers, particularly in manufacturing, construction, mining, and defence.[2]

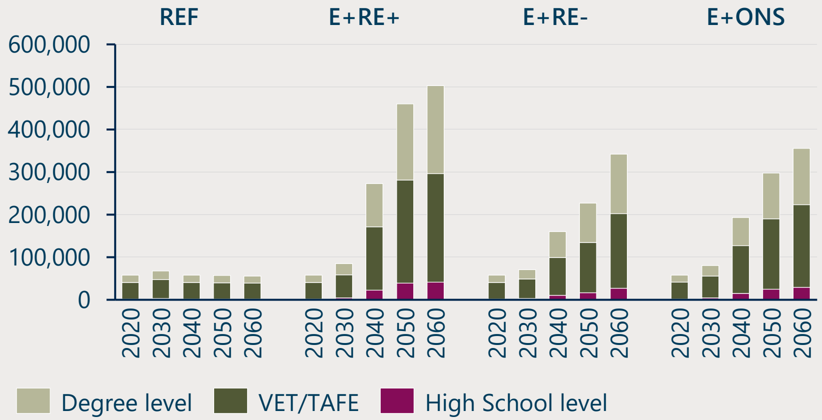
Domestic energy jobs increase significantly between 2030-2040.

Gross *domestic* energy sector employment over time (FTE).



From 2040, export jobs more than triple in all Scenarios.

Gross *export* energy sector employment over time (FTE).



WHAT MUST HAPPEN BY 2030?

Plan and implement complementary measures to grow sectoral employment, education, and immigration.

1. Net Zero Australia, 2023, Downscaling – Employment impacts.
2. Clean Energy Council, 2022, Skilling the Energy Transition.
3. Cadetships were once a common feature of educating the workforce in Australian industry and have largely disappeared. These could be paid for by the employer, and their costs passed on, forming part of an approvals process that government manages. For example, these cadetships could be considered a part of 'local content rules' that are now common in major projects.
4. Electrical Trades Union et al., 2022, Tomorrow's Trades to Power Australia's Future: Skills Shortfall Policy Document.

Re-orient industry strategies and policies towards our comparative advantages in decarbonisation and our strategic interests.

The modelling reports a huge increase in trade and construction of inputs to the energy transition (e.g. solar panels, batteries, transmission, electrolysers, and heat pumps). This will create new opportunities for import replacement and local content, the scale of which warrants a revision of industry development strategies and plans.

We can capture benefits from these new supply chains and increase energy security; a strategic and targeted approach will minimise the possible costs.

Local content requirements can capture more value in the supply chain, increase employment, and diversify our economies. However, support to catalyse local production can impose net costs and slow deployment, unless it is targeted[1] towards:

- Significant and sustainable **comparative advantage** with low opportunity costs, recognising that our labour, capital and resources will be in high demand to implement the transition.
- **National security** (including supply chain security) and/or geopolitical advantages.
- High **socio-economic value** (e.g. a just transition of fossil fuel regions).

Detailed **analysis and planning is needed** to identify the potential composition, size and location, of new local industries to replace imports.

Some candidates are mentioned elsewhere in this report, in particular, **processing of Australian ores**, which is both an export and local content opportunity.

- Another example is production of **clean fertiliser**, to reduce offshore emissions and increase supply security for a strategic input (see page 45).
- **Equipment to decarbonise** both export and domestic emissions, may reach a scale that warrants consideration of local manufacturing (see solar PV example).

Government support may be required to catalyse new industries. Education and training bodies must prepare to build the required skills early, and in the right locations.

The direct costs and opportunity costs of local production should be carefully assessed, including impacts on mobilisation of the net zero transition.

SNAPSHOT – SOLAR PV PRODUCTION

Australia may need, in the order of 3 TW of large-scale solar PV panels by 2060,[2] some of which should be locally manufactured.

Australia should consider developing a multi-GW capacity domestic solar manufacturing industry, supported by clean energy.[3]

There is currently only one, small domestic solar PV manufacturer in Adelaide,[4] but the National Reconstruction Fund has allocated up to $3 billion in funding for solar panel production, components of wind turbines, battery storage, and hydrogen electrolysers.

As well as manufacturing, it may be feasible to explore local recycling and/or circular economy facilities for solar panels and other manufactured products to reduce environmental impacts.

While Net Zero Australia did not estimate costs for local manufacturing, a solar manufacturing industry could generate employment – the IEA estimates up to 1,300 full-time manufacturing jobs could be created per 1 GW of per-year solar capacity.[5]

Manufacturing could be located in declining fossil fuel or manufacturing regions, particularly as manufacturing sites have more locational flexibility than raw exports and can be placed near larger worker populations. However, the availability and capability of labour for manufacturing must be considered, in the context of increasing labour needed for clean energy.

WHAT MUST HAPPEN BY 2030?

Identify opportunities to increase local industry content, including locations and types of manufacturing, taking into account varied benefits and opportunity costs.

1. Peterson Institute for International economics, 2021, Local content requirements threaten renewable energy uptake
2. Under the E+, E+RE+ and E- Scenarios – see: Net Zero Australia, 2023, Downscaling – Solar, wind and electricity transmission siting.
3. CSIRO, 2022, Australian Silicon Action Plan.
4. Renew Economy, 2023, Australia's only solar manufacturer launches $11m production and innovation facility.
5. Parliament of Australia, 2023, Powering Australia.

Develop and implement an import replacement strategy.

Import replacement is an opportunity to create employment and growth.

- Stimulating production of some domestic goods to replace imports made with high emissions overseas could be economic, if it reduces net global emissions and creates economic and social benefits that justify any costs.

Opportunities include production of urea, hydrogen and aviation and marine fuels.

- **Clean urea,** produced with both blue and green hydrogen, could replace imports that are made with natural gas overseas. This was not modelled but warrants further investigation of potential benefits including:[1] reduced global emissions; efficient use of off-gases from hydrogen production (nitrogen and CO_2); scope to add inhibitors which reduce emissions of nitrous oxide (N_2O); increased security of supply of a critical input to agriculture; and a new export opportunity.
- **Hydrogen** as an option to replace fossil fuels such as diesel in heavy transport and remote power generation. Though the cost of hydrogen is currently high, hydrogen fuel pumps and Australian-manufactured hydrogen trucks are being trialed in Tasmania with operation expected in 2023.[2]
- **Sustainable aviation fuel** (SAF) and **sustainable marine fuel** (SMF) options are under development internationally (e.g. jet fuel from biomass or green hydrogen, and green methanol for marine vessels). Australia's renewable resources could support our aviation and marine industries by localising fuel production near major ports.
- **Other opportunities** including electric motors for public transport could be explored.

Government support would be needed to grow these industries early, to initially compete with unabated competitors, and to accelerate and lower the cost of large-scale deployment. An integrated mix of mandates and transitional subsidies is likely to be needed.

A strategy for developing import replacement industries, such as those above, should be prioritised, and should consider specific forms of government support.

CASE STUDY – SUSTAINABLE AVIATION FUEL

Australia's first sustainable aviation fuel biorefinery is planned for Gladstone, with operation beginning in 2025.[3]

Queensland's focus on biofuels is significant, given its available feedstocks and existing infrastructure.[4] The Queensland Government hosted a roundtable in 2022[5] and is exploring options to expand its aviation fuel industry.

The Gladstone project will use feedstock sourced in Australia including tallow, used cooking oil, and canola. Demand is increasing as airlines, such as Qantas, set targets for 10 per cent SAF by 2030.[6]

CASE STUDY 2 – SUSTAINABLE MARINE FUEL

Sustainable marine fuels are in development and may increase as 'Green Corridors' are established.

Early demonstrations of hydrogen, ammonia and battery-powered vessels have been increasing.[7] These are emerging technologies and costs are currently limiting commercial viability.

Supporting this shift are 'Green Corridors', where ships with zero, or near-zero emissions are prioritised, though in the short term, the industry may have to rely on CCUS. BHP, Rio Tinto and others are assessing the feasibility of a corridor between Australia and East Asia.[8]

WHAT MUST HAPPEN BY 2030?

Develop and begin implementing a strategy for import replacement industries, such as urea, hydrogen, and specialised fuels, taking into account the benefits to employment, reductions in global emissions, costs, and mechanisms for stimulating domestic demand.

1. International Energy Agency, 2021, Ammonia Technology Roadmap.
2. ABC News, 2022, Hydrogen fuel pumps are on the way in Australia — so how long until the vehicles arrive?.
3. Oceania Biofuels, 2022, Our Australian Project: Port of Gladstone.
4. Queensland Government, 2015, Queensland Biofutures 10-Year Roadmap.
5. Queensland Government, 2022, Roundtable accelerates take-off for Queensland green aviation fuels industry.
6. Sydney Morning Herald, 2023, Plans are taking off for Australia's first sustainable jet fuel refinery.
7. Global Maritime Forum, 2022, Mapping of Zero Emission Pilots and Demonstration Projects.
8. BHP, 2022, BHP signs Letter of Intent for Australia-East Asia iron ore Green Corridor.

Plan to take responsibility for our share of aviation and shipping emissions, through local production of zero carbon fuels.

Australia should now accept its share of international aviation and shipping emissions and plan to contribute to decarbonisation of those sectors. These emissions are external to national contributions covered under the Paris Agreement,[1] and progress by the International Civil Aviation Organisation and International Maritime Organisation, is reported as insufficient to reach net zero by 2050.[2]

It would be prudent and responsible to plan for those abatement tasks. Australia is likely to be allocated a share of emissions from inbound, and outbound, air and maritime traffic in future, so best to prepare early. As a likely net exporter of energy, the production of decarbonised fuels will likely fall to us.

Australia should increase its responsibility and prioritise the consideration of bioenergy for this use, including the consideration of local production of sustainable aviation fuels (SAFs) and sustainable marine fuels (SMFs).

AVIATION

Our modelling found it is cheaper to implement renewable-powered Direct Air Capture with CCUS than make SAFs. However, local production will increase supply chain security, and may be compelled by private and international moves to require SAFs.[3] Qantas has committed to 60% SAFs by 2050, and has allocated $290 million towards supporting domestic production of SAFs.[4]

It is arguable, that global offsetting of aviation emissions is not a viable decarbonisation strategy, but this is beyond the scope of our analysis.

SHIPPING

Decarbonisation of shipping faces challenges which are in tension with each other:

- **International innovation and coordination is required.** To decarbonise international shipping will require the adoption of new fuels such as ammonia, which will not be feasible unless the growth of production and bunkering is coordinated internationally, and propulsion systems using those fuels become commercially available.
- **Long shipping vessel life creates an impetus to decarbonise quickly.** Retrofitting is significant for maritime vessels to use SMFs – a cargo ship has a 25+ year lifespan.[5] Impact on operations will be felt most greatly between 2040-2050 where shipping scales up from 50% to 100% sustainable.

TRANSPORT SECTOR TRANSITION TIMELINES (E+ Scenario)

Stock data in the E+ Scenario for maritime shipping (% ammonia), and aviation.[6]

Stock data

Category	2022[2]	2025	2030	2035	2040	2045	2050
Maritime shipping							
Intl shipping *% Ammonia*			10%		50%		90%
Domestic shipping *% Ammonia*			10%			50%	67%
Aviation	No change						

WHAT MUST HAPPEN BY 2030?

WHAT MUST HAPPEN BY 2030?
Take responsibility for, and plan to abate, Australia's share of emissions from international aviation and shipping.
Actively support the coordination of robust international action to reduce all international aviation and shipping emissions.
Explore options to locally produce aviation and shipping fuels.

1. United Nations Framework Convention on Climate Change, n.d., Emissions from fuels used for international aviation and maritime transport.
2. Climate Action Tracker, 2022, Aviation emissions, and 2021, International shipping.
3. UK Government, 2021, Mandating the use of sustainable aviation fuels in the UK.
4. Qantas, 2023, Qantas to set up climate fund as it tracks towards net zero.
5. Global Maritime Forum, 2022, Alternative fuels: Retrofitting ship engines,
6. Net Zero Australia, 2023, Downscaling – Transport sector energy transition

Fast-follow technologies for the domestic transition and prioritise early adoption of clean export technologies.

Where innovation and new technologies are required, Australia will be reliant on other nations to set the pace of our change.

Decarbonisation efforts locally will be tied to the global effort. Domestic commitment will be undermined by perceptions that the rest of the world is not moving as fast.

But slow movers may experience disbenefits, such as stranded assets, increased energy costs, diplomatic damage, and regulatory scrutiny.

Australia, as a technology importer, will continue to rely on the manufacturing capabilities of trading partners.

Though there are some opportunities for import replacement, our small workforce is best deployed to our comparative advantages, particularly clean energy resources and minerals.

Manufacturing countries with larger populations have an incentive to grow production and lower the cost of clean technologies that should be adopted quickly in Australia.

Our comparative advantage in clean energy exports justifies early action.

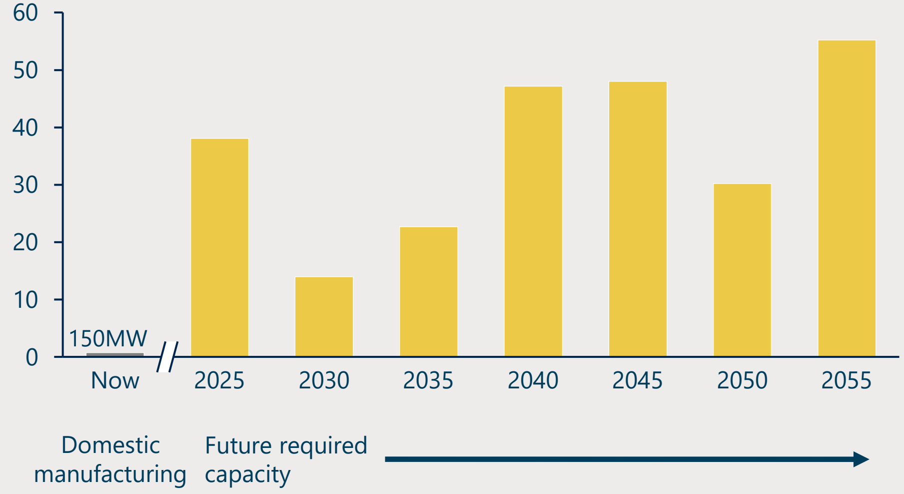
Early action can position Australia as a hub for research and development, and rebuild Australia's international reputation for climate action.

Australia should establish itself as a global leader to attract foreign investment and create new opportunities – to contribute to decarbonisation and maintain our trading strength, as coal and LNG exports decline.

The Inflation Reduction Act (IRA) in the US has attracted investor interest in developing clean energy industries.[1] The US is not a likely source of exports to energy-dependent countries such as Japan and the Republic of Korea, and as such investors remain interested in Australia as an exporter. However, the IRA underlines the need for government support to lower costs in the early stages of a new industry.

Australia will be a net importer of technology, capital and skills.

GW new large-scale solar capacity required domestically every 5 years, compared to historic domestic manufacturing (E+ Scenario).



WHAT MUST HAPPEN BY 2030?
Enable early, voluntary adoption of new use technologies by reforming regulations, and catalysing essential infrastructure.
Monitor the cost and availability of use technologies and accelerate adoption with government mandates and subsidies where required, consistent with a fast-following strategy.
Capture early clean export opportunities by building early demand and attracting investment in demonstrations and commercialisation, including, through planning and funding for common use infrastructure, financial incentives to locate projects in Australia, and active trade and investment diplomacy.

1. Australia Financial Review, 2023, Opportunities beckon under IRA, but converting them is another story.

6 – Impact mitigation

Section summary

TOPIC	STRATEGIC MESSAGE	PAGE
Land use change	Prepare to increase the speed of land use change while reducing conflicts.	50
	Conduct integrated planning of renewable energy and biodiversity zones and establish coordinated delivery.	51
	Prioritise equity and shared ownership with First Nations peoples throughout the transition.	52
	Support farmers to overcome challenges and benefit from the opportunities of decarbonisation.	53
	Reform planning and land use policy and establish benefit-sharing with sustained community inclusion and government leadership.	54
Fossil fuel regions	Develop new anchor industries to mitigate impacts of decarbonisation on fossil fuel regions.	55
	Establish policy mechanisms to ensure orderly asset closures.	56
Low-income households	Support low-income households to decarbonise and incentivise landlords and strata management to act.	57
Productivity	Manage productivity limitations during the investment period.	58

Prepare to increase the speed of land use change while reducing conflicts.

Land use change will be substantial and requires proactive management.

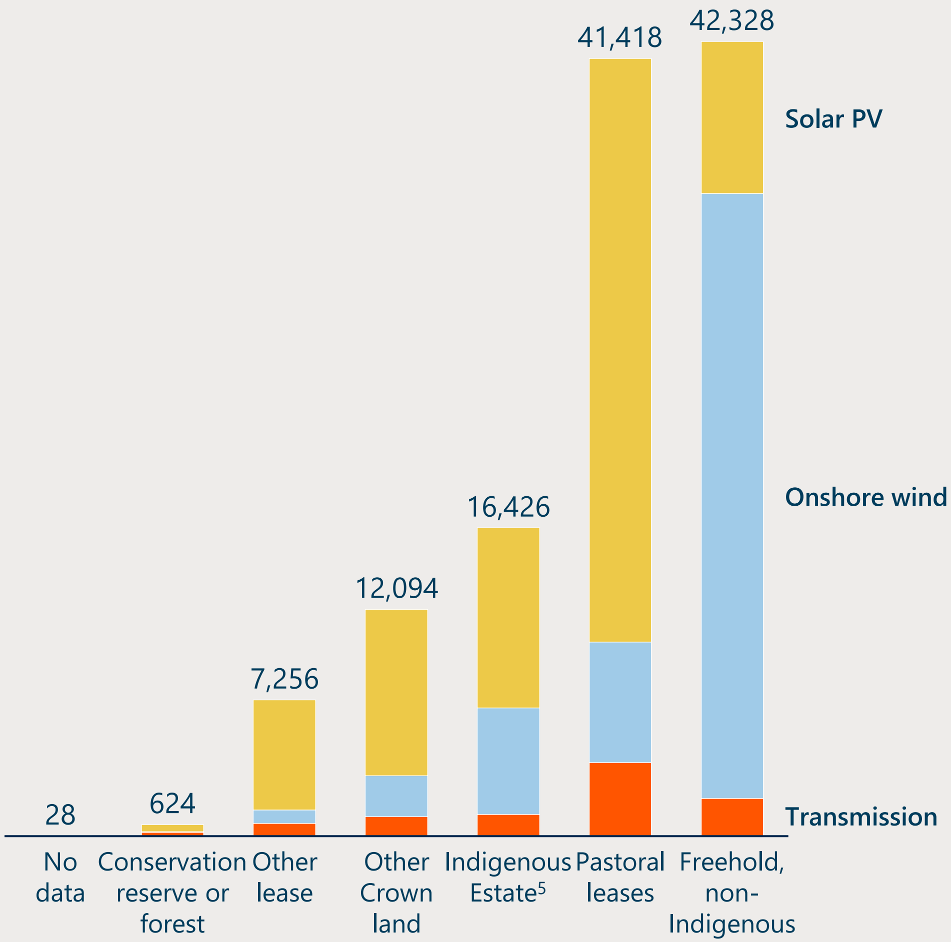
- Land use change will impact communities and habitats across Australia. First Nations, farmers, and biodiversity face significant changes. E+ estimates the area of land use change at 120,179 km,[1] equivalent to over half the area of Victoria.
- Current project-by-project approaches to developments are insufficient for the pace, scale, and cumulative impacts of the transition. Trends in the US,[2] South Korea[3] and Europe,[4] show that environmental and land value concerns are causes for nearly half of delayed or cancelled projects.
- The scale and pace of the transition requires land use change to be managed proactively to gain landowner and community engagement and speed up deployment. Some opposition is inevitable, but a partnership approach should minimise delay and maximise options.

The following pages discuss land use change in the context of the most affected stakeholder groups, and finish by summarising how a scheme that increases speed of approvals and reduces conflicts, might be achieved.

FOCUS	SUMMARY MESSAGE	SLIDE
Biodiversity	Australia must achieve net gain in biodiversity alongside net zero, building on current policy mechanisms.	51
First Nations	Indigenous Estate should be accessed by agreement with First Nations communities.	52
Farming communities	Access to private land, and agreements on benefit sharing with communities, should be primarily achieved by negotiation with compulsory acquisition a last resort.	53
Land use change reforms	Energy system planning under national and state laws, must be reformed to be compatible with net zero.	54

NZAu developments require significant amounts of land change on various land tenure types across Australia.

Total VRE and transmission infrastructure footprint area (km squared) on the various categories of Land Tenure, for the E+ Scenario in 2060.



1. Net Zero Australia, 2023, Downscaling – Net-zero transitions, Australian communities, the land and sea.
2. Susskind et al., 2022, Sources of opposition to renewable energy projects in the United States, Energy Policy, Volume 16.
3. Kim, Lee, and Koo, 2020, Research on local acceptance cost of renewable energy in South Korea: A case study of photovoltaic and wind power projects, Energy Policy, Volume 144.
4. Segreto et al., 2020, Trends in Social Acceptance of Renewable Energy Across Europe - A Literature Review, Int J Environ Res Public Health, 17(24):9161.
5. Including freehold Indigenous land, Crown purposes – Indigenous, Indigenous – other use, and pastoral lease – Indigenous).

Conduct integrated planning of renewable energy and biodiversity zones and establish coordinated delivery.

We need to rapidly accelerate approvals while addressing biodiversity.

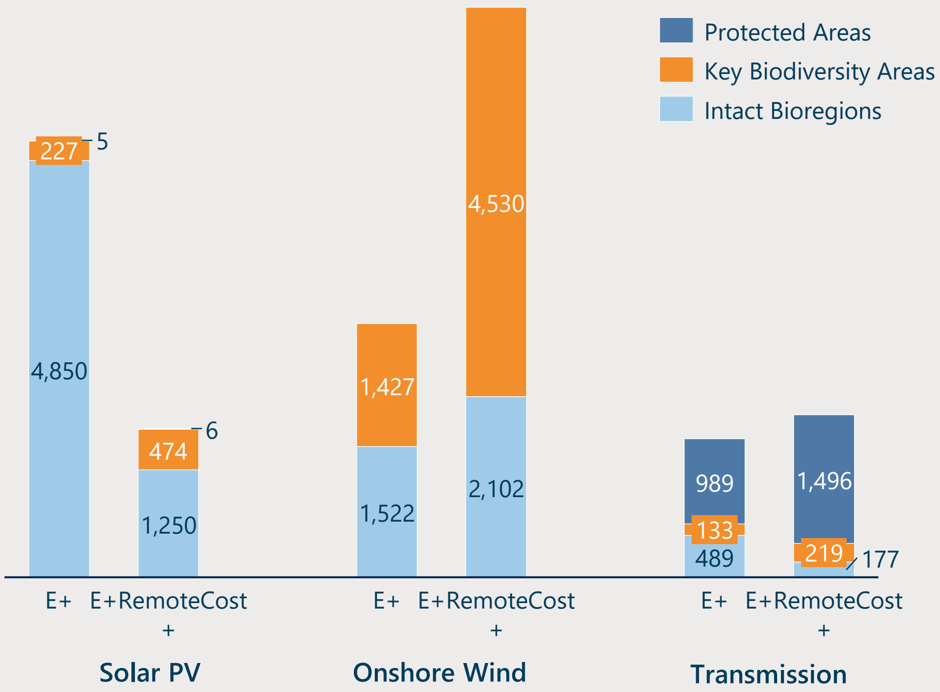
- Net zero requires unprecedented development, and development lead-times in Australia are 2-3 years for solar and 3-6 years for onshore wind.[1]
- However, clean energy projects also have significant environmental impacts including land damage, habitat loss, wildlife destruction and displacement, and other pollutants (e.g., noise, reflections, heat, waste).
- Revegetation for carbon sequestration can enhance biodiversity (e.g. renewing vulnerable or threatened habitats, species and ecosystems), but land clearing for renewables and transmission will generally reduce it.
- Further, there will be cumulative impacts from multiple projects in clean energy zones which are not assessed in individual project approvals.

Australia must achieve net gain in biodiversity alongside net zero, building on current policy mechanisms.

- To achieve both net gain and net zero with speed and scale arguably requires their planning to be integrated, and delivery coordinated, because each needs to be pursued as a major priority in its own right.
- Placing biodiversity offset obligations on each project would impose large transaction costs and may be an inefficient way to protect biodiversity.
- Instead, areas with high biodiversity value could be protected and restored through integrated planning and 'biodiversity zones' – in addition to identifying areas with low or already degraded biodiversity for renewable energy zones. This aligns with Australia's incoming environmental standards and regional planning.
- Zones could: enable quicker project deployment through efficient, early and adaptive partnerships between governments and communities; allow offsets on a regional scale; ensure robust biodiversity data[2] and the accurate measuring of impacts and rehabilitation; and create net and cumulative biodiversity and environmental gain while reaching net zero.
- There is also an urgent need for better understanding of protection of marine biodiversity, and selection of 'safe build zones' for offshore wind projects.

Between 7-8% of NZAu infrastructure will impact currently-mapped biodiversity areas, protected areas, and/or intact bioregions.

Total infrastructure footprint (km^2, E+ and E+RemoteCost+, 2060). NZAu modelling acknowledges significant limitations in available data on Australian biodiversity.[2]



WHAT MUST HAPPEN BY 2030?

Implement integrated planning, and coordinated delivery for renewable energy zones and biodiversity zones, to achieve net zero with net gain.

1. Clapin, L. and Longden T., 2022, Waiting to generate: an analysis of wind and solar project development lead-times in Australia's National Electricity Market, ZeroCarbon Energy for the Asia-Pacific ZCEAP Working Paper ZCWP07-22.
2. The NZAu modelling, despite exclusion zones, falls short of a comprehensive and systematic approach to biodiversity modelling due to the lack of comprehensive spatial data on Australian biodiversity (e.g. formal critical habitat mapping is missing for >99% of endangered species). See Net Zero Australia, 2023, Downscaling – Net-zero transitions, Australian communities, the land and sea.

Prioritise equity and shared ownership with First Nations peoples throughout the transition.

First Nations communities will be significantly impacted by, and critical to, decarbonisation.

- Under the E+ Scenario, 43% of NZAu infrastructure (51,600 km squared) falls on the Indigenous Estate by 2060, primarily for the energy export supply chain.[1] Though the direct footprint (e.g. solar PV mount) is somewhat lower than the total area,[1] the development of these solar export hubs will transform the socio-economic, cultural and physical landscape.
- Communities must give Free, Prior, and Informed Consent (FPIC), to any export infrastructure. This would require more robust regulation and implementation of FPIC in best practice, and in domestic law[2].
- Communities also face upside opportunities, including equity sharing, local energy security, and employment opportunities.

Indigenous Estate should be accessed by agreement with First Nations communities.

- Agreements should provide for large community gains through jobs, better energy supply and social services, infrastructure, and funding streams for development. Consideration should be given to requests for equity.

Shared ownership and early capability building are factors for success.

- First Nations ownership and equity models are essential, alongside genuine partnerships that have deep levels of trust, reconciliation efforts, and a sense of community.[3] Benefit-sharing must start early (before impacts are felt), to build and sustain trust, and maintain momentum.
- Best practice frameworks for clean energy projects such as, First Nations Better Practice Community Engagement[4] and the First Nations Clean Energy Network,[5] should be used across all projects impacting the Indigenous Estate. Factors including a commitment to cultural heritage and land stewardship, protecting Country, sharing economic and social benefits through strategic partnerships, and ensuring cultural competency.

NATIONAL NATIVE TITLE COUNCIL RESPONSE

The National Native Title Council responded to Net Zero Australia's modelling report by saying that:

- The modelled scale of clean energy infrastructure on Indigenous Estate calls for a re-conceptualisation of the role of First Nations in development, learning from mistakes of the resource extraction industry.
- Clean energy and transmission projects need to focus on equity for First Nations communities through First Nations ownership, co-ownership and community-controlled projects.
- First Nations communities need access to finance and other critical support to manage Country and take a pro-active role in renewable energy projects, including equity – for which Government funding is needed.
- A legal right is needed to Free, Prior and Informed Consent (hence veto) to projects, including renewable energy.
- Governments should set targets for jobs, spending and procurement involving First Nations people and companies.
- It supports the First Nations Clean Energy Network's development of a First Nations Clean Energy Strategy, to enable Aboriginal and Torres Strait Islander people to play a role in the country's energy transformation.

1. Net Zero Australia, 2023, Downscaling – Net-zero transitions, Australian communities, the land and sea.
2. Wynn-Pope, R., et al, 2023, FPIC in the Australian context: now and into the future.
3. Hoicka, C., Savic, K. and Campney, A., 2021, Reconciliation through renewable energy? A survey of Indigenous communities, involvement, and peoples in Canada. Energy Research & Social Science, 74.
4. The Energy Charter, 2022, First Nations Better Practice Community Engagement.
5. First Nations Clean Energy Network, Aboriginal and Torres Strait Islander Best Practice Principles for Clean Energy Projects.

Support farmers to overcome challenges and benefit from the opportunities of decarbonisation.

Farming areas face many impacts from decarbonisation.

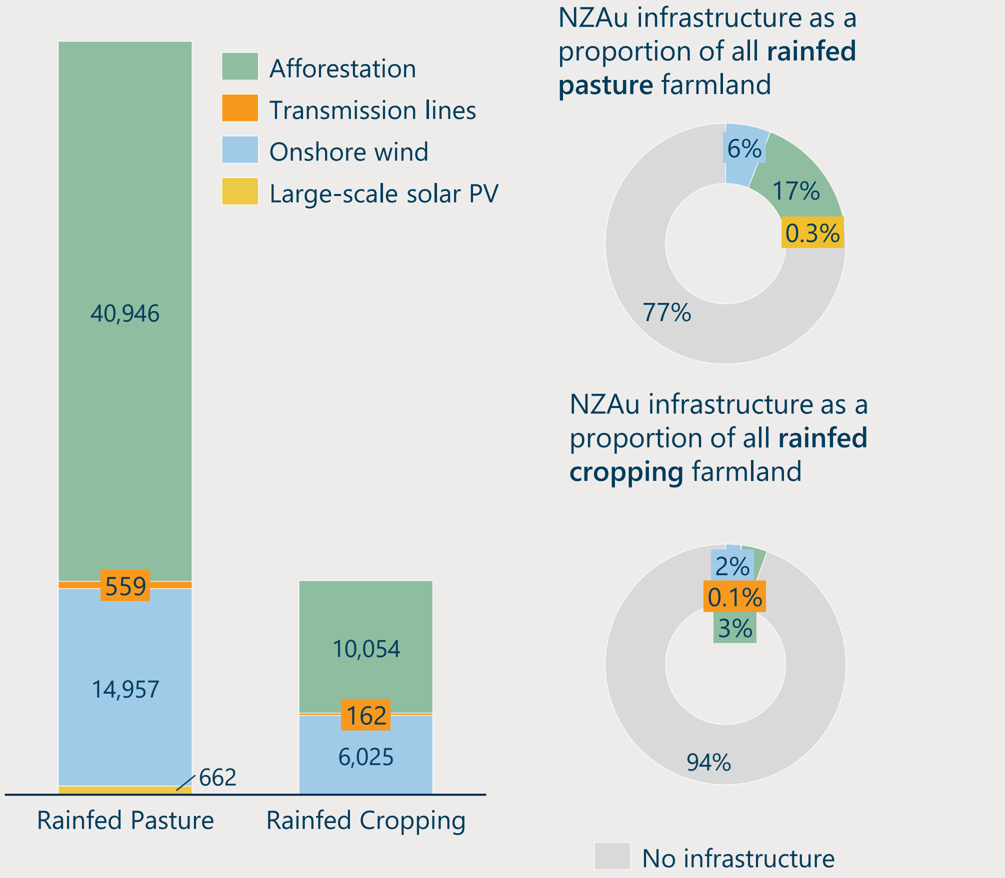
- Afforestation as an abatement measure will affect many farms, as will converting to farm machinery, household appliances, vehicles that use clean energy, and managing animal waste.
- Many farms in Renewable Energy Zones (REZs) will host wind or solar farms or transmission lines. The impact of renewable infrastructure on farming varies from minor to significant, depending on the type of infrastructure and farm.
- Farm communities in REZs will compete for labour with companies developing clean energy projects and will share roads with large loads during construction. Some farms may need to reduce enteric emissions.
- Divisions between regional and urban areas may compound as regions face disproportionate impacts from the transition and climate change.
- Rental payments for hosting infrastructure will give landowners an independent and stable income, and revegetation can provide wider benefits to farm production. Global decarbonisation and reduced climate variability should reduce long-run risks to farm viability.

Access to private land, and agreements on benefit sharing with communities, primarily should be achieved by negotiation.

- Access to private land and benefit sharing agreements should primarily be achieved by negotiation. It will be crucial to avoid protracted disputes, and governments and developers must act as neighbours to build social licence.
- Compulsory acquisition should only be used as a last resort, to procure easements for linear network infrastructure, where alternatives are not available or too costly.
- Benefits should begin to flow early and relate to the infrastructure projects, and can include local jobs, road upgrades, better services, and payments.
- Early engagement is essential, and local advisory committees should have a decisive say, and be supported to build their negotiating capability.

Rainfed pasture and cropping are the main farmland types affected, with afforestation the biggest impact.[1]

Total km^2 (entire facility boundary) required for new net zero infrastructure or afforestation, by farmland type (E+ Scenario in 2050). Other farmland types have negligible land change required for transmission only (25km^2 for irrigated cropping, pasture and sugar, and 1km^2 for rainfed sugar).



1. Note – this is the result of some inputs that excluded irrigated farmland from some uses. See the relevant downscaling report for more information.

Reform planning and land use policy and establish benefit-sharing with sustained community inclusion and government leadership.

As established in the discussion above, planning and land use policy needs urgent and substantial reform.

- Planning approvals processes do not suit the scale and pace, of a net zero transition.
- Lessons from innovation in community engagement and benefit sharing, should underpin 'highest common denominator' reforms to be adopted nationally.
- Energy system planning under national and state laws, must be reformed to be compatible with net zero (including by extension to new networked commodities like hydrogen).

Engagement and benefit sharing must be prioritised, proactive, and based on principles of inclusion, agreement, and net gain.

- Engagement is a joint responsibility, and close collaboration and partnerships will be required between governments, developers, and communities.
- Governments may have to lead negotiations for benefit sharing agreements across multiple inter-related projects (e.g. REZ with new transmission and several wind/solar farms).
- Building social licence needs to be a high priority, and an issue that we approach on the front-foot. More concerted and coordinated approaches are required.

Government leadership and coordination is required to address cumulative impacts.[1]

Negotiations will need to address the cumulative impact of several projects that individual developers cannot deal with, for example:

- Impacts on local roads of the movement of large pieces of equipment for multiple wind and solar farms
- Impacts of a large influx of workers on employment, wages and housing
- Landscape impacts on cultural heritage

These negotiations between government, developers and communities must consider:

- Fair compensation packages, including (for example) the provision of employment and training and a prioritisation of the procurement of goods and services from the region
- Funding and support for engagement to ensure informed communities
- Minimisation of environmental impacts and supporting local biodiversity conservation
- Coordination of lead and supporting roles for negotiations, and implementation of benefit sharing in inter-related projects (e.g. renewable hubs or zones)

WHAT MUST HAPPEN BY 2030?
Establish budgets, governance and reporting frameworks for benefit sharing in Renewable Energy Zones (REZs).
Build community capability to negotiate transition agreements.
Further expedite the transition by reforming planning and environment approvals.

1. International Finance Corporation, 2019, Local Benefit Sharing in Large-Scale Wind and Solar Projects, Discussion Paper.

Develop new anchor industries to mitigate impacts of decarbonisation on fossil fuel regions.

Workers in concentrated fossil fuel regions will experience job losses, with broader community impacts.

Fossil fuel-producing regions such as central Queensland, Hunter Valley, Latrobe Valley and the Pilbara will experience job losses,[1] business closures and significant community impacts as fossil fuel use declines.

Many of these regional economies lack diversity so are vulnerable to the loss of a sector. The most effective mitigant is to leverage the region's advantages to grow a new anchor industry.

Impacts could be offset by siting new zero-carbon industries in fossil fuel regions.

As discussed on slide 42, Australia has significant optionality on where to locate export zones, including both for export of hydrogen, and onshoring of clean minerals and chemicals. Choosing to locate new industries in regions facing decline, and with existing infrastructure, could contribute to a just transition and provide a new source of 'anchor jobs', but requires careful coordination to balance economic incentives. Both clean energy and onshoring industries provide permanent jobs in operations and maintenance, and production.[1]

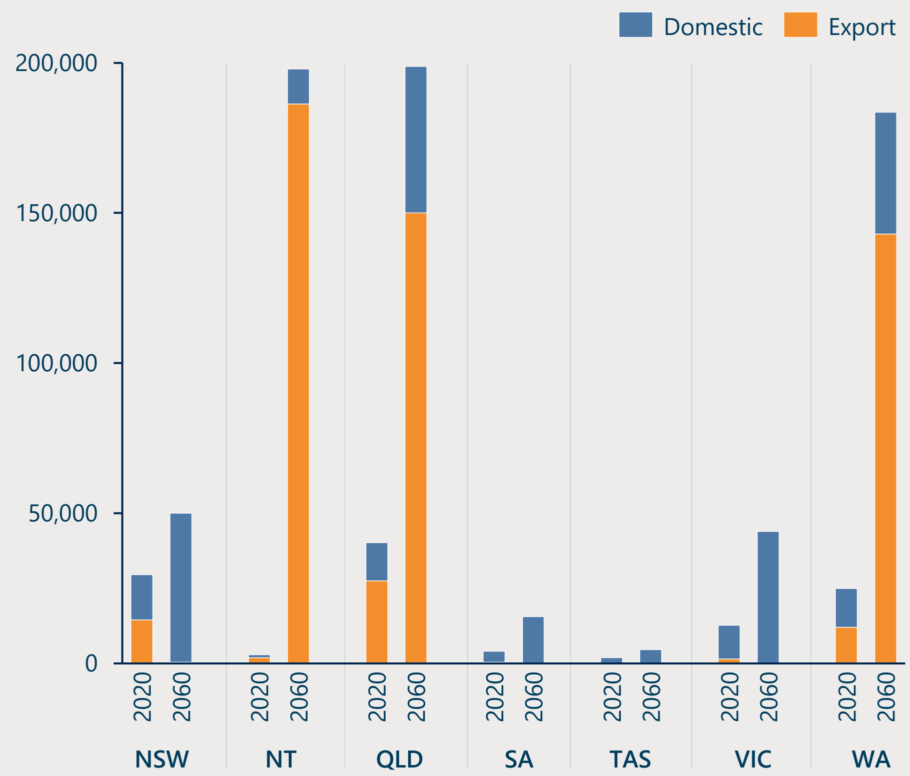
In general, fossil fuel regions lack large renewable energy resources so must leverage other advantages. In Gippsland's Latrobe Valley, lignite with CCUS could make blue hydrogen and urea, at a hub into which green hydrogen from offshore wind can be blended in future.

In other cases, such as the Hunter Valley, industrial land could be repurposed to add value to green hydrogen made inland by processing Australian minerals (e.g. iron ore from Pilbara). This is explored above.

Even if a new industry can be grown, many existing fossil fuel workers and businesses will not be suited to transitioning to it. Governments will need to provide support for workers and businesses to exit. The menu of supports should be broad, including retraining, retooling and relocating. Collaboration between all levels of governments will be needed.

In NZAu modelling, the clean energy export system creates thousands of new jobs which could mitigate the impacts of decarbonisation on fossil fuel regions.

Gross energy sector jobs under the E+ sector by state/territory and sector comparing 2020 and 2060. Note the increase in jobs may be less than modelled due to unforeseen circumstances (e.g. automation, technology development).



1. Net Zero Australia, 2023, Downscaling – Employment impacts.

Establish policy mechanisms to ensure orderly asset closures.

Stranded assets will occur in the transition and government must decide where and how to provide support.

Compensation has already been paid or mooted for coal-fired generators and gas networks. A value loss due to decarbonisation of itself, is not a policy rationale for compensation to owners. However, energy assets provide an essential service, and continued operation becomes uncommercial as revenues fall and costs rise. Closure dates meeting shareholder obligations may seriously impact users yet to transition.

Governments require certainty of closure dates to minimise public impacts, which can be achieved through multiple policy mechanisms.

Exit agreements can require energy providers to continue operating until new energy and system security resources are in place. Contracts should be paid on a zero-profit basis and should include a schedule for faster retirement of generating units than agreed, based on when suitable replacement capacity comes online.[1]

Mandatory notice periods for closure with upfront financing could be considered. Currently, owners of large power stations are required to give at least 3.5 years notice. However, financial penalties for the breach these rules are applied ex-post, where the entity may be insolvent. Requiring owners to provide an upfront bond is likely to decrease the risk of early closure.[1]

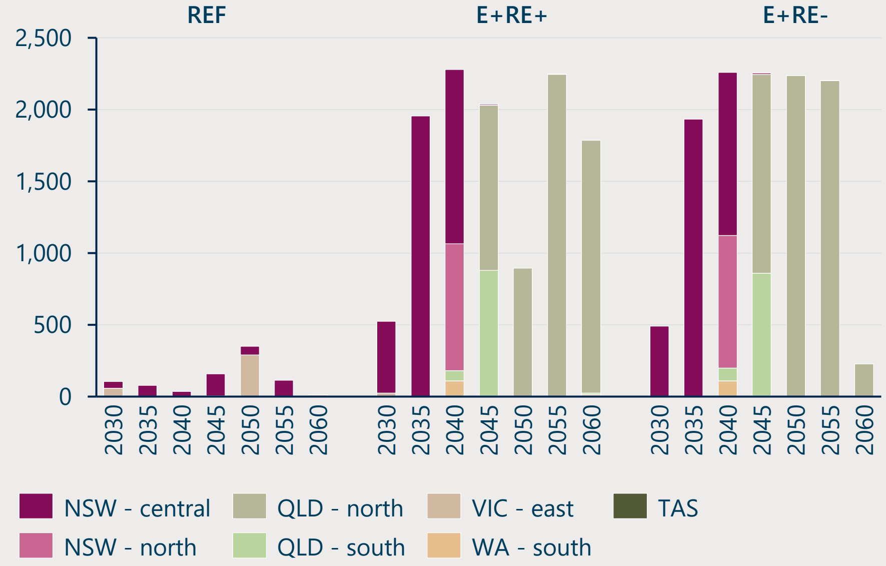
There will be many closures that need to be coordinated with user transitions and new supplies, so it is arguably imperative for a mechanism to be established to do this in a repeatable and orderly manner, at the least overall cost. Whether these costs should be borne by shareholders, taxpayers or consumers will be a political judgement for which there is not a clear policy answer.

WHAT MUST HAPPEN BY 2030?

Governments should establish a repeatable and effective policy and mechanism for orderly asset closures, initially for coal generators.

Many early retirements of black and brown coal mines will occur.

Capacity of early retirements for black and brown coal mines by region (PJ/y).



CASE STUDY – NEW ZEALAND

Raising existing price ceilings to account for accelerated depreciation

New Zealand implemented policy to balance price rises for gas users with the need for gas pipeline businesses to continue to invest appropriately to maintain safe and reliable supply. The New Zealand Commerce Commission determined the maximum prices gas pipeline businesses can charge end consumers by incorporating consideration for the accelerated depreciation of gas distribution assets. This will result in an average increase of household gas bills of about 3.8% per annum. This cost-sharing model can be applied in industries where prices are regulated by the government (e.g. Australia's gas pipelines).[2]

1. Institute for Energy Economics and Financial Analysis, There's a Better Way to Manage Coal Closures Than Paying to Delay Them, September 2021.
2. Commerce Commission New Zealand. Default price-quality paths for gas pipeline businesses from 1 October 2022. Final Reasons Paper. May 2022.

Support low-income households to decarbonise and incentivise landlords and strata management to act.

Significant upfront costs to decarbonise means low-income and vulnerable households are more likely to delay major replacements and retrofits.

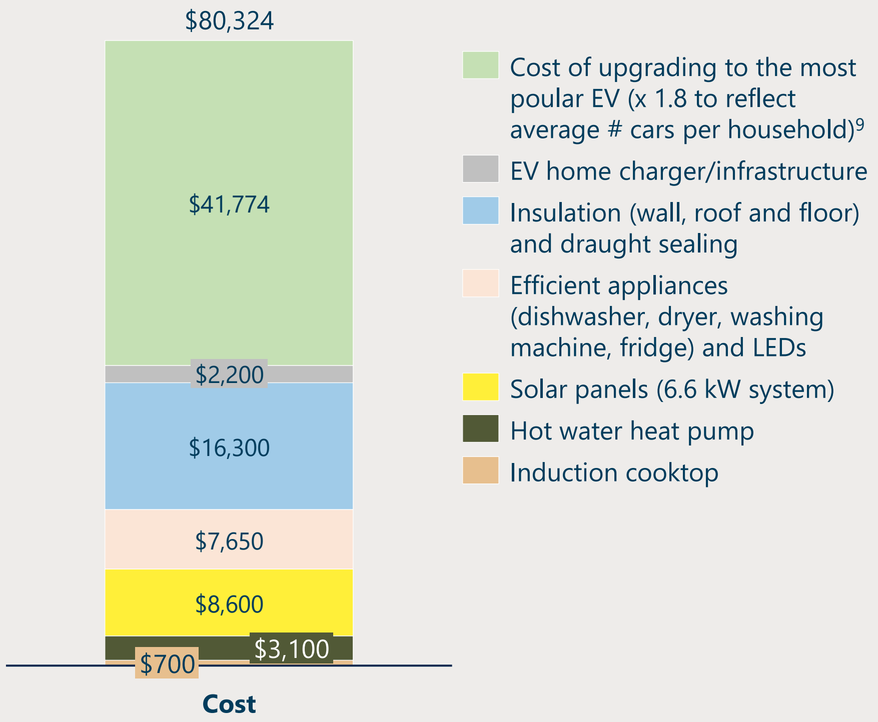
- Replacements and retrofits are significant capital investments for households (see right): approximately 70% of households have less than $36,000 in annual savings[1] and the average home loan is $585,000.[2]
- However, uncoordinated sequencing of household and system investment, also creates parallel risks of increasing portions of income spent on energy bills (higher gas network charges for remaining connected homes, or higher electricity network charges for non-electrified homes via any network augmentation required for electrification). In 2018, the average low-income household[3] spent four times their income on energy (6.4%), compared to the 1.5% spent by the highest 20% of households.[4] (The impact on energy bills in our Scenarios is difficult to calculate, and requires further work.)
- Without support, the transition may therefore compound existing wealth inequality and reduce public support for the transition from individuals and households which are hardest hit and/or most vulnerable.

Financial support for low-income households and incentives for landlords, are needed early to support the transition.

- Not all costs will be simultaneous, some could be recovered over time, not all purchases will be new (particularly cars), and progressive repayments or borrowing should be considered.
- For renters, much of the impetus is on landlords, who have less incentive to retrofit. Considerations should therefore be made to incentivise landlords. This could extend to homeowners with strata management (e.g. high-rise apartments, townhouses), who can face higher administrative burdens to change and may not have 'behind the meter' access to low-cost electricity.
- Energy companies and the government should consider a dynamic definition of 'vulnerable' consumers, for example, people with disabilities, low-paid work, large families, and the elderly, to ensure an equitable transition.[4] Engaging with low-income households could improve public support for the transition, and ensure policies are timely and targeted.

Today's upfront cost for an electrified household is significant.

Indicative costs ($) for solar panels,[6] Australia's best-selling EV relative to a top 10 selling conventional vehicle,[7] and other retrofitting and appliances.[8]



WHAT MUST HAPPEN BY 2030?

Governments should target low-income and vulnerable households to provide timely financial support and education for the transition.

Regulations and/or incentives should be designed to support the transition for those renting, or owners with strata management.

1. ABS, 2022, Australian National Accounts: Distribution of Household Income, Consumption and Wealth.
2. Average loan size for owner-occupier dwelling, see: ABS, 2023, Lending indicators, May 2023.
3. Quintile with lowest disposable income (<$415/week), see: ABS, 2022, Household Income and Wealth.
4. ACOSS, Brotherhood of St Laurence, ANU, 2018, Energy Stressed in Australia.
5. Toynbee Hall, Fair by Design, Ofgem, 2022, Net Zero Transition for Low-income Consumers.
6. Based on 2021 prices, see: CSIRO, 2021, GenCost 2020-21.
7. Base model car prices, see Drive, 2023, Australia's best-selling electric cars of 2022 and RACV, 2022, Australian new car sales 2022.
8. 2021 prices, see: Climate-KIC Australia et al., 2021, Pathways to scale: Retrofitting One Million+ homes.
9. ABS, 2022, Transport: Census.

Manage productivity limitations during the investment period.

Investing in the transition will have an impact on productivity.

- Governments are facing requests from Australians to meet many demands, including to build more affordable housing, decarbonise, reduce cost of living pressures, and improve health care.
- Australia's economy is at close to full capacity, labour force participation is at record levels, and there are skill shortages across many industries and regions.

Governments have to prioritise and sequence priorities – there are limits to what we can deliver as a nation at any point in time.

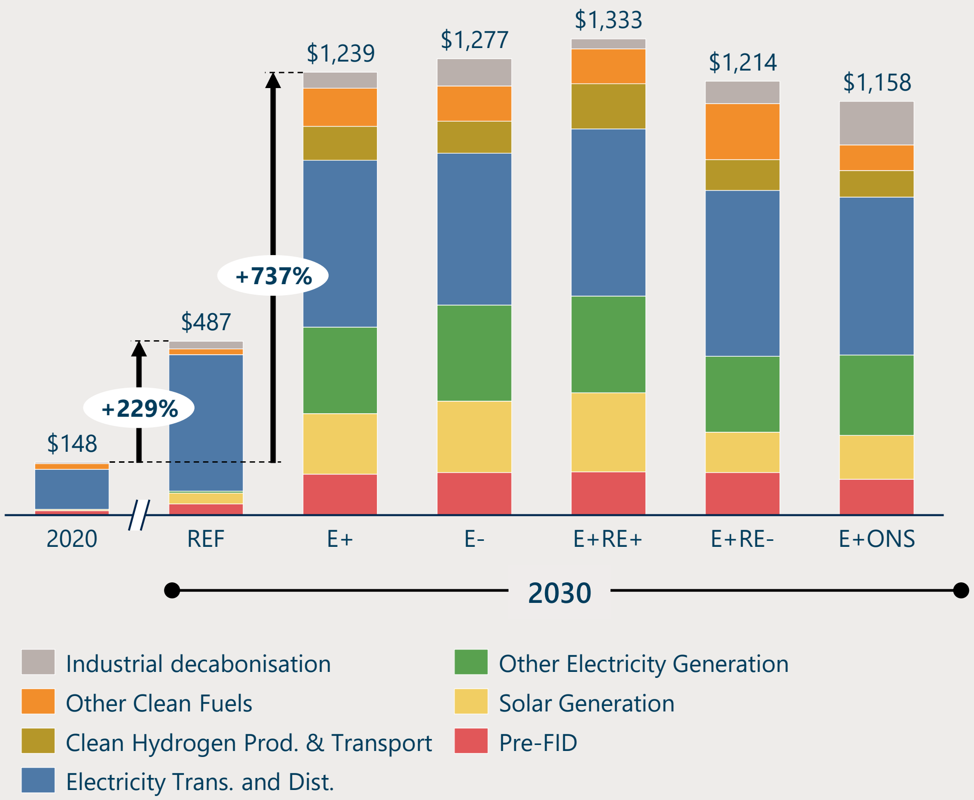
- For Australia to decarbonise as efficiently and effectively as possible, resources need to be allocated to where they provide the greatest value. This is likely to require a reassessment and rebalancing of national investment priorities.
- Costs of the transition, including replacing infrastructure to produce the similar standards of living, will slow productivity growth in the short term. Business and investors face uncertainty over the coming years, changing regulations, workforce shortages and uncertain supply chains create planning challenges.

Significant long run productivity opportunities are available.

- The transition will attract investment in new technology, which could improve productivity, open new industries and create new jobs and skills.
- Productivity is measured as the amount of Gross domestic product (GDP), a given amount of labour and capital can produce. GDP does not capture benefits associated with lower emissions, or improved health benefits. Adding the emissions reduction benefit of net zero to GDP would obtain a more accurate measure of outcomes delivered than traditional measures of GDP and productivity.

In reaching net zero, massive additional investment is needed by 2030 compared to the REF Scenario.

AUD billion of investment required to 2030, by Scenario.



WHAT MUST HAPPEN BY 2030?

Consider the allocation of national resources to infrastructure investments and the need to rebalance those priorities to invest in this transition.

7 – Roles and coordination

Section summary

TOPIC	STRATEGIC MESSAGE	PAGE
Roles & capital	Trust in government institutions and businesses involved in the transition is foundational to its success.	61
	Governments must stimulate and coordinate action largely achieved by private actors, and decide who pays, and how.	62
	Private sector investment risk will be too high in many cases, unless mitigated by government.	63
Carbon pricing	Multi-sector carbon pricing is desirable in theory but is neither necessary nor sufficient.	64
Labour & materials	Building net zero workforces and supply chains requires a certain, large and long pipeline of clean investments.	65
Commitment	Net zero must be a high national priority for decades, requiring sustained leadership and collaboration.	66

Trust in government institutions and businesses involved in the transition is essential to its success.

The leadership of public institutions and businesses is essential to decarbonisation.

Most investment to decarbonise will be made by businesses in Australia, and overseas – for example, in renewable energy, energy storage, transmission, electric vehicles, and revegetation.

The scale and impact of investment will require increased oversight and influence by public institutions on investment and planning decisions.

Citizens must trust these groups for an effective transition. They will need to realise the requirement for change, understand the role of relevant institutions and businesses, believe these groups have the capability, and trust them to act in the collective interest. Without trust as a foundation, social licence will not be achieved, projects will be delayed and disorganised, and the necessary coordination and collaboration will not occur.

Public trust is currently low.

Australia has seen multiple decades of 'climate wars'[1] and is divided over key decarbonisation topics (e.g. energy responsibilities, the use of gas), in the context of rising energy bills[2] and a changing climate. Public trust has lowered over time[3] and an increase in recent corruption scandals saw the establishment of the National Anti-Corruption Commission in July 2023.

As established previously, developers are increasingly facing social licence constraints, and previous research highlights public acceptance of the renewable transition, is lowest when people had low trust in the responsible parties.[4]

Trust must be built as the transition proceeds.

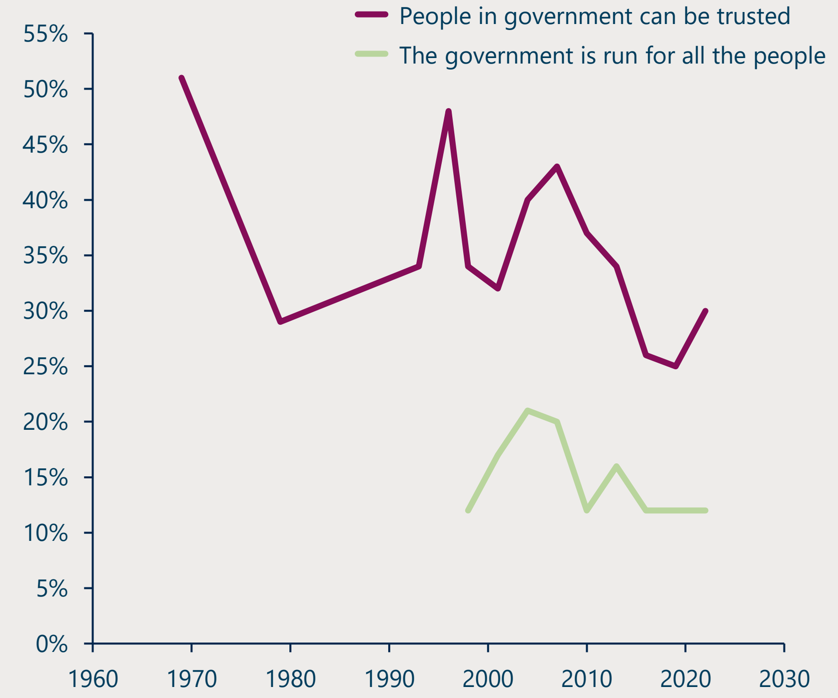
Trust is crucial to the success of a complex and costly task, and will have to be built as decarbonisation occurs. It is essential for the coordination, collaboration and social licence which is needed between institutions, industry and the public.

Building trust will require:

- **Widespread public engagement** to improve understanding of the transition's possible pathways, uncertainties, benefits and costs, and what is required to make it happen.
- **More capable and better-resourced public institutions** in recognition of the size of the task, and the skill that is required to lead and coordinate it.
- Improving **governance, transparency** and **accountability** of institutions. Companies leading the transition must publicly track and communicate their progress.

Trust in Australian democracy and institutions has declined over time.

Trends from the Australian Election Study 1987– 2022.[3]



WHAT MUST HAPPEN BY 2030?

Develop trust by implementing large-scale education campaigns and engagement, improving the capability and capacity of public institutions, and improving governance, transparency, and accountability.

1. Crowley, K., 2021, Climate wars, carbon taxes and toppled leaders: the 30-year history of Australia's climate response, in brief, The Conversation.
2. Australian Financial Review, 2023, Power bills to jump as much as 25pc (again).
3. Cameron, S., McAllister, I., 2022, Trends in Australian Political Opinion: Results from the Australian Election Study 1987– 2022.
4. Liu, L et al., 2019, Effects of trust and public participation on acceptability of renewable energy projects in the Netherlands and China

Governments must stimulate and coordinate action largely achieved by private actors, and decide who pays and how.

STIMULATING VOLUNTARY ACTION

Most investment to decarbonise energy supply, energy use, and agriculture will be made by **businesses** in Australia, and overseas. **Households** will invest substantially in the use of clean energy and production, and storage.

Some decarbonisation may be voluntary because it is cheaper than continuing to emit, or to 'do the right thing': in effect, to pay a private carbon price. There is some evidence that this is happening. Electric vehicle purchases are occurring despite being more expensive than petrol cars, though at a low level. Commercial and industrial users are voluntarily buying renewable power to meet corporate ESG goals, in some cases at a net cost. It is possible that the willingness to pay extra will grow as prices fall and/or public support for decarbonisation grows.

However, the **willingness to voluntarily pay for decarbonisation is too low** to reach the required scale and pace[1] – so government will need to accelerate action by business and households. Possible methods include providing **information**, **mandating** clean technologies, paying **subsidies** to make clean alternatives attractive, **carbon prices** to make emissions more expensive, expediting decarbonisation project **approvals** by identifying preferred **development zones** and improving processes, and mitigating or offsetting adverse **social and environmental impacts** (also using public funds and regulation).

FUNDING THE TRANSITION

The transition is modelled to require between $7 and $9 trillion of capital commitments by 2060. Most of those funds will come from business, and some from households.

Exports will be paid for mostly by overseas customers. Governments will need to make a large, minority contribution to domestic transition costs – to make decarbonisation commercially viable for investors and affordable for consumers.

Governments' contributions are ultimately paid for by **taxpayers,** which would be socio-economically progressive but mutes price signals, which may discourage some efficient investments and behaviour change. Governments can also **allocate costs** to **consumers** (e.g. through mandatory purchasing of clean goods) and **business** (e.g. through regulation of emissions). Imposts on business will be passed on in some proportion to shareholders and customers - a **user-pays** model is more economically efficient and more regressive.

Inevitably a blend of these approaches will be used, based on policy advice and political judgement. This project has not sought to identify an optimal mix.

COORDINATING ACTION

Government action is also needed to coordinate decarbonisation measures by different parties, to resolve many chicken-and-egg problems. For example, prospective investors in wind and solar farms may need the shared transmission network to be extended, to transport their output to load centres. However, transmission developers are reluctant to progress upgrades, unless they are confident that renewable generation will be developed to use the new capacity.

Supply and demand measures will need to be coordinated and optimised. Underwriting supply has limited or no value if demand is not stimulated. This is especially complex for supply and network investments which are predicated on a rapid growth in demand, whether from electrification or conversion to clean hydrogen. In that case, investment in all three sequential segments of the supply chain need to be coordinated and de-risked for their concurrent development to proceed. It is a core role for government to unlock this investment.

ESTABLISHING MECHANISMS TO ACHIEVE TARGETS

The transition is too large, complex and commercially risky for broad-based targets (emissions and renewables) to work on their own. Interim targets which are market-tested and adaptive will be needed, whether or not a national carbon price is implemented (which is explored below).

Mechanisms to achieve targets are essential to make full use of market initiative. Statutory schemes to drive and coordinate private sector investment, by establishing a predictable pipeline of investment support and developing common use infrastructure (e.g. energy networks and ports), are effective ways to deploy commercially mature technologies, at scale and least cost.

WHAT MUST HAPPEN BY 2030?

- Stimulate business and household voluntary action with information, incentives, and regulation.
- Etablish stakeholder tested mechanisms to achieve net zero and interim targets, including statutory schemes

1. International Energy Agency, 2021, Do we need to change our behaviour to reach net zero by 2050?

Private sector investment risk will be too high in many cases, unless mitigated by government.

A precondition for mobilising finance, is to improve understanding of the decarbonisation task, to inform corporate and government plans and targets. However, while necessary, these will not be sufficient.

DE-RISKING NET ZERO INVESTMENTS

Decarbonisation finance faces **high commercial risks** due to the uncertainties that arise from large numbers of sequential, concurrent and interdependent investments and closures that will occur in compressed time frames.

Capital returns are subject to **much more uncertainty** than energy investments have faced since the electricity sector moved to its current, disaggregated, marketised, and mostly privatised form. The high capital intensity of renewable sources adds to this risk.

A lack of development capital has been identified as a major constraint on project development globally. Financing of project construction is also inhibited by the high cost of technologies in the early stages of mass deployment.

The commercial risk of decarbonisation is likely to remain high, as the transition accelerates, and may increase.[1] There will be a need for **even greater government support to de-risk net zero investments**.

This support should have the benefit of lowering the investors' required cost of capital. However, it accentuates the risk that governments will support uneconomic projects. Rigorous assessment of projects, and the use of market mechanisms, where feasible, will limit this risk.

There are at least two investment hurdles that need to be lowered: development funds and capital for construction. Both can be unlocked by long pipelines of investment opportunity, and some level of subsidy, or long-term underwriting of offtake revenues.

WHAT MUST HAPPEN BY 2030?

- De-risk net zero investments, including through rigorous assessment of projects, use of market mechanisms, and planning and coordination.

IMPLEMENTING MECHANISMS

To de-risk investments, Governments have responded with a range of interventions in Australia and overseas,[2] including:

A. Subsidising, or underwriting the **development costs** of decarbonisation projects, that are exposed to competition

B. Subsidising the extra costs of **commercialising immature technologies**, including through certificate schemes, contracts for difference, or grants.

C. Underwriting long-run capital returns for **capital-intensive projects** using contracts for difference or similar instruments**.**

D. Run **tenders for support**, including the measures summarised in A-C.

E. Stimulating **demand** for clean energy to support investments in supply, through mandates or subsidies.

F. Supporting **coordinated investment** across supply chains, particularly in energy supplies and transmission networks.

G. Establishing **legislated schemes** which increase the certainty and transparency of a long-term and large pipeline of supported investments.

Government funding can have a catalytic effect in unlocking far larger amounts of private capital, and the foundation to do this needs to be established in the 2020's. Governments will need to spend billions to unlock trillions. Regulatory action and reform (e.g. faster approvals), can also have a vital catalytic effect. Competition from other sectors, and countries, will need to be considered in working out how to attract the required volume of capital.

A careful balance is needed. With too little support, finance may be constrained or attracted to more generous support schemes in other jurisdictions, and progress to net zero will be impeded. With too much support, consumers and taxpayers may pay more than necessary to secure investment.

1. International Monetary Fund, 2023, Transboundary Climate-related Risks: Analysing the Impacts of a Decarbonisation of the Global Economy on International Trade, Finance, and Money.
2. United Nations, 2022, NDC Synthesis Report.

Multi-sector carbon pricing is desirable in theory but is neither necessary nor sufficient.

Broad-based carbon pricing is desirable in theory. Equally pricing carbon aims to shift production and consumption away from carbon-intensive goods and services, theoretically achieving decarbonisation.[1] A carbon price can be narrowly or broadly-based, and can take the form of an explicit price or a regulatory obligation (e.g. not to exceed an emissions-intensity cap, or buy emission permits).

All current broad-based carbon prices are complemented by targeted decarbonisation measures such as regulations, subsidies and certification schemes.[2] Analysis of carbon prices supports a general conclusion that they can achieve significant decarbonisation, do not incur substantial costs, and can gain social acceptance.[3,4] However, some analysts conclude that carbon prices are better suited to incremental decarbonisation, not reaching net zero emissions.[5]

A broad-based carbon price is not necessary to achieve decarbonisation, nor is it sufficient without targeted incentives. Further, carbon prices can temporarily expose an emitter to risks it cannot manage (e.g. the need for shared transmission network upgrades to support its renewable power purchases, or common-use pipeline investments and injection approvals to enable CCUS). An emitter in this situation may be forced to purchase offsets, or pay a shortfall penalty which diminishes the funds available for abatement. This would prompt requests for relief from carbon price obligations.

Instead, end-to-end solutions are needed. A mobilisation framework must 'choose' the most efficient transition pathways and end state, and reveal current and forecast decarbonisation costs to inform those choices. A broad-based carbon price would do this in theory, but its practical limitations, and the need for more direct drivers, makes it not recommended as a priority.

CASE STUDY | Delays to the renewable rollout decreases the effectiveness of broad-based carbon pricing for heavy industry.

Mechanisms can have inadvertent impacts on 'hard to abate' industries such as aluminium, especially in the short term. Electricity accounts for ~70% of total aluminium production emissions, meaning producers are constrained by renewable deployment to decarbonise. Greener technology (e.g. inert anodes) is in development, but faster progress is needed. In the short term, this could lead to:

- Producers being exposed to risks they could be unable to manage (e.g. the need for shared transmission network upgrades to support renewable purchases), which could then force purchasing offsets and diminish abatement funds.
- Greenwashing due to difficulties with compliance.
- Producers moving out of Australia.

If carbon pricing is implemented, targeted enablers are essential to ensure overall decarbonisation.

1. Roser, M., 2021, The Argument for a Carbon Price.
2. World Bank, 2023, Carbon Pricing Dashboard.
3. Roth, J., Laan, T., 2020, Green Recovery Know-How from the Nordics.
4. Jonsson, S., Ydstedt, A., Asen, E., 2020, Looking Back on 30 years of Carbon Taxes.
5. Proceedings of the National Academy of Sciences, 2023, Why carbon pricing is not sufficient.

Building net zero workforces and supply chains requires a certain, large and long pipeline of clean investments.

Major growth of the skilled workforce and supply chains will be needed to build clean infrastructure, against global competition for skilled people and specialised equipment.

SUPPLYING JOBS

A large shift in career choices and education is needed to **engineering and technical trades**, which experience in previous investment booms suggests will have to be supplemented by **skilled immigration**.

Large population increases will occur in renewable energy zones. Under our E+ Scenario, the population of northern Australia might increase by millions.[1] An increase of this size will only be achieved with a major investment in services and infrastructure, and encouraging workers to move to areas which are generally dry, hot, and prone to extreme weather events, will require high wages and other incentives.

Much of the population would have to be housed on the Indigenous Estate, which would require negotiation and agreement to prevent the marginalisation of First Nations communities in social and economic terms.

If **export jobs are distributed more evenly** across the country, the population growth challenges might be reduced, but would still be significant, requiring planning, negotiation and investment.

Attracting local jobs in clean technology is possible in the processing of Australia's natural resources for domestic and export use. Our major opportunities come in advanced manufacturing (where labour ratios are low), or in large-component manufacturing (where shipping costs are high). However, Australia does not have a large enough population or market to support a large manufacturing sector – we will likely remain a global resource exporter, and technology importer.

If local manufacturing is pursued, its success will require a major, coordinated investment of both government and private sector. Business will need government price support or grants to invest into markets which are not initially competitive with imports.

SECURING SUPPLY CHAINS

The rapid expansion of **supply chains** for clean energy infrastructure, will require an ambitious collaboration of the public, and private sectors to do the required planning, attract and supply investment, seek and provide approvals, and train and recruit workforces. Supply chain investment will be made most attractive to investors and industry, if they are confident that the **pipeline of opportunities** is long and large.

Our hypothesis is that investment will be most attractive if governments' contribution is provided by **statutory bodies, legislated processes**, and **contracts for support** that are least vulnerable to political shifts. This approach will also make investment in **local manufacturing** more attractive.

Competition for equipment and skilled workers will increase **pressure on costs and wages**. Maintaining a **healthy export sector** will support our exchange rate, our living standards, and the affordability of skilled immigrants, and imported equipment. The **transition from fossil fuels to clean exports** needs to be managed as a risk to our domestic, economic, as well as our international relations.

WHAT MUST HAPPEN BY 2030?

- Establish mechanisms to secure supply chain investment that leverage our comparative advantages and maximise our benefits.

1. Net Zero Australia, 2023, Downscaling – Employment impacts.

Net zero must be a high national priority for decades, requiring sustained leadership and collaboration.

The net zero transition will be among the **largest and fastest economic transformations** in history. It will require concerted action by all actors and progress must be maintained for decades.

This will require **sustained commitment by the public, business, and government,** which in turn, will require **close engagement** and extraordinary cooperation to build support, coordinate investment, and mitigate adverse impacts. Engagement will need to encompass our trading partners given that our exports will undergo a major transformation.

Our **political and business leaders** will need to place the transition among their highest priorities. For three decades, economic policy has been based on the principle that private sector **competition** and a minimal role for government are preconditions for prosperity.[1] Because the **role, capability and capacity of governments** has been designed for a modest pace of structural economic change, and not the scale and pace of decarbonisation, it will need to be greatly strengthened.

We are in a period of **polarisation** of political and public discourse. Competition will remain important in the transition to net zero. Business competition will lower costs and increase innovation. Political competition can improve policy, and reverse bad decisions. However, **collaboration is needed** so that momentum on a highly complex task is maintained.

This is likely to require a far more **bipartisanship** approach than now occurs. It will require partnerships and alliances across communities, workforces, business, and government, including to develop clean energy zones and close emitting plants.

That collaboration will need to extend overseas. It will not be possible to decarbonise unless countries that are now forming trading blocs, work closely with each other. Australia cannot become a self-contained economy when our resources are vital to others, and their manufactures and skills are crucial to our transition.

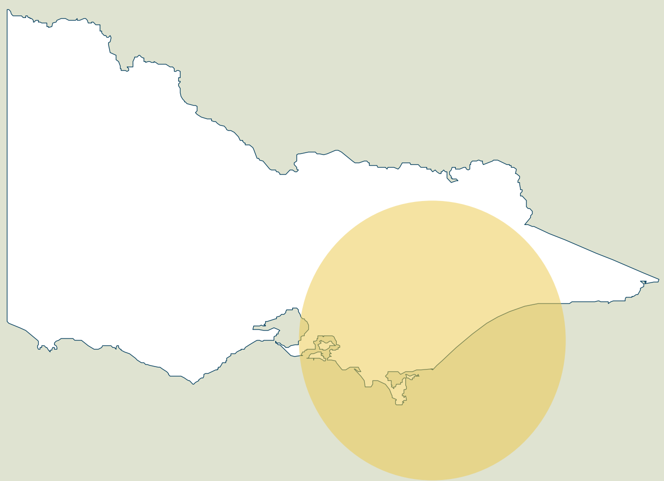
Our **progress must be comprehensively tracked** and made transparent**.** Achieving net zero will be a long, unclear path. We must be able to adapt and reset directions when assumptions change, which requires a detailed understanding of our progress, and the relative impact of individual policies and actions. Our modelling identifies many relevant indicators of progress, which would need to assembled and analysed regularly.

A sustained, large government **budget commitment** will be needed. Decarbonisation is a public good. It will only occur with strong institutions that are well-resourced with the capacity and capability to coordinate action, drive collaboration, and catalyse investment.

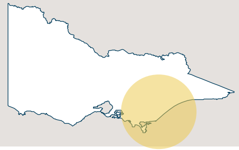
WHAT MUST HAPPEN BY 2030?
• Strengthen the role, capability, and capacity of governments to coordinate action and drive collaboration.
• Regularly and comprehensively track progress towards net zero.

1. Australian Government Treasury, 2018, Australia's Experience with Economic Reform.
2. Colvin, R., Jotzo, F., 2021, Australian voters' attitudes to climate action and their social-political determinants.

REGIONAL ILLUSTRATION
GIPPSLAND



Gippsland is leading national efforts to develop an offshore wind sector and faces significant change



REGION OVERVIEW

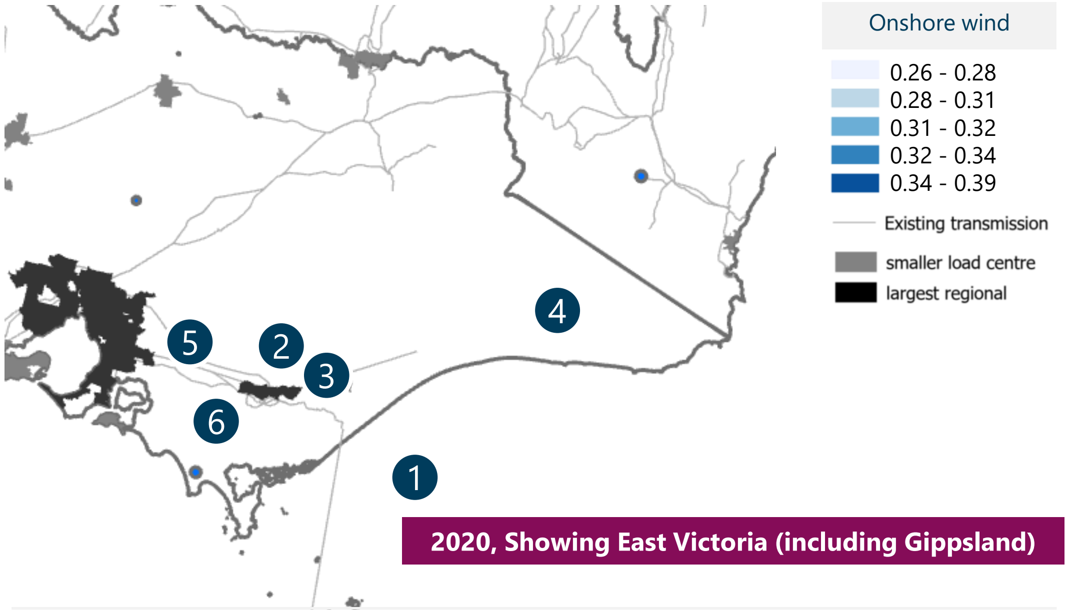
- Population 300,850,[1] predicted to grow 15.5% by 2036
- 110,944 jobs[2] with 54% in the labour force[1] in 2021
- Significant environmental and tourism value – its catchments provide 60% of Melbourne's water, and 67% of land is forests, national parks and/or reserves
- Declared as Australia's first offshore wind region in late 2022, with development applications in progress

Top industries by employment and gross value add (GVA) (2020)[3]

Top employers	Workers	Top GVA	$
Healthcare	17,100	Mining	4.3b
Retail/tourism	11,800	Construction	1.4b
Construction	11,400	Healthcare	1.2b
Ag., forestry & fisheries	10,300	Ag., forestry & fisheries	1.0b
Education	10,200	Energy, water & waste	978m
Manufacturing	8,900	Manufacturing	870m

1. Australian Bureau of Statistics, 2021, Latrobe – Gippsland SA4 Census QuickStats.
2. Regional Development Victoria, 2022, Regional Snapshot: Gippsland.
3. Department of Jobs, Precincts and Regions, 2022, Gippsland Regional Economic Development Strategy – Summary.
4. A ratio of 2 indirect job for every direct job was derived from Department of Industry, Innovation, Science, Research and Tertiary Education, 2013, Lessons learnt from large firm closures.

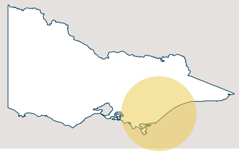
CURRENT REGIONAL SNAPSHOT



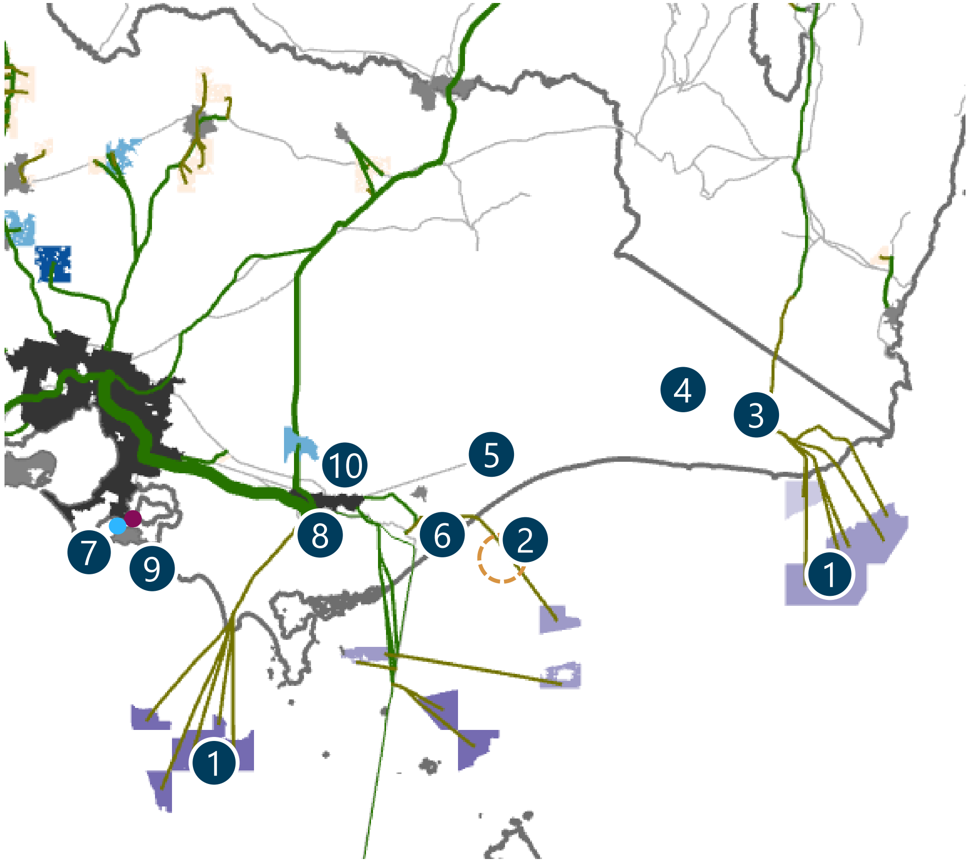
2020, Showing East Victoria (including Gippsland)

1	Offshore wind	First Australian **offshore wind region** approved in 2022, supported by two main ports – Barry Beach and Port Welshpool.
2	Coal phase-out	Three major coal fired power stations in the Latrobe Valley (4.73 GW), powered by two mines containing **nearly 90% of Australia's brown coal** reserves, likely to be **phased out by mid-2030s.**
3	Mining workforce	**1,310 workers** are directly employed in the mining sector,[1] with an estimated **2,600** related jobs.[4]
4	Land use	Key land use industries include **farming and forestry** – 64% of Gippsland is covered by trees, and 24% by rainfed cropland and pastureland, contributing to industrial agriculture processes.
5	Transmission	Existing **transmission** can be repurposed, adding to the strong connections with Melbourne and Tasmania.
6	Education	Multiple educational institutions – 13 TAFE campuses and Federation University – to **support skills growth** for net zero industries.

Gippsland could be a major provider of wind energy, ammonia, CCUS and bioenergy



2050 REGIONAL SNAPSHOT (E+ Scenario)



VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.16 - 0.22	0.26 - 0.28	0.36 - 0.48
0.22 - 0.25	0.28 - 0.31	0.48 - 0.56
0.25 - 0.27	0.31 - 0.32	0.56 - 0.62
0.27 - 0.28	0.32 - 0.34	0.62 - 0.69
0.28 - 0.29	0.34 - 0.39	0.69 - 0.76

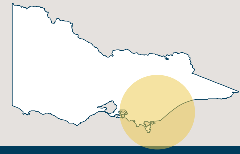
Facilities and assets

New	Existing
Haber Bosch plant (ammonia)	H2 production nodes
Desalination	Existing transmission
Carbon storage facility	smaller load centre
	largest regional

New electricity TX (GW)

1	**Offshore wind**	**100 TWh** will be generated with offshore wind off Gippsland's coast by 2050 (E+ Scenario) – **under RE-, triple that** production (300 TWh) is modelled.
2	**CCUS**	Facilities will include one **DAC site**, one **carbon storage site**, and **major new CO_2 transmission pipelines**: 50 Mtpa in the E+ Scenario, or 250 Mtpa in the RE- Scenario.
3	**Bioenergy**	Using native and plantation forestry residue, **10+ new biogasification sites** with carbon capture will produce 140 PJ/year and require $10B in capital investment (E+).
4	**Afforestation**	Between **114,000 and 144,000 hectares of new afforestation needed** by replacing rainfed pastures – currently used for agriculture – with closed trees by 2050.
5	**Transmission**	**12 GW of new electricity transmission capacity** will be needed to connect Gippsland to broader Australia, predominantly supplying western Victoria and NSW. Peak electricity load will **nearly triple**.
6	**Hydrogen storage**	E+ Scenario requires underground hydrogen storage capable of storing **15,000 tonnes** (0.5 TWh), or **10x this amount under the RE-** Scenario (5 TWh).
7	**Ammonia**	Ammonia production will occur at Port Hastings, but **36x more will be produced under the RE- Scenario** (220 TWh) compared to E+ (6 TWh) by 2050.
8	**Gas**	In Victoria, **57%** of new gas capacity (up to 2060) can be constructed on **brownfield coal power stations**.
9	**Desalination**	The increase in water demand can be met through new **desalination plants**
10	**Workforce**	Significant increase in the **skilled energy workforce** is needed for new clean industries.

Major prioritisation and coordination decisions are needed to rapidly upscale new industries



	Change	Key message
Industry	↓↓ ↑↑	Major change as coal power stations close, however hydrogen and CCUS industries will emerge.
Populations	—	Gippsland will remain a regional centre of Victoria, with a similar population level.
Jobs	↓ ↑	Anchor jobs in coal power stations will be lost and only some will be able to reskill into offshore wind, CCUS and manufacturing.
Regional investment	↓ ↑↑	Significant investment in new energy infrastructure is expected (electricity transmission, CO2 and hydrogen pipelines).
Land and environment	↑	Portions of Gippsland land use will be repurposed to host new energy infrastructure.

MULTIPLE INDUSTRIES EMERGE AS COAL DECLINES

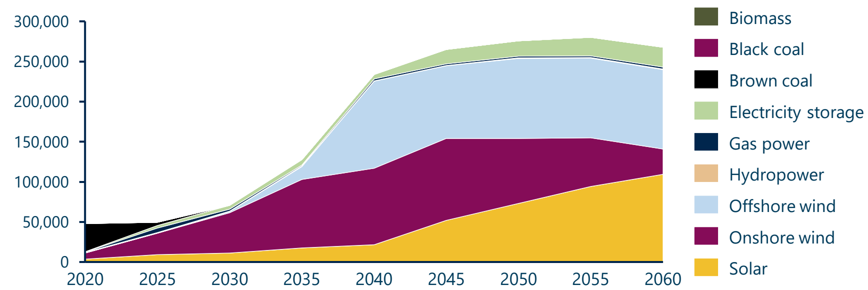
- **New offshore wind, hydrogen, bioenergy and CCUS industries will change workforce composition.** Gippsland's $4b coal industry will decline rapidly in the next decade, but multiple new industries will emerge simultaneously. Appropriate planning, skills development and investment can bring major benefits and growth to the region, though not all coal workers will be able to get jobs in new industries.
- **Major investment is needed to scale up and transform infrastructure.** Gippsland's multiple mine closures will need rehabilitation and undergo capital loss, while some brownfield sites will be transitioned to renewable power sources or gas-powered stations. New industries identified will need major investment, and though the modelling looks at the most cost-effective inputs, there are multiple investment options to consider.
- **Communities across Gippsland will require tailored support.** The Latrobe Valley must manage a major transition away from coal. The Hazelwood closures resulted in significant job losses with few opportunities for re-employment of similar value, and this needs to be mitigated for future closures. Predicted new offshore wind and transmission regions such as Mallacoota will undergo significant expansion and require new social infrastructure and educational facilities. Opportunities are available for workforce mobility and retraining within the region.
- **Achieving social licence will be essential for select new, and transitory, Gippsland industries (e.g. CCS, blue hydrogen, coal use).** Gippsland's coal resources and proximity to CCUS facilities may mean the use of coal is more efficient in some industries as renewables scales up. Using coal combined with CCUS to produce blue hydrogen, ammonia and/or urea could provide valuable employment opportunities as the region transitions, reduce Australia's reliance on imported fertilisers, and help existing industries transition to the net-zero goal. However, capturing these benefits will necessarily require active community engagement, support and social licence.

COMPETITION FOR INFRASTRUCTURE AND LAND WILL ACCELERATE

- **Forests will see competing demand for industry, carbon sequestration, and biomass production.** Gippsland's forestry industry faces competing challenges, as it must expand into current agricultural rainfed pastures to sequester large amounts of carbon. The forestry industry will also need to provide ~50 PJ of biomass per year for bioenergy production. While making feedstocks available, the industry must also reduce its own emissions and meet demand for existing paper and pulp industries.
- **Transmission corridors will expand and carry multiple resources.** New transmission pipelines and easements will be needed for gas, water, hydrogen and CO_2, alongside the upscaling electricity transmission and port infrastructure. These pipelines may face competitions if industries expand at the same time, and new corridors will need to be identified, changing land uses.

Victoria's energy generation will rapidly scale up offshore wind, largely off the coast of Gippsland

Victorian installed energy generation, E+ Scenario, GWh



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