Final modelling results

April 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

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FUTURE ENERGY EXPORTS Cooperative Research Centre

FUTURE FUELS CRC

MINDEROO FOUNDATION

Worley energy | chemicals | resources

Gift and grant agreements protect the project's independence

ADVISORY GROUP

Crucial input is being provided by diverse advisers

AUSTRALIAN CONSERVATION FOUNDATION

ENERGY CONSUMERS AUSTRALIA

CLIMATE COUNCIL

National Farmers Federation

THE ETHICS CENTRE

St Vincent de Paul Society NATIONAL COUNCIL of AUSTRALIA Inc. good works

National Native Title Council

INDEPENDENT MEMBERS

SPONSOR NOMINEES

ENGAGEMENT

Numerous briefings have been provided to:

COMMONWEALTH MINISTERS AND DEPARTMENTS

STATE MINISTERS AND DEPARTMENTS

NON-GOVERNMENT ORGANISATIONS

RESEARCH BODIES

A website has also been established 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.

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About the study

What *does* this study do?

This study **illustrates pathways to net zero**, that reflect the boundaries of the Australian debate.

Our purpose is to help individuals, communities, companies and governments appreciate:

- the **scale, complexity and cost** of the net zero task,
- different ways in which **the future could unfold**,
- **how we all might contribute** to the required changes, and
- how **unintended consequences** might be avoided and **negative impacts** reduced.

What *doesn't* this study do?

This study **does not make predictions**. What will actually happen over the coming decades may be within the boundaries of our Scenarios. However it will not be the same as any one of them.

We do not know if any one Scenario is more or less achievable than the others, and our study **does not recommend one pathway over any other**. The synchronisation of actions by many governments, businesses, communities and households, that would be required to achieve net zero by any pathway, will be explored in the mobilisation workstream.

Our study also **does not consider fossil fuel supply constraints** such as those that have driven recent rises in coal and LNG prices, and which would likely narrow the cost gap between the Reference Scenario and net zero Scenarios.

Our study **does not model the costs of inaction** on climate change, which would add substantially to the costs of the reference case.

We do not model **demand for clean energy exports**, which is uncertain.

2. Our modelling approach

About the modelling: approach and scenarios

Modelling approach

We are modelling a straight line reduction from 2020 to net zero in 2050 for Australia's **domestic emissions**.

We are modelling a straight-line reduction from 2030 to net zero in 2060 of **offshore emissions from fossil fuel exports**. The target date reflects commitments by major trading partners.

We have also modelled **faster decarbonisation** – net zero in 2040 for domestic emissions, and 2050 for exports.

We project **energy demand** (e.g. for lighting, cooling, mobility, and industrial production) using assumptions of economic and population growth, and energy saving.

We use projections of **future technology costs** that are drawn from the most authoritative, independent sources and tested with experts, though the inherent uncertainty of cost projections means they are only indicative.

The model **optimises** for the lowest-cost mixes of energy resources and energy uses to meet the net zero target, subject to constraints imposed in each Scenario.

We have used 'downscaling' to model **changes in land and sea use** at a fine resolution.

We have run **sensitivities** to understand how the results change when different assumptions are varied (listed on the next slide).

Our public **MASS pack** (see website) details our methodology, assumptions, scenarios and sensitivities for our regional investment modelling. The complete methodology for our downscaling is published in companion downscaling reports.

Design of Scenarios

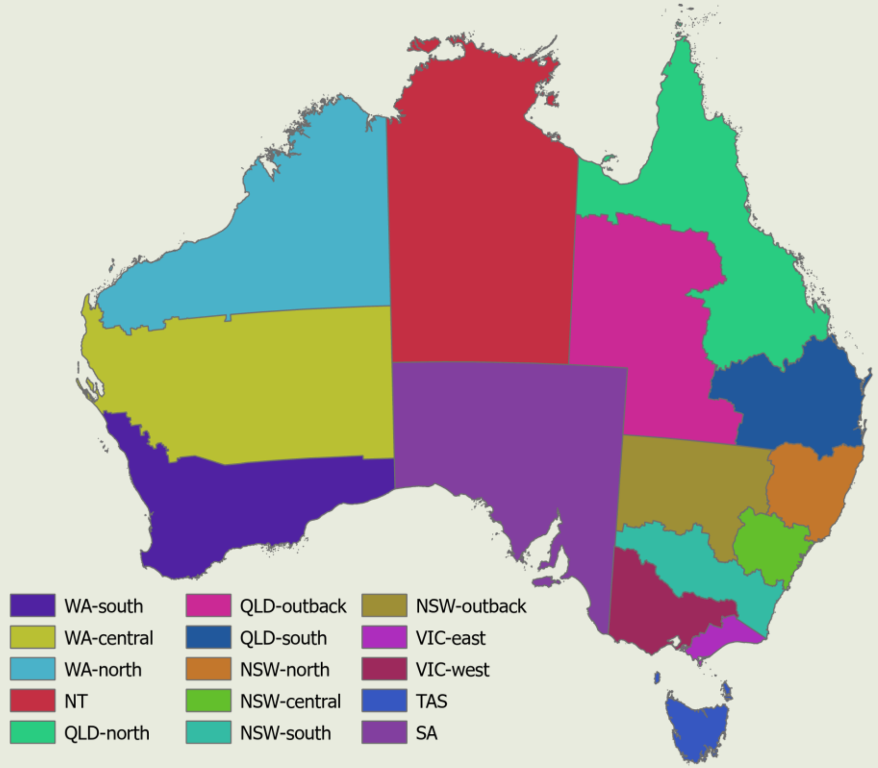
We have chosen Scenarios that reflect the **boundaries of the Australian debate** on how to achieve net zero emissions.

- Most Scenarios place rarely constrain the **renewable rollout rate**. One scenario (E+RE−) tests what happens if we do hit a limit, which could result from numerous factors including supply chain constraints, opposition to land use change, and skills shortages.
- One Scenario (E+RE+) allows **only renewables** for new build energy production. The **others allow the option of fossil fuels** with carbon capture, utilisation and storage (CCUS) together with renewables.
- We have set different limits on the rate at which carbon dioxide can be injected into **geological storage**. These limits are based on the advice of specialists and enable net zero emissions in all Scenarios.
- Opportunities for **domestic electrification** are assumed to be fully realised by 2050 in most Scenarios (E+). One Scenario imposes a **slower rate of electrification** (E−).
- We have assumed a much higher rate of **energy productivity improvement** than historical rates, and these arise from both electrification and energy efficiency.
- We have excluded **nuclear** from the core scenarios but have run a sensitivity in which nuclear power competes in the energy mix.

Energy supply and demand is modelled over 16 regions

Energy flows between regions, and necessary transmission, are incorporated into the model.

15 DOMESTIC REGIONS



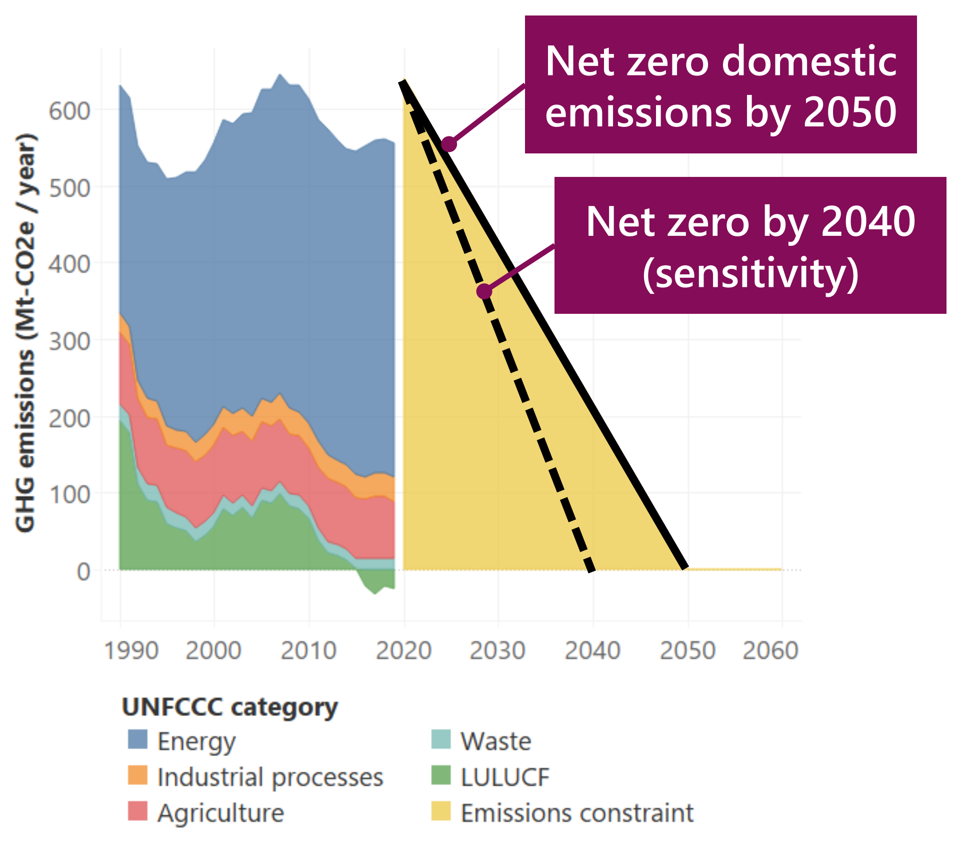
1 EXPORT REGION

Note: To see the full set of assumptions, and associated discussion and explanation, refer to the NZAu Methods, Assumptions, Scenarios and Sensitivities document.

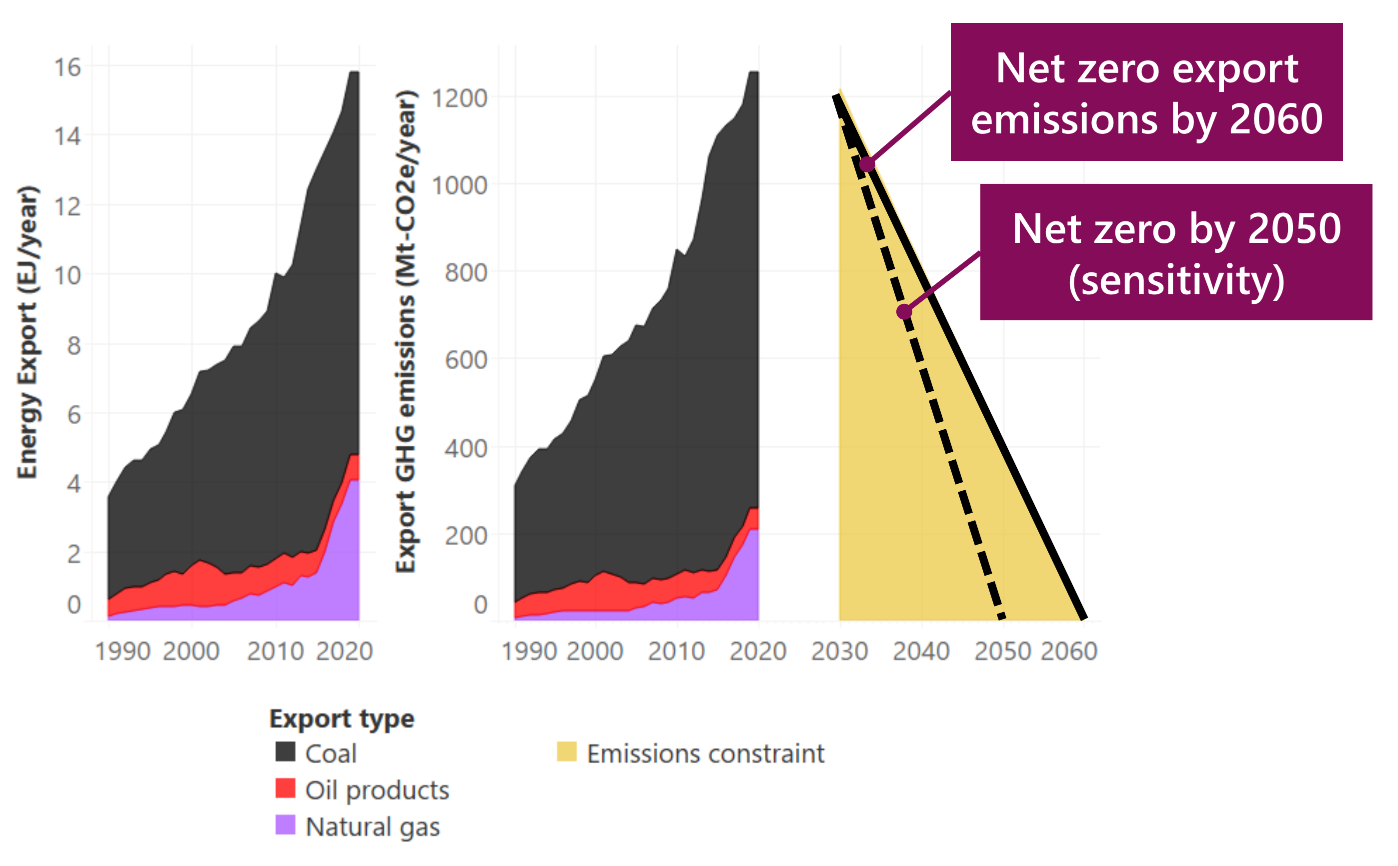
NZAu imposes straight-line emissions trajectories for domestic and exports

We model pathways for 1.8 Gt-CO_2e/year GHG emissions abatement, while providing 15EJ of clean energy to the world.

Domestic emissions



Fossil fuel energy export emissions



Notes:

- Conservative assumptions in modelling of agriculture, LULUCF and waste sector emissions mean that the 2020 domestic emissions constraint is required to be higher than actual Australian domestic emissions in 2020.
- Initial export emissions constraint based on 2020 fossil exports, using Australian inventory emissions factors.
- 34% of total GHG emissions from domestic sources, 66% from export – ~1.8Gt-CO_2e/year emissions abatement modelled.
- Net zero domestic emissions by 2040 (export by 2050) also modelled as a sensitivity (dotted lines).

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.

Key assumptions underlie the modelling across scenarios

Growth assumptions underlie forecasted energy demand:

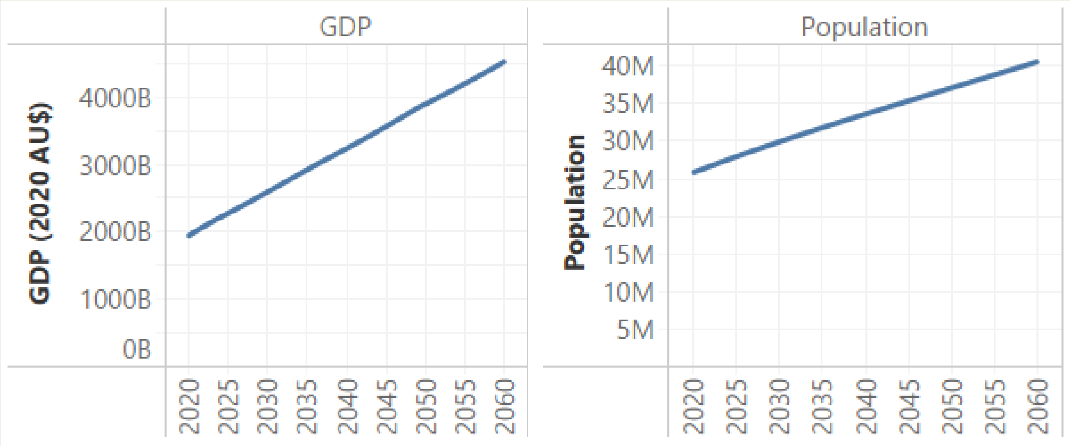
- GDP: 2.1% per year on average from 2020
- Population: 1.2% per year on average from 2020
- Climate scenario modelled using an IPCC Representative Concentration Pathway (RCP 8.5)

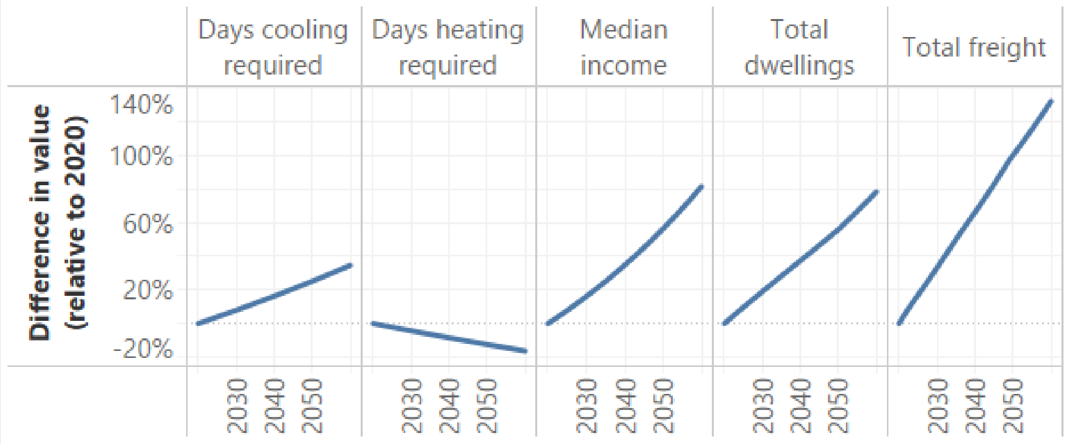
Capacity constraints are assumed, including:

- Geologic storage of CO_2 capped at 150 Mt-CO_2 p.a. (in all scenarios except for E+RE−, which caps it at 1.2 Gt-CO_2 p.a.)
- Biomass supply capped at ~1,100 PJ p.a.

Our assumptions are:

- Drawn from the most authoritative and traceable references
- Grounded in what is currently occurring





Note: To see the full set of assumptions, and associated discussion and explanation, refer to the NZAu Methods, Assumptions, Scenarios and Sensitivities document.

Detailed overview of the NZAu's modelling approach

NZAu MODELLING FRAMEWORK

DEMAND-SIDE TRANSITION

EnergyPATHWAYS Tool from Evolved Energy Research (EER)

- **Bottom-up, stock accounting** model that projects demand for energy services and the evolution of end-use technologies to meet that demand.

Energy vector demand profiles

Their evolution over time

SUPPLY-SIDE OPTIMISATION

Regional Investment and Operations (RIO) Tool from EER

- Spatially- and temporally-resolved, **energy system optimisation** of energy technology portfolios and operation.
- Supplies electricity, fuel blends and carbon storage at **lowest system cost** while respecting scenario constraints (e.g. net zero).
- Runs **every five years** with perfect foresight **from 2020 to 2060**, with **1h time resolution** and **60 representative days**.

Asset capacity and schedule by region

SECTORAL DEEP DIVES AT HIGHER GRANULARITY

As-needed 'Downscaling' of aggregated RIO results

- **Validation** and visualisation of results from RIO through **spatially explicit analysis**
- Downscaling covers **land and sea use**, **labour**, **water** use, **capital flows** and other **sectoral deep dives**.

Some iteration required for internal consistency

Outputs

Sited assets that meet regional capacity

Note: To see the full set of assumptions, and associated discussion and explanation, refer to the NZAu Methods, Assumptions, Scenarios and Sensitivities document.

3. Key insights

Key insights from Net Zero Australia modelling

	WHAT IT WOULD TAKE TO REACH NET ZERO	WHAT AUSTRALIA MUST DO
1	Grow **renewables** as our main domestic and export energy source	**Deliver an energy transformation** unprecedented in scale and pace
2	Establish a large fleet of **batteries**, **pumped hydro** and **gas-fired firming**	
3	Greatly increase **electrification** and **energy efficiency**	
4	Develop a large **carbon capture, utilisation and storage** industry	
5	Greatly expand our **energy transmission and distribution networks**	
6	Attract and invest $7-9 trillion of **capital** to 2060	
7	No role for **nuclear** unless costs fall sharply and renewables are constrained	
8	Transition to **clean energy** and **clean minerals exports**	**Transform our exports** an essential contribution to global decarbonisation
9	**Locate** these **new export industries** in the north; possibly also in the south	
10	Expand a **skilled workforce** from about 100,000 today to 7-800,000 by 2060	**Invest in our people and land** to reduce impacts and share benefits
11	Move the **land sector** towards net zero and potentially to net negative	
12	Carefully manage major **land use changes**, including the Indigenous Estate, ecosystems and agriculture	

For a summary of the key insights of the study, please refer to our 'final results summary pack' (presented at the public launch event)

netzeroaustralia.net.au/final-modelling-results

4. Final modelling results

Structure of the final modelling results

The following results are the technical and quantitative findings of the modelling to date.

Results are structured around:

- **Six pillars of decarbonisation**
- **Other general insights**
- **Downscaling**
- **Sensitivities.**

For detailed background information, see the Methods, Assumptions, Scenarios and Sensitives document on the NZAu website.

4.1 STUDY OVERVIEW

Overall energy, emissions, and exports

4.2 SIX PILLARS OF DECARBONISATION

1. End use energy efficiency, electrification
2. Clean electricity (wind and solar generation, transmission, firm power)
3. Zero-carbon fuels and feedstocks (including bioenergy)
4. CO_2 capture, transport, utilisation and storage
5. Non-CO_2 emissions
6. Enhanced land sinks

4.3 GENERAL INSIGHTS

- Systems capital and costs
- Employment
- Water
- Fossil fuel industries

4.4 DOWNSCALING

- Solar, wind & electricity transmission siting
- Implications of solar, wind & electricity transmission siting
- Bioenergy, CO_2, and H_2 infrastructure

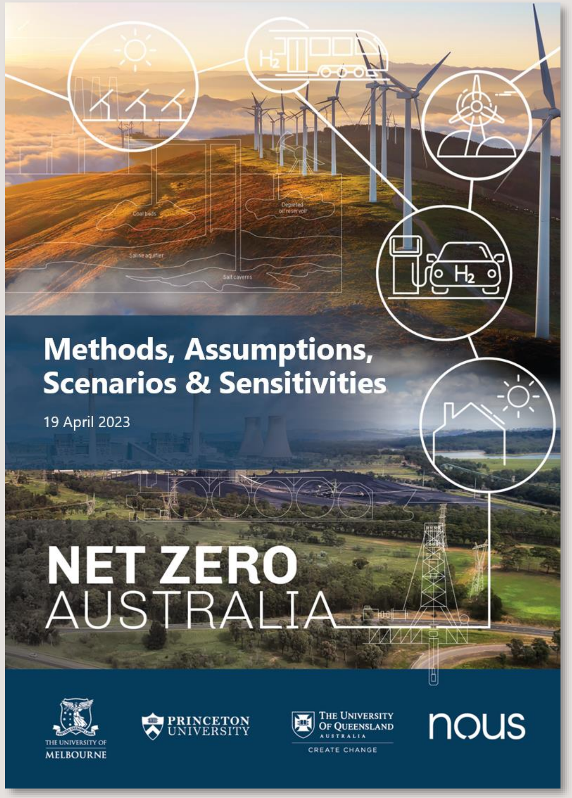
4.5 SENSITIVITIES

- What is required for faster emissions reduction?
- Could nuclear energy play a role?
- Is interstate transmission critical?
- What if the land CO_2 sink expands?
- What if projected solar PV cost reductions are not realised?
- Might energy exports be more evenly distributed around the nation?
- What is the impact of altering geological sequestration potential?

The final summary report and 17 detailed downscaling reports available on our website

SUMMARY REPORT

DETAILED ASSUMPTIONS (~200pg)



DOWNSCALING REPORTS (17 reports)

netzeroaustralia.net.au

FINAL MODELLING RESULTS

4.1 Study overview: Overall energy, emissions, and exports

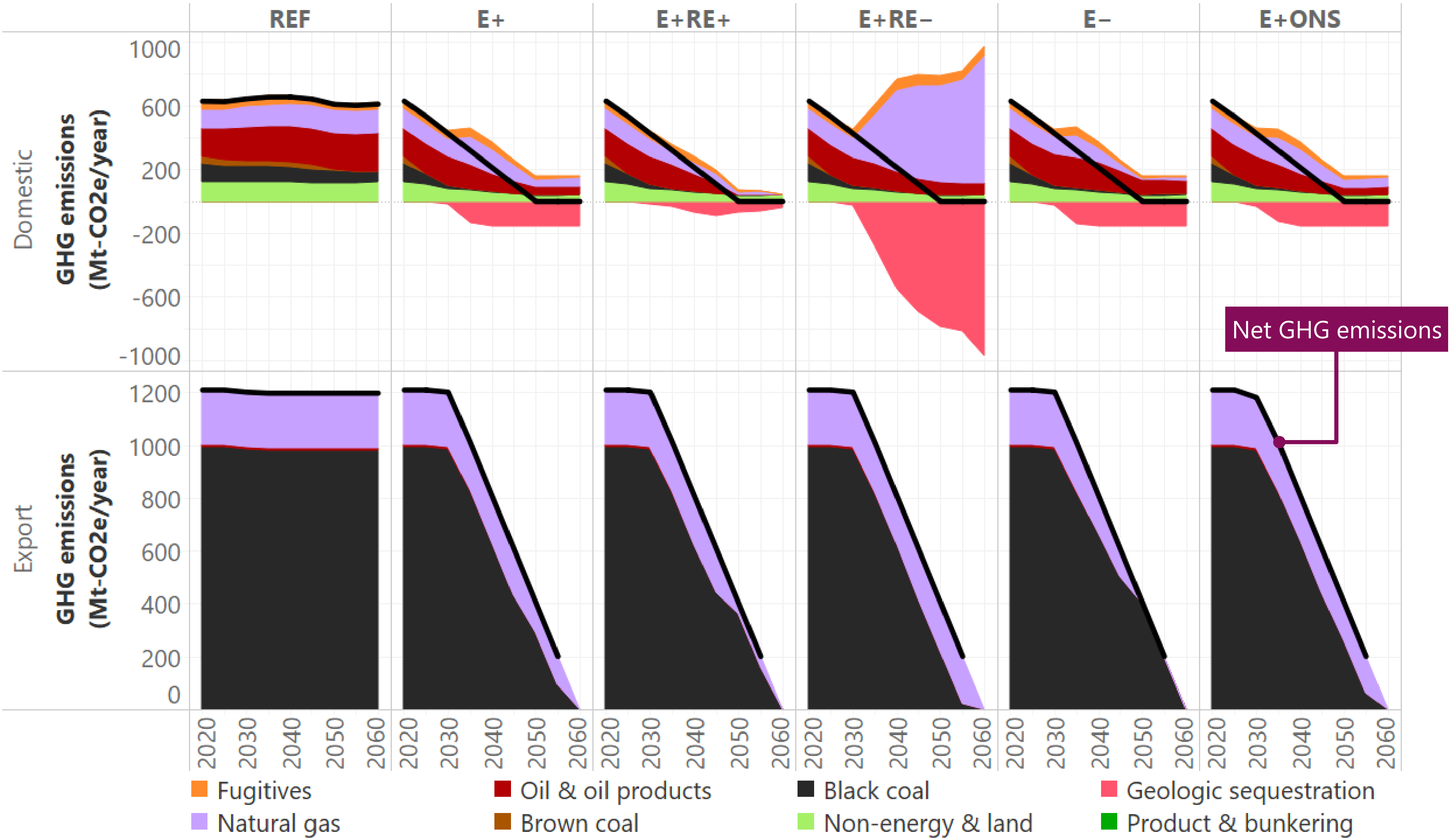
Study overview: **Overall energy, emissions, and exports**

KEY FINDINGS

Net zero pathways for Australia, and for Australian energy exports, are available	• Domestic emissions target is net zero by 2050; export emissions target is net zero by 2060 • Wind and solar dominate primary energy supply • Fossil energy exports are replaced by low-emissions energy carriers • Most clean energy exports are from Western Australia, Queensland and Northern Territory

Domestic emissions target is net zero by 2050; export emissions target is net zero by 2060

Projected domestic and export emissions (Mt-CO_2e/year). Note varying y-axis scales.

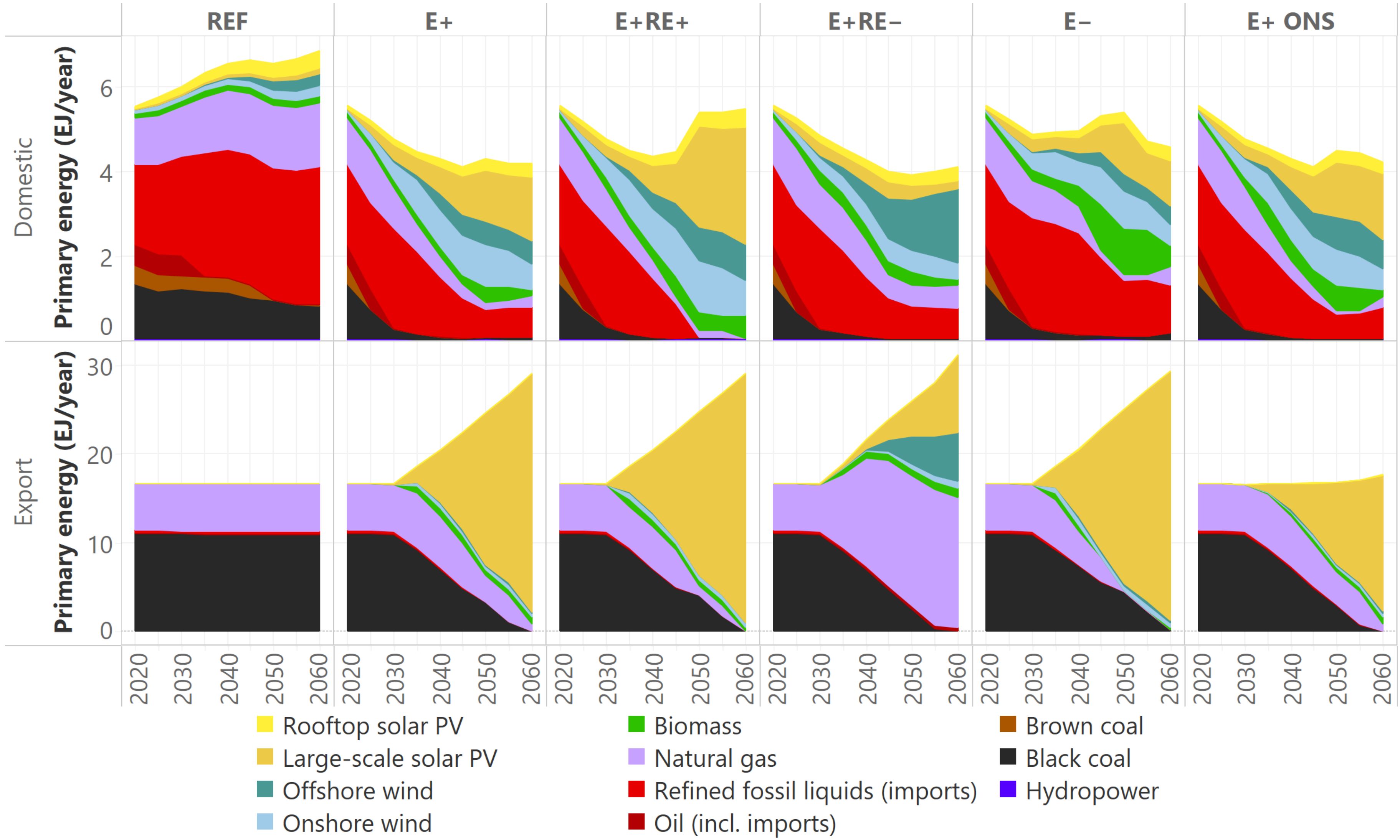


KEY TAKEAWAYS

- Domestic coal emissions decline most rapidly, followed by oil and gas.
- Geological sequestration does not increase from 2040 in both E+ and E− (low end of the CCUS range).
- Export decarbonisation abates 2× the annual emissions of the domestic system.

Wind and solar dominate primary energy supply

Projected primary energy (EJ/year). Note varying y-axis scales.



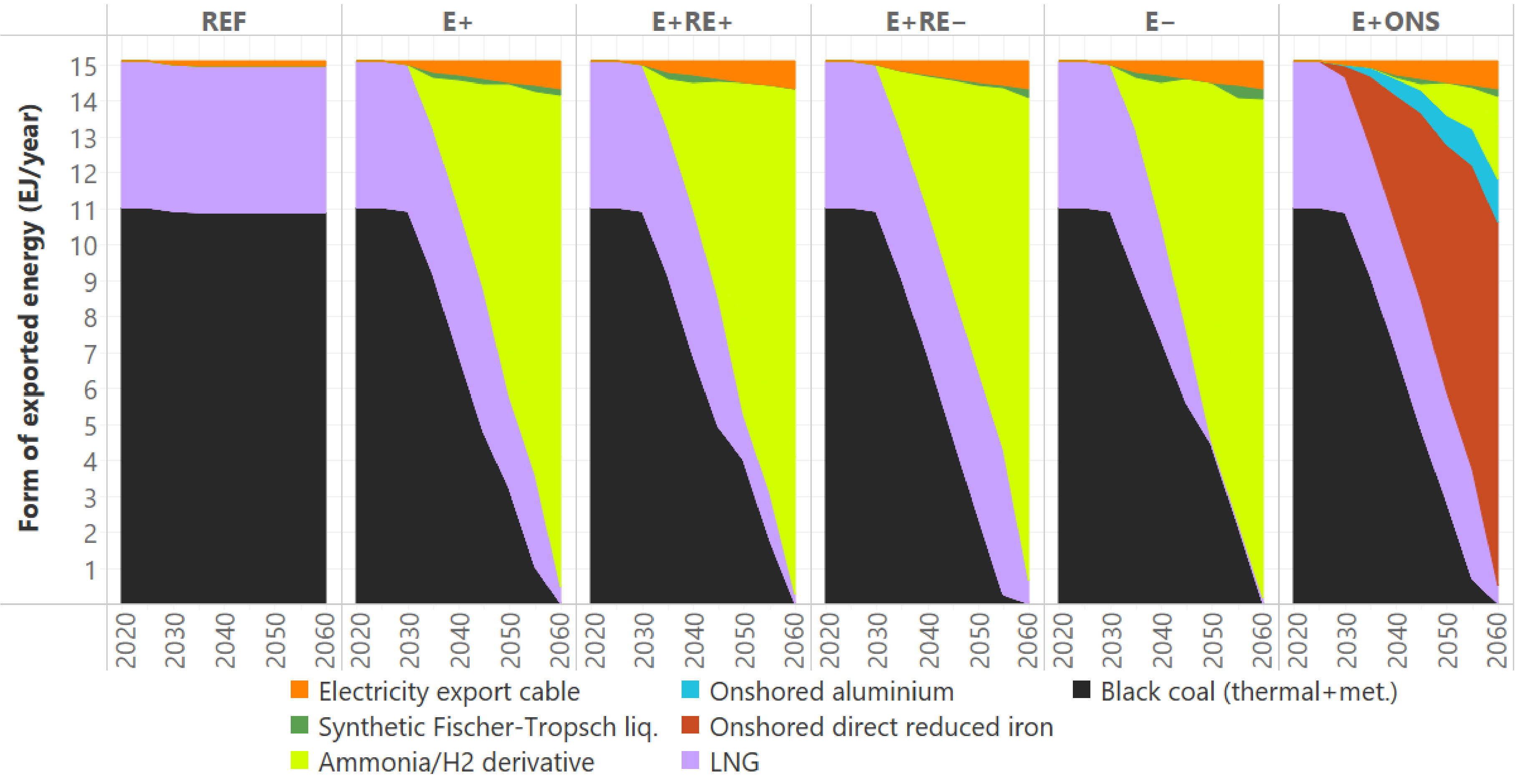
KEY TAKEAWAYS

- Primary energy supply for exports is much higher than domestic supply, noting that final export demand is held constant.
- Renewable electricity leads energy supply except in E+RE−, where natural gas dominates exports due to constraints on renewable deployment and changes to maximum CCUS rate.
- Total domestic primary energy supply is lower than REF in all Scenarios, due to productivity gains from end-use electrification and efficiency improvements.
- Large rise in primary energy for exports (except for onshoring in E+ONS) is due to losses from converting renewable power to low-emission carriers and fuels.
- Offshore wind competes domestically on cost in all Scenarios and is significant in E+RE− exports.

Fossil energy exports are replaced by low-emissions energy carriers

OVERALL ENERGY, EMISSIONS, AND EXPORTS

Projected form of exported energy (EJ/year)



KEY TAKEAWAYS

- Ammonia/Hydrogen derivative dominates energy exports except in E+ONS, where onshored processing of Australian iron and alumina ores (E+ONS) displaces the majority of current energy exports.
- Coal and LNG exports drop rapidly from 2030.
- Undersea electricity cable link to Singapore is a modest share of export energy. (NZAu modelling was conducted prior to recent developments in AUS>SGN energy projects)

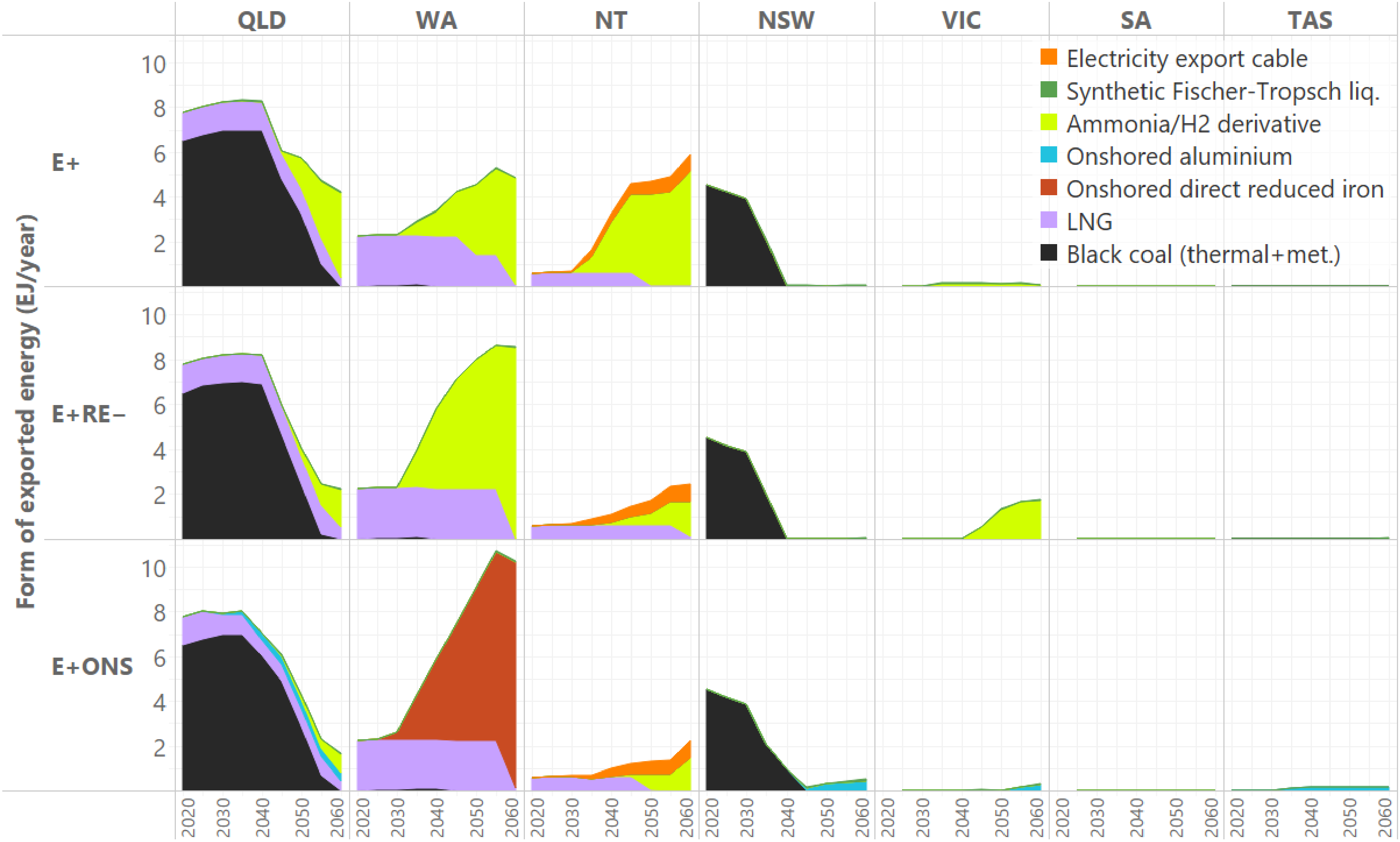
Modelling note

- **Energy export demand is held constant at 15 EJ/year** – about 3× 2050 domestic demand.

Most clean energy exports are from Western Australia, Queensland and Northern Territory

OVERALL ENERGY, EMISSIONS, AND EXPORTS

Projected form of exported energy, by state of export (EJ/year)



KEY TAKEAWAYS

- Queensland and New South Wales no longer export coal.
- Hydrogen derivative exports (ammonia assumed here) originate from the states with the best solar resources.
- In E+RE−, Victoria also exports clean energy, driven by offshore wind.
- In E+ONS, onshored iron is exported from Western Australia, while onshored aluminium is exported from Queensland, New South Wales, Victoria and Tasmania.

FINAL MODELLING RESULTS

4.2 Six pillars of decarbonisation

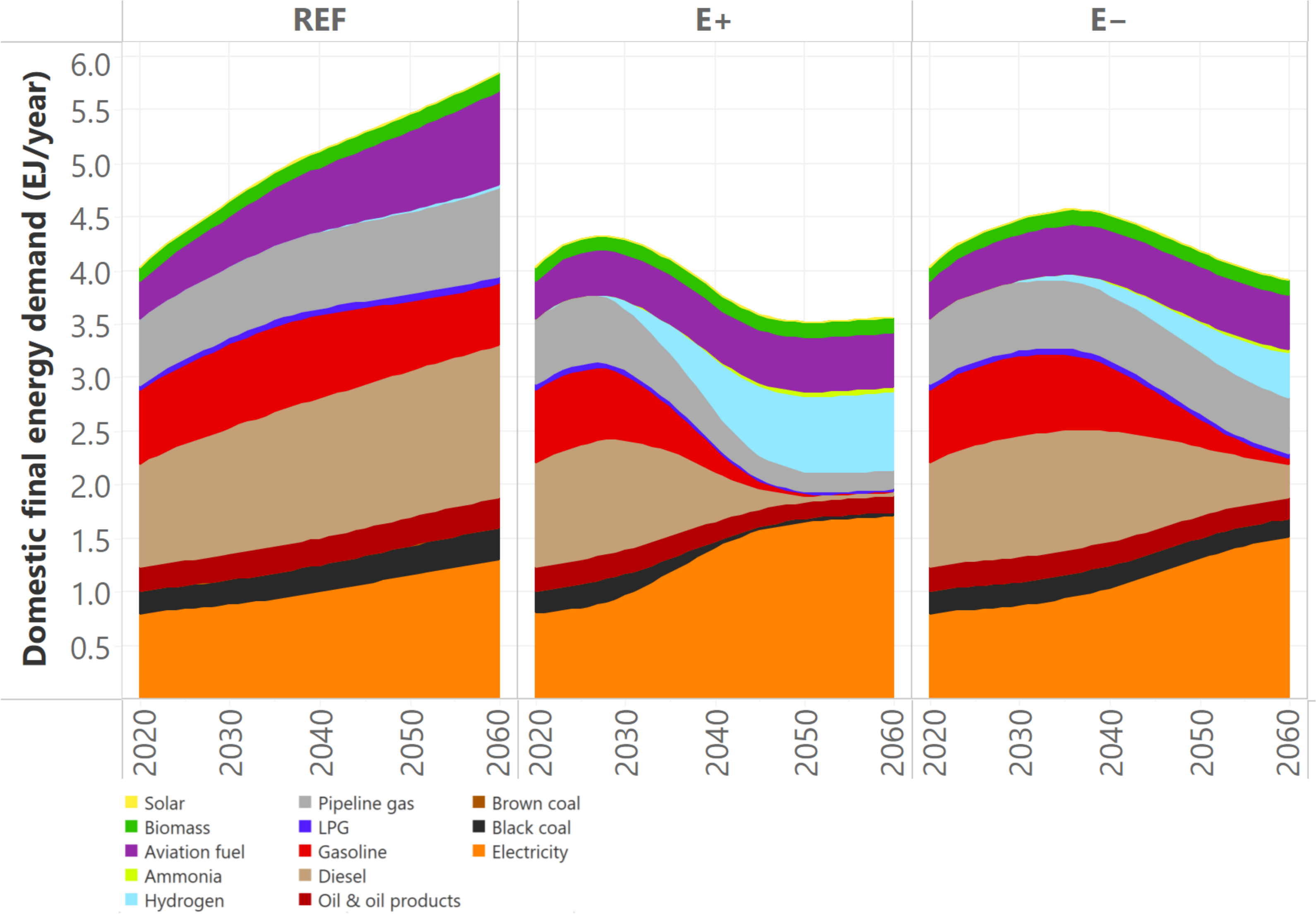
PILLAR 1: **End use energy efficiency and electrification**

KEY FINDINGS

Energy productivity will keep Australia's domestic energy demand in 2060 at – or below – 2020 levels	• Domestic energy productivity improves from efficiency and fuel switching • Electrification drives significant energy productivity gains in all sectors – except aviation • All domestic sectors electrify, with largest electricity demand growth in transport • Uptake of light-duty EVs in 2020-30s enables saturation of zero-emissions fleet by 2050-60s • 86% of light-duty battery EVs are located in major cities and inner regional Australia • Over 2 million public EV chargers are needed to support zero-emissions vehicles in 2050

Domestic energy productivity improves from efficiency improvement and fuel switching

Domestic final energy demand (EJ/year).



KEY TAKEAWAYS

- Domestic energy demand drops significantly compared to REF.
- Energy efficiency improvements drive ~40% of productivity gains, averaging ~0.5% p.a. for REF and ~1% p.a. for other scenarios.
- End-use electrification drives ~60% of productivity gains.
- Residual demand for fossil fuels in E− requires decarbonisation before final consumption.
- Domestic energy demand in 2050 is ~1/3 of export energy demand (which is held constant at 15 EJ/year).

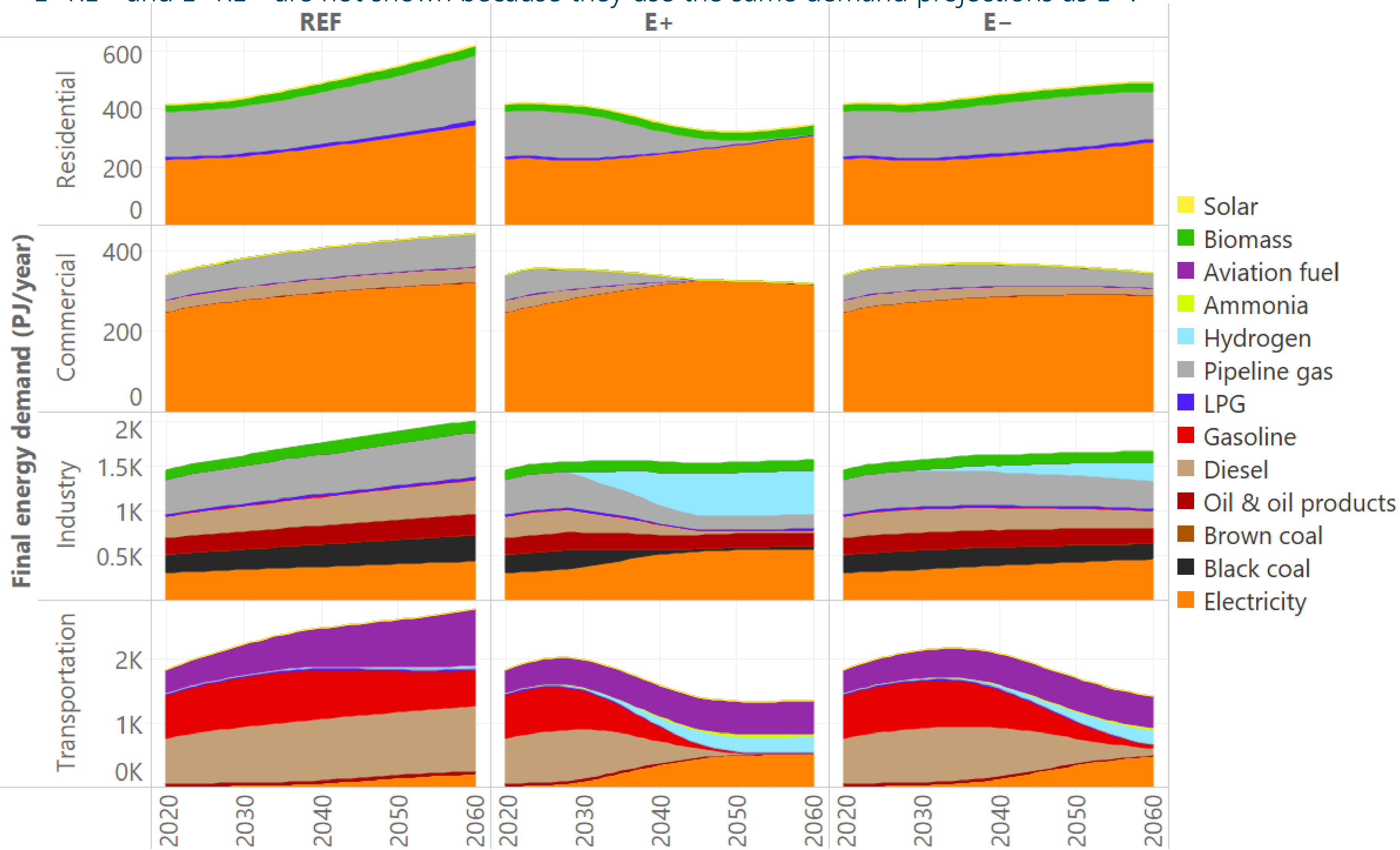
Modelling note

- Domestic demand is driven by population, GDP, technology efficiency and fuel switching.

Electrification drives significant energy productivity gains in all sectors – except aviation

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

E+RE+ and E+RE− are not shown because they use the same demand projections as E+.



KEY TAKEAWAYS

- **Residential and commercial sectors** are nearly fully electrified by 2050 in E+. E− retains similar volumes of pipeline gas (methane) which is decarbonised by producing bio-synthetic natural gas and through carbon sequestration
- **Industry** energy demand electrifies and switches to hydrogen, where possible. Residual demand for liquid and gaseous fuels requires production of low-emissions fuels (made from wind, solar, biomass and fossil fuels with CCUS), or offsetting.
- **Transport** undergoes extensive electrification, but fuels will still need to supply demand in aviation, shipping and some land transport.

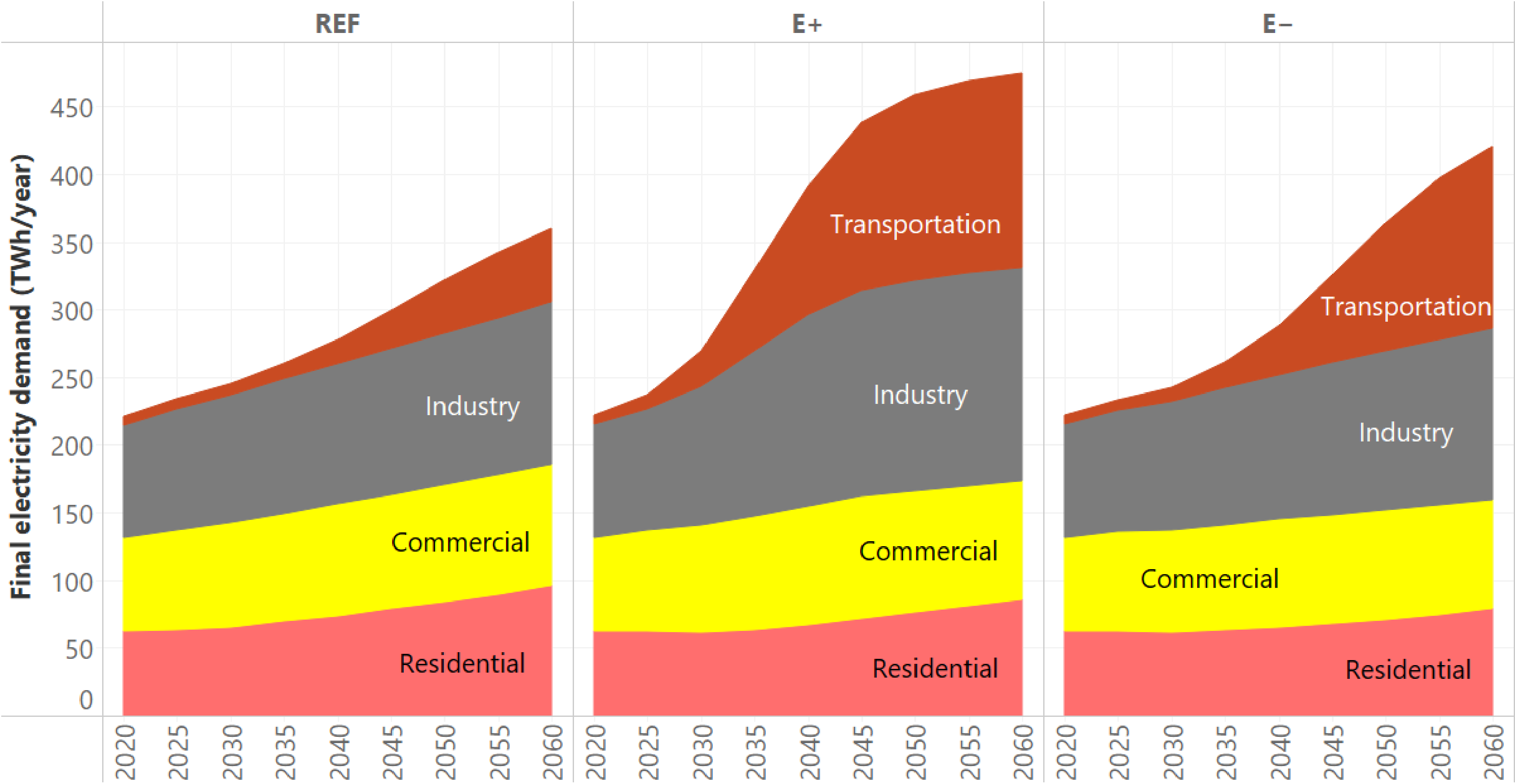
All domestic sectors electrify, with largest electricity demand growth in transport

PILLARS

1 2 3 4 5 6

End use energy efficiency and electrification

Projected growth in domestic final electricity demand, by sector (TWh/year)

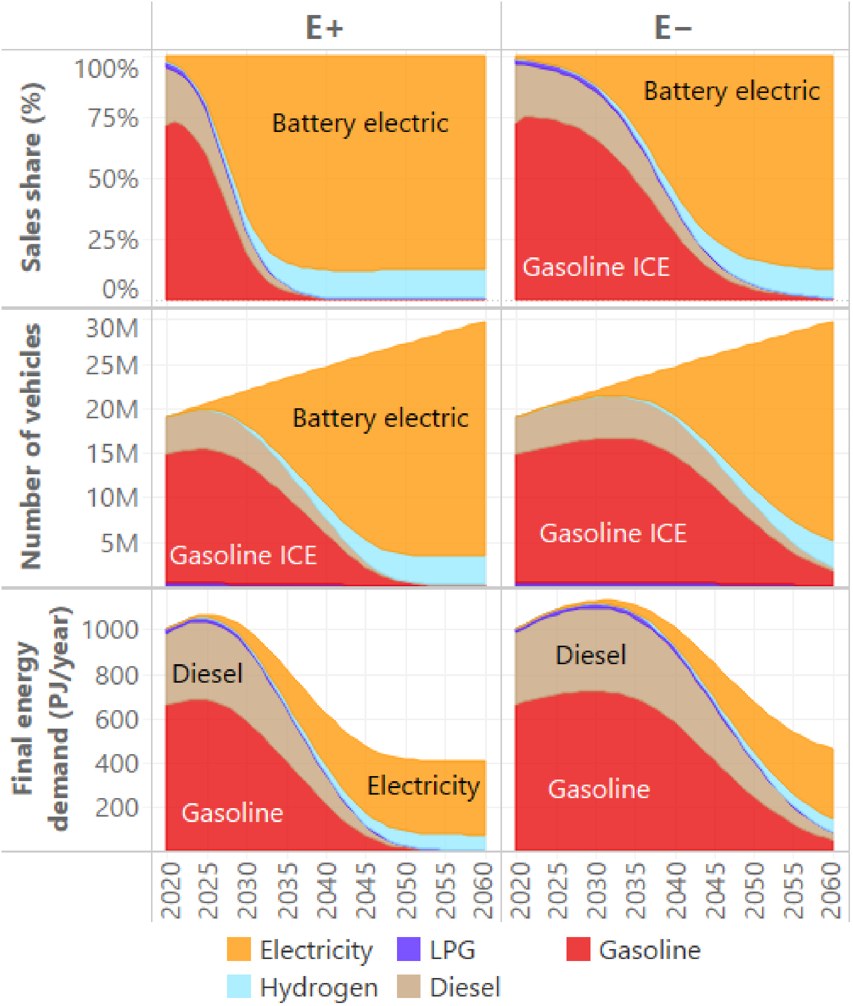


KEY TAKEAWAYS

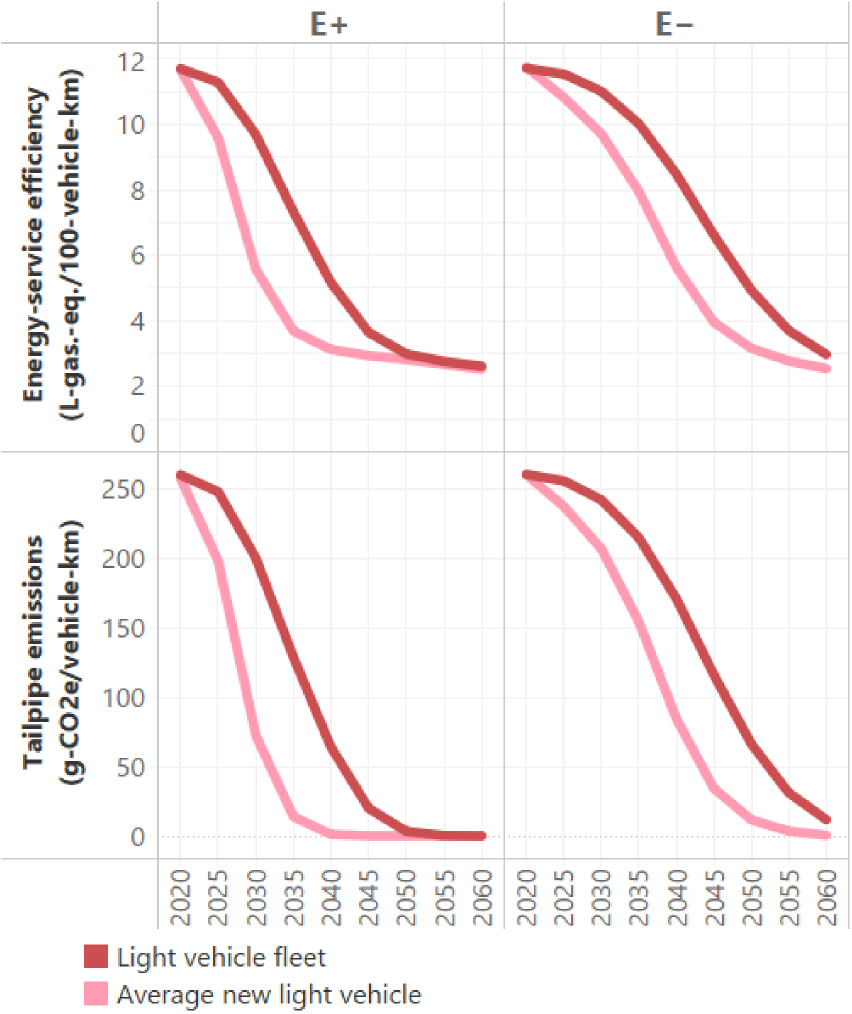
- All sectors experience an increase in final demand for electricity.
- Of the end-use sectors, transportation experiences the greatest increase in final demand for electricity in all Scenarios, with the largest and most rapid growth occurring in E+.
- Final electricity demand of the national transport sector increases from 6 TWh in 2020 to 137 TWh in 2050 (E+ Scenario).

Uptake of light-duty EVs in 2020-30s enables saturation of zero-emissions fleet by 2050-60s

Light-duty vehicle sales share (%), **vehicle stock** (Number), **and final energy demand** (PJ/year)



Light-duty vehicle fuel economy (L/100-km) **and tailpipe emissions** (g-CO_2e/km)

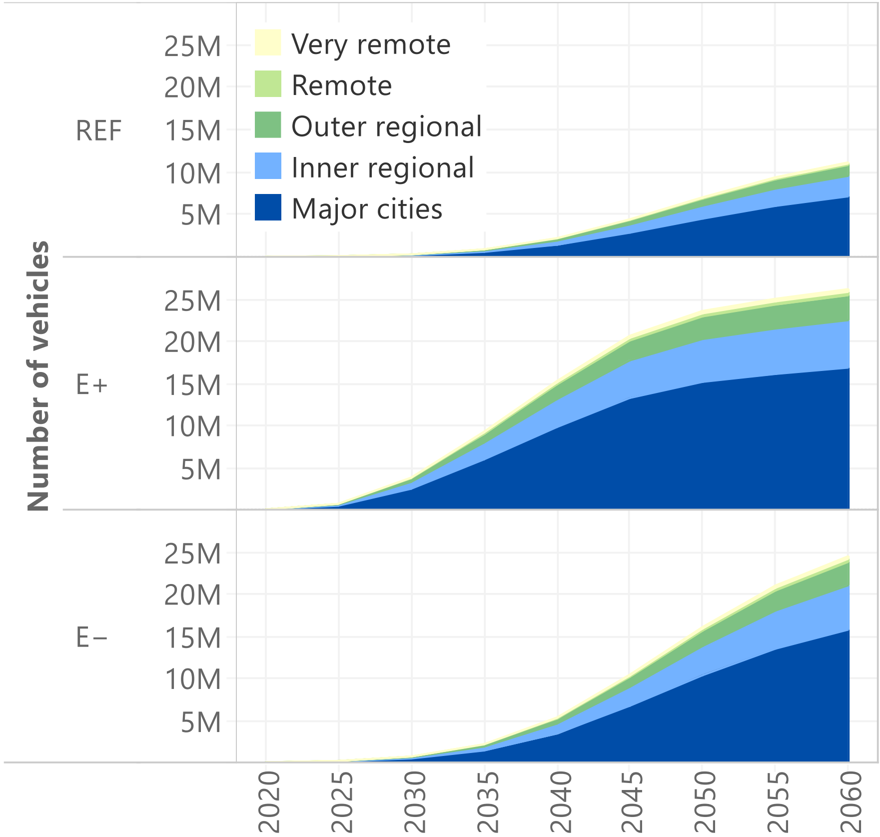


KEY TAKEAWAYS

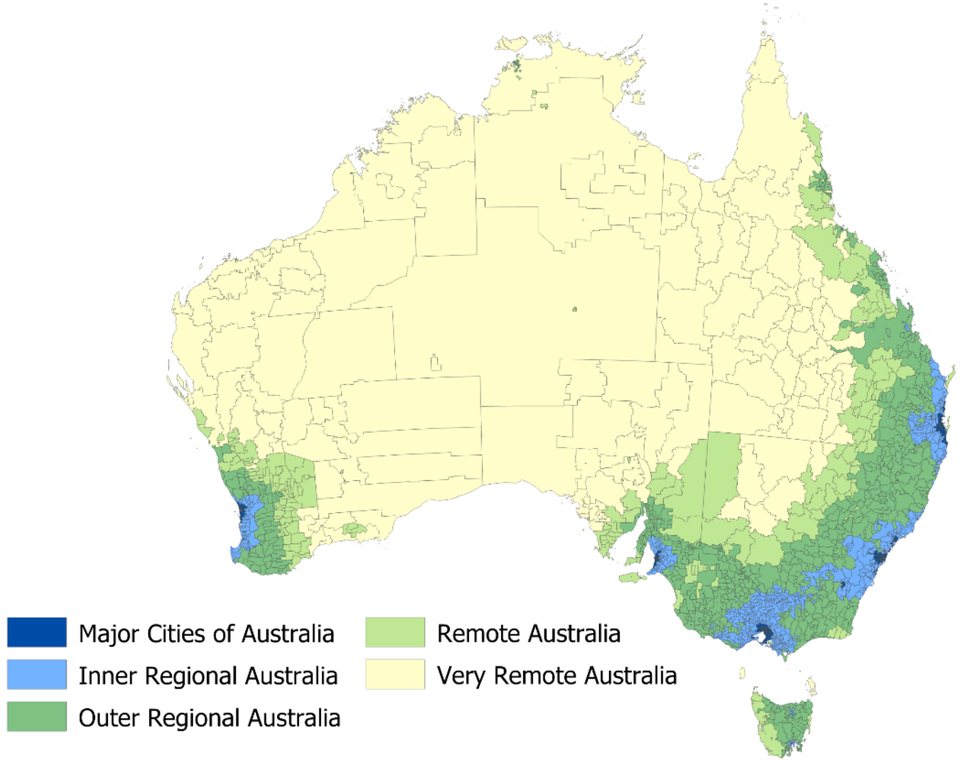
- New sales for light-duty fleet (passenger vehicles, light commercial vehicles) rapidly switch from internal combustion engine vehicles to electric-drive vehicles (EVs) that do not produce tailpipe GHG emissions.
- Average new vehicle tailpipe emissions drop quickly, with average fleet emissions lagging as existing vehicle stock is changed over.
- Residual demand for liquid transport fuels in E− necessitates the use of bio-fuels, E-fuels, or offsets.
- Hydrogen plays a greater role in heavy-duty road transport.

86% of light-duty battery EVs are located in major cities and inner regional Australia

Number of light-duty battery EVs (millions), by *remoteness* of postcode of registration.



Remoteness of Australian postcodes



Remoteness is a measure used by the ABS.
It is an objective measure of relative access to services.

KEY TAKEAWAYS

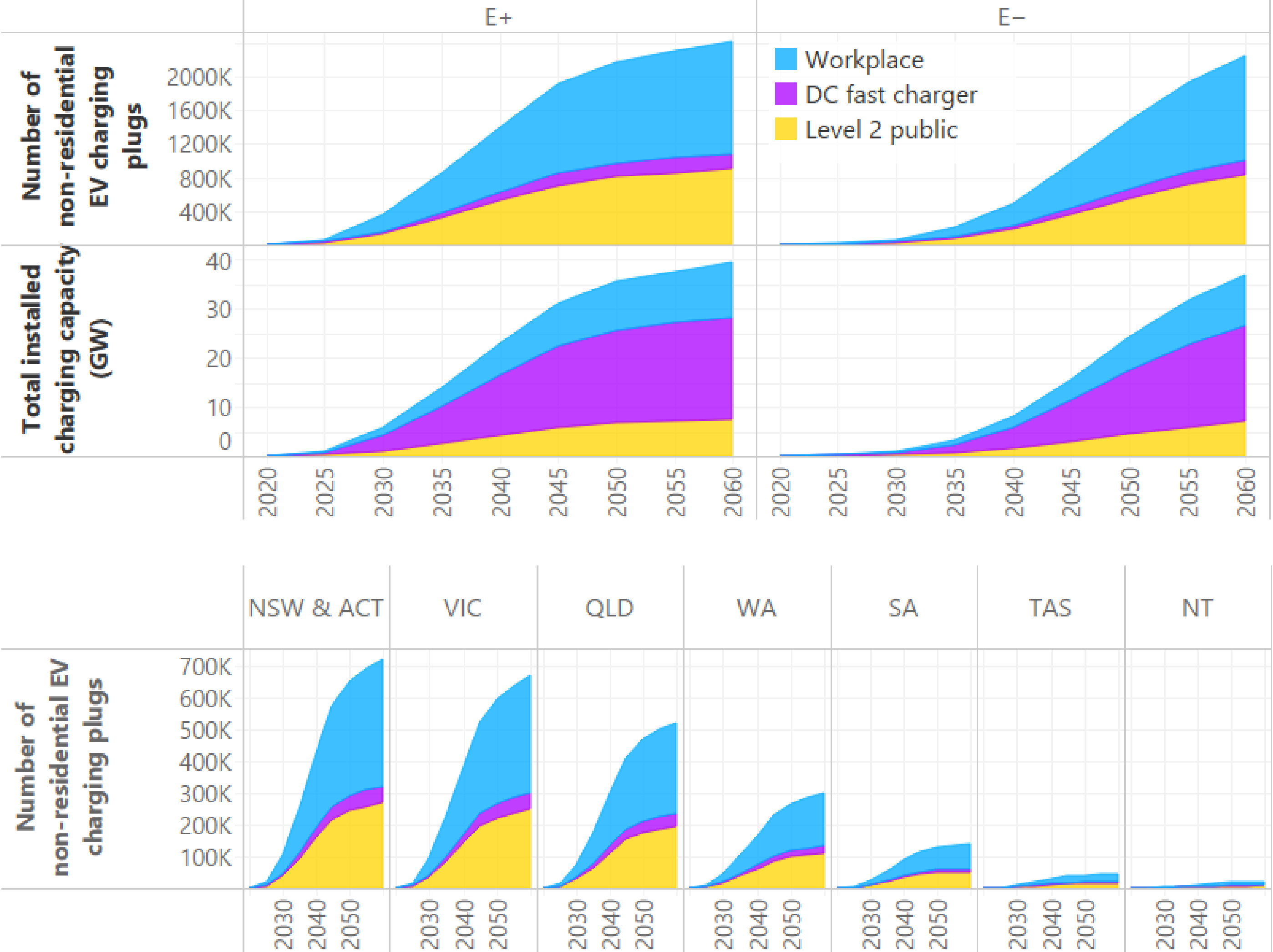
- 64% of light-duty battery EVs are located within Major Cities, with a further 22% located in inner regional Australia, across the Scenarios and years modelled.
- The vast majority of EV enabling infrastructure could be located in capital cities and their surrounds.

Modelling note

- Remoteness assessment uses the ABS' Remoteness Structure.

Over 2 million public EV chargers are needed to support light-duty transport in 2050

Number of non-residential EV charging plugs (Number) **and their total installed charging capacity** (GW).
Number of non-residential charging plugs by state for E+ is also shown (bottom)



KEY TAKEAWAYS

- Much of the future EV charging task will be performed at home with Level 1 (~2 kW charging power from standard AC power point) and Level 2 (~7 kW dedicated AC unit) chargers.
- Public infrastructure is also required, with over 2 million chargers needed in 2050, with over half of those in the workplace.
- Public infrastructure is particularly important to: relieve pressure on distribution networks through charging at workplaces and destinations; provide access to households with no at-home charging availability; and assuage range anxiety.

PILLAR 2: **Clean electricity: wind and solar generation, transmission, firm power**

PART 1: Wind and solar generation, and transmission

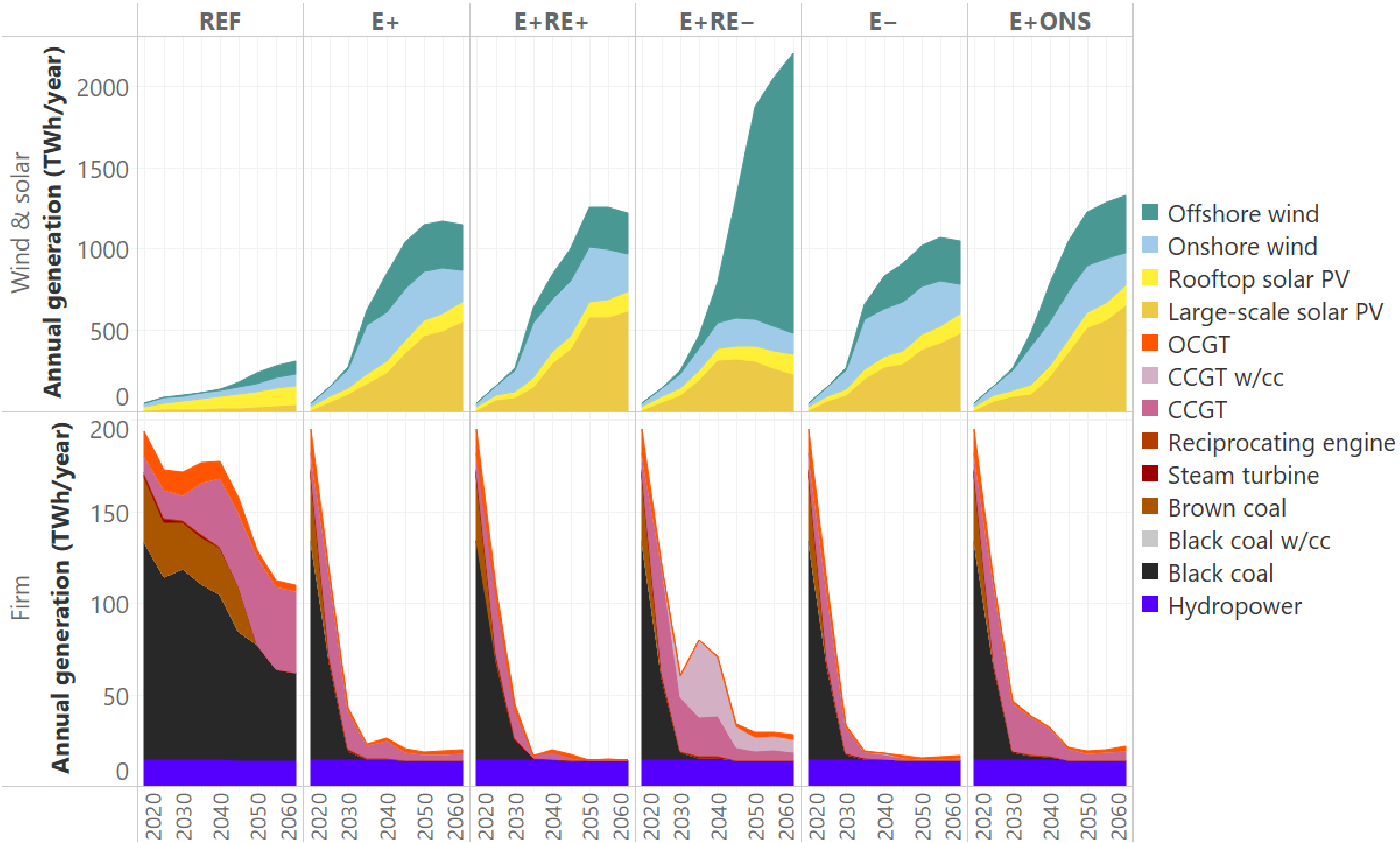
KEY FINDINGS

Renewables will rapidly replace fossil fuels, with large expansions in transmission driven by energy exports.

- Rapid growth in renewable electricity generation outpaces a rapid fall in fossil fuel generation
- Renewable deployment scales up to install 40-80GW of capacity every 5 years.
- The make-up of each state's electricity system varies, with more firming capacity required in populous states
- Exports will drive electricity generation in 2050 to 10-23× current levels
- Solar PV across the northern sunbelt is the primary energy supply for clean energy exports
- 60-130 GW expansion of inter-regional electricity transmission is required in all core scenarios

Rapid growth in renewable electricity generation outpaces a rapid fall in fossil fuel generation

Projected domestic electricity generation, by technology (TWh/year). Note varying y-axis scales.

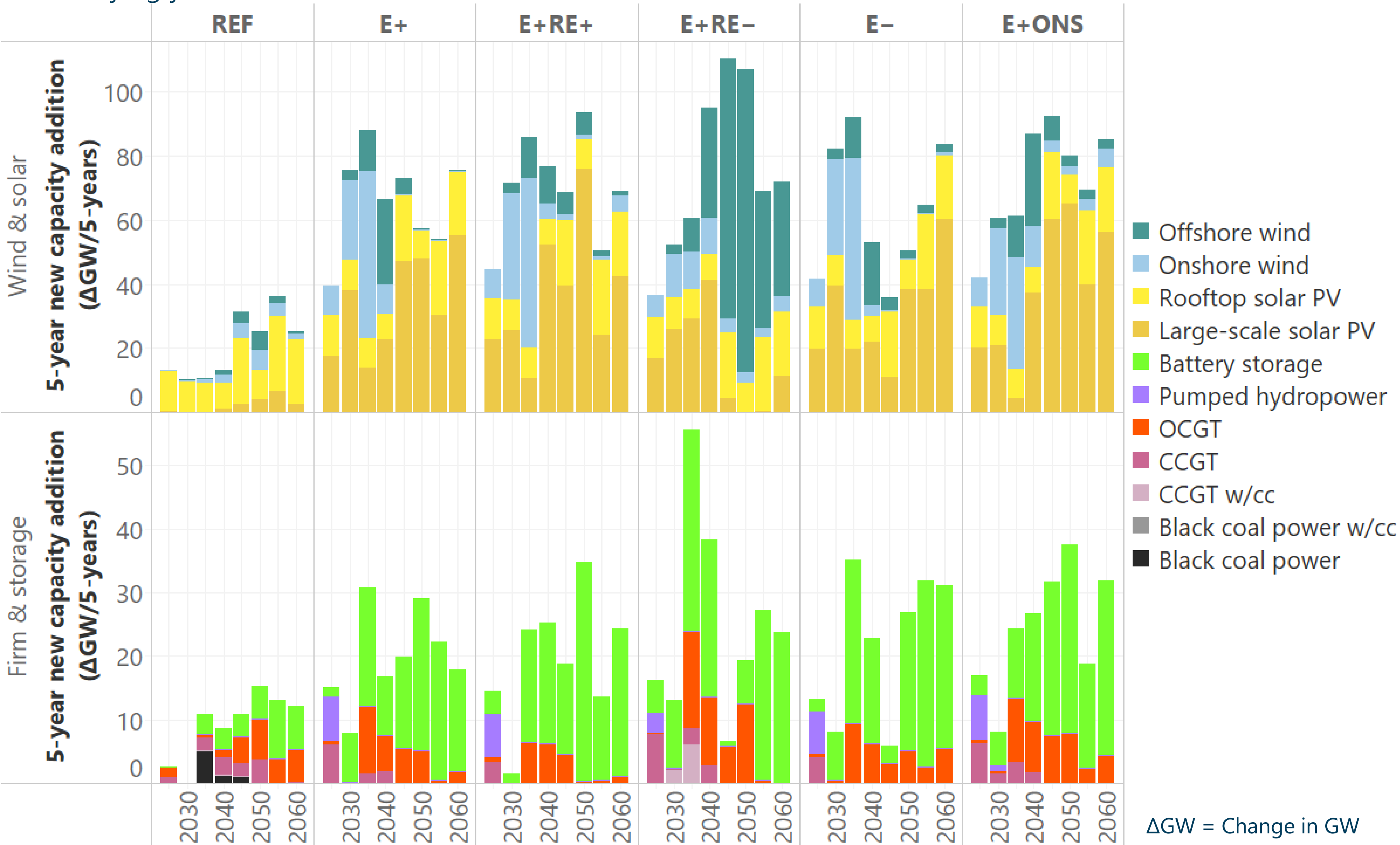


KEY TAKEAWAYS

- Electricity generation from fossil fuels rapidly declines – by ~80% from 2020 to 2030.
- Fossil fuel electricity generation with CCUS does not play a significant role in most Scenarios as CCUS is constrained and needed for hard-to-abate sectors.
- Fossil fuel electricity generation with CCUS is only prospective in E+RE− with constrained renewable build rates and expanded CO_2 sequestrations rates and infrastructure.
- Offshore wind is higher in the RE- Scenario (constrained renewables) than RE+ Scenario (full renewables rollout), as the model reaches the constrained build rate for onshore wind.

Renewable deployment scales up to install 40-80GW of capacity every 5 years

Projected 5-year capacity additions to domestic electricity system (New GW / 5-years).
Note varying y-axis scales.



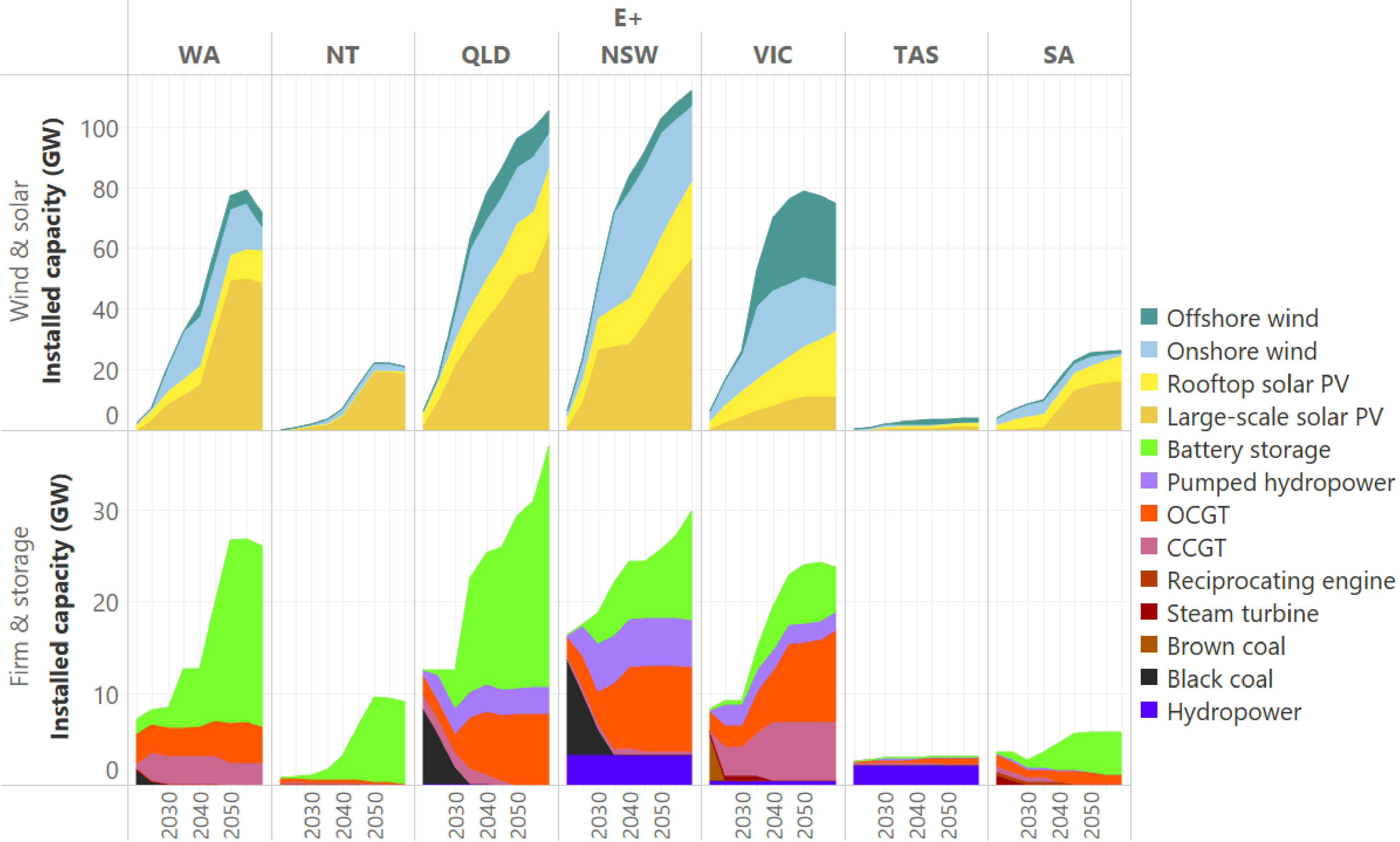
ΔGW = Change in GW

KEY TAKEAWAYS

- All Scenarios require vast increases in deployed capacity and storage compared to REF.
- New gas *capacity* is required in all scenarios, with build out occurring consistently across the transition.
- In all Scenarios other than E+RE−, deployment of offshore and onshore wind is greatest between 2020 and 2040. Solar deployment continues until 2060.
- In E+RE−, offshore wind dominates generation deployment, while greater gas firming and storage capacity is required due to constrained deployment of renewables.
- Large deployment of new batteries is needed in all years, across all Scenarios.

The make-up of each state's electricity system varies, with more firming capacity required in populous states

Projected domestic electricity capacity in E+, by technology and state (GW).
Note varying y-axis scales.

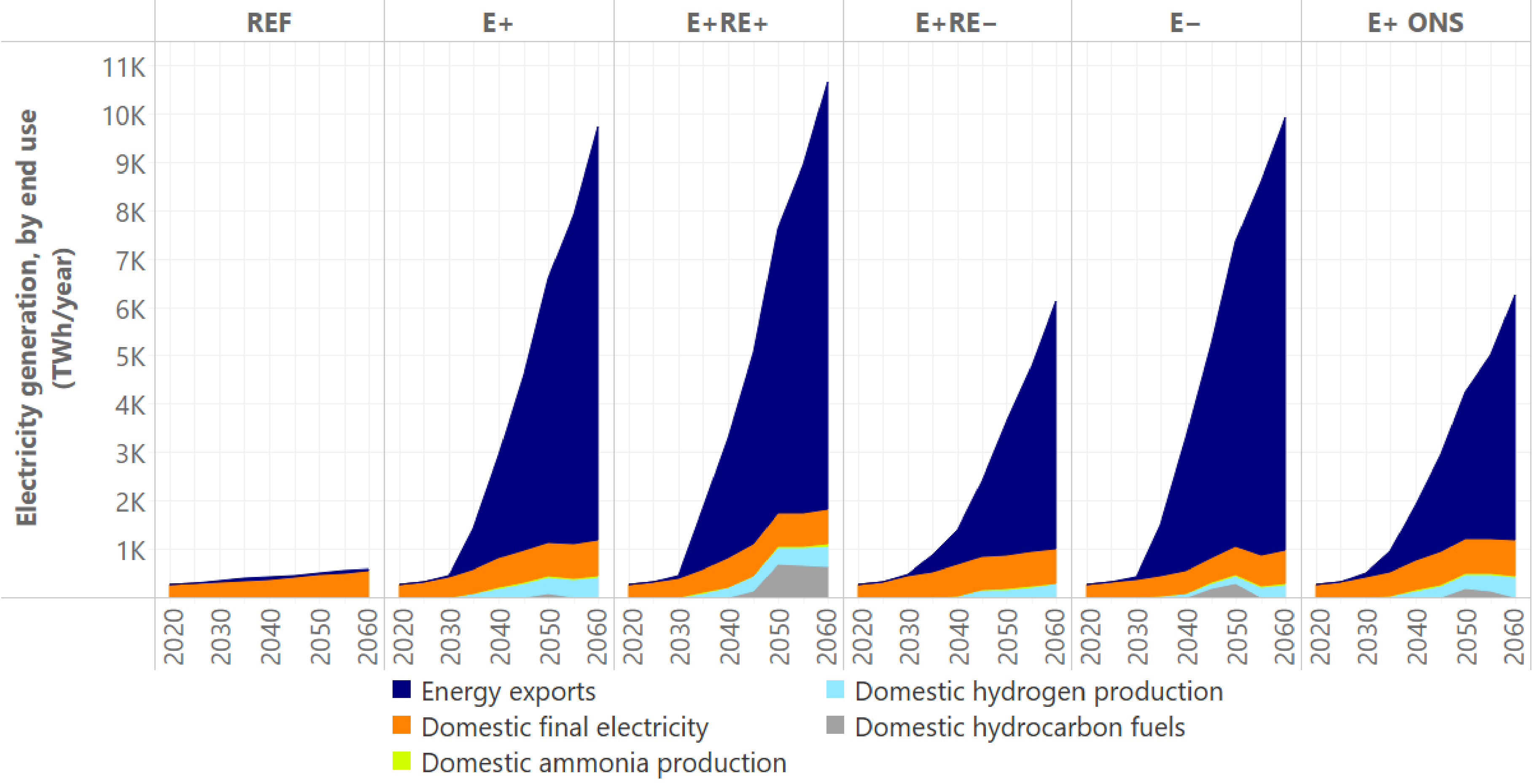


KEY TAKEAWAYS

- All states house significant solar infrastructure, with Victoria dominating the supply of offshore wind capacity.
- Substantial new battery and OCGT capacity is needed in populous states to firm renewables.
- Victoria requires ~17GW of gas turbines capacity (OCGT and CCGT) in 2060
- Queensland rapidly installs ~20GW of battery capacity over 2030-2060.
- Western Australia and Queensland experience the largest growth in battery storage, in part due to the larger proportion of solar power generation.

Exports will drive total electricity generation in 2050 to 10-23× current levels

Projected electricity generation, by end use (TWh/year)

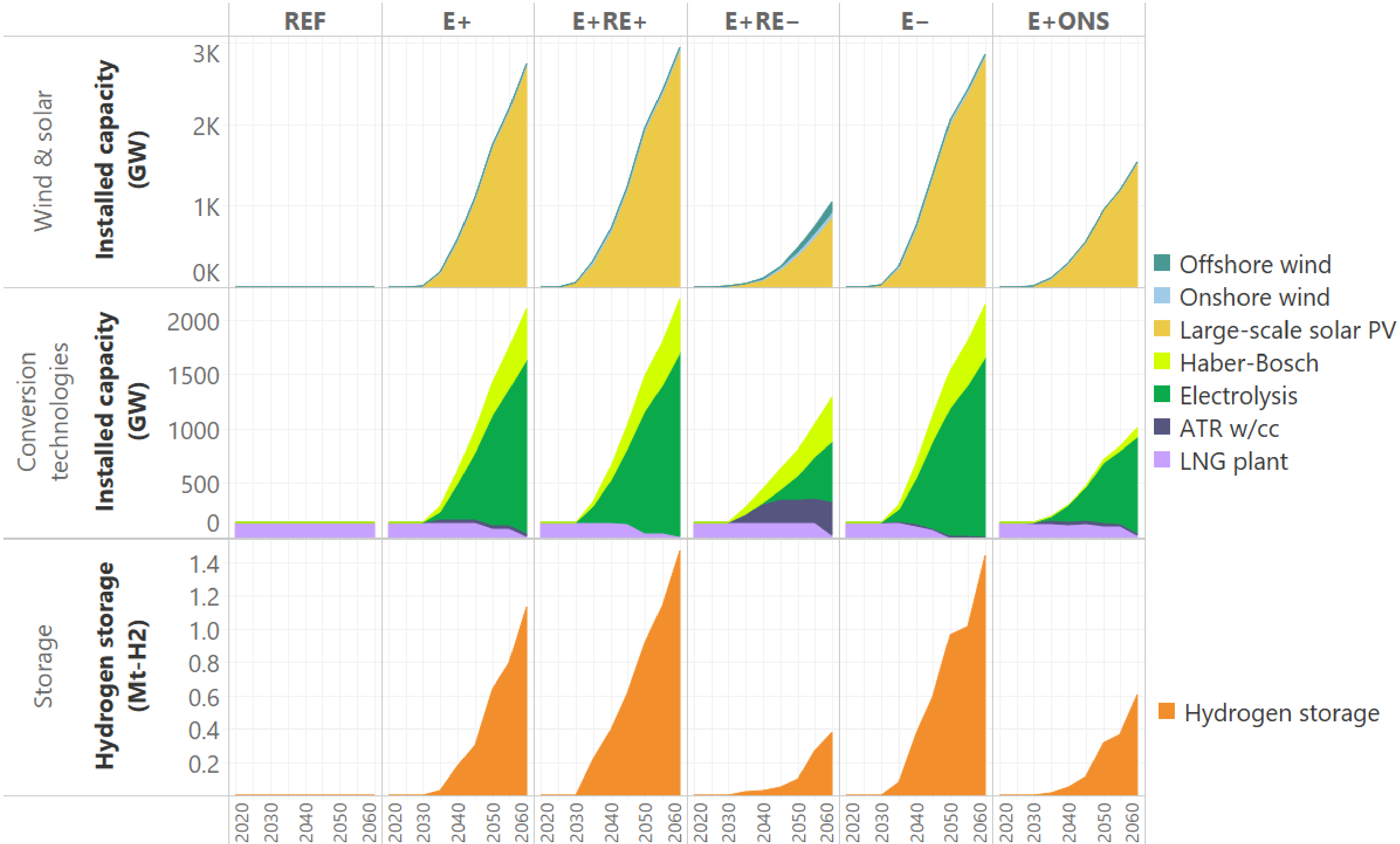


KEY TAKEAWAYS

- 80% of total electricity generation is used to serve energy exports.
- 20-60% of electricity generation for domestic use is to produce clean fuels (liquid and gas).
- In E+RE+, where fossil fuels are not allowed after 2050, e-fuels are required instead, particularly for aviation.
- In E−, e-fuels are required in 2050 due to the larger residual demand for liquid and gaseous fuels across residential and industrial sectors.

Solar PV across sunbelt is the dominant primary energy supply for clean energy exports

Projected export system electricity generation and conversion capacity, by technology (GW), **and hydrogen storage** (Mt-H_2). Note varying y-axis scales.

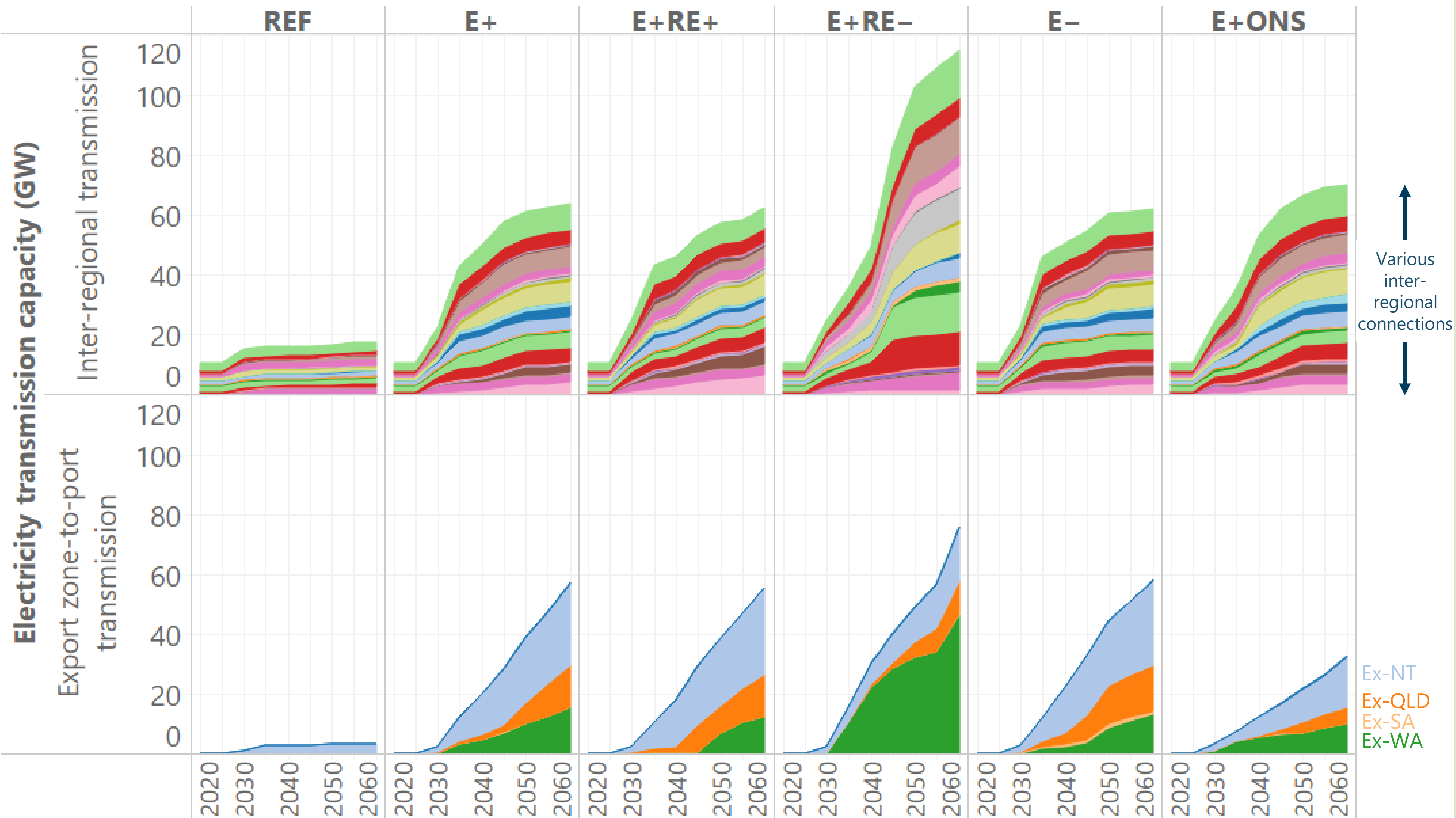


KEY TAKEAWAYS

- Almost all electricity serving the export market is generated from large scale Solar PV (1-3 TW).
- Solar PV electricity is converted to the final energy carrier for shipping via electrolysis and Haber-Bosch synthesis in all Scenarios.
- Where renewable build rates are constrained, export energy is supplemented by autothermal reforming of natural gas with carbon capture (ATR w/cc).
- Modelling requires that the supply of energy to meet export demand is constant across every hour of the year. This requires significant hydrogen storage (0.4 – 1.4 million tonnes of hydrogen storage), together with some battery storage (not shown here).

60-130 GW expansion of inter-regional electricity transmission required in all core scenarios

Projections of inter-regional and export-to-port electricity transmission capacity (GW)



KEY TAKEAWAYS

- A 60-130GW expansion of inter-regional electricity transmission occurs in in all Scenarios compared to the REF Scenario.
- Twice the inter-regional transmission needed in E+RE– compared with other Scenarios, driven by greater use of wind, which is less proximate to demand than solar.
- Electricity transmission between export energy zones and ports is low compared to generation capacity because hydrogen transmission is favored as the cheapest form of bulk energy transport (see hydrogen transmission downscaling).
- This means transmission to ports is used only for desalination and conversion to ammonia (it is assumed HB plant is port-side).

PILLAR 2: **Clean electricity: wind and solar generation, transmission, firm power**

PART 2: Storage and firm power

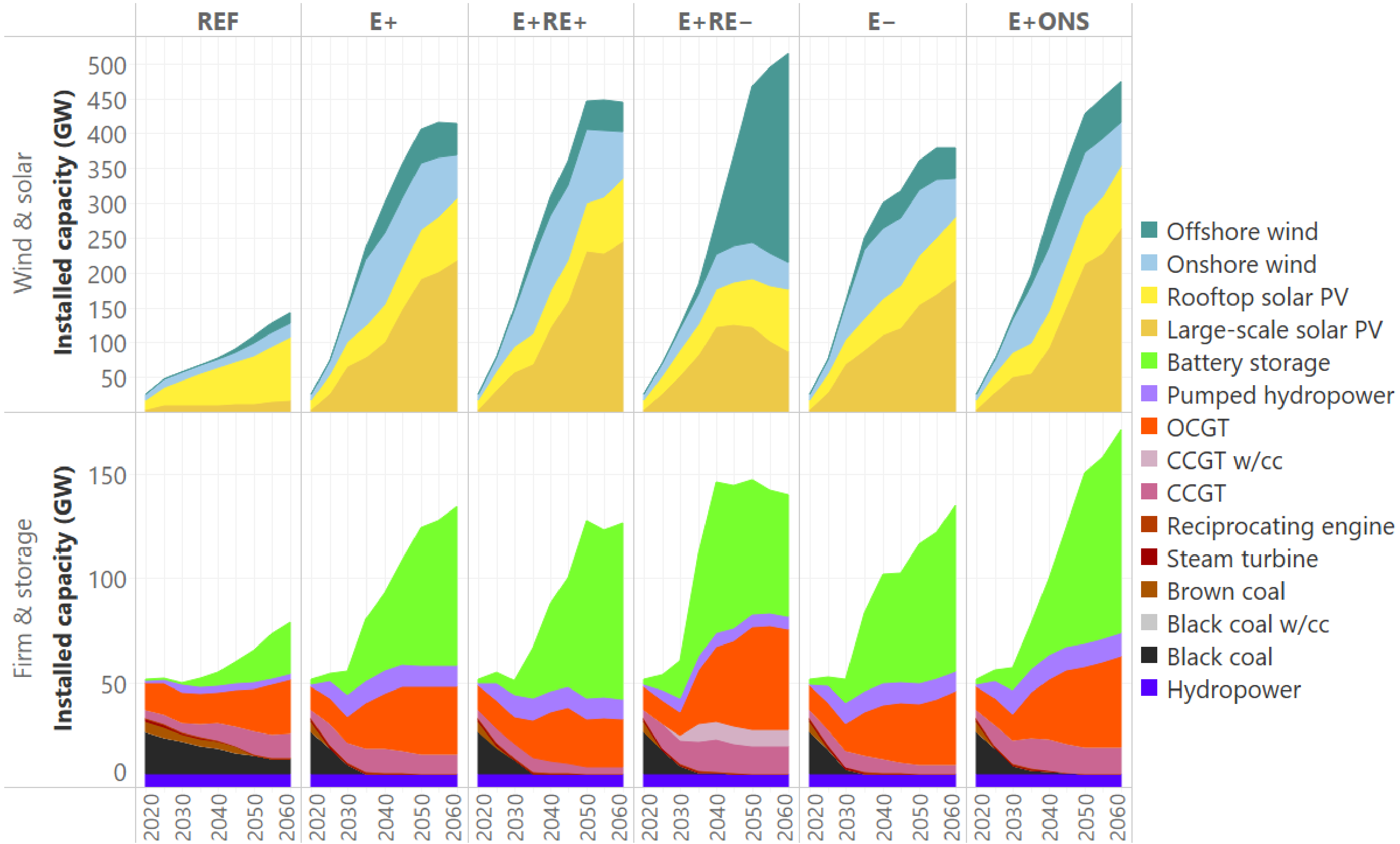
KEY FINDINGS

90-120GW of battery and hydro storage is required, with new gas capacity needed as a low-use strategic energy reserve in all Scenarios.

- Significant domestic storage and generation capacity is needed to firm renewables
- Electricity storage is provided by batteries and pumped hydro with a range of storage durations
- Higher renewable penetrations increase generation variability and require storage for hourly balancing
- As the transition progresses, the utilisation of OCGT and CCGT assets falls substantially
- Total gas use for power decreases, but new gas capacity is needed a strategic reserve in support of renewables and storage
- Existing thermal generation is gradually phased out by the uptake of zero-carbon technology
- Early and end-of-life asset retirements allow brownfield siting of most new thermal generation

Significant domestic storage and generation capacity is needed to firm renewables

Projected domestic electricity capacity, by technology (GW). Note varying y-axis scales.

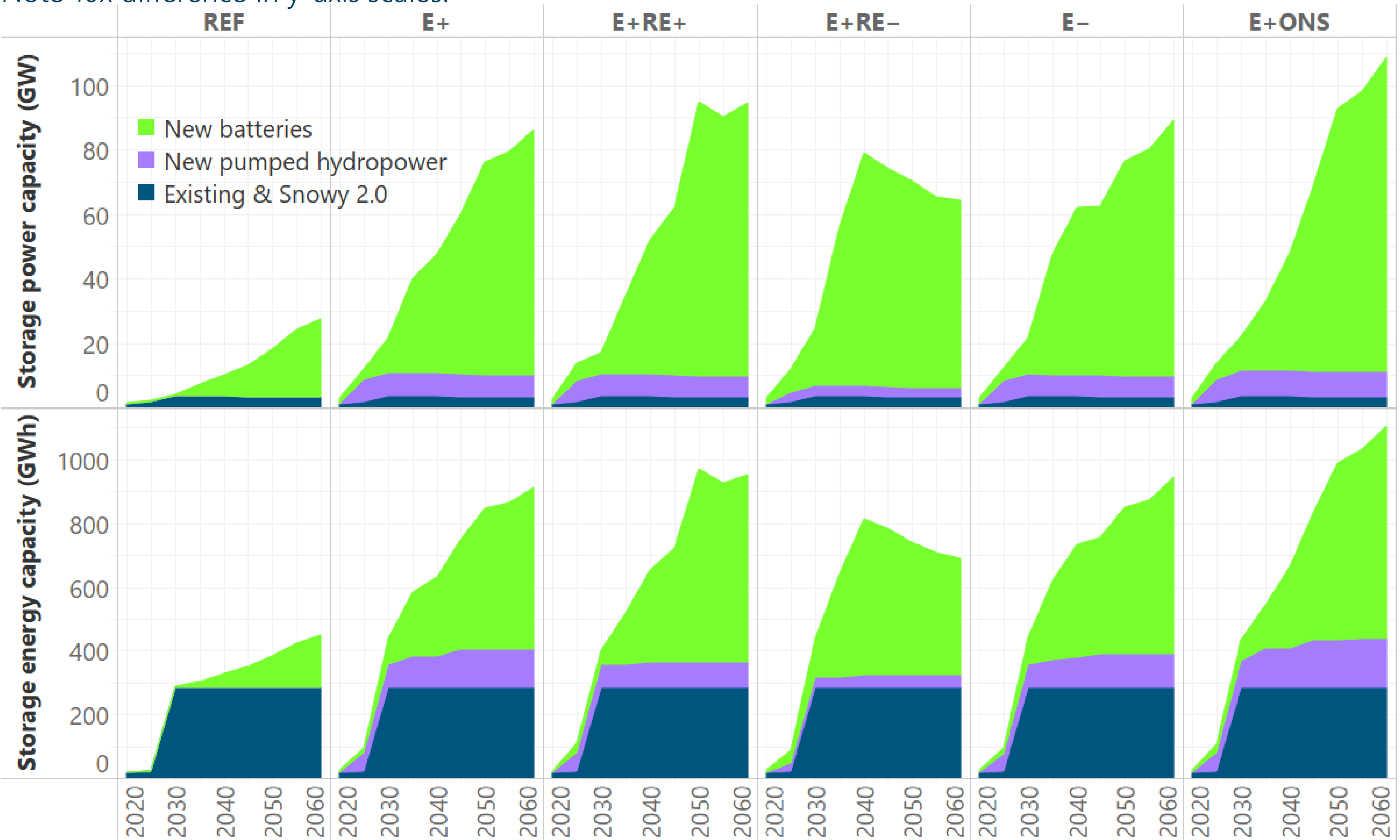


KEY TAKEAWAYS

- Domestic renewable capacity grows to 380-500GW, including 70GW of rooftop solar PV.
- Domestic offshore wind supplies domestic demand in all net zero Scenario and is highest in E+RE− (150 GW).
- Total dispatchable thermal generation capacity remains at current levels or grows.
- 70-120 GW of electricity storage (mostly batteries) help to firm growing variable renewable generation.
- 30-50 GW of firm generation also needed – mostly hydro and gas turbines burning natural gas (and zero-carbon fuels in E+RE+).

Electricity storage is provided by batteries and pumped hydro with a range of storage durations

Projected domestic electricity storage capacity, by technology (GW and GWh).
Note 10x difference in y-axis scales.



KEY TAKEAWAYS

- Major battery deployment is modelled across all Scenarios, playing a significant role in time shifting daytime solar generation to evening peaks.
- 70-110 GW of battery storage, ~10 GW of pumped hydro are domestically needed by 2050.
- Average durations of storage (GWh/GW) are 7h and 15h for batteries and pumped hydro, respectively.
- Hydrogen storage (not shown here) is also used to provide energy storage over long durations.

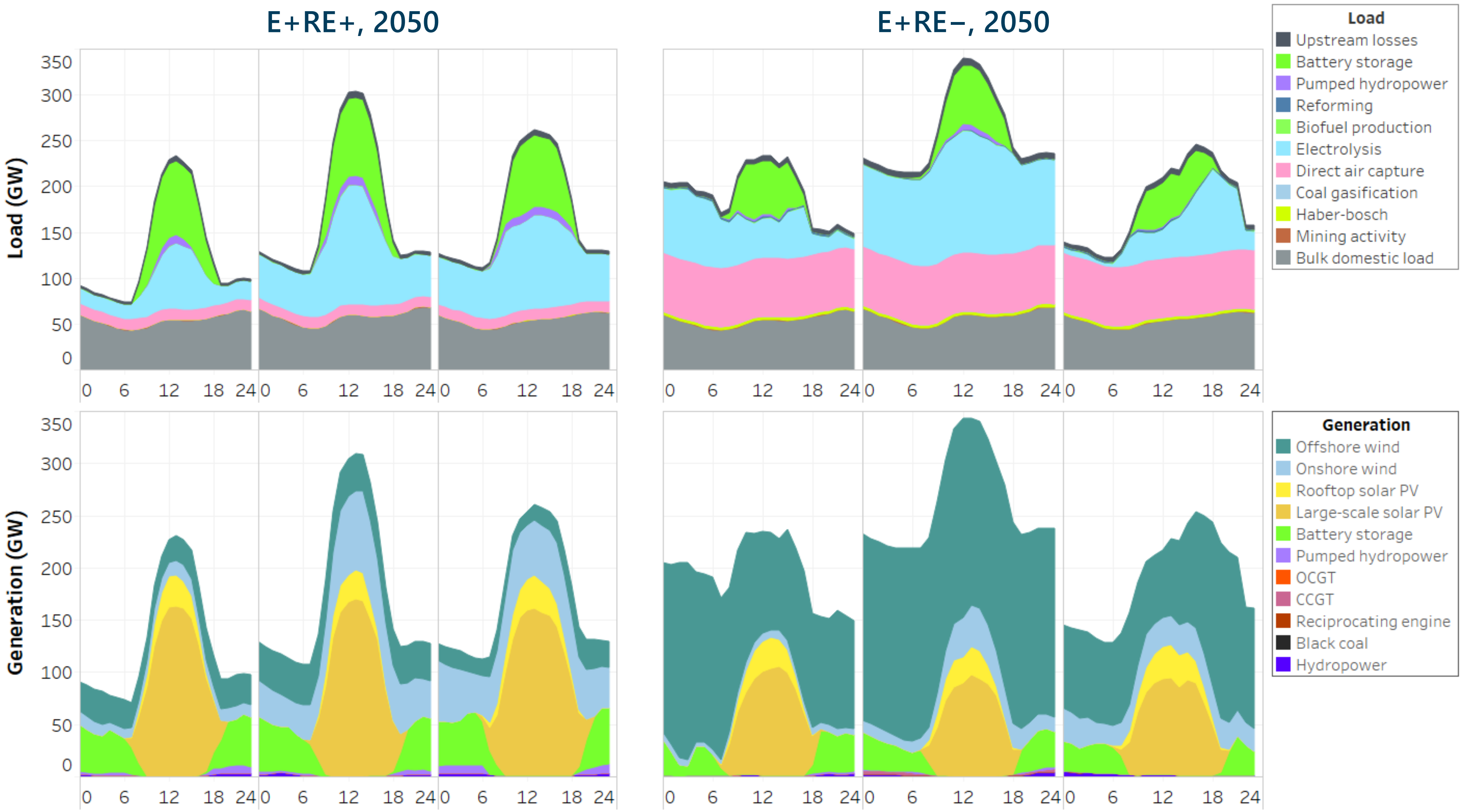
Higher renewable penetrations increase generation variability and require storage for hourly balancing

PILLARS

1 2 3 4 5 6

Clean electricity

Projected 2050 domestic load and generation hourly profiles for E+RE+ and E+RE− (GW).
Hourly dispatch on selected days

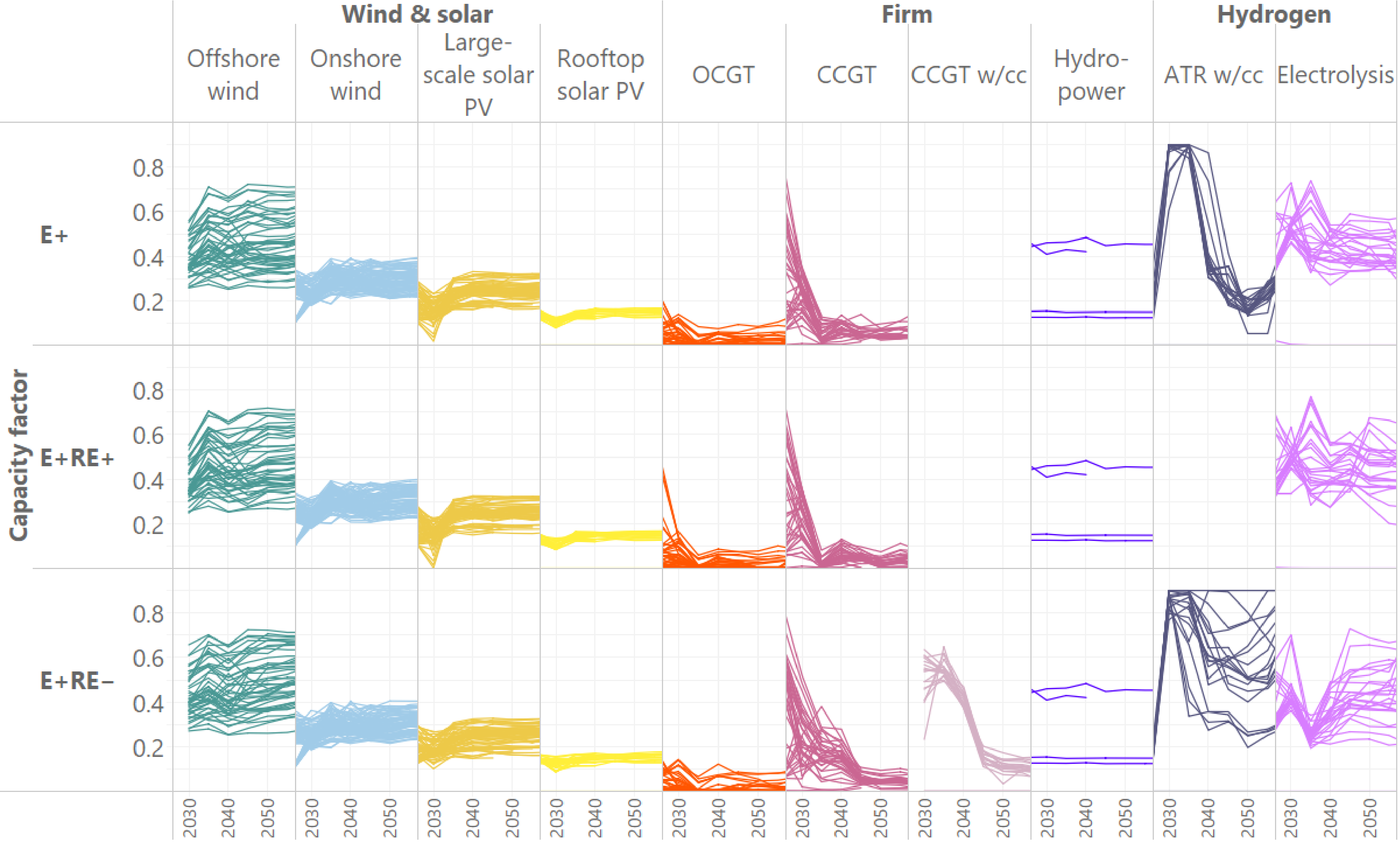


KEY TAKEAWAYS

- Peak generation increases by more than five times from 2020 to 2050.
- Thermal generation becomes a minor part of the daily generation mix, with natural gas used only for grid firming (mostly in the E+RE− Scenario).
- Higher reliance on utility-scale solar PV in E+RE+ Scenario results in a peak generation in the central hours of the day, balanced by ~600 GWh of batteries.
- Higher reliance on offshore wind in E+RE− Scenario results in more overnight generation, balanced by ~410 GWh of batteries.

As the transition progresses, the utilisation of OCGT and CCGT assets falls substantially

Capacity factors of selected technologies in each modelled region (Proportion, 0 to 1)



KEY TAKEAWAYS

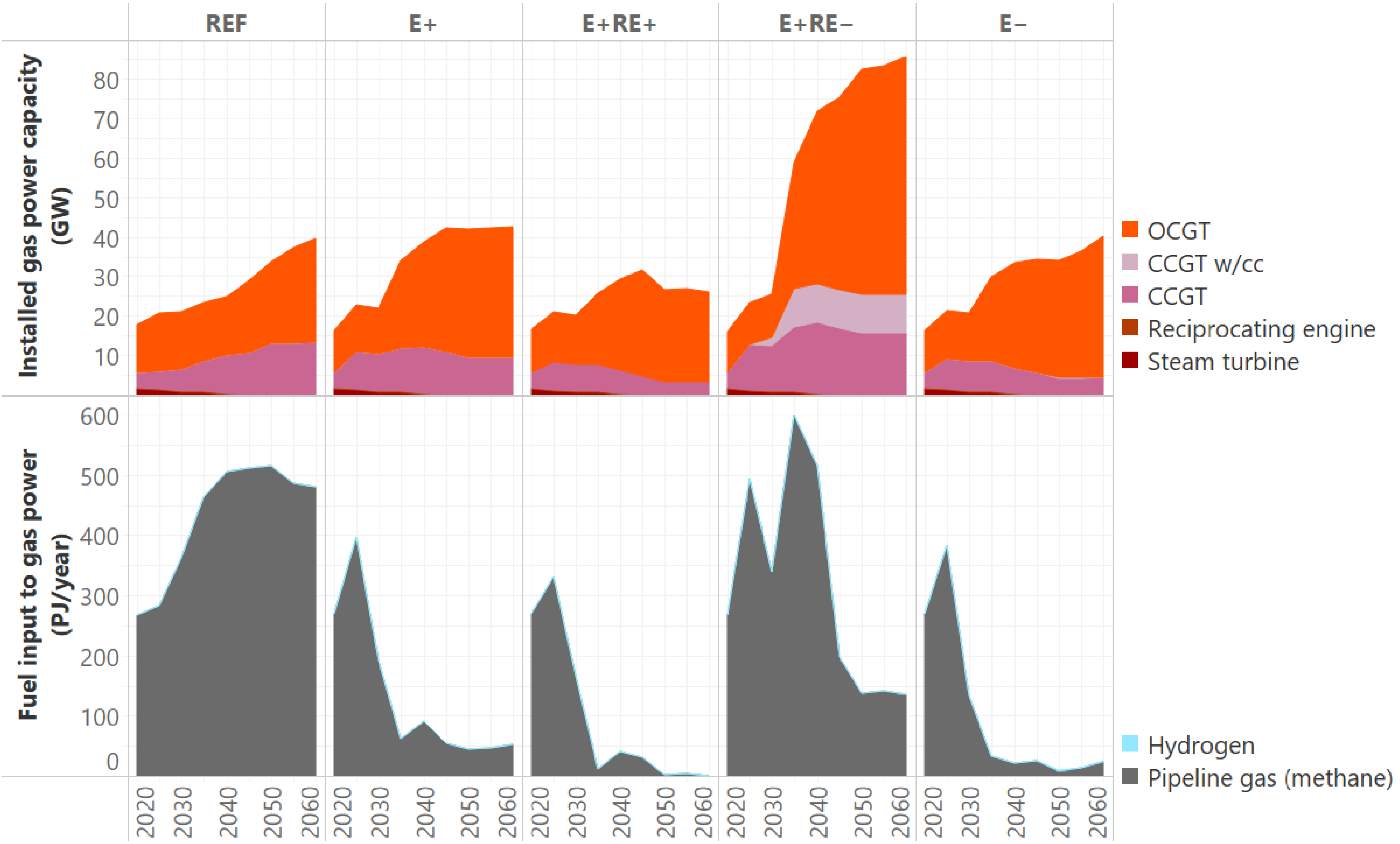
- The capacity factors of gas turbines starts high, then fall to <10% by 2060.
- The capacity factors of autothermal reforming (ATR) starts high and falls.
- Future low-capacity factors of assets raises questions about the need for new investment signals and/or the establishment of gas-fired power as a strategic reserve.
- Utilisation fluctuates over time as the system switches over between domestic electrification and domestic hydrogen.

Interpreting the graph

- Capacity factor measures proportion of time an energy asset is running at full capacity (0 to 1, where 1 is 100%)
- Each line represents a different region and group of assets.

Total gas *use* for power decreases, but new gas *capacity* is needed a strategic reserve in support of renewables and storage

Gas power – installed capacity (GW), **and fuel input** (PJ/year).

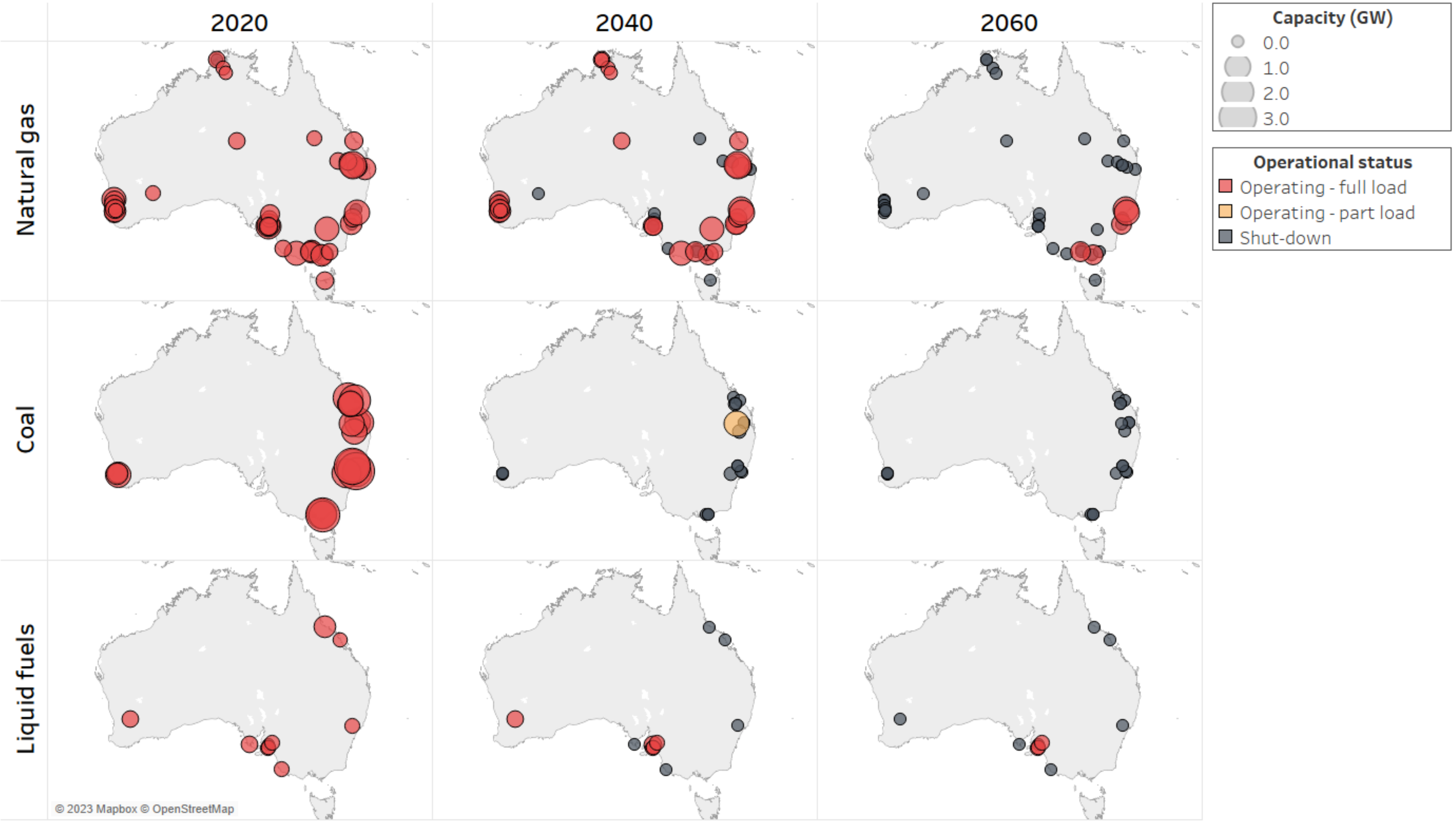


KEY TAKEAWAYS

- New gas power capacity is required across all regions in all scenarios.
- However, gas power is used much less often, with capacity factors reduced to <10%.
- Gas turbines respond to reliability events just a handful of times per year. These are mostly associated with prolonged periods of low renewable generation.
- Much new capacity could be sited on brownfield sites of retiring coal generators.
- We find minimal blending of hydrogen into gas power.
- In some Scenarios, pipeline gas is made renewable via bioenergy.

Existing thermal generation is gradually phased out by the uptake of zero-carbon technology

Operational status of existing thermal generation assets in the E+RE– Scenario.
Bubble sizes scale with asset capacity (GW)

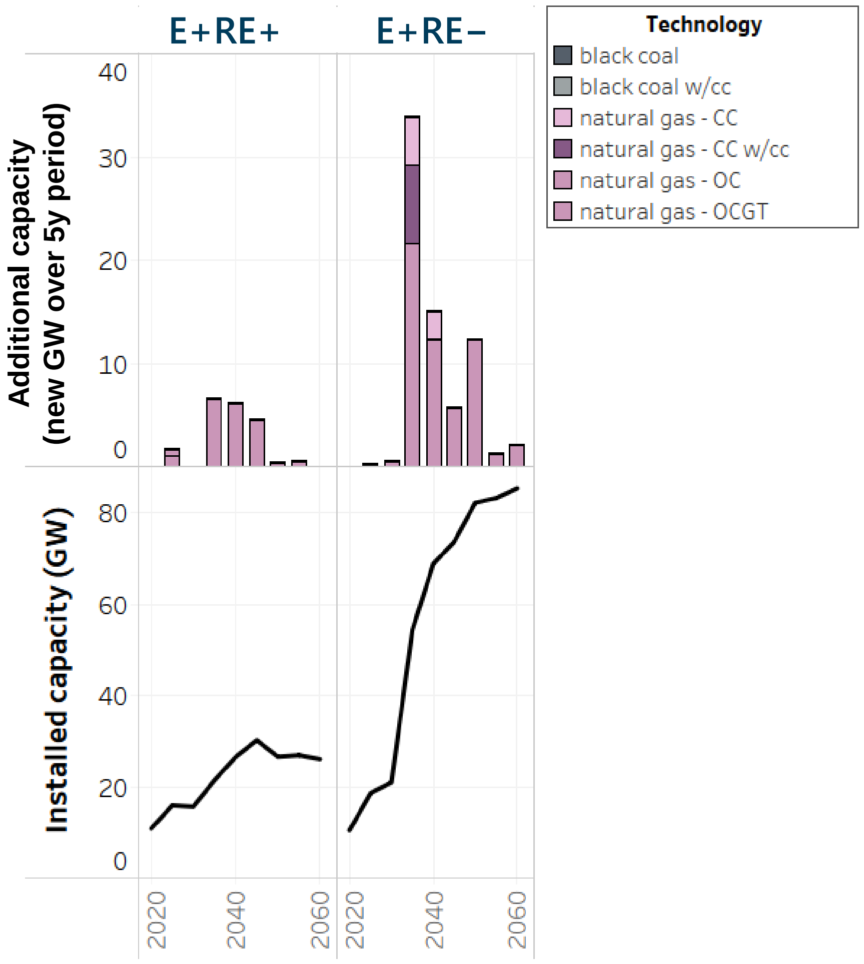


KEY TAKEAWAYS

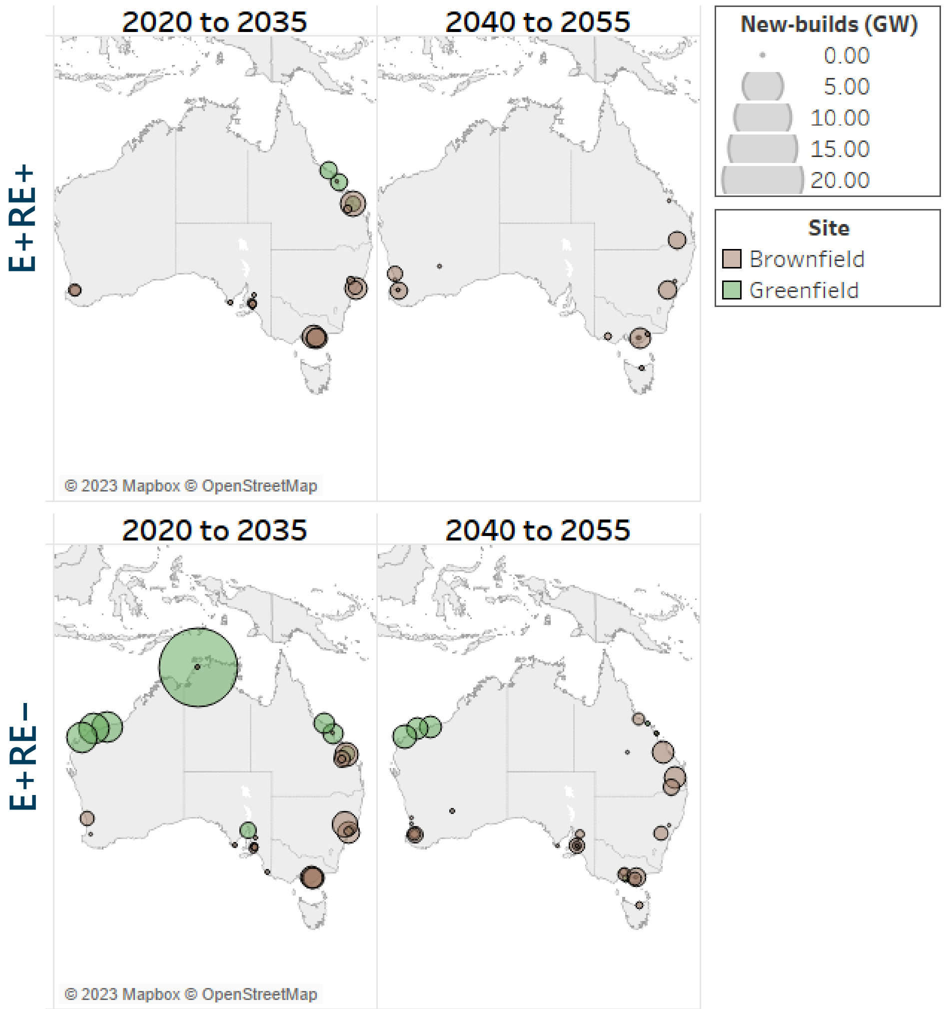
- Even with constraints on the build rates of renewable generation, most of the existing thermal generation fleet is retired by 2050, except for some residual natural gas generation.
- There is no coal generation past 2040 in any of the net-zero Scenarios.
- Between 21 and 29 GW of existing coal and liquid fuel generation are retired earlier than their intended end of life.
- Existing natural gas generators are operated until their intended end of life across all Scenarios.

Early and end-of-life asset retirements allow brownfield siting of most new thermal generation

Gas generation capacity
(GW)



Schedule of brownfield and greenfield site development for new generation capacity
GW, coloured by site type, two scenarios only



KEY TAKEAWAYS

- Most new natural gas generation capacity can replace retiring assets on brownfield sites in order to accelerate permits acquisition and exploit existing infrastructure.
- 14-22 GW of natural gas plants (30-70% of the new generation) are sited on brownfields, with differences across Scenarios.
- The majority of brownfield sites become available between 2030 and 2050.
- 2.5-36 GW of new capacity (12-50% of total new generation) is located on greenfield sites at ports.
- Levelised costs for brownfield sites are 9-28% lower than greenfield installations.

PILLAR 3: **Zero-carbon fuels and feedstocks** (including bioenergy)

KEY FINDINGS

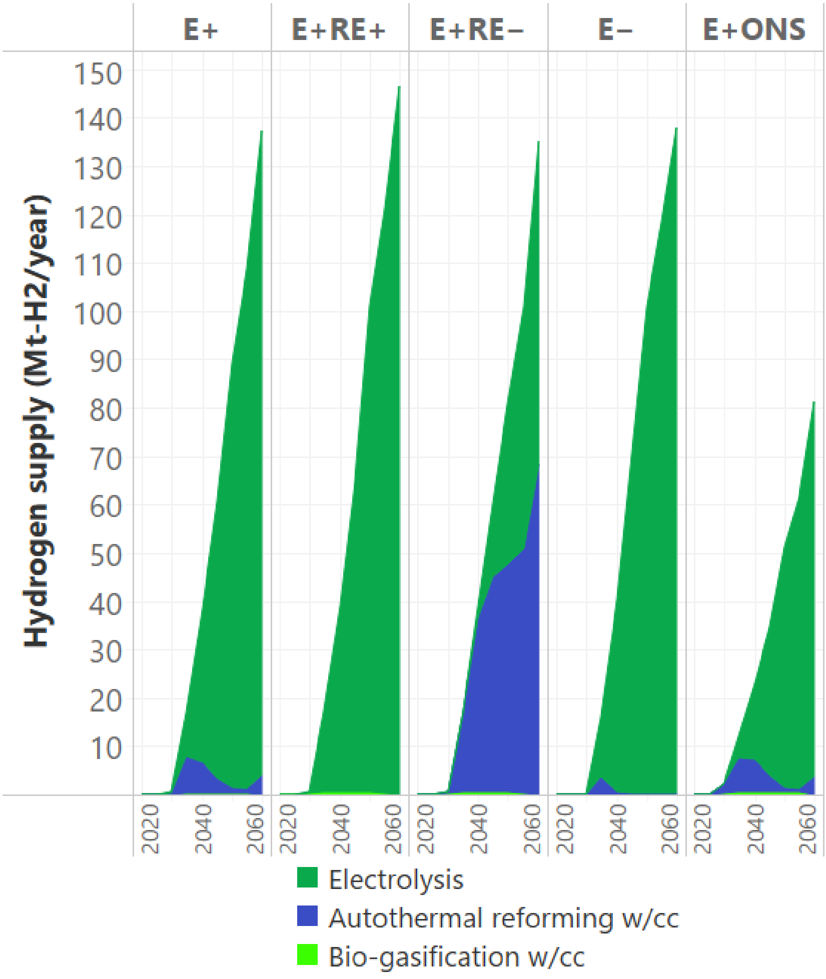
Clean fuel production will use 25-50% of domestic electricity – but 90% of all electricity, given export demand

- Most Australian hydrogen will be produced through electrolysis and exported (as clean energy or clean minerals)
- Major underground hydrogen storage capacity is needed for the domestic system, and multiples more for exports
- Significant build of hydrogen transmission infrastructure is largely associated with export projects
- Most Scenarios significantly reduce production and use of pipeline methane gas by 2060, except for E+RE−, where production expands for H_2 production with CCS
- Bioenergy potential is limited by sustainable supply of biomass, but still expands by 8.5× to ~1,100 PJ/year
- Bioenergy facilities are rapidly installed from 2030, and are regionally distributed based on location of distributed biomass resources
- Aviation remains fully dependent on fossil fuels, except in E+RE+, which prohibits fossil fuel use

Most Australian hydrogen will be produced through electrolysis and exported (as clean energy or clean minerals)

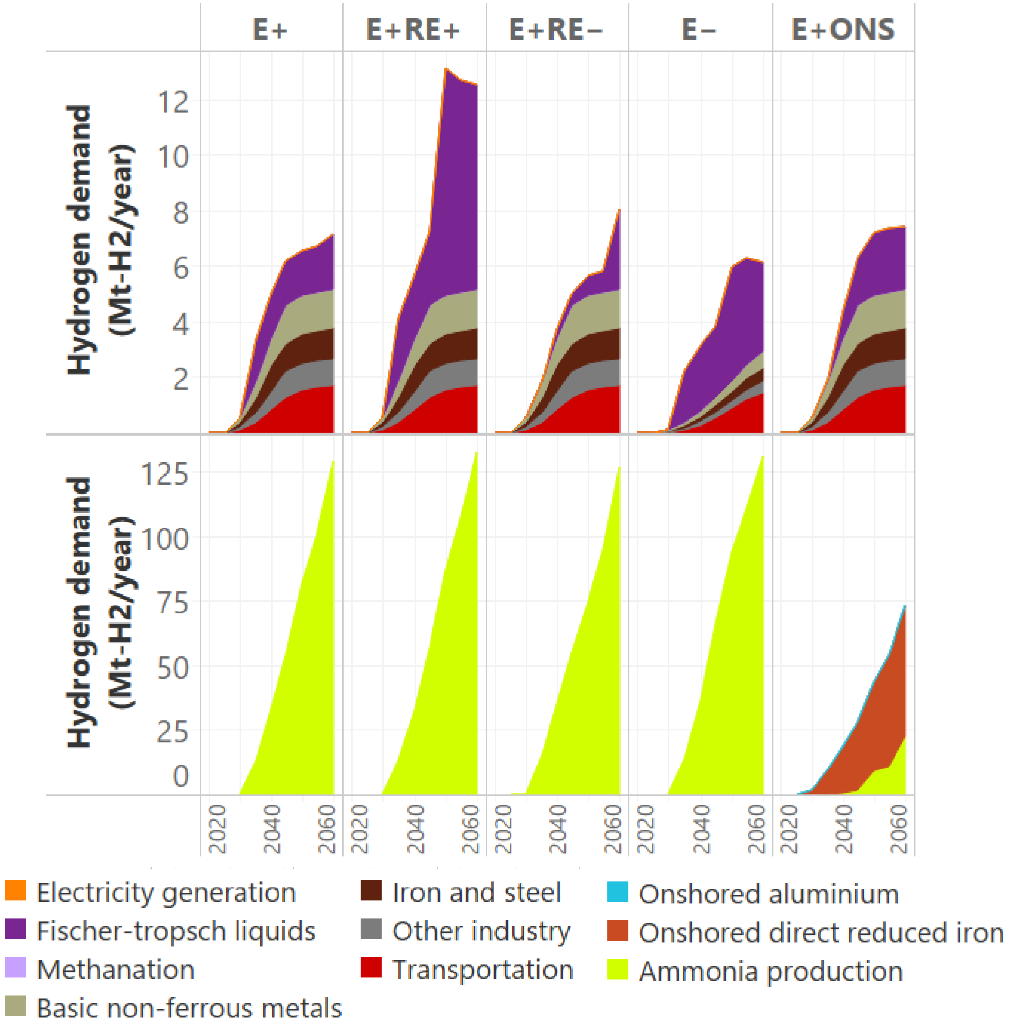
Projected hydrogen supply, by technology

($Mt\text{-}H_2$/year)



Projected hydrogen use, by sector/technology

($Mt\text{-}H_2$/year). Note 10× difference in y-axis scale

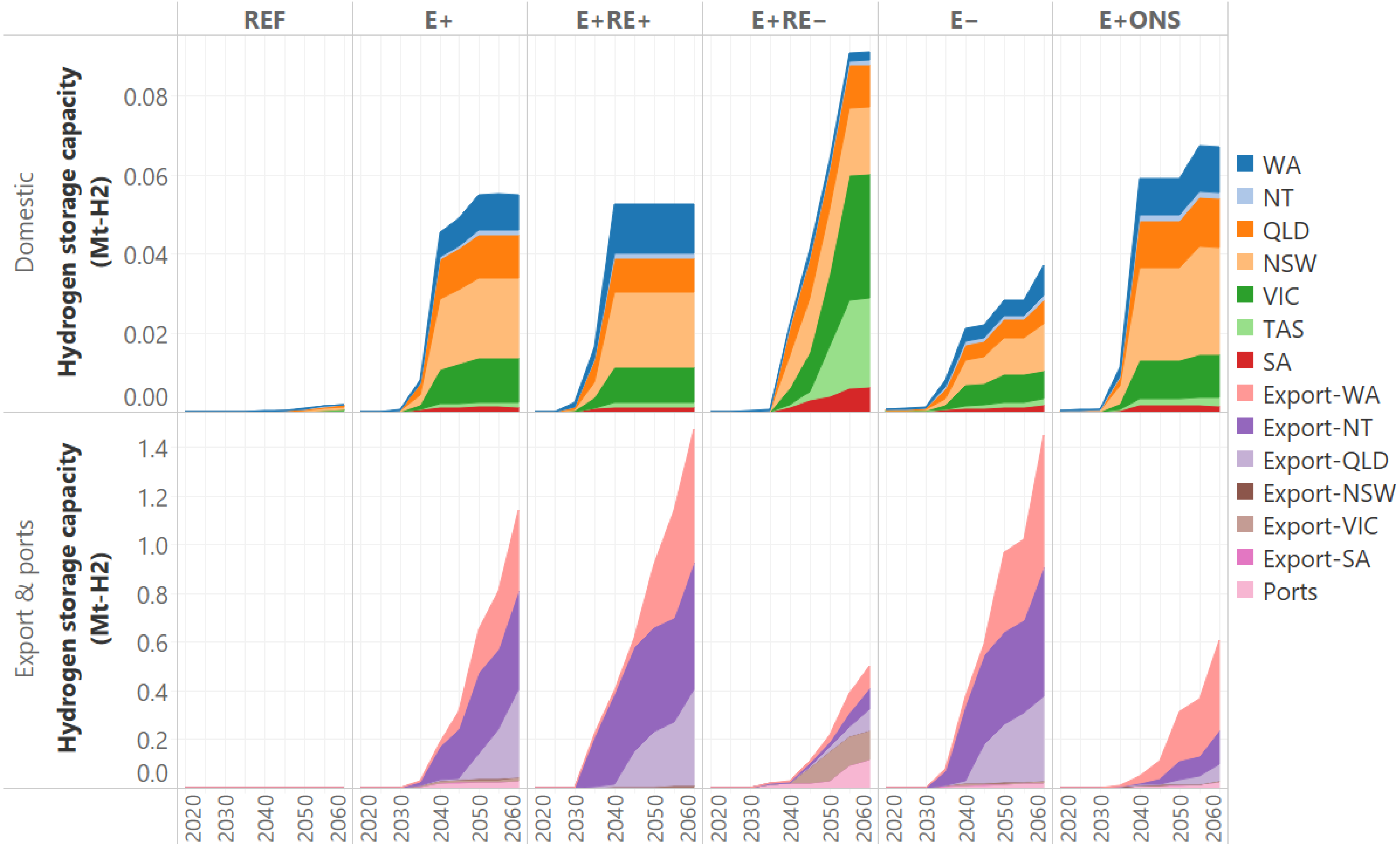


KEY TAKEAWAYS

- Haber-Bosch ammonia production is assumed for exports. Other hydrogen forms/derivatives (LH_2, methanol, etc.) may be more prospective.
- Around 140 Mt/year of hydrogen produced to substitute current fossil energy exports with clean carriers, except for ONS where only 80 Mt/year is produced
- Electrolysis dominates hydrogen production capacity in most scenarios.
- Blue hydrogen supplies a small early share in E+ and E−, none in E+RE+, and substantial share in E+RE−, due to increase in maximum CCUS capacity and renewable rollout constraints.
- Domestic role for hydrogen is small, relative to that produced for export.

Major underground hydrogen storage capacity is needed for the domestic system, and multiples more for exports

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

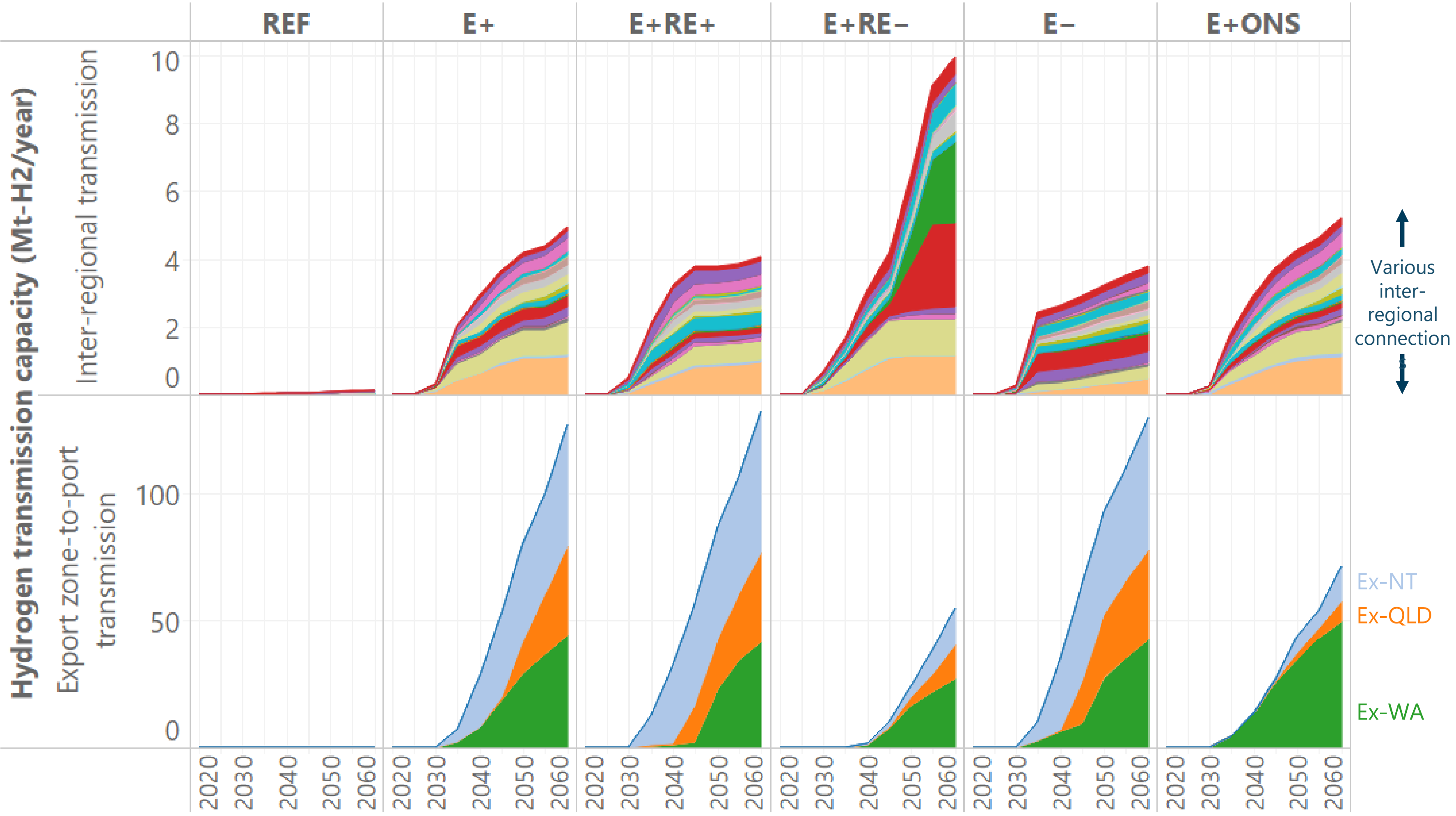


KEY TAKEAWAYS

- Major underground hydrogen storage capacity is needed across the country to serve the domestic system. 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.

Significant build of hydrogen transmission infrastructure is largely associated with export projects

Projections of inter-regional and export-to-port hydrogen transmission capacity
(Mt-H_2/year). Note 10× difference in y-axis scale

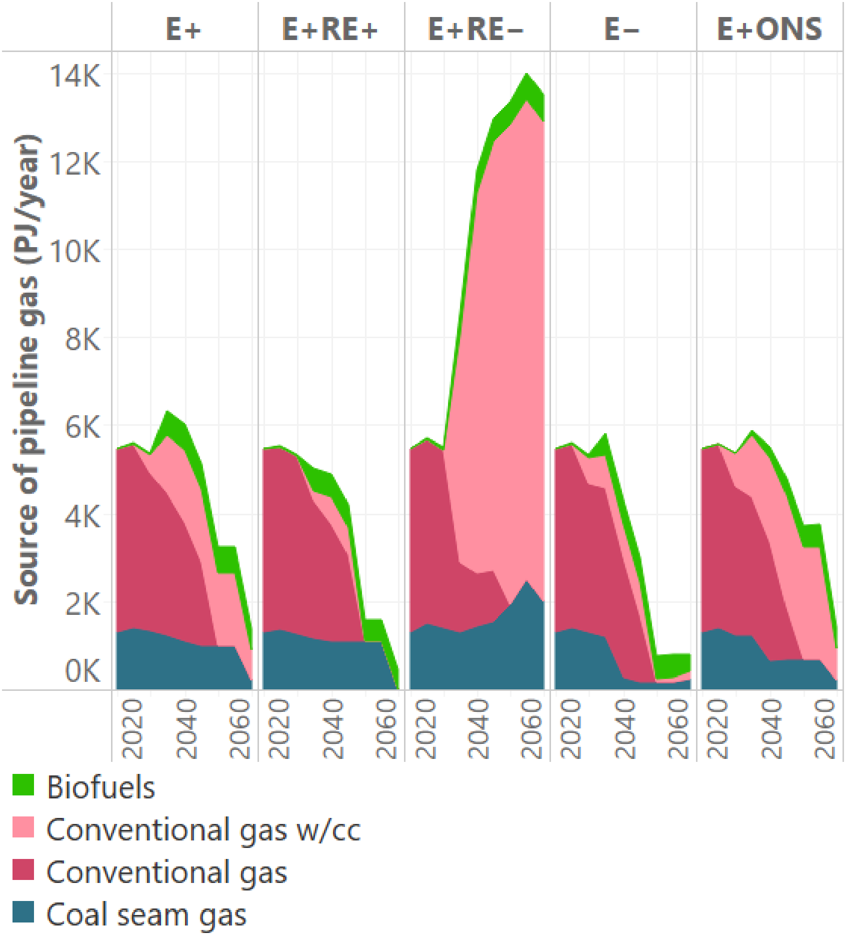


KEY TAKEAWAYS

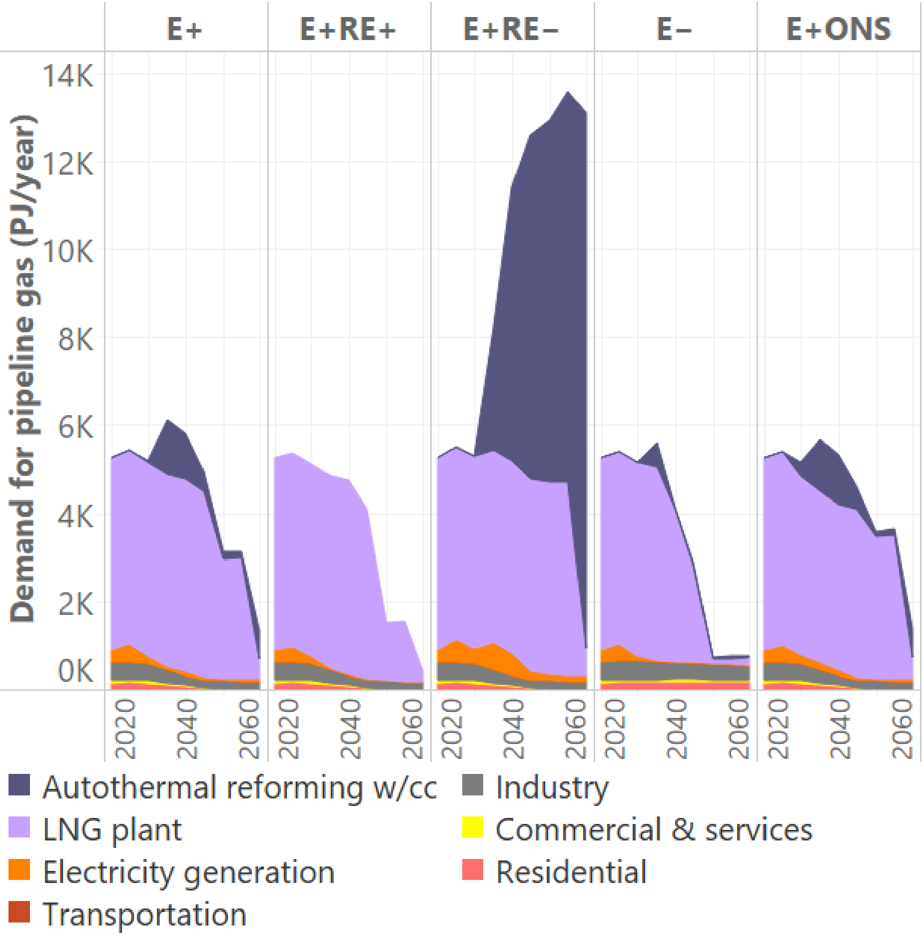
- Inter-regional hydrogen transmission infrastructure is minimal, compared with that needed for energy exports.
- Hydrogen transmission via pipeline is the favoured mode of energy transport from location of renewable energy generation (solar PV in export zones) to point of export (conversion to shipping vector at ports).
- These H_2 transmission capacity outputs from macro-scale energy system modelling have been downscaled to specific routes and mapped (see downscaling results).

Most Scenarios significantly reduce production and use of pipeline methane gas by 2060, except for E+RE−, where production expands for H2 production with CCS

Source of methane gas into pipelines
(PJ/year)



Demand for methane, by use/sector
(PJ/year)

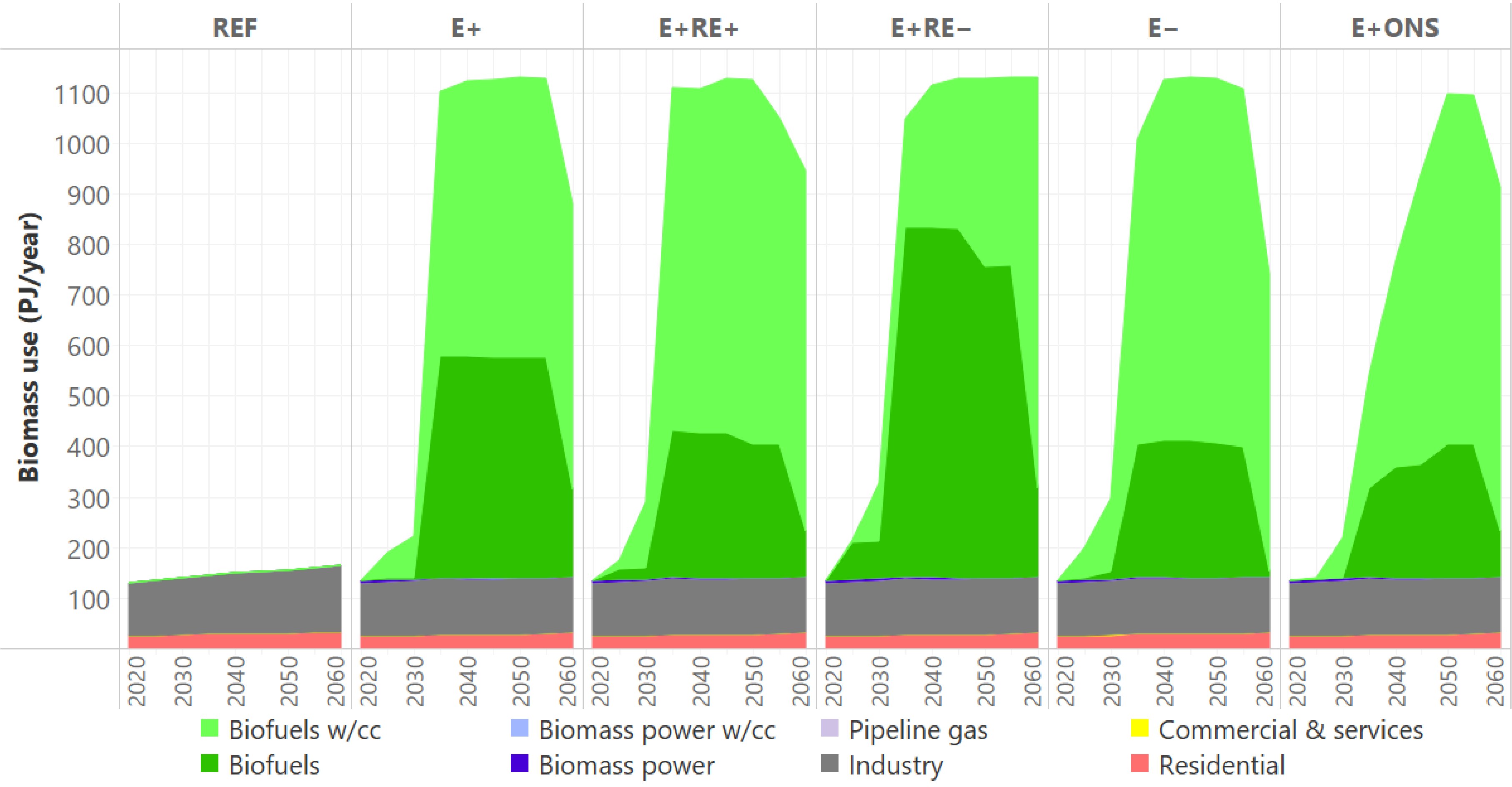


KEY TAKEAWAYS

- The demand for methane gas reduces significantly in residential, commercial, electricity generation sectors, and for LNG export across most Scenarios.
- The slower electrification E− Scenario retains some (<1000 PJ/year) demand for gas in residential and industrial sectors.
- The emissions of residual methane gas use are reduced through the production of bio-synthetic natural gas, retrofit of carbon capture on conventional gas production facilities, and negative emissions (DAC with renewables or biomass gasification, both with CCUS).
- Only E+RE− illustrates expansion of new gas production facilities. Used in autothermal reforming with carbon capture to maintain energy exports, given constrained renewables.

Bioenergy potential is limited by sustainable supply of biomass, but still expands by 8.5× to ~1,100 PJ/year

Projected biomass use, by sector/technology (PJ/year)



KEY TAKEAWAYS

- Australia's limited biomass supply used up to sustainable resource availability in all Scenarios to produce biofuels, including bio-synthetic natural gas, hydrogen, and bio-oils.
- 40-70% of biofuel production is coupled with CCUS, which constitutes atmospheric CO_2 removal (i.e. negative emissions).
- The majority of biofuel production comprises bio-synthetic natural gas, which is injected into gas pipelines and used across residential and industry sectors.

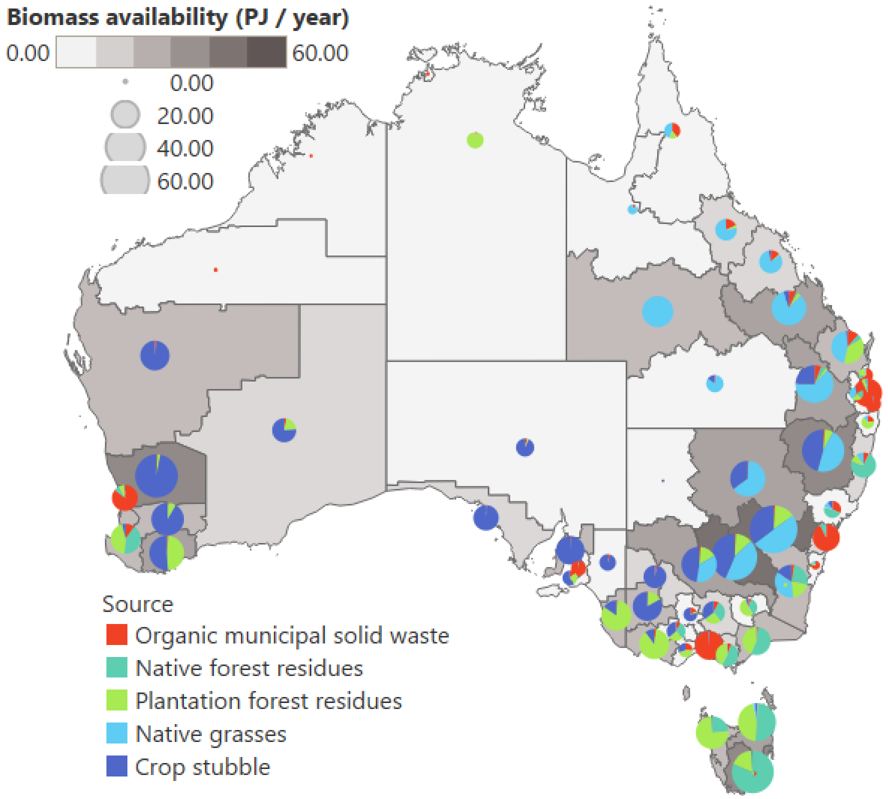
Bioenergy facilities are rapidly installed from 2030, and are regionally distributed based on location of distributed biomass resources

PILLARS

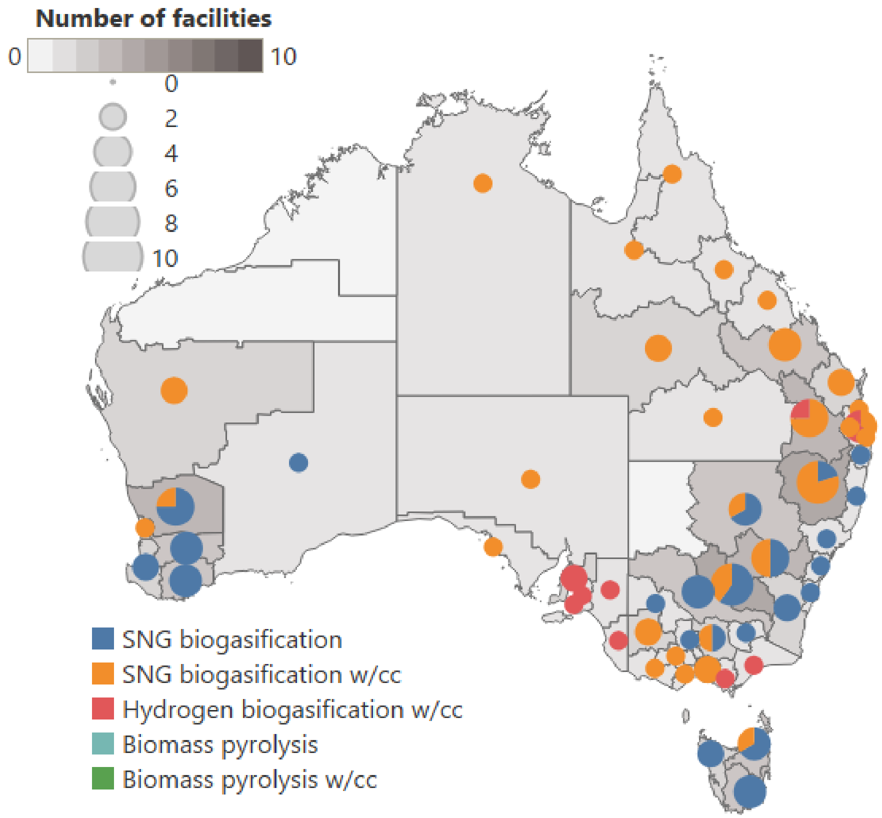
1 2 3 4 5 6

Zero carbon fuels and feedstocks

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



Number of bioenergy conversion facilities, E+ 2050.
Aggregated by plant type and ABS statistical division



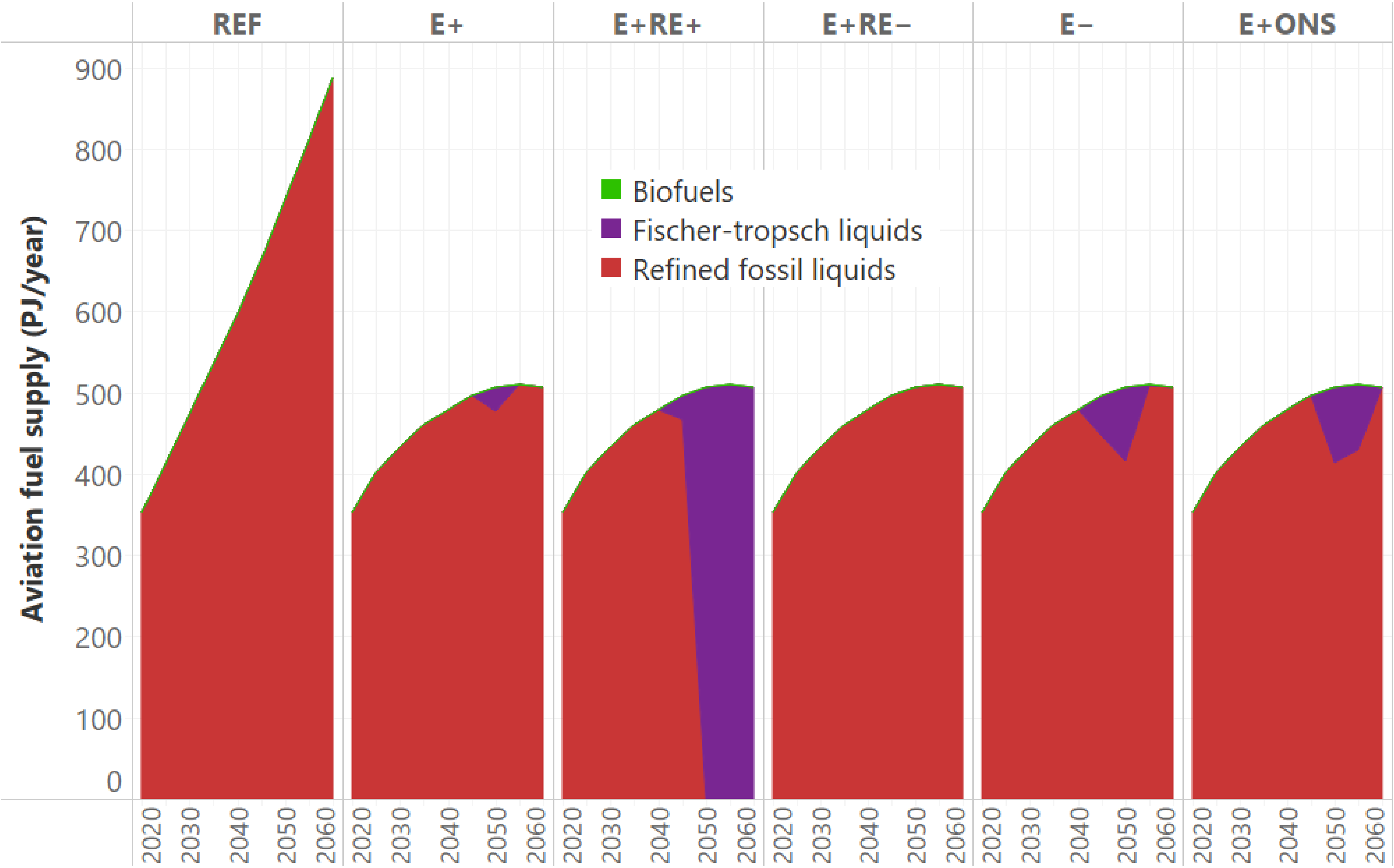
Each facility processes ~700 kilotonne biomass annually.
Note: We have downscaled precise location of facilities and are included with CCS infrastructure maps.

KEY TAKEAWAYS

- Approx. 1000 PJ/year (~80,000 kt/year) available dry biomass resource, comprising organic municipal waste from cities, waste residues from cropping and forestry, and native grasses.
- Biomass used primarily to produce low-emissions gaseous fuels (methane/SNG and hydrogen via biogasification) for pipeline injection.
- Limited liquid biofuels production in some scenarios.
- Many bioenergy facilities with carbon capture, connected to CO_2 use and sequestration pipelines.

Aviation remains largely dependent on fossil fuels, except in E+RE+, which prohibits fossil fuel use

Projected aviation fuel supply, by source (PJ/year)



KEY TAKEAWAYS

- Other than E+RE+, residual aviation emissions would be offset with negative emissions (DAC with renewables or biomass gasification, both with CCUS).
- 1.5% p.a. energy efficiency improvement avoids significant fossil fuel use (relative to REF) and is much greater than recent historical trends.
- Rigorous testing of synthetic aviation fuels for airworthiness required before a change to standards could be made to enable the 100% synthetic jet fuels.

PILLAR 4: CO_2 capture, transport, utilisation and storage

KEY FINDINGS

CCUS expands rapidly across all scenarios, including the high renewables scenario (E+RE+)

- Carbon capture, utilisation and storage (CCUS) expands rapidly across all Scenarios after 2030
- Direct air capture features in all scenarios, but E+RE− uses most, to offset residual emissions from high CCUS operations

Carbon capture, utilisation and storage (CCUS) expands rapidly across all Scenarios after 2030 (1/2)

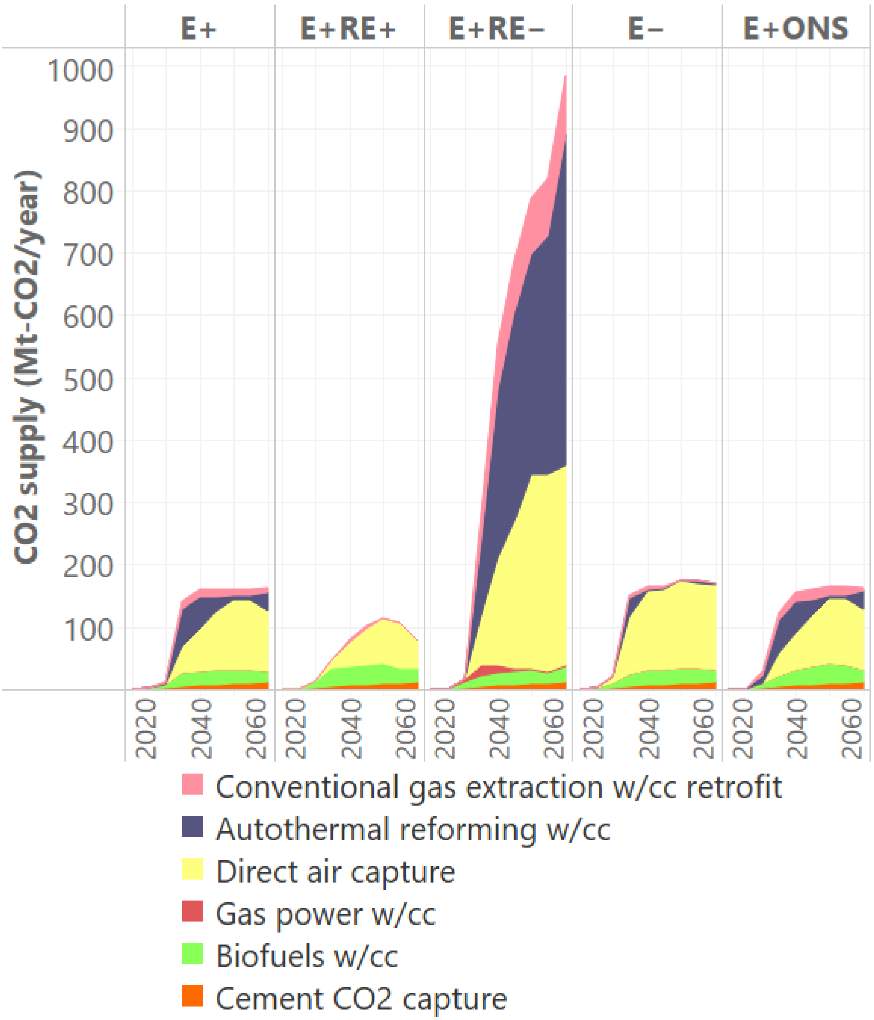
PILLARS

1 2 3 4 5 6

CO_2 capture, transport, utilisation and storage

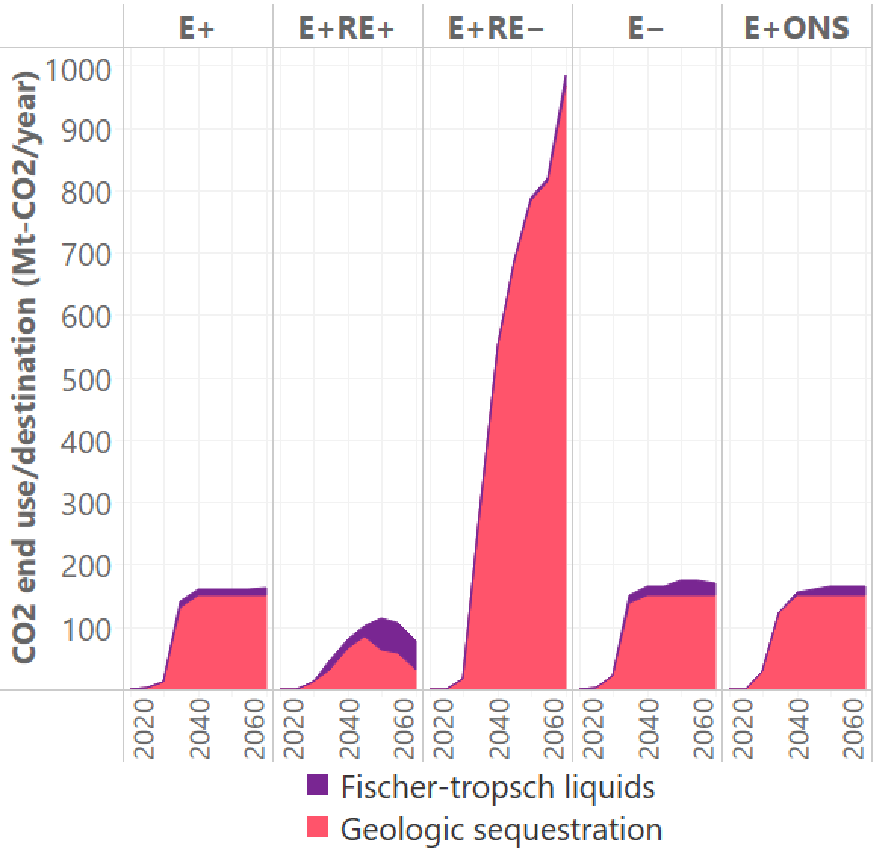
Projected CO_2 supply, by technology

(Mt-CO_2/year)



Projected CO_2 end use/destination

(Mt-CO_2/year)



KEY TAKEAWAYS

- Geological sequestration limit is rapidly reached in E+, E−, and E+ONS by 2040; used for cement process emissions, biofuels, and direct air capture (DAC).
- DAC provides carbon for net-zero hydrocarbons, and negative emissions (atmospheric CO_2 removal).
- Even E+RE+ requires CO_2 infrastructure for residual hard-to-abate emissions (cement and other industry/transport), and net withdrawals (BECCS/DAC).
- E+RE− requires expanded geologic sequestration potential to meet constant annual export energy demand.
- Expansion of conventional gas production in E+RE− requires capture and sequestration of process CO_2 emissions from both gas extraction and autothermal reforming.

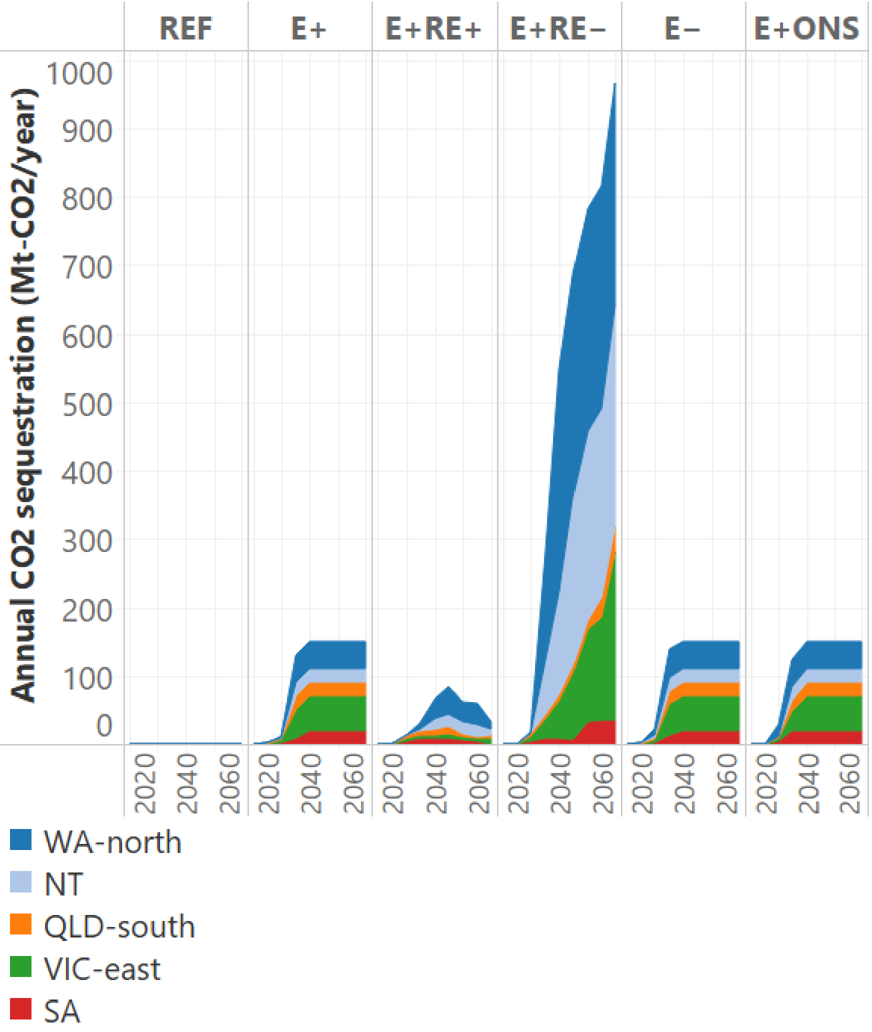
Carbon capture, utilisation and storage (CCUS) expands rapidly across all Scenarios after 2030 (2/2)

PILLARS

1 2 3 4 5 6

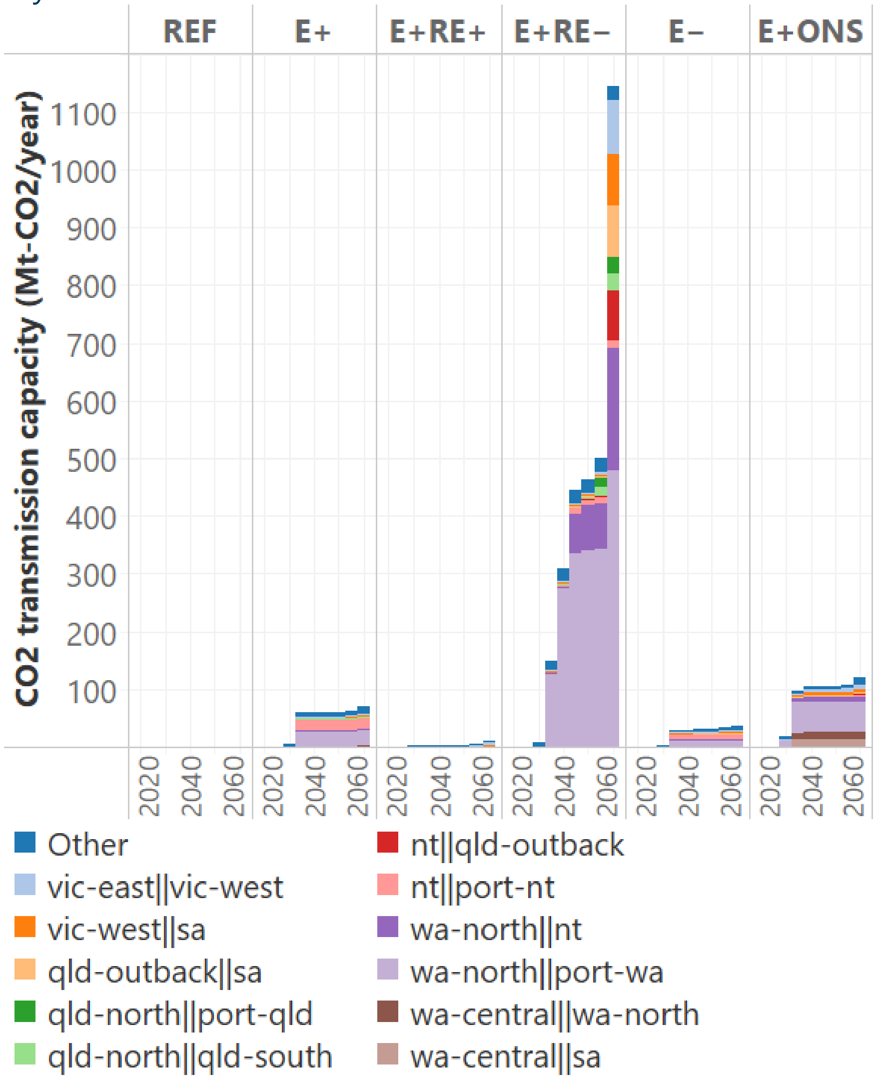
CO_2 capture, transport, utilisation and storage

Projected CO_2 sequestration ($Mt\text{-}CO_2$/year)



Projected CO_2 transmission capacity ($Mt\text{-}CO_2$/year)

Only select lines are shown



KEY TAKEAWAYS

- Geological sequestration limit is rapidly reached in E+, E−, and E+ONS by 2040.
- Significant transmission capacity required to transfer CO_2 to sequestration sites – except in E+RE+.
- CO_2 transmission capacity is typically less than total sequestered because DAC is located near sequestration sites, avoiding the need for CO_2 transmission.
- The largest geo-sequestration and CO_2 transmission is required in E+RE−, mostly for energy export activities.
- These CO_2 transmission capacity outputs energy system modelling have been downscaled to specific routes and mapped (see downscaling).

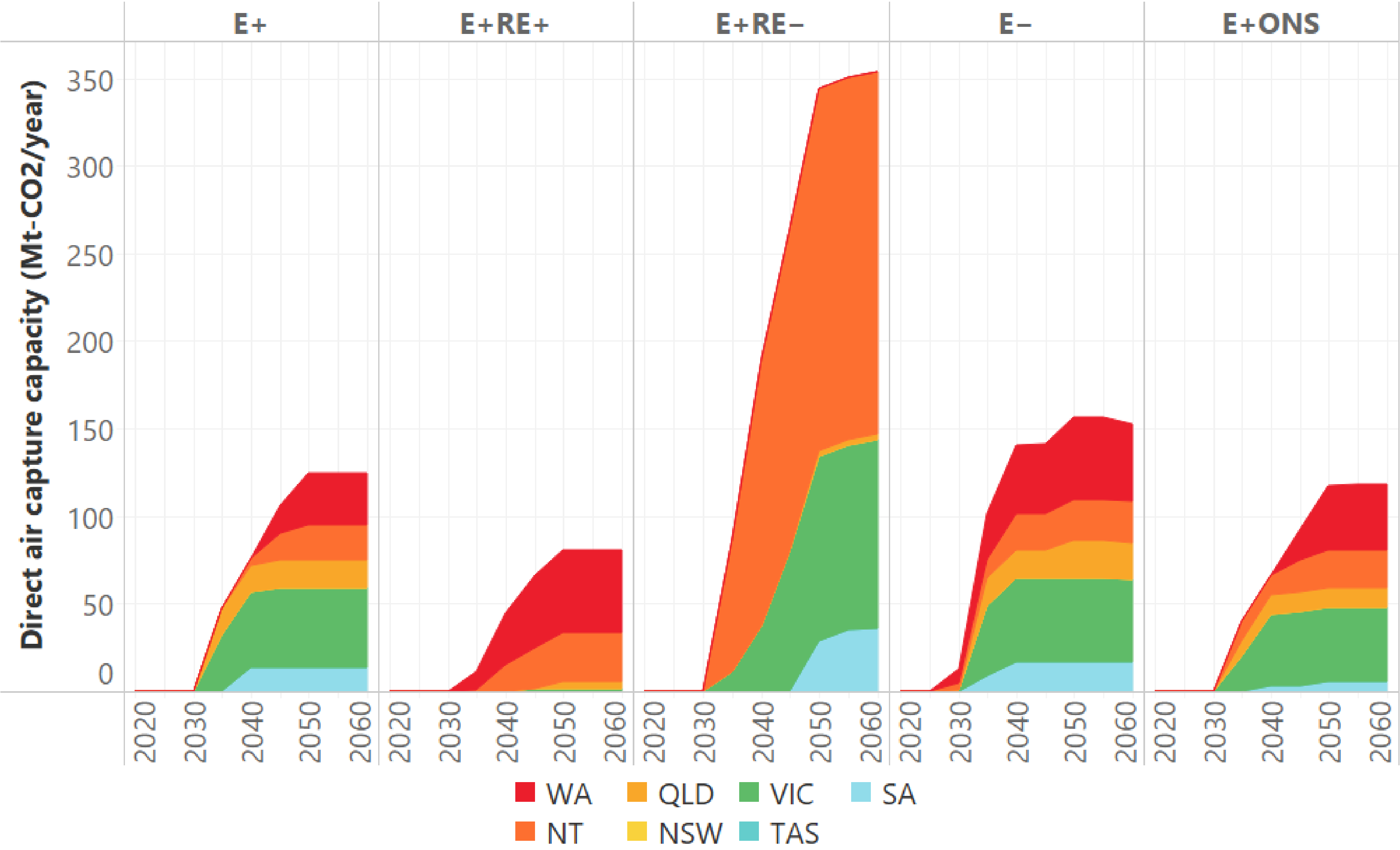
Direct air capture features in all Scenarios, but E+RE− uses most, to offset residual emissions from high CCUS operations

PILLARS

1 2 3 4 5 6

CO_2 capture, transport, utilisation and storage

Projected direct air capture capacity, by state/territory (Mt-CO_2/year)



KEY TAKEAWAYS

- E+RE− has larger sequestration potential and therefore has 3-5× DAC rollout of other Scenarios to offset expanded natural gas use.
- DAC facilities are located in regions with CO_2 sequestration potential, to avoid the need for extensive CO_2 transmission.

PILLARS 5&6: **Non-CO_2 emissions and land sinks**

KEY INSIGHTS

Non-CO_2 and land sector GHG emissions are projected to reduce, but remain a small net source of emissions

- Non-CO_2 and land sector GHG emissions are projected to reduce, but remain a small net source of emissions
- Afforestation of 5.1 million hectares of farmland would save ~50 Mt of CO2 per year

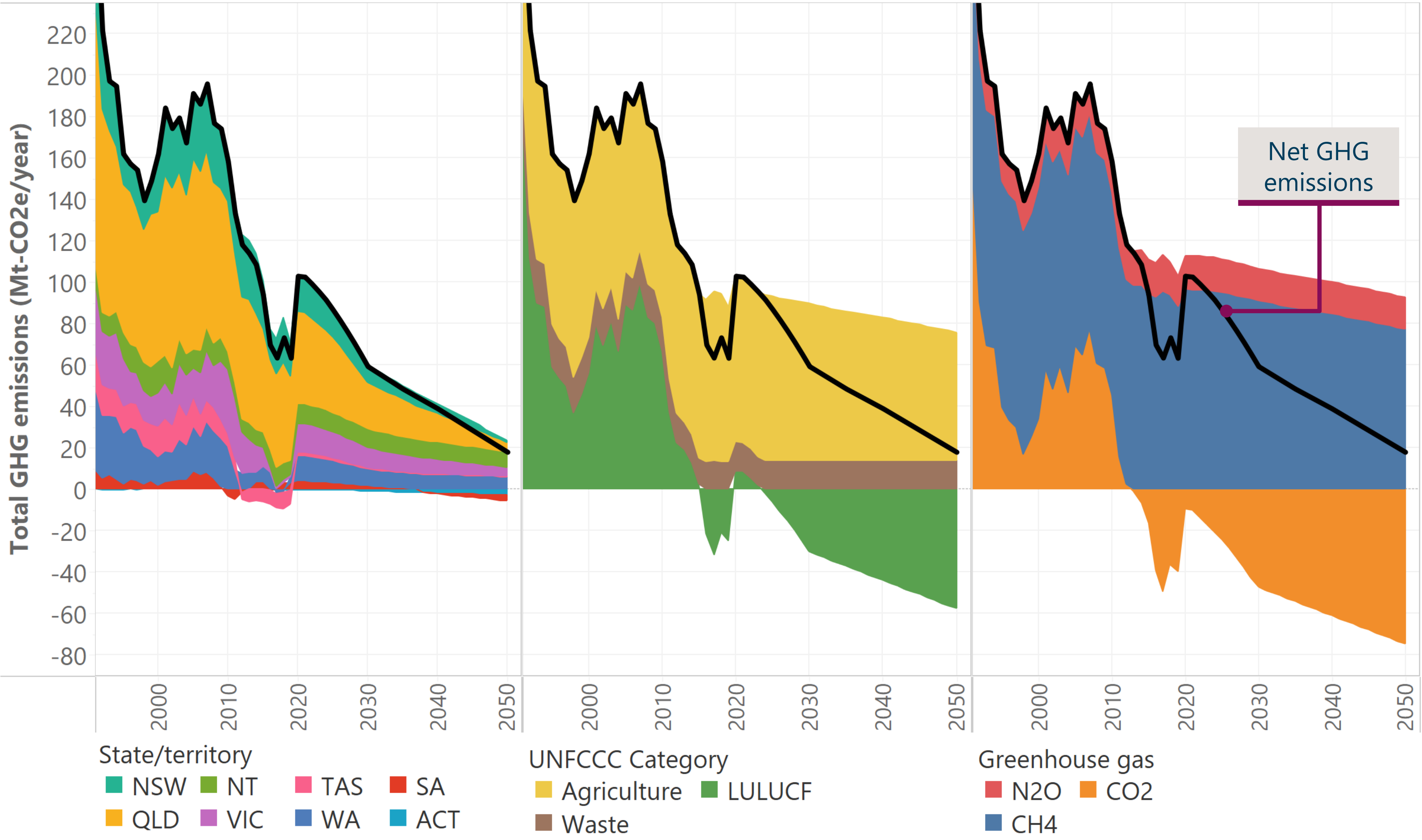
Non-CO_2 and land sector GHG emissions are projected to reduce, but remain a small net source of emissions

PILLARS

1 2 3 4 5 6

Non-CO2 emissions; Enhanced land sinks

Historical and projected Agriculture; Land Use, Land Use Change and Forestry; and Waste sector GHG emissions (Mt-CO_2e/year), by State/Territory, UNFCCC category, and GHG.



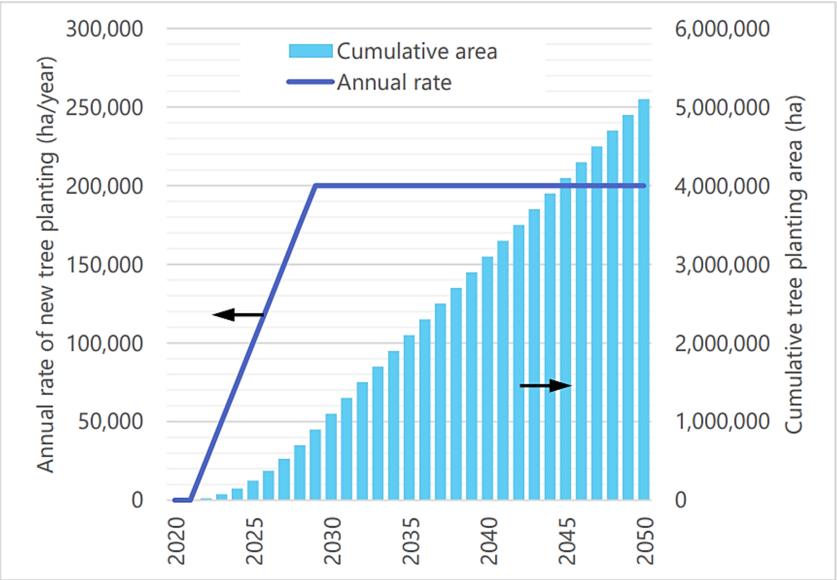
KEY TAKEAWAYS

- Agriculture and waste sectors remain GHG sources.
- Agriculture emissions projected to reduce through several measures: feed additives (i.e. 3-NOP) to reduce enteric fermentation, covered anaerobic ponds for manure management, and precision agriculture (slow-release nitrogen fertiliser).
- LULUCF can drive a net reduction through the lowering of land clearing rates and concerted afforestation of farmland.
- Modelled afforestation comprises 5.1 million hectares of new tree plantings to provide a net sink of 51 Mt-CO_2/year.
- Residual 19 Mt-CO_2e/year must be offset using DAC with renewables or biomass gasification, both with CCUS.

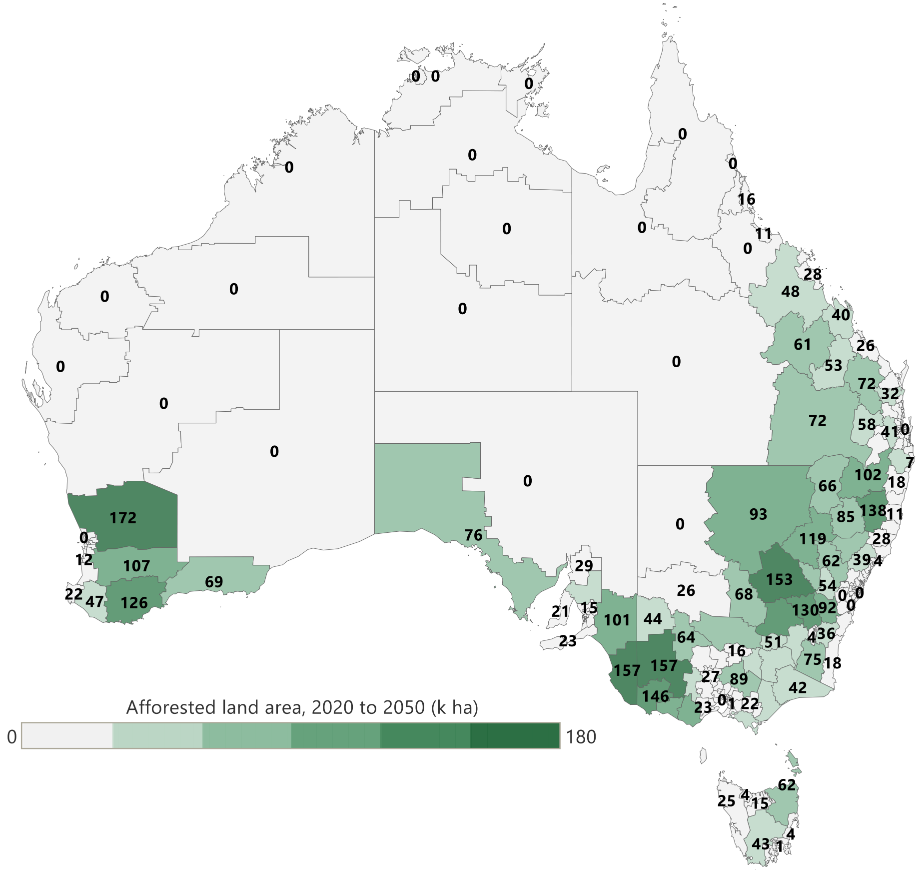
PILLARS
1 2 3 4 5 6
Non-CO2 emissions;
Enhanced land sinks

Afforestation of 5.1 million hectares of farmland would save ~50 Mt of CO2 per year

Projected annual rate (ha/year) **and cumulative area** (ha) **of new tree planting on agricultural land.**



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



KEY TAKEAWAYS

- In 2050 ~3% of current non-irrigated cropping land and ~15% of current non-irrigated pastureland may host new trees.
- A national average of 10tCO_2e/ha/year sequestration is plausible, with greater rates in higher rainfall areas.
- Approximately 10% of new trees (~5000 hectares) could be established as new timber plantation.
- Any program establishing trees on farmland should consider: the impact of natural disturbances and climate change, the need for carbon monitoring improvement, and the impacts on stakeholders.

FINAL MODELLING RESULTS

4.3 General insights

General insights: **System costs and capital**

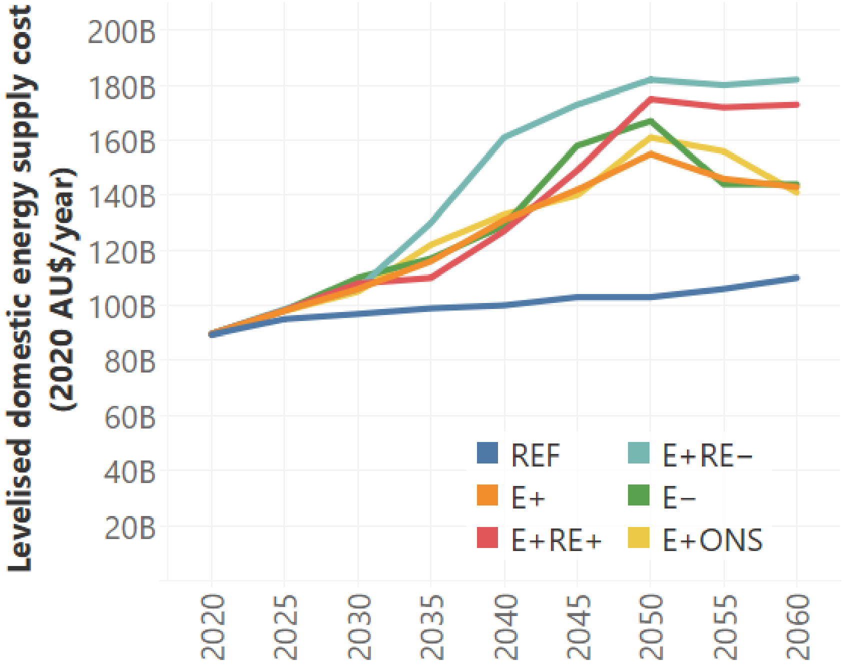
KEY FINDINGS

Domestic system costs will fall as a percentage of GDP, while export system costs will rise to reflect the economics of green energy exports

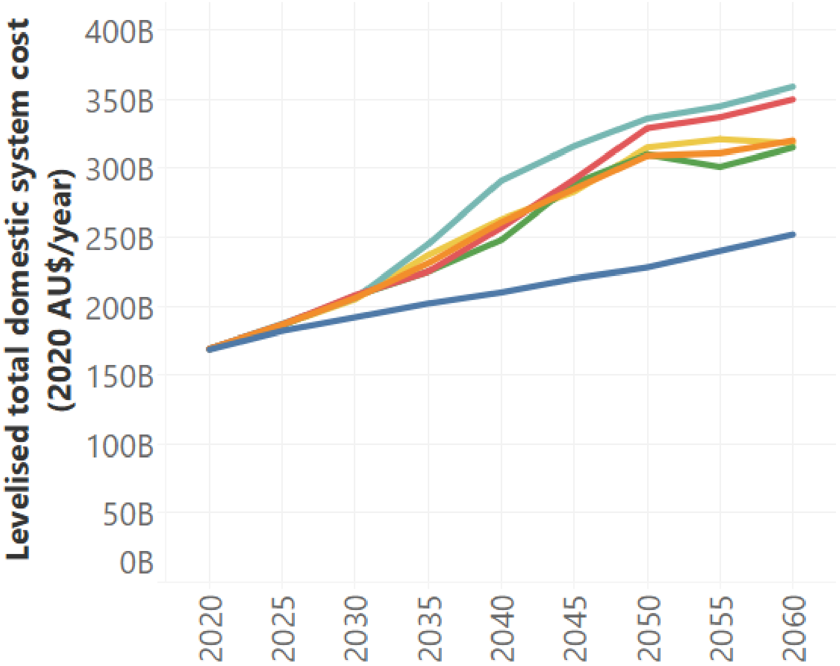
- Domestic system costs rise in absolute terms (1.3-1.5× reference case by 2050), with supply costs comprising around 50% of the total
- Domestic energy system costs stay around the same share of GDP to 2050, then fall
- Decarbonised export system will cost 5× more than reference case
- Capital costs of clean energy export supply chains drive the cost of the export system
- Costs of domestic emissions abatement are similar to net zero studies of other countries
- Net-zero transitions are capital intensive, requiring commitments of $7-9 trillion of supply-side capital to 2060

Domestic system costs rise in absolute terms (1.3-1.5× reference case by 2050), supply costs around 50% of total

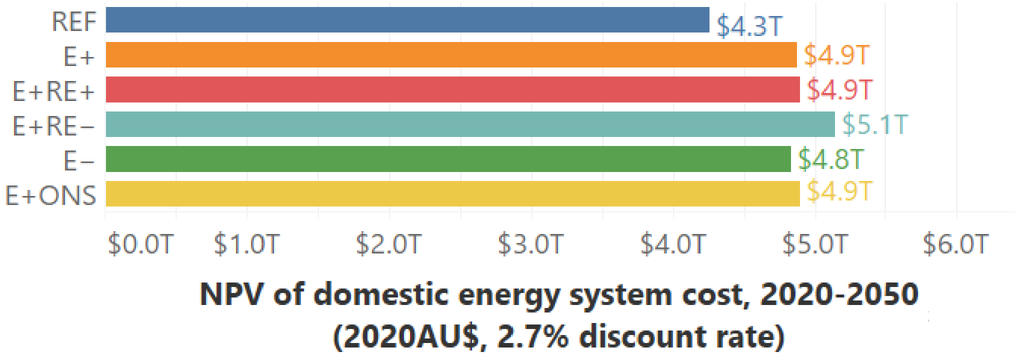
Levelised domestic energy supply cost
(2020 AUD billion/year)



Levelised domestic total system cost
(2020 AUD billion/year)



Net Present Value (NPV) of domestic energy system cost, 2020 to 2050
(2020 AUD trillion, 2.7% discount rate)



KEY TAKEAWAYS

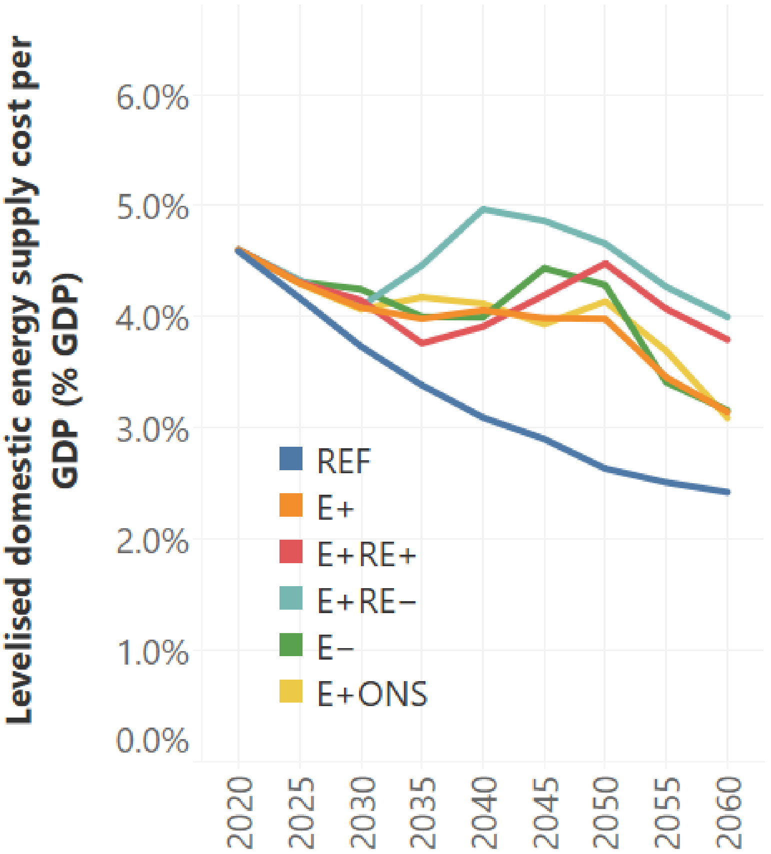
- Net-zero Scenarios have a discounted total cost of $600-900 billion NPV more than the reference Scenario (REF) from 2020 to 2050.
- Domestic energy supply costs are about 50% of total system costs.
- Slower electrification (E−) tends to have higher energy supply-side costs than rapid electrification (E+). However, these are counterbalanced by lower demand-side costs, so E+ and E− have similar total domestic costs.

What are 'domestic system costs'?

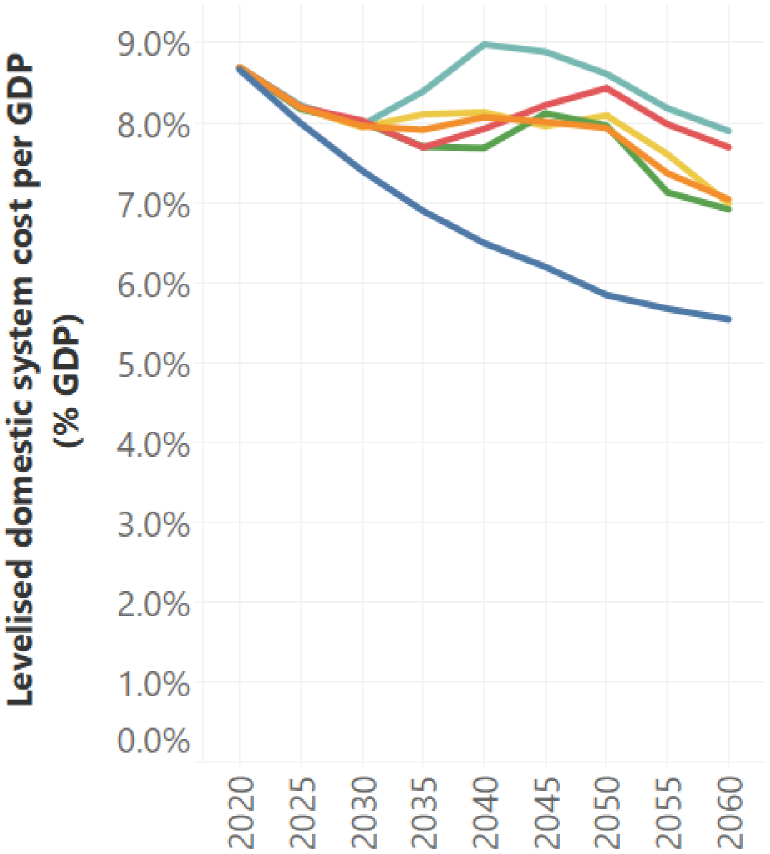
Total domestic system costs include both the energy demand-side costs (e.g. vehicles, home appliances, energy efficiency measures) plus the cost of supplying domestic final energy.

Domestic energy system costs stay around the same share of GDP to 2050, then fall

Levelised domestic energy supply costs as share of GDP (%GDP)



Levelised domestic total system costs as share of GDP (%GDP)



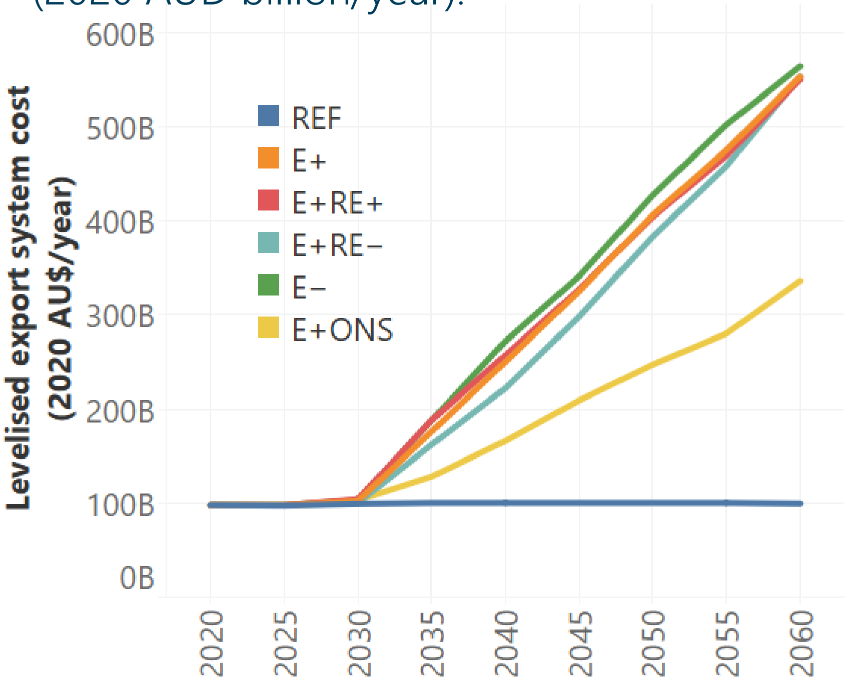
DOMESTIC SYSTEM COSTS

KEY TAKEAWAYS

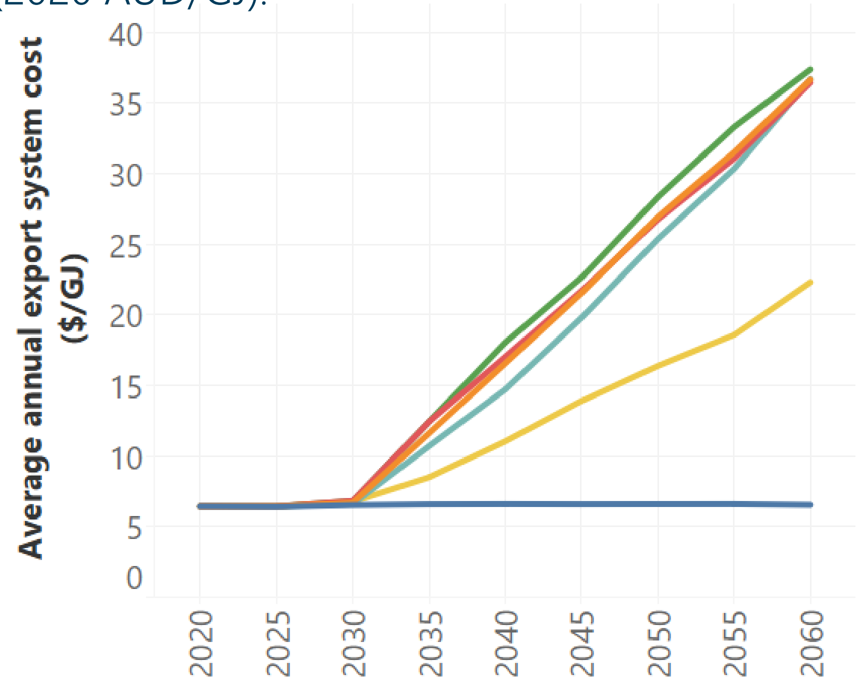
- Domestic system costs are mostly lower than the current share of GDP until 2050 (but 1.3-1.5× REF), and fall more rapidly thereafter.
- Peak domestic energy system costs are associated with the timing of the net-zero emissions constraint, but then ease as electrification, energy efficiency measures and build out of renewables continue.
- The Reference case (REF) assumes that fossil fuel costs remain consistently low, which is deeply uncertain, has not been modelled, and does not account for recent high fossil fuel prices.
- REF also does not take account of the expected decline in availability of fossil fuel-using technologies, or the costs of inaction on climate change.

Decarbonised export system will cost 5× more than reference case

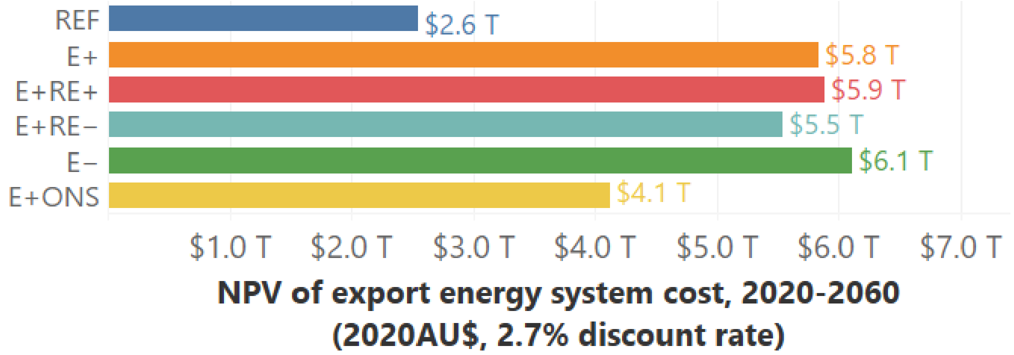
Levelised export system cost
(2020 AUD billion/year).



Average annual export cost
(2020 AUD/GJ).



Net Present Value (NPV) of export energy system cost, 2020 to 2060,
(2020 AUD trillion, 2.7% discount rate)



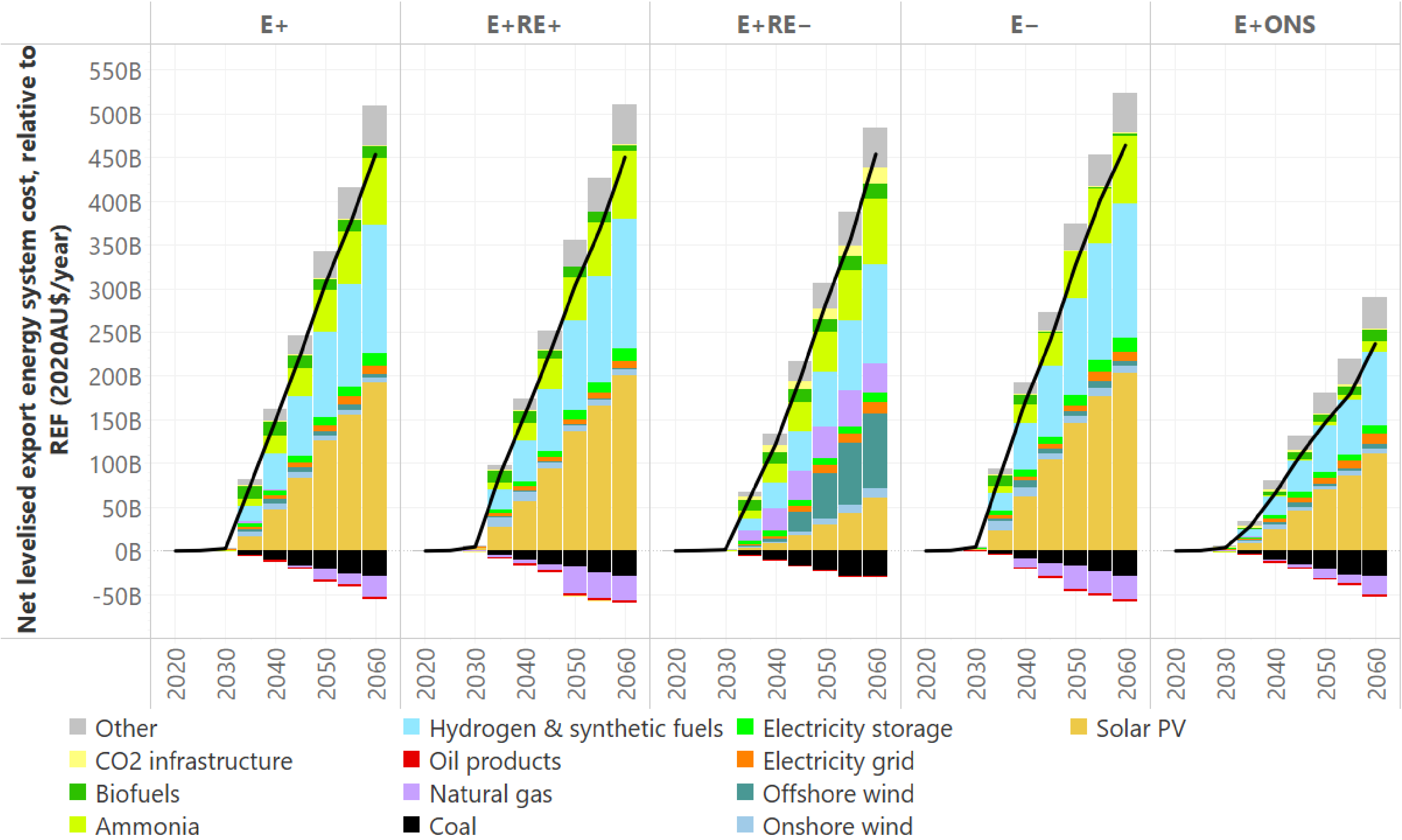
KEY TAKEAWAYS

- Cost between net zero Scenarios are relatively similar, except for the onshoring scenario.
- Direct processing of Australian resources (iron and aluminium ores) with Australian energy has significant energy efficiency benefit, and therefore also, lower cost, compared with the export of energy (see E+ONS)
- Energy exports costs are 5× REF – due to high starting costs, and energy conversion losses which counteract assumed renewable energy cost reductions.
- In a carbon constrained world, the cost of internationally traded energy is likely to increase, and Australia is likely to remain a competitive provider of energy. However, onshoring may be crucial to export competitiveness.

Capital costs of the clean energy export supply chain drive the cost of the export system

Net levelised export system cost, relative to REF, by cost components

(2020 AUD billion/year)



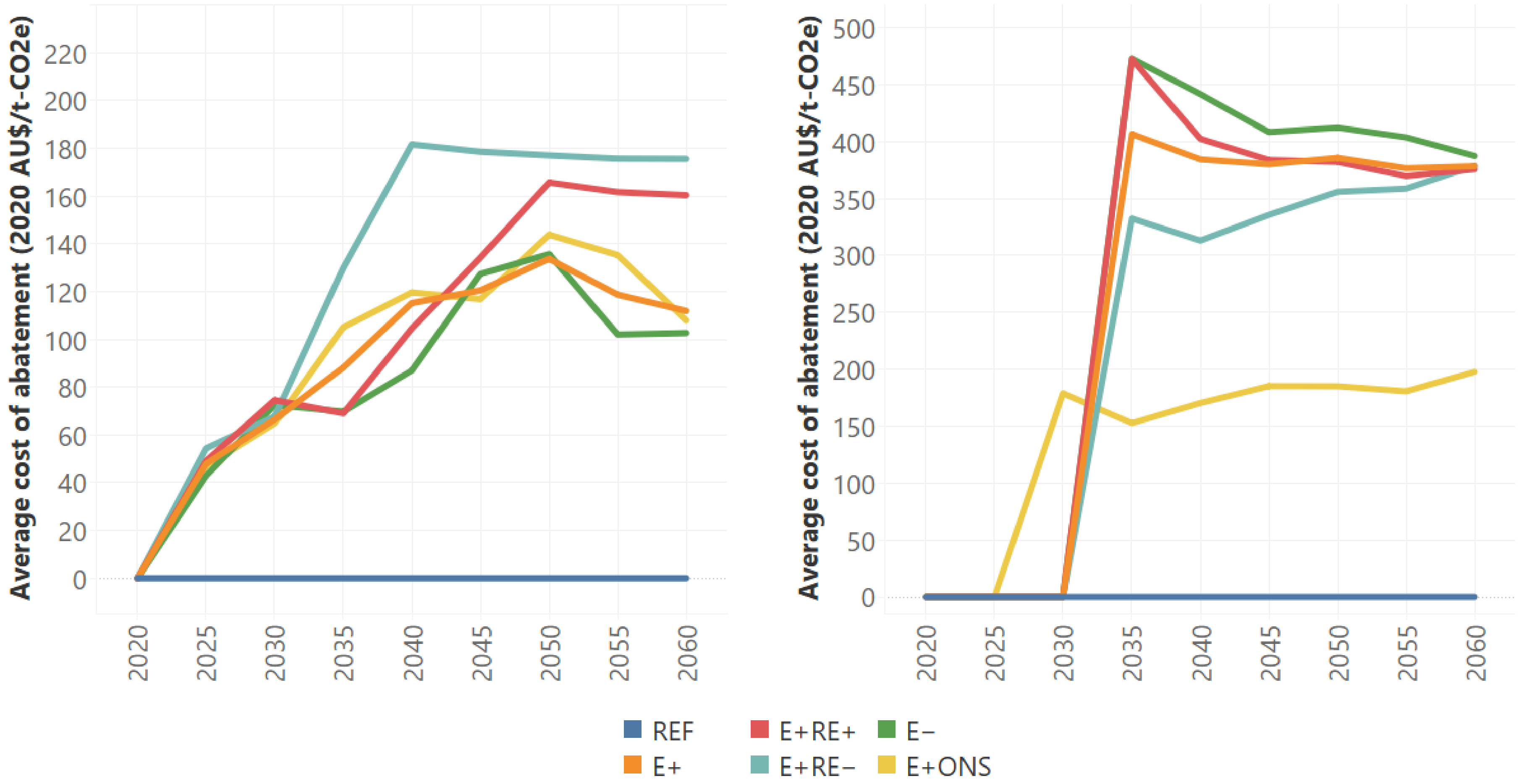
KEY TAKEAWAYS

- Export system costs are dominated by the capital costs of the energy export supply chain: **renewable electricity** (mostly solar PV) → **electrolysis** (some ATR w/cc) → **hydrogen storage** → **ammonia synthesis** → **shipping** (included in 'Other' category).
- Coal and natural gas production costs are avoided through the net-zero transition and appear here as net negative costs.

Costs of domestic emissions abatement are similar to net zero studies of other countries

Average domestic cost of abatement
(2020 AUD/t-CO_2e)

Average export cost of abatement
(2020 AUD/t-CO_2e)



ABATEMENT COSTS

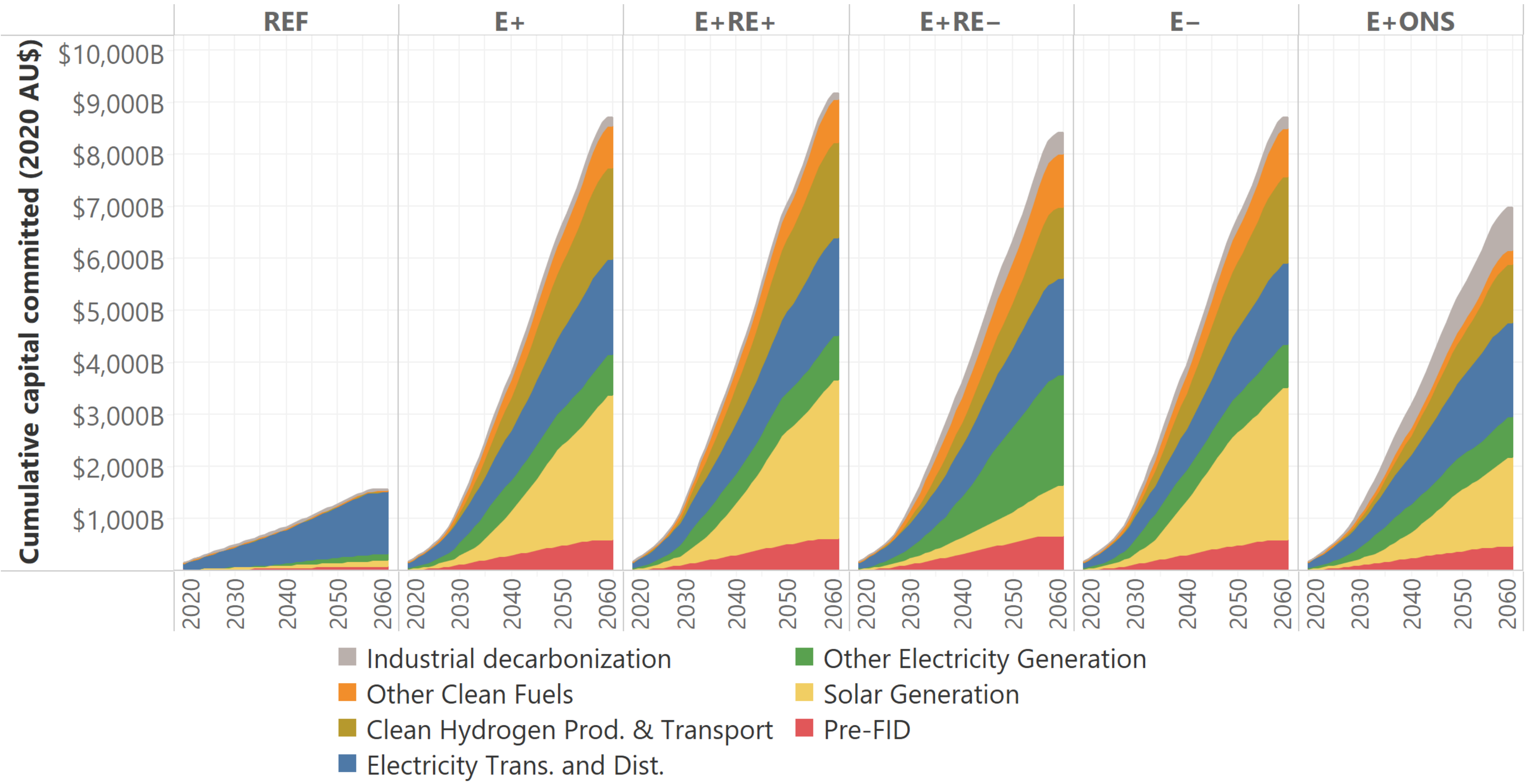
KEY TAKEAWAYS

- Average domestic system costs of emissions abatement rise to ~$150/t-$CO_2$e in 2050, which is a similar value to that found for other countries' net-zero decarbonisation studies (e.g. by the Net Zero America study).
- Average export costs of abatement rise to >$350/t-$CO_2$e, except for the onshoring scenario which is closer to ~$200/t-CO2e due to increased energy efficiency.

What is the 'cost of abatement'?
Average cost of abatement is the net levelised cost in a year (relative to REF), divided by the emission saved in that year (relative to REF).

Net-zero transitions are capital intensive, requiring commitments of $7-9 trillion of supply-side capital to 2060

Cumulative supply-side capital committed by year, for all sectors (2020 AUD billion)



CAPITAL MOBILISATION

KEY TAKEAWAYS

- Net-zero scenarios are 4.3 – 5.7 times as capital intensive as the REF scenario (to 2060).
- Clean electricity infrastructure investment represents 65-77% of total capital requirements.
- E+ capital demand is driven by a solar PV driven export transition.
- E+ONS capital demand has a much higher share of capital demand from industrial decarbonisation, driven by the onshoring of iron and aluminium industry & solar PV based hydrogen production.

Modelling note

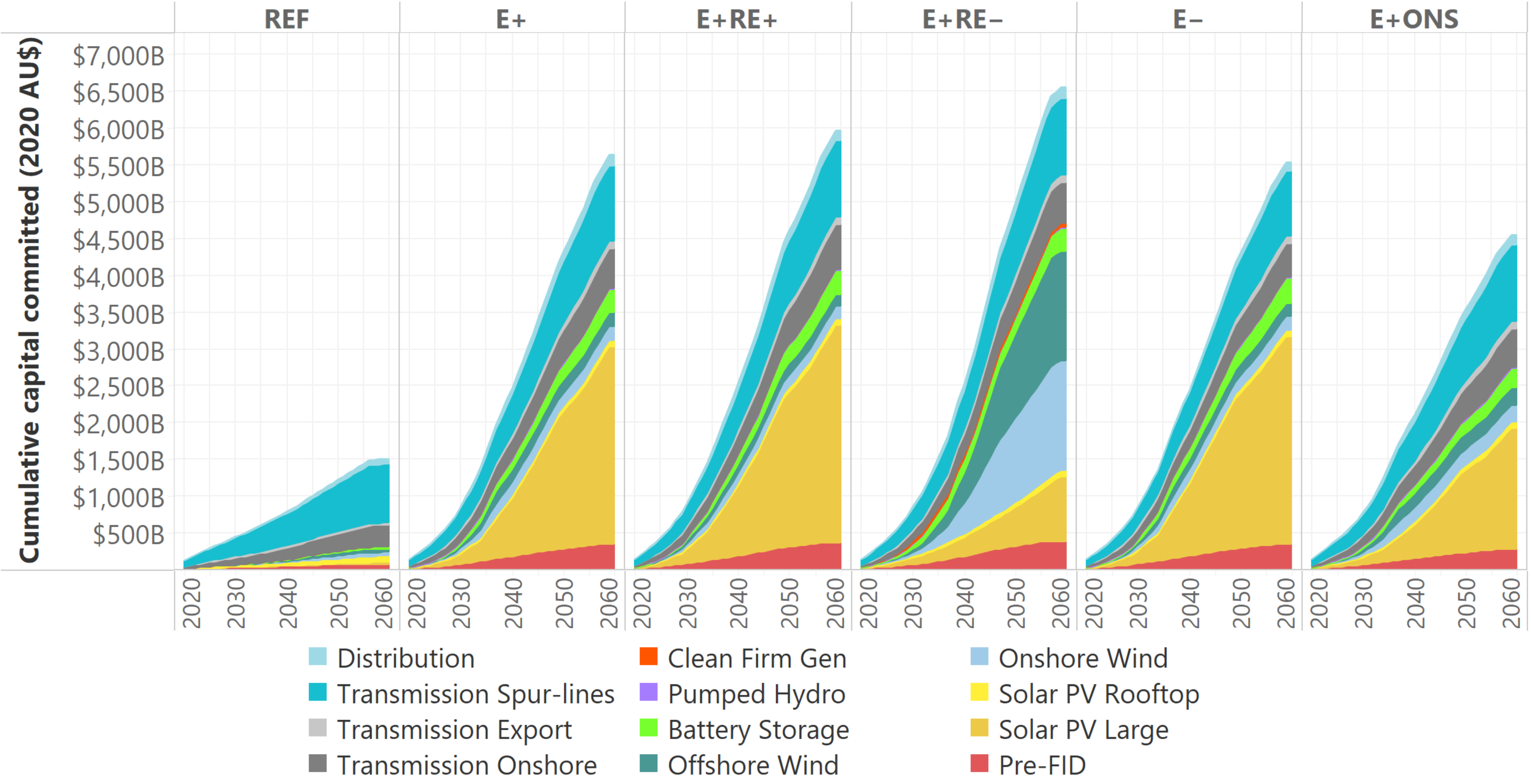
CO2 transport & storage is excluded from the capital needs, however these are typically small relative to CO2 capture capital, which is also small relative to electricity infrastructure and other clean fuels.

Net-zero transitions are capital intensive, requiring commitments of $7-9 trillion of supply-side capital to 2060

CAPITAL MOBILISATION

Cumulative supply-side capital committed by year, for clean electricity

(2020 AUD billion)



KEY TAKEAWAYS

- Capital demand across scenarios is driven by a solar PV dominated export transition, except for E+RE- which shares capital demand across wind, solar and natural gas.

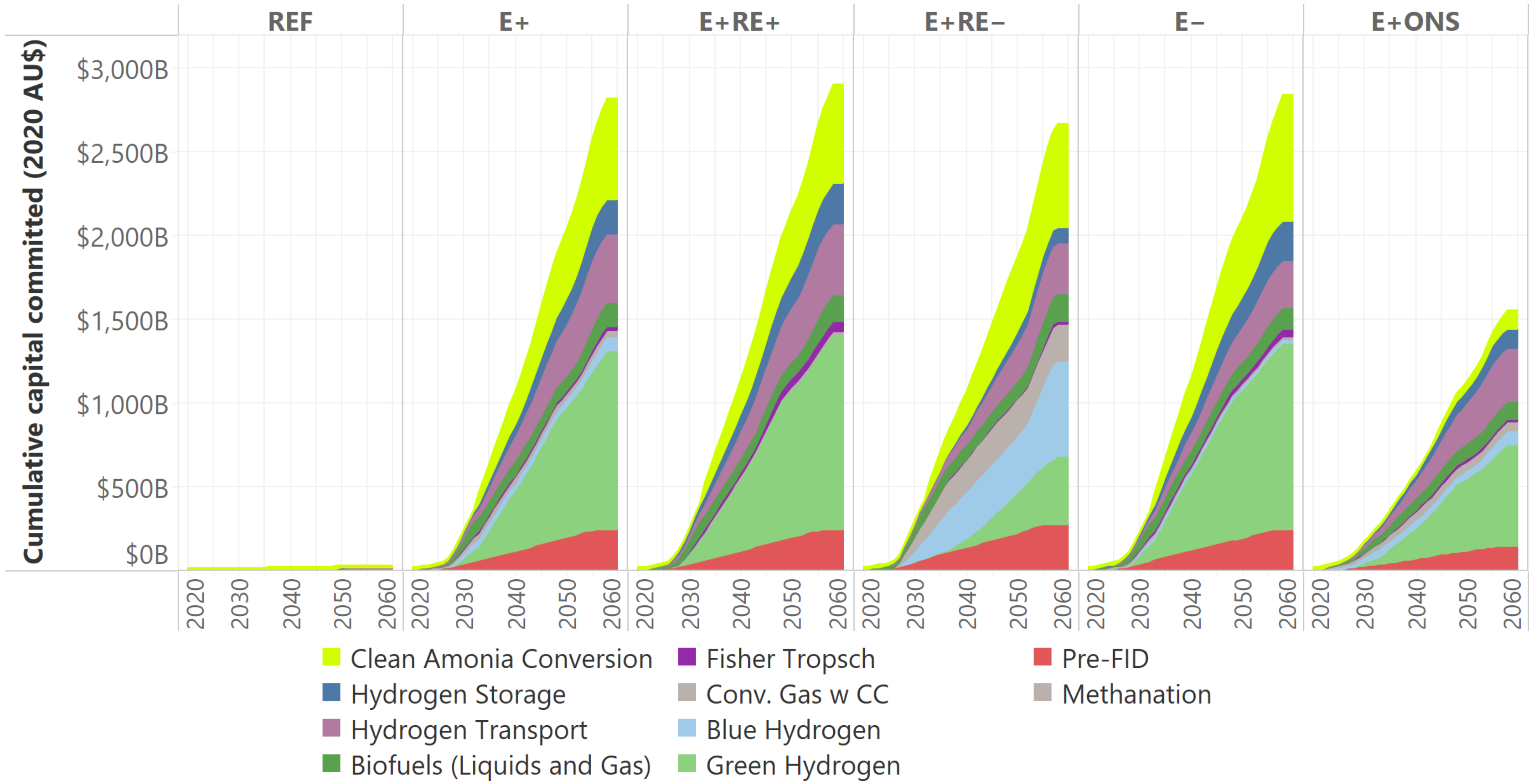
Modelling note

CO_2 transport & storage is excluded from the capital needs, however these are typically small relative to CO_2 capture capital, which is also small relative to electricity infrastructure and other clean fuels.

Net-zero transitions are capital intensive, requiring commitments of $7-9 trillion of supply-side capital to 2060

CAPITAL MOBILISATION

Cumulative supply-side capital committed by year, for clean fuels (2020 AUD billion)



KEY TAKEAWAYS

- Clean fuel capital requirements are similar across scenarios
- However, unlike other scenarios E+RE- splits hydrogen investment between blue and green.

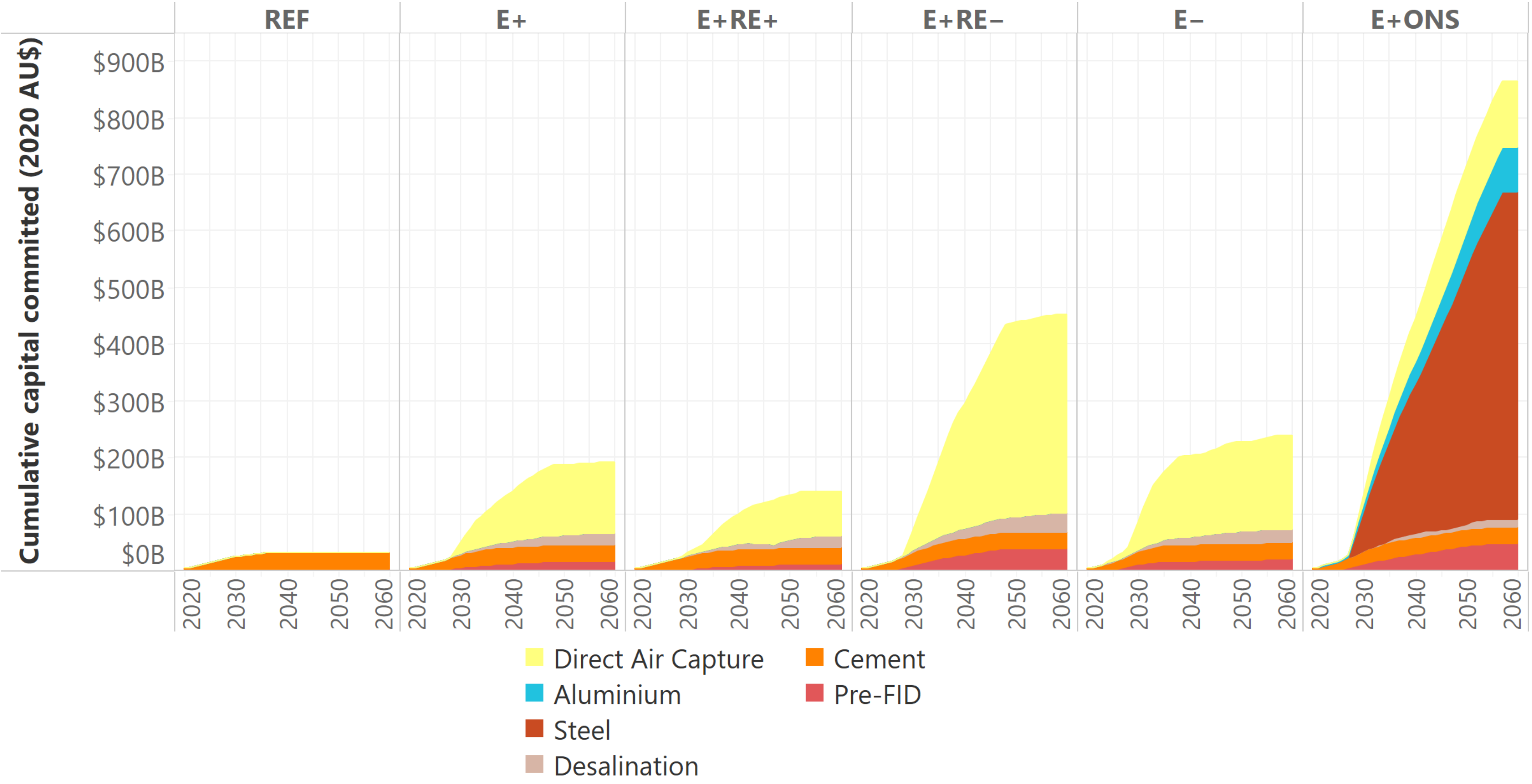
Modelling note

CO2 transport & storage is excluded from the capital needs, however these are typically small relative to CO2 capture capital, which is also small relative to electricity infrastructure and other clean fuels.

Net-zero transitions are capital intensive, requiring commitments of $7-9 trillion of supply-side capital to 2060

CAPITAL MOBILISATION

Cumulative supply-side capital committed by year, for industry decarbonisation and direct air capture (2020 AUD billion)



KEY TAKEAWAYS

- Direct Air Capture requires significant capital investment across all scenarios, with 2-3x investment required in E+RE- compared to other scenarios
- E+ONS capital demand has a much higher share of capital demand from industrial decarbonisation, driven by the onshoring of iron and aluminium production using domestically mined ores and hydrogen made with solar PV.

Modelling note

CO2 transport & storage is excluded from the capital needs, however these are typically small relative to CO2 capture capital, which is also small relative to electricity infrastructure and other clean fuels.

General insights: **Employment**

KEY FINDINGS

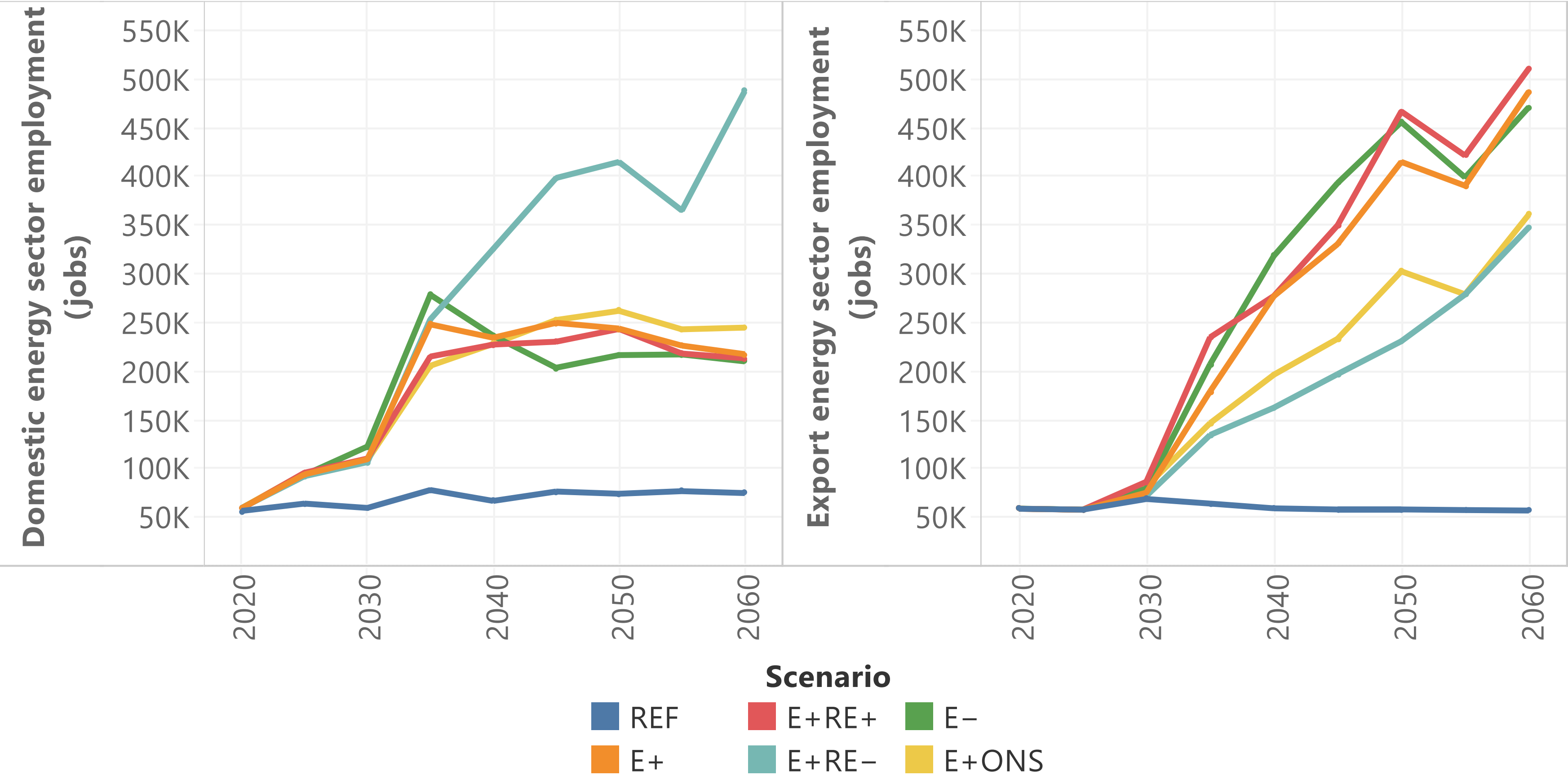
Across all net zero scenarios, the transition will create an additional ~550 thousand jobs in the energy sector.

- Gross energy sector employment could be 610 – 840 thousand by 2060, across both domestic and export energy systems
- Net increase of 470-700 thousand jobs in the energy sector, of which 290-450 thousand will support exports
- A large proportion of jobs are ongoing roles, in operations and maintenance.
- There will be significant job growth at all levels, with the largest growth in VET roles
- The largest job opportunities will be serving exports in Australia's north, in WA, NT and Queensland

Gross energy sector employment could be 610 – 840 thousand by 2060, across both domestic and export energy systems

EMPLOYMENT

Gross jobs by Scenario for the domestic (left) and export (right) energy systems.
(Full Time Equivalent (FTE) jobs).



KEY TAKEAWAYS

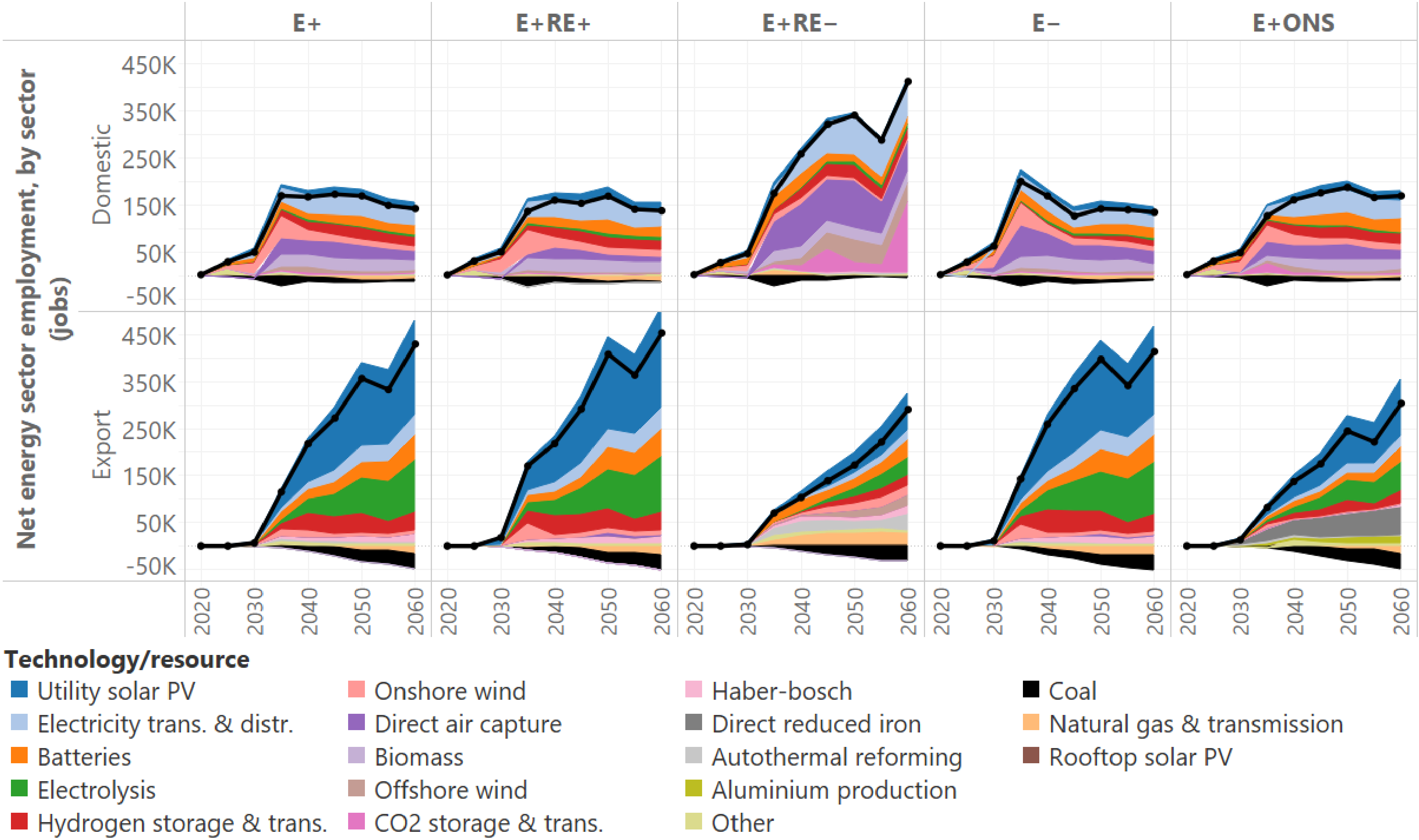
- Thousands of jobs are needed to serve the domestic and export energy systems in all Scenarios.
- Gross domestic jobs vary little between most Scenarios, with between 210-250 thousand jobs required in 2060 for the E+, E+RE+, E− and E+ONS Scenarios.
- Gross domestic jobs in the E+RE− Scenario are significantly higher, at 490 thousand jobs in 2060, due to greater coupling of domestic and export sectors.
- Gross export jobs also do not significantly vary, with between 350-510 thousand jobs modelled for all net zero Scenarios in 2060.

Modelling note

- Gross jobs represent the total number of jobs in each year employed in the energy sector.

Net increase of 470-700 thousand jobs in the energy sector, of which 290-450 thousand will support exports

Net employment (relative to REF), by technology (Full Time Equivalent (FTE) jobs).



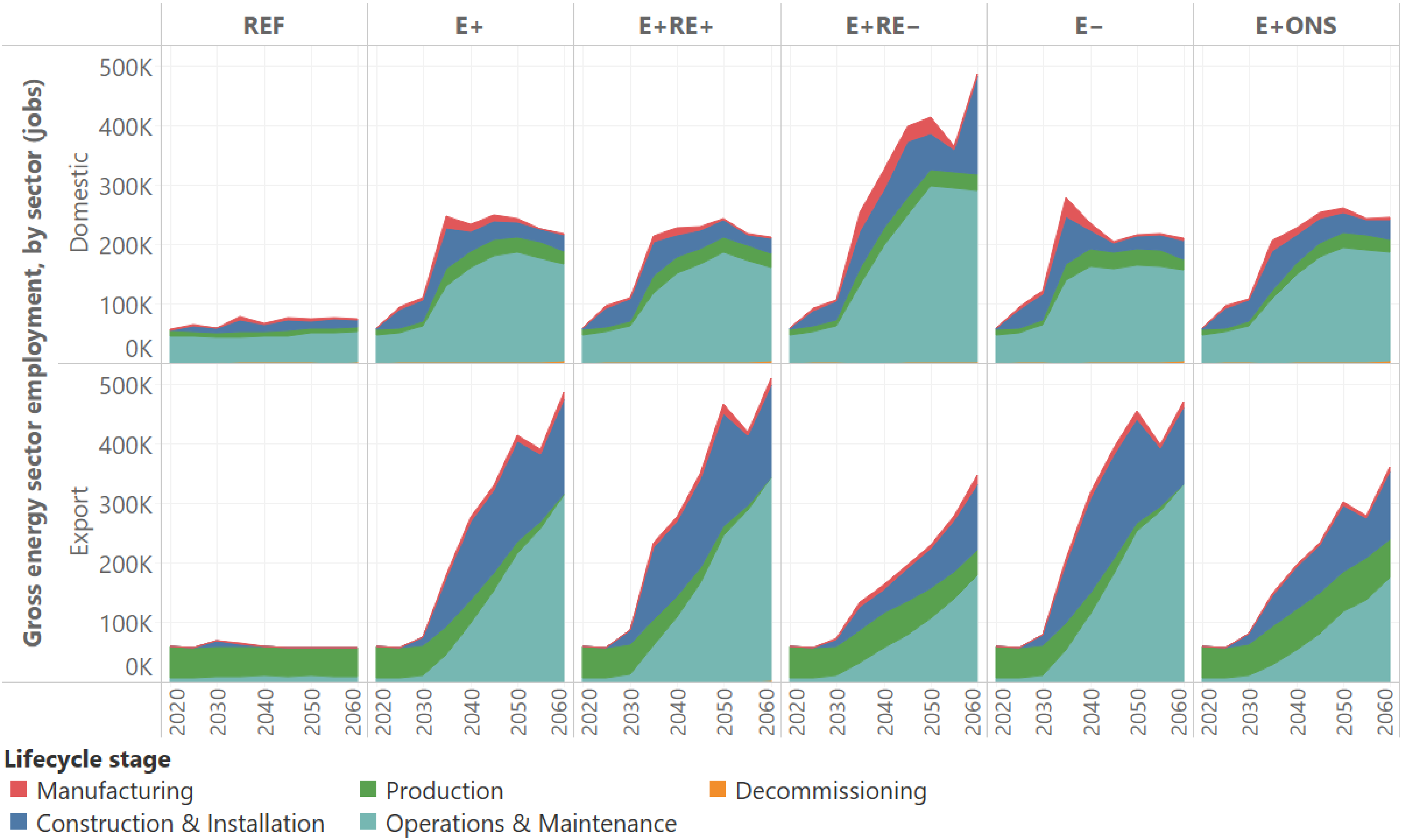
EMPLOYMENT

KEY TAKEAWAYS

- Job losses are concentrated in coal and natural gas sectors, largely serving exported energy demand.
- Net domestic coal jobs peak at −23,000 in 2035. Net coal jobs is similar to the reference case in 2060 as the reference case also models a reduction in coal jobs.
- Majority of new jobs serve export demand in technologies that dominate the export energy supply chain, i.e. utility solar PV, electricity transmission, batteries, electrolysis and hydrogen storage and transmission.
- New jobs serving the energy export market will also generate many additional, supporting jobs (e.g., health care, services, etc.) as new settlements are established.

A large proportion of jobs are ongoing roles, in operations and maintenance.

Gross jobs by type (stage in project lifecycle) (Full Time Equivalent (FTE) jobs).

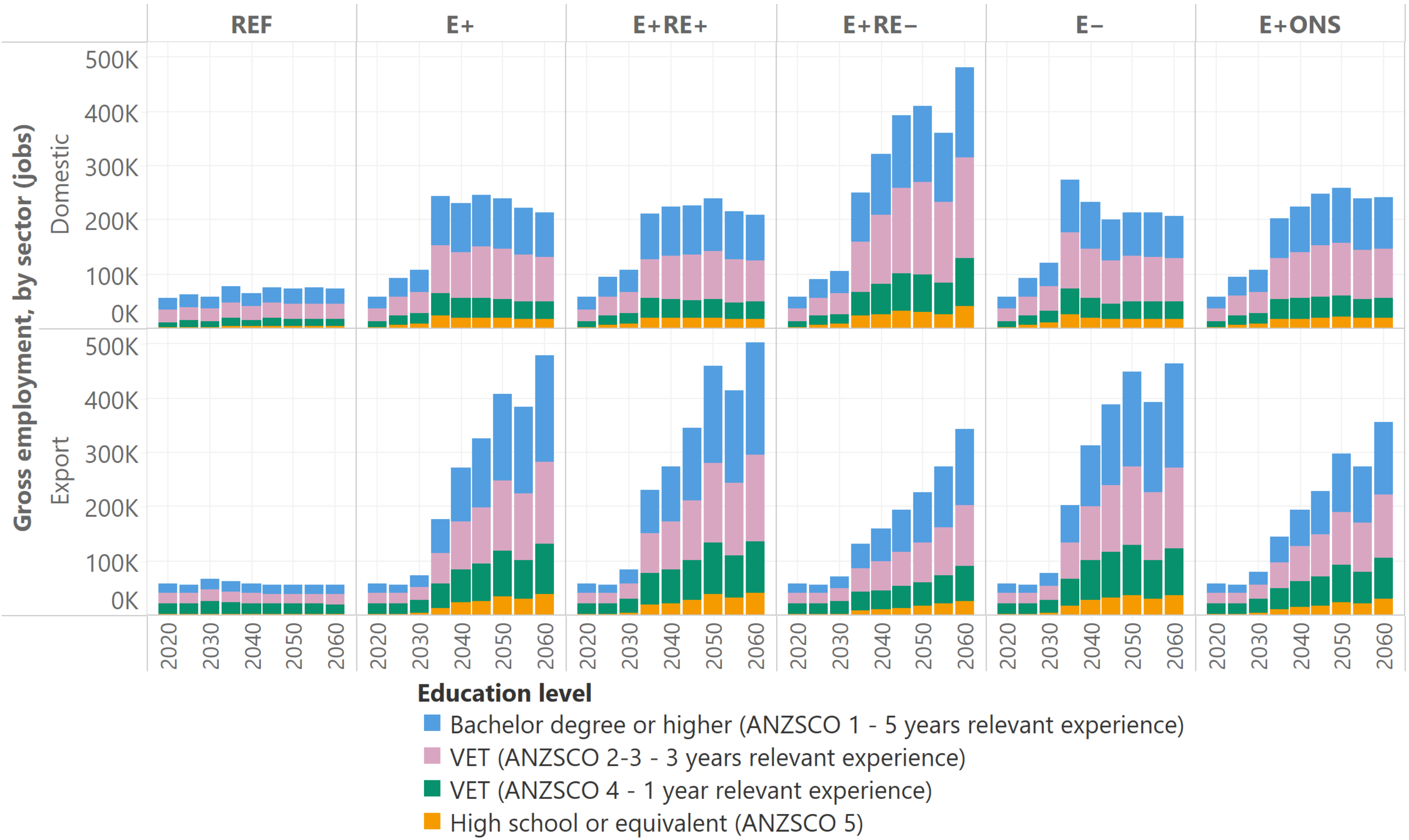


KEY TAKEAWAYS

- Net zero scenarios will require 160 to 290 thousand ongoing domestic system operations and maintenance (O&M) jobs.
- New jobs are initially mostly construction and installation roles, but then transition to be mostly O&M roles by 2030s.
- O&M roles increase from ~50% of energy sector employment to ~75% by 2050-60.
- Production jobs in coal and natural gas extraction generally decrease, partially offset by biomass production jobs.
- Manufacturing jobs consistently contribute between 1-3% of total jobs throughout 2030-2060, due to Australia’s currently limited manufacturing capacity.

There will be significant job growth at all levels, with the largest growth in VET roles

Gross jobs by level of education (Full Time Equivalent (FTE) jobs).



EMPLOYMENT

KEY TAKEAWAYS

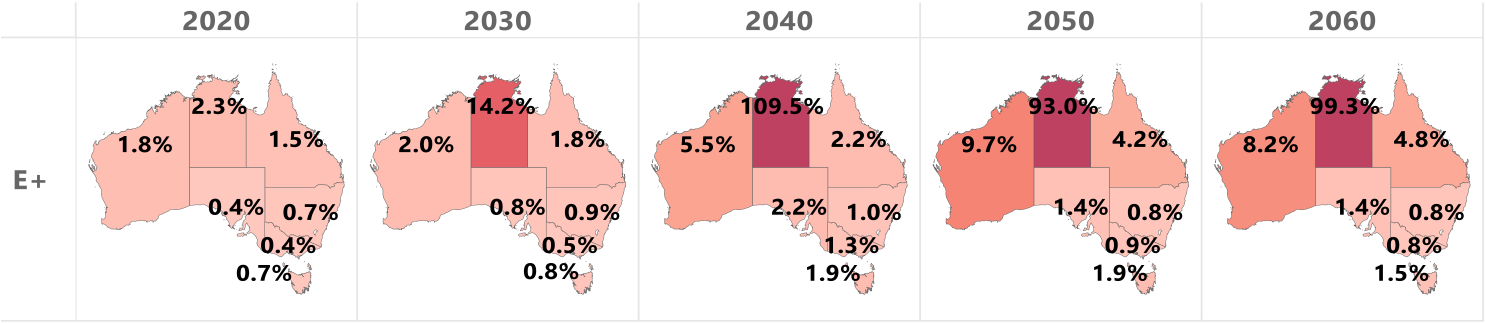
- Large growth in jobs of all types.
- Majority of jobs created are for VET/TAFE graduates.
- Domestic sector proportional employment by skill level is generally stable, with most skill levels fluctuating a few percentage points throughout 2020-2060 but growing significantly.
- There is more change in the export sector as lower-skilled jobs in coal mining are replaced by occupations at skill levels 1-3. Specifically, this includes drillers, miners and shot firers which currently occupy a large proportion of the export workforce.

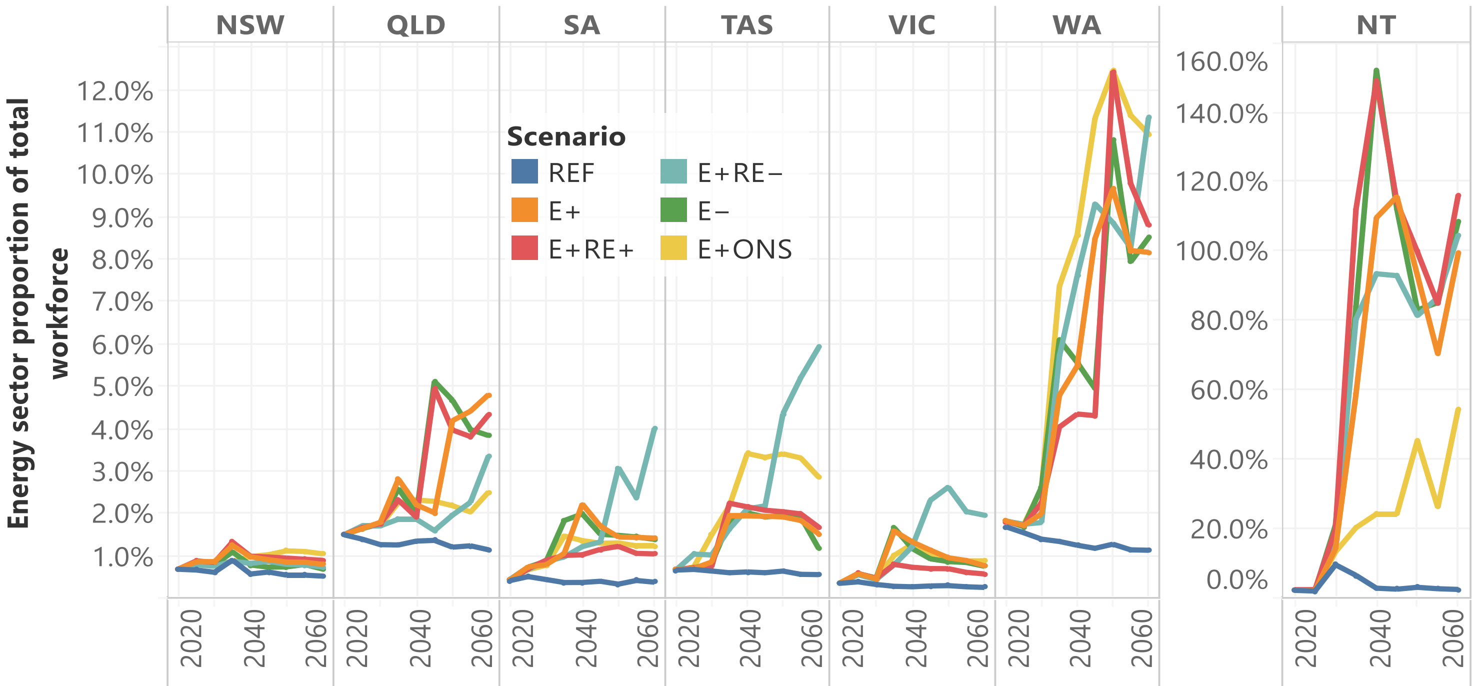
EMPLOYMENT

The largest job opportunities will be serving exports in Australia's north, in WA, NT and Queensland

Proportion of projected workforce employed in energy sector by state

(Percentage of workforce working in energy sector)





KEY TAKEAWAYS

- Current energy sector jobs account for less than ~2% of jobs in each State.
- The majority of new energy sector jobs are driven by the large clean energy export task and are concentrated across the sunbelt of WA, NT and QLD.
- In WA, the energy sector accounts for up to 12% of all work in 2060, whereas in the NT, the energy sector workforce is projected to exceed the total projected workforce in almost all Scenarios.
- The distribution of employment across States varies substantially with changes to key assumptions This is explored in the reporting of relevant sensitivities.

General insights: **Water**

KEY FINDINGS

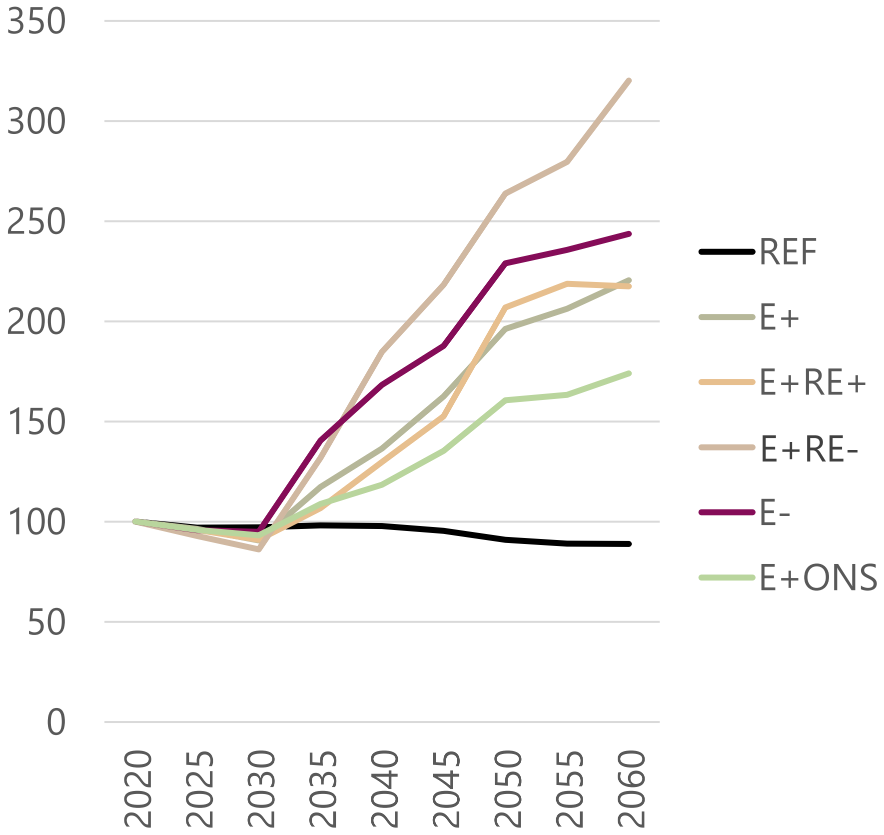
Water consumption will increase, but strategic use of desalination can free up significant freshwater for other uses

- Total water consumption increases 2-3.5×, driven by DAC, Electrolysis, ATR w/CC and Haber-Bosch fuels.
- Net fresh water demand falls as major coastal desalination plants are built.
- New desalination plants are built in most states

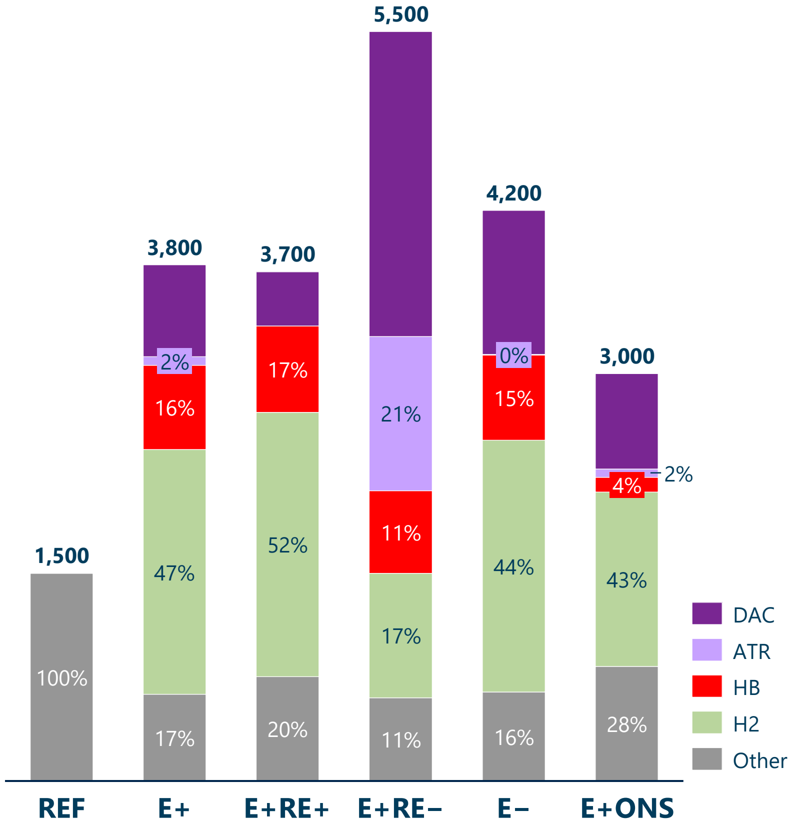
Total water consumption increases 2-3.5×, driven by DAC, Electrolysis, ATR with CCUS, and Haber-Bosch fuels

WATER

Annual total water consumption
(indexed at 100 using 2020 GL: 1,720 GL)



Total water consumption in 2060
(GL)

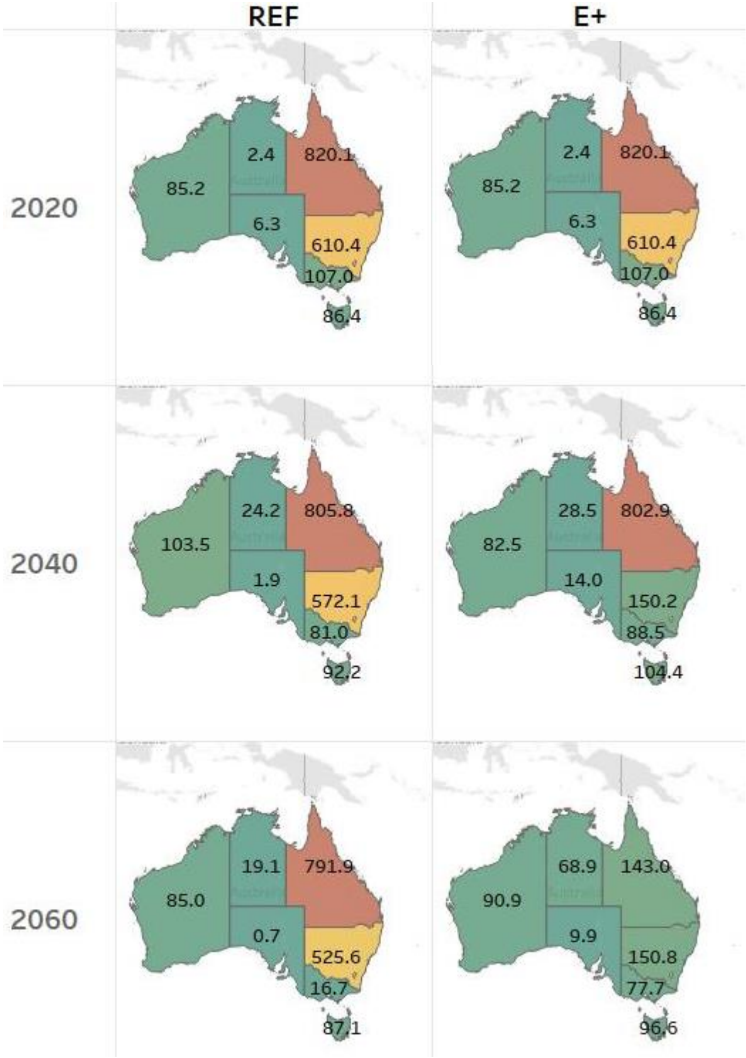


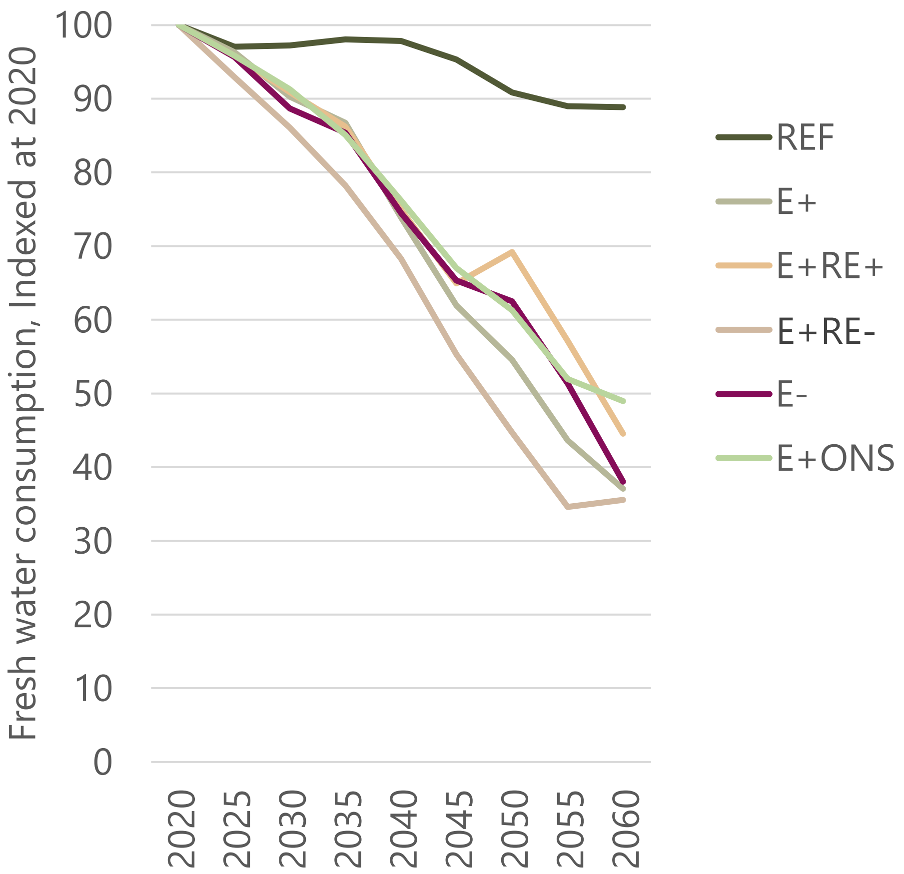
KEY TAKEAWAYS

- Energy sector water consumption in 2020 is ~1,720 GL.
- In 2060 Water consumption increases roughly 2-3 times the 2020 level.
- Water consumption is lowest in E+ONS (3,000 GL) and highest in E+RE− (5,500 GL).
- Highest water consumption in E+RE− is contributed to by direct air capture and auto-thermal reforming (ATR) of natural gas with CCUS.
- Up to 89% of total water is consumed by 4 energy activities: DAC, electrolysis, ATR with CCUS, and Haber Bosch (HB).
- Electrolysis (denoted by H2) dominates water consumption in E+, E− and E+RE+.

Net fresh water demand falls as major coastal desalination plants are built

Fresh water consumption, by State (GL) **and change in fresh water** (indexed at 100 using 2020 GL)





KEY TAKEAWAYS

- Fresh water consumption reduces by up to 40% of 2020 water consumption – and varies by state.
- This drop is due to reduced coal processing and is concentrated in Queensland and New South Wales.
- Fresh water consumption increases significantly in the Northern Territory to serve new energy export industries.
- Fresh water use is reduced the most in E+RE– (-65%), and the least in in E+ONS (-50%)

New desalination plants are built in most states

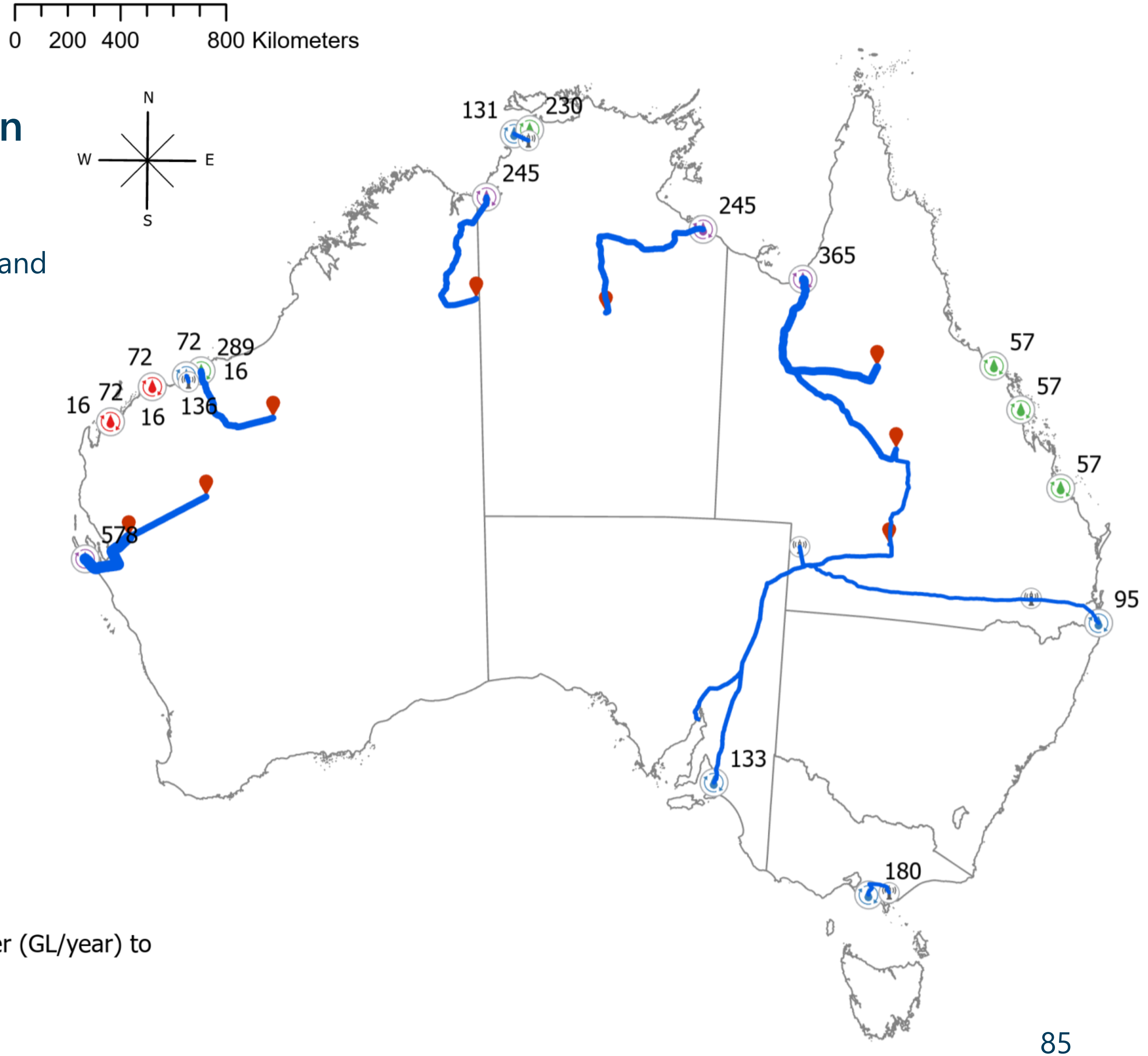
KEY TAKEAWAYS

- Separate desalination plants are required for electrolysis, DAC and Haber Bosch plants to reduce brine discharge in a location.
- Existing Gold Coast, Wonthaggi (Victoria) and Adelaide desalination plants are assumed to expand and supply water for DAC.
- Water networks are linked for resilience.

INDICATIVE ONLY

Coastal desalination plants

E+ 2060, serving: DAC, electrolysis, ATR with CCUS and Haber Bosch fuels



Pipeline water flows (GL/day)

- 0
- 0.5
- 1
- 1.5

- Electrolysis sites
- DAC Sites

Desalination plant supplying water (GL/year) to

- Autothermal reforming w/cc
- Direct air capture (DAC)
- Haber-Bosch
- Electrolysis

General insights: **Fossil fuel industries**

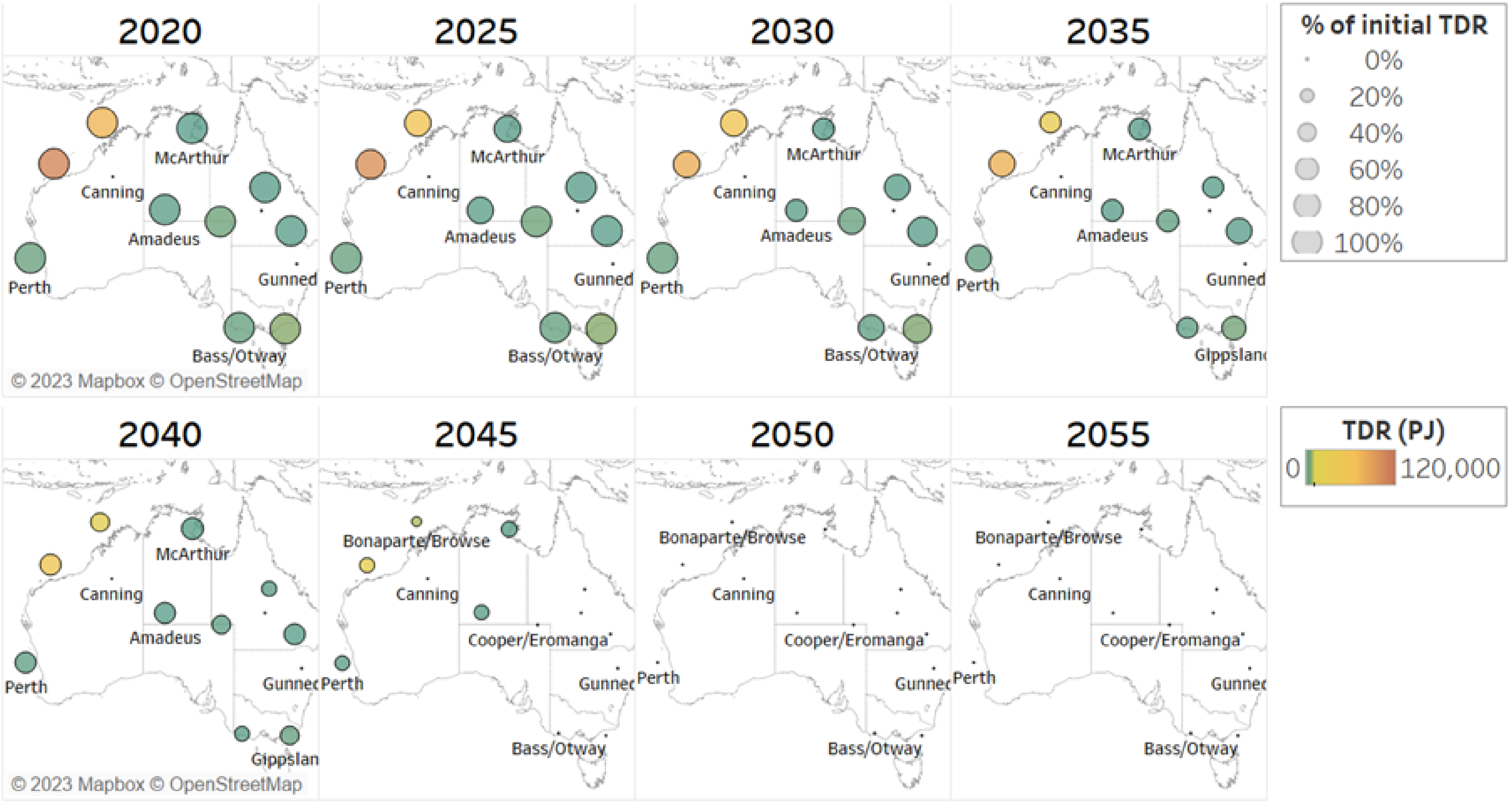
KEY FINDINGS

Net zero scenarios heavily relying on natural gas require more than currently demonstrated fossil fuel resources.

- Current levels of total demonstrated resources (TDR) cannot sustain a net-zero transition highly reliant on fossil fuels with carbon capture
- All coal-fired thermal generation is phased out by 2045, alongside coal extraction facilities

Current levels of total demonstrated resources (TDR) cannot sustain a net-zero transition highly reliant on fossil fuels with carbon capture

In E+RE– Scenario, conventional gas resources are depleted by 2050 and coal seam gas by 2055. Evolution over time of TDR in conventional natural gas basins for the E+RE− Scenario. Coloured by TDR



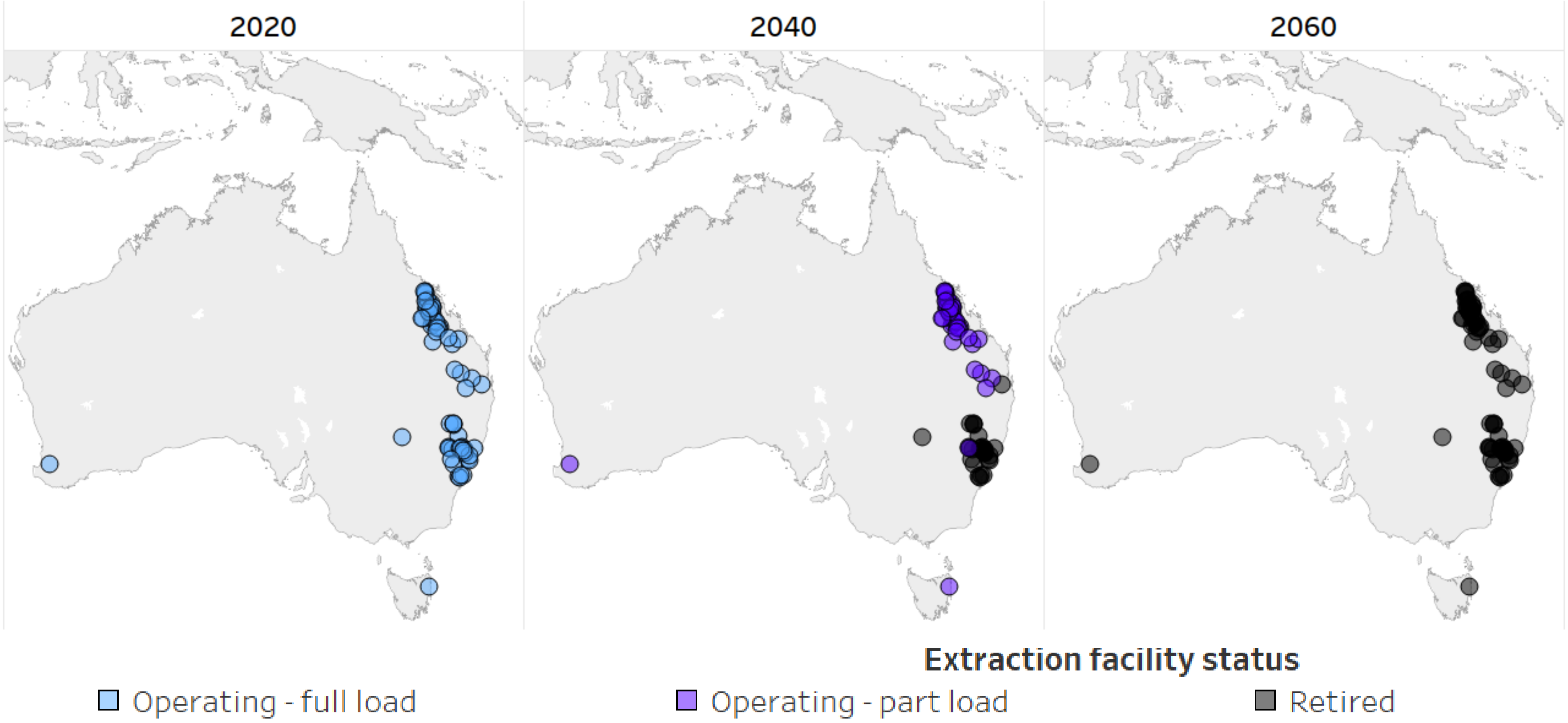
FOSSIL FUEL INDUSTRIES

KEY TAKEAWAYS

- Current fossil fuel resources are insufficient for sustaining Australia's net-zero transition in the E+RE− Scenario.
- Larger uptake of renewables relieves pressure on TDR. In E+RE+ Scenario, 65 EJ of gas and 1 EJ of coal seam gas is still available in 2060.
- Similar conclusions apply to the oil basins, which are depleted by 2045 in the E+RE− Scenario, while 1.5 EJ are still available in 2060 in E+RE+.

All coal-fired thermal generation is phased out by 2045, alongside coal extraction facilities

Phase out of black coal mines in the E+RE+ Scenario. Coloured by operational status



FOSSIL FUEL INDUSTRIES

KEY TAKEAWAYS

- All coal-fired power generation is phased out by 2045.
- All coal mining is shut down by 2060, as exports are decarbonised.

FINAL MODELLING RESULTS

4.4 Downscaling results

Downscaling has encompassed numerous areas

'Downscaling' involves deeper dives into sectoral energy transitions and siting of modelled energy assets.

DOWNSCALING AREAS

- Employment impacts
- Capital mobilisation
- Solar, wind and electricity transmission siting
- Land use impacts on Australian communities, the land and sea
- Firm generation and pumped hydro energy storage
- Transport
- Buildings, including rooftop solar PV and batteries
- Electricity and gas distribution systems
- Hydrogen and synthetic fuel production, transmission and storage
- Water use and transmission
- Bioenergy systems
- CO_2 capture, transmission, use and storage
- Natural gas and synthetic methane transmission
- Agroforestry and strategies for enhancing land sinks
- Fossil fuel industries
- Energy export systems
- Onshoring of industry

This final results pack covers select highlights across all downscaling work

Full reports for each of these downscaling areas are available at: netzeroaustralia.net.au

We have downscaled across 17 areas: key messages (1/2)

DOWNSCALING AREA	KEY MESSAGE
Employment impacts	600-750 thousand energy sector jobs by 2060, disaggregated by region, sector, type, occupation and skill level.
Capital mobilisation	Net zero scenarios require $7-9 trillion of cumulative capital investment to 2060.
Solar, wind and electricity transmission siting	New detailed and granular mapping of potential locations for renewable energy infrastructure across the country available.
Land use impacts on Australian communities, the land and sea	Energy system footprints on the indigenous estate, farming land, ecological communities, and opportunities for impact mitigation.
Firm generation and pumped hydro energy storage	Electricity firming requires 30-80 GW gas plants (30-70% sited on brownfields) and ~10 GW (~400 GWh) of pumped hydro.
Transport sector energy transition	Analysis of vehicle and energy transitions, together with enabling infrastructure for all transport sub-sectors.
Buildings, including rooftop solar PV and batteries	Solar PV to be installed on 80% of private buildings by 2060, 30% of buildings to have battery storage.
Electricity and gas distribution systems	$5-10 billion p.a. investment, mostly to renew and augment electricity distribution networks.

We have downscaled across 17 areas: key messages (2/2)

DOWNSCALING AREA	KEY MESSAGE
Hydrogen and synthetic fuel production, transmission and storage	Major hydrogen transmission needed from export hubs to ports, hydrogen transmission across the east coast is needed (less in E+RE–)
Water use and transmission	Siting of new desalination plants and associated water transmission, increase in total water consumption but reduced energy sector freshwater use.
Bioenergy systems	Expansion of a bioenergy industry with siting and investment analysis for ~80 bioenergy facilities across regional Australia.
CO_2 capture, transmission and storage	Major CO_2 transmission between key CCS basins, and between SA, Victoria and NSW
Natural gas and synthetic methane transmission	Current methane pipeline capacity is expected to be exceeded, with changes to import/export status of various states.
Agroforestry and strategies for enhancing land sinks	5.1 million hectares of new trees sited across Australian farmland.
Fossil fuel industries	Insufficient current levels of fossil fuel total demonstrated resources to support a net-zero transition heavily reliant on fossil fuels with carbon capture.
Energy export systems	Candidate energy export facilities are expected to be located portside and include a combination of Haber Bosch, desalination, ATR, CCS and hydrogen storage facilities.
Onshoring of industry	Onshoring energy exports is significantly more cost competitive due to efficiency gains from not converting hydrogen to an exportable form (e.g. ammonia).

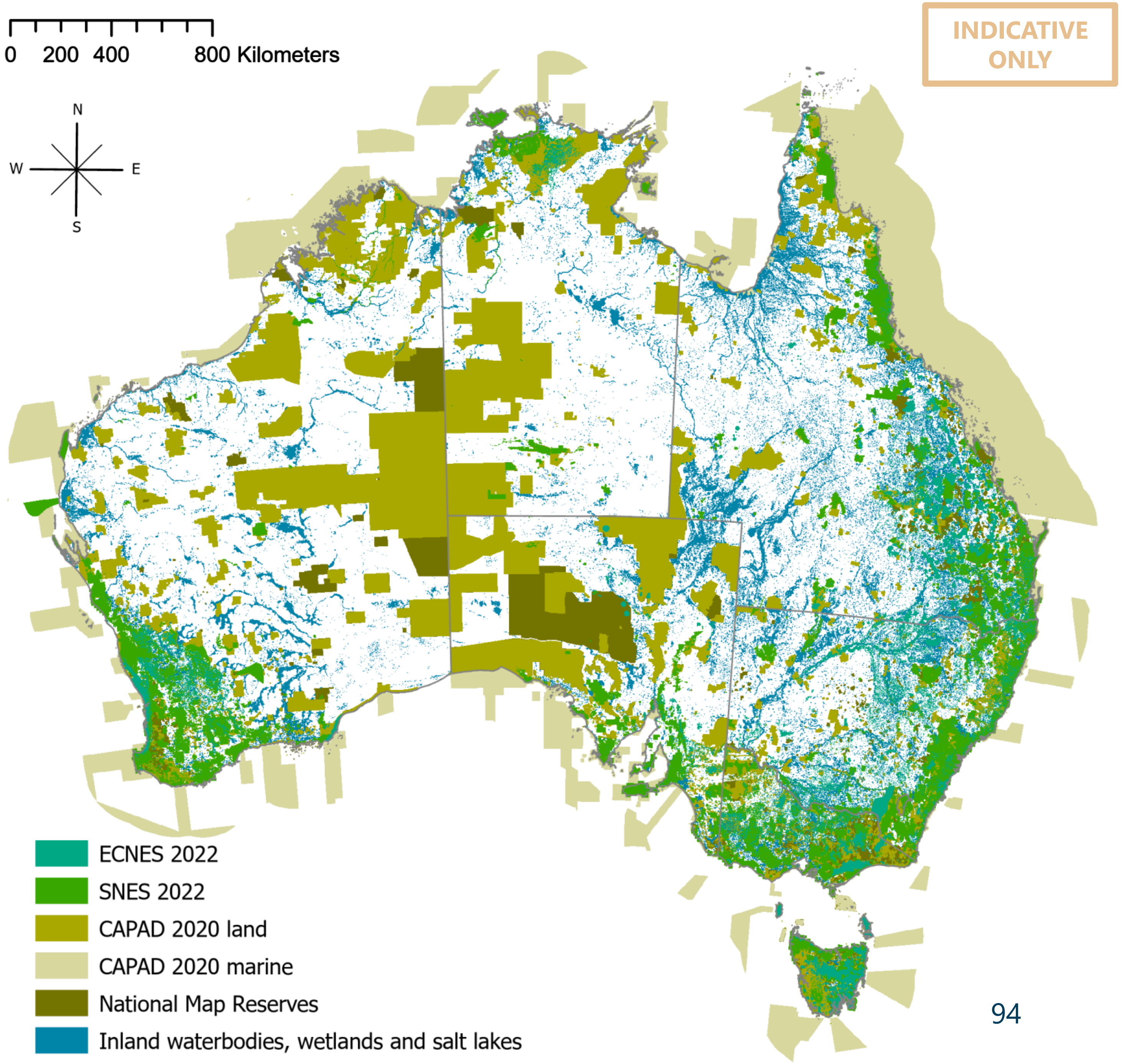
DOWNSCALING RESULTS

Solar, wind and electricity transmission siting

LAND/SEA USE

Conservation

- Our base exclusions include reserve areas, protected areas (CAPAD), and water areas.
- We also exclude all 'likely' habitats of Critically Endangered, Endangered, and Vulnerable ecological communities (ECNES) and species (SNES) below a threshold area that is several times larger than our largest wind farm.
- Our approach is conversation aware but falls short in safeguarding biodiversity[1]



Acronyms

- **CAPAD:** Collaborative Australian Protected Areas Database
- **ECNES:** Ecological Communities of National Environmental Significance
- **SNES:** Species of National Environmental Significance

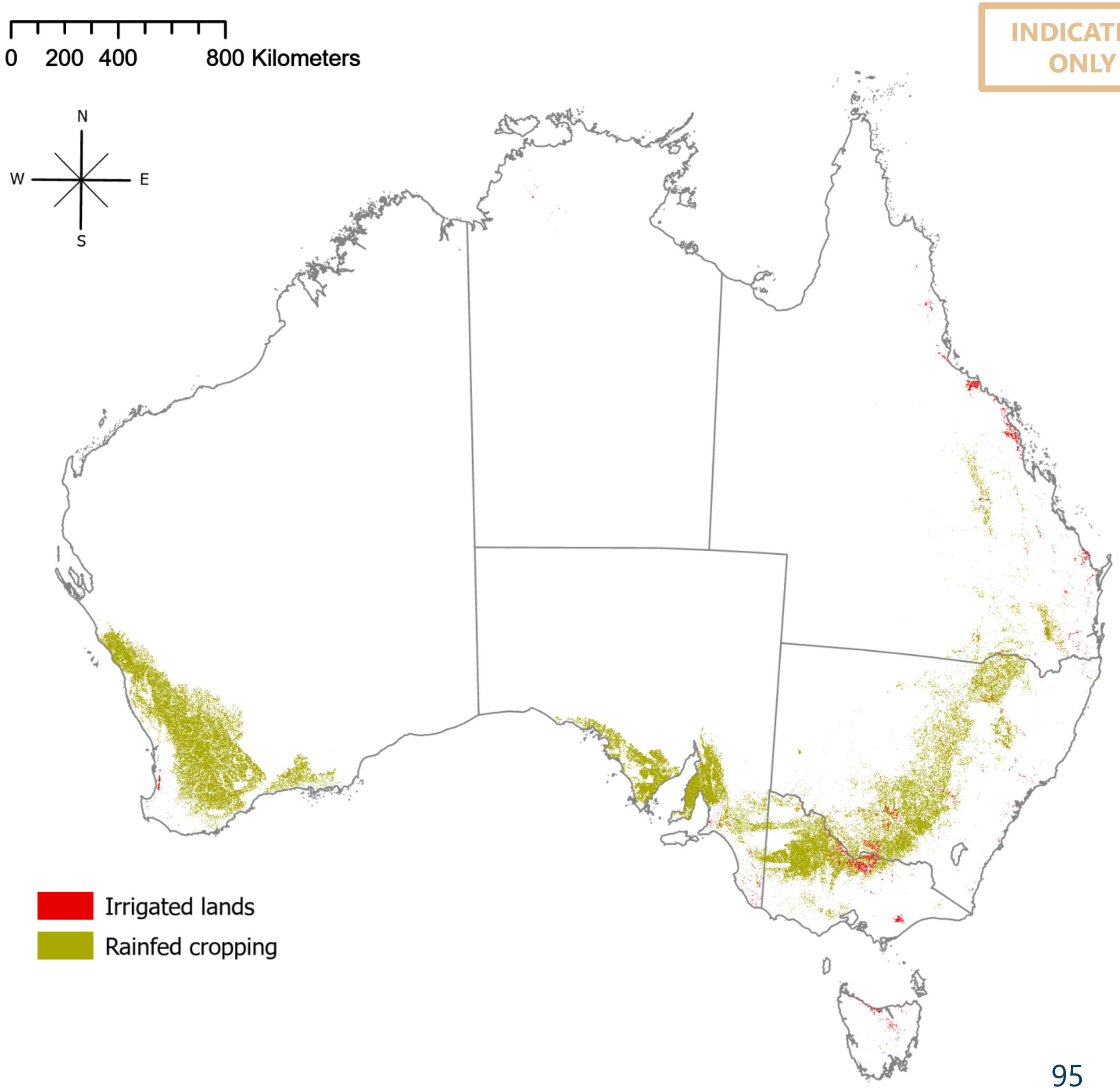
Modelling note #1: To date there has been no comprehensive spatial assessment undertaken around the minimum levels of protection and restoration that are needed to ensure that Australia's biodiversity persists.

LAND/SEA USE

Farming and Agriculture

- All irrigated lands (cropping, pasture, sugar) excluded from solar PV, wind and transmission siting.
- Full exclusion for solar PV on rainfed cropping land.

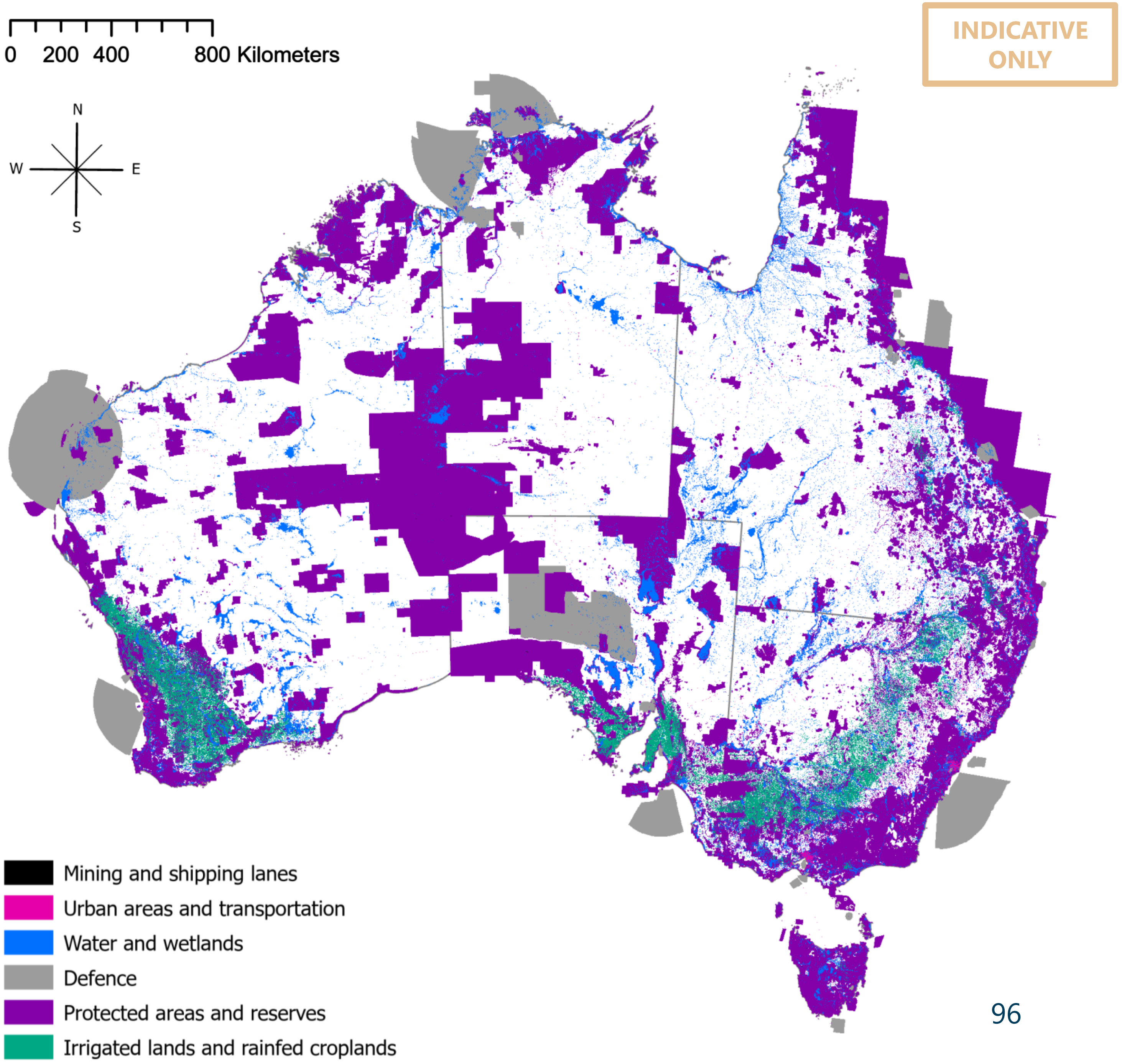
INDICATIVE ONLY



LAND/SEA USE

All solar PV exclusion areas

- Additional exclusion areas for mining sites, urban areas, air travel infrastructure, and defence areas
- Full exclusion for solar PV on rainfed cropping land.

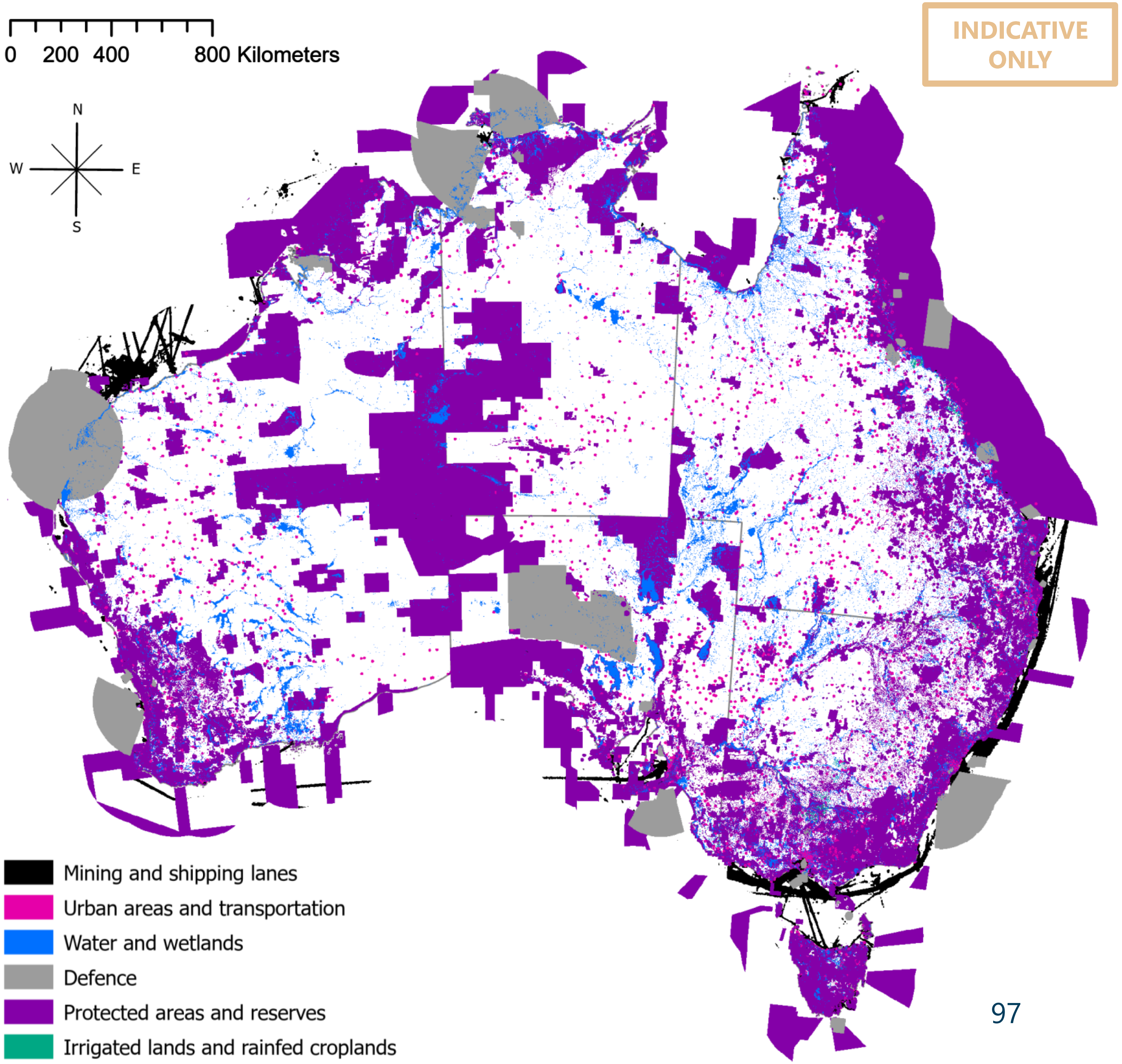


* In alignment with stakeholder consultations we have not constrained VRE build on Indigenous Estate (unless in CAPAD); and no VRE is sited on irrigated lands, or solar PV on rainfed croplands. Our approach is conservation aware, but falls far short of input data and methods needed to safeguard biodiversity (not yet developed).

LAND/SEA USE

All wind exclusion areas

- Additional exclusion areas for mining sites, shipping lanes, urban areas, air travel infrastructure (larger buffer than PV), offshore protected areas, and defence areas
- Wind allowed on rainfed cropping land.



* In alignment with stakeholder consultations we have not constrained VRE build on Indigenous Estate (unless in CAPAD); and no VRE is sited on irrigated lands, or solar PV on rainfed croplands. Our approach is conservation aware, but falls far short of input data and methods needed to safeguard biodiversity (not yet developed).

VRE and transmission maps guide

Variable Renewable Energy generation mapping

- **Minimum project sizes** on maps are 5 MW for solar, 50MW for onshore wind, and 100MW for offshore wind.
- **Actual land footprints vary** from what is presented in these maps. Neither Solar PV or wind project areas include transmission.

Solar PV	Wind
• **Presented mapped area is 5x the project area** (for visibility on maps and siting flexibility). In other words, the project total area listed in tables only cover 20% of the area shown on maps.	• **Presented mapped area is equal to project area**
• **Direct footprint area** (physical infrastructure footprint) is **91% of total project area**	• **Direct footprint area** (physical infrastructure footprint) is **1% of total project area**

Transmission mapping

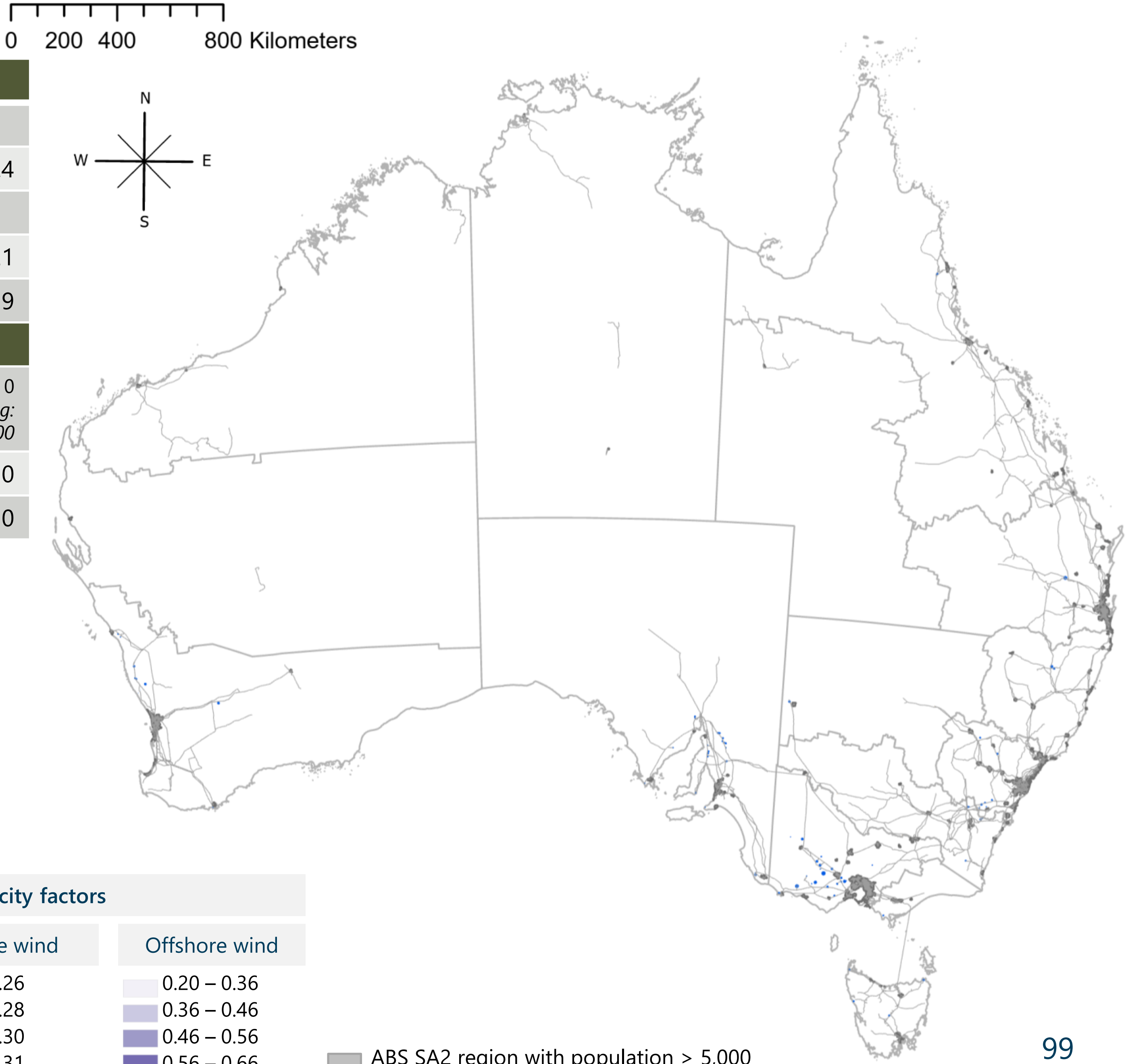
- **Transmission expansion is mapped to follow existing rights of way** for existing Transmission > 132kV, national roads, railroads, pipelines; paths are indicative not definitive.
- **Some inter-regional transmission is not shown** as downscaling suggests further consideration of other local system solutions (e.g. marginal new local generation/storage). Thresholds are:
  - < 500 MW (any km)
  - 1 GW (>1000km)
  - 2 GW (>1500km)
  - 3 GW (>2000km)
- All transmission expansions (except for spur lines) are **built five years before the VRE** they serve.

2020
(for context)

- Estimated transmission capacity for Transmission > 132 kV in 2020 is 28,000 GW-km , covering ~46,600 km of transmission. Domestic capacity totals from 2025 are additional to this base number.

INDICATIVE ONLY

2020	Wind	Solar
Capacity installed (GW)		
	11.2	9.4
Area used (1000 km²)		
Total	4.1	0.21
Direct	0.04	0.19
Transmission added (GW-km)		
Capacity domestic area		0 *Existing: 28,000*
Capacity export zone		0
Capacity not shown		0



Transmission (MW)
- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

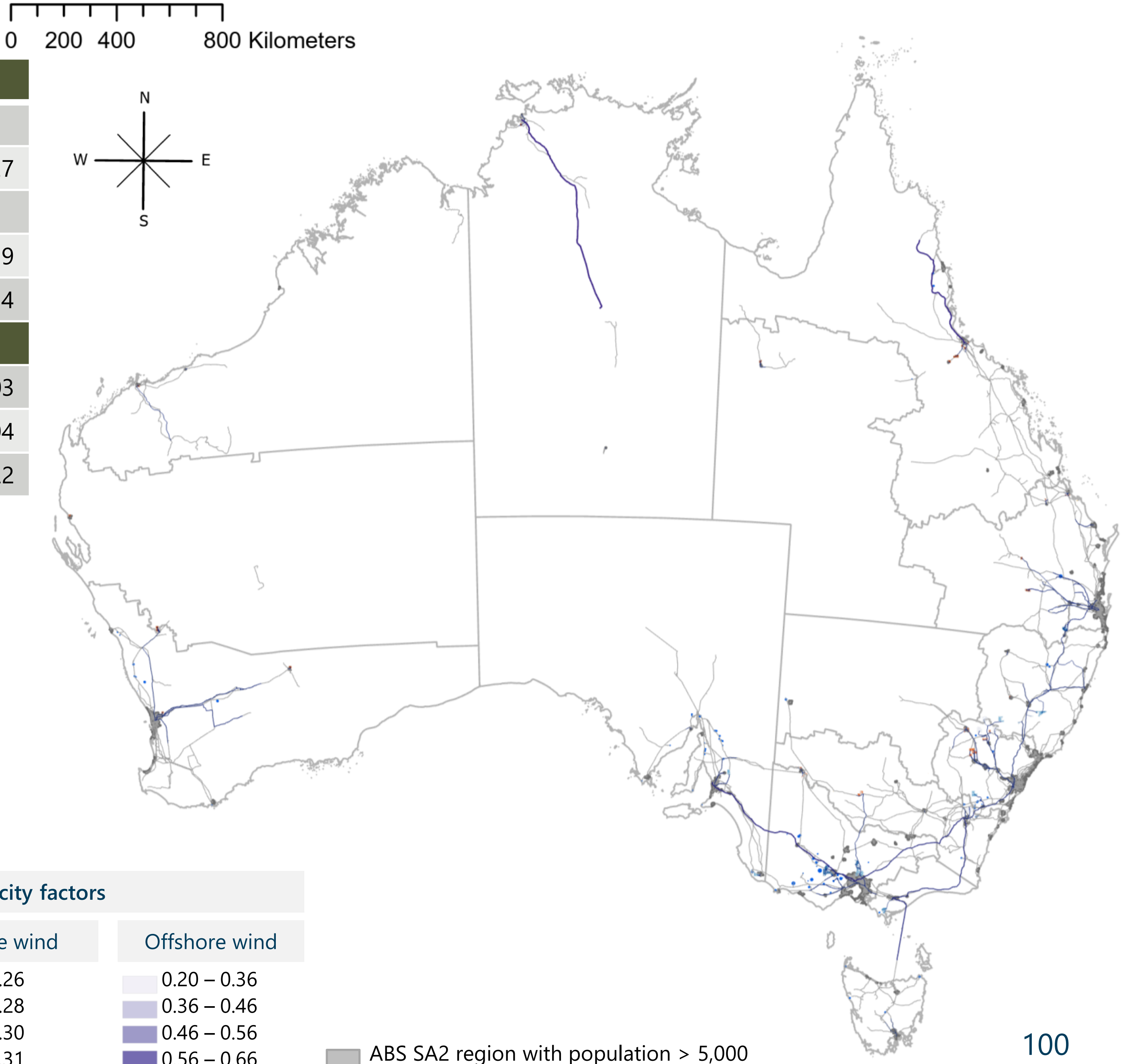
ABS SA2 region with population > 5,000 people & density > 100 people/km²

E+ 2025

- VRE (47 GW) and TX (~0.45× TX in 2020) expansions focus on domestic decarbonisation
- 11,00 GW-km of transmission capacity is not shown, as the capacity may be substituted by other system solutions (e.g. minor incremental local generation and storage).
- Preparations to export ammonia from NT in 2030

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	20	27
Area used (1000 km2)		
Total	7.44	0.59
Direct	0.07	0.54
Transmission added (GW-km)		
Capacity domestic area	11,203	
Capacity export zone	1,704	
Capacity not shown	11,222	



Transmission (MW)
<1,000
6,600
13,300
20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

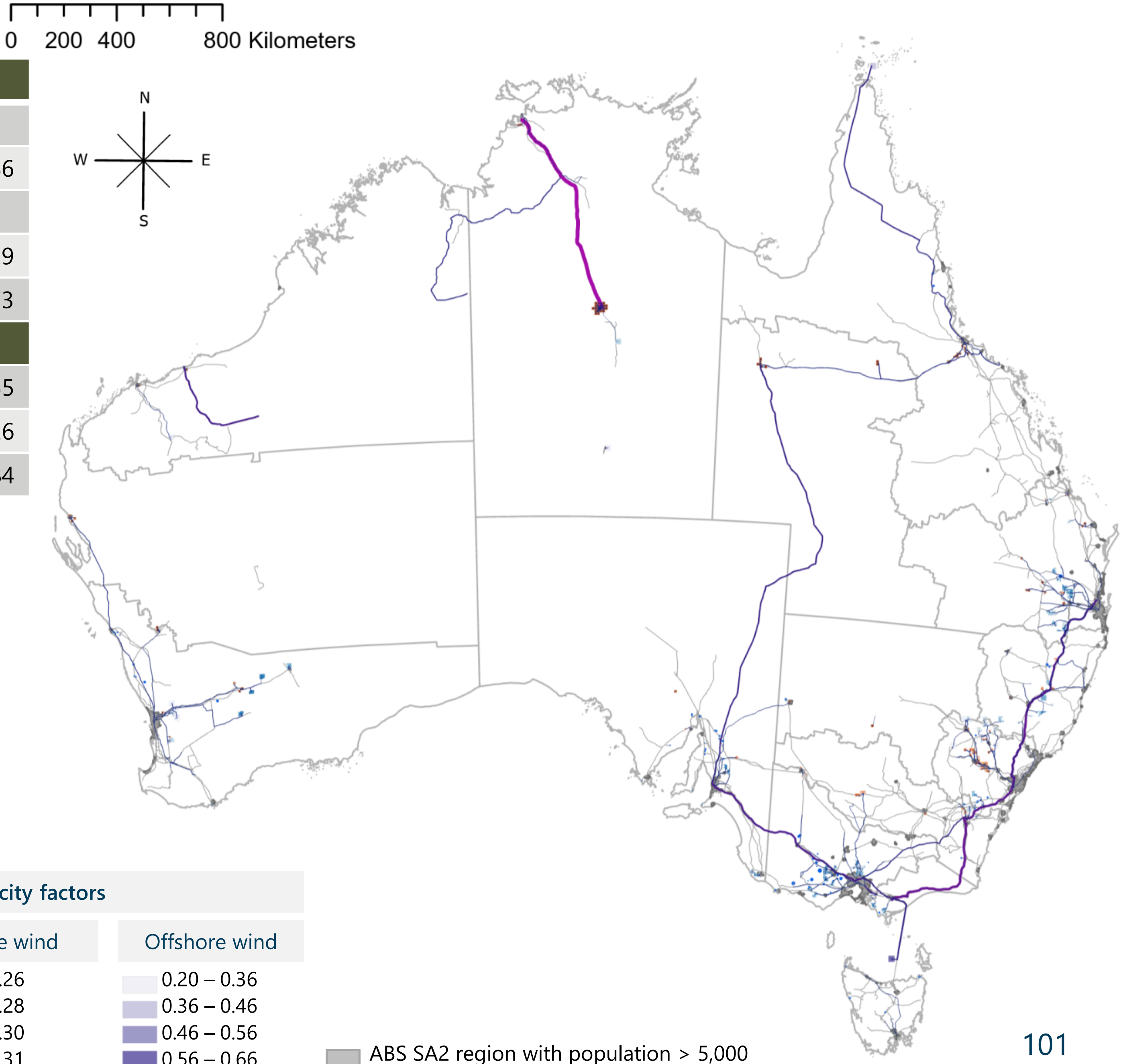
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ 2030

- VRE (134 GW) and TX (1.6× TX in 2020) expansions focus on domestic decarbonisation
- Solar PV capacity roughly 2× wind capacity
- Export electricity transmission build (20% of total build) serves new industry in export ports

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	48	86
Area used (1000 km2)		
Total	17.2	1.9
Direct	0.17	1.73
Transmission added (GW-km)		
Capacity domestic area		35,855
Capacity export zone		9,226
Capacity not shown		14,784

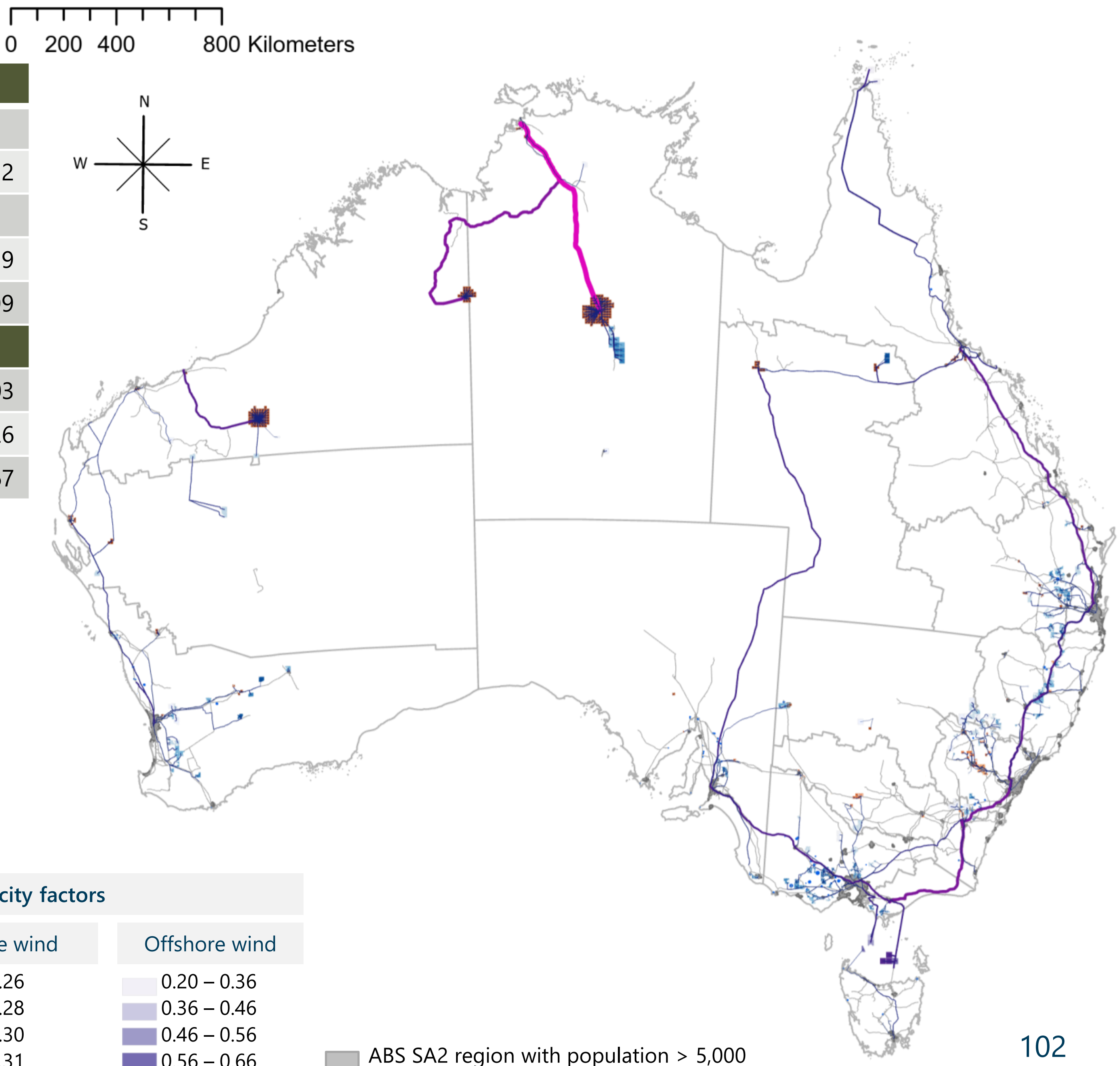


E+ 2035

- VRE (382 GW) and TX (2.9× TX in 2020) expansions focus on domestic decarbonisation
- Solar PV capacity roughly 2× wind capacity
- Export electricity transmission build represents 31% of total build

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	130	252
Area used (1000 km2)		
Total	45.87	5.59
Direct	0.46	5.09
Transmission added (GW-km)		
Capacity domestic area		55,403
Capacity export zone		25,126
Capacity not shown		14,367



Transmission (MW)
- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

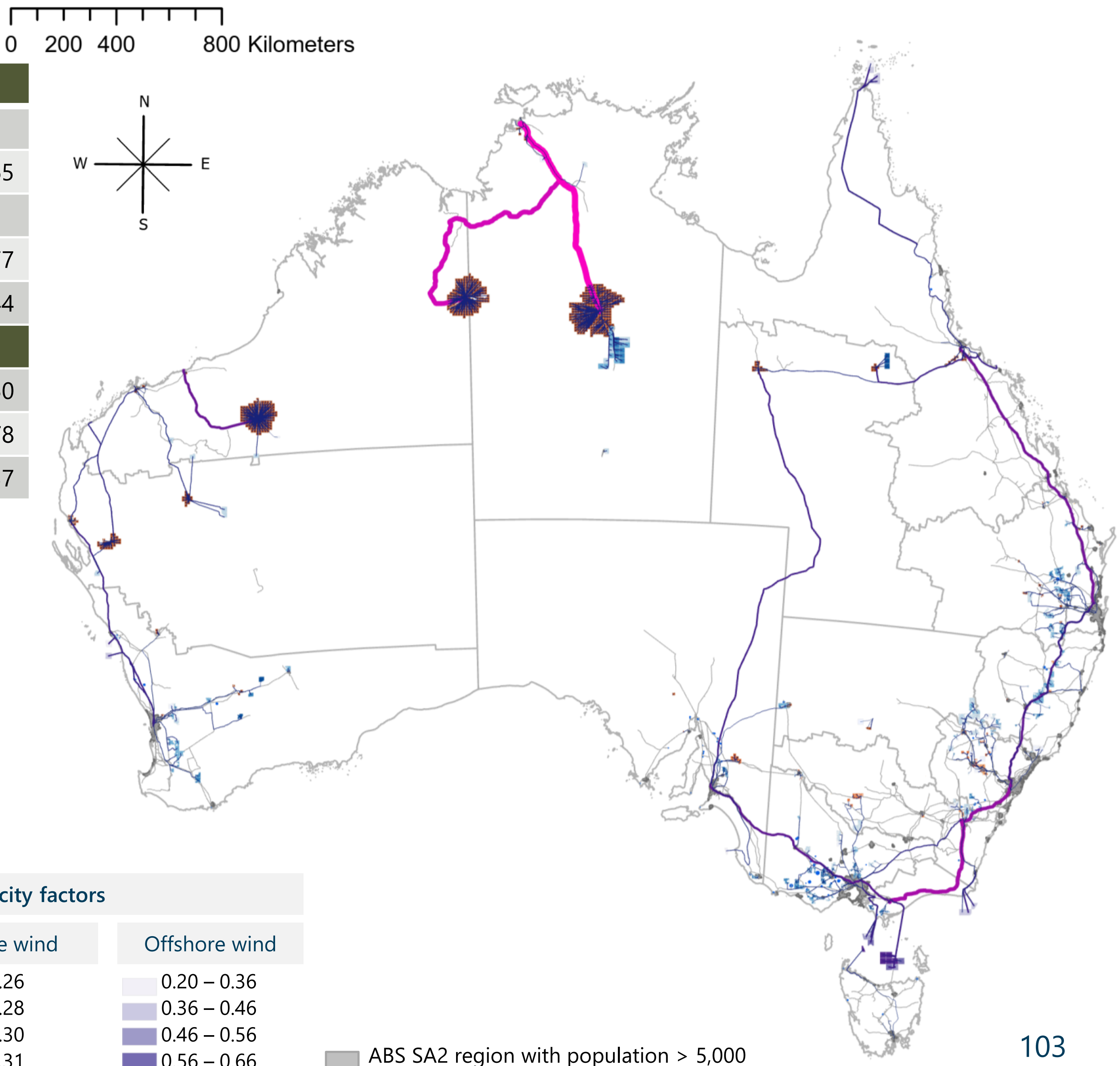
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ 2040

- Focus shifts to export related VRE and TX
- 840 GW of VRE
- Solar PV capacity 4× wind capacity
- TX in domestic areas ~2.5× TX in 2020
- TX in export zone nearly equivalent to domestic build ~61,000 GW-km

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	175	665
Area used (1000 km2)		
Total	58.59	14.77
Direct	0.59	13.44
Transmission added (GW-km)		
Capacity domestic area		69,950
Capacity export zone		60,778
Capacity not shown		16,537



Transmission (MW)
- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
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0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

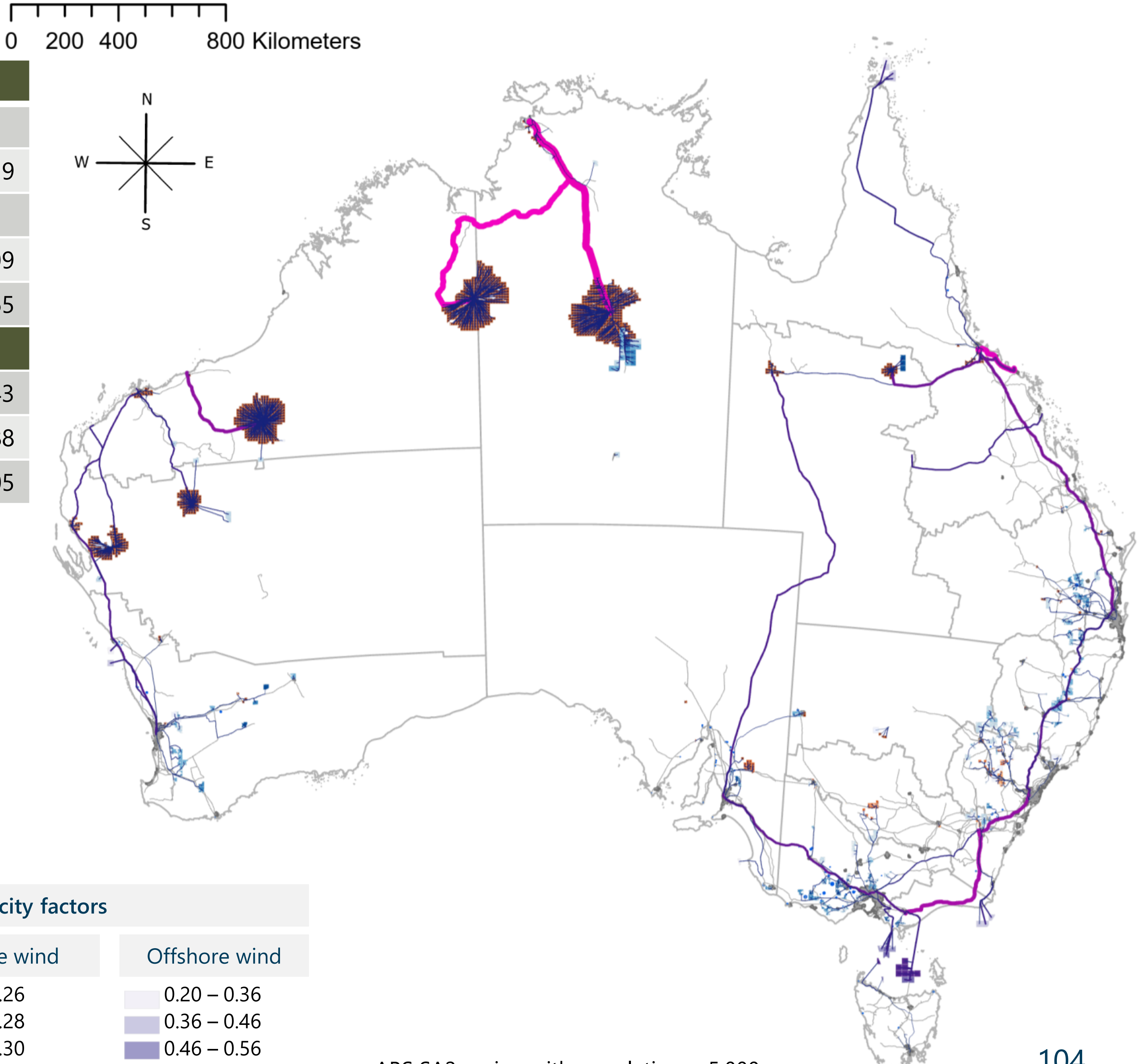
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ 2045

- Domestic VRE and TX slows
- 1.4 TW of VRE
- Solar PV capacity 7× wind capacity
- TX in domestic areas ~2.8× TX in 2020
- TX in export zone now 60% of total build ~115,000 GW-km

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	177	1,219
Area used (1000 km2)		
Total	58.66	27.09
Direct	0.59	24.65
Transmission added (GW-km)		
Capacity domestic area		77,843
Capacity export zone		114,688
Capacity not shown		17,805



Transmission (MW)

- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

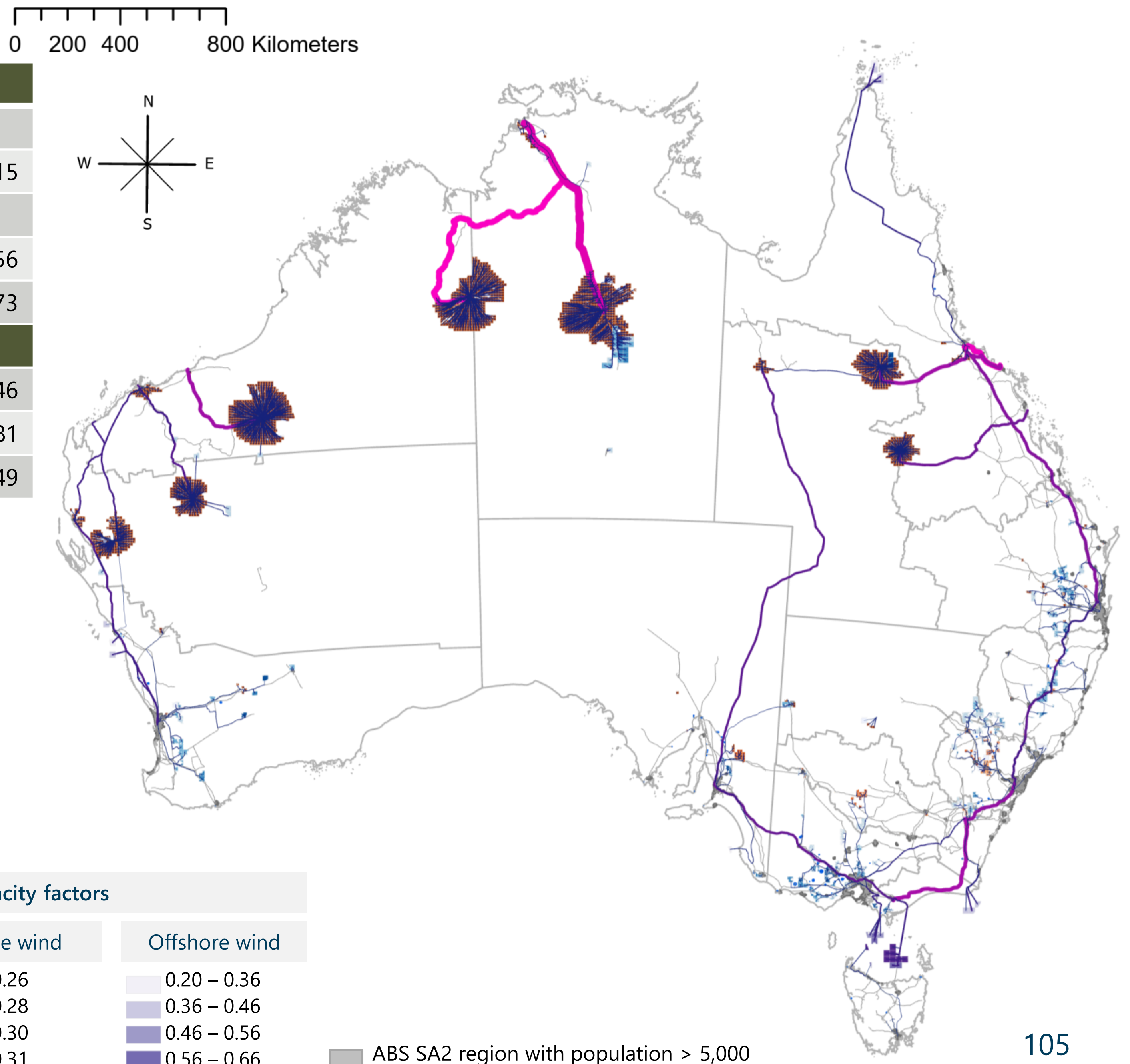
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ 2050

- Nearly all VRE and TX additions in export zones
- 2.1 TW of VRE
- Solar PV capacity 11× wind capacity
- TX in domestic areas ~2.9× TX in 2020
- TX in export zone now 69% of total build ~177,000 GW-km

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	174	1,915
Area used (1000 km2)		
Total	57.57	42.56
Direct	0.58	38.73
Transmission added (GW-km)		
Capacity domestic area		80,946
Capacity export zone		177,481
Capacity not shown		18,349



Transmission (MW)
- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
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0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

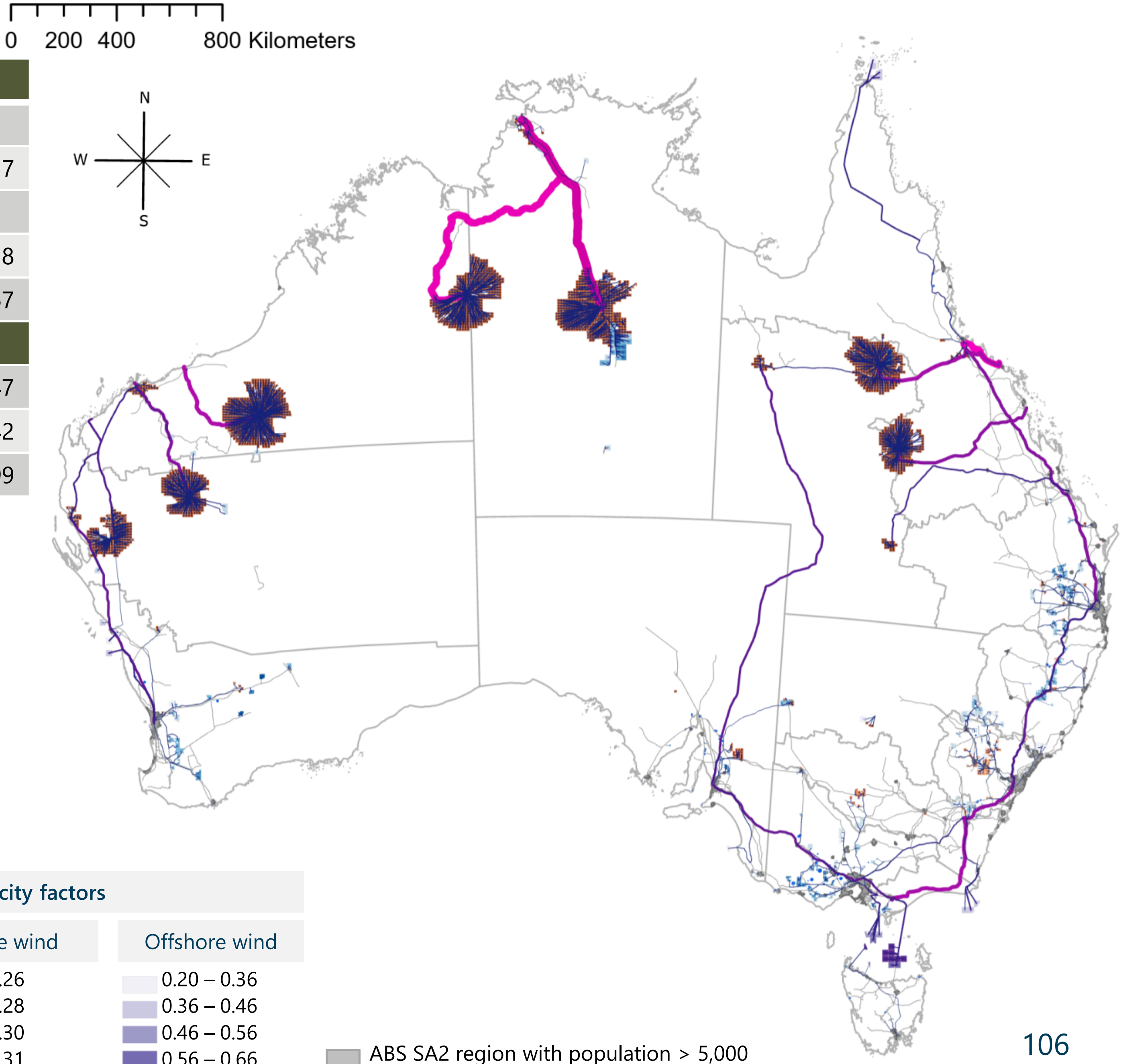
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ 2055

- All growth export; efficiency gains and PV replacing wind in domestic area results in TX reduction
- 2.5 TW of VRE
- Solar PV capacity 14× wind capacity
- TX in domestic areas ~2.8× TX in 2020
- TX in export zone now 74% of total build ~228,000 GW-km

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	165	2,357
Area used (1000 km2)		
Total	53.96	52.38
Direct	0.54	47.67
Transmission added (GW-km)		
Capacity domestic area		79,047
Capacity export zone		228,242
Capacity not shown		18,099

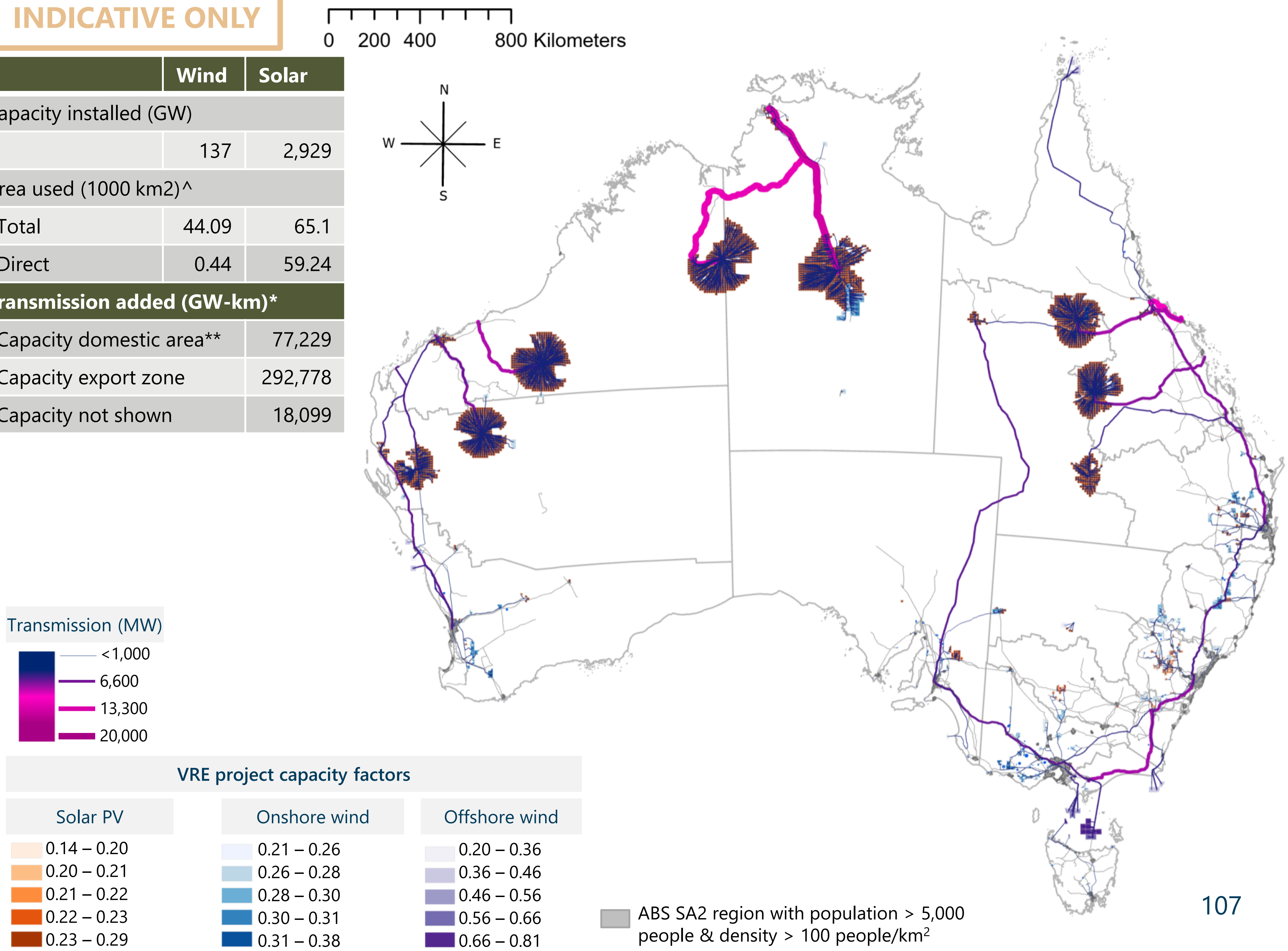


E+ 2060

- All growth export; efficiency gains and PV replacing wind in domestic area results in TX reduction
- 3.1 TW of VRE
- Solar PV capacity 21× wind capacity
- TX in domestic areas ~2.8× TX in 2020
- TX build in export zone ~10× domestic TX in 2020 and ~4× domestic NZAu build

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	137	2,929
Area used (1000 km2)^		
Total	44.09	65.1
Direct	0.44	59.24
Transmission added (GW-km)*		
Capacity domestic area**		77,229
Capacity export zone		292,778
Capacity not shown		18,099



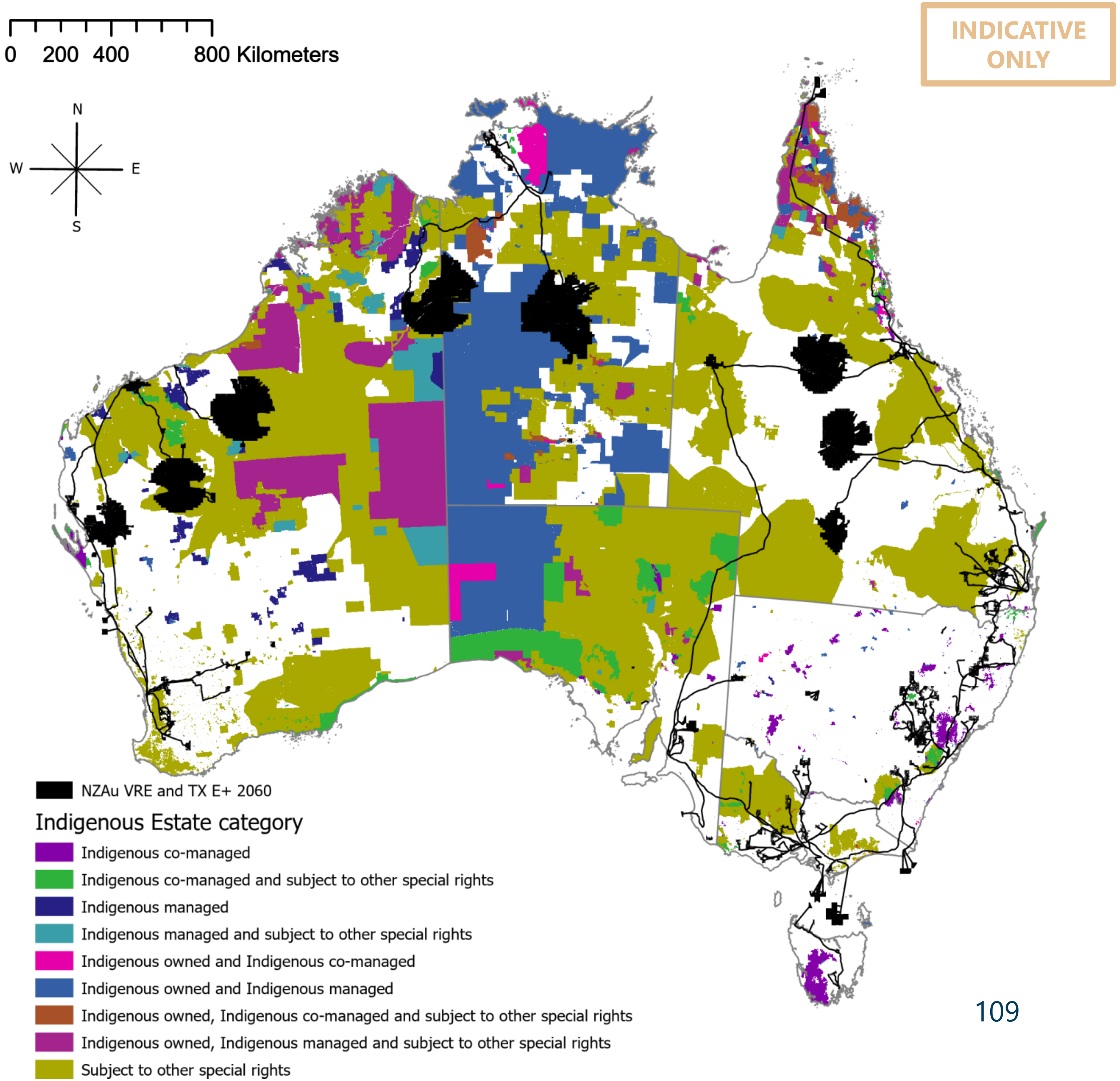
DOWNSCALING RESULTS

Implications of solar, wind and electricity transmission siting

LAND IMPACTS E+ 2060

Indigenous Estate

- No Indigenous Estate [1] category was excluded from the siting of VRE or transmission (unless part of CAPAD).
- Our land use impact analysis quantifies the footprint of sited assets on various categories of Indigenous Estate.



[1] ABARES, "Australia's Indigenous land and forest estate (2020)." Aug. 03, 2022. Accessed: September 14, 2022. [Online]. Available: https://www.agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/spatial-data/indigenous-land-and-forest

LAND IMPACTS E+ 2060

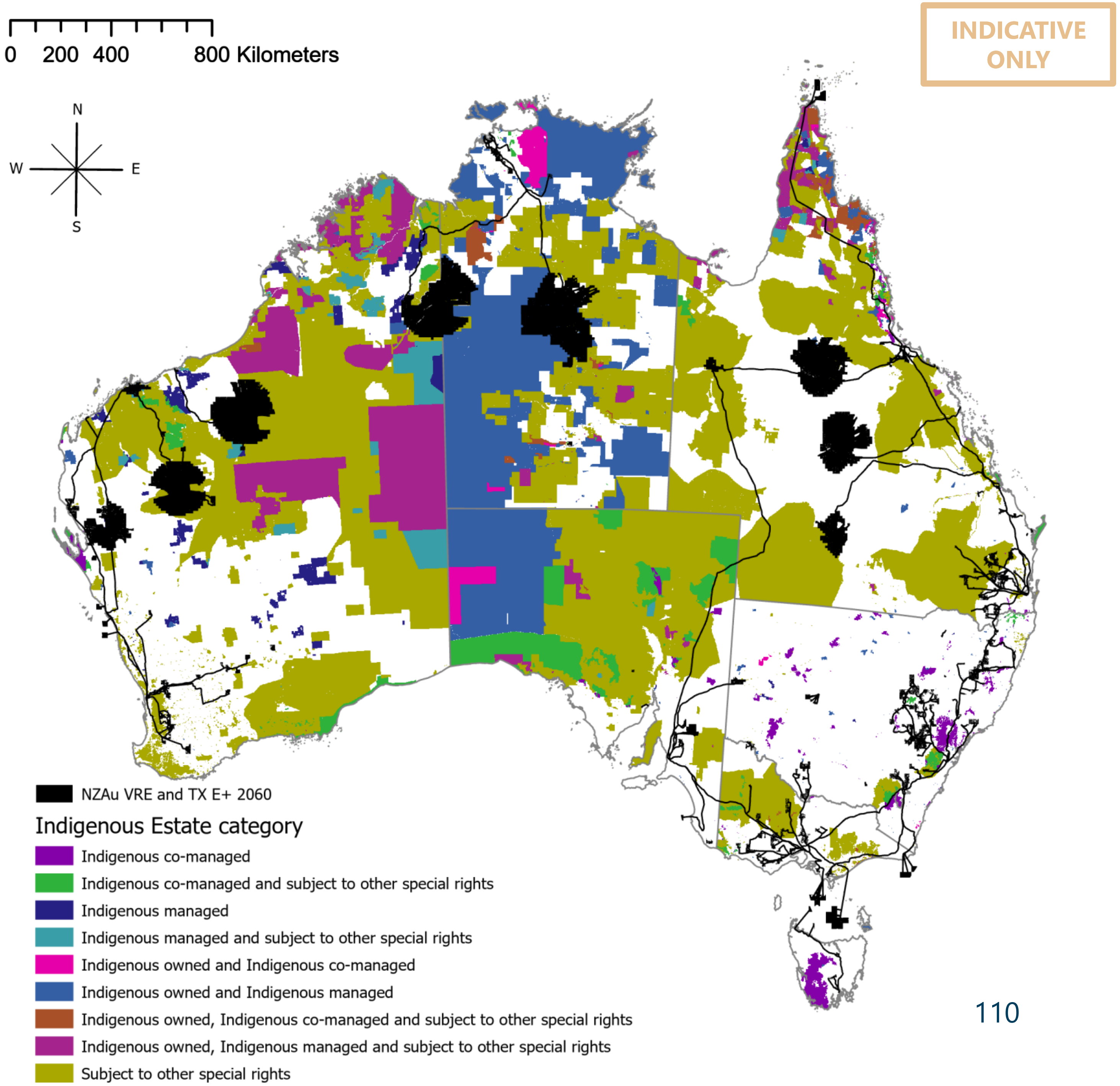
Indigenous Estate

Indigenous estate category [1]	Total build area (km²)	Share of NZAu build (%)	Share of category area (%)
Indigenous co-managed	33	< 0.1	<1
Indigenous managed	1,958	1.6	2.2
Indigenous owned	17,465	14.5	2.2
Subject to other special rights	32,186	27	1.2
Combined total	51,642	43	1.2

- Total area in km² represents the sum of all VRE project boundaries and transmission rights-of-way in each category

Note: the specific location of export zones are assumed not optimised

[1] ABARES, "Australia's Indigenous land and forest estate (2020)." Aug. 03, 2022. Accessed: September 14, 2022. [Online]. Available: https://www.agriculture.gov.au/abares/forestsaustralia/forest-data-maps-and-tools/spatial-data/indigenous-land-and-forest



LAND IMPACTS E+ 2060

Farmland

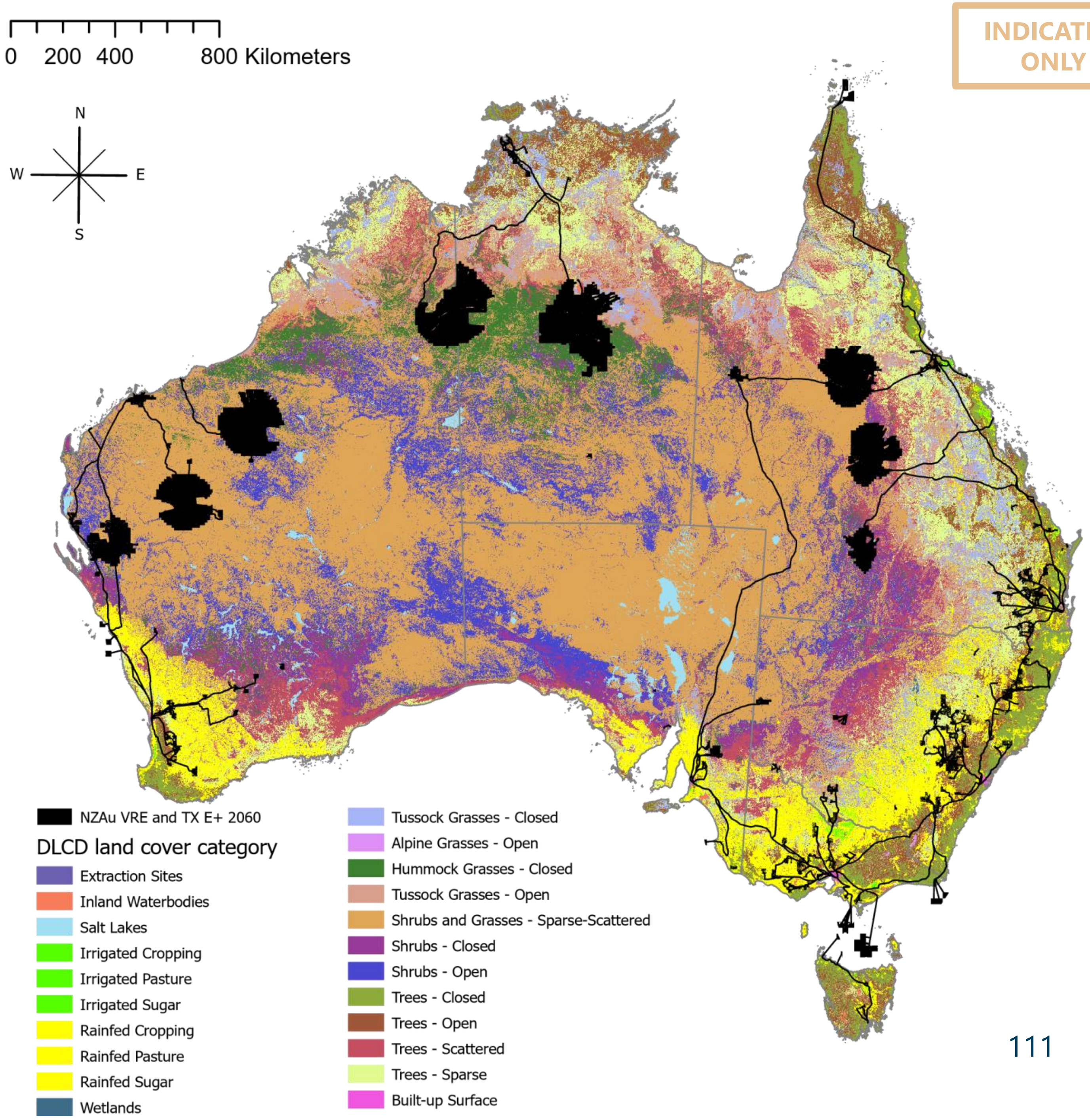
Farmland category [2]	Total build area (km²)	Share of NZAu build (%)	Share of category area (%)
Irrigated Cropping	14	< 0.1	< 0.1
Irrigated Pasture	4	< 0.1	< 0.1
Irrigated Sugar	10	< 0.1	< 0.1
Rainfed Cropping	6,199	4.7	2.1
Rainfed Pasture	16,574	12.5	5.8
Rainfed Sugar	1	< 0.1	< 1

- Irrigated results are due to transmission lines
- Total area in km² represents the sum of all VRE project boundaries and transmission rights-of-way in each category

Note: the specific location of export zones are assumed not optimised

[2] L. Lymburner, P. Tan, A. McIntyre, M. Thankappan, and J. Sixsmith, "Dynamic Land Cover Dataset Version 2.1," Geoscience Australia, Canberra, 2017. Accessed: June 21, 2021. [Online]. Available: http://pid.geoscience.gov.au/dataset/ga/83868a

INDICATIVE ONLY

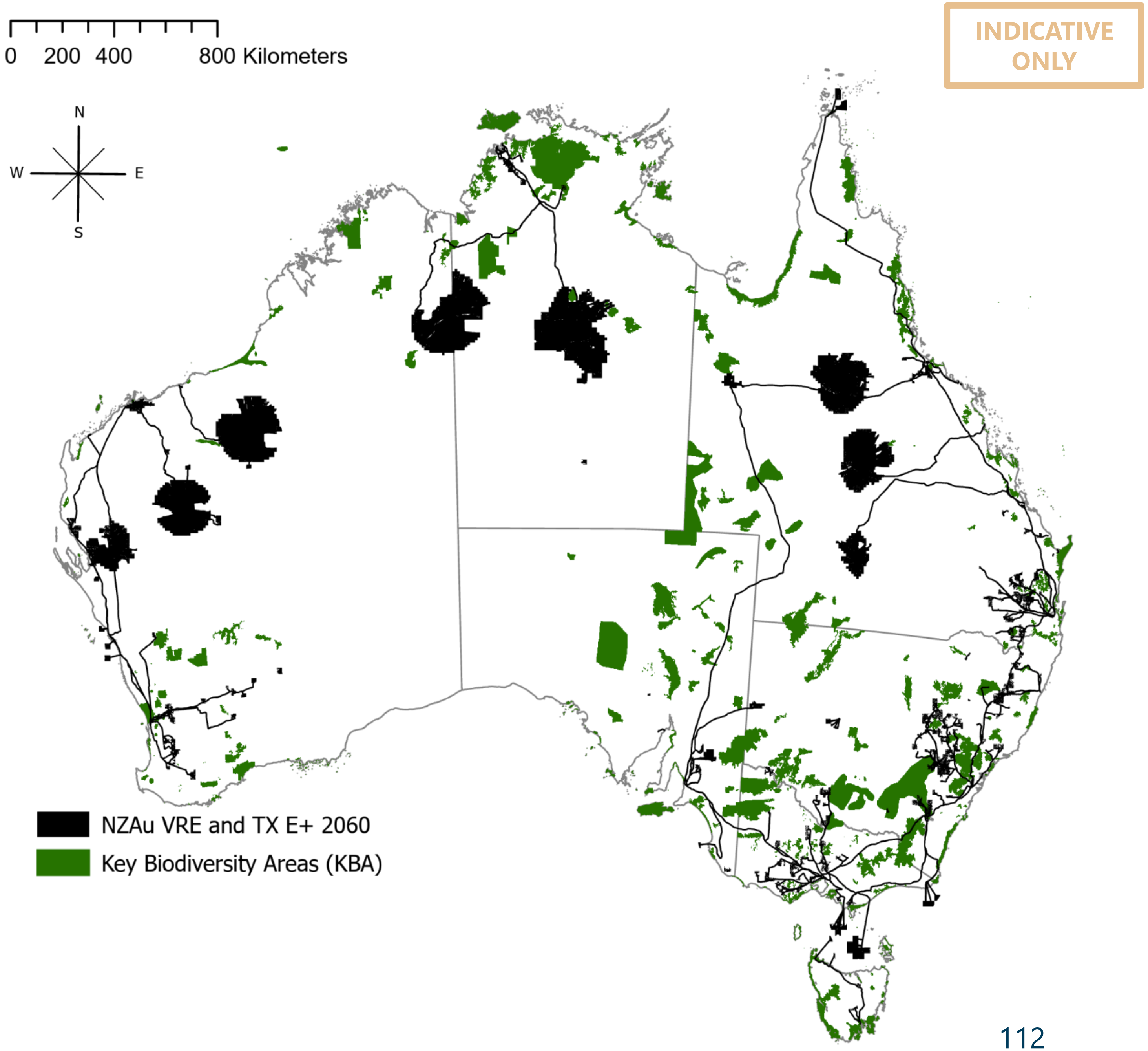


LAND IMPACTS E+ 2060

Key Biodiversity Areas (not excluded from siting)

Key Biodiversity Areas [4] with more than 1% of KBA crossover with NZAu VRE and TX	% of each KBA (total area in km²)
Traprock	27.9 (179)
Hanging Rock and associated hydrobasin	14.3 (22)
Barmah-Millewa	7.7 (202)
Gidgegannup	3.8 (1)
South-west Slopes of NSW	3.5 (900)
Goonoo	3.3 (35)
Extension of Labertouche Creek B.R.	1.8 (<1)
Moora	1.8 (<1)
Lockerbie Scrub	1.5 (2)
Lake Woods	1.5 (18)
Bundarra-Barraba	1.2 (42)
Yinberrie Hills	1.1 (11)
Rushworth Box-Ironbark Region	1.1 (5)
Arnhem Plateau	1.1 (222)

- Total area in km^2 represents the sum of all VRE project boundaries and transmission rights-of-way in each KBA



Note: the specific location of export zones are assumed not optimised

[4] Australia's KBA National Coordination Group, "Key Biodiversity Area resources and spatial data," Bird Life Australia, 2022. Accessed: Feb. 01, 2023.
[Online]. Available: https://www.keybiodiversityareas.org.au/resources

DOWNSCALING RESULTS

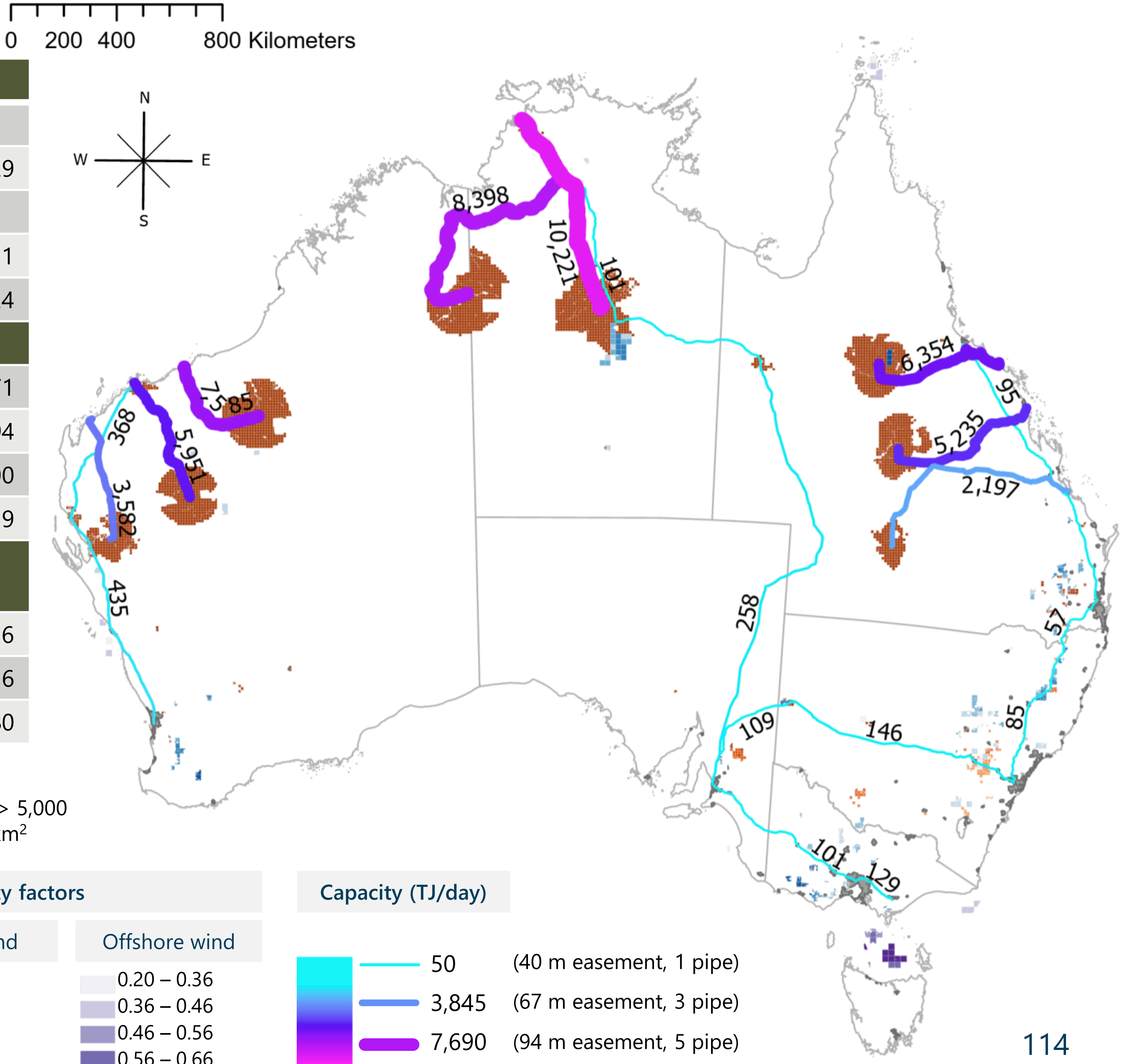
Bioenergy, CO_2 and H_2 infrastructure

E+2060 hydrogen transmission

- There is a substitution effect for CO_2 and H_2 pipelines, if less of one is built, means more of the other is needed (e.g. compare E+ and E+RE−)
- Very large hydrogen pipelines connect renewable hubs to export ports
- New hydrogen transmission connects the east coast – with a north-south link between Darwin and Adelaide

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	137	2,929
Area used (1000 km2)^		
Total	44.09	65.1
Direct	0.44	59.24
H2 transmission added (GW-km)*		
Capacity domestic area**		19,371
Capacity export zone		421,194
Capacity not shown		4,700
Length (km)**		14,839
H2 Production and Ammonia Exports		
H2 blue produced (PJ)		536
H2 green produced (PJ)		18,916
Ammonia exported (PJ)		13,680



ABS SA2 region with population > 5,000 people & density > 100 people/km^2

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
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0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

Capacity (TJ/day)

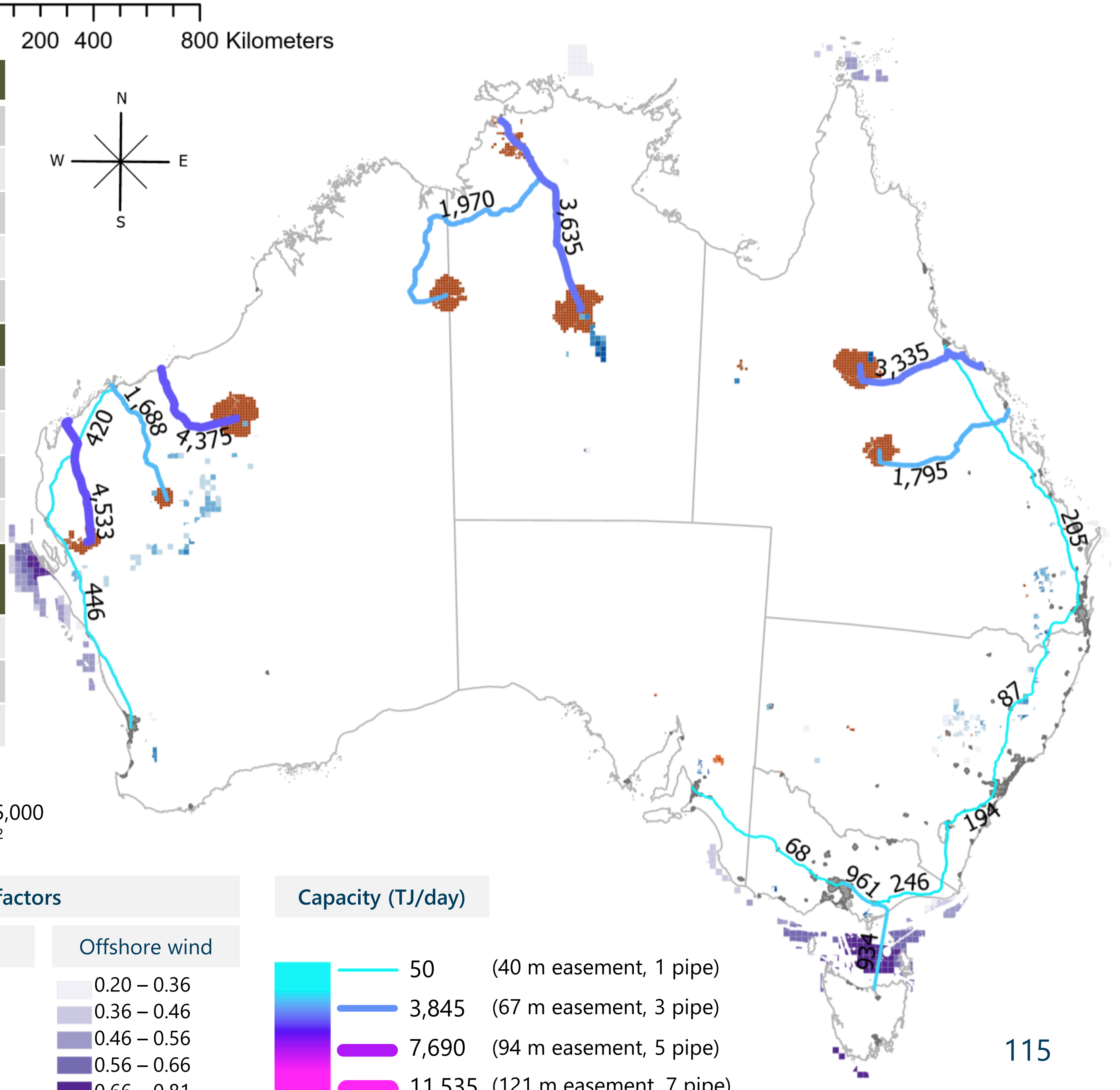
50	(40 m easement, 1 pipe)
3,845	(67 m easement, 3 pipe)
7,690	(94 m easement, 5 pipe)
11,535	(121 m easement, 7 pipe)

E+RE− 2060 hydrogen transmission

- There is a substitution effect for CO_2 and H_2 pipelines, if less of one is built, means more of the other is needed (e.g. compare E+ and E+RE-)
- In E+RE−, transmission serving renewable export hubs shrink as ATR gas is key export fuel
- East cost transmission follows the coast and is not connected to Northern Territory

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	525	945
Area used (1000 km2)^		
Total	134.5	20.99
Direct	1.35	19.1
H2 transmission added (GW-km)*		
Capacity domestic area**		19,292
Capacity export zone		157,975
Capacity not shown		4,614
Length (km)**		10,286
H2 Production and Ammonia Exports		
H2 blue produced (PJ)		9,690
H2 green produced (PJ)		9,476
Ammonia exported (PJ)		13,440

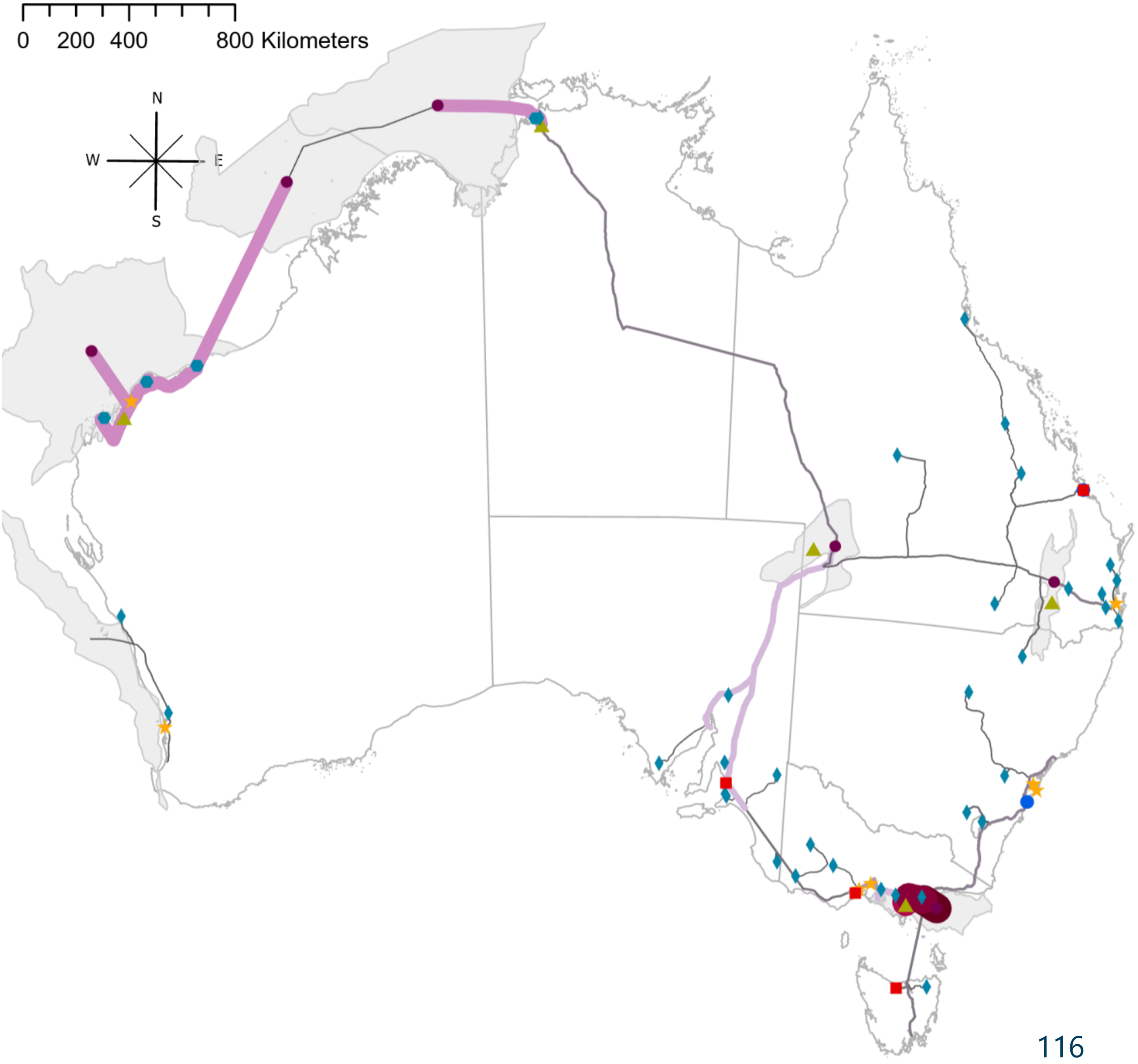


E+ 2060 CCUS

- There is a substitution effect for CO_2 and H_2 pipelines, if less of one is built, means more of the other is needed (e.g. compare E+ and E+RE−)
- Major offshore carbon transmission infrastructure will be needed – particularly offshore from NT, WA, and Gippsland (VIC)
- Onshore carbon transmission between Adelaide and Melbourne; and between Brisbane and Cooper basin

Source(+)/Sink(−)	Mtpa
Cement w/cc	12.1
Power w/cc	0.0
ATR * CGE with CCUS	35.5
Direct Air Capture	96.9
Biofuels with CCUS	16.4
Fischer-Tropsch liquids	−12.1
Geological storage	150.0
CO_2 transmission	
Capacity (Mtpa-km)	82,639
Length (km)	16,787

INDICATIVE ONLY



CO_2 Sources and Sinks

- ATR w/cc
- ATR & CGE w/cc
- Storage site (sink)
- Direct air capture
- Fischer-Tropsch liquids (sink)
- Biofuels w/cc
- Cement w/cc
- Power generation w/cc

CO_2 Pipelines (Mtpa)

0.5
8
16
50

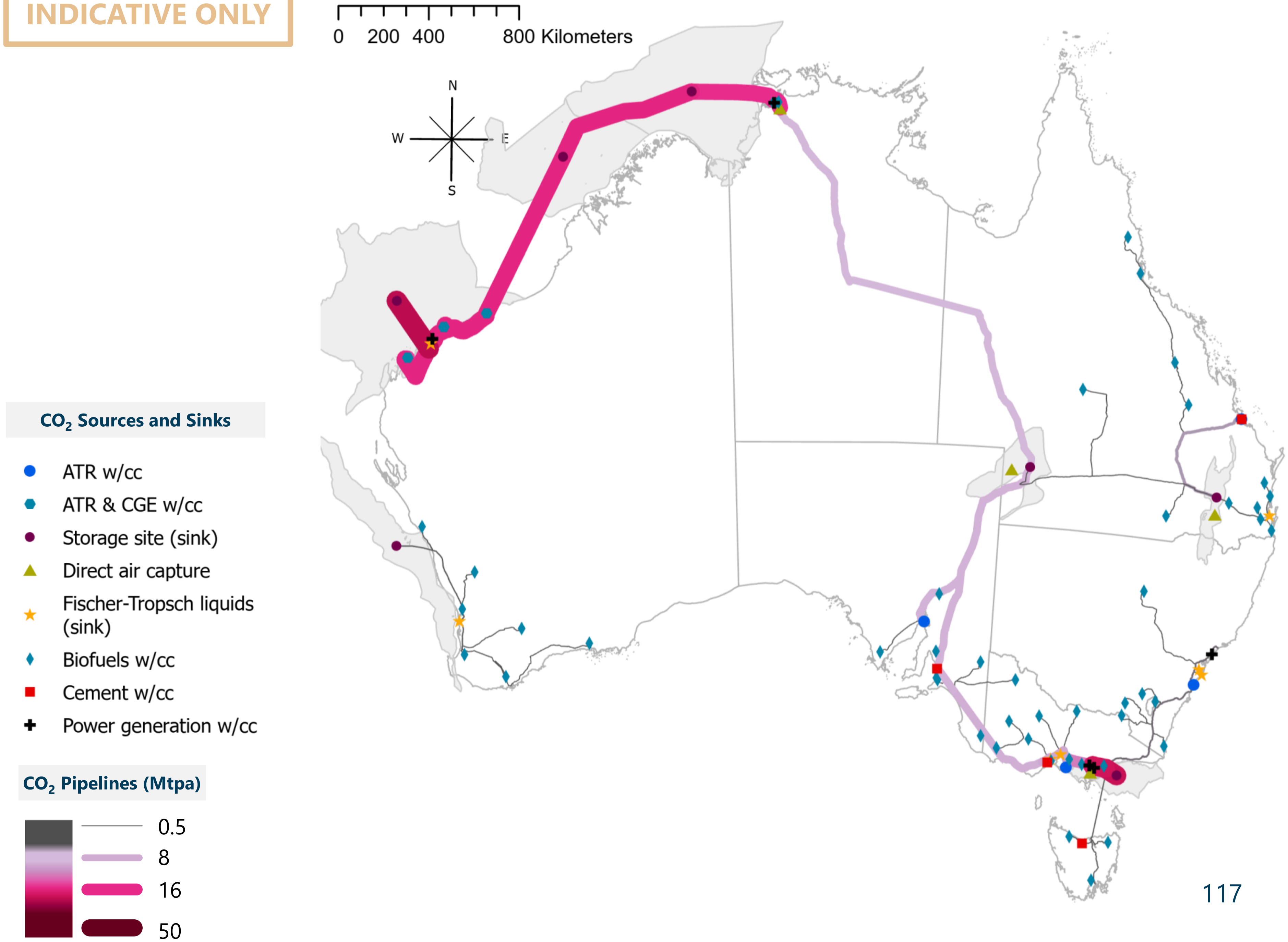
CGE = Conventional Gas Extraction

E+RE− 2060 CCUS

- There is a substitution effect for CO_2 and H_2 pipelines, if less of one is built, means more of the other is needed (e.g. compare E+ and E+RE−)
- In E+RE−, similar networks emerge to in E+ but at a far greater scale. Pipeline capacity (Mtpa-km) is 13× larger

Source(+)/Sink(−)	Mtpa
Cement with CCUS	12.1
Power with CCUS	3.1
ATR * CGE with CCUS	546.6
Direct Air Capture	318.2
Biofuels with CCUS	23.4
Fischer-Tropsch liquids	−17.8
Geological storage	−966.2
CO2 transmission	
Capacity (Mtpa-km)	**1,062,710**
Length (km)	20,404

INDICATIVE ONLY



FINAL MODELLING RESULTS

4.5 Sensitivity analyses

We have modelled 23 sensitivities

SCENARIO(S)		SENSITIVITY	SHORT DESCRIPTION
E+	E–	Faster	Domestic net-zero by 2040, export net-zero by 2050.
E+		Drivers+	Higher GDP and population growth.
E+		Drivers–	Lower GDP and population growth.
E+	E+ONS	Export+	Energy exports increased to 30EJ by 2060.
E+		Export–	Energy exports reduced to 5EJ by 2060.
E+		CleanExport–	Only 50% export decarbonisation by 2060 (assuming abatement overseas with CCS).
E+	E+RE–	RemoteCost+	Remote northern regions have higher capital costs.
E+	E+RE–	DistributedExport	Export task is more evenly distributed across the country.
E+		Solar–	Less ambitious capital cost trajectory for Solar PV.
E+		Transmission–	All inter-regional transmission capacity is frozen.
E+RE–		Nuclear	Nuclear power is allowed from 2035.
E+	E+RE–	CheapNuclear	Cheaper nuclear power is allowed from 2035.
E+RE+		Land+	Combined land sector goes to modest net negative emissions.
E+	E–	Sequestration+	Constraint on annual geologic sequestration of CO_2 is expanded.
E+RE–		Sequestration–	Constraint on annual geologic sequestration of CO_2 is reduced.
E+		Sequestration+ WACC+	×2 costs of capital and ×1.5 on social discount rate. Expanded constraint on geologic sequestration.
E+		Sequestration+ Fossil+	×2 fossil fuel costs. Expanded constraint on geologic sequestration.

Further detail on the sensitivity definitions and results are available at: netzeroaustralia.net.au

This pack reports selected highlights across the sensitivity analyses

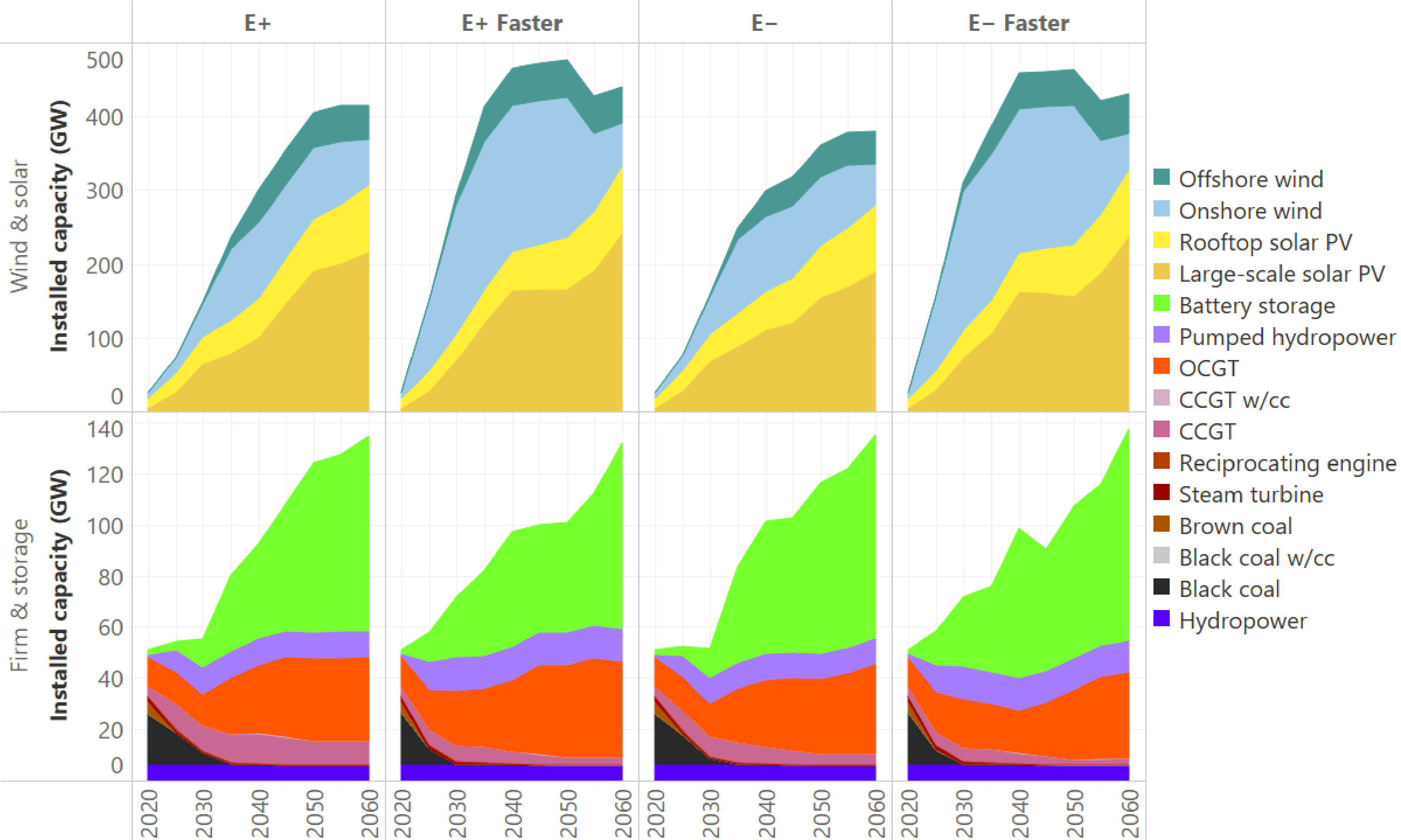
SENSITIVITY	KEY MESSAGE
What is required for faster emissions reduction?	Net zero 2040 requires us to build twice as much renewables in next 10 years as we would in net zero 2050. Onshore wind would play a greater role.
Could nuclear energy play a role?	No, unless both renewable deployment is constrained, and nuclear capital costs are ~30% lower than our best estimate.
What if the land CO_2 sink expands?	Enhanced land sinks could displace need for geologic sequestration and direct air capture in our full renewables rollout scenario. Methods face high levels of uncertainty in estimates of carbon accounting, additionality, barriers to adoption and technical and social feasibility.
Is transmission expansion critical?	No, we could build marginally more storage instead
What if projected solar PV cost reductions are not realised?	More wind (onshore and offshore), and reduced, but still significant, need for batteries.
Could energy exports be more evenly distributed around the nation?	Yes, +/– 15% to 30% CapEx swings in regional Australia are enough to shift export investment across the nation.
What is the impact of altering geological sequestration potential?	To meet export demand, sequestration and renewable build cannot both be constrained.

SENSITIVITIES KEY RESULTS

What is required for faster emissions reduction?

Renewable capacities peak at 2040, onshore wind expands as fast as solar PV

Projected domestic electricity generation capacity by technology (GW). Note varying y-axis scales.



SENSITIVITY

Faster

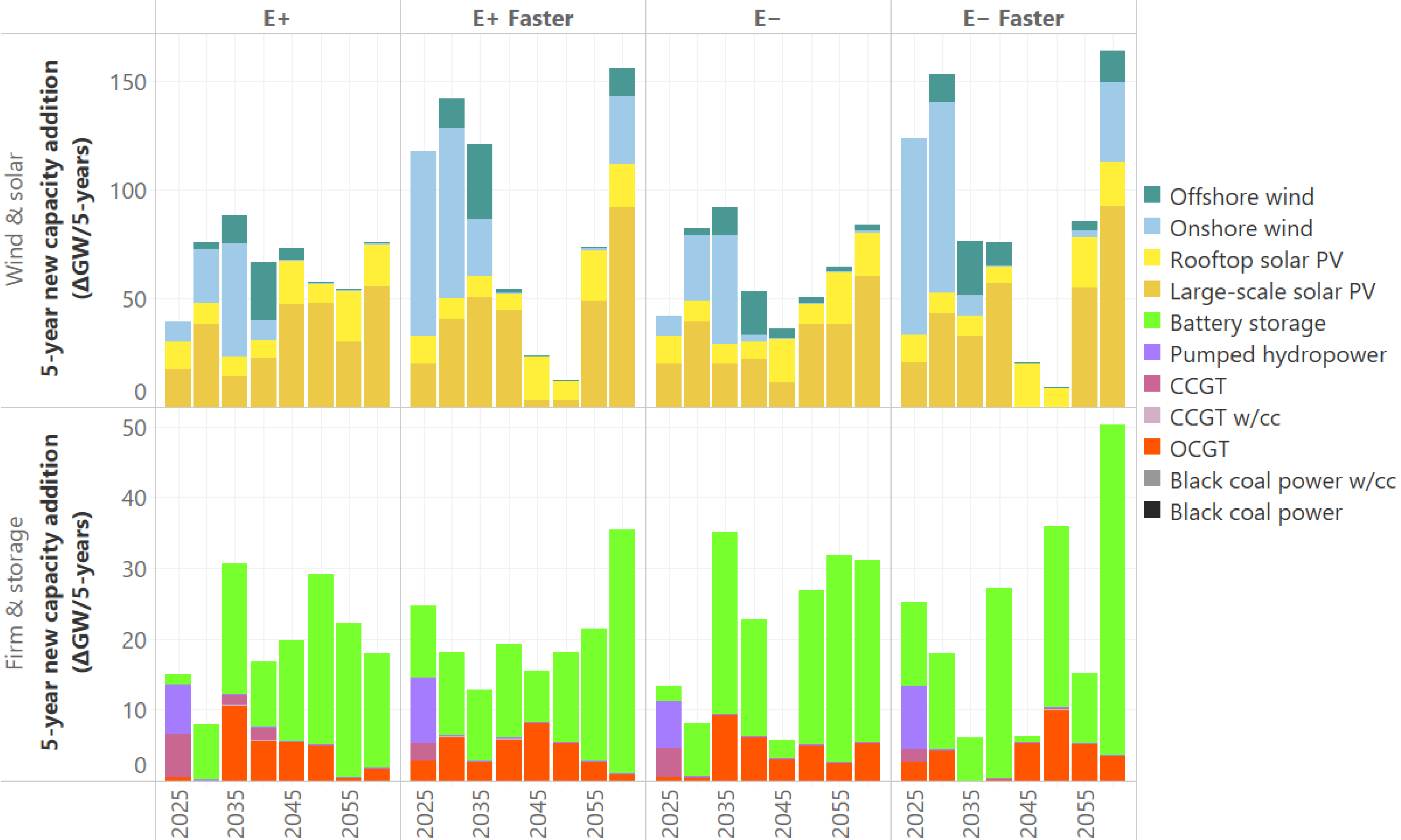
Domestic net-zero by 2040, export net-zero by 2050

KEY TAKEAWAYS

- The total firming and storage rollout is similar, irrespective of a net zero 2050 or 2040 target (though it accelerates more quickly in the first 10 years).
- Onshore wind plays a far greater role when the transition is compressed.
- *E+ Faster* has 43% higher NPV of total (domestic and export) energy system costs over 2020 to 2060 (relative to E+).
- *E− Faster* has 45% higher NPV of total (domestic and export) energy system costs over 2020 to 2060 (relative to E−).

2040 net zero requires renewable deployment over 2025-2030 to triple compared to core Scenarios

Projected 5-year capacity additions to domestic electricity system (ΔGW/5-years). Note varying y-axis scales.



SENSITIVITY

Faster

Domestic net-zero by 2040, export net-zero by 2050

KEY TAKEAWAYS

- Much more rapid deployment must be sustained over the 2030s, (up to 2×).
- The deployment of firming and storage assets is also front-loaded.

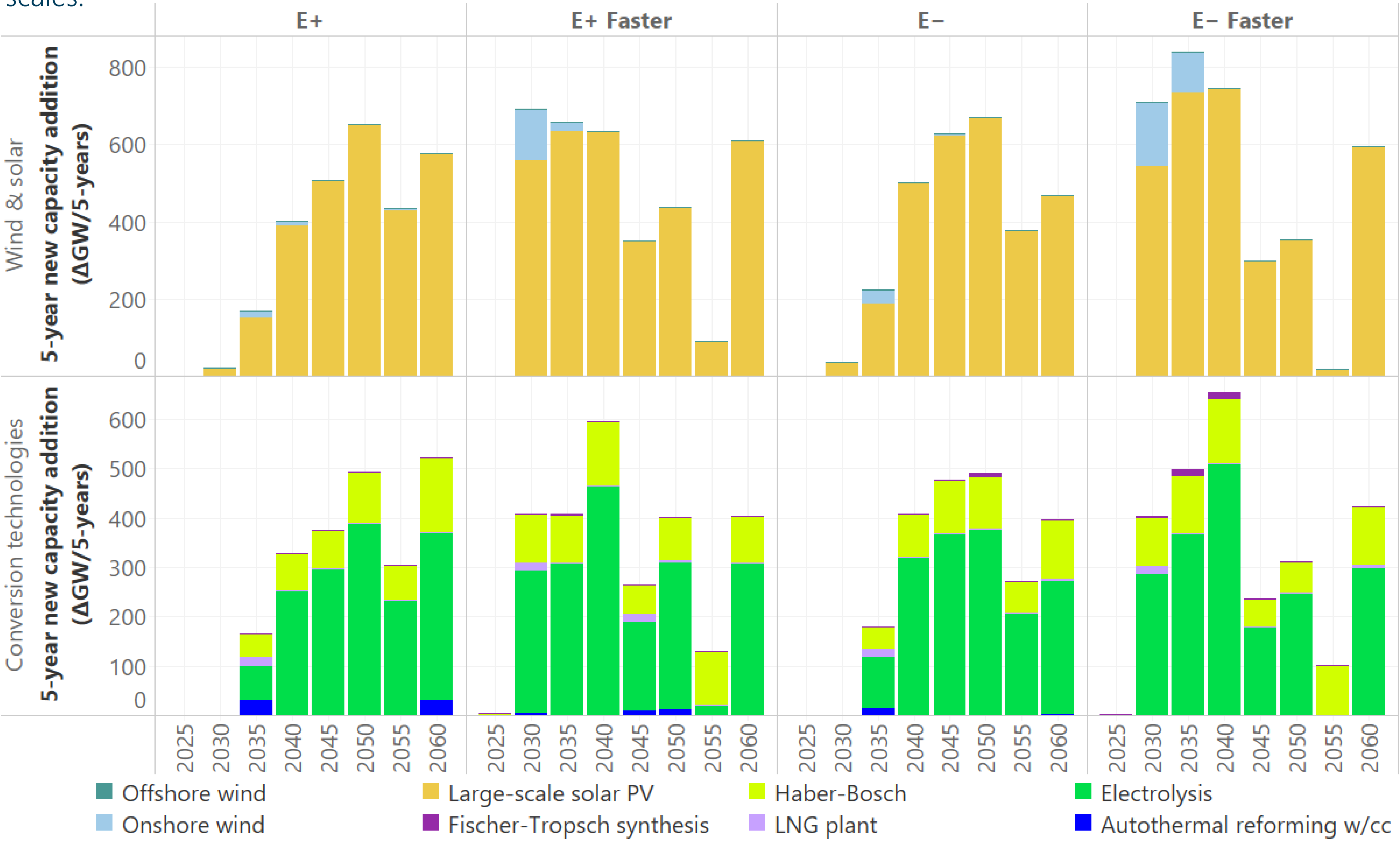
Net zero exports by 2050 requires a renewable build of over 120 GW per year, sustained 2025 to 2040.

SENSITIVITY

Faster

Domestic net-zero by 2040, export net-zero by 2050

Projected 5-year capacity additions to export energy system (ΔGW/5-years). Note varying y-axis scales.



KEY TAKEAWAYS

- Net zero exports by 2050 requires more rapid, sustained, and immediate deployment of renewables compared to net zero by 2060 which allows for gradual growth in renewable build rate.

SENSITIVITIES KEY RESULTS

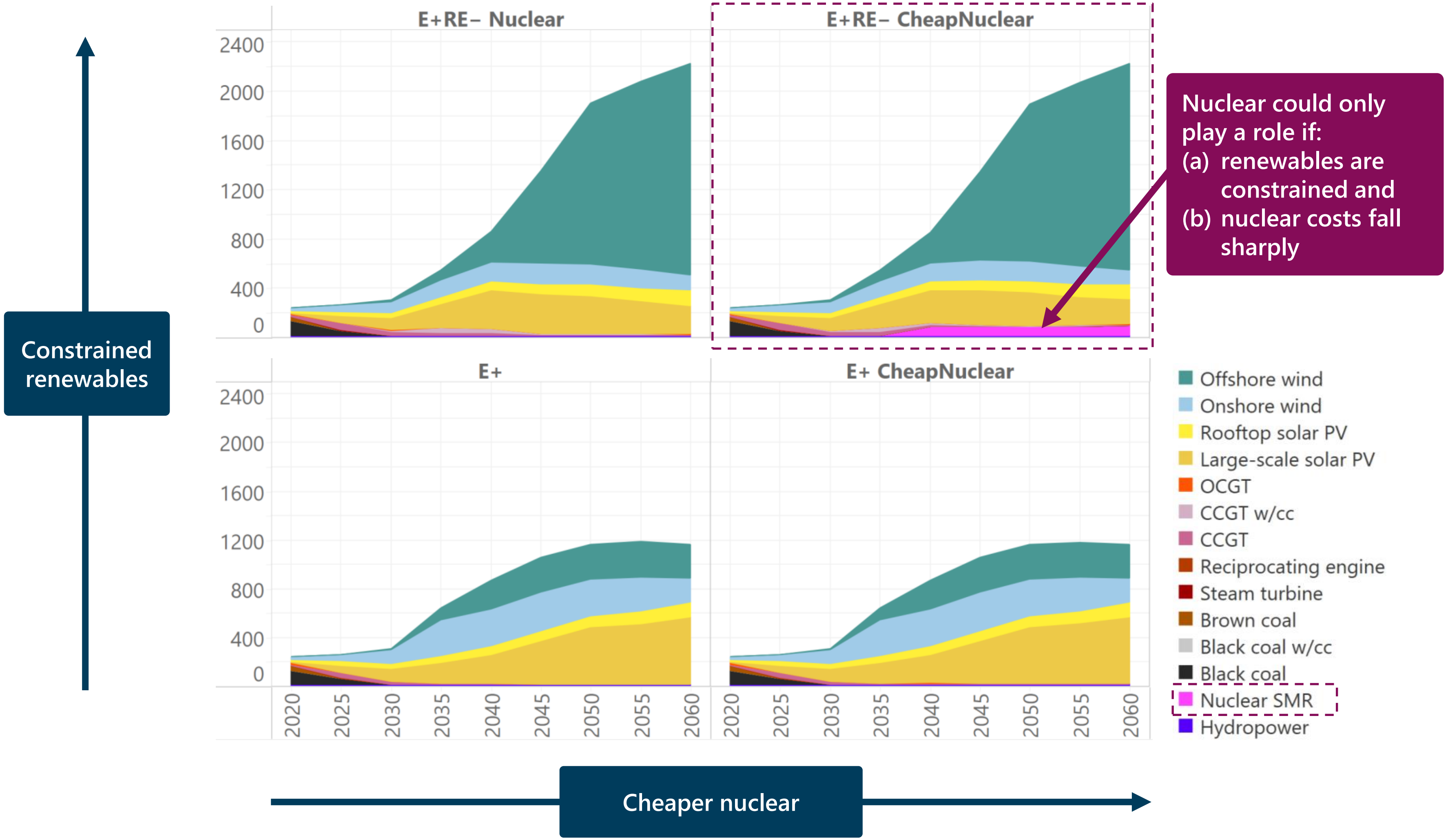
Could nuclear energy play a role?

No role for nuclear energy unless costs fall sharply, and renewable energy growth is constrained

Nuclear; Cheap Nuclear

Nuclear power is allowed from 2035; Cheaper nuclear power is allowed from 2035

Domestic electricity generation (TWh / year)



KEY TAKEAWAYS

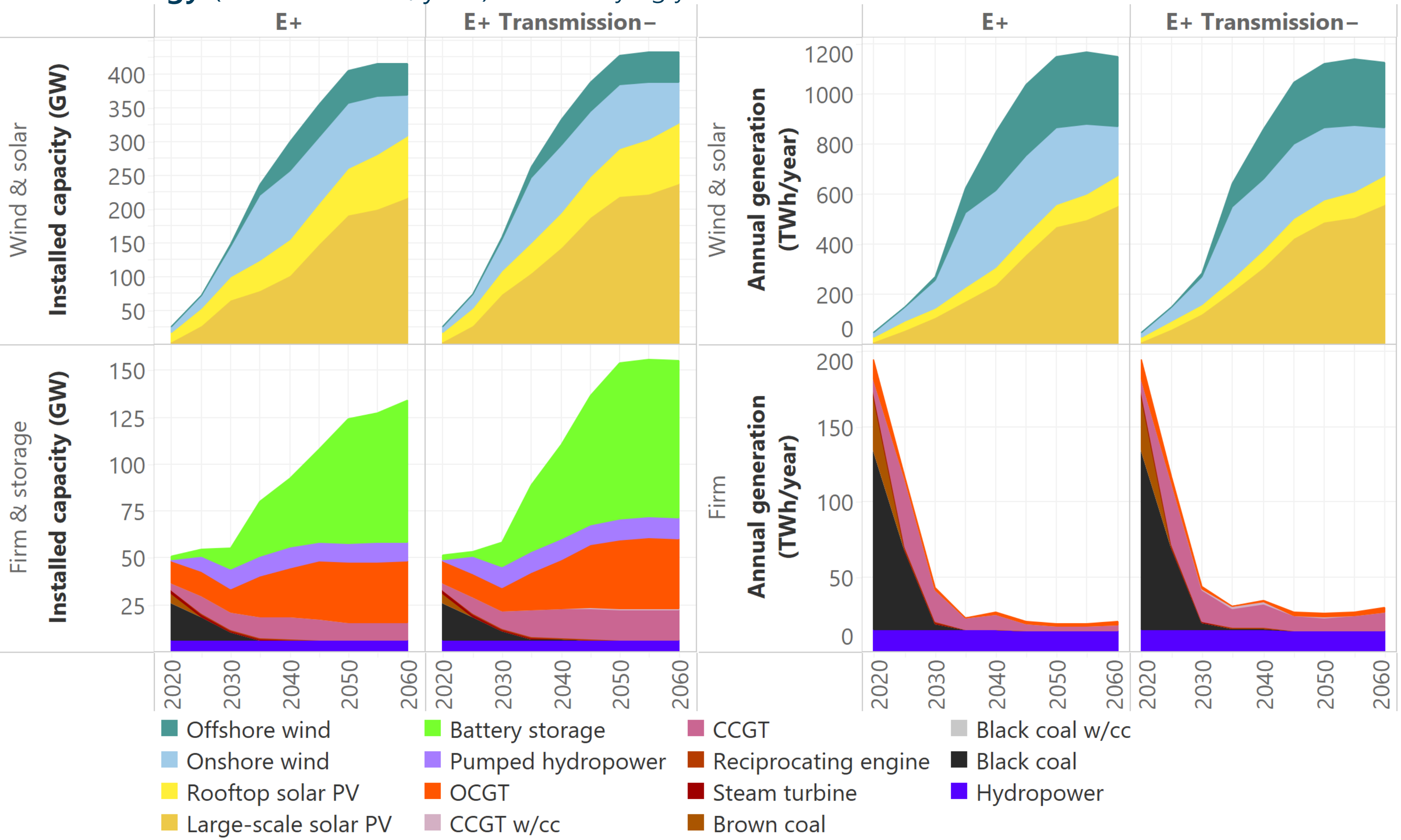
- We find that nuclear electricity capacity is installed only when its capital cost is 30% lower than current international best practice (at ~5,200 $/kW), and when renewable build rates are constrained.
- In this case, the proportion of nuclear generation is a modest share of domestic electricity generation, and an even smaller share of total export and domestic energy.
- At a nominal cost of ~7,200 $/kW nuclear technology never plays a role.

SENSITIVITIES KEY RESULTS

Is interstate transmission expansion critical?

Constrained transmission requires more firming and storage capacity

Projected domestic electricity system capacity (left) and annual generation (right), by technology (GW and TWh/year). Note varying y-axis scales.



SENSITIVITY

Transmission–

All inter-regional transmission capacity is frozen

KEY TAKEAWAYS

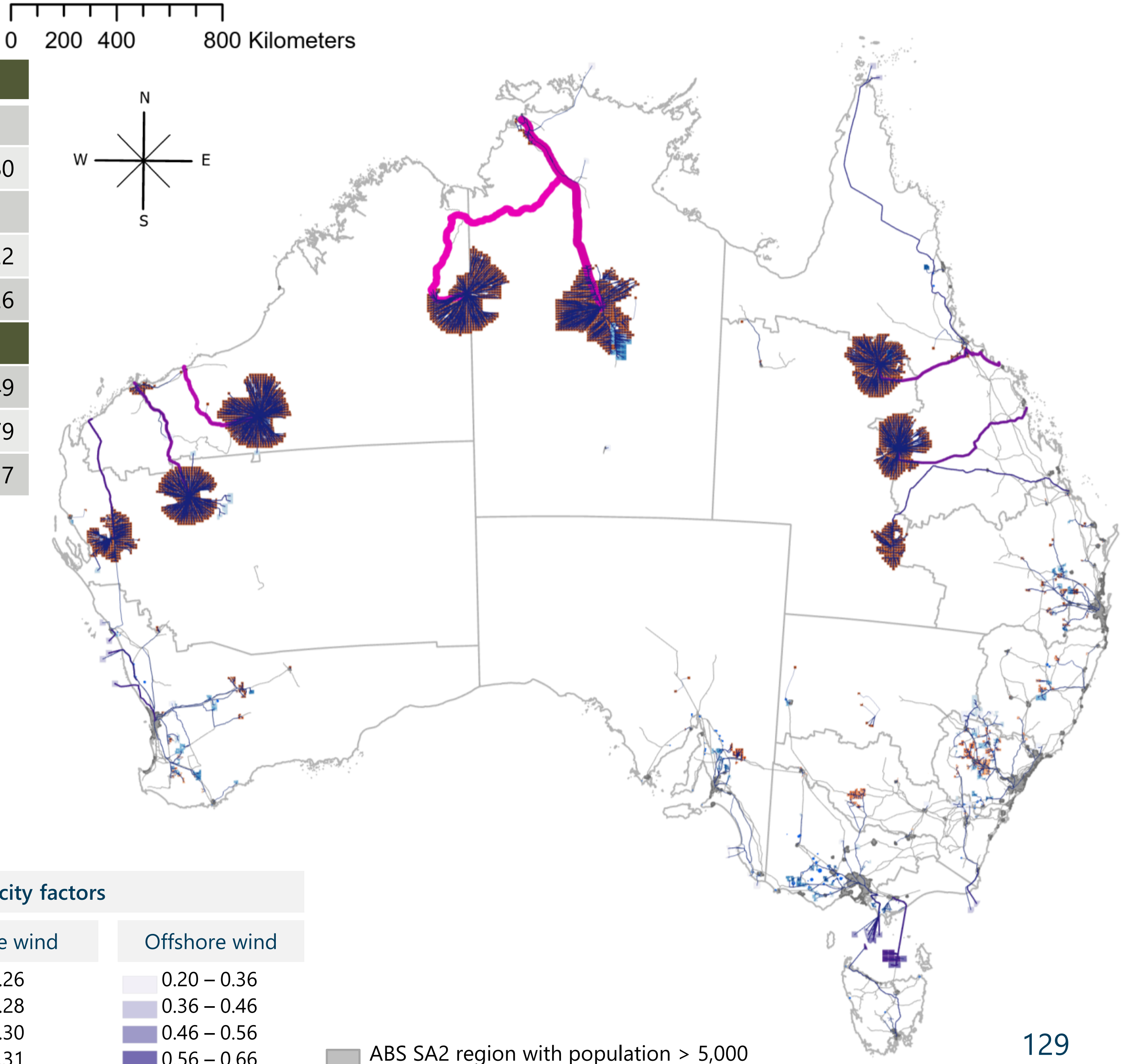
- Constraining interregional transmission capacities to current capacities creates greater need for both gas turbine firm capacity and battery storage.
- *E+ Transmission–* installs an additional 5 GW of OCGT, 7 GW of CCGT and ~20 GW of batteries, relative to E+.
- NPV of total energy system costs is $130 billion higher (2% of domestic system costs) over 2020 to 2060 relative to E+.
- Additional requirements are spread across all regions, with the most populous regions requiring the most additional capacity.
- Increased use of gas turbines increases GHG emissions by 4 Mt-CO2e/year, which is offset by reduced use of oil products in the transport sector.

E+Transmission – 2060

- Inter-regional transfers of electricity are not allowed in this sensitivity (although transmission to closest population locations may cross regional borders)
- Solar PV capacity 22.9× wind capacity
- TX in domestic areas ~1.7× TX in 2020
- TX in export areas ~10.5× TX in 2020

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	130	2980
Area used (1000 km2)^		
Total	41.8	66.22
Direct	0.42	60.26
Transmission added (GW-km)*		
Capacity domestic area**		46,749
Capacity export zone		294,679
Capacity not shown		57

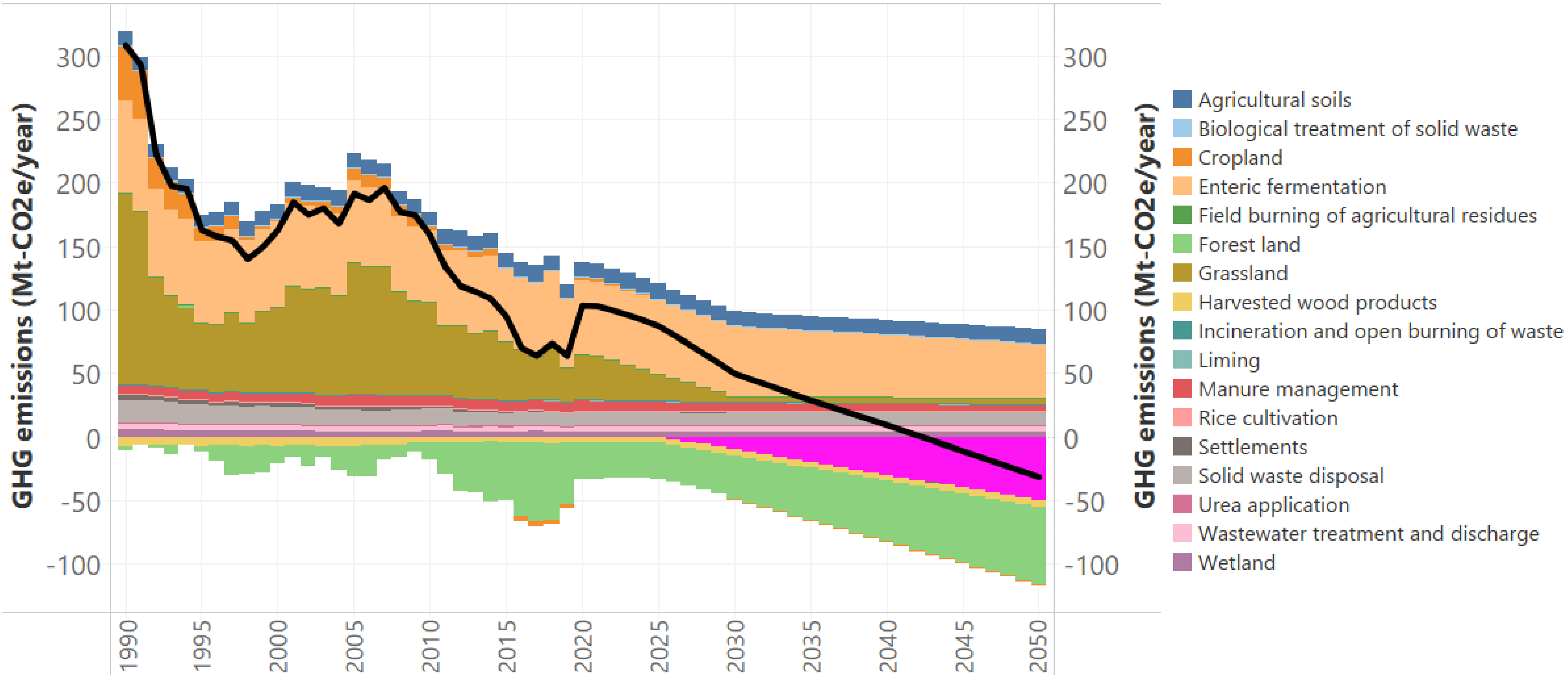


SENSITIVITIES KEY RESULTS

What if the land CO_2 sink expands?

A number of emerging methods for enhancing Australian land CO_2 sink could have implications for wider system

GHG emissions trajectory for the combined land sector (agriculture, waste and LULUCF) (Mt-CO_2e/year). Black line shows net GHG emissions



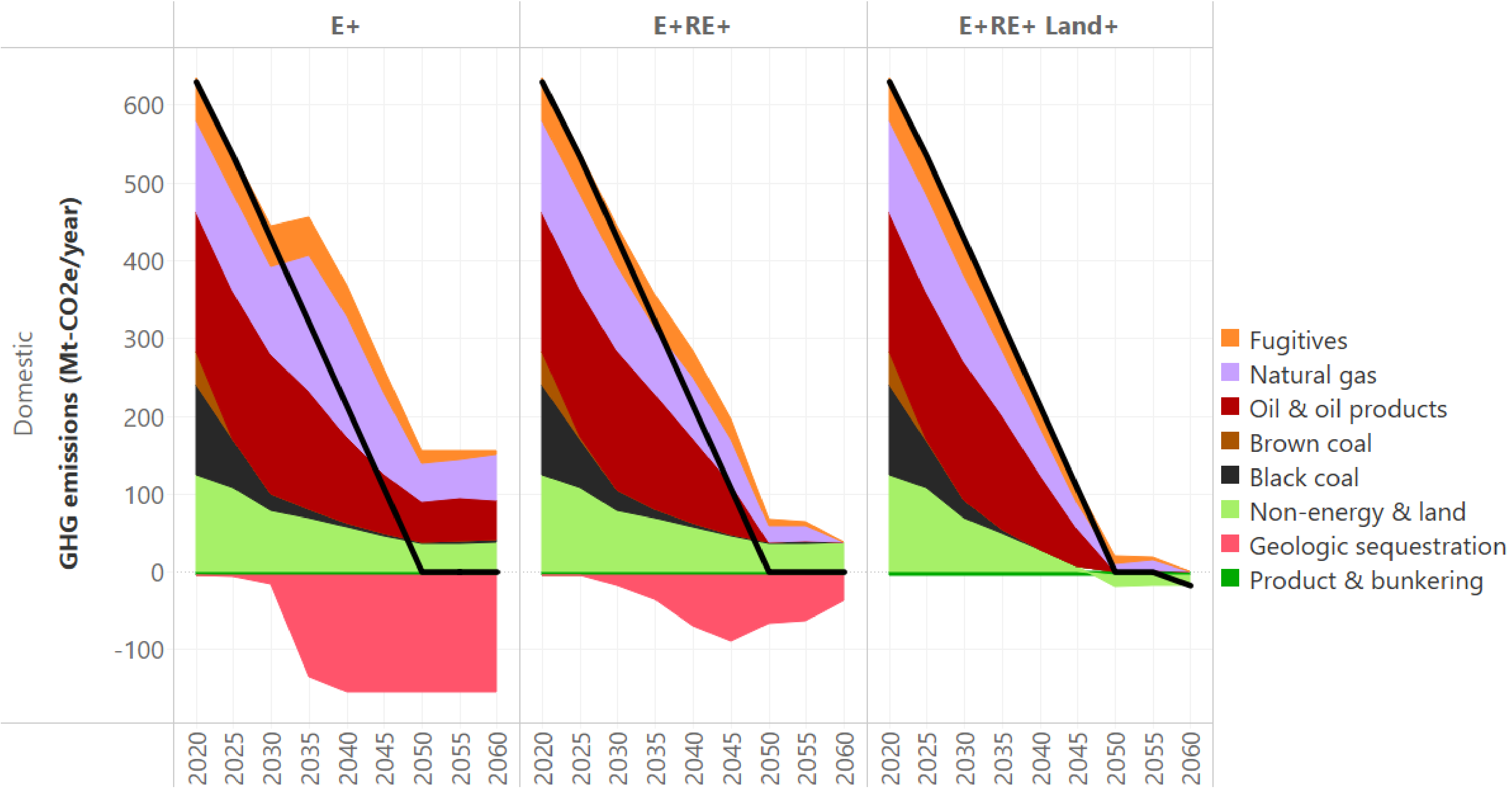
Land+ Sensitivity adds bio-sequestration shown as: Land+

KEY TAKEAWAYS

- Core Scenarios' projected net LULUCF sink does not fully compensate for residual agriculture and waste emissions by 2050.
- Other options for reducing emissions or enhancing the land CO_2 sink may emerge, with varying levels of uncertainty in estimates of carbon accounting, additionality, barriers to adoption and technical and social feasibility.
- This could include a whole-of-rangeland restoration approach, including: integrated savannah burning, feral animal control, and human-induced (re)generation of deep-rooted rangeland plant species.

In E+RE+, higher land sinks could potentially replace the need for geological sequestration

Projected domestic emissions (Mt-CO_2e/year).



KEY TAKEAWAYS

- E+RE+ has the lowest need for carbon sequestration of Scenarios modelled.
- In this scenario, the additional bio sequestration in Land+ sensitivity can displace the need for geological requestion of CO2.
- DAC and biofuels are still needed, but to a lesser extent, to make synthetic liquid fuels.

SENSITIVITIES KEY RESULTS

What if projected solar PV cost reductions are not realised?

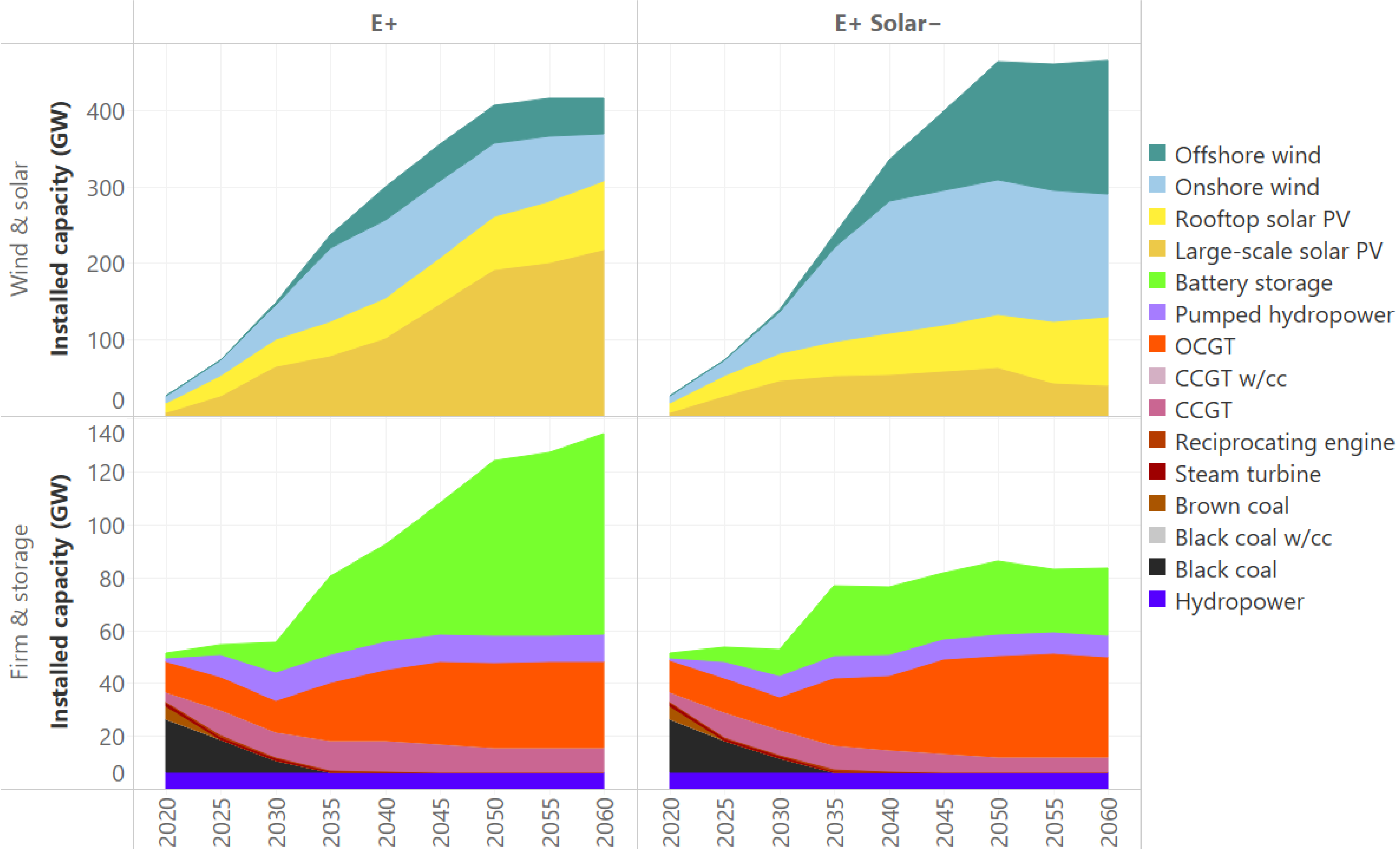
Higher solar costs shift domestic system towards wind and away from batteries

SENSITIVITY

Solar−

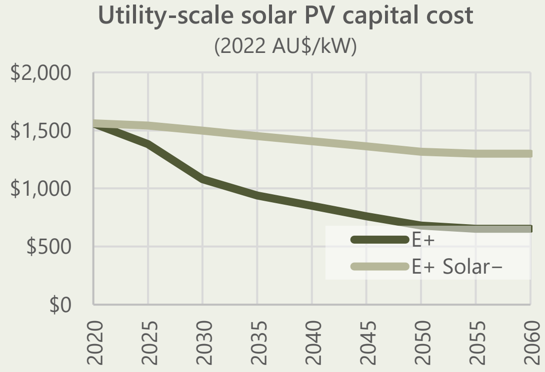
Less ambitious capital cost trajectory for Solar PV

Projected domestic electricity system capacity, by technology (GW). Note varying y-axis scales.



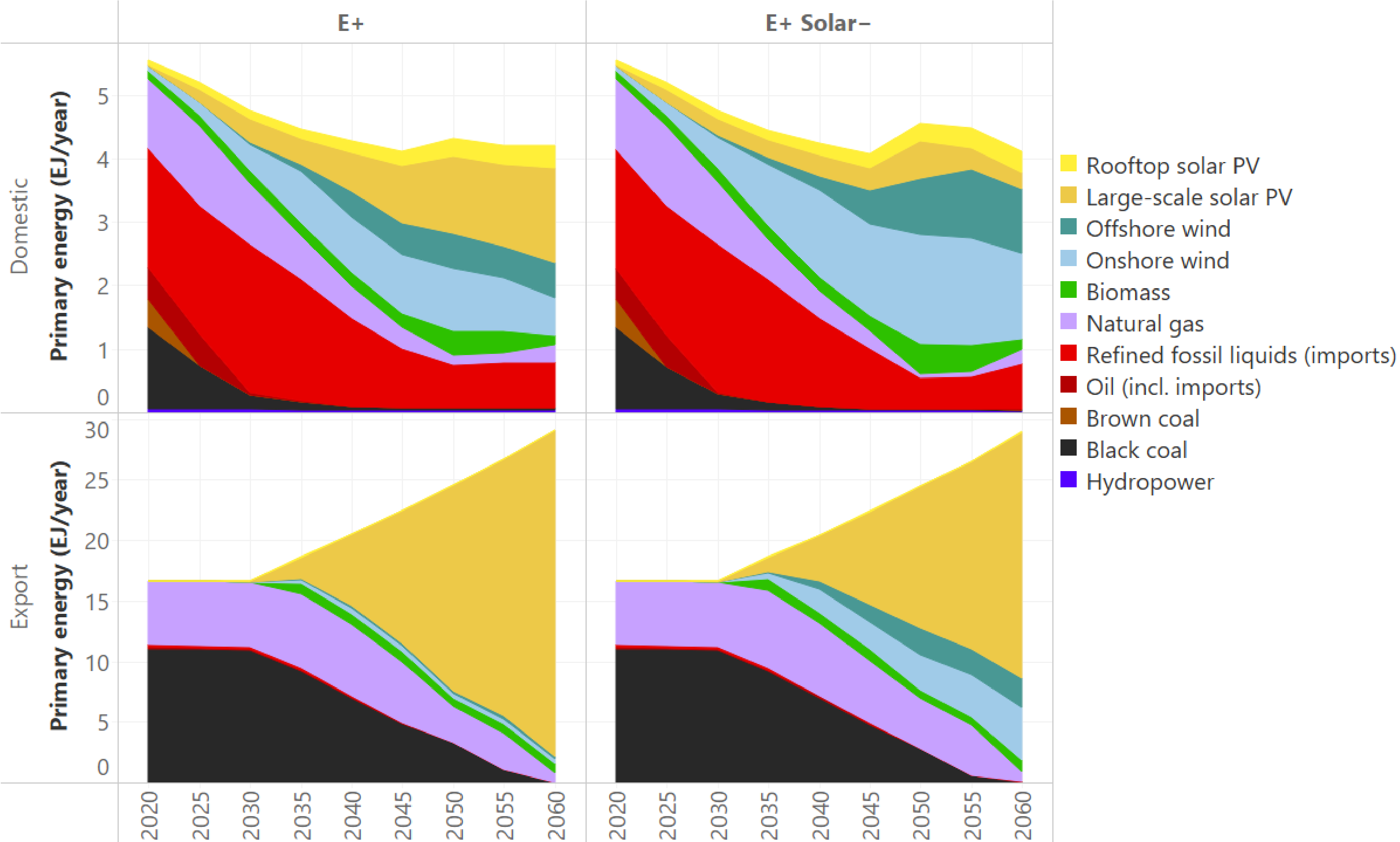
KEY TAKEAWAYS

- Using a less ambitious cost curve for Solar PV, both onshore and offshore wind play a much greater role in domestic energy supply.
- Battery storage falls, highlighting its role in shifting solar generation to evening peaks.
- *E+ Solar−* has $610 billion (5%) higher NPV of total (domestic and export) energy system costs over 2020 to 2060 (relative to E+).



Solar remains dominant supplier of primary energy exports, but wind dominates domestic

Projected primary energy (EJ/year). Note varying y-axis scales.



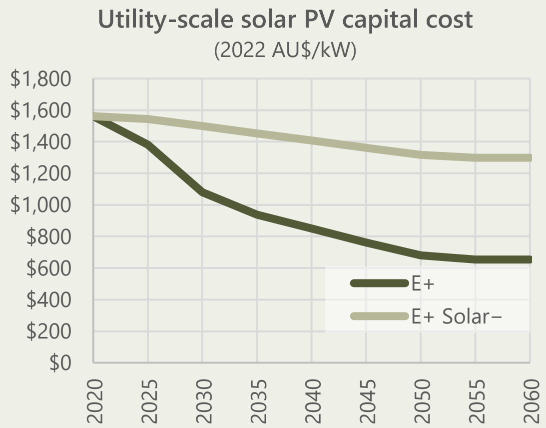
SENSITIVITY

Solar–

Less ambitious capital cost trajectory for Solar PV

KEY TAKEAWAYS

- Some clean energy exports shift from Western Australia, Northern Territory and Queensland to Victoria, although the northern states/territories remain the dominant clean energy exporters.
- *E+ Solar–* has $610 billion (5%) higher NPV of total (domestic and export) energy system costs over 2020 to 2060 (relative to E+).



SENSITIVITIES KEY RESULTS

Could energy exports be more evenly distributed around the nation?

NSW, Victoria and SA could export clean energy, alongside northern States and Territories

SENSITIVITY

DistributedExport; RemoteCost+

Remote northern regions have higher capital costs; Export task is more evenly distributed across the country

Projected exported energy form in the E+ Scenario/Sensitivities, by state of export (EJ/year)

KEY TAKEAWAYS

- 30% higher capital costs in northern WA and NT, and 15% higher in northern Queensland, shift export investment east and south.
- This has a similar effect to enforcing a more distributed sharing of the export task.
- However, under E+ RemoteCost+ Queensland sees a major boom in solar exports (despite higher costs in its north), as Western Australia and Northern Territory are penalised for 30% higher costs.

Sensitivity definitions

- **DistributedExport**: A maximum of 3 EJ/year of ammonia may be exported from any one state's/territory's port
- **RemoteCost+:** capital costs +30% in WA-north and WA-export. +15% in QLD-north and QLD-export

Exported energy is supplied by solar in NSW and SA, and offshore wind in Victoria.

SENSITIVITY

DistributedExport; RemoteCost+

Remote northern regions have higher capital costs; Export task is more evenly distributed across the country

Projected primary energy serving exports in the E+ Scenario/Sensitivities, by state of export (EJ/year).

KEY TAKEAWAYS

- Exported energy supplied by solar in New South Wales and South Australia, offshore wind in Victoria.
- E+ DistributedExport has $90 billion. (<2% of export system) higher NPV of total energy system costs over 2020 to 2060 (relative to E+).
- E+ RemoteCost+ has $460 billion. (8% of export system cost) higher NPV of total energy system costs over 2020 to 2060 (relative to E+).

Sensitivity definitions

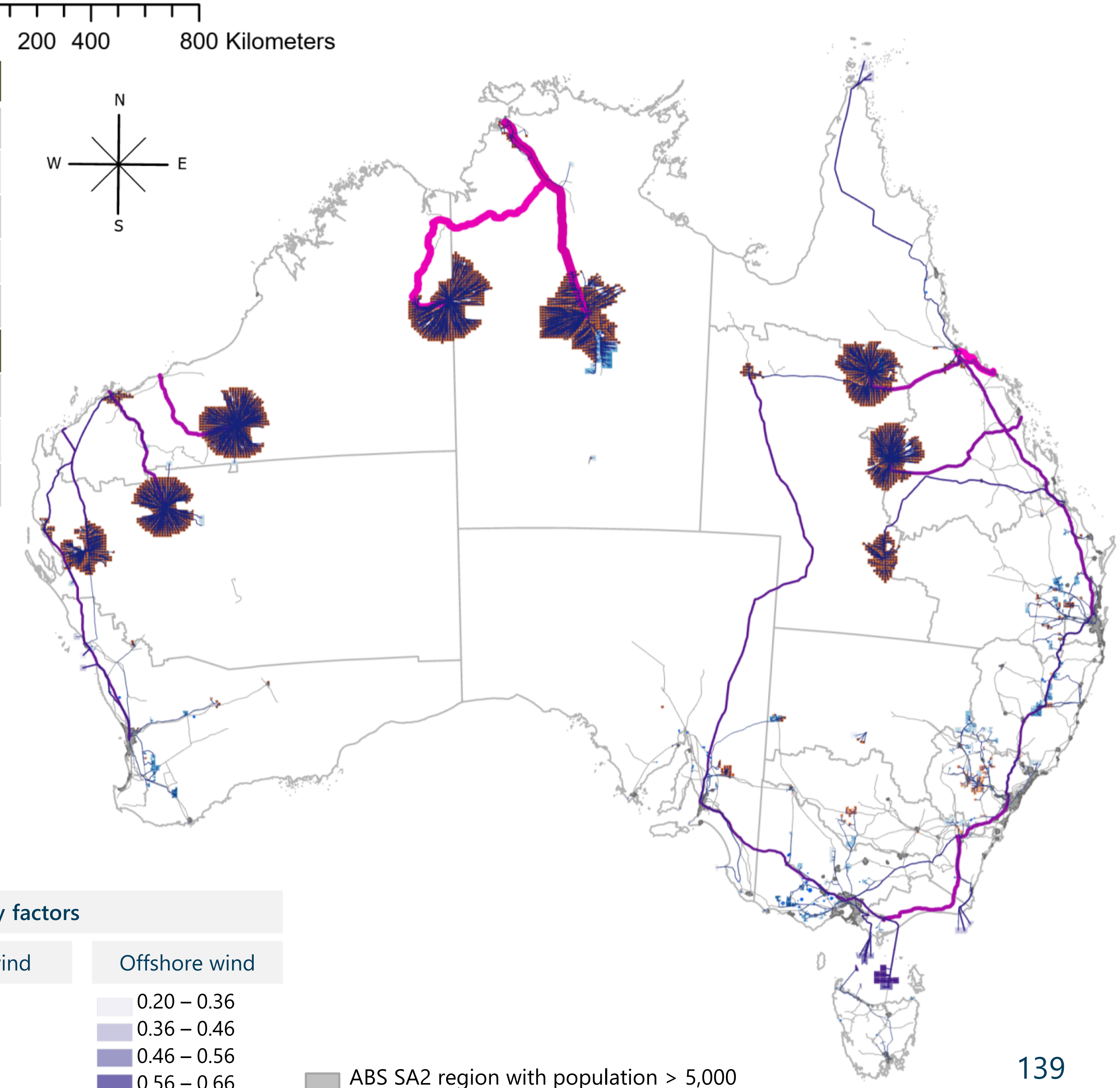
- **DistributedExport**: A maximum of 3 EJ/year of ammonia may be exported from any one state's/territory's port
- **RemoteCost+:** capital costs +30% in WA-north and WA-export. +15% in QLD-north and QLD-export

E+ 2060
(for context)

- Solar PV capacity 21× wind capacity
- TX in domestic areas ~2.8× TX in 2020

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	137	2929
Area used (1000 km2)^		
Total	44.09	65.1
Direct	0.44	59.24
Transmission added (GW-km)*		
Capacity domestic area**	77,229	
Capacity export zone	292,778	
Capacity not shown	18,099	



Transmission (MW)

- <1,000
- 6,600
- 13,000
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+RE– 2060 Constrained renewables

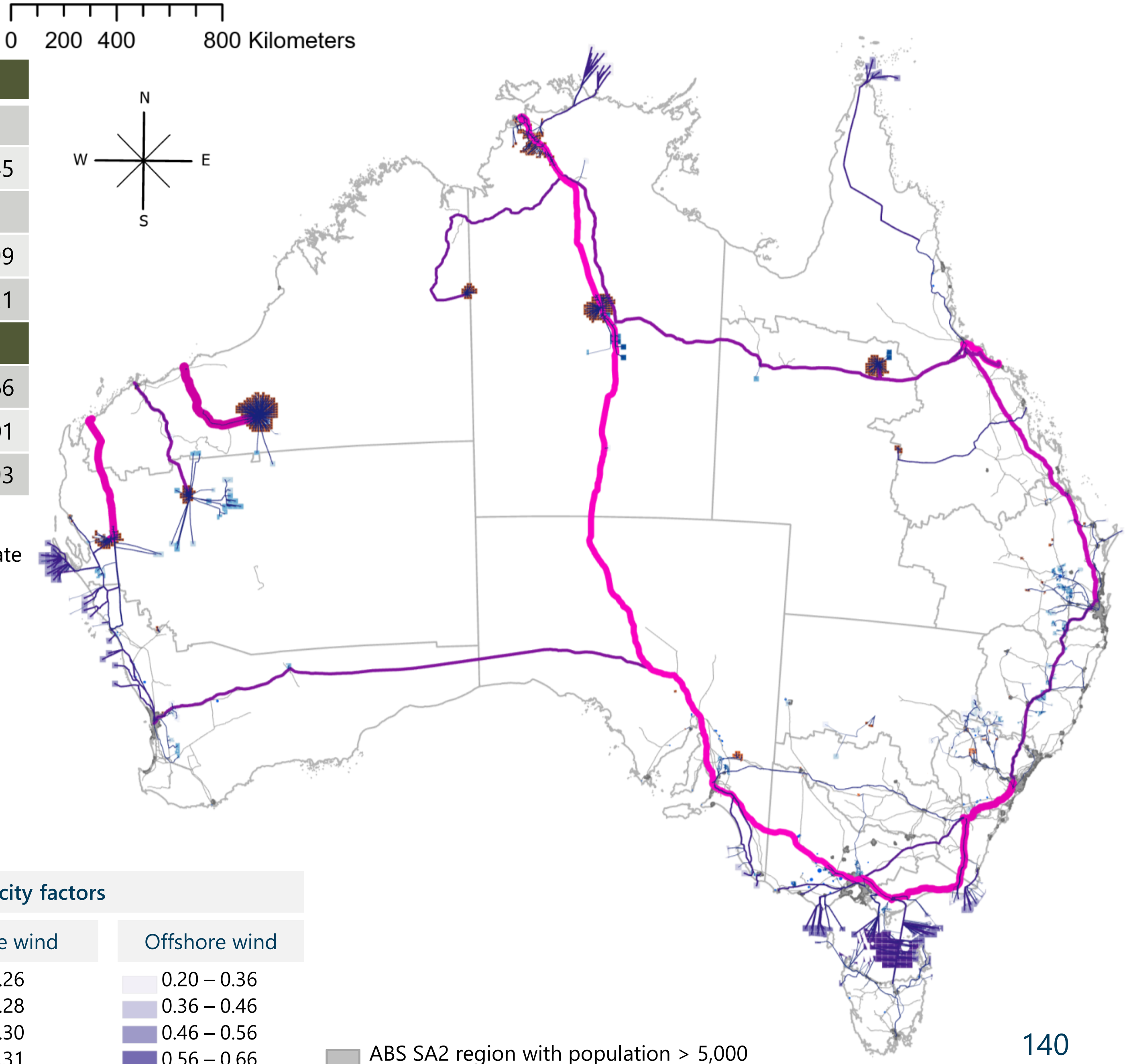
- Further constraints on onshore renewables lead to more siting of offshore wind
- Solar PV capacity only 1.8× wind capacity
- TX in domestic areas ~8.7× TX in 2020 (supporting exports from VIC)
- TX in export zones only half of TX in 2020

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	525	945
Area used (1000 km2)^		
Total	134.5	20.99
Direct	1.35	19.1
Transmission added (GW-km)*		
Capacity domestic area**	244,766	
Capacity export zone	148,601	
Capacity not shown	8,993	

Core scenario definition

- More constrained renewable rollout rate
- Higher cap on annual underground carbon storage (to make net zero exports achievable)



Transmission (MW)

- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
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0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ONS 2060 Onshoring

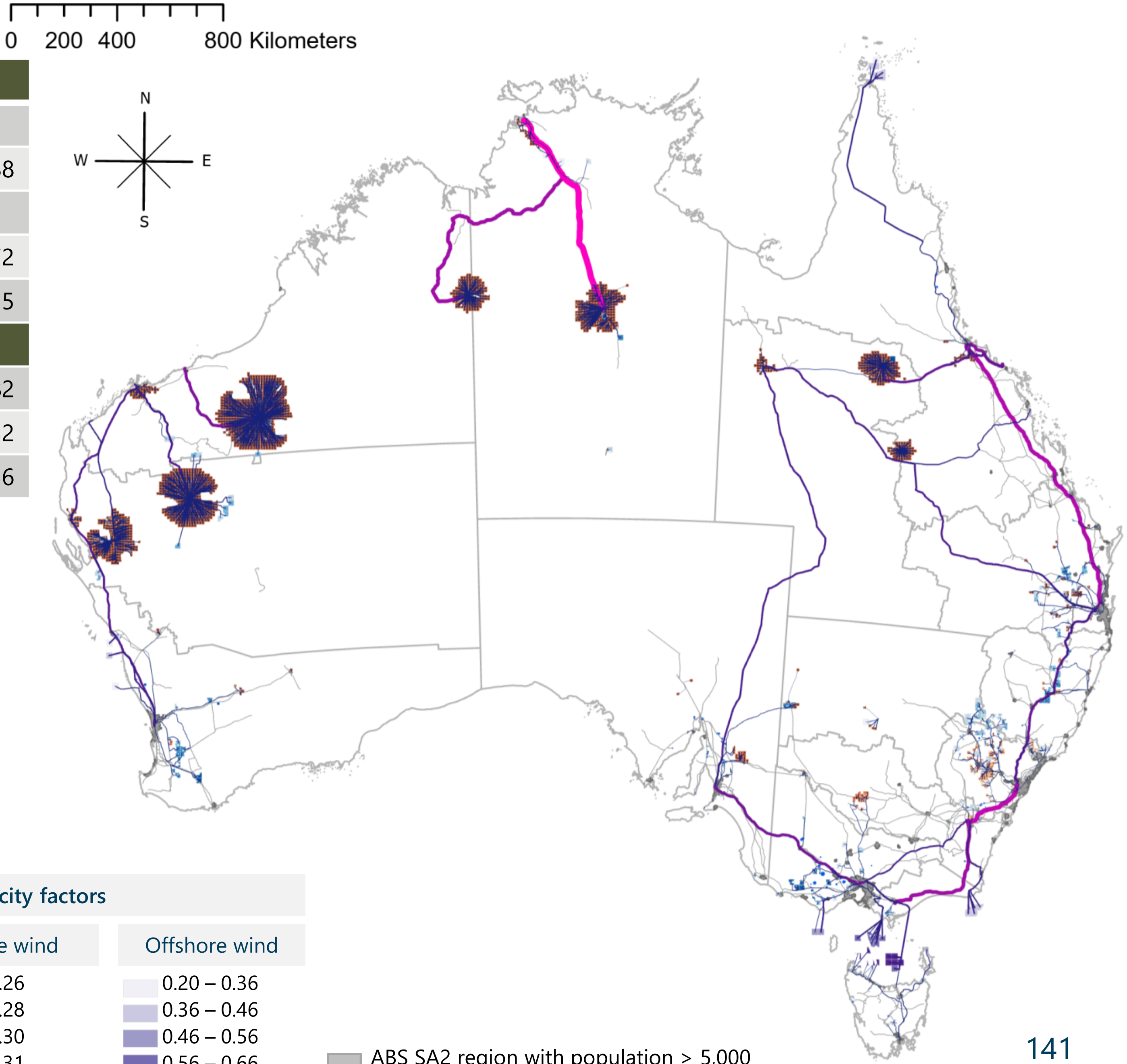
- Major new DRI facilities in northern WA supported by green hydrogen hubs
- Solar PV capacity 13.4× wind capacity
- TX in domestic areas ~3.4× TX in 2020
- TX in export areas ~5× TX in 2020

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	133	1788
Area used (1000 km2)^		
Total	40.77	39.72
Direct	0.41	36.15
Transmission added (GW-km)*		
Capacity domestic area**		95,082
Capacity export zone		139,532
Capacity not shown		16,836

Core scenario definition

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



Transmission (MW)

- <1,000
- 6,600
- 13,300
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
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0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

ABS SA2 region with population > 5,000 people & density > 100 people/km^2

E+ Distributed Export 2060

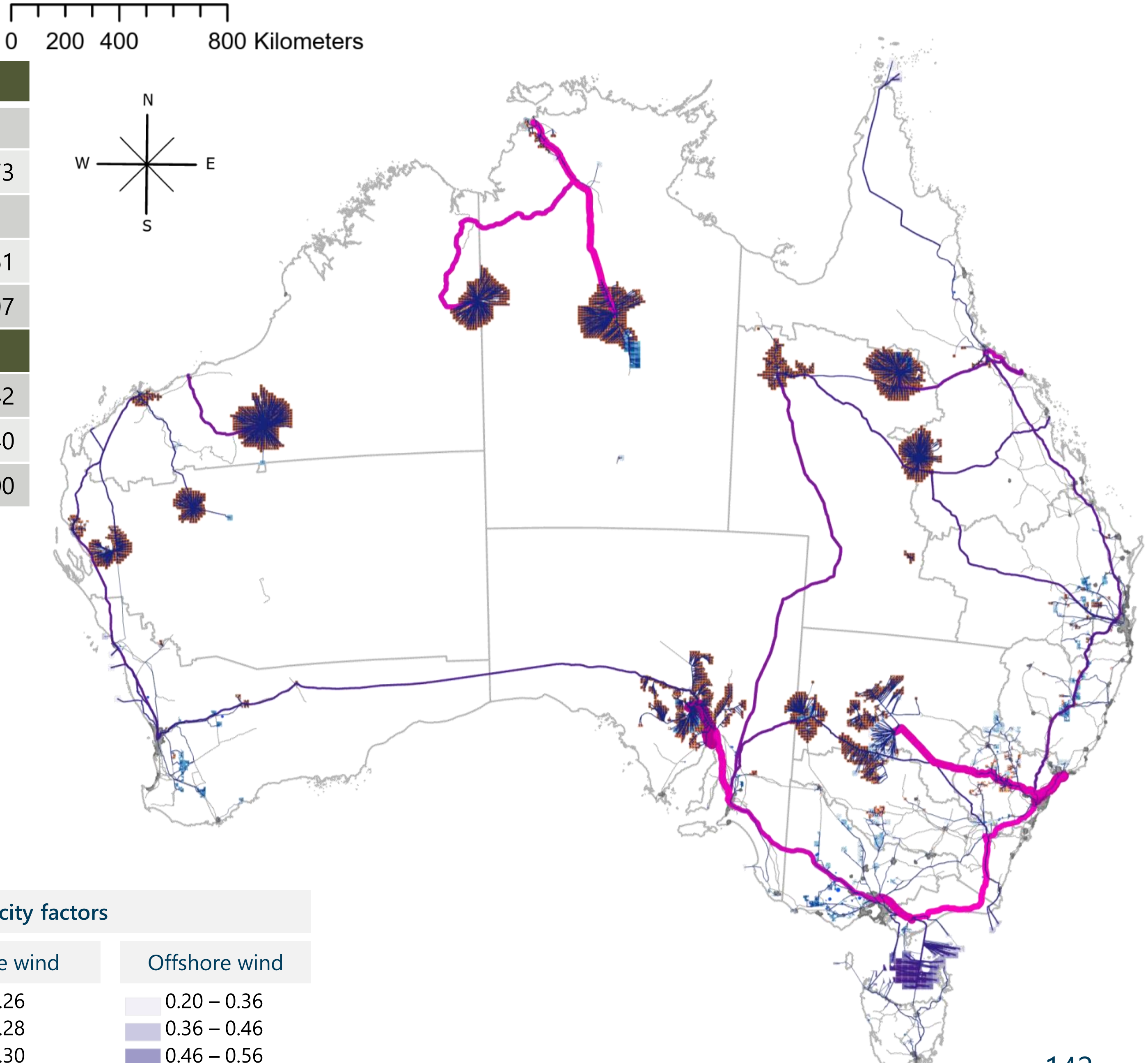
- Major new renewable export hubs in South Australia, West New South Wales, and within the Bass Strait.
- Solar PV capacity 10.7× wind capacity
- TX in domestic areas ~5.5× TX in 2020
- TX in export areas ~9.6× TX in 2020

INDICATIVE ONLY

	Wind	Solar
Capacity installed (GW)		
	258	2773
Area used (1000 km2)^		
Total	78.01	61.61
Direct	0.78	56.07
Transmission added (GW-km)*		
Capacity domestic area**		153,642
Capacity export zone		269,340
Capacity not shown		11,200

Sensitivity definition

DistributedExport: A maximum of 3 EJ/year of ammonia may be exported from any one state's/territory's port



Transmission (MW)

- <1,000
- 6,600
- 13,000
- 20,000

VRE project capacity factors

Solar PV	Onshore wind	Offshore wind
0.14 – 0.20	0.21 – 0.26	0.20 – 0.36
0.20 – 0.21	0.26 – 0.28	0.36 – 0.46
0.21 – 0.22	0.28 – 0.30	0.46 – 0.56
0.22 – 0.23	0.30 – 0.31	0.56 – 0.66
0.23 – 0.29	0.31 – 0.38	0.66 – 0.81

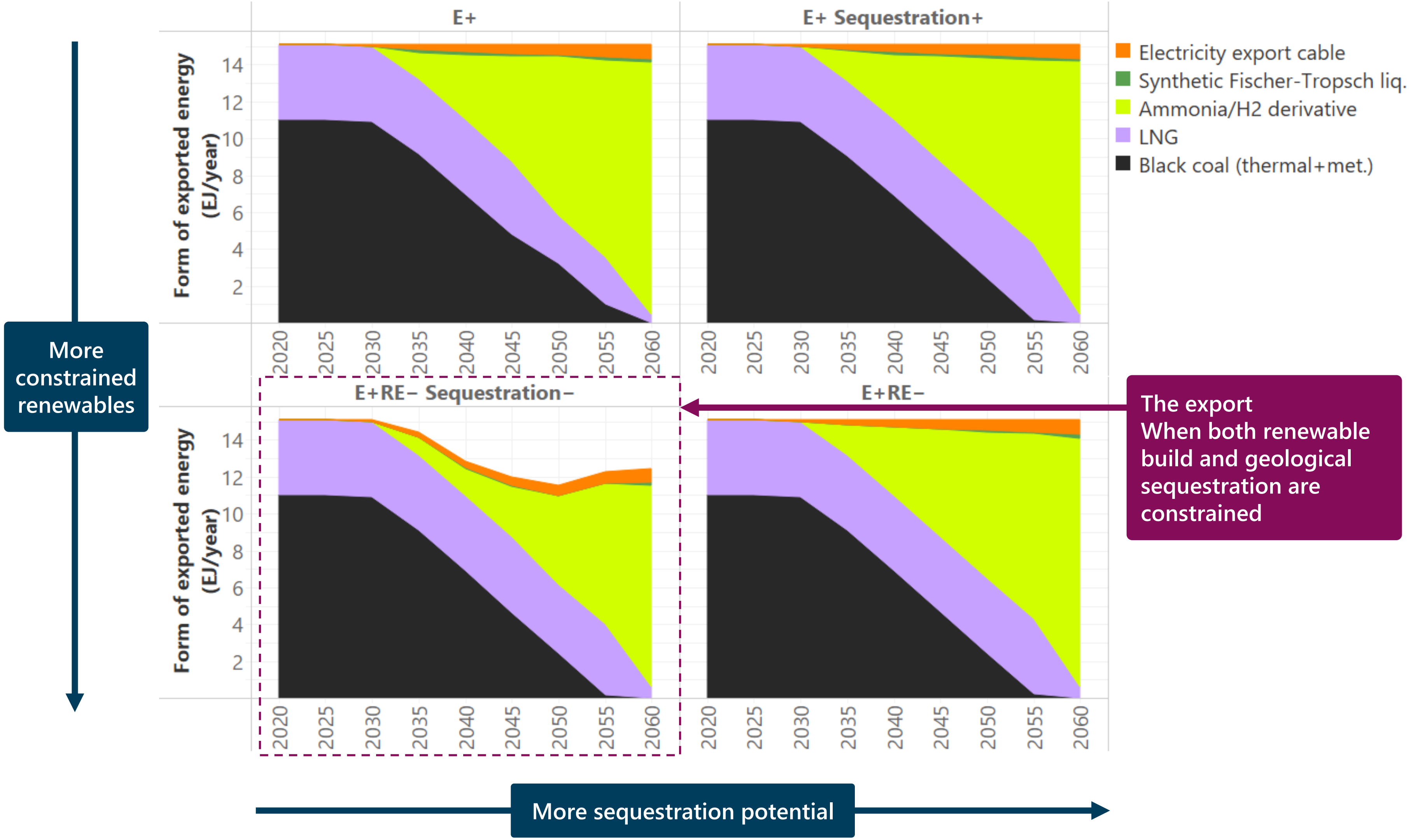
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

SENSITIVITIES KEY RESULTS

What is the impact of altering geological sequestration potential?

To meet export demand, sequestration and renewable build cannot both be constrained

Projected exported energy form (EJ/year)



SENSITIVITY

Sequestration+; Sequestration−

Constraint on CO_2 geological sequestration is expanded; Constraint on CO_2 geological sequestration is reduced

KEY TAKEAWAYS

- When both renewable build rates and geologic sequestration are constrained (bottom left, E+RE−Sequestration−), maintaining the 15 EJ/year export task is difficult.

Sensitivity definitions

- **Sequestration+:** Constraint on geologic sequestration of CO2 is expanded to 1166 Mt-CO2/year, which is the upside of appraised capacities and is used in E+RE−.
- **Sequestration−:** Constraint on geologic sequestration of CO2 is reduced from 1166 Mt-CO2/year to 150 Mt-CO2/year, which is the same as other Core Scenarios.

Thank you

Contact us at: https://www.netzeroaustralia.net.au/contact/

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