Final results summary

Public launch | 19 April 2023

NET ZERO AUSTRALIA

The University of Melbourne

The University of Queensland Australia
Create Change

Princeton University

nous

Welcome

Professor Deborah Terry AO (VC and President, The University of Queensland)

Introduction

Professor Robin Batterham (Chair, Net Zero Australia study)

Outline of today's presentation

1	About the study		Katherin Domansky
2	What we’ve modelled		Katherin Domansky
3	What it would take to achieve net zero	 	Simon Smart Michael Brear
4	What Australia must do; and must decide		Richard Bolt

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

- apa
- Dow
- 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.

The Net Zero Australia team

STEERING COMMITTEE

Robin Batterham
University of Melbourne & Chair

Katherin Domansky
Independent Member

Michael Brear
University of Melbourne

Simon Smart
University of Queensland

Chris Greig
Princeton University

Richard Bolt
Nous Group

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Sarah Simon
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Georgie Pickett-Heaps
Nathalie Swainston

Evolved Energy Research

Ben Haley
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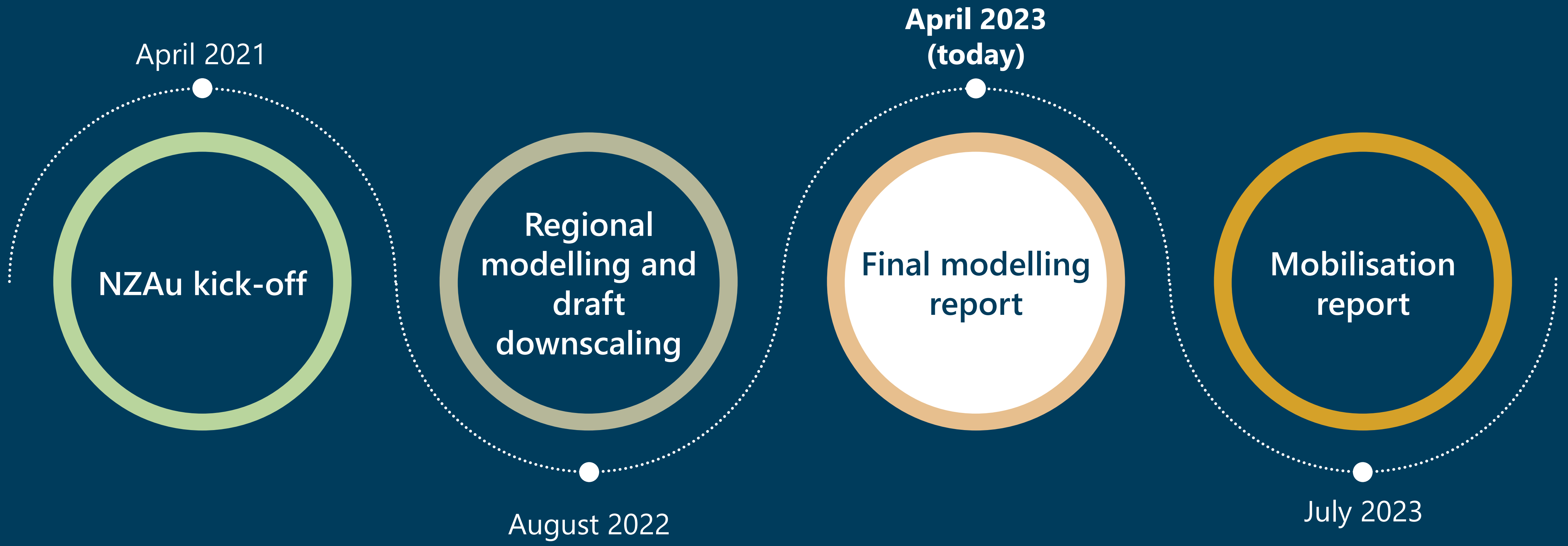
Today we are presenting our final modelling results

NET ZERO AUSTRALIA STUDY TIMELINE



1. What has been modelled?

What we've modelled

MODELLING APPROACH

- Linear emissions reduction for domestic and export
- Several scenarios
- Best available inputs and assumptions
- Least cost optimisation
- 'Downscale' to model changes at a fine resolution.

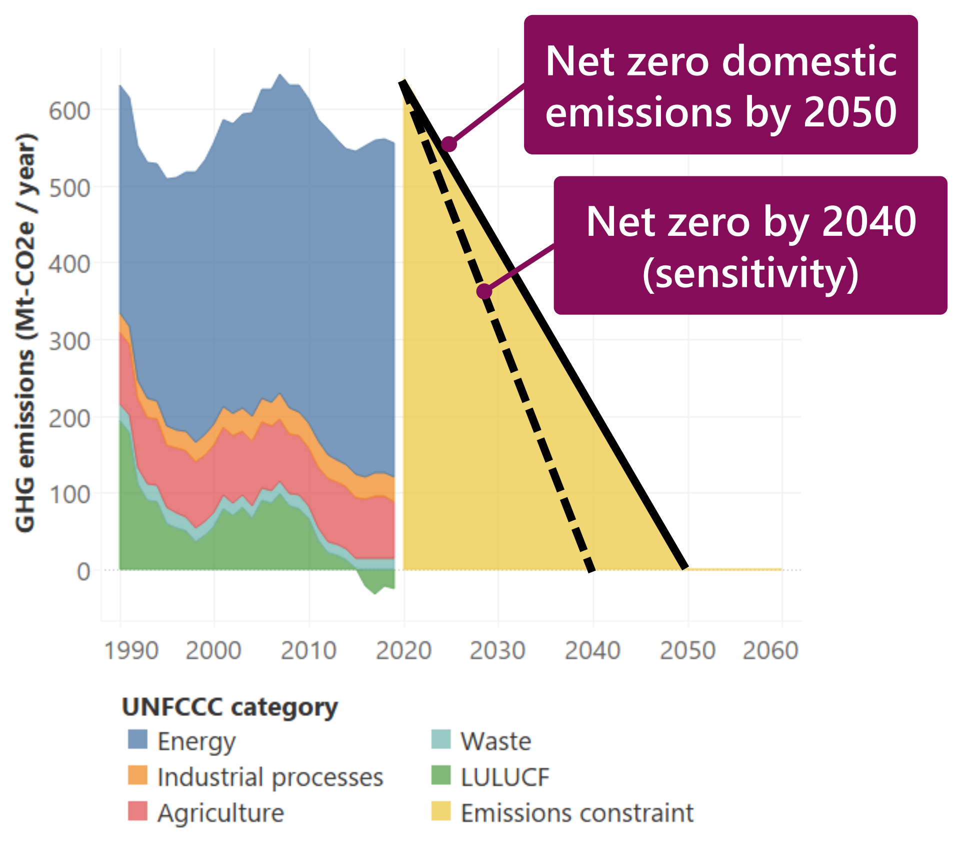
DESIGN OF SCENARIOS

Reflect the boundaries of the Australian debate:

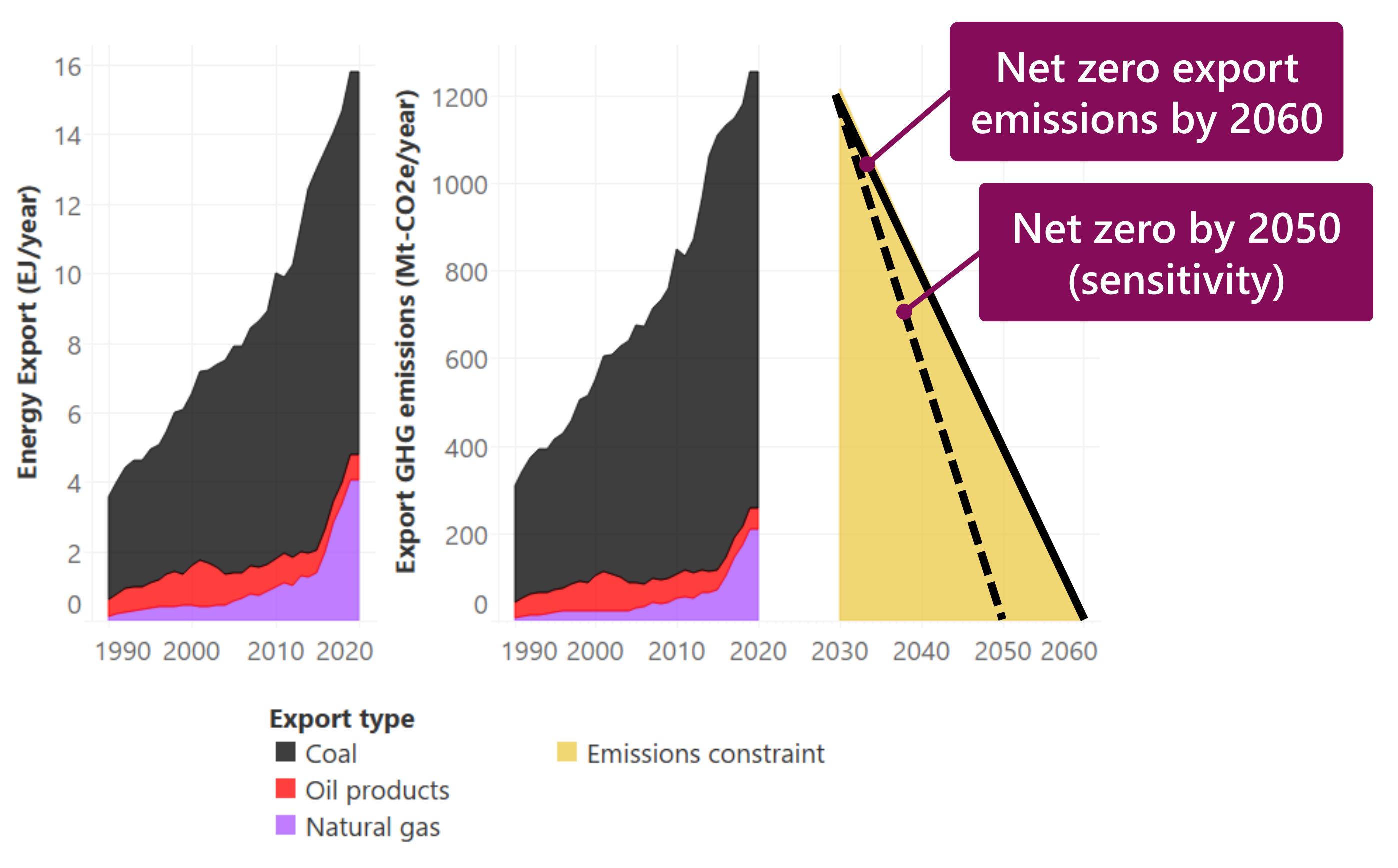
- Rate of electrification
- Renewable build rates
- Limits on fossil fuels
- Carbon storage.

We model linear reductions to net zero

Domestic emissions



Fossil fuel energy export emissions



We have 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.

About the study

What *does* this study do?

Model pathways to net zero to illustrate:

- Scale, complexity and cost
- Implications of key choices
- Impacts across society, economy and environment.

What *doesn't* this study do?

- Make predictions
- Consider fossil fuel supply constraints
- Analyse costs of inaction on climate change
- Model demand for clean energy exports.

2. What it would take to achieve net zero

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 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	**Deliver an energy transformation** unprecedented in scale and pace
8 Transition to **clean energy** and **clean minerals exports** 9 **Locate** these **new export industries** in the north; possibly also in the south	**Transform our exports** an essential contribution to global decarbonisation
10 Expand a **skilled workforce** from about 100,000 today to 7-800,000 by 2060 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	**Invest in our people and land** to reduce impacts and share benefits

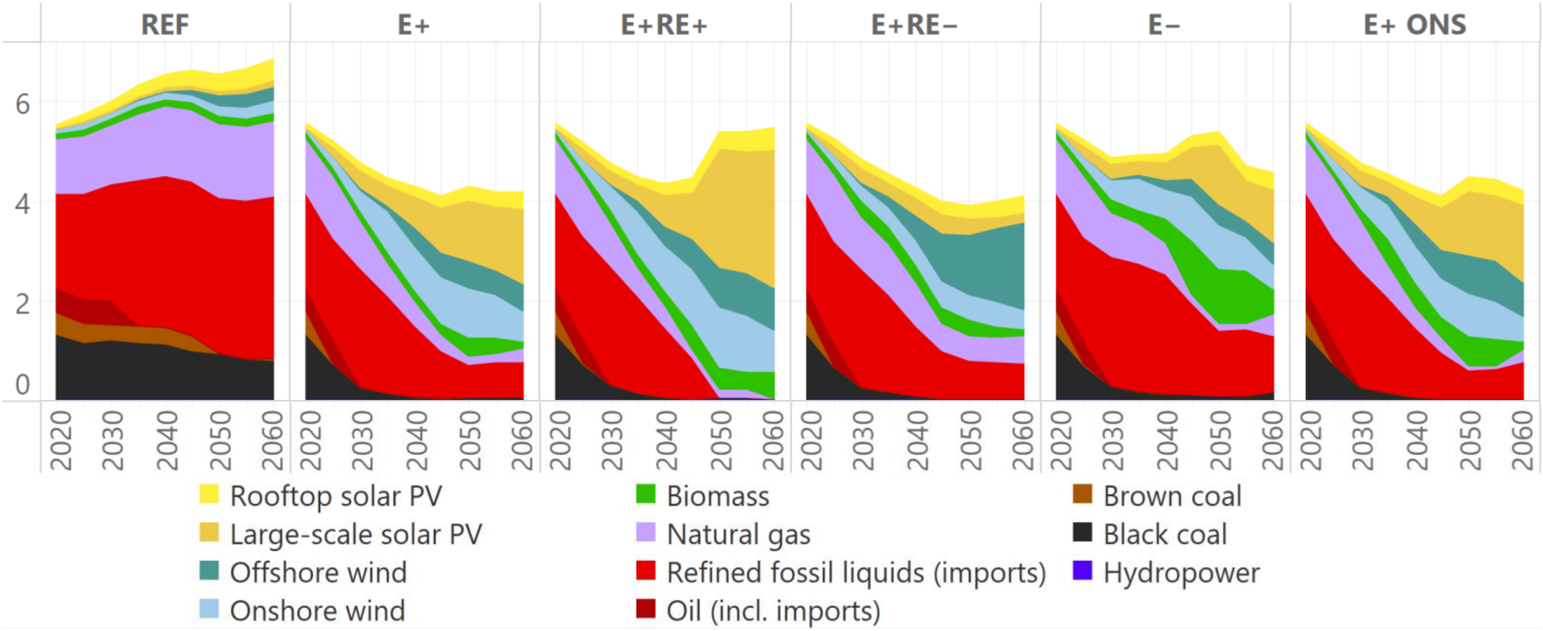
2. WHAT IT WOULD TAKE TO ACHIEVE NET ZERO

Deliver an energy transformation – unprecedented in scale and pace

Grow renewables as our main domestic and export energy source, to 40 times current National Electricity Market capacity – for direct use and clean fuel production

1

Projected domestic primary energy (Exajoules / year)



Renewables are the main energy source – mostly **solar and wind** power.

Modelled **deployment rates** for renewables are much higher than historical rates.

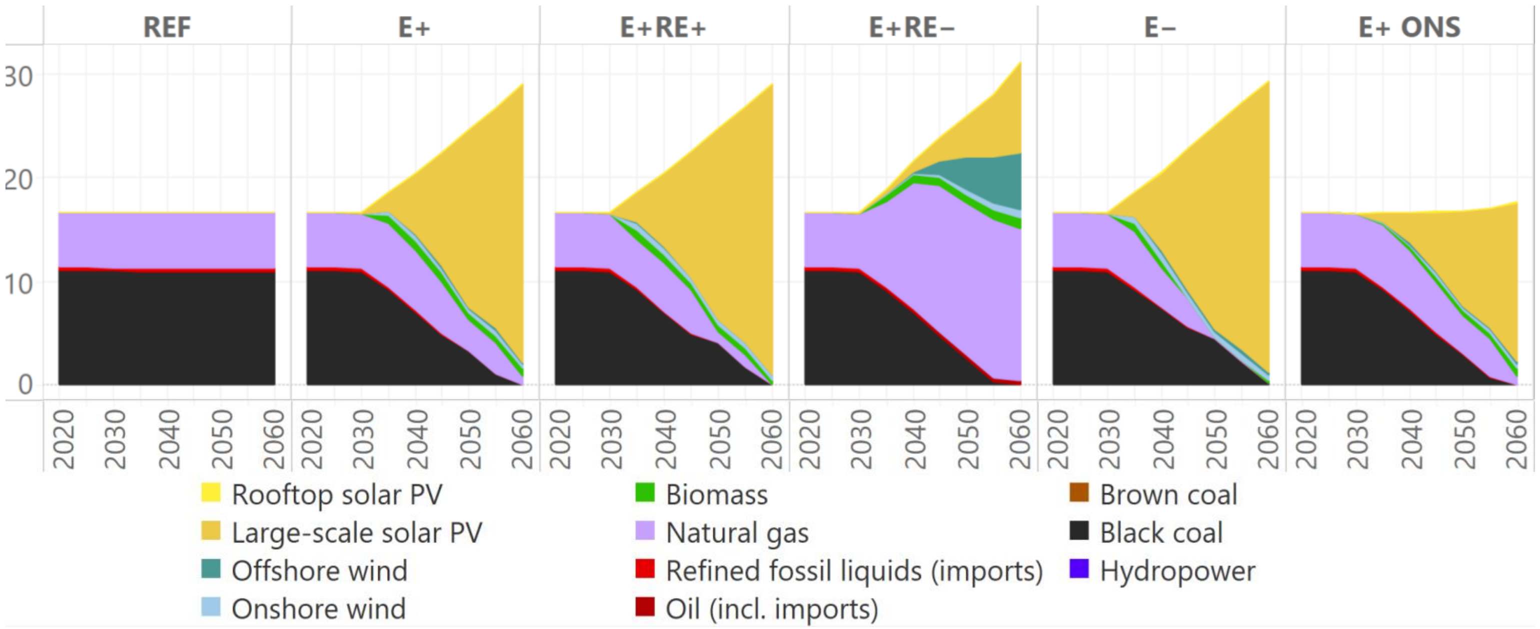
Offshore wind grows from around 2030 to make a significant contribution.

Natural gas and oil products play a significant role in all Scenarios (with CCUS) except if not permitted (as in E+RE+).

Grow renewables as our main domestic and export energy source, to 40 times current National Electricity Market capacity – for direct use and clean fuel production

1

Projected export primary energy (Exajoules / year)



Final export demand is held constant at 2020 levels, so **primary energy supply for exports is much higher** than for domestic use.

Natural gas dominates exports in E+RE- due to constraints on renewable deployment and changes to the maximum CCUS rate.

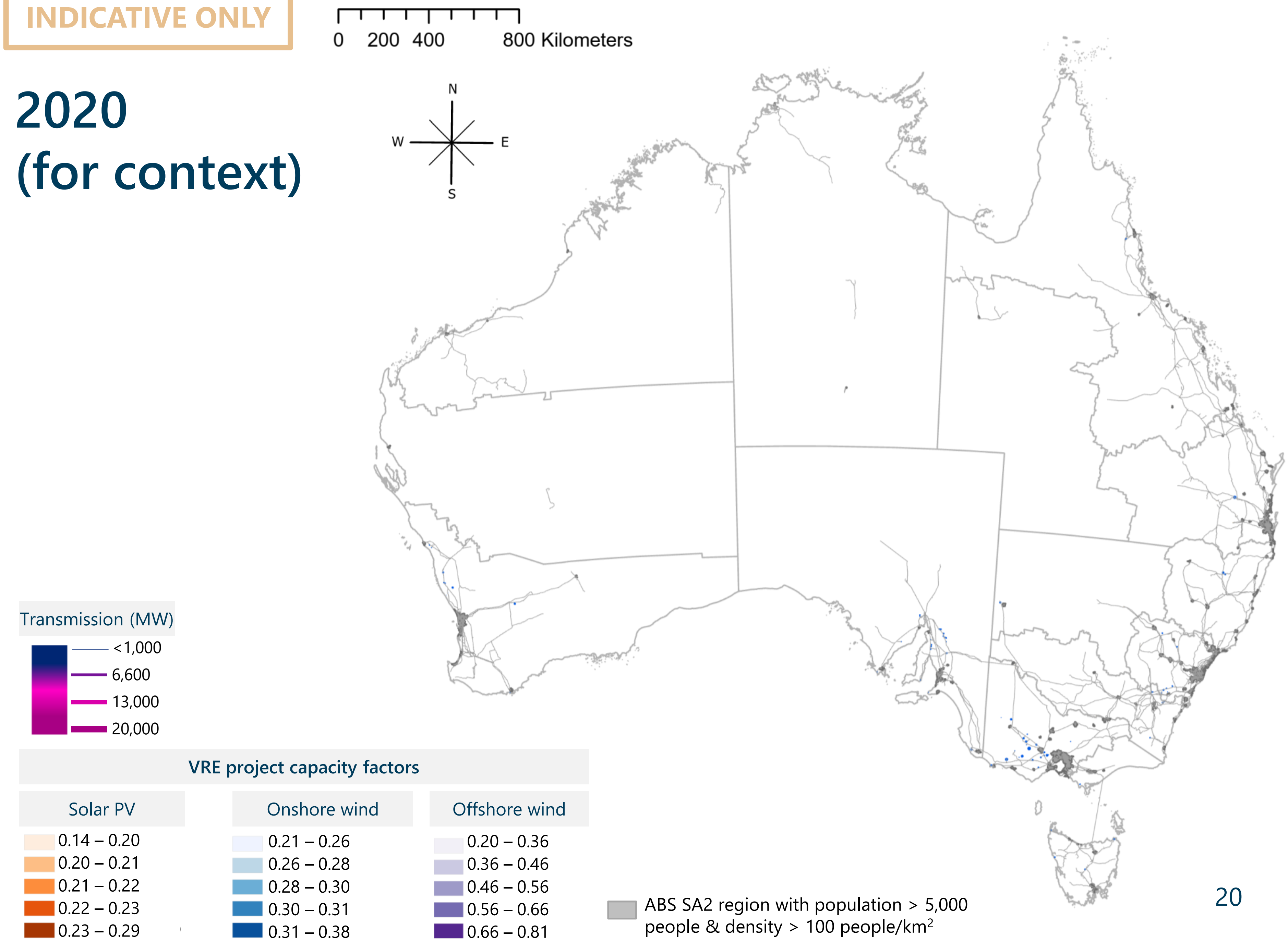
The large **rise in primary energy** for exports is **due to losses** from converting renewable power to low-emission carriers and fuels.

1

Grow renewables as our main domestic and export energy source, to 40 times current National Electricity Market capacity – for direct use and clean fuel production

INDICATIVE ONLY

2020 (for context)



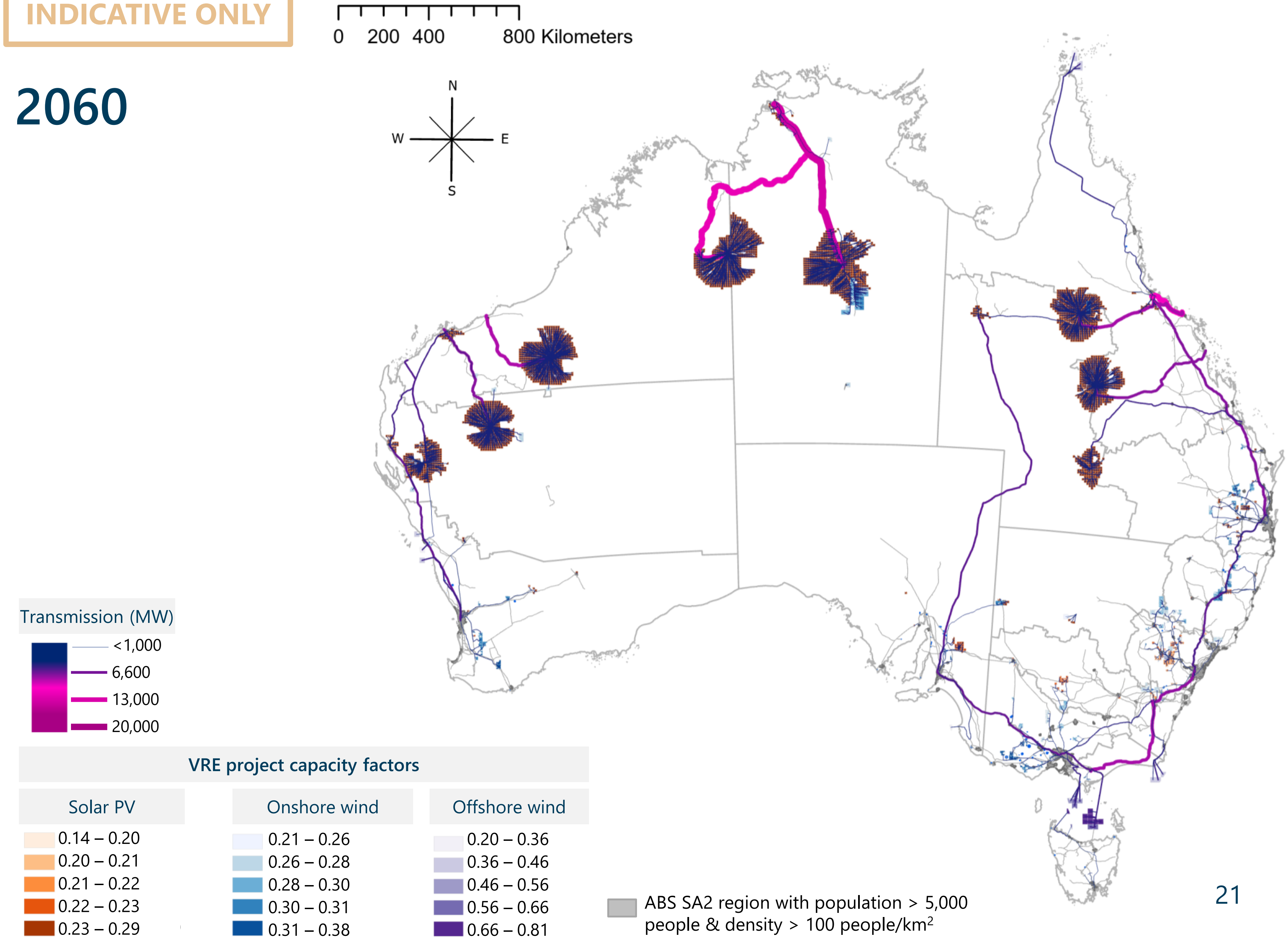
1

Grow renewables as our main domestic and export energy source, to 40 times current National Electricity Market capacity – for direct use and clean fuel production

E+ 2060

INDICATIVE ONLY

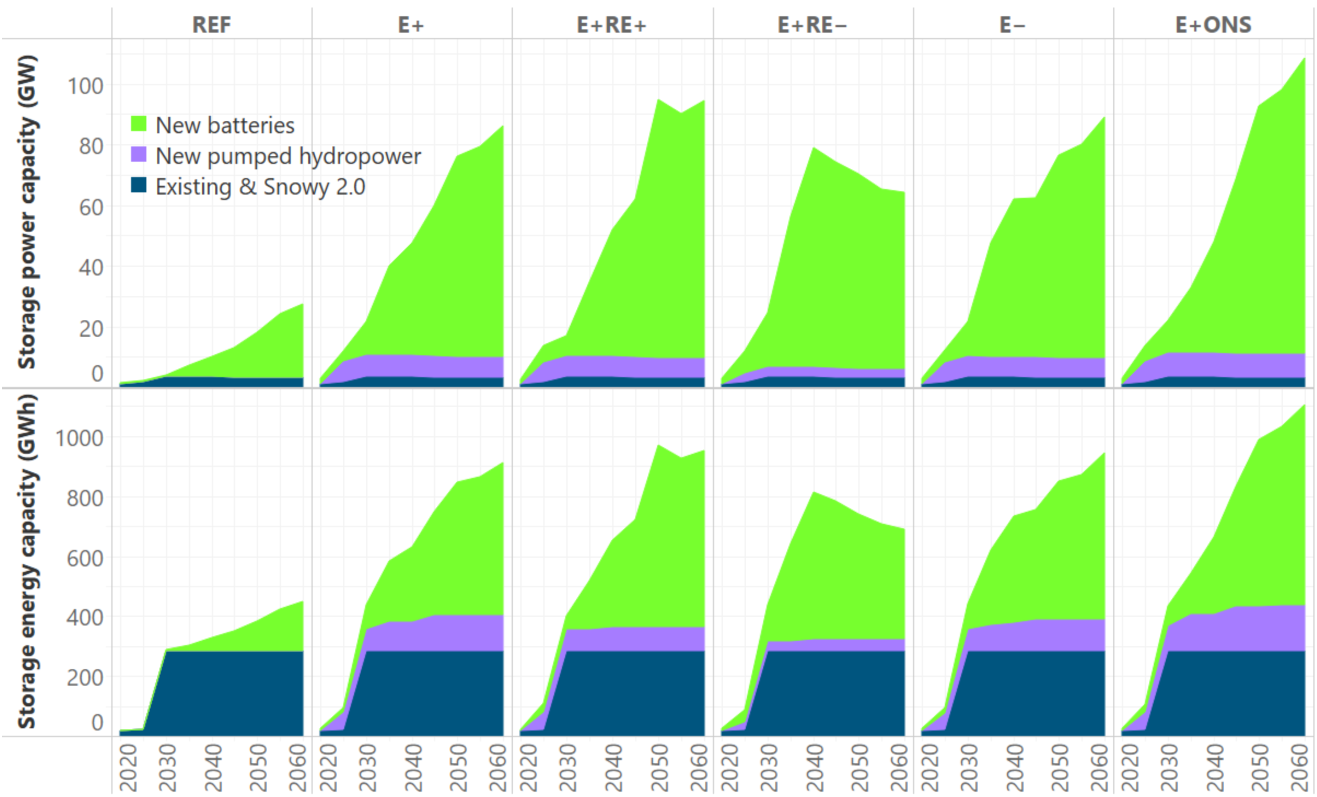
2060



Establish a large fleet of batteries, pumped hydro, and gas-fired firming capacity with low and declining gas use

2

Projected domestic electricity storage capacity, by technology (GW and GWh)



Major battery deployment is modelled across all Scenarios, playing a significant role in time shifting daytime solar generation to evening peaks.

Medium to long duration storage is needed. Average durations of total storage deployed is:

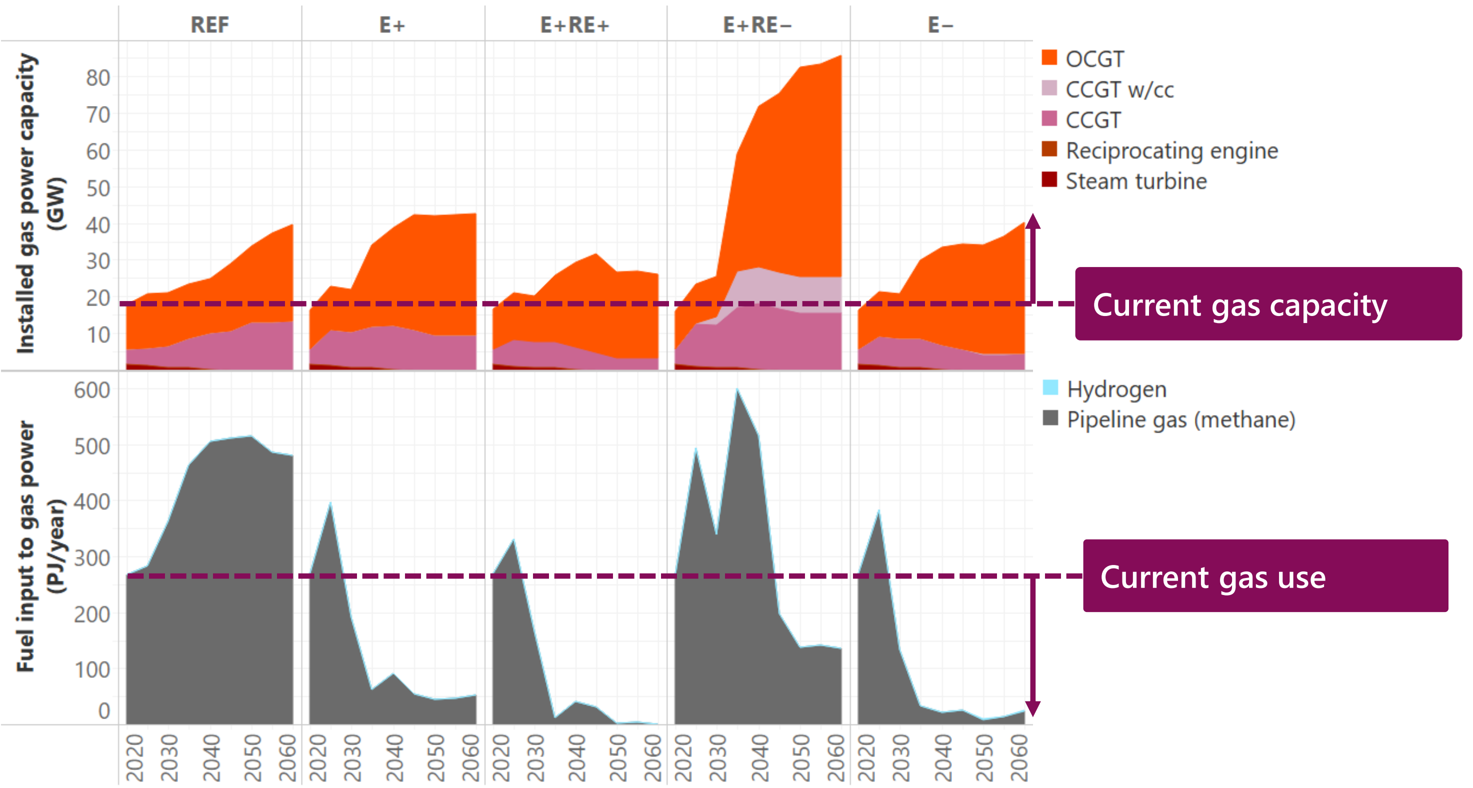
- 7 hours for batteries
- 15 hours for pumped hydro.

CHART 1 OF 2

Establish a large fleet of batteries, pumped hydro, and gas-fired firming capacity with low and declining gas use

2

Gas power – installed capacity (GW), and fuel input (Petajoules / year)



A large build of **new gas turbines** would provide a **strategic reserve** in support of renewables and storage.

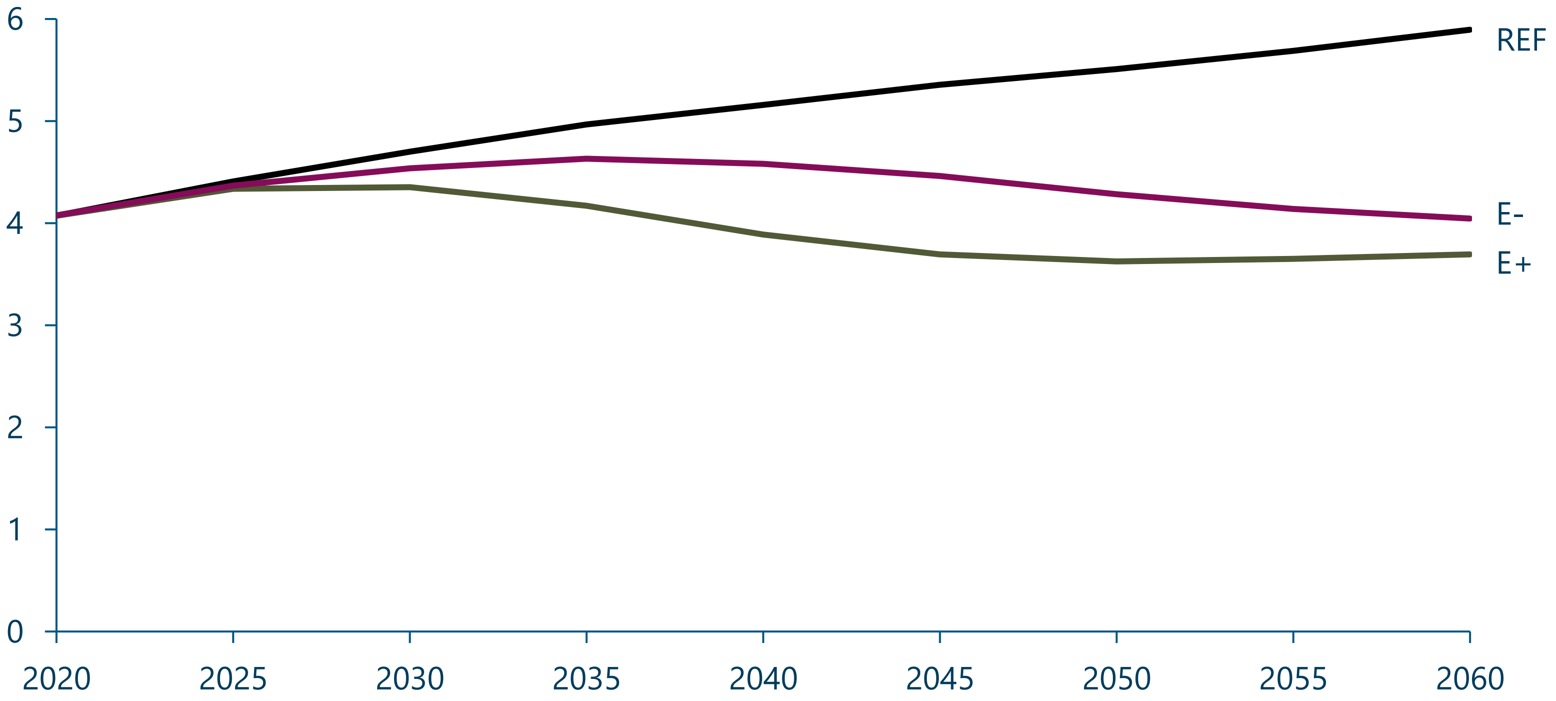
The expanded gas fleet would be used **sparingly** in the near term, **and rarely** in the long term (remaining emissions are offset by direct air capture with CCS).

The one exception is when the renewable build is constrained (E+RE-), in which **combined cycle gas turbines with CCS** provide significant power.

Greatly increase electrification from 20% to 50% of all energy use, switch to clean fuels for some industrial and transport uses, and rapidly grow energy efficiency

3

Projected domestic final energy demand (Exajoules / year)



Progressive adoption of more **energy-efficient technology** keeps 2060 energy demand to around 2020 levels – despite growth in population (1.2%) and GDP (2.1%).

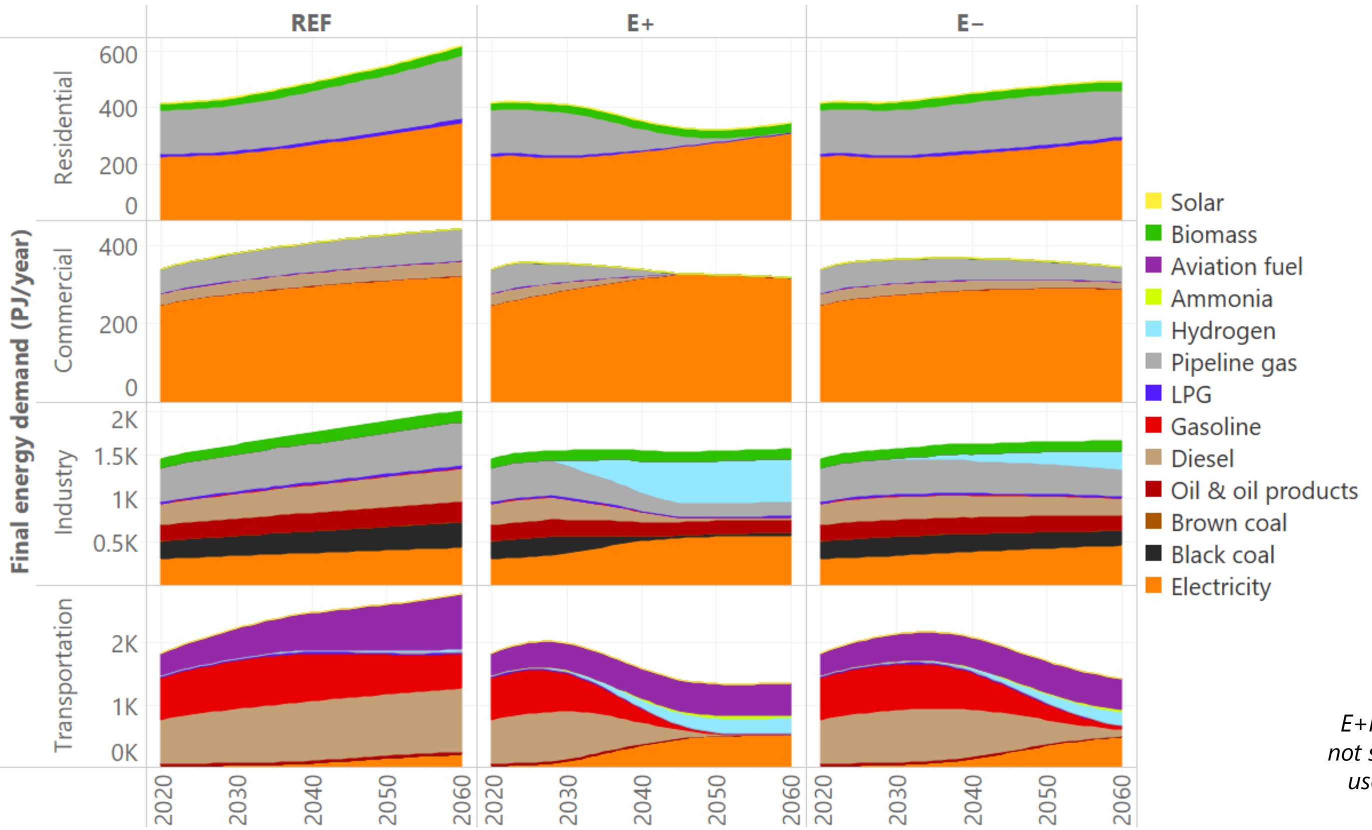
Some efficiency will come from **electrification**: switching to new uses such as electric vehicles and heat pumps.

Some efficiency will also come from **upgrading technologies** now in use.

Greatly increase electrification from 20% to 50% of all energy use, switch to clean fuels for some industrial and transport uses, and rapidly grow energy efficiency

3

Projected domestic final energy demand by sector (Petajoules / year)



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

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

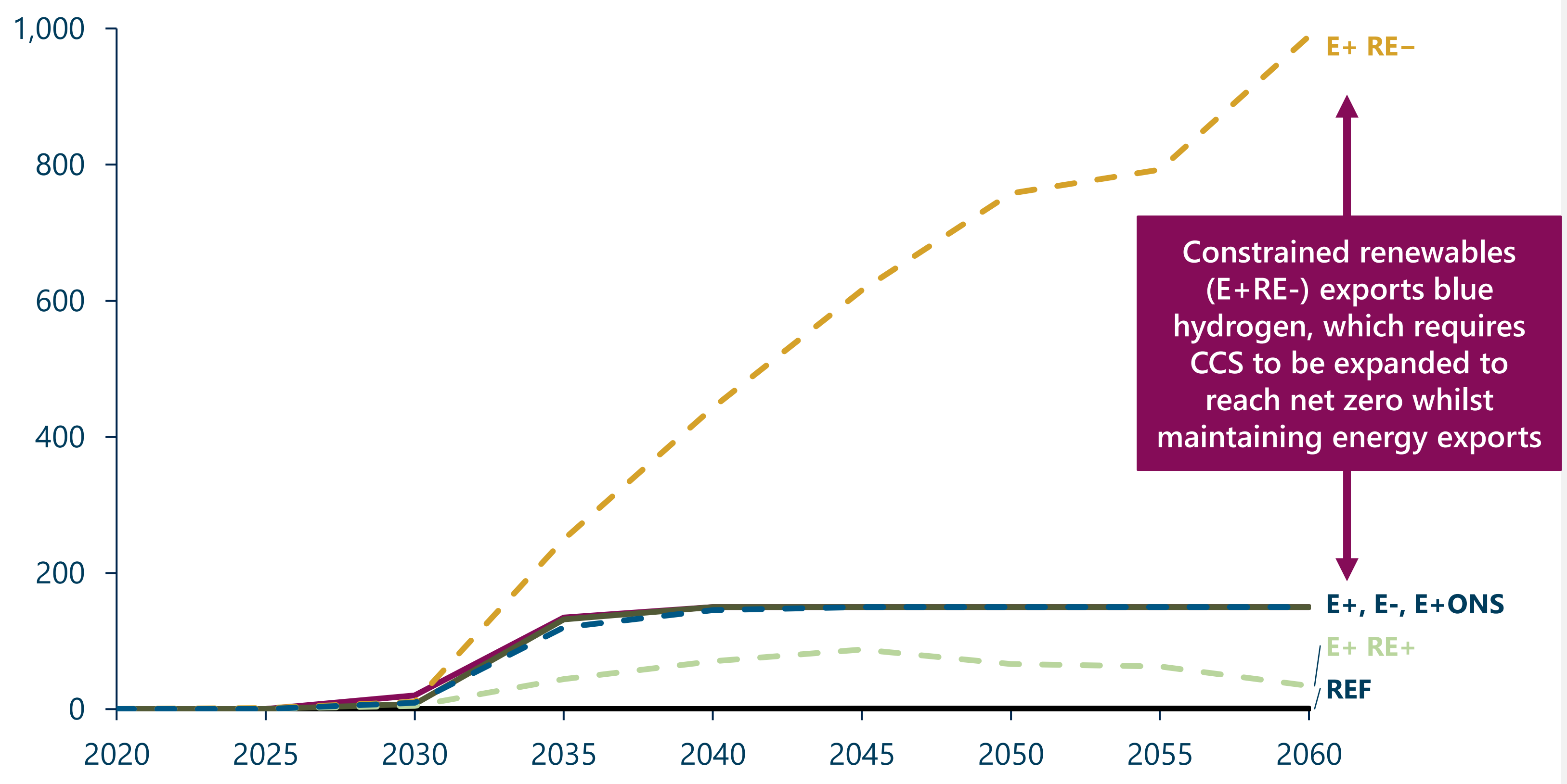
Industry's energy use shows **modest electrification** and a transition to **decarbonised fuels**.

Transport is significantly electrified, but fuels supply aviation, shipping and some land transport.

Develop a large carbon capture, utilisation and storage industry – to permanently store 80-1000 Mt/yr of CO2 to make clean fuels and negative emissions

4

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



CCUS is needed for:

- **non-energy uses**
- **producing 'negative emissions'**, i.e. storing carbon emissions taken out of the atmosphere.

Also, when renewable and transmission builds are constrained, **CCUS with fossil fuels** helps to reach net zero.

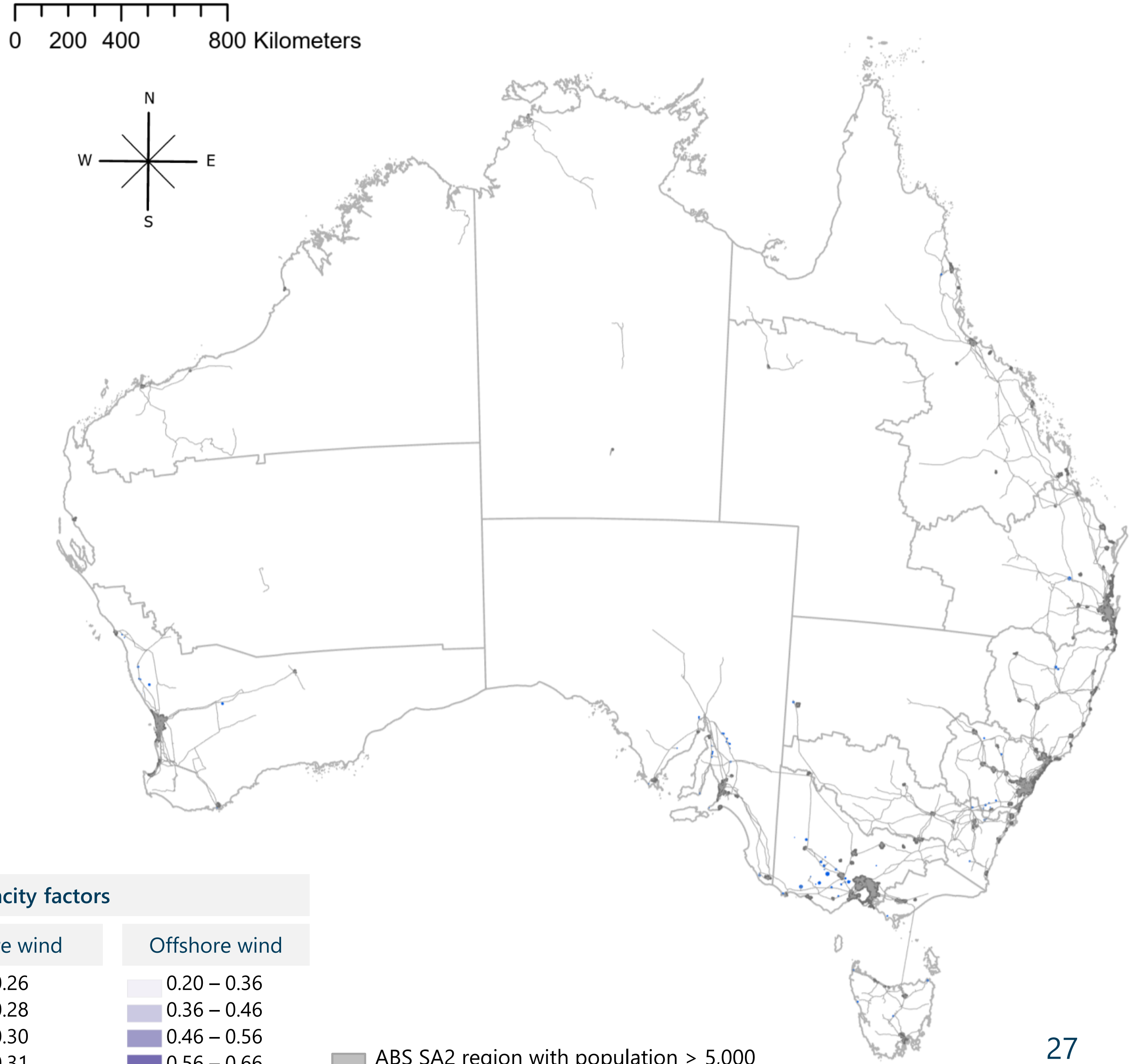
CCUS is needed in all scenarios and sensitivities, except for 100% renewable power (E+RE+) and a net negative land sector (Land+).

5

Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

INDICATIVE ONLY

2020 (for context)



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

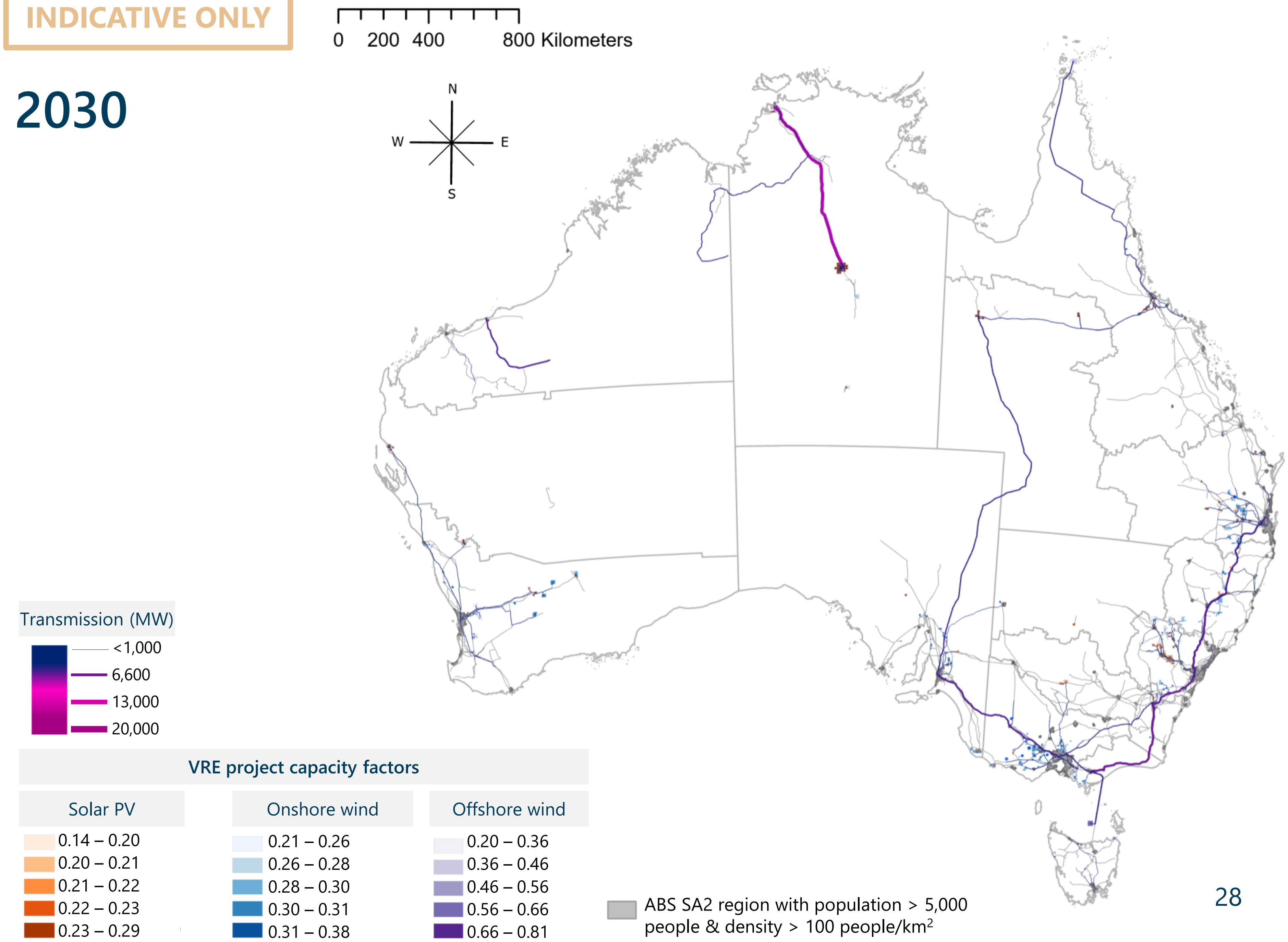
ABS SA2 region with population > 5,000 people & density > 100 people/km^2

5

Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

INDICATIVE ONLY

2030



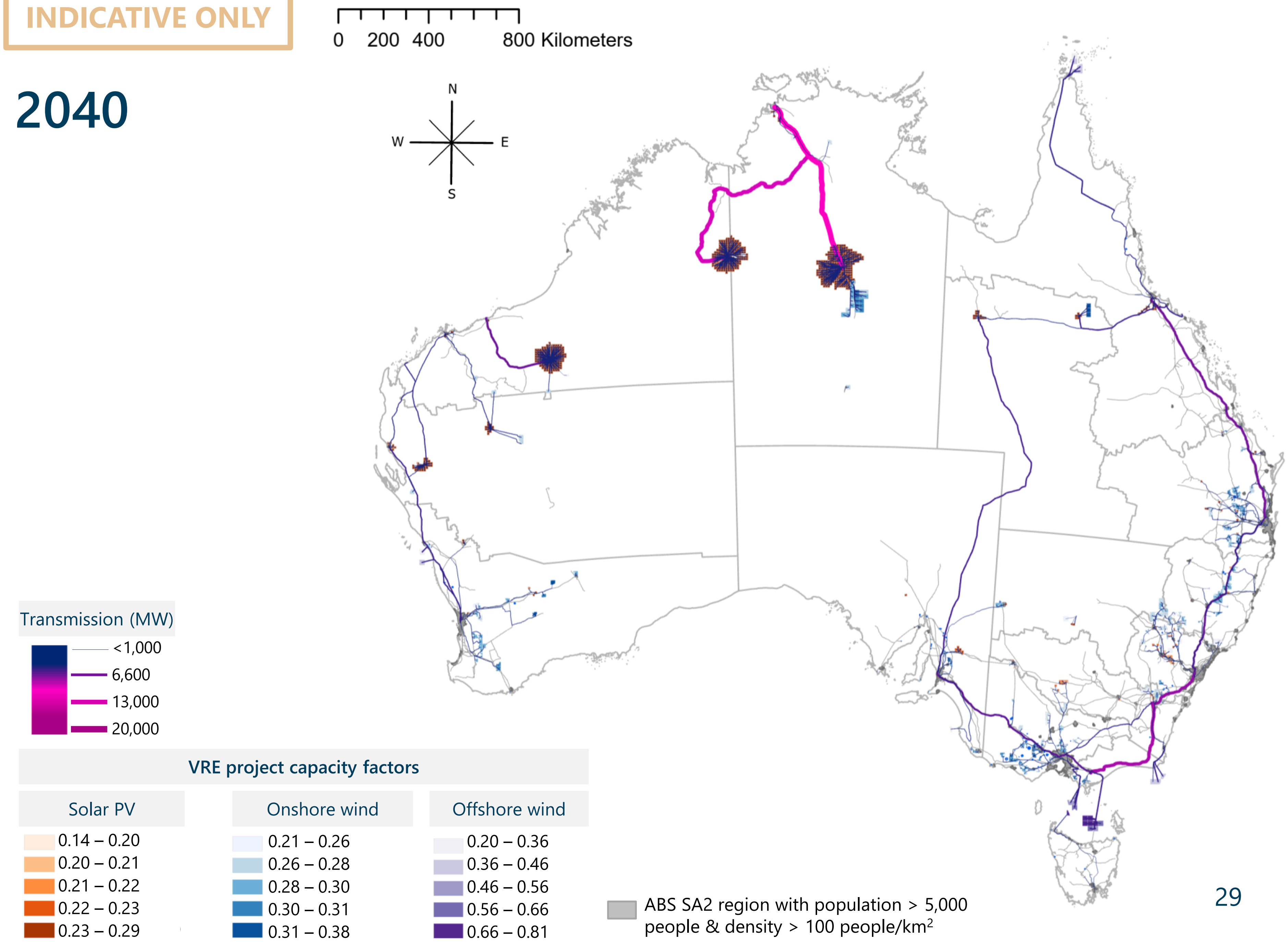
5

Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

E+ 2040

INDICATIVE ONLY

2040

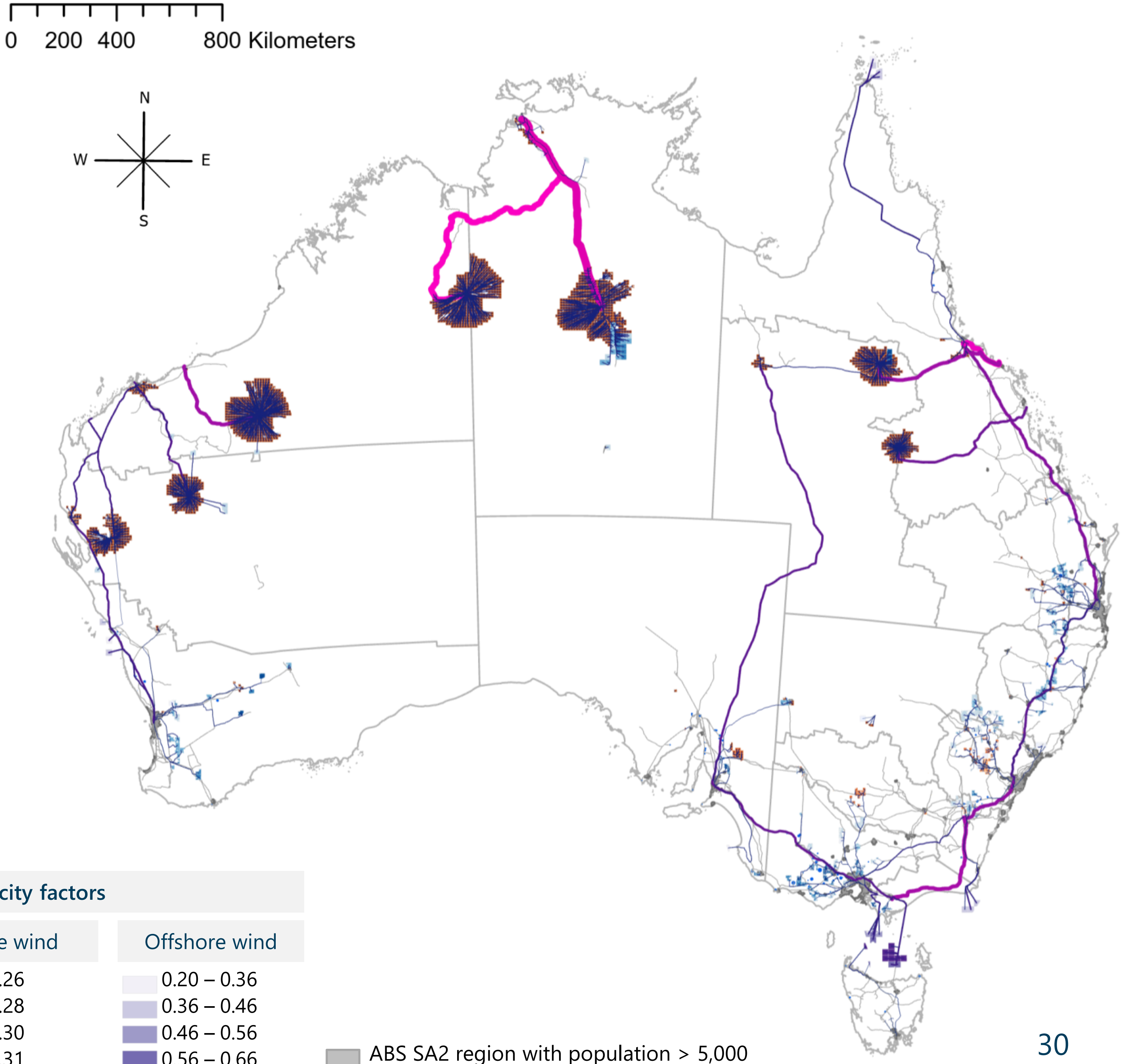


5

Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

INDICATIVE ONLY

2050



Transmission (MW)

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

VRE project capacity factors

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

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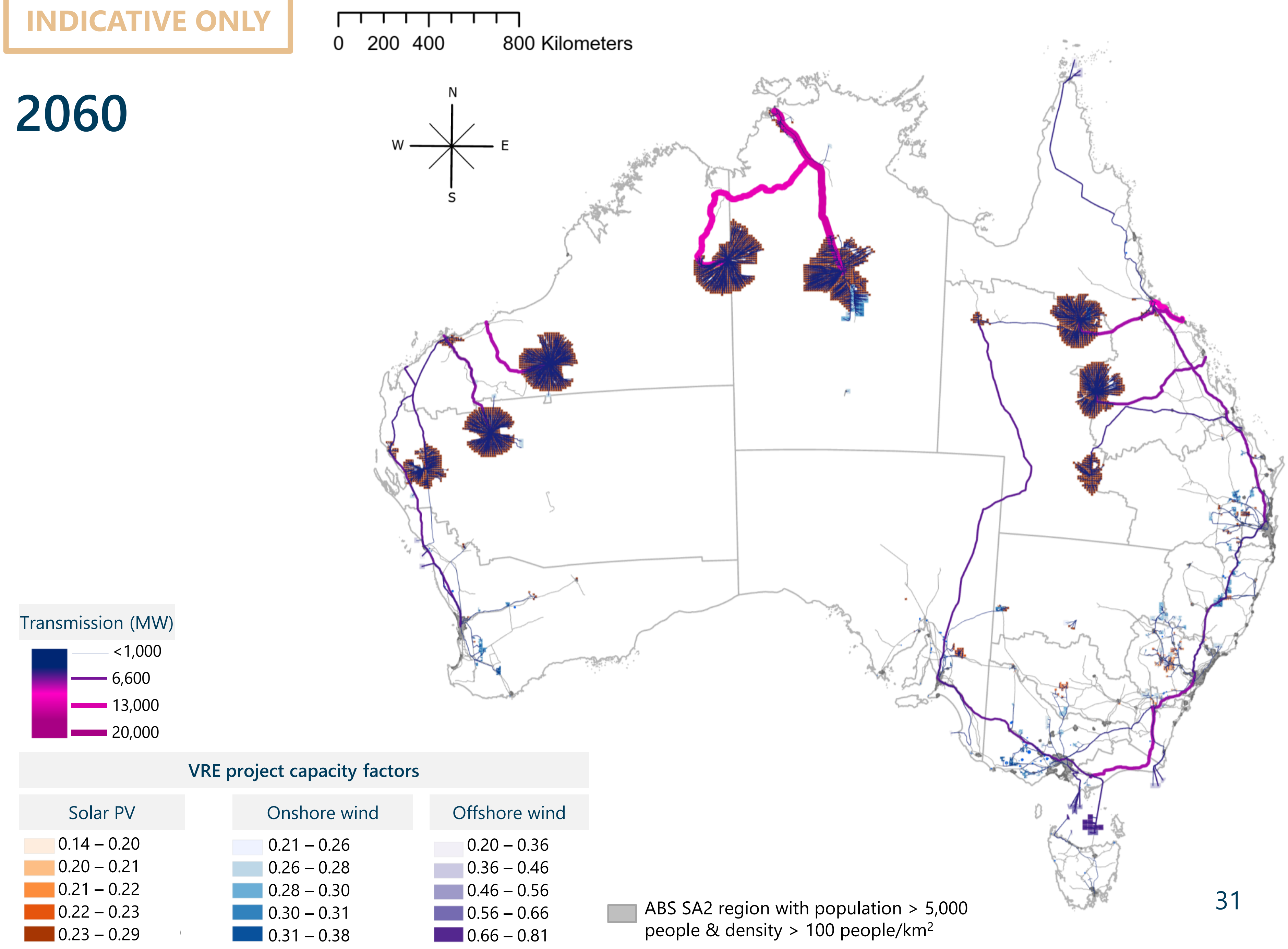
Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

INDICATIVE ONLY

2060



E+ 2060

5

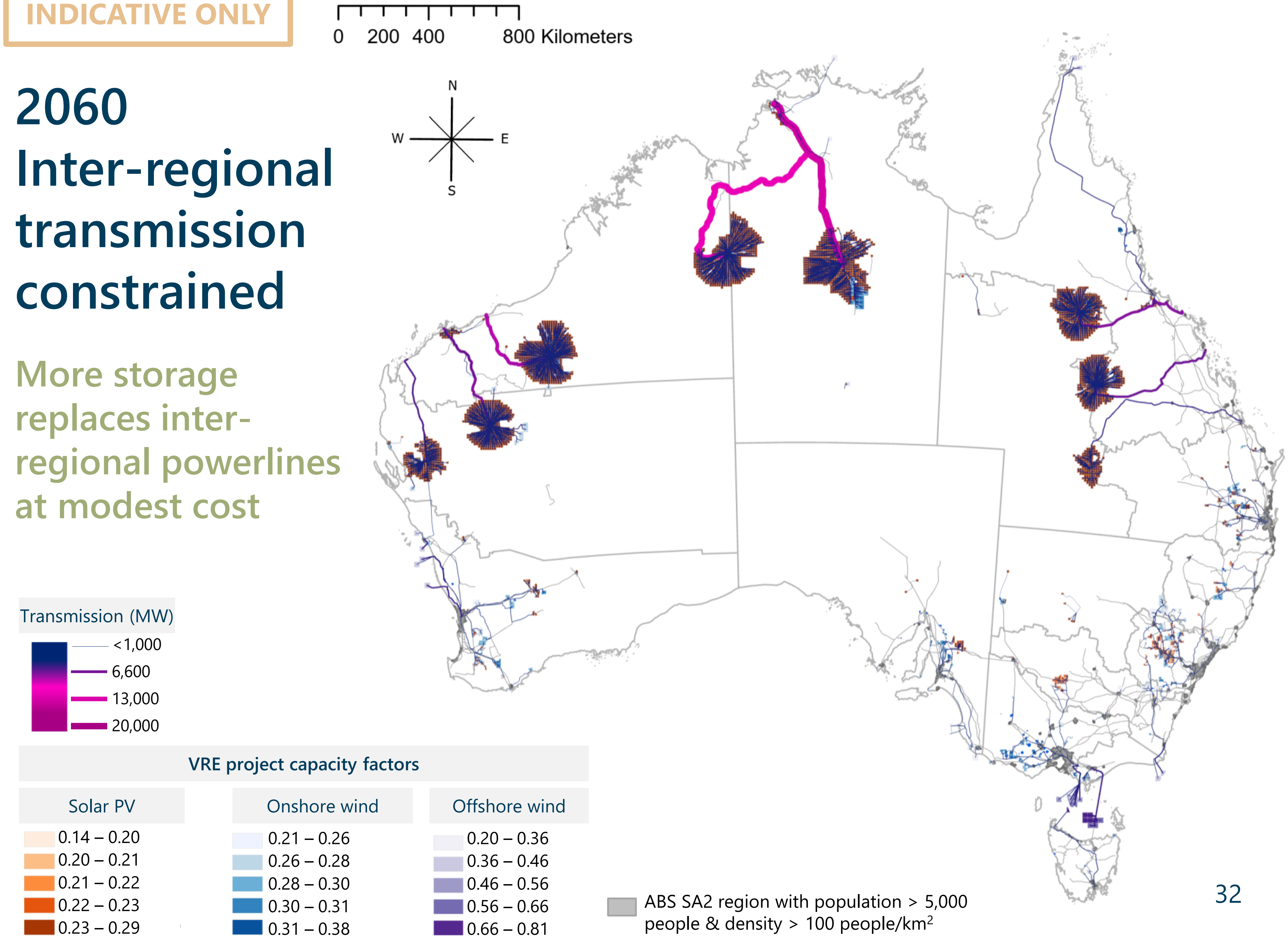
Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

E+ 2060 Sens: Transmission-

INDICATIVE ONLY

2060 Inter-regional transmission constrained

More storage replaces inter-regional powerlines at modest cost



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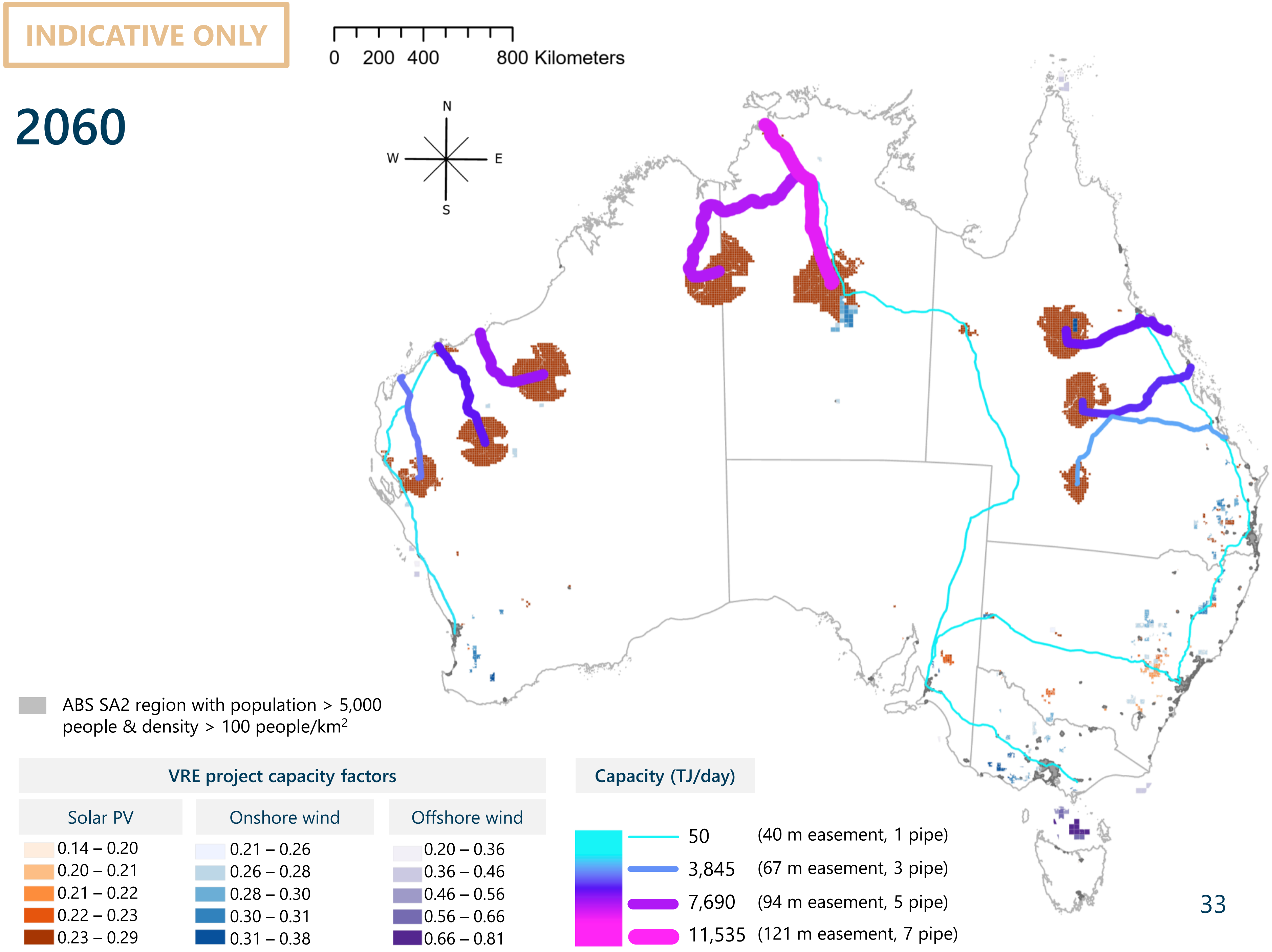
Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water



E+ 2060

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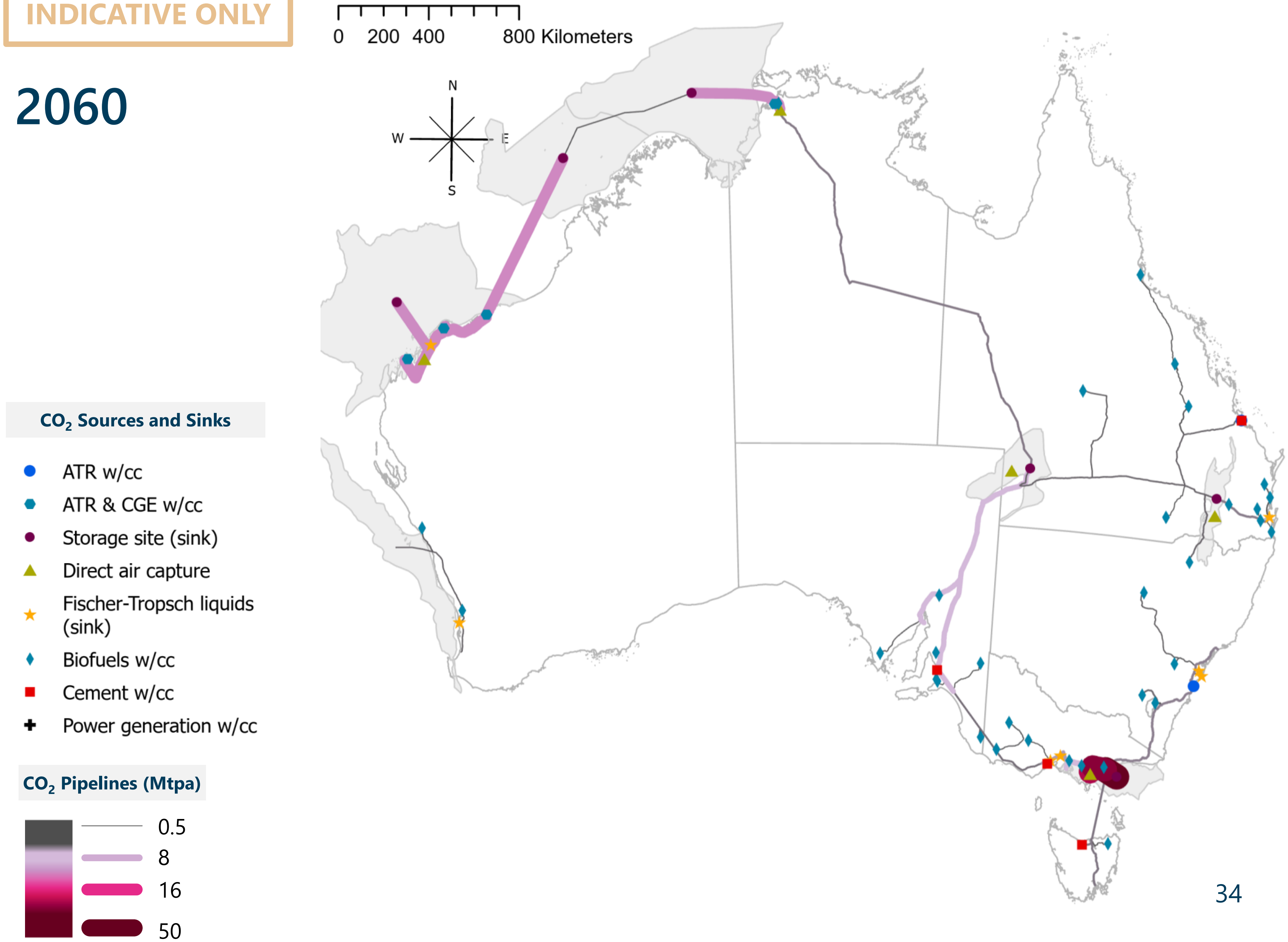
INDICATIVE ONLY

2060



E+ 2060

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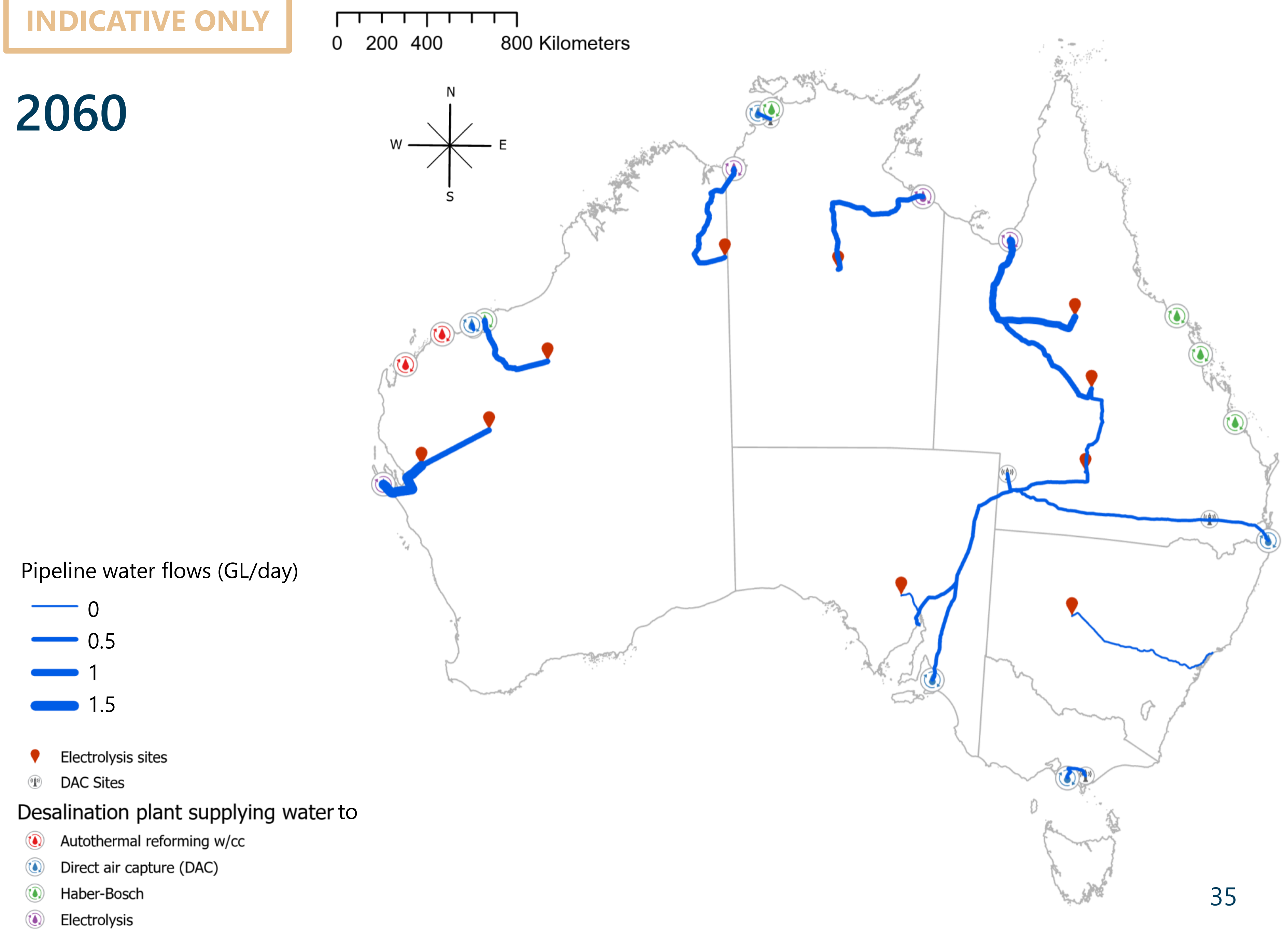
Greatly expand our energy and ancillary networks: powerlines carrying renewable energy, and pipelines carrying hydrogen, CO2 and desalinated water

E+ 2060

INDICATIVE ONLY

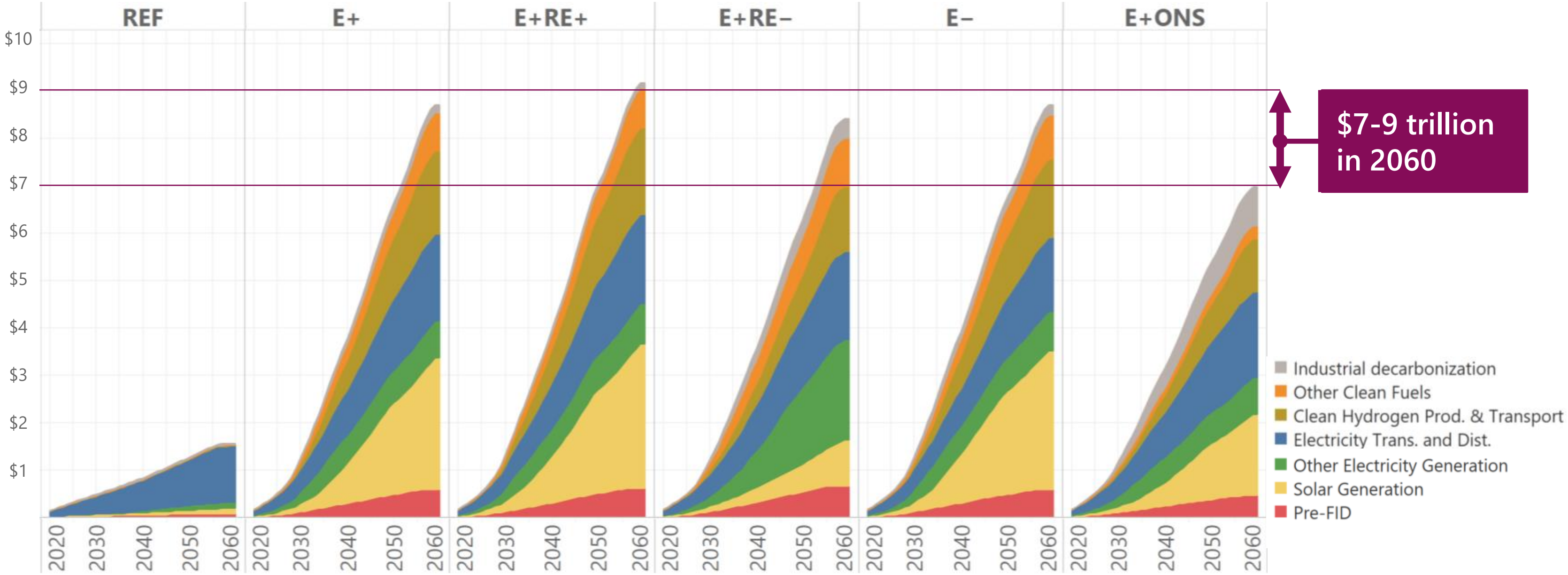
2060



Attract and invest $7-9 trillion of capital to 2060 from international and domestic sources

6

Cumulative supply-side capital committed by year (2020 AUD trillions)



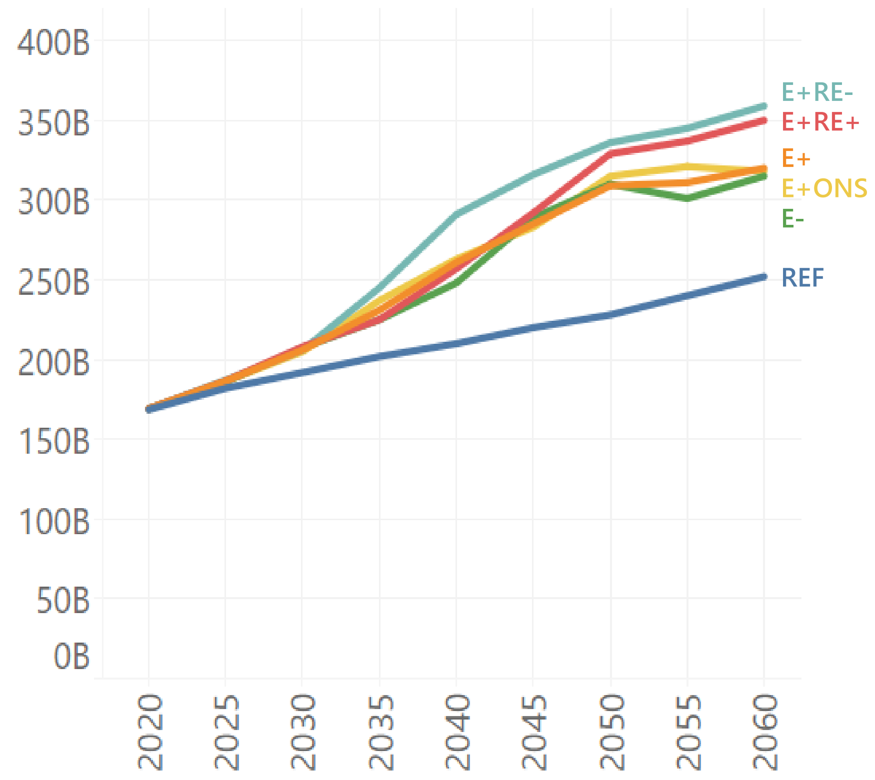
Investment is much higher in the net zero transition than continuing to use fossil fuels. However:

- Decarbonisation will **reduce our reliance on gas and oil imports**.
- The Reference case **assumes that fossil fuel costs remain consistently low**, which is deeply uncertain and has not been modelled.
- **Conventional technologies that use fossil fuels** will become less available.
- The **costs of inaction** would be substantial

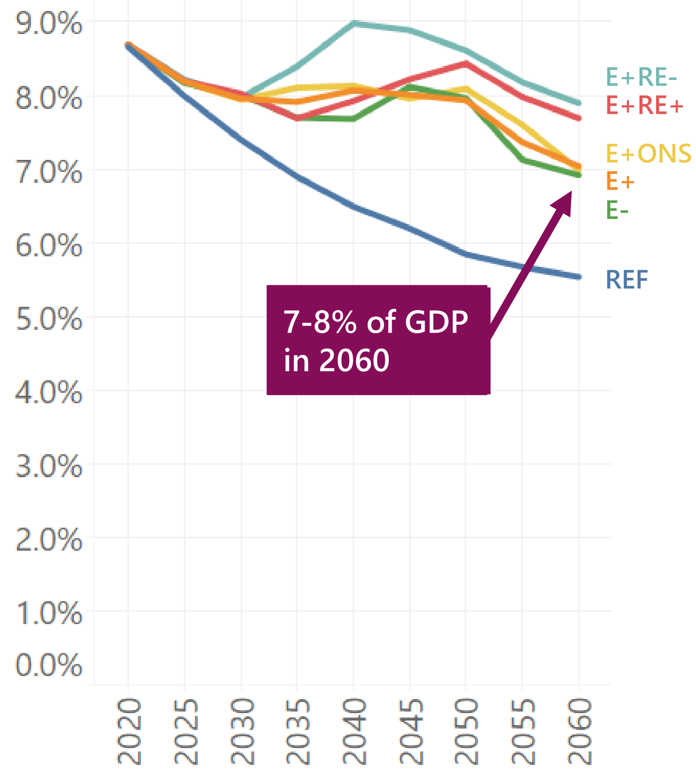
CHART 1 OF 3

Attract and invest $7-9 trillion of capital to 2060 from international and domestic sources

Levelised domestic energy total costs (2020 AUD billions / year)



Levelised domestic energy total costs as share of GDP (% Australian GDP)

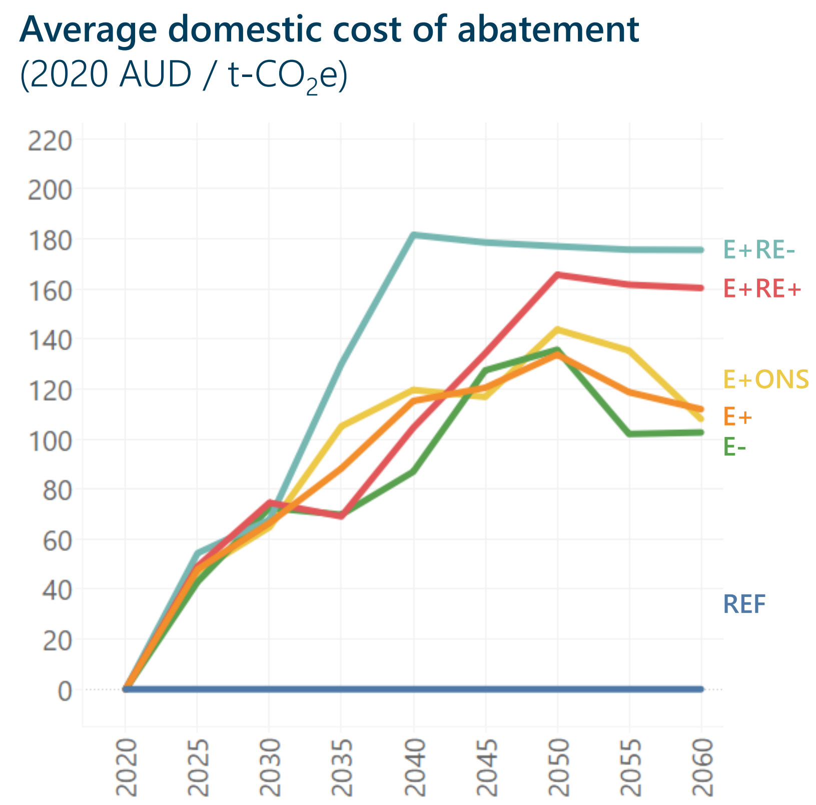


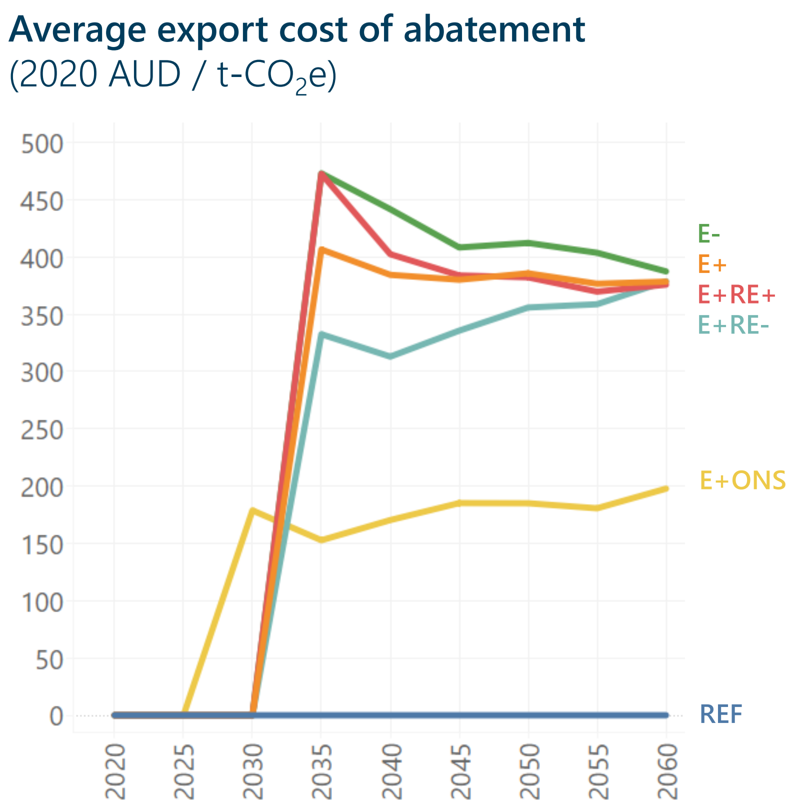
Domestic total energy total costs are similar to their share of GDP today.

Domestic **total costs** include the costs of electricity, gas and oil derivatives delivered to the customer; and the cost of end-use appliances (e.g. new vehicles, heaters and cookers).

Attract and invest $7-9 trillion of capital to 2060 from international and domestic sources

6





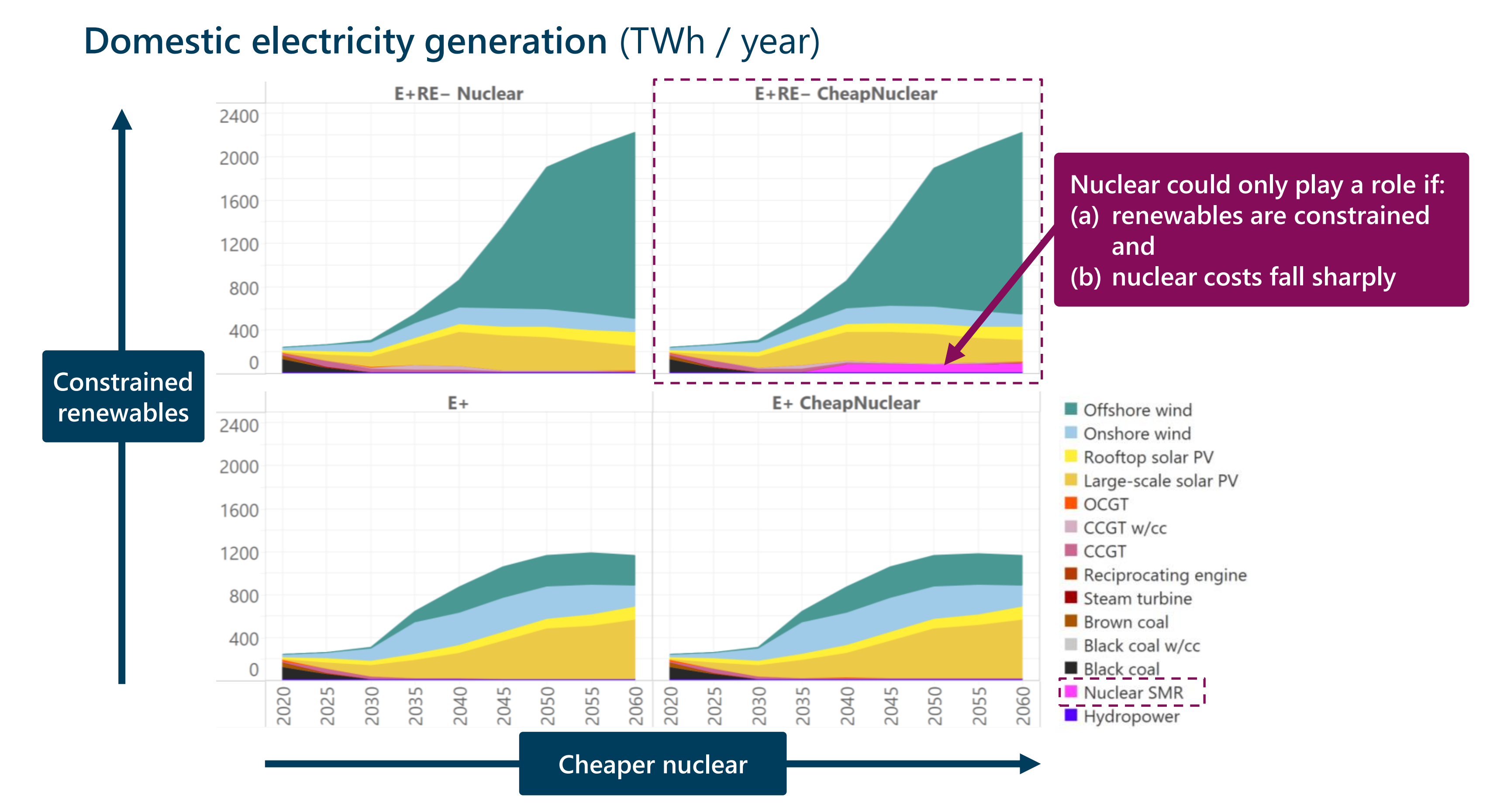
The **cost of abatement** is calculated in all net zero cases **relative to the REF Scenario**

Domestic emissions abatement costs rise to **similar values found in other countries'** net-zero decarbonisation studies (e.g. Net Zero America)

Onshoring provides a significant abatement cost saving ~$200/t-CO2e down from >$350/t-CO2e due to increased energy efficiency. It aligns global **decarbonisation,** the interests of **international customers** and the **domestic build task**

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

7



Nuclear could **only play a role** when:

- nuclear costs are ~30% lower than current international best practice; and
- renewable build out is constrained (E+RE-).

In this case, the **proportion of nuclear** generation is:

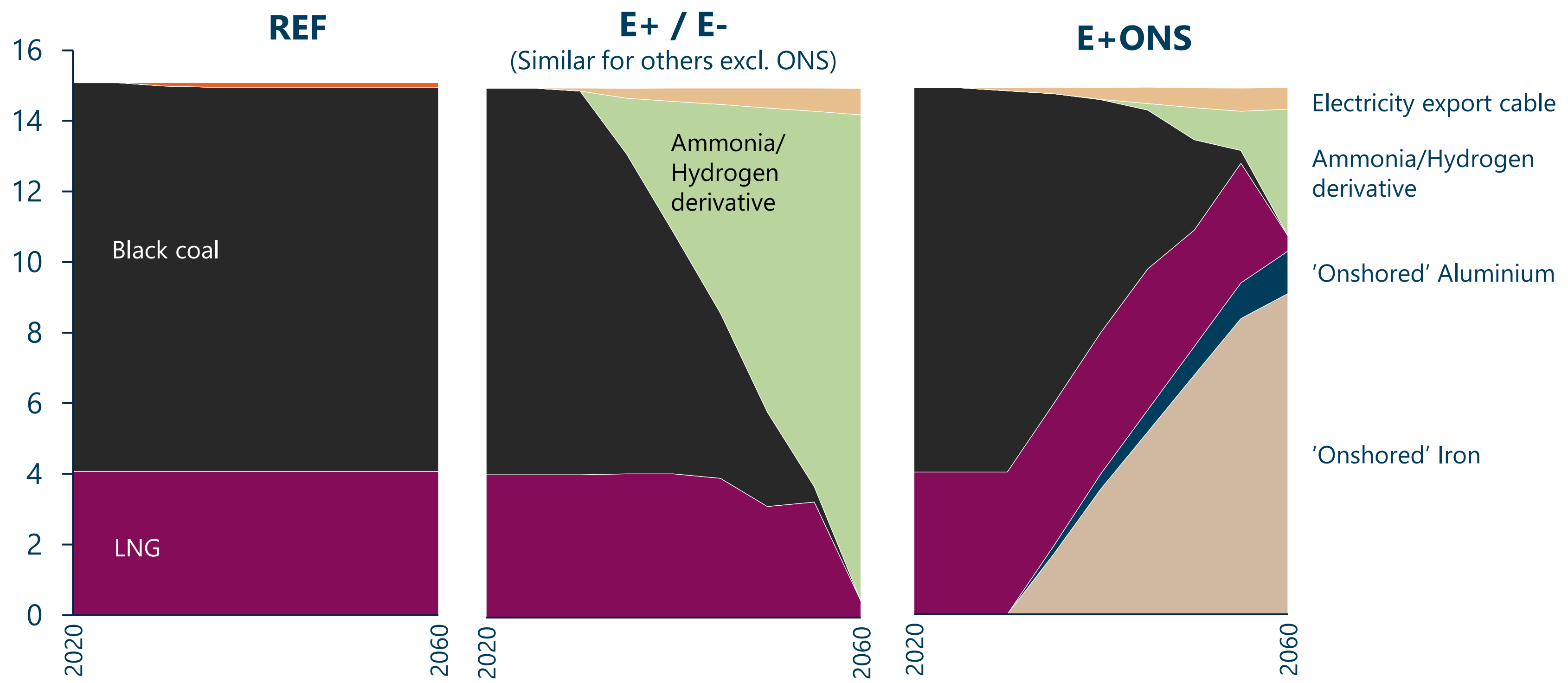
- a modest share of domestic electricity generation; and
- an even smaller share of total export and domestic energy.

2. WHAT IT WOULD TAKE TO ACHIEVE NET ZERO

Transform exports – as an essential contribution to global decarbonisation

Transition to clean energy and clean mineral exports, in line with global demand

8



Australia has the resources to build a new **clean export industry** by:

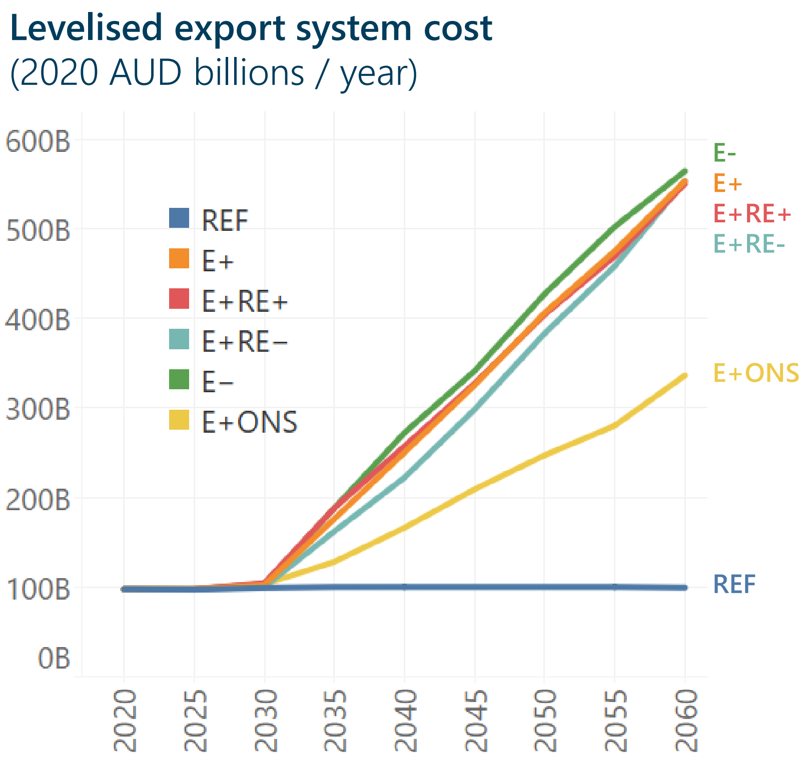
- producing **clean energy carriers**
- **'onshoring'** the processing of minerals using clean energy.

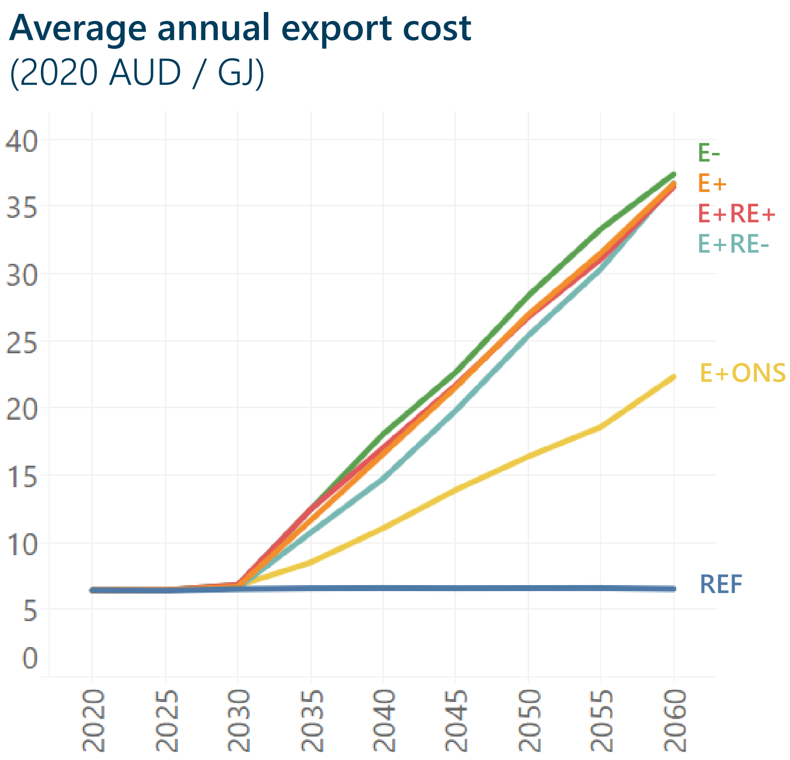
Under the constrained renewable scenario (E+RE-), in which half of exports are ammonia made from gas with CCUS, Australia may **exhaust total demonstrated resources of gas** (TDR) by 2050/2055.

CHART 1 OF 2

Transition to clean energy and clean mineral exports, in line with global demand

8





Export system costs are dominated by the capital costs of the **energy export supply chain**.

Onshoring energy exports is significantly more cost competitive due to efficiency gains from not converting hydrogen to an exportable form (e.g. ammonia).

Coal and natural gas production costs are avoided through the net-zero transition and are incorporated in these figures as savings.

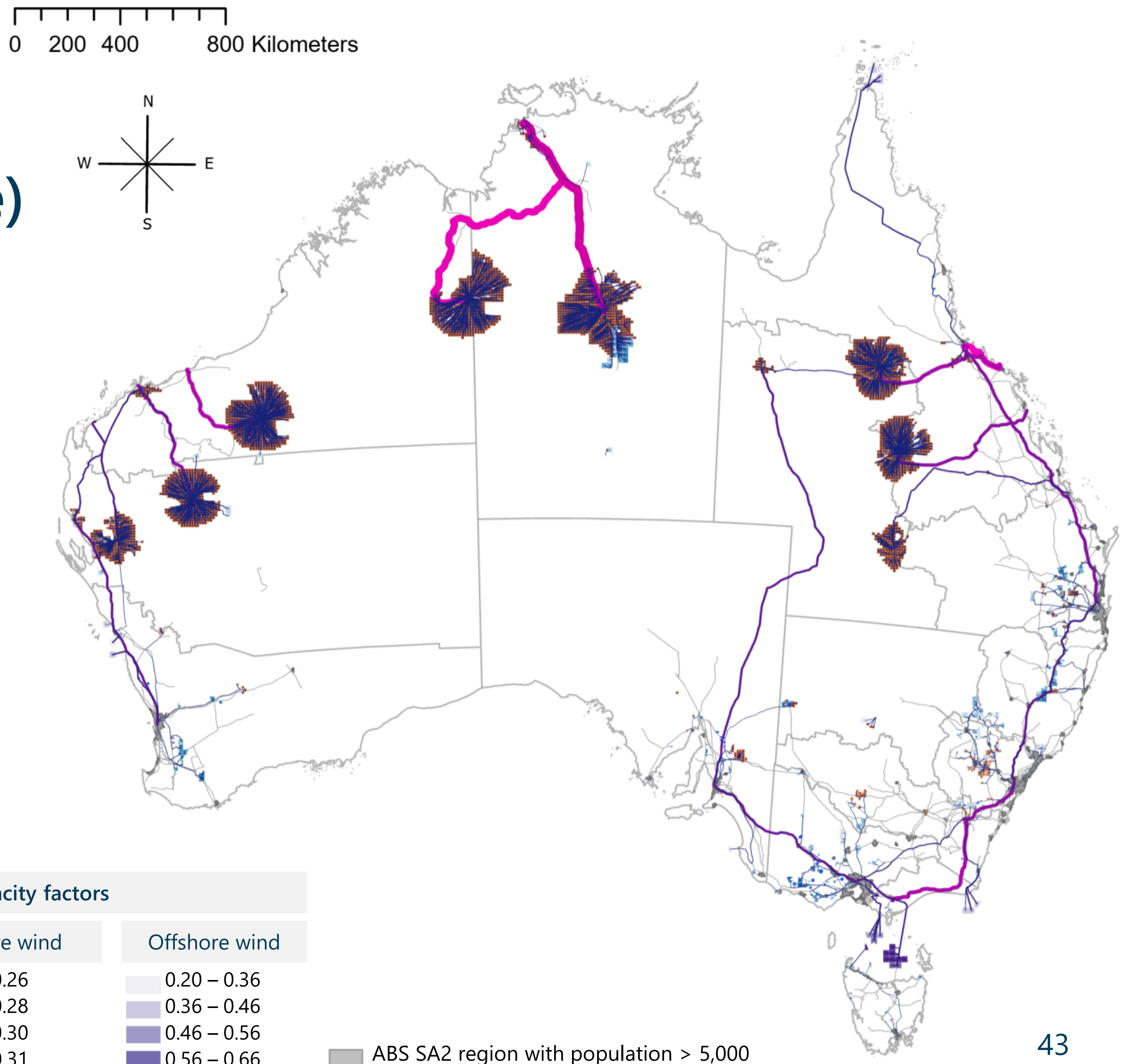
CHART 2 OF 2

8

Transition to clean energy and clean mineral exports, in line with global demand

INDICATIVE ONLY

2060 (for reference)



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

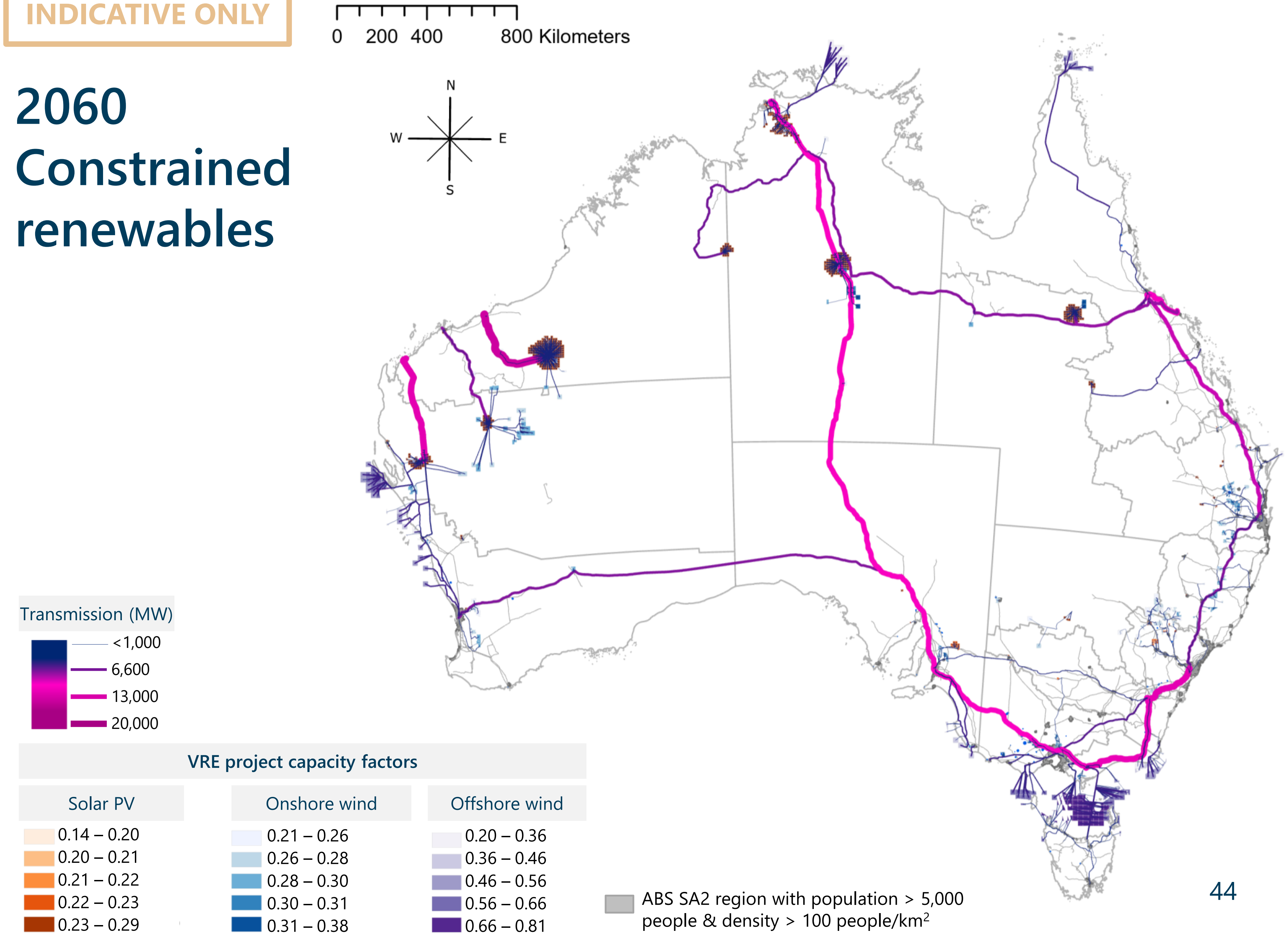
E+ 2060

8

Transition to clean energy and clean mineral exports, in line with global demand

INDICATIVE ONLY

2060 Constrained renewables



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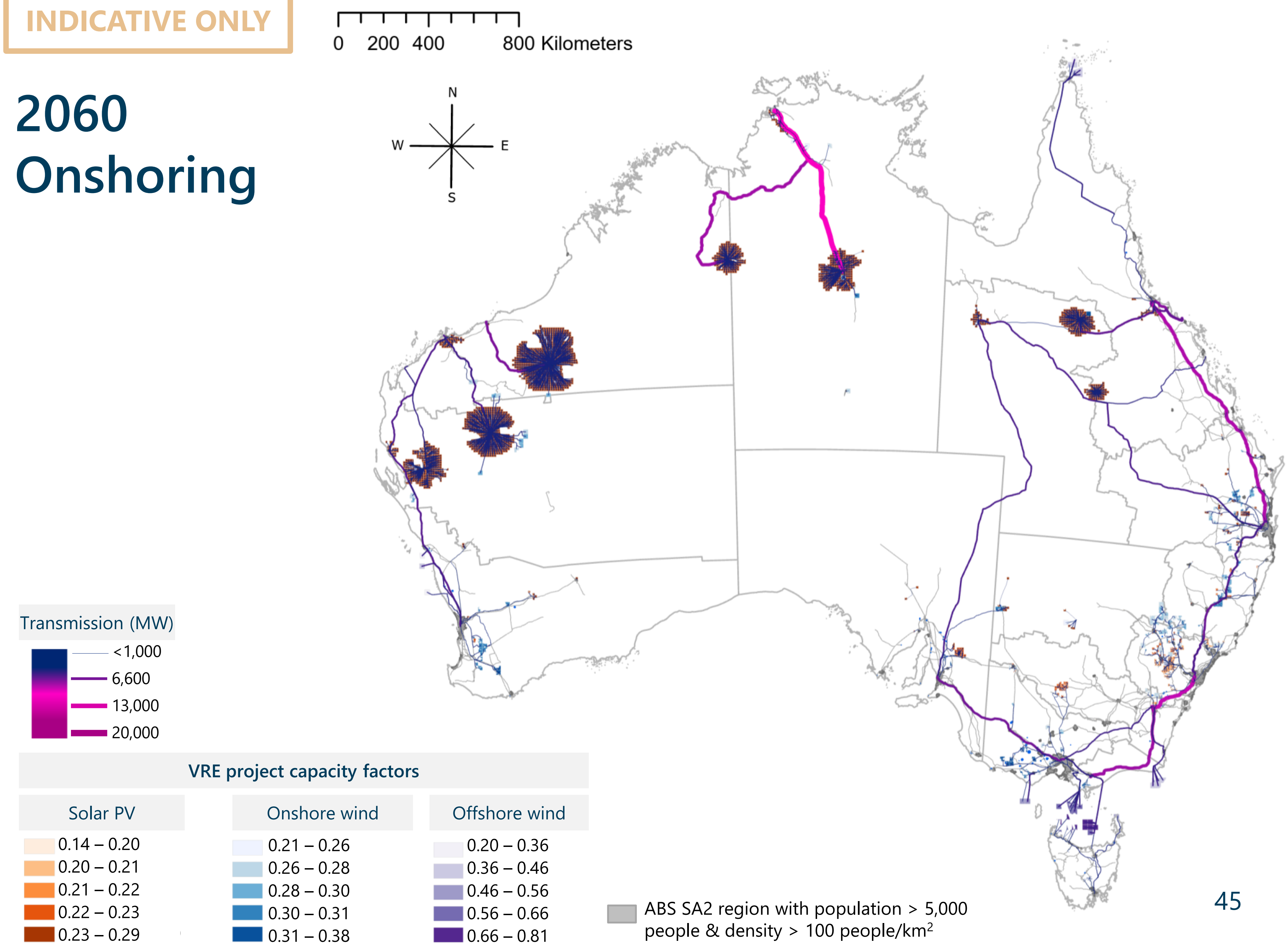
Transition to clean energy and clean mineral exports, in line with global demand

INDICATIVE ONLY

2060 Onshoring



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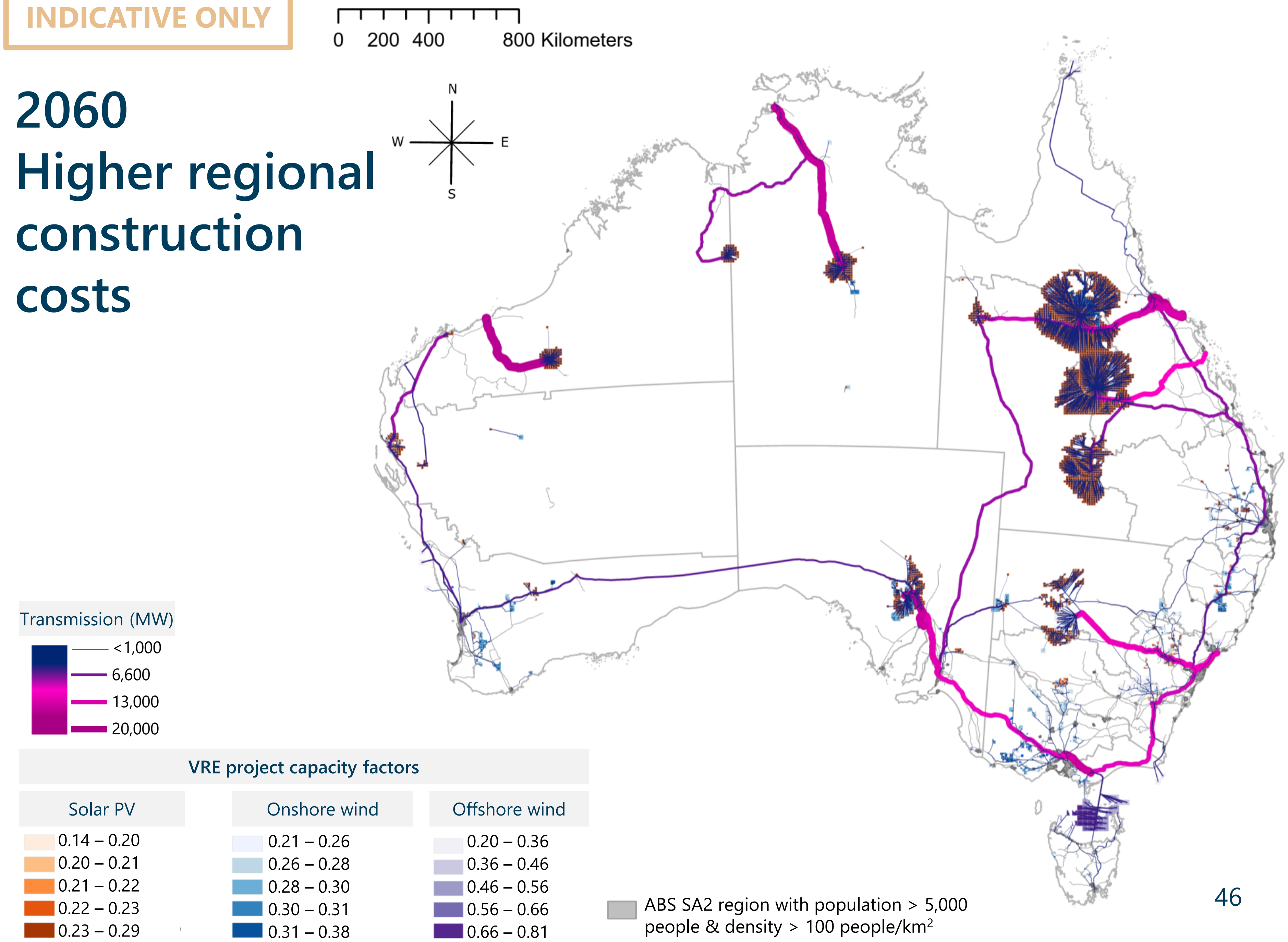
Locate these new export industries in the north, and possibly also in the south

E+ 2060 Sens: RemoteCost+

INDICATIVE ONLY

2060 Higher regional construction costs



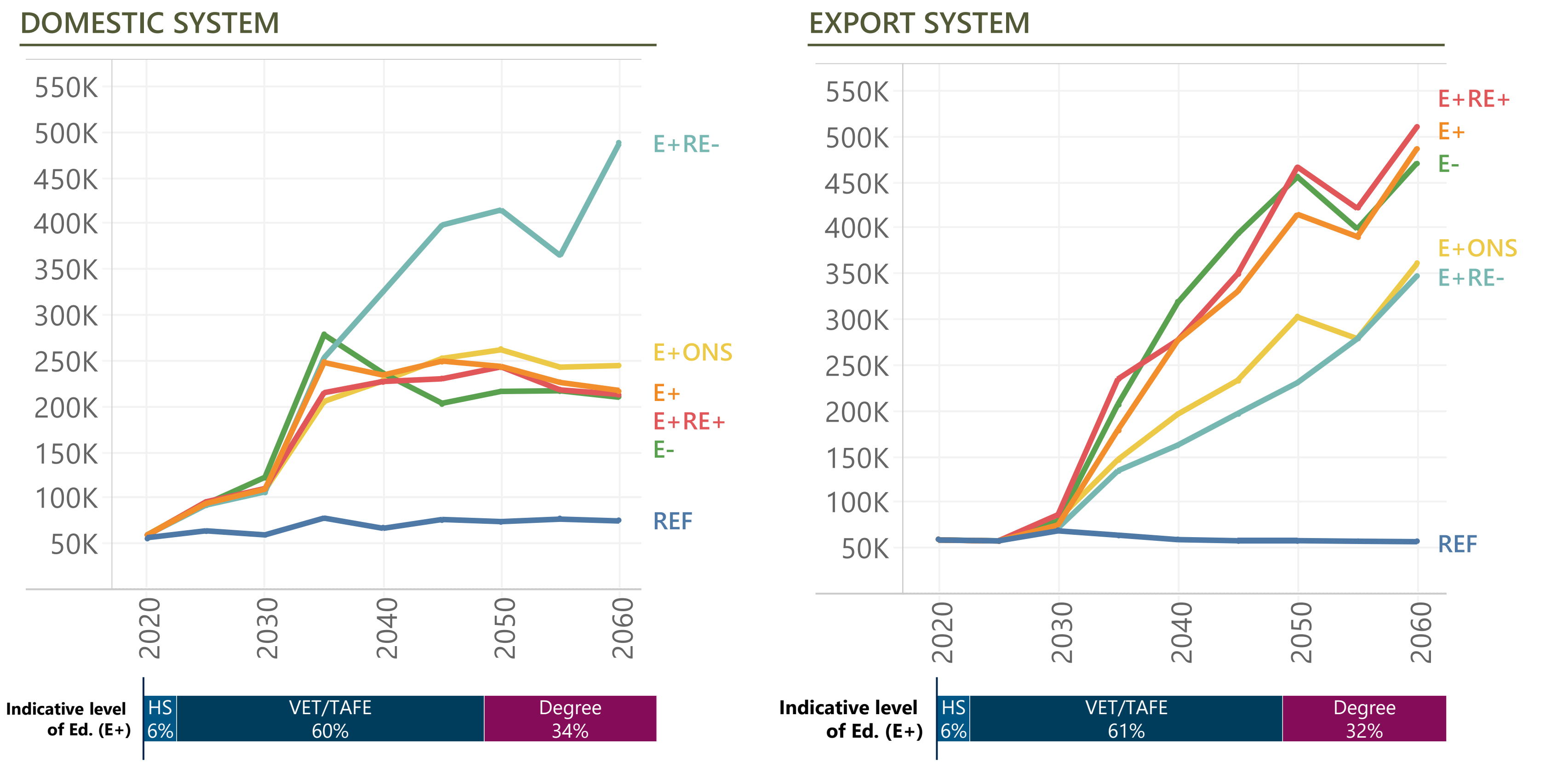
2. WHAT IT WOULD TAKE TO ACHIEVE NET ZERO

Invest in our people and land – to reduce impacts and share benefits

Expand a skilled workforce from about 100,000 today to 700,000 - 850,000 by 2060

10

Gross energy sector employment (full time equivalent jobs)



By 2060, the current energy sector workforce of 100,000 would expand to **700,000 - 850,000 workers** – most with **technical skills**.

Most new workers will be in **regional and remote Australia**, which would experience **significant population growth**.

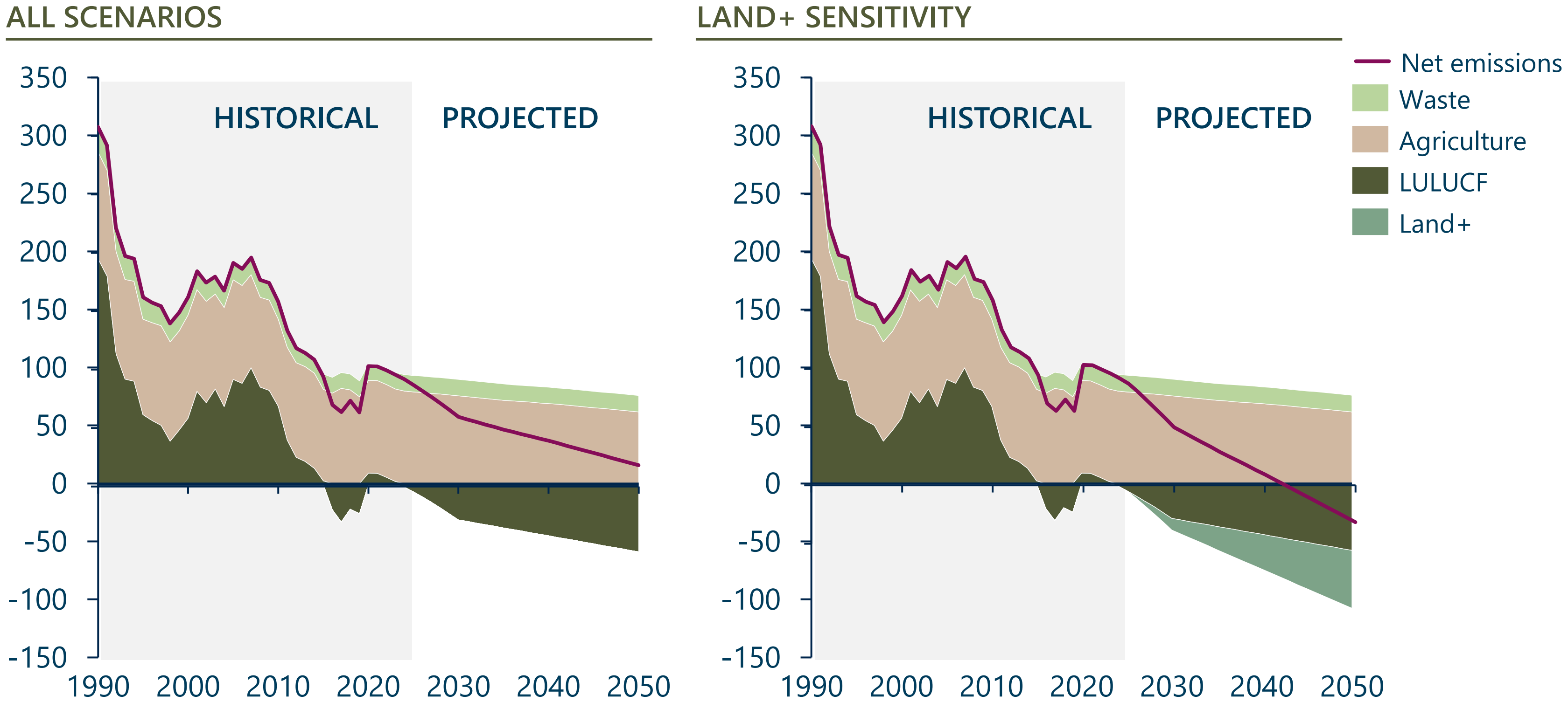
This has significant implications for **First Nations** peoples, **national security** and **immigration.**

Workforce growth would be needed for both **domestic and export** decarbonisation.

Move the land sector towards net zero and potentially net negative – by reducing livestock emissions by 20 Mt/yr and expanding revegetation by 50 Mt/yr

11

Historical and projected GHG emissions (Mt-CO_2e / year).



Land sector emissions are reduced by:

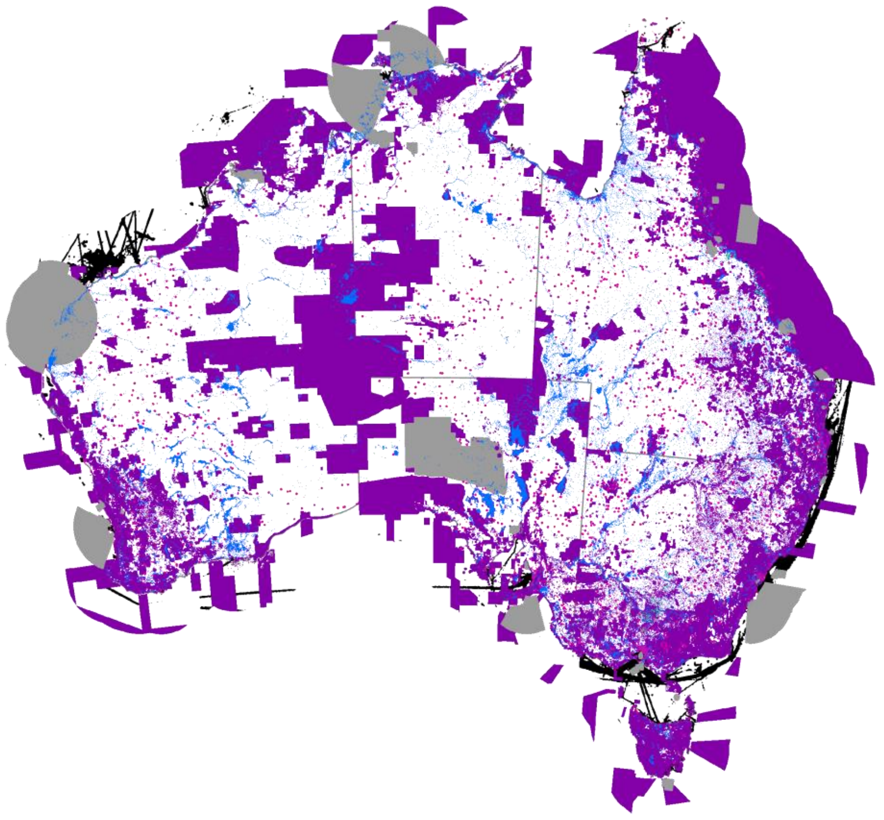
- feeding supplements
- Revegetation
- adding fertiliser inhibitors
- using waste methane.

Land sector **does not quite reach net zero** in our Core Scenarios, and reaches modest net negative in our Land+ sensitivity (from better management of rangeland).

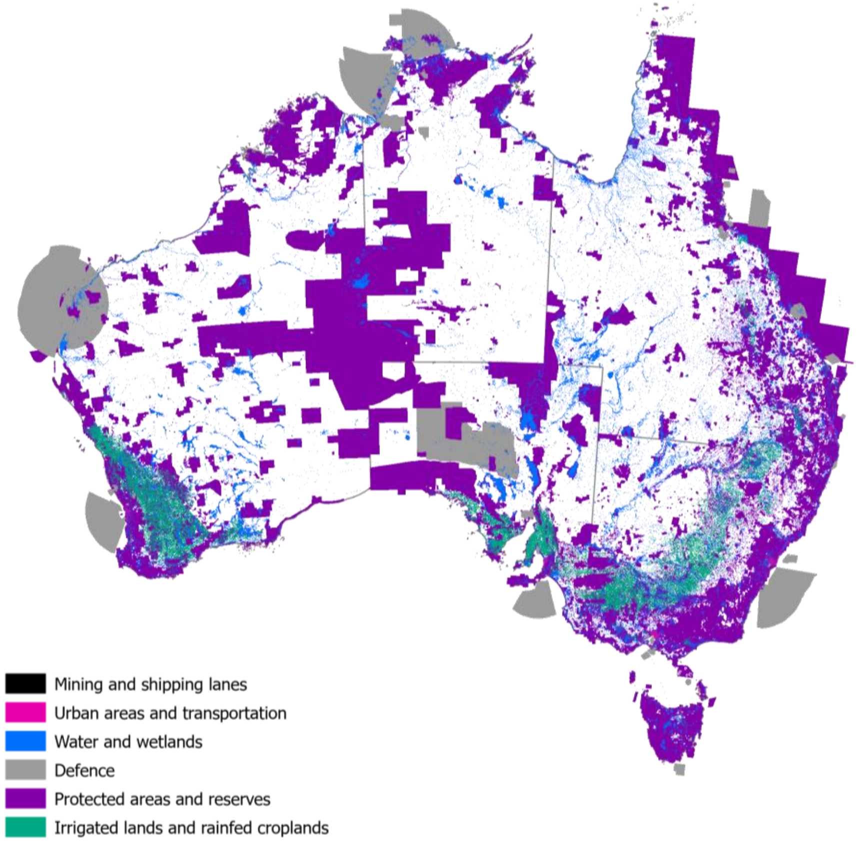
Energy and industry can not plan to rely on significant **offsets** from the land sector.

Carefully manage major land use changes, including to the Indigenous Estate, ecosystems and agriculture

Wind generation exclusion areas



Solar PV generation exclusion areas



Our exclusion process for land and sea areas

1. Removes areas protected by law
2. Removes areas supported by empirical evidence, research, or stakeholder interaction
3. Updates as risks and threats evolve, collaborations deepen, and data allow

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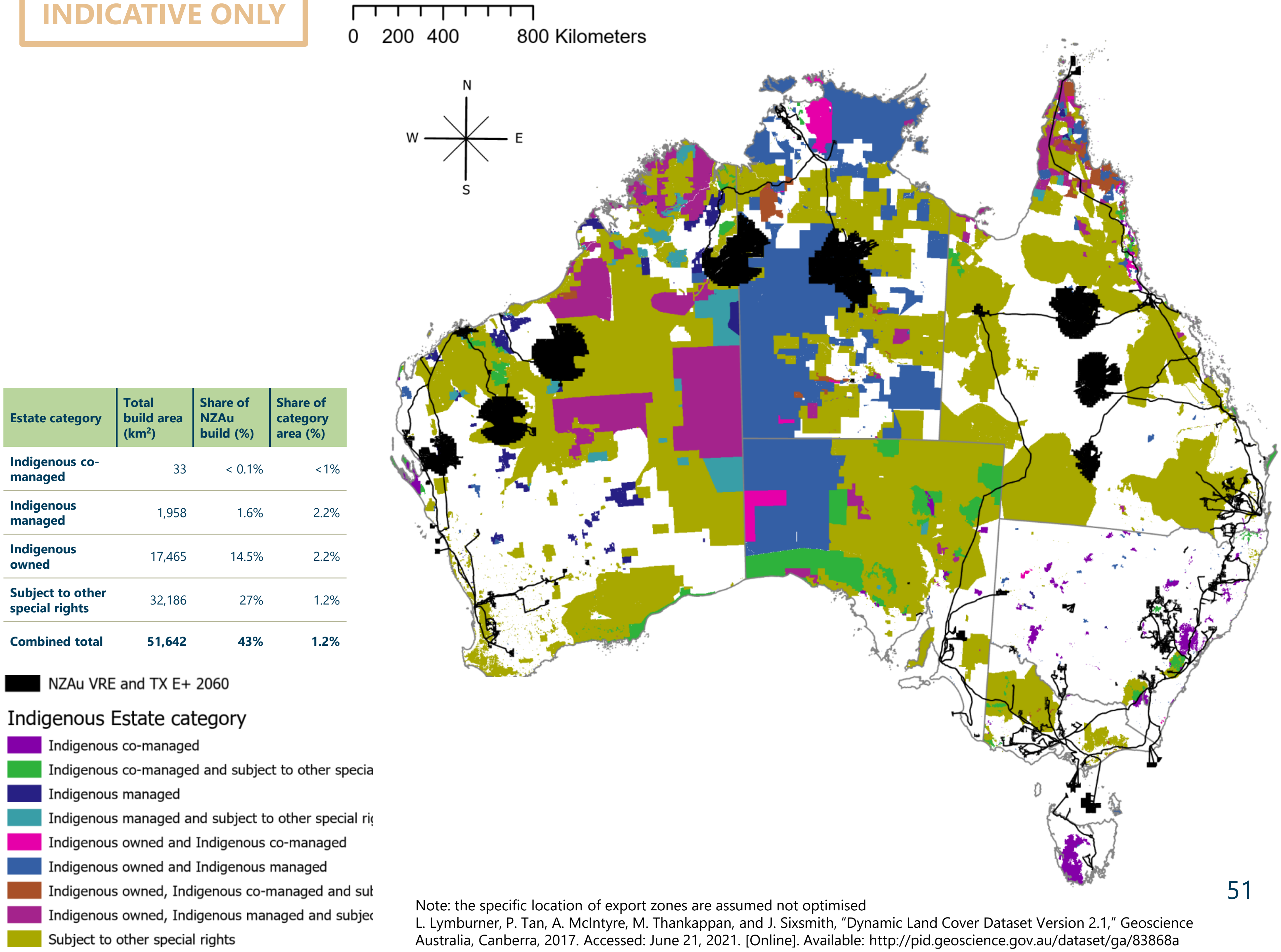
Carefully manage major land use changes, including to the Indigenous Estate, ecosystems and agriculture

INDICATIVE ONLY

Estate category	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%**



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

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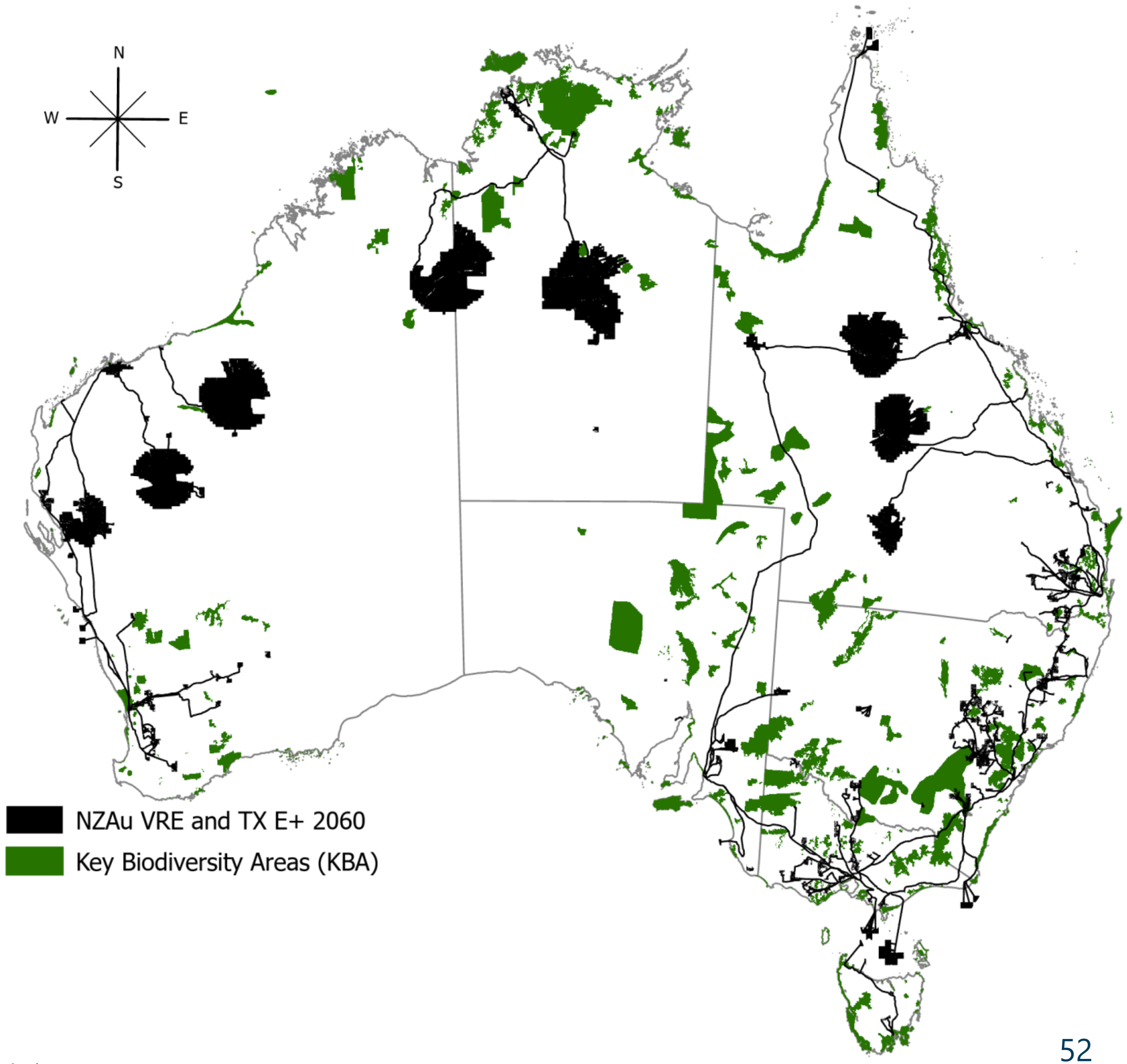
Carefully manage major land use changes, including to the Indigenous Estate, ecosystems and agriculture

INDICATIVE ONLY



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

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

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Carefully manage major land use changes, including to the Indigenous Estate, ecosystems and agriculture

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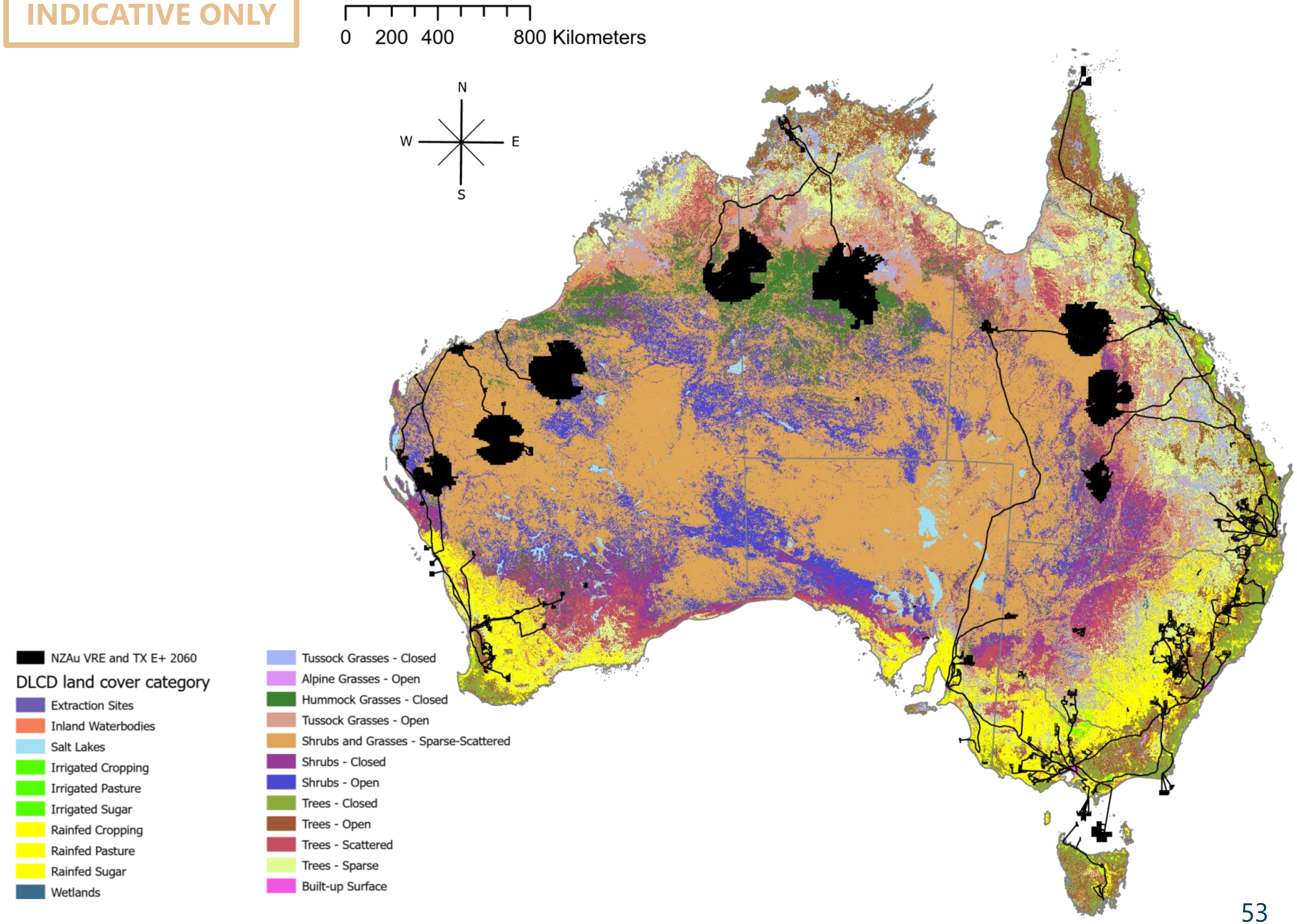

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3. What Australia must do

What Australia must do

Deliver an energy transformation

unprecedented in scale and pace

Transform our exports

as an essential contribution to global decarbonisation

Invest in our people and land

to reduce impacts and share benefits

4. What Australia must decide

What Australia must decide

1. What are the roles of governments, businesses and households in achieving net zero?

- Will decarbonisation be delivered mainly by markets – or will more government planning, regulation, subsidy and investment be needed?
- Should we establish a whole-of-economy carbon price or sectoral decarbonisation drivers?
- How do we balance coordination (to capture scale economies and minimise supply and price shocks) with competition (to drive efficiency and innovation), for the domestic and export transitions?
- How do we sustain public, corporate, and political commitment to net zero over decades?

2. What role in global decarbonisation do we want to play?

- Is global decarbonisation achievable without clean exports from Australia?
- What is the benefit to national wealth of transitioning to clean exports?
- Should we prioritise exports of clean energy or clean minerals and chemicals?
- Should we be early movers, fast followers or late adopters of clean technologies?

What Australia must decide

3. Which essential net-zero options should we prioritise and accelerate?

- Which renewable sources and storages should we accelerate deployment of?
- How should we accelerate deployment of CCUS? For what uses?
- Should we allow new coal or gas fields to be brought into production?
- How will we develop networks to move electricity, hydrogen, CO2 and water?
- Should we make nuclear energy an option? Why and how?

4. How should we distribute investment and jobs across the nation?

- Should exports come from northern Australia or across the States and Territories?
- Should we prioritise locating clean jobs in vulnerable fossil fuel regions?
- Should we subsidise local jobs in manufacturing clean technologies?

What Australia must decide

3 of 3

5. How should we mitigate the impact of large land and sea use changes?

- Should more planning be done to identify suitable areas for new infrastructure?
- Should biodiversity impacts be offset project-by-project, or more strategically?

6. How should decarbonisation costs and benefits be distributed?

- How should benefits be shared with affected communities and cohorts?
- Should benefit sharing be the responsibility of governments, developers, or both?
- Should essential energy businesses which experience major losses from decarbonisation receive support? Which ones, why and how?

Panel discussion

Panel discussion with the Steering Committee

Robin Batterham
University of Melbourne and Chair

Katherin Domansky
Independent Member

Michael Brear
University of Melbourne

Simon Smart
University of Queensland

Richard Bolt
Nous Group

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	

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NET ZERO AUSTRALIA

THE UNIVERSITY OF MELBOURNE

THE UNIVERSITY OF QUEENSLAND AUSTRALIA
CREATE CHANGE

PRINCETON UNIVERSITY

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