Final results summary

Public launch | 19 April 2023

NET ZERO AUSTRALIA



THE UNIVERSITY OF QUEENSLAND AUSTRALIA CREATE CHANGE







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
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3	what it would take to achieve het zero	Michael Brear
4	What Australia must do; and must decide	Richard Bolt

About the Net Zero Australia study

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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



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



THE UNIVERSITY **OF OUEENSLAND**

CREATE CHANGE





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



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



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



Fossil fuel energy export emissions

We have modelled six Core Scenarios

REFERENCE

REF

E+

F-

- Projects historical trends, does <u>not</u> 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.

RAPID ELECTRIFICATION

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

SLOWER ELECTRIFICATION

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

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).

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).

ONSHORING

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

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

- Grow **renewables** as our main domestic and export energy source 1
- Establish a large fleet of **batteries**, **pumped hydro** and **gas-fired firming** 2
- Greatly increase **electrification** and **energy efficiency** 3
- Develop a large **carbon capture**, **utilisation and storage** industry 4
- Greatly expand our energy transmission and distribution networks 5
- Attract and invest \$7-9 trillion of **capital** to 2060 6
- No role for **nuclear** unless costs fall sharply and renewables are constrained 7
- Transition to **clean energy** and **clean minerals exports** 8
- **Locate** these **new export industries** in the north; possibly also in the south 9
- 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

WHAT AUSTRALIA MUST DO

		Deliver an energy transformation unprecedented in scale and pace
		Transform our exports an essential contribution to global decarbonisation
)	Î	Invest in our people



and land

to reduce impacts and share benefits

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

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

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 lowemission carriers and fuels.

CHART 2 OF 2

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



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



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



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.

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





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

Projected domestic final energy demand (Exajoules / year) 6 REF 5 4 3 2 0 2020 2025 2030 2035 2040 2045 2050 2055 2060



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

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

REF E+ E--600 Residential 400 200 Solar 0 Biomass Final energy demand (PJ/year) 400 Commercial Aviation fuel Ammonia 200 Hydrogen Pipeline gas 0 LPG 2K Gasoline Industry 1.5K Diesel Oil & oil products 1K Brown coal 0.5K Black coal Electricity Transportation 2K 1K F+RF+ and F+RF- are 0K not shown because they use the same demand 2020 2030 2040 2050 2060 2020 2030 2040 2050 2060 2020 2030 2040 2050 2060 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 biosynthetic 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

Geological carbon dioxide (CO₂) sequestration (Mt-CO₂ / 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+).

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

5



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2060 Inter-regional transmission constrained

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More storage replaces interregional powerlines at modest cost



VRE project capacity factors

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200 400

800 Kilometers

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+ 2060 Sens: Transmission-

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



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

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



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





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

Average domestic cost of abatement (2020 AUD / t-CO₂e)



500 450 E-400 E+ E+RE+ 350 E+RE-300 250 E+ONS 200 150 100 50 REF 0 2030 2025 2035 2040 2045 2050 2055 2060 2020

Average export cost of abatement (2020 AUD / t-CO₂e)

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

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Domestic emissions abatement costs rise to **similar values found in other countries'** netzero 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



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

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- 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.

Transform exports – as an essential contribution to global decarbonisation

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

Energy exports (Exajoules / year)



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.

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



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

E-

E+

E+RE+

E+RE-

E+ONS

REF

2060

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

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

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E+RE- 2060

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

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E+ONS 2060

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

9



E+ 2060 Sens: RemoteCost+

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

Gross energy sector employment (full time equivalent jobs)



EXPORT SYSTEM



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

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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

Historical and projected GHG emissions (Mt-CO₂e / year).



Land sector emissions are reduced by:

- feeding supplements
- Revegetation

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- 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. Wind generation exclusion areas

Solar PV generation exclusion areas

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

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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



E+ 2060

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

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%	
NZAu VRE	and TX E+	2060		
Indigenous E	Estate ca	tegory		
Indigenous	co-manage	d		
Indigenous	co-manage	d and subjec	t to other spec	cia
Indigenous	managed			
Indigenous	managed a	nd subject to	o other special	rię
Indigenous	owned and	Indigenous	co-managed	
Indigenous	owned and	Indigenous	managed	
Indigenous	owned, Ind	ligenous co-r	managed and s	uł
Indigenous	owned, Ind	ligenous mar	naged and subj	ec
Subject to	other specia	l rights		

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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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INDICATIVE ONLY



E+ 2060

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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 of 3

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

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

- 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?

- 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 2 of 3

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

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

- 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?

- 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?

6. How should decarbonisation costs and benefits be distributed?

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

- 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

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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

- Grow **renewables** as our main domestic and export energy source 1
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