Response to website feedback and the public launch Q&A

2 December 2022

NET ZERO AUSTRALIA

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The Net Zero Australia (NZAu) project is a collaborative partnership between the University of Melbourne, The University of Queensland, Princeton University and management consultancy Nous Group. The study identifies plausible pathways and detailed infrastructure requirements by which Australia can transition to net zero emissions, and be a major exporter of low emission energy and products, by 2050.

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The inherent and significant uncertainty in key modelling inputs means there is also significant uncertainty in the associated assumptions, modelling, and results. Any decisions or actions that you take should therefore be informed by your own independent advice and experts. All liability is excluded for any consequences of use or reliance on this publication (in part or in whole) and any information or material contained in it.

About this document

Since the public launch on 25 August, 2022, many further questions and feedback have been sent to the Net Zero Australia (NZAu) project. This includes unanswered questions and feedback that was not responded to on the night of the launch, given time constraints. Further questions and feedback have been received through the 'Contact' page on the Net Zero Australia website, https://www.netzeroaustralia.net.au/.

This document summarises our responses to these questions and feedback. We have aggregated comments by theme (numbered headings). The feedback and questions are presented as **bolded bullet points**, and the Net Zero Australia team's response below in an *italicised call out box*.

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1 Intended audience

- **Who is the intended audience of this report?**

We intend this project to be relevant to a broad audience. 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.

2 Modelled consumption patterns, energy efficiency/productivity

- **There is a need for discussion about reduced consumption – less meat, air travel etc. It appears your project assumes no societal shift to less consumption and simpler lives.**
- **Message of your work is with investment and tech, Australia can continue enjoying high standard of living without need to change consumption.**
- **The scenarios don't appear to incorporate aggressive enough energy efficiency assumptions, or demand management.**

We agree that lower consumption of many things would be a good thing. However, the NZAu project is not prescribing what people should or should not do. Rather, we wish to help individuals, communities, companies and governments appreciate the scale, complexity and cost of the net zero task. Also, our two demand-side scenarios, E+ rapid electrification and E– slower electrification, explore the effects of energy productivity improvement. The E+ scenario models 1% p.a. end-use energy efficiency improvement and significant rates of electrification which drive large energy productivity improvement. We therefore consider that our scenarios adequately examine the effects of energy efficiency.

3 Negative emissions technologies

- **The project canvasses only a few negative emissions technologies. There are a range of other opportunities.**

This work considers three methods of CO2 removal from the atmosphere (negative emissions technologies):

1. *CO2 sequestration in 5.1 million hectares of new trees, which largely decarbonises the combined land (agriculture, waste, LULUCF) sector and does not provide credits to other sectors;*
2. *bioenergy with CCS (BECCS) which is a candidate technology for making biofuels from biomass waste/residues and using or geologically sequestering the captured biogenic CO2; and*
3. *direct air capture (DAC) with use or geologic sequestration of the captured CO2.*

We note that for BECCS and DAC to be considered negative emissions the captured carbon must be sequestered in geologic formations permanently. While we are aware of other potential net negative emissions technologies, such as soil carbon enhancement, enhanced weathering and ocean alkalinisation, we have not considered them as part of our work because we simply cannot examine every option for decarbonisation and since most of these other options are more uncertain. We will nonetheless study some of these further as the project progresses.

4 Alignment with AEMO Integrated system plan

- **Your modelled split between batteries and pumped hydro does not align with the ISP. We suspect assumed disposal costs or design life of batteries may cause this.**
- **The 'energy Tasmania's' do not really align with AEMO's renewable energy zones.**
- **How does model incorporate expected development of REZs.**

We have not attempted to align our modelling of a future electricity system with AEMO's Integrated System Plan for three reasons:

1. *we undertake this project across the whole country, and across all sectors;*
2. *the capacities projected for the renewable energy zones in the ISP are insufficient to decarbonise both the entire domestic consumption of energy and all of Australia's energy exports; and*
3. *the models we are using are different to AEMO's models.*

However, we have used many of the same technology cost assumptions as the ISP, and our preliminary results have shown good agreement with the ISP in some areas. For example, we have found that the technologies projected to be installed in the NEM regions that serve domestic electricity demand have a similar mix, and have also found similar choices of inter-regional transmission augmentation.

5 Nuclear

- **Why are you / are you not considering nuclear technologies?**

Net Zero Australia is not for or against any energy source or energy technology. We have not considered nuclear technologies in our core scenarios as this is consistent with Australian Federal legislation.

However, we acknowledge that nuclear technology has been shown overseas to have a role to play in decarbonising energy systems. As discussed at the public event, we will therefore examine the potential role for nuclear electricity generation in Australia in our planned modelling. Of course, legislative change must occur for nuclear power to be deployed in Australia, and Small Modular Reactors (SMRs) are not yet generating. Our study of nuclear will therefore include an estimate of the delay before nuclear generation could be operational in Australia.

6 Firm generation and system reliability

- **I agree with the need for gas turbines for reliability, as batteries are important for grid stability but do not cut it for load shifting.**
- **It is unclear that you have modelled the energy system hourly, accounting for hourly and seasonal renewable variability.**

We have modelled the energy system with hourly timesteps, accounting for hourly variation in wind and solar resource, as well as in electricity demand, across a full year and across 15 modelled regions. We account for renewable variation within each modelled region with up to 7 distinct and geographically representative hourly wind and solar resource availability profiles. These hourly profiles are based on historical data and are discussed in detail in our Methods, Assumptions, Scenarios & Sensitivities document (NZAu 2022).

Incorporation of at least hourly profiles is important for the modelling of energy systems with very high penetrations of variable renewable resources, to ensure that sufficient firm generation and storage resources are also modelled for system reliability (i.e. for supply to match demand). However, we note that while we incorporate hourly variation in resource and demand, as well as capacity reserve requirements, any detailed assessment of energy system reliability and security would be a large undertaking that is outside the scope of the present project.

7 Capital investments and costs

- **Levelised system cost per year is a confusing term and should be defined. Suggest reporting the wholesale price of energy to achieve a breakeven financial position at the WACC ($/MWh).**
- **Suggest reporting capital investment by system component every year – alongside levelised costs – and compare with other expenditure.**
- **Is GDP a modelled output or an input from some other source? I would have thought GDP would be dependent on huge capital investment.**
- **What is relative role for government vs. private sector? Do we expect transition to be privately led? Could Australia's superannuation funds be a significant answer to financing?**
- **Do costs include infrastructure needed to support workforce growth and re-distribution?**

We agree that our presentation of system costs (both domestic and export) could be clarified and presented in more detail. Our ongoing 'downscaling' work is also exploring the capital investment requirements in further detail. This will be clarified and more extensively presented in the final project reports.

We have not modelled GDP as dependent on the energy system, but rather use projections from the ABS historical data and the AEMO ISP. The extent to which GDP is dependent on our modelled energy system transition is uncertain, requires a different set of analysis and modelling tools, and is therefore outside the scope of the project. Our analysis of the relative roles for different sectors in financing the transition, and the need for investment in auxiliary infrastructure that supports the energy transition will be presented in more detail in our final reports.

8 Energy storage

- **Suggest presenting both the power and energy capacity (hours of storage).**
- **What technologies and storage durations have you modelled and will this ensure reliability?**
- **Is thermal storage considered?**
- **What emphasis is placed on increased natural gas storage to underpin firming capacity?**

In future reports we will present both the power capacity and energy capacity of the energy storage modelled. As candidate energy storage technologies, we allow batteries, pumped hydropower and hydrogen storage in underground engineered caverns, but not thermal storage. The power and energy capacities (and therefore the storage duration) are independently optimised for each storage technology in each modelled region, so that system reliability is ensured with a range of energy storage types and durations.

Most scenarios modelled feature a significant reduction in natural gas consumption, however we find that natural gas fuelled gas turbines have a role to play as a source of firm capacity but operating with very low capacity factors.

9 Carbon capture (use) and storage

- **What confidence do you have in the feasibility of CCUS scaling to the required level?**
- **Is your CCS modelling based on proven technology and what advances are required to successful store CO2 in long term?**
- **What are risks of future leaks from storage and will this cause problems for future generations?**
- **Does CCUS include BECCS?**

Net Zero Australia is not for or against any energy source or energy technology, and we have therefore included a wide range of candidate technologies that have been examined in energy system decarbonisation analyses by groups including the IPCC, IEA, AEMO, and in the Net Zero America study. These include technologies delivering a wide range of energy services and of various technical maturity.

Also, the term 'CCUS' applies to a diverse range of activities both in terms of the sources of CO2 and the forms of storage used. As such, difficulties with any one project do not necessarily apply to others. Our modelling does not find that coal or natural gas fired electricity generation would be introduced with CCUS. Rather, the main role for CCS in our modelling is in hydrogen production from natural gas with autothermal reforming (ATR) in some scenarios.

Furthermore, irrespective of the current efficacy of CCUS, the study has also found that CCUS may be required to achieve net zero for:

1. *non-energy uses such as making cement and chemicals;*
2. *producing 'negative emissions', i.e. storing carbon emissions taken out of the atmosphere using renewables ('direct air capture'), to offset other emission if agriculture and forestry does not perform this role.*

10 Technology breakthroughs

- **What technology breakthroughs are required to enable these scenarios?**
- **How does modelling account for rate at which technologies become commercially viable?**

Net Zero Australia is not for or against any energy source or energy technology, and we have therefore included a wide range of candidate technologies that have been examined in energy system decarbonisation analyses by groups including the IPCC, IEA, and in the Net Zero America study. These include technologies delivering a wide range of energy services and of various technical maturity.

The rate at which such technologies become commercially viable is incorporated into the modelling through use of cost projections over the modelling timeframe. While these cost projections are uncertain, we have endeavoured to use the most recent and authoritative sources of cost projections for Australia. In addition, to understand the sensitivity of the energy transition to these cost projections and technological development, we are undertaking a range of sensitivity studies that will be presented with our final reports.

11 Energy exports

- **What do you think actual international demand for our hydrogen will be? Does Australia actually have a natural advantage in energy transition?**
- **An alternative scenario would be to use renewable energy to make higher added value products like plastics. Was this considered?**
- **Renewable energy exports could mean exposure to export parity prices – should there be domestic reservation policy?**
- **Do you consider export of carbon removal as a service?**
- **Are export zones modelled with their own dedicated cost of transmission, do to cost recovery in regulated transmission networks? How much supply from export zones goes to domestic consumption?**

Our modelled pathways illustrate clean energy exports replacing our current fossil fuel exports. The global demand for clean exports is of course very uncertain and will depend on many factors that we could not model. The cost of our decarbonised exports is nonetheless expected to be higher than average pre-COVID prices of our coal and LNG exports. However:

1. *current crude oil and LNG spot prices are comparable to our projected clean energy export costs, and our Reference Scenario does not include the impact of future fossil fuel supply constraints and disruptions;*
2. *there is significant potential for innovation in electrolysis and renewables, which would lower export costs;*
3. *these costs would be paid for by those receiving the energy, not by Australians; and the relative lack of land available for renewable energy production in some of our primary trading partners (e.g., Japan and South Korea) is a significant constraint on their potential for energy self-sufficiency, and this is borne out by their interest in Australia as an exporter.*

Also, our onshoring scenario considers displacement of energy exports with domestically processed iron and aluminium resources. While this does not consider other value adding processes, Australia may have significant prospects for clean processing of numerous other resources and products.

12 Global climate scenarios and emissions constraint

- **Why did you choose a linear trajectory, instead of an emissions budget with Australia's fair share of emissions?**
- **Have you considered carbon budgets in the different scenarios? What temperature limits do scenarios approximate to?**
- **What global climate outcomes are associated with these scenarios?**

We acknowledge that there are many ways to impose this constraint, and each have their merits, drawbacks and assumptions. Our choice to model a linear annual emissions trajectory was primarily because it is simple. Also:

1. *serendipitously, a linear trajectory has since been chosen for current Commonwealth legislation;*
2. *our ongoing work is assessing the sensitivity of the modelled energy transition pathways to faster decarbonisation timeframes for both the domestic and export emissions systems, which will have reduced modelled absolute emissions budgets.*

Also, our modelling of the decarbonisation of both our domestic energy and exports complicates any determination of Australia's 'fair share' in a global emissions budget. We note that our scenarios model 1440 million tonnes-CO2e of annual emissions abatement by 2050, and 1845 million tonnes-CO2e by 2060, relative to 2020 levels, while providing significant clean energy exports globally that we assume stay constant on an energy basis from 2020. However, Australia's historical energy exports have grown significantly over the last few decades and could plausibly grow further or reduce as the world decarbonises. For this same reason it is also problematic to suggest the global climate outcomes and temperature limits that our modelling aligns with, as this requires us to assume some global response that is outside the scope of our project.

As such, we instead consider that the two sets of linear trajectories that we have chosen (i.e. domestic/export net-zero by 2050/60 and 2040/50 separately) are within the boundaries of the Australian debate and are reasonable limits to an infinite number of trajectories within that range.

13 Climate change adaption

- **Droughts will be more prevalent in future – how do we supply enough water for increasing population and for energy assets?**
- **How might bushfires impact agriculture, and LULUCF assumptions?**
- **How is projected habitability of areas been considered in planning, e.g. amid increasing temperatures in northern Australia?**

Climate change is already having a significant impact on habitability of areas of Australia, as well as the operability of existing energy assets. To ensure resilience of our modelled energy systems to changes in water availability, we have accounted for all water requirements of energy infrastructure through the use of desalination. The energy requirements for desalination are accounted in the energy system modelling, and our ongoing work is considering optimal siting of these plants and their land and sea use impacts.

The impact of an increasing prevalence of bushfires on the agriculture and LULUCF assumptions is uncertain, particularly with regard to carbon flows during and in the years following a bushfire disturbance. We do not model such effects but will discuss what these could mean for Australia's national greenhouse accounts in our ongoing work.

Finally, while we are not assessing the habitability of the areas in which new energy assets will be located, our ongoing sensitivity studies will assess a range of factors that may affect asset siting.

14 Transmission

- **What benefits are provided by trans-continental transmission?**
- **Was Marinus Link included?**
- **How did modelling consider tradeoffs between electricity and gas transmission?**

Our energy system modelling includes only current transmission infrastructure, and therefore does not include Marinus Link. We include transmission infrastructure cost for both electricity and hydrogen as candidate transmission lines, and then the models optimise the required electricity and hydrogen network augmentation and new build.

Rather than include proposed transmission lines, we assess the modelling outputs to determine the transmission investments required along certain routes. This work is ongoing and final reports will examine further which transmission routes are most prospective across different scenarios, including any potential trans-continental transmission.

15 System resilience?

- **Will high reliance on renewable energy lead to lower resilience of the energy sector?**

Studies of system 'resilience', like those of system security, are outside the scope of this project because such an assessment at the National scale is not computationally tractable. Nonetheless, we do see the projected reliance on renewables to present substantial system security and resilience challenges that need serious further study.

16 Renewable deployment rates

- **Renewable deployment rates are immense – how do they compare with even the most heroic deployment across the world?**

Our constrained renewable deployment scenario, E+RE−, limits annual deployment rates of solar PV, onshore wind and offshore wind to 10, 5, and 1 GW/year in 2030, which grows to 40, 10 and 15 GW/year by 2050. These constrained deployment rates were chosen to represent roughly 5-10 times the highest historical onshore build rates in Australia.

However, in the years 2015-2020, China installed an average of 83 GW/year of renewable capacity, while Europe and the U.S. deployed 31 and 22 GW/year on average, with more than half of global renewable capacity additions in this time frame being solar PV (IEA 2021).

17 Energy centralisation

- **To what extent do you see greater (or less) decentralisation of electricity generation and storage?**

Our modelling to date has found that large coal generators are replaced rapidly by large-scale renewable generation with a mix of energy storage technologies and firming. We expect that a significant portion of the large build out of battery storage could be contributed by small-scale behind-the-meter installation, and the analysis of this is ongoing. We also project that approximately 70 GW of rooftop solar PV will be installed by 2050, which is in the range 23-40% of the installed solar PV capacity serving domestic electricity consumption. We will present further examination of energy system decentralisation in our final reports.

18 Global supply chains

- **Global supply chains for renewables growth are likely to be constrained. Even domestically available materials and resources will be constrained. How have these been considered?**
- **What is the impact of different international energy prices on modelling?**
- **Does modelling consider embodied emissions of new system assets?**

We agree that global energy supply chains are uncertain, volatile, and may be significantly constrained during the global energy system transition. Presently, we consider that all technologies will be available for construction and installation when required, and our ongoing work is seeking to quantify and account for some of these constraints. Furthermore, our constrained renewable deployment scenarios, E+RE−, is intend to (in part) explore factors such as supply chain delays and skilled labour shortages.

We account for all Australian scope 1 emissions, including those from our manufacturing industries. We do not account for those emissions embodied in any imported energy assets, on the basis that those emissions are accounted in our trading partners' inventories and that their manufacturing emissions are decarbonised in this study.

19 Agriculture

- **Agriculture emissions do not reduce much over time. Why?**
- **How much direct air capture is required to offset residual ag./waste/LULUCF emissions?**

Our agriculture and forestry sector experts have considered a range of solutions for emissions abatement in the agriculture sector and projected plausible uptake rates for those solutions. The details of these projections are discussed extensively in our MASS document (NZAu 2022). The nature of much of Australia's agriculture means that emissions abatement in this sector is challenging, with residual GHG emissions in agriculture modelled to be approximately 60 Mt-CO2e/year. We have also modelled a significant uptake of new trees on Australia's farmland, which could sequester ~50 Mt-CO2e/year by 2050. In our modelling, the combined agriculture/waste/LULUCF sectors have a residual 19 Mt-CO2e/year by 2050, which would therefore require negative emissions in another sector, such as direct air capture and CCS.

Also, our further work is examining the system-wide benefits and impacts of more ambitious land sector abatement.

20 Impacts on First Nations' land

- **How can we create genuine Indigenous economic opportunities?**
- **Unprecedented capital investment (from global north) will make global south indigenous communities nervous. Will this be a just transition?**
- **To what extent are assumptions around access to land realistic? Planning regimes, small scale land owner decision making, First Nations priorities can all make land access and use complicated.**

Net Zero Australia's modelling provides evidence of the potential impact of the transition on the Indigenous Estate. This modelling is ongoing and is being undertaken in regular consultation with the National Native Title Council. Our final results will present more evidence on this topic, and our mobilisation work will offer insights and options that may assist a just transition.

21 Planning and mobilisation

- **Has the study considered decision making processes being changed to ensure achievement?**
- **What policy levers are going to determine which scenario is most likely?**
- **Will mobilisation reports include policy recommendations?**

The mobilisation component of the Net Zero Australia study is assessing actions that could be taken by governments, companies, and the public to achieve net zero. This work includes identifying and analysing the strategies and policies that governments may adopt. We do not plan to recommend specific policies, though we will suggest options that have enough merit to warrant consideration.

22 Just transition

- **Would you consider socio-economic modelling that looks at different degrees of welfare distribution?**

The impacts of decarbonisation will fall unevenly on the Australian community, which may widen existing inequalities in some cases, and may reduce it in others. We will identify cohorts on which adverse impacts are likely to fall disproportionately, and identify how these may be mitigated. It is well beyond our scope to model the future distribution of welfare, in part because it will be the product of many influences and not solely decarbonisation.

23 Models

- **What tool/software are you using?**
- **How do you plan to validate your model?**

NZAu uses a combination of methods for analysing Australia's net-zero transition. The energy system modelling uses two tools developed by Evolved Energy Research, namely EnergyPATHWAYS a demand-side model, and the Regional Investment and Operations (RIO) tool that models the energy system supply-side. Both of these models were initially developed to model the U.S. in work that was peer-reviewed and published (Williams et al. 2021) and were also used in the Net Zero America study (Larson et al. 2021). We have adapted these models in NZAu with Australian-specific inputs, the process of which is extensively documented in our Methods, Assumptions, Scenarios & Sensitivities document (NZAu 2022).

The use of these adapted models for Australia has been validated by comparison of model outputs of energy activity and resulting emissions in the first modelled timestep, 2020. We found that the model replicates current energy activity and the 2019 GHG emissions inventory closely across the categories Energy (Fuel Combustion and Fugitives) and Industry.

The next phase of the project downscales the results of the energy system modelling and use a number supplementary methodologies, including various mapping methods and decisions, which will each be documented in reports accompanying project finalisation.

24 References

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