

Topical Report #3

Biodiversity and Energy System Planning

26 March 2026

NET ZERO AUSTRALIA



EVOLVED
ENERGY
RESEARCH



DOI 10.26188/31166836

ISBN 978 0 7340 5745 7

Wintle, B., Rogers, A., Zhang, Y., Davis, D., Wade, B., Greig, C., Smart, S. and Brear, M., 2026, 'Biodiversity and Energy System Planning', Net Zero Australia, 10.26188/31166836, <https://www.netzeroaustralia.net.au>

The Net Zero Australia (NZAu) Project is a collaborative partnership between The University of Melbourne, The University of Queensland and Princeton University.

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Disclaimer

The inherent and significant uncertainty in key modelling inputs and methods 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. Also, the authors of this report do not purport to represent Net Zero Australia Project Supporters and Advisory Group member positions or imply that they have agreed to our inputs, methodologies or results.

Outline of Topical Report

1 About the study

2 Methods

3 Summary of results

4 Results

4a Biodiversity value mapping

4b Estimated impacts of biodiversity protection on system planning and costs

4c Estimated impacts of biodiversity offsets

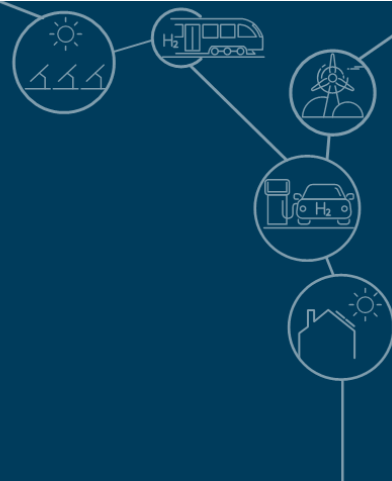
4d Comparing renewable energy land use to other land uses

5 Implications of results



Return to
outline

1 About the study



Net Zero Australia's areas of focus.

Phase 2 of Net Zero Australia is completing deeper analysis of specific challenges and aims to make practical recommendations on decarbonisation while acknowledging environmental and social objectives.

1

A unified approach to decarbonisation

Informing nation-wide strategies for planning, governing, and implementing large-scale decarbonisation projects.

2

Biodiversity, land use and GHG management

Informing integrated approaches for balancing ecological preservation, agricultural productivity, and carbon management.

3

People, trust and the workforce

Informing measures that balance community benefits, workforce preparedness, and household engagement in the energy transition.

* The NZAu Project has consulted widely with our Advisory Group members and many other stakeholders but is independent of them all. NZAu does not purport to represent their positions or imply that they have agreed to our methods or results.

Project governance

Steering Committee

Responsible for the Project's strategy, scope and management.

Advisors and Supporters

Crucial input is being provided by diverse Advisors*, with generous support provided by several organisations. Gifts and grants ensure the Project's independence.

NZAu Team

Researchers and advisors across the Universities of Melbourne and Queensland, Princeton University, and Evolved Energy Research.

Visit our website for more information:

netzeroaustralia.net.au

Purpose and scope of this Report from the NZAu Project.

This third Topical Report integrates national maps of biodiversity value into energy system planning to **quantify the trade-off between siting renewables and transmission and biodiversity protection during the transition towards net zero emissions.**

REPORT PURPOSE

1. Identify priority areas for biodiversity impact avoidance.
2. **Integrate biodiversity protection into energy system planning.**
3. **Estimate the costs** associated with increasing levels of biodiversity protection in a **net zero domestic energy system.**

IN SCOPE

- Generate national maps of **priority biodiversity areas** based on the spatial distribution of threatened species (TS) and threatened ecological communities (TECs).
- **First-of-a-kind integration of biodiversity protection into energy system planning**, quantifying how increasing biodiversity protection can affect asset siting and economics **at a scale consistent with the net zero task**, i.e. at a scale *much* larger than current build.

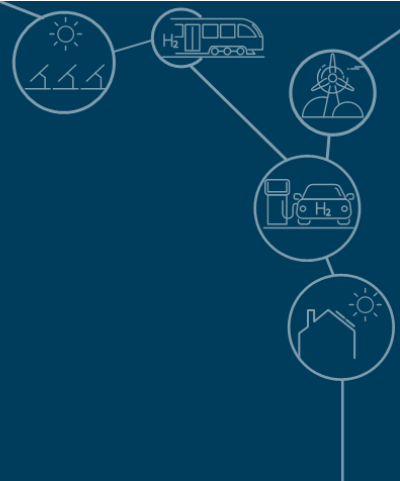
OUT OF SCOPE

- **Biodiversity impact assessment of any specific current or future project.** Real projects have long and complex development times, our mapping is only indicative, and the methods in this Report are insufficiently resolved for local assessments to the required standards.
- **Assessment of the biodiversity impact of a potential clean energy export system.** This will be considered later in the NZAu Project and is an important consideration.



Return to
outline

2 Methods



We develop a national priority biodiversity value map based on biodiversity (species and ecological community) mapping and existing conservation areas.

National biodiversity value maps incorporate 2,033 terrestrial/freshwater EPBC species/ecological communities (ECs)

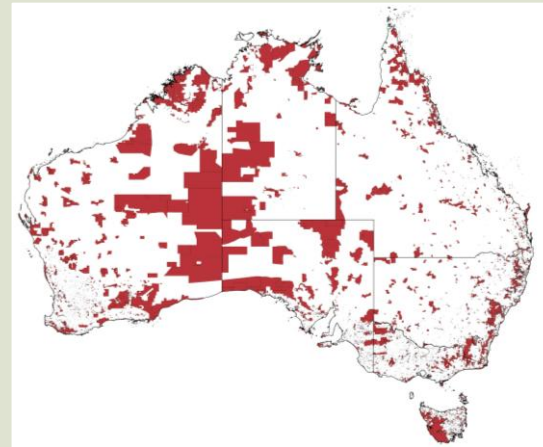
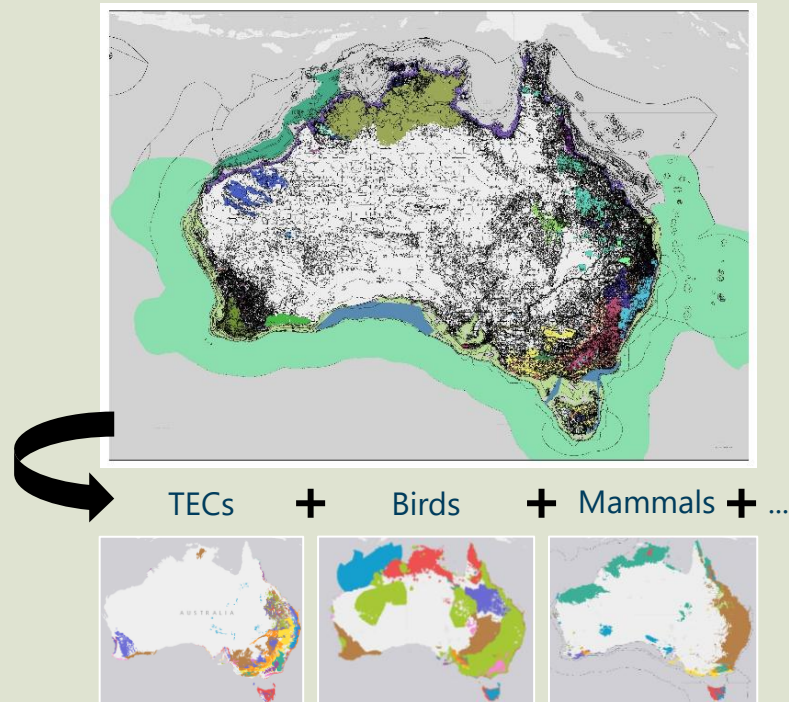
EPBC-listed species and threatened ecological communities (TECs) 'likely to occur' distributions¹



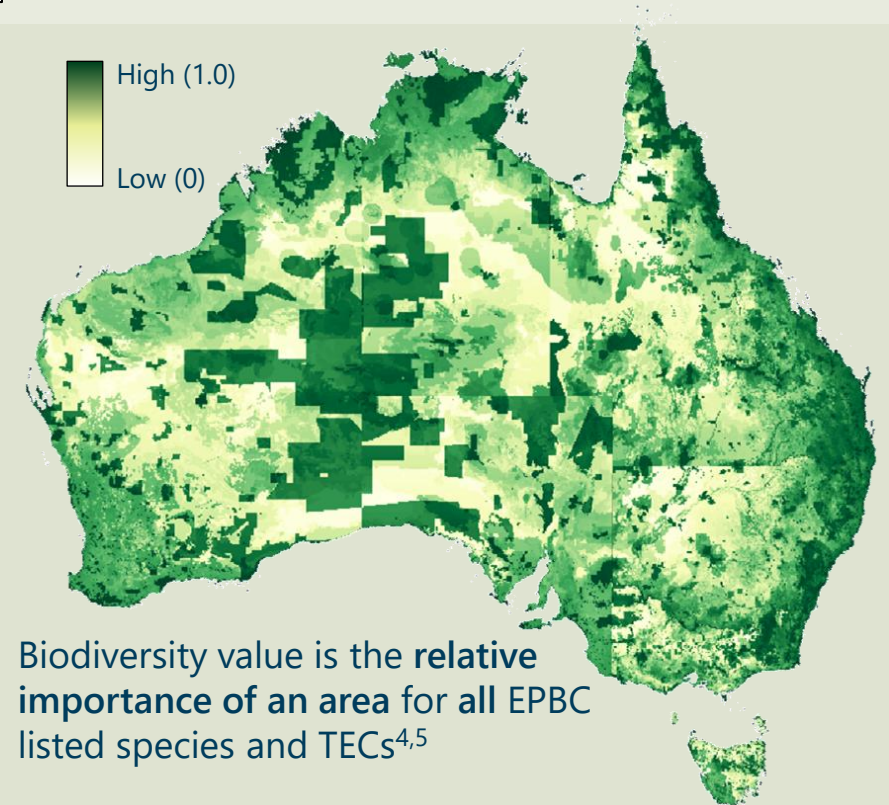
BAU conservation areas²



Priority Biodiversity Value areas³



Red areas denote existing protections including national parks and Indigenous Protected Areas.

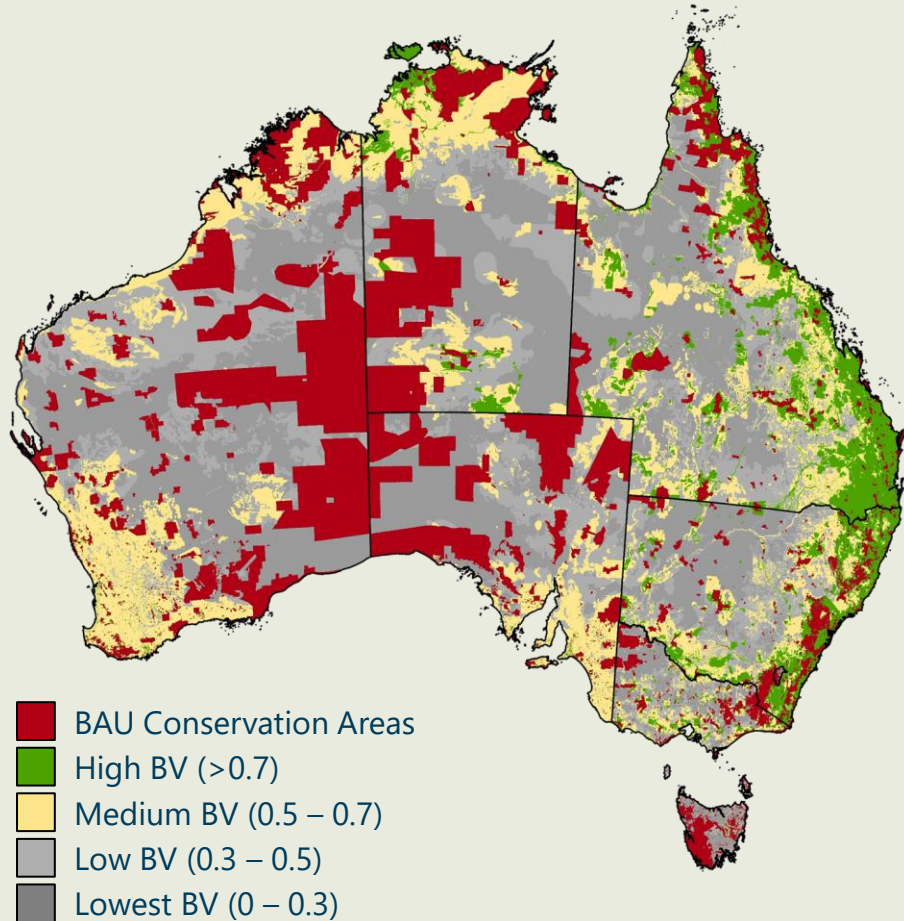


Biodiversity value is the **relative importance of an area** for all EPBC listed species and TECs^{4,5}

1. Matters of National Environmental Significance (MNES), Species of National Environmental Significance and Ecological Communities of National Environmental Significance.
2. Protected Areas Database (CAPAD), Ramsar wetlands, World Heritage Areas, and irreplaceable habitat for small- range, Critically Endangered species.
3. Developed using spatial conservation prioritisation software *Zonation 5*.
4. This approach considers the total number of species and proportion of each species range that occurs in each area. Existing (BAU) protected areas are classified high biodiversity value by default.

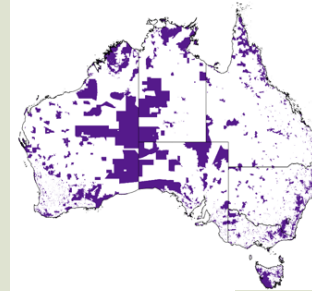
Biodiversity value maps are then used to develop four 'Avoidance Scenarios' for application to energy system modelling.

National biodiversity map, by value (BV)



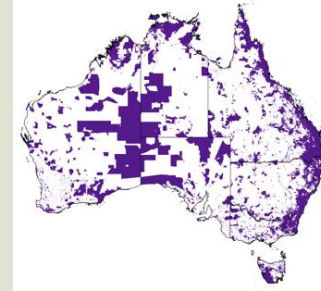
Avoidance Scenarios used in energy system planning

Scenario 1: BAU



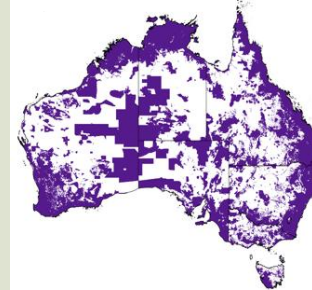
No additional exclusion: only existing conservation areas cannot be built on.

Scenario 2: Top 30%



Areas representing the top 30% of biodiversity value cannot be built on. (includes BAU)

Scenario 3: Top 50%



Areas representing the top 50% of biodiversity value cannot be built on. (includes BAU)

Scenario 4: Top 70%



Areas representing the top 70% of biodiversity value cannot be built on. (includes BAU)

Other exclusion layers constrain energy infrastructure development options.

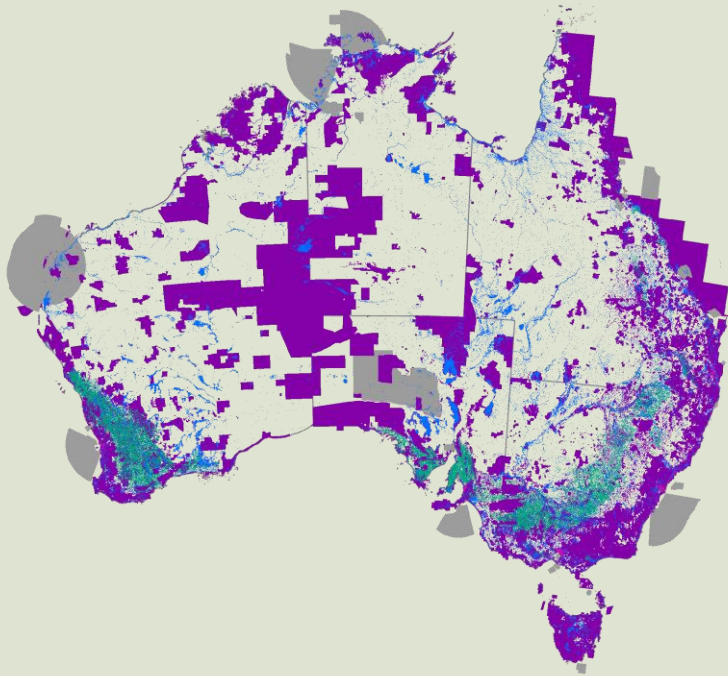
National energy maps present *cost-optimal options for solar and wind energy generation*, subject to biodiversity protection constraints (previous slide) and additional exclusions* (this slide).

Biodiversity 'Avoidance Scenarios'

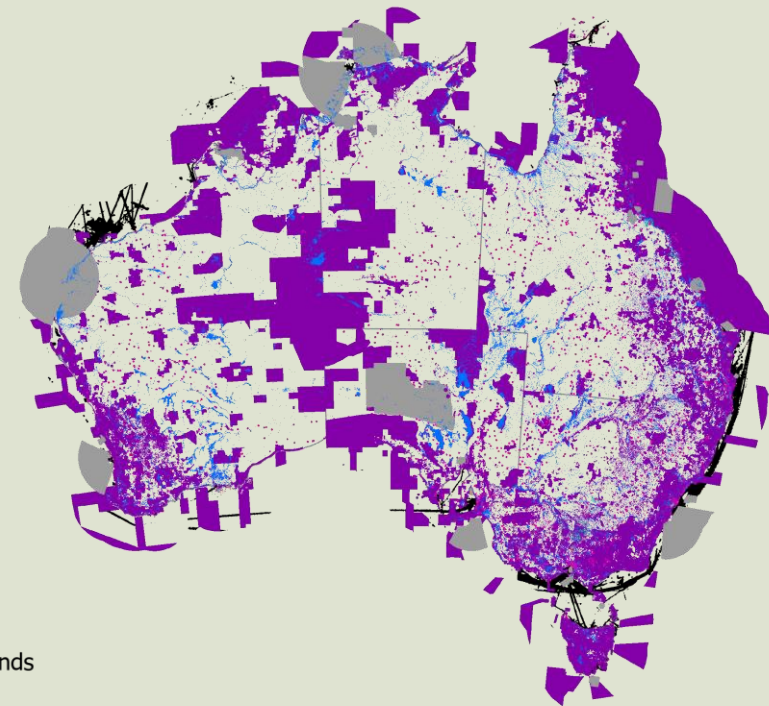


Additional exclusion layers

Additional solar exclusion layers



Additional wind exclusion layers



- Mining and shipping lanes
- Urban areas and transportation
- Water and wetlands
- Defence
- Protected areas and reserves
- Irrigated lands and rainfed croplands

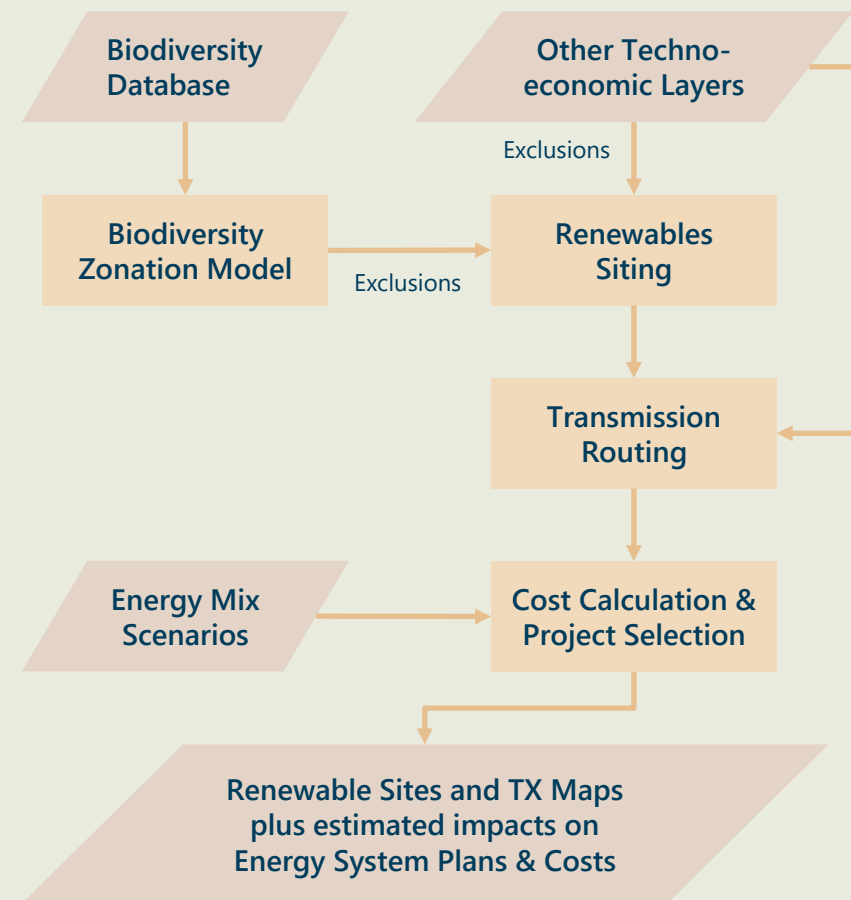
* See Section 12.8 titled 'Renewables supply curves' in our [NZAu Project Methods](#) Report.

Energy system planning methods*

Overview

- The NZAu Project's *Net Zero 2050 Scenario* sets the renewable capacities and features nearly full electrification by 2050. **It therefore should be our domestic Scenario with the most significant biodiversity impacts.**
- Our planning method selects least-cost combinations of renewables and transmission, by:
 - selecting renewable (VRE) sites using local solar and wind resource;
 - mapping **electricity** transmission (TX) by length;
 - integrating spatial constraints including biodiversity and other exclusions such as mines, communities, defence areas and existing infrastructure; and
 - can be extended to other systems and sub-systems, e.g. H₂ and CO₂ transmission.

Biodiversity-integrated energy system planning



* See Section 12.8 titled 'Renewables supply curves' in our [NZAu Project Methods](#) Report.

Energy system planning methods*

Land use for renewables and transmission

- The **Project Area** is the total land required by a renewable (utility solar or onshore wind) asset.
- The **Direct Footprint** is the area occupied by the infrastructure and therefore is most relevant to biodiversity impact assessment.

Solar PV	Wind	Transmission
• The area per solar PV asset presented in our maps is $\times 5$ the Project Area so that they are visible. • The Direct Footprint for solar PV is 91% of the Project Area*.	• The area per wind asset presented in our maps is equal to the Project Area. • The Direct Footprint for wind is 1% of the Project Area*.	• Easement widths range from 50m for 132 kV to 80m for 500kV transmission. • Existing transmission lengths are subtracted from modelled transmission lengths when presenting data on new builds and new build areas. • The Direct Footprint is the line length times the easement width*.

* See Section 12.8 titled 'Renewables supply curves' in our [NZAu Project Methods](#) Report.

Limitations of our methods*

Biodiversity protection methods

- ▶ Granularity of species and TEC mapping is sufficient for the current exercise of analysing options for VRE and transmission at a national-scale, but **requires refinement and updating for formal and fine-scale planning.**
- ▶ The scale of our analysis precludes exploration of species-specific and temporal impacts and mitigation measures. More granular mapping of habitats and species-specific analysis of impacts and mitigation options would likely identify additional area suitable for VRE and transmission that would not adversely impact biodiversity.
- ▶ Our methods do not yet fully represent the offset burden given limitations in data availability. A more complete treatment of offsets is required, and this is expected to support the case for integrated planning further.

Energy system modelling methods

- ▶ Our modelling only adds to *existing and committed generation and existing transmission***. Adding more committed or commenced builds would change our results, but should have a small impact on this Report's findings out to 2050.
- ▶ We have not yet conducted detailed technical assessment of energy system security and reliability. These are substantial tasks that should modify our current results, but which should also have a small impact on this Report's findings out to 2050.
- ▶ Our modelling assumes that current demand centres continue to grow whilst implementing aggressive energy productivity measures. These assumptions have several major impacts, particularly by reducing total capacity builds and forcing electrical transmission to industrial centres that may be unviable.

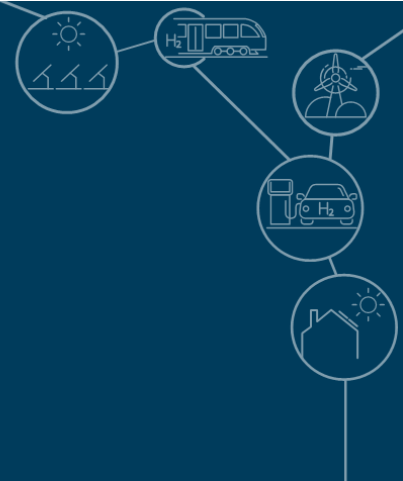
* All modelling is incomplete by definition. This slide therefore highlights what we consider are the main limitations of this Report's methods and is not intended to be exhaustive.

** These definitions and associated data are from [AEMO's 2025-26 Inputs, Assumptions and Scenarios \(IASR\) Report](#).



Return to
outline

3 Results summary



Summary of results

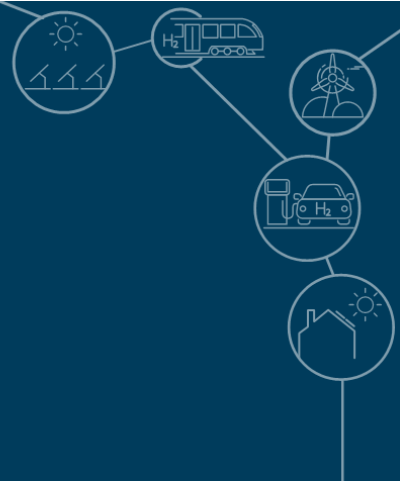
Biodiversity value mapping	• Current biodiversity protection differs by state in terms of area and efficiency. Some states with larger protected areas have relatively low biodiversity value protection under BAU. • Species tend to clump in high biodiversity richness areas, making it possible to conserve large proportions of priority species ranges with smaller but targeted additional area protections. • Avoiding development on lands with the top 30-50% of biodiversity value would protect 70-92% of EPBC species / TEC distributions nationally, compared with about 44% currently.
Impacts on energy system planning and costs	• We estimate that a net zero energy system in 2050 that avoids development on land with the top 30-50% of biodiversity value adds ~1% to electricity costs cf. BAU protection. • These economic impacts of biodiversity protection should be even smaller when we include the many other investments that must be made in any future energy system*.
Land use by net zero energy systems	• The projected average annual renewable and transmission build over 2025-2050 has a much smaller area than 1 average year of historic land clearing for all uses. Thus, the biodiversity impact of renewable and transmission build should be much smaller than that of other land uses. • Approximately 45% of the total investment in renewables and transmission is projected to occur on the Indigenous Estate in our NZ2050 Scenario, with numerous other investments and significant job creation also projected.

* A [recent Report](#) from the NZAu Project showed that the total cost of the energy system over 2025-2050 totals **several \$Tr irrespective of the decarbonisation trajectory**. This current Report finds that the total biodiversity-related costs of renewables and electricity transmission in a net zero future are ~10 \$B including biodiversity avoidance and offset payments.



Return to
outline

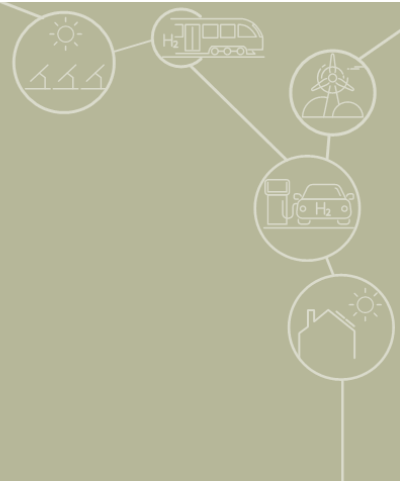
4 Results





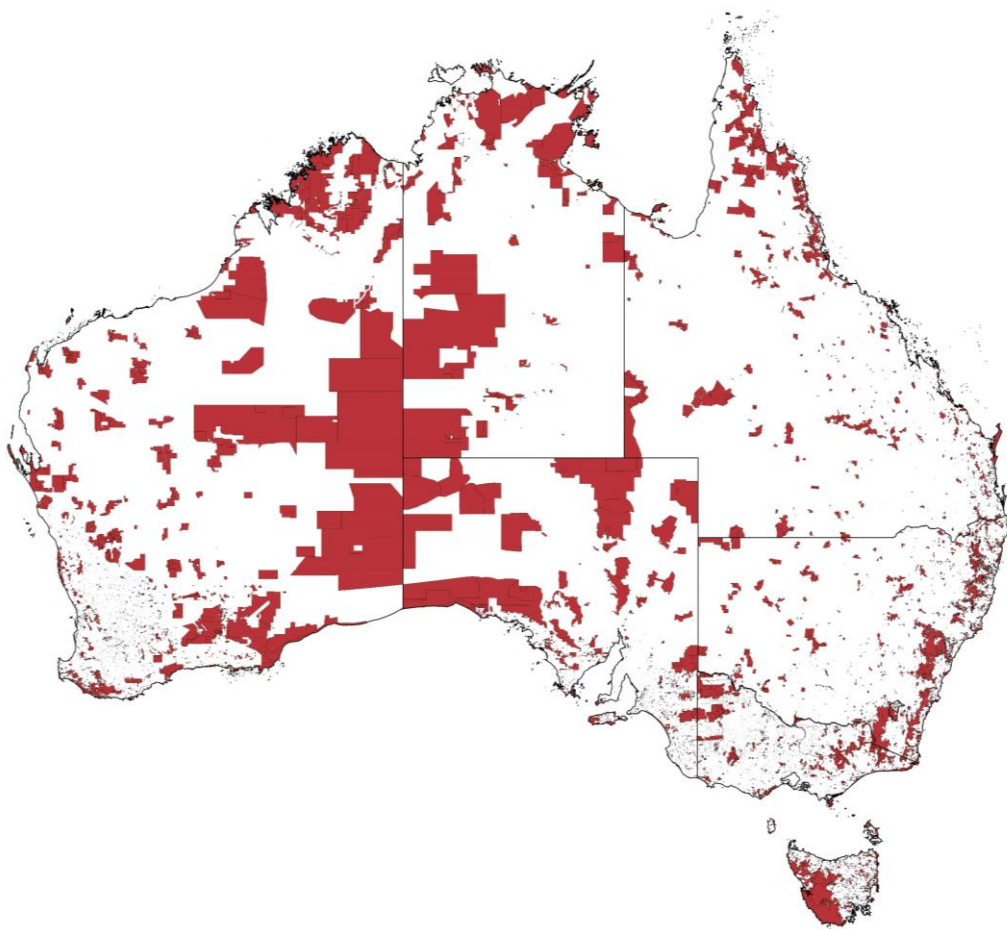
[Return to
outline](#)

4a Biodiversity value mapping



Current protection differs by state, with Tasmania protecting over 50% of the state already. But high area protection does not guarantee high biodiversity protection.

Current coverage (in red) of BAU conservation/protection/avoidance areas



Existing protected area coverage nationally and by state/territory
(% of total area)

Region	% of each state covered by BAU protected areas
AUST	22 %
ACT	72%
TAS	52 %
SA	32 %
WA	32 %
NT	25 %
VIC	22 %
NSW	13 %
QLD	10 %

- Total BAU protection area is not equal to biodiversity value protection because many states have large protected areas in places with relatively low *EPBC Act biodiversity value*.
- There is large variation across the states in both the extent of current protected areas and how well those protected areas protect threatened species.

Avoiding development on 30-50% of land area with the highest biodiversity value protects 70-92% of EPBC Act-listed species ranges across Australia.

Average percent of all EPBC-listed animal, plant, and ecological community *ranges* protected in each Avoidance Scenario, rounded to nearest %.

Avoidance Scenario	AUS	NSW	NT	QLD	SA	TAS	VIC	WA
BAU (% of state area already protected)	44% (22%)	53% (13%)	38% (25%)	39% (10%)	31% (32%)	56% (52%)	43% (22%)	41% (32%)
Top 30%	70%	93%	87%	94%	31%	56%	70%	41%
Top 50%	92%	97%	96%	98%	96%	56%	86%	99%
Top 70%	97%	99%	99%	99%	99%	93%	94%	99%

Avoiding development on land comprising the top 30% of biodiversity value increases national protection by $70\% - 44\% = 26\%$, relative to today.

Avoiding development on 50% of the land area with highest biodiversity value protects 92% of all species ranges nationally.

- The BAU results show significant current differences in biodiversity protection across states, alongside greater variation in the proportion of state areas currently protected.
- The heterogeneity in current protection and protected area fractions by state suggest that different states might contribute to a national objective differently.
- There is little national biodiversity benefit to increasing protection beyond the Top 50% of highest biodiversity value lands.
- Avoiding impacts on at least 30% of the nation is consistent with the Commonwealth's [30 by 30](#) national target.

Species tend to clump in high biodiversity richness areas, making it possible to conserve lots of species with relatively small additional area protections.

The number of threatened species/ECs entirely avoided in each exclusion scenario in each state (total number of EPBC listed species & ECs).

Avoidance Scenario (total species)	ACT (81)	NSW (756)	NT (148)	QLD (589)	SA (281)	TAS (199)	VIC (586)	WA (596)
BAU	17	105	10	20	10	19	46	54
Top 30%	17	597	101	489	10	19	243	54
Top 50%	17	682	130	539	245	19	343	564
Top 70%	17	715	134	562	267	135	403	585

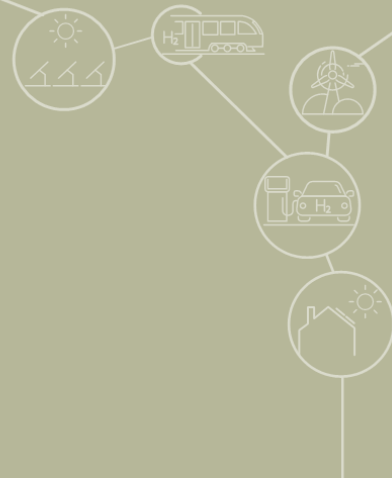
- Going from BAU to Top 30% of protection **entirely avoids** siting infrastructure on an **additional ~470 EPBC species in Queensland**, compared to only 20 that are protected today.
- **Similar trends exist for NSW**, which sees an additional ~492 species protected in the Top 30% Avoidance Scenario.
- Nationally, avoidance of the top 30%-50% areas leads to complete protection for 50%-90% of species and TECs.
- **Biodiversity value is 'clumped' in regions of high species richness**, making efficient conservation possible with relatively little extra area protection.



[Return to
outline](#)

4b

Estimated impacts of biodiversity protection on system planning and costs



Recap:

Previous results with limited biodiversity protection

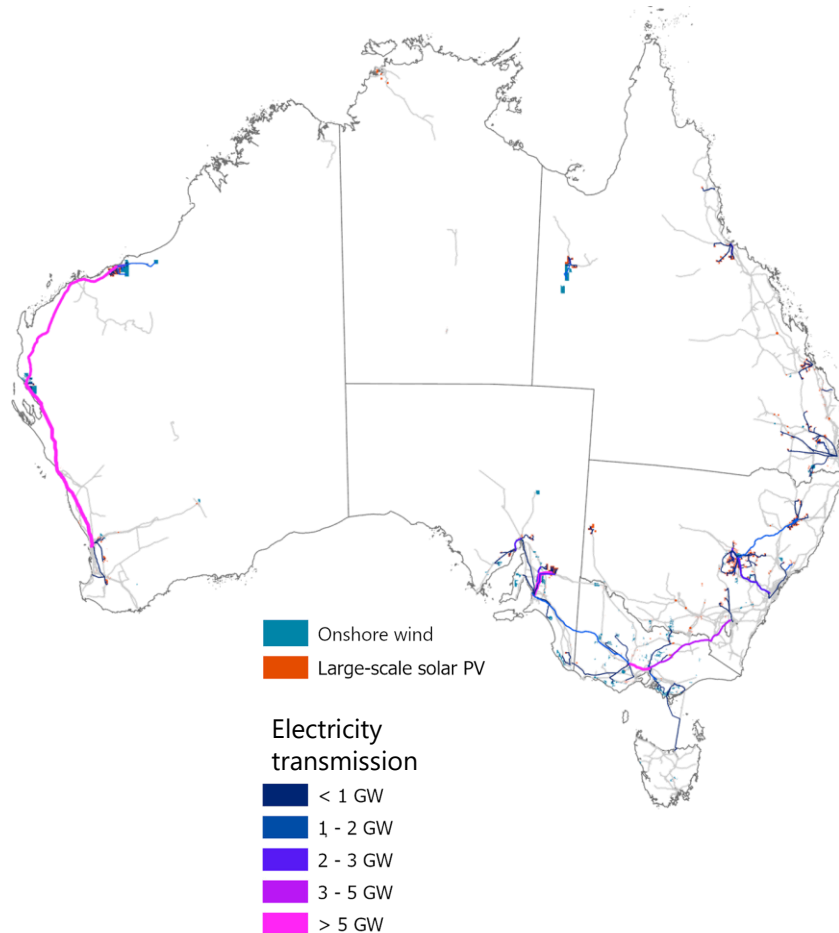
NZ2050: 2050

Note:

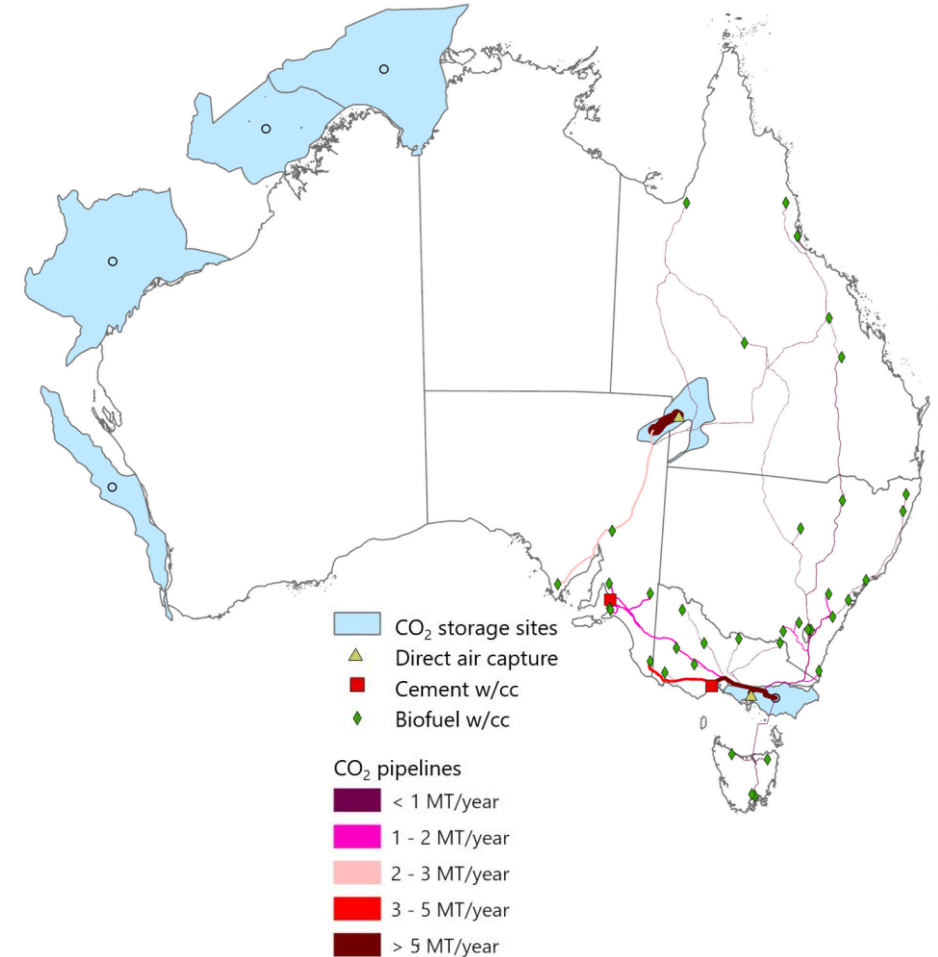
1. This map shows *indicative* investments in two networked systems – electricity and CO₂ – that are part of a modelled net zero energy system in 2050. There are also many other investments in a net zero energy system. These results were published recently but had a more limited treatment of biodiversity than this current Report.
2. This current Report uses our previous exclusions that are not related to biodiversity, i.e. candidate projects are still restricted from being built on: active mines; communities; inland water bodies; defence zones; transport infrastructure; existing energy infrastructure; irrigated areas; areas with a slope greater than 10 degrees; offshore shipping lanes; populated areas; and protected areas.

INDICATIVE ONLY

Electricity System



Carbon Dioxide (CO₂) System



- Whilst all investments have a biodiversity impact, renewables and electricity transmission should have the largest impact in a low emission energy system given their larger total direct footprint that includes renewable generation and wider transmission easements than the direct footprints of other commodities.
- The methods for protecting biodiversity in this Report can be extended to analyse these other investments.

BAU:

INDICATIVE ONLY

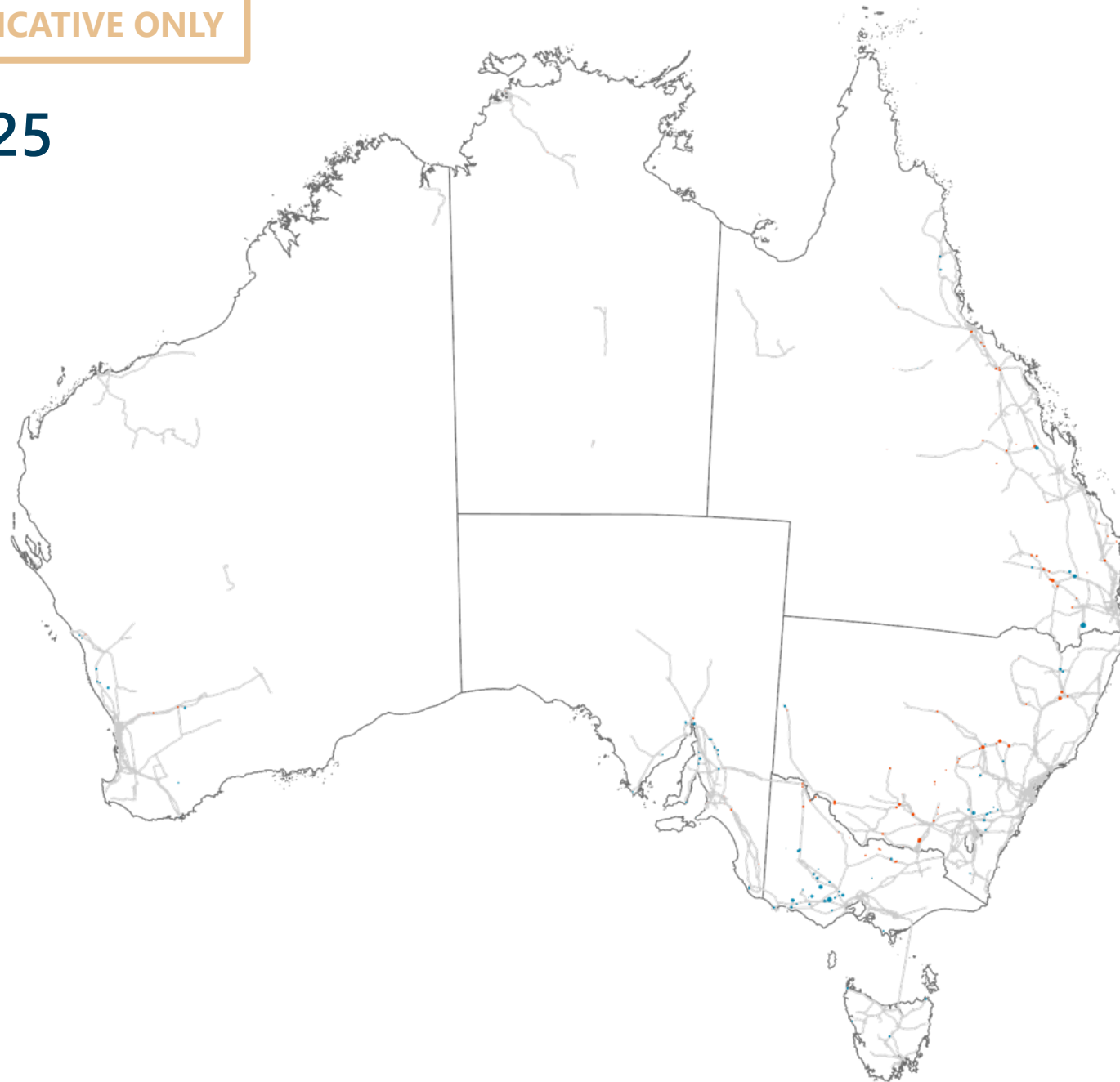
No additional biodiversity protection, other than protected areas

NZ2050: 2025

Note:

1. This map shows the total investments in renewable and electrical transmission infrastructure in 2025.
2. These renewable capacities are slightly lower than those reported recently, which also supplied energy directly to green hydrogen transmission.

2025



Onshore wind
Large-scale solar PV

Electricity transmission

< 1 GW
1 - 2 GW
2 - 3 GW
3 - 5 GW
> 5 GW

BAU:

No additional biodiversity protection, other than protected areas

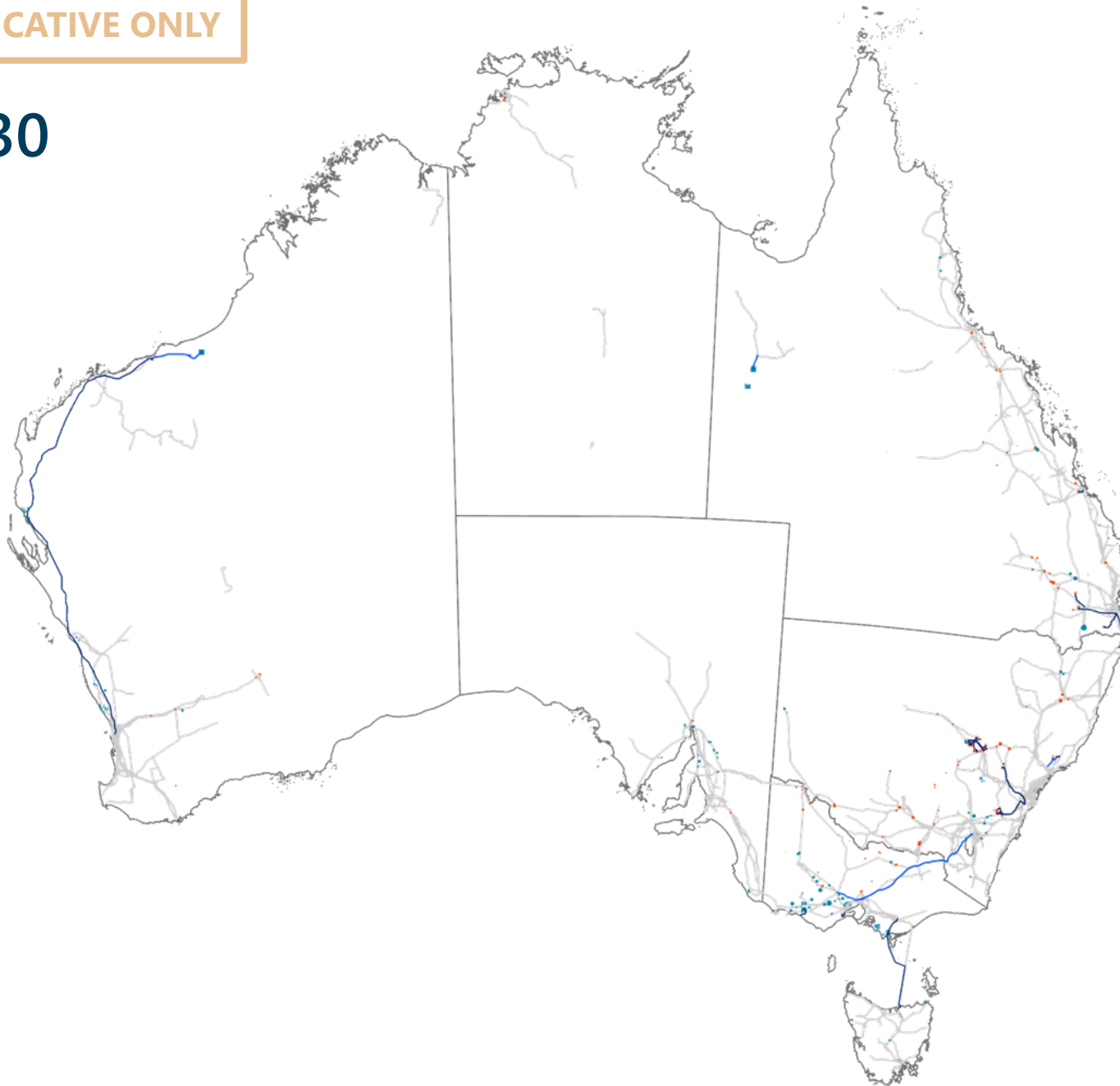
NZ2050: 2030

Note:

1. This map shows indicative investments in renewable and electrical transmission infrastructure that are part of a modelled net zero energy system in 2050 under this Report's BAU biodiversity impact avoidance scenario. Note: the tabulated capacities are renewable builds since 2025.
2. These renewable capacities are slightly lower than those reported recently, which also supplied energy directly to green hydrogen transmission.

INDICATIVE ONLY

2030



National

18 GW solar
9 GW wind

Onshore wind
Large-scale solar PV

Electricity transmission

< 1 GW
1 - 2 GW
2 - 3 GW
3 - 5 GW
> 5 GW

BAU:

No additional biodiversity protection, other than protected areas

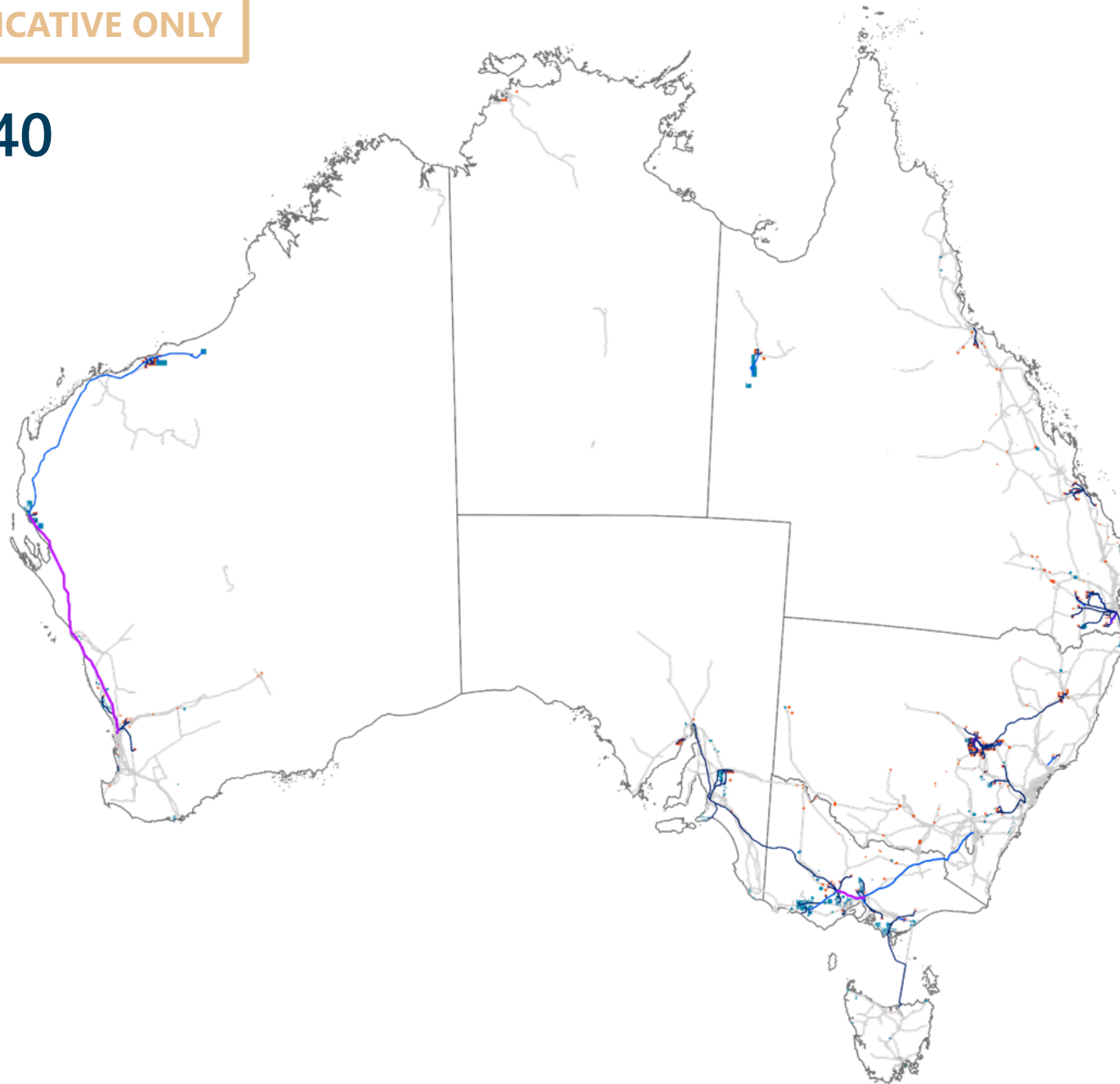
NZ2050: 2040

Note:

1. This map shows indicative investments in renewable and electrical transmission infrastructure that are part of a modelled net zero energy system in 2050 under this Report's BAU biodiversity impact avoidance scenario. Note: the tabulated capacities are renewable builds since 2025.
2. These renewable capacities are slightly lower than those reported recently, which also supplied energy directly to green hydrogen transmission.

INDICATIVE ONLY

2040



National

106 GW solar
28 GW wind

Onshore wind
Large-scale solar PV

Electricity transmission

< 1 GW
1 - 2 GW
2 - 3 GW
3 - 5 GW
> 5 GW

BAU:

No additional biodiversity protection, other than protected areas

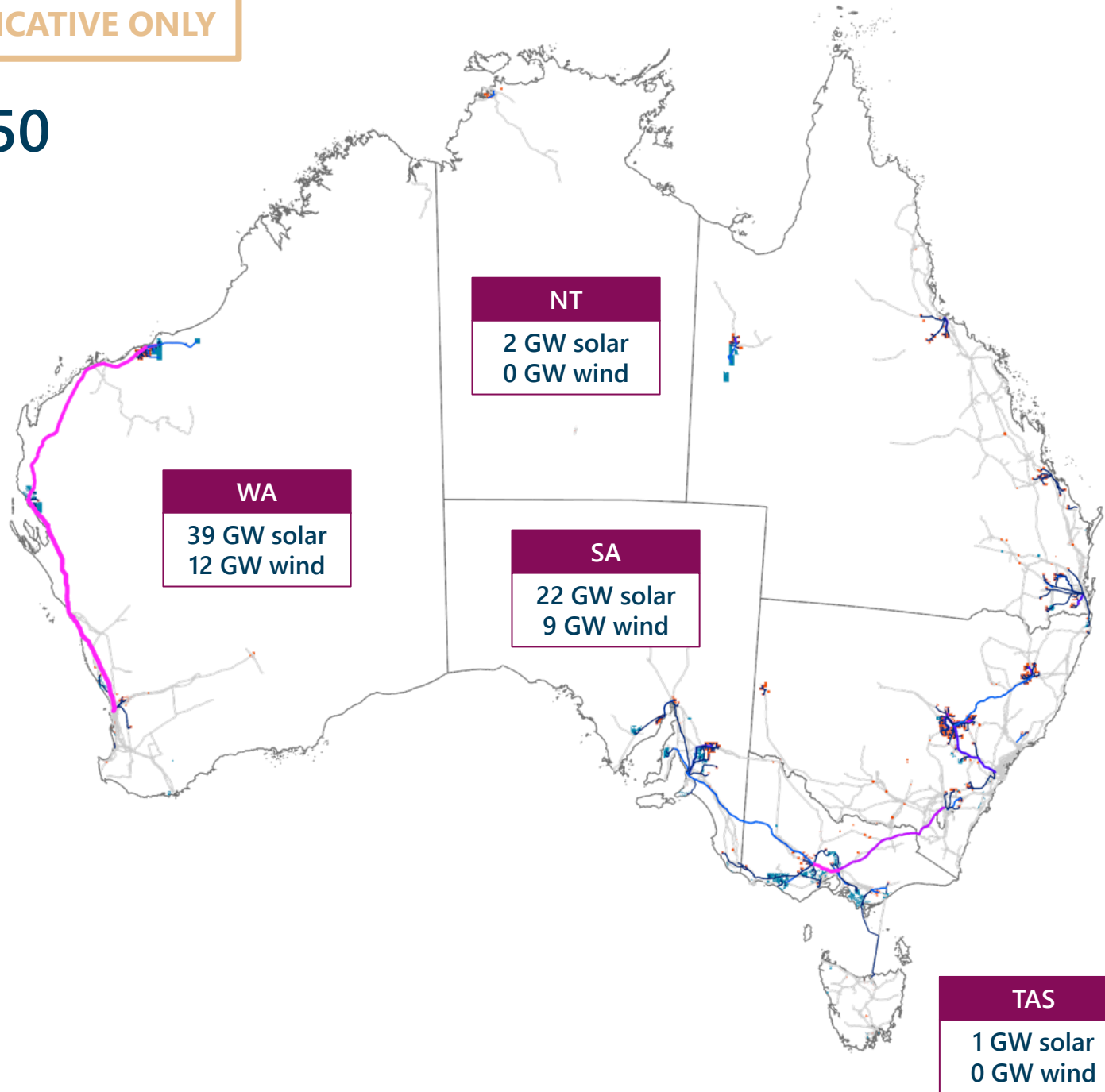
NZ2050: 2050

Note:

1. This map shows indicative investments in renewable and electrical transmission infrastructure that are part of a modelled net zero energy system in 2050 under this Report's BAU biodiversity impact avoidance scenario. Note: the tabulated capacities are renewable builds since 2025.
2. These renewable capacities are slightly lower than those reported recently, which also supplied energy directly to green hydrogen transmission.

INDICATIVE ONLY

2050



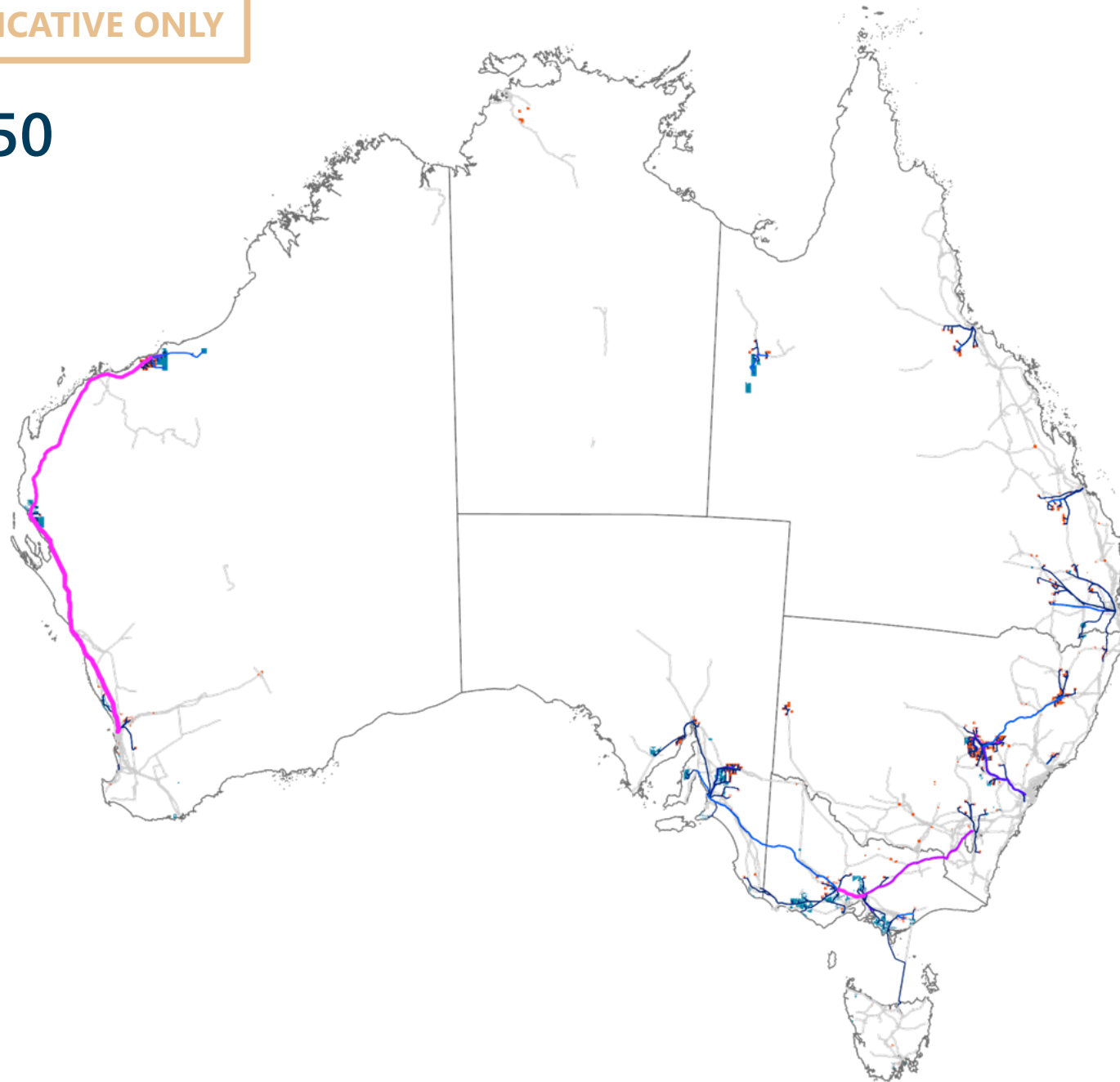
30% Protection:

Protecting the top 30% of the land, ranked by biodiversity value.

NZ2050: 2050

INDICATIVE ONLY

2050



National

203 GW solar
43 GW wind

Onshore wind
Large-scale solar PV

Electricity transmission

< 1 GW
1 - 2 GW
2 - 3 GW
3 - 5 GW
> 5 GW

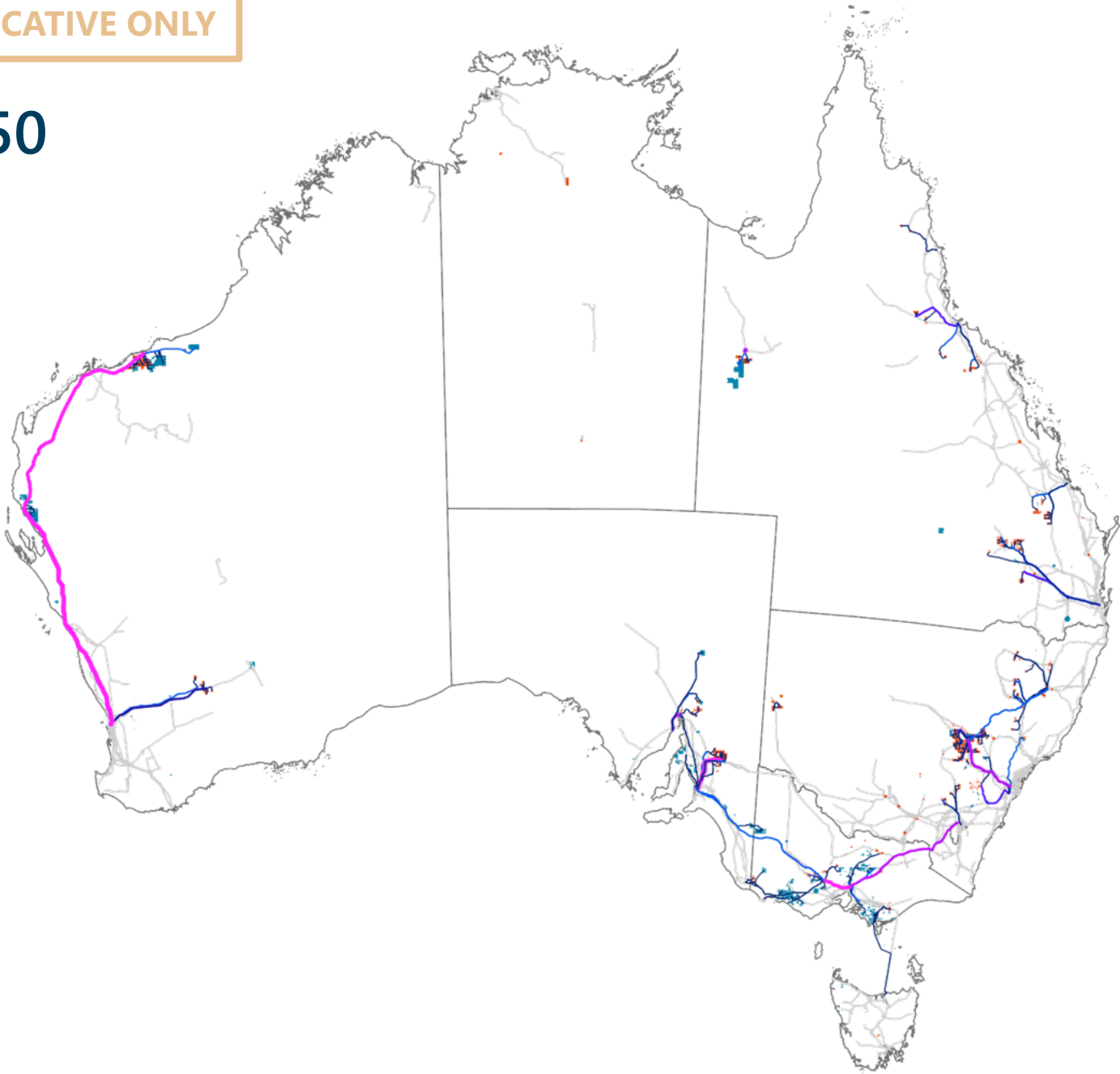
50% Protection:

Protecting the top 50% of the land, ranked by biodiversity value.

NZ2050: 2050

INDICATIVE ONLY

2050



National
203 GW solar
43 GW wind

- Onshore wind
- Large-scale solar PV

Electricity transmission

- < 1 GW
- 1 - 2 GW
- 2 - 3 GW
- 3 - 5 GW
- > 5 GW

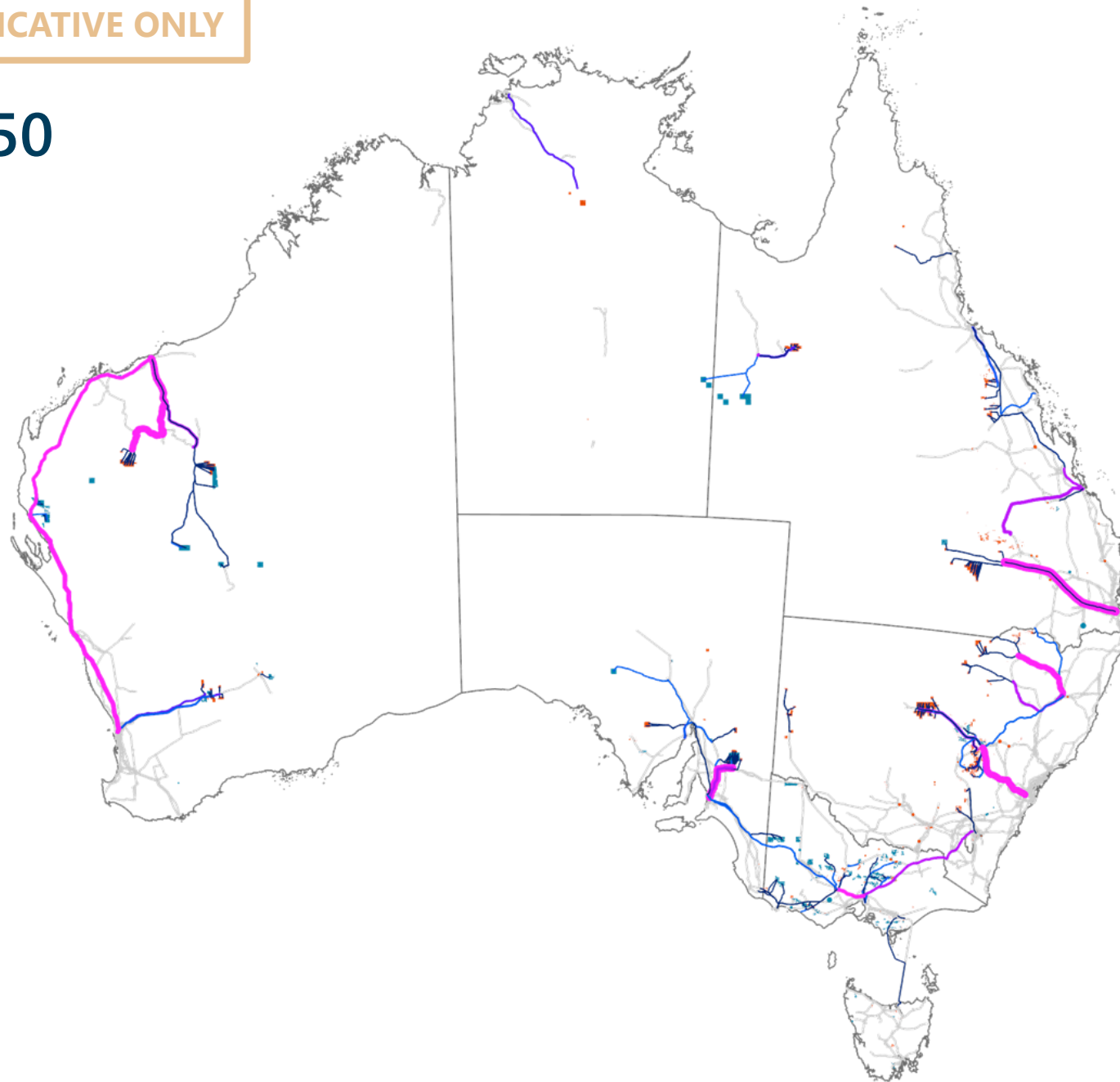
70% Protection:

Protecting the top 70% of the land, ranked by biodiversity value.

NZ2050: 2050

INDICATIVE ONLY

2050



National

203 GW solar
43 GW wind

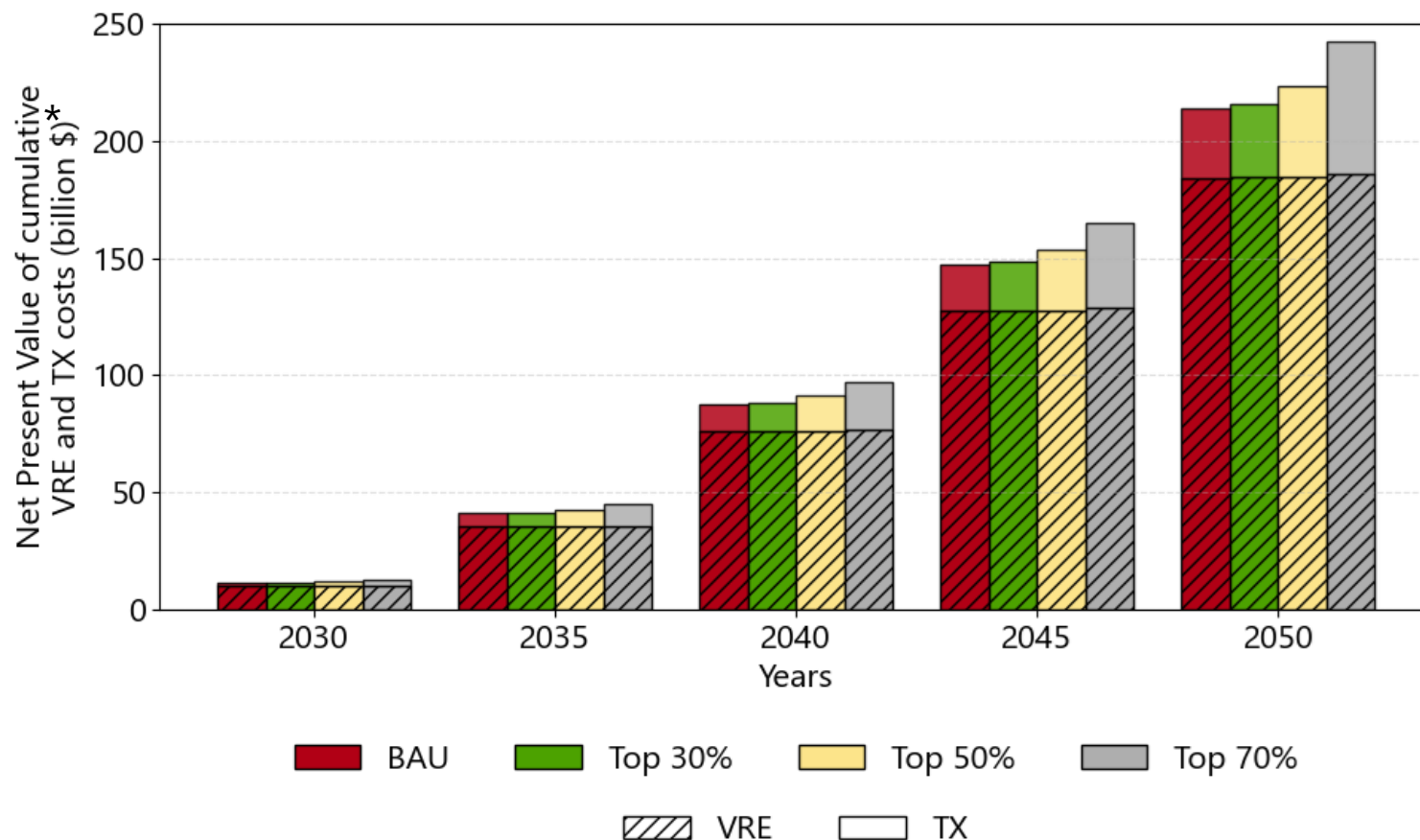
Onshore wind
Large-scale solar PV

Electricity transmission

< 1 GW
1 - 2 GW
2 - 3 GW
3 - 5 GW
> 5 GW

Avoiding development on land with the top 30-50% of biodiversity value has small impacts on renewable and transmission capital investment.

Net present value of cumulative renewable (VRE) and transmission (TX) costs* for increasing levels of biodiversity protection (AUD \$2025B)



* The cumulative VRE and TX costs are discounted at a social discount rate of 2.7%.

- Avoiding development on land representing the **top 30%-50%** of biodiversity areas gives high levels of biodiversity protection (see previous slides) whilst also accommodating other land uses.
- Avoiding development on the top 30%-50% of lands has a minor impact on energy system investments because:
 - the capacity factor compromises that arise from siting renewables in lower biodiversity value areas are small; and
 - transmission costs remain smaller than renewables costs, even as transmission builds increase.

Avoiding development on land with the top 30-50% of biodiversity value increases electricity costs by ~1%.

Impact on retail electricity costs in a net zero, 2050 world for increasing levels of biodiversity value protection.

		BAU	Top 30	Top 50	Top 70
Cost components:					
Wholesale electricity cost	\$/MWh	131	131	131	132
Transmission (TX) network cost	\$/MWh	38	39	41	49
Distribution network (DN) cost	\$/MWh	90	90	90	90
Industrial DN cost	\$/MWh	55	55	55	55

Industrial	\$/MWh	224	225	227	236
Increase relative to BAU %	%		0%	1%	5%

Residential	\$/MWh	259	260	262	271
Increase relative to BAU %	%		0%	1%	5%

Industrial electricity cost = wholesale cost + TX cost + industrial DN cost

Residential electricity cost = wholesale electricity cost + TX cost + DN cost

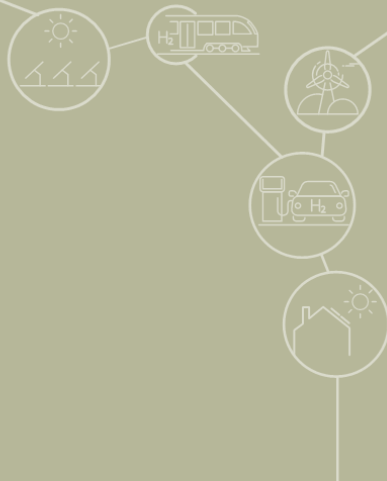
- The cost of integrating biodiversity protection into the energy system planning task is small.
- Indeed, ~1% increases in costs are much smaller than the economic uncertainty of the net zero task.
- Cost increases are more significant for 70% biodiversity protection. This is because projects are deployed in more remote regions, requiring more transmission infrastructure. However, 70% protection offers little extra biodiversity conservation value cf. 50% protection, as noted earlier.



Return to
outline

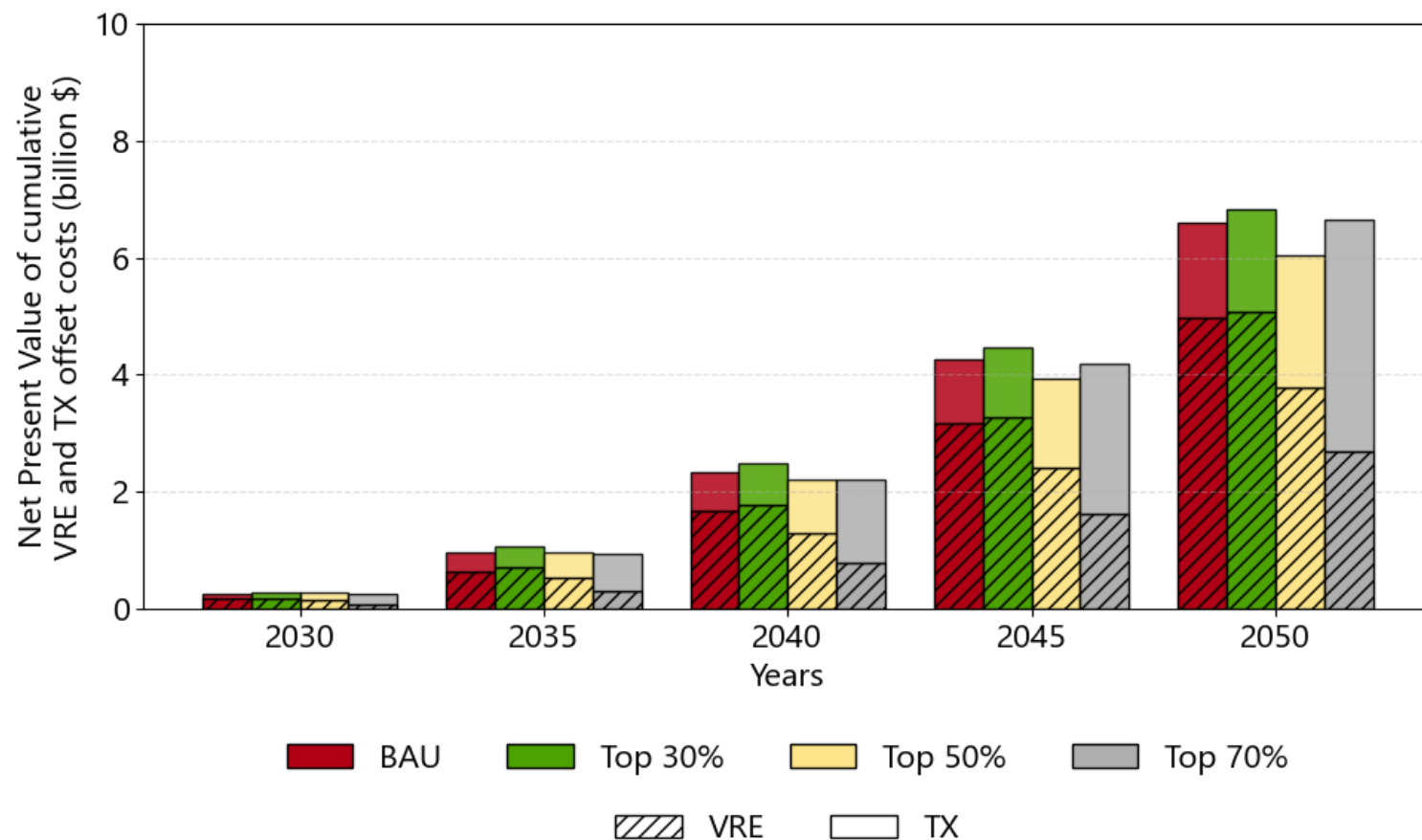
4c

Estimated impacts of biodiversity offsets



Estimating biodiversity offset costs under different avoidance scenarios*.

Total estimated offset costs within renewable (VRE) project areas and transmission (TX) easement areas over 2025-2050 (AUD \$2025B)

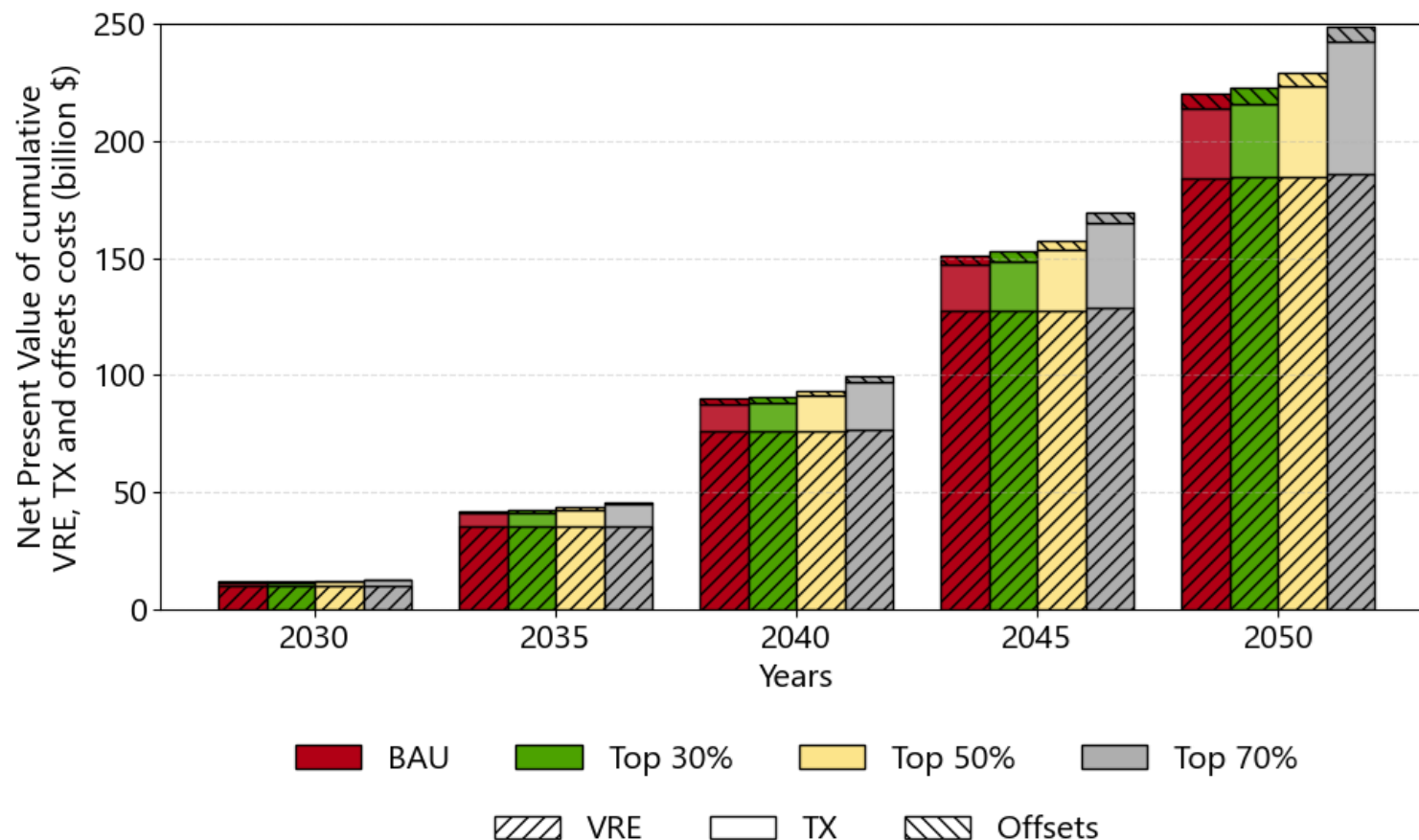


* See the Appendix for our calculation method, noting the paucity of reported offset costs from different projects, our preliminary methods and therefore the need to undertake further analysis on this matter.

- Whilst avoiding builds on higher biodiversity value areas reduces overall biodiversity impacts, there are still biodiversity impacts from builds outside these areas. We therefore also estimate the cost of biodiversity offsets associated with build outside of the avoidance area.
- Offset costs for solar and wind projects generally decrease with increasing biodiversity avoidance, while offset costs for transmission increase because longer lines to more remote renewable projects have larger easement areas.
- Offset costs could be reduced further by using mitigation measures (e.g. smart curtailment) and more granular biodiversity maps.

Offset costs are estimated to be a small part of total renewable and transmission costs, and so have a proportionally smaller impact on delivered electricity costs.

Net present value of cumulative renewable (VRE), transmission (TX) and TEC offset costs* for increasing levels of biodiversity protection (AUD \$2025B)



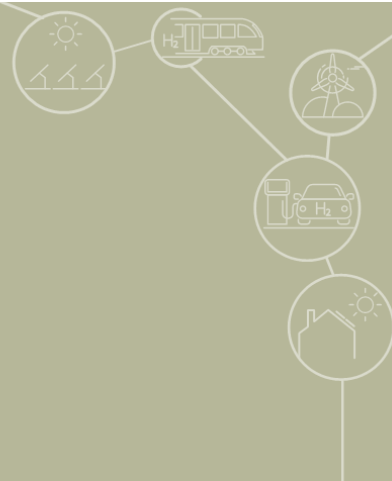
* All costs are discounted at a social discount rate of 2.7%.

- Offset costs are estimated to be <4% of total renewables and transmission investment by 2050 across all biodiversity avoidance scenarios.
- These **additional** costs of purchasing biodiversity offsets *outside* of the higher biodiversity protected areas are estimated to have a small impact on the total costs of renewables and transmission.
- This should result in an even smaller impact on delivered electricity costs given the many other investments in a complete electricity system.
- However, further analysis is required to quantify all offset costs more rigorously.



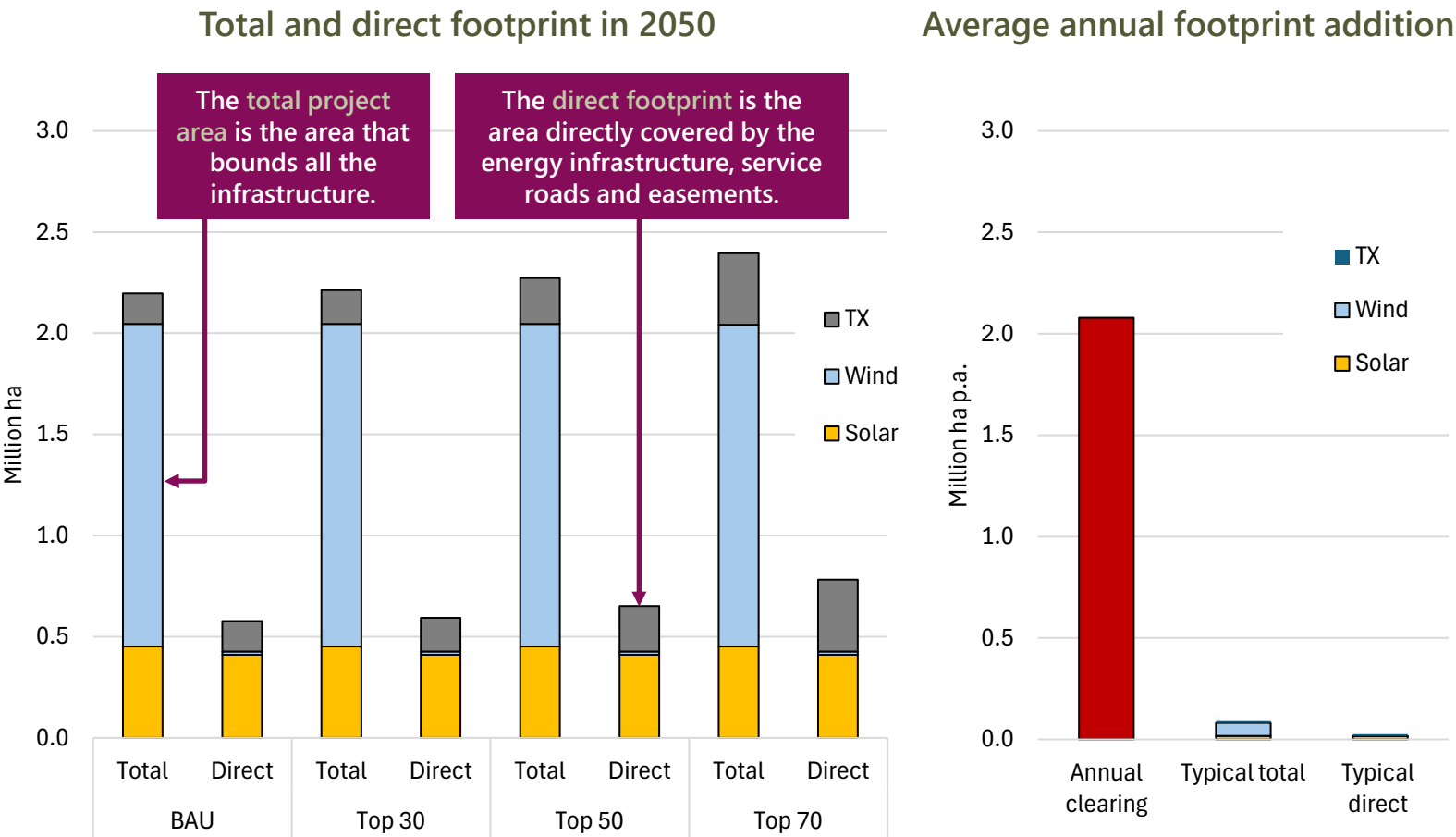
[Return to
outline](#)

4d Comparing renewable energy land use to other land uses



The total project areas and direct footprints of renewables and transmission by 2050 are small compared to other forms of land use.

Total and direct footprint of utility solar, wind, and transmission from 2025-2050 relative to national average annual land clearing over 1990-2022*.



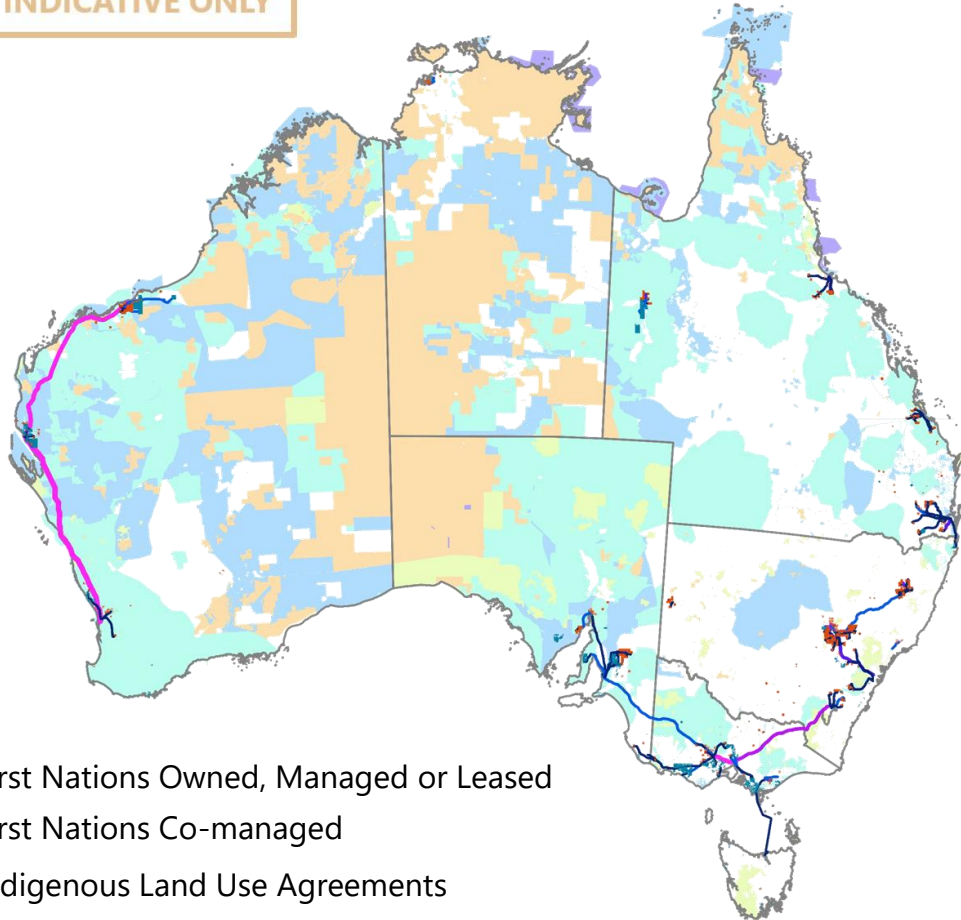
- The **total project area** for renewables and transmission build over 2025-2050 is ~2.0 million ha in our NZ2050 Scenario, whilst their **direct footprints** sum to ~0.5 million ha.
- Over 2025-2050, these total project area additions p.a. and direct footprint additions p.a. are **much smaller than historical annual land clearing rates**.
- The biodiversity impact of renewables and transmission during the transition towards net zero emissions should therefore be much smaller than that of other land uses.

* Historic annual clearing of forest and woody cover over 1990–2022. Source: DCCEEW, Australia's National Greenhouse Accounts 2023, LULUCF Activity Tables 1a and 5, 1990-2023

Projected builds on the Indigenous Estate over 2025-2050.

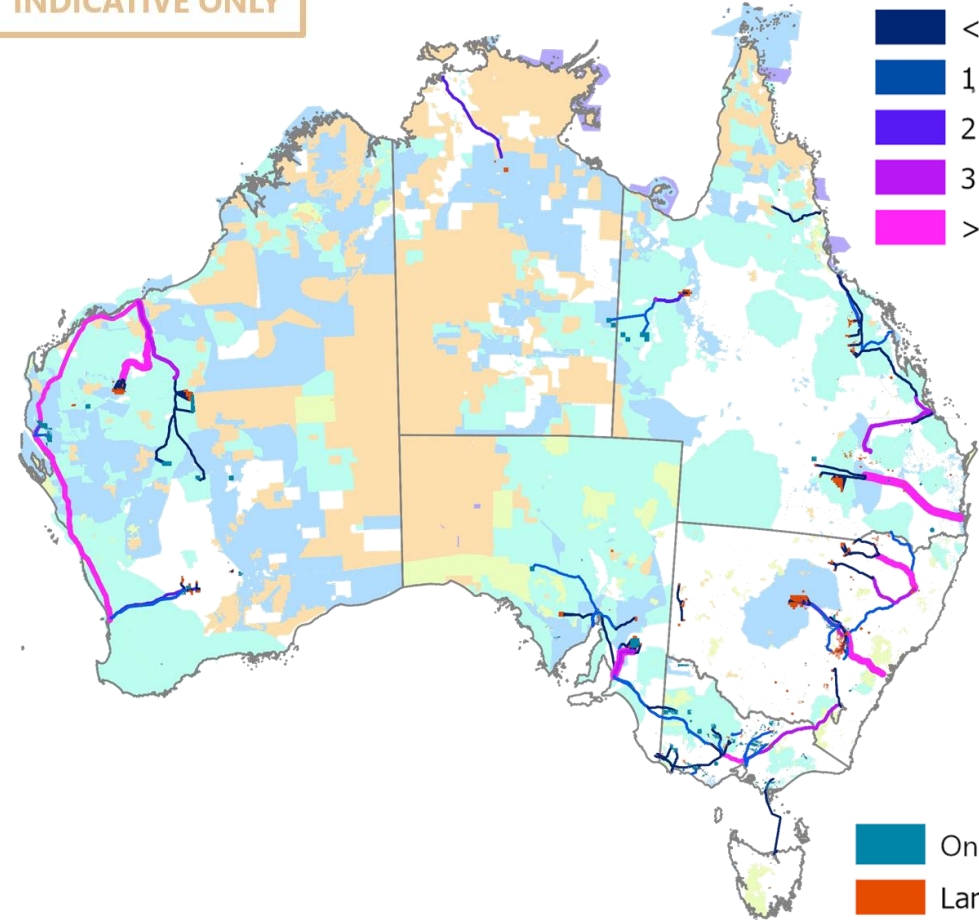
BAU biodiversity protection

INDICATIVE ONLY

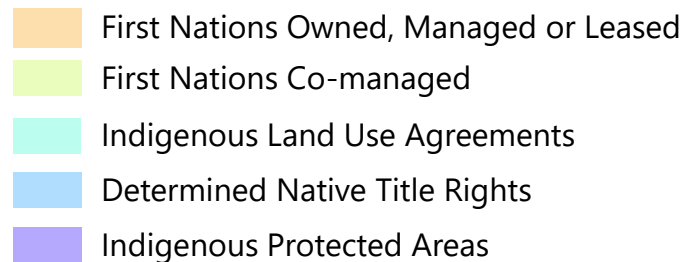
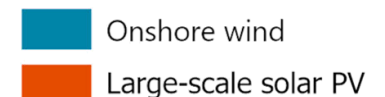
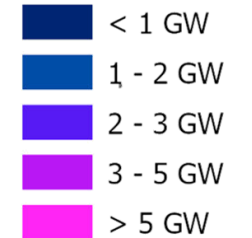


Top 70% biodiversity protection

INDICATIVE ONLY

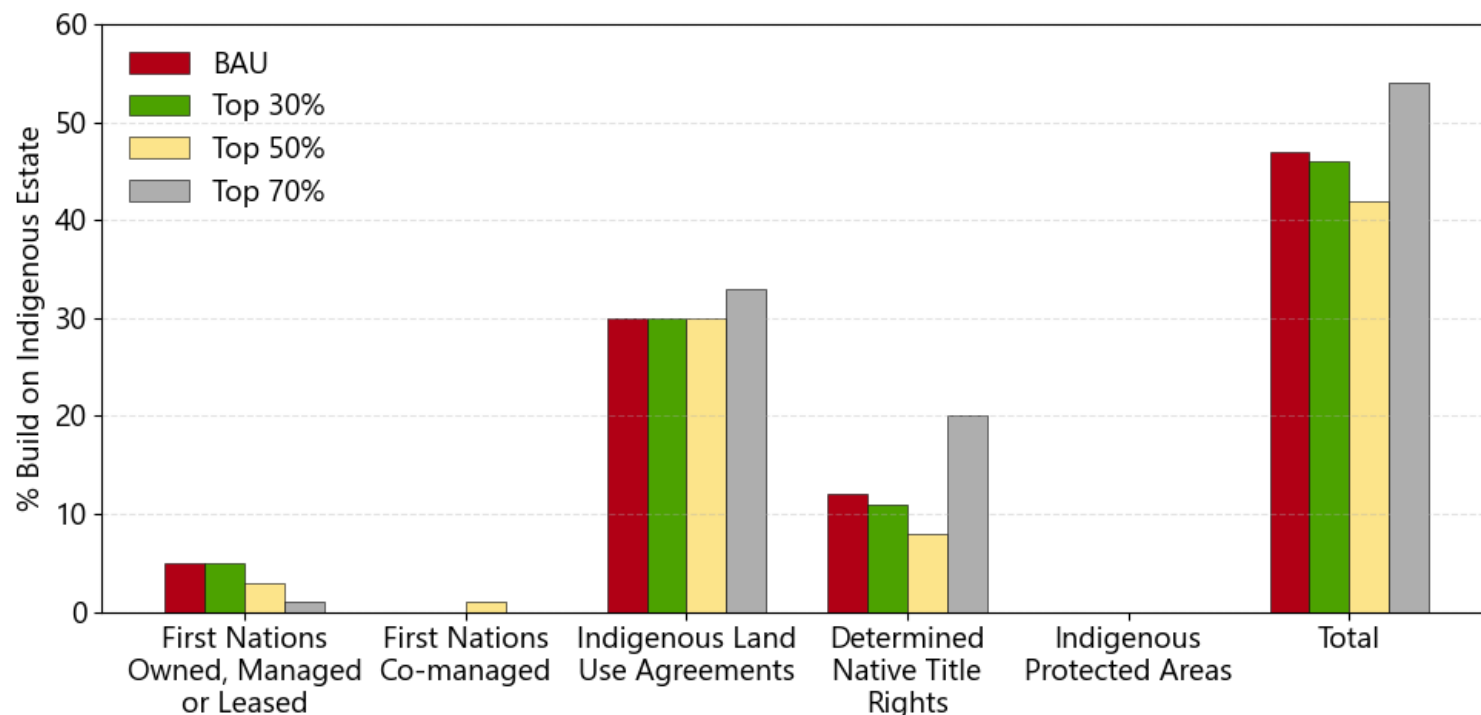


Electricity transmission



Investment in renewables and transmission on the Indigenous Estate is ~45% of these total investments over 2025-2050.

Proportion of cumulative capital investment in renewables (VRE) and transmission (TX) made on the Indigenous Estate* over 2025-2050 in our NZ2050 Scenario.



* Sources: 'First Nations Owned, Managed or Leased' data and 'First Nations Co-managed' data are from ABARES (2024); 'Indigenous Land Use Agreements' and 'Determined Native Title Rights' are from the NNTT (2025), and the 'Indigenous Protected Areas' are from DCCEEW (2026).

- Using results from previous slides, these estimates infer the following scales of renewable and transmission investment on the Indigenous Estate over 2025-2050:

Total = ~95-100 \$B

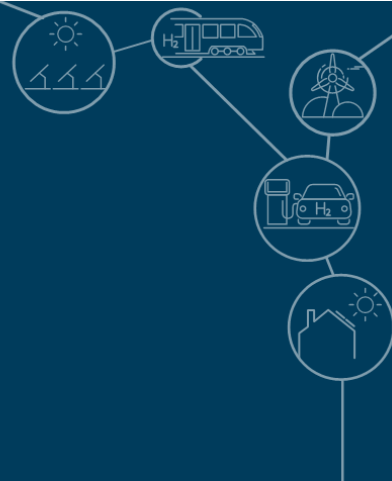
Average = ~4 \$B p.a.

- There are also other investments and benefits that this Report doesn't consider, but which we have quantified in our last 2 reports, e.g.
 - [investments](#) in energy storage, other forms of firming, biofuels, H₂ and CO₂ networks, CCS, etc.
 - [associated](#) creation of new jobs, which our last report estimated to be ~100k by 2050.



Return to
outline

5 Implications of results



Summary of results

Biodiversity value mapping	• Current biodiversity protection differs by state in terms of area and efficiency. Some states with larger protected areas have relatively low biodiversity value protection under BAU. • Species tend to clump in high biodiversity richness areas, making it possible to conserve large proportions of priority species ranges with smaller but targeted additional area protections. • Avoiding development on lands with the top 30-50% of biodiversity value would protect 70-92% of EPBC species / TEC distributions nationally, compared with about 44% currently.
Impacts on energy system planning and costs	• We estimate that a net zero energy system in 2050 that avoids development on land with the top 30-50% of biodiversity value adds ~1% to electricity costs cf. BAU protection. • These economic impacts of biodiversity protection should be even smaller when we include the many other investments that must be made in any future energy system*.
Land use by net zero energy systems	• The average annual renewable and transmission build over 2025-2050 in our NZ2050 Scenario has a much smaller area than 1 average year of historic land clearing for other uses. This means that their biodiversity impact should be much smaller than that of other land uses. • Approximately 45% of the total investment in renewables and transmission is projected to occur on the Indigenous Estate in our NZ2050 Scenario, with numerous other investments and significant job creation also projected.

* A [recent Report](#) from the NZAu Project showed that the total cost of the energy system over 2025-2050 totals **several \$Tr irrespective of the decarbonisation trajectory**. This current Report finds that the total biodiversity-related costs of renewables and electricity transmission in a net zero future are ~10 \$B including biodiversity avoidance and offset payments.

Summary of results

What *does* this Report say?

- ▶ Integrating biodiversity protection into the energy system planning task is possible, with protection on 30-50% of highest biodiversity value lands likely having a very small impact on electricity costs as we transition towards a net zero emission energy system, i.e. one with hundreds of GW of renewables and supporting transmission.
- ▶ The biodiversity impact of renewables and electricity transmission during this transition should be much smaller than that of other land uses.
- ▶ Integrating biodiversity protection into energy system planning at the scale of the net zero task **may also help reduce uncertainty, speed up approvals, and reduce costs.**

What *doesn't* this Report say?

- ▶ It *doesn't* comment on any specific current or future project. Real projects have long and complex development times, our mapping is only indicative, and the methods in this Report are insufficiently resolved for local assessments to the required standards.
- ▶ It *doesn't* say that builds cannot occur in higher biodiversity value areas. However, this requires very careful placement and appropriate mitigation measures.
- ▶ It *doesn't* find that current transmission projects and planning out to ~2030-2035 are inadequate. Indeed, [our previous Report](#) (slide 35) found that the sum of current transmission projects align with the 2050, net zero task.
- ▶ This report *doesn't* comment on the biodiversity impact of a potential, clean energy export system. This impact could be much larger than that of our domestic system and will be considered later in the NZAu Project.

Implications of results

Biodiversity value mapping

Results

- Current biodiversity protection differs by state in terms of area and efficiency. Some states with larger protected areas have relatively low biodiversity value protection under BAU.
- Species tend to clump in high biodiversity richness areas, making it possible to conserve large proportions of priority species ranges with smaller but targeted additional area protections.
- Avoiding development on lands with the top 30-50% of biodiversity value would protect 70-92% of EPBC species / TEC distributions nationally, compared with about 44% currently.

Impacts on energy system planning and costs

Land use by net zero energy systems

Implications

1. **Strategic planning is required to minimise the impacts on high biodiversity value areas.** This includes a consistent treatment of biodiversity protection across state borders.
2. Our scenarios required biodiversity avoidance targets (e.g. 30% or 50% avoidance) be achieved in each state. **A national analysis that is blind to state borders may give slightly different results** whilst also being consistent with Commonwealth efforts, e.g. the '30 by 30' national target.
3. The **lack of granularity in biodiversity data limits energy system planning.** Better maps of irreplaceable habitat for threatened species should reveal more areas suitable for renewable and transmission siting closer to cities and other, larger load centres.

Implications of results

Biodiversity value mapping

Impacts on energy system planning and costs

Land use by net zero energy systems

Results

- We estimate that a net zero energy system in 2050 that avoids development on land with the top 30-50% of biodiversity value adds ~1% to electricity costs cf. BAU protection.
- These economic impacts of biodiversity protection should be even smaller when we include the many other investments that must be made in any future energy system.

Implications

1. Enhancing biodiversity protection on the **top 30-50% of lands should have a very small impact on electricity costs**. This should be the case when biodiversity offsets are also included.
2. Avoiding builds on higher biodiversity value land **could also increase build rates by reducing approval times**; an objective of the recent EPBC Act reforms that addresses a key constraint on decarbonisation*. This could **reduce uncertainty, increase the pace of decarbonisation and reduce costs****.
3. These results also suggest **opportunities for realising other benefits**, such as:
 - benefit-sharing with Indigenous communities;
 - accommodating reasonable local concerns; and
 - siting of infrastructure for new industries and nearer existing workforce.

* 'Design and approval' times are currently the major contributors to wind and utility solar project development times. See slides 28-29 in [Topical Report #2](#) from the NZAu Project.

** This Report hasn't quantified these potential benefits.

Implications of results

Biodiversity value mapping

Impacts on energy system planning and costs

Land use by net zero energy systems

Results

- The average annual renewable and transmission build over 2025-2050 in our NZ2050 Scenario is much smaller than 1 average year of historic land clearing. This means that the biodiversity impact of renewables and transmission should be much smaller than that of other land uses.
- Approximately 45% of the total investment in renewables and transmission is projected to occur on the Indigenous Estate in our NZ2050 Scenario, with numerous other investments and significant job creation also projected.

Implications

1. Whilst land use and clearing for renewables and transmission are important considerations as we decarbonise our domestic energy system, historical data suggests that **other forms of land use and land clearing are likely to have much more significant biodiversity impacts** over this period.
2. The significant proportion of renewable and transmission build on the Indigenous Estate also demonstrates **the importance of protecting cultural heritage** as well as the environment.
3. Renewable energy exports, if they eventuate, will likely use significantly more land than the domestic system. They are therefore likely to challenge biodiversity protection and land use much more. **The planning task for a potential clean energy export system is therefore expected to be very important.**

Thank you

For more information, visit
netzeroaustralia.net.au



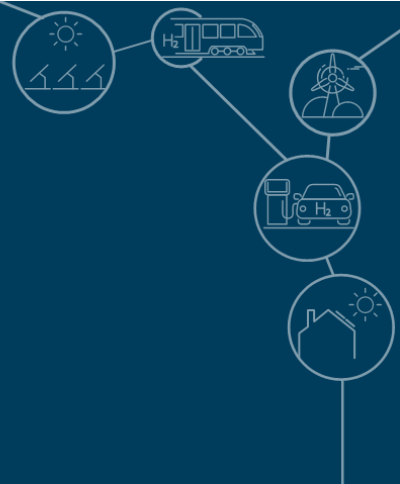
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[Return to
outline](#)

Appendix: Our method for estimating biodiversity offsets



Estimating biodiversity offsets: power densities of utility solar PV and wind

A review of the literature

Solar PV Power density (MW/km ²)	Onshore Wind Power density (MW/km ²)	Reference
45*	2.7*	Larson, E., Mayfield, C., Jenkins, J., Pacala, S., Greig, C., Kwakkel, J., Olsen, T., Meyer, B., ... & Schivley, G. (2021). Net-zero America: Potential pathways, infrastructure, and impacts (Final Report). Princeton University. https://netzeroamerica.princeton.edu/
24	2.6	Miller, L. M., & Keith, D. W. (2018). Observation-based solar and wind power capacity factors and power densities. Environmental Research Letters, 13(10), 104008.
57		Li, X., Hernandez, R. R., Armstrong, A., Liu, P., & Jordaan, S. M. (2026). Global land and solar energy relationships for sustainability. Joule.
33		Heath, G., Ravikumar, D., Ovaitt, S., Walston, L., Curtis, T., Millstein, D., ... & McCall, J. (2022). Environmental and circular economy implications of solar energy in a decarbonized US grid (No. NREL/TP-6A20-80818). National Renewable Energy Laboratory (NREL), Golden, CO (United States).
59		Bolinger, M., & Bolinger, G. (2022). Land requirements for utility-scale PV: an empirical update on power and energy density. IEEE Journal of Photovoltaics, 12(2), 589-594.
65	2.9	Nøland, J. K., Auxepaules, J., Rousset, A., Perney, B., & Falletti, G. (2022). Spatial energy density of large-scale electricity generation from power sources worldwide. Scientific Reports, 12(1), 21280.
47	2.7	Average

* The [NZAu Project methods](#) uses the figures from Larson et al. (2021), which is very close to the average of the literature above. The areas above are *project areas*, i.e. the total area occupied by the solar or wind farm. We also assume that *the direct footprint* is 91% of the project area solar and 1% of the project area for wind as stated in this reference.

Estimating biodiversity offsets: a summary of *reported* offset costs and associated estimates

Project	Reported information					NZAu Project estimates			
	capacity MW or kV	offset costs \$M	capex \$M	TX length km	offset area ha	capex \$M	offset costs / capex	direct footprint km ² ¹⁰	offset cost / direct footprint \$/ha
Wind farms									
Wind Farm ¹	n/a	1% of capex	n/a			n/a ¹⁰		n/a	90
Wind Farm ¹	n/a	1% of capex	n/a			n/a ¹⁰		n/a	90
Transmission									
VNI West Option 5A ²	500	85	3499	409		2%	2%	32.7	26
Snowy 2.0 Transmission Connection project ^{3,4,5}	330	25	150	9	118	17%	17%		211
Project Energy Connect ^{6,7}	330	170	2335	860		7%	7%	60.2	28
Humelink Option 3C ^{8,9}	500	502	4881	365		10%	10%	29.2	172
Average									103

Note: all the offset costs above consider both Threatened Ecological Communities (TECs) and Threatened Species (TS).

Sources:

1 Private communications with Project Developers

2 https://www.aemo.com.au/-/media/files/electricity/nem/planning_and_forecasting/victorian_transmission/vni-west-rit-t/reports-and-updates/vni-west-pacr-volume-1.pdf?la=en

3 <https://www.lumea.com.au/media/50oecwbc/snowy-2-0-biodiversity-offset-package-fact-sheet-final.pdf>

4 <https://lumea.com.au/media/ncpl3cvi/b18-biodiversity-offset-package-v60.pdf>

5 https://www.industry.gov.au/sites/default/files/aip/snowy_2.0_generator_connection_project_-_executive_summary-ydgmqrqc.pdf

6 <https://www.aer.gov.au/system/files/AER%20-%20Final%20Decision%20-%20TransGrid%20-%20Project%20EnergyConnect%20Contingent%20Project%20-%20May%202021.pdf>

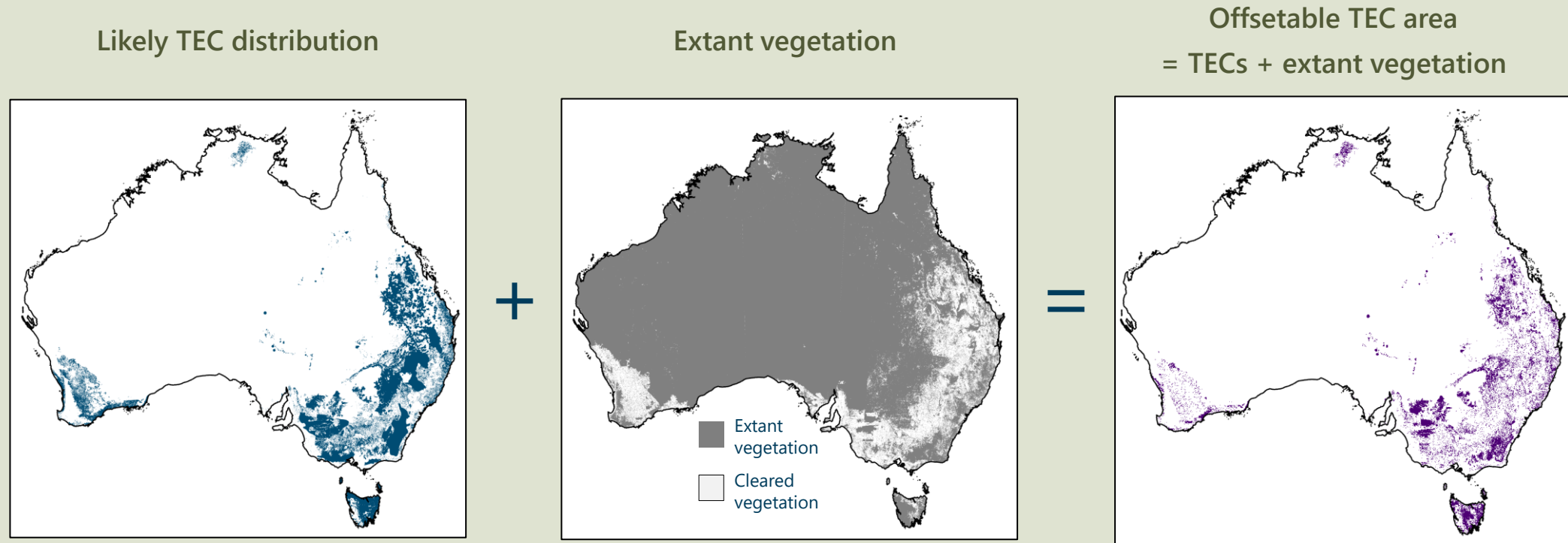
7 <https://www.aer.gov.au/system/files/AER%20-%20Final%20Decision%20-%20ElectraNet%20-%20Project%20EnergyConnect%20Contingent%20Project%20-%20May%202021.pdf>

8 <https://www.transgrid.com.au/media/q4snvri/humelink-material-change-circumstance-mcc-assessment-report-feb-24.pdf>

9 <https://www.transgrid.com.au/media/oa3hcdts/humelink-biodiversity-offset-package.pdf>

10 Calculated using [NZAu Project methods](#).

Estimating biodiversity offsets: likely habitat area potentially requiring offsets



- The likely range of TECs were overlaid with the extant vegetation layer (NVIS 7), to generate a raster of 'Offsetable TEC area' at a 1 ha resolution.

Estimating biodiversity offsets: method

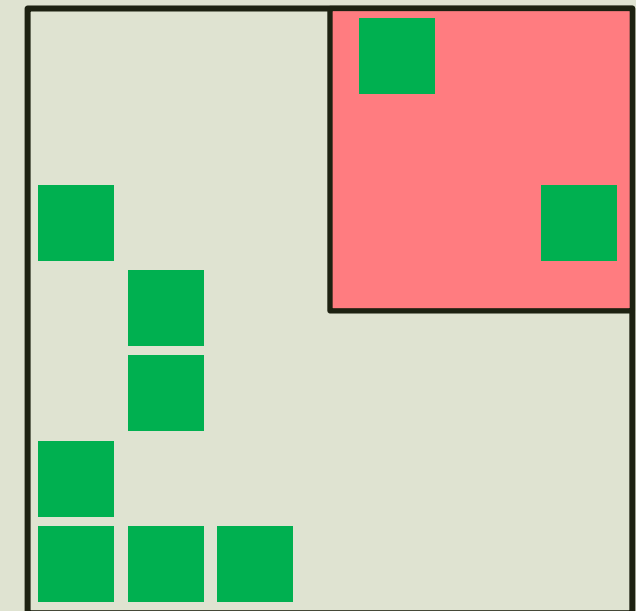
- *Candidate Project Areas (CPAs)* are 10 km × 10 km zones for utility solar and 20 km × 20 km zones for wind across Australia with exclusion layers subtracted from these zones. These exclusion layers and our associated energy system planning methods are stated in the [NZAu Project methods](#) Report and summarised earlier in this Report.
- These CPAs are ranked from lowest to highest renewable energy costs, including transmission costs, and these are first used to determine the required energy system capacities in our capacity optimisation modelling. The *subsequent* energy system planning then allocates builds (investments) from lowest to highest cost CPAs up to these modelled, optimal capacities.
- We then estimate the biodiversity offset costs for *a given* energy system plan with *a given set of exclusions* that *may already* include exclusions based on biodiversity value:

$$\text{biodiversity offset cost (\$)} = \text{offset cost (\$/ha}_{df}) \times \frac{\text{direct footprint}}{\text{project area}} \times \text{total project area (TPA) (ha)} \times \frac{\text{fraction of TPA with TECs and/or TS}}{\text{and/or TS}}$$

where:

- the *offset cost* = 50 \$/ha_{df} if **only TECs or TS** are considered and 100 \$/ha_{df} if **both TECs and TS** are considered;
- (direct footprint) / (project area) = 0.01, 0.91 and 1.0 for wind, utility solar and transmission respectively, as per the [NZAu Project methods](#);
- the *total project area* uses the calculated power densities and capacities for wind and utility solar or the mapped length multiplied by its easement width for transmission, as per the [NZAu Project methods](#);
- the *fraction of TPA with TECs and/or TS* is obtained by spatial analysis of a given energy system plan; and
- the *total biodiversity offset costs* are then obtained by summing the 3 offset costs obtained from this equation for the cases i) with TECs only, ii) with TS only and iii) with both TECs and TS.
- Note:
 - This *fraction of TPA with TECs and TS* assumes that the direct footprint is as likely to be impacted as other land in a CPA. This should overestimate offset costs since higher biodiversity value land in each CPA should be less likely to be built upon.
 - As shown earlier, 100 \$/ha_{df} is representative of offset costs that include both TECs and threatened species (TS).

A representative CPA



■ TEC area

■ Total project area (TPA) within that CPA