The Emissions-based Social Benefits of Large-Scale Transmission

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Research Topic Context

Transforming the electricity sector around the world is a pivotal component of mitigating global warming (IEA, 2021). In Australia, the largest contributor to domestic greenhouse gas emissions (GHG) is the electricity sector, which comprises roughly one third of the nation's total emissions (Australian Government Department of Industry, Science, Energy and Resources, 2021). The latest Quarterly Update of Australia's Greenhouse Gas Inventory notes that the electricity sector in Australia has experienced an emissions decrease of 23.3% since 2009, but current trends are not aligned with the Paris Agreement target of limiting atmospheric warming to 1.5°C. Therefore, a review of decarbonisation efforts and investment decision-making in the National Electricity Market (NEM) is necessitated.

The Integrated System Plan (ISP) is a whole-of-system plan that provides a roadmap for the development of the NEM over the next few decades. Specifically, the Australian Energy Market Operator (AEMO), the publisher of the ISP, notes that the report is intended to reflect a plan for "efficient" development of the NEM, with a primary objective of maximising value to electricity consumers through lowest-cost energy system investments (AEMO, 2022). Carbon emissions carry a significant damage cost for all humans on Earth. Where GHG emissions are not included in cost-benefit analyses for infrastructure investment within NEM, AEMO may be inaccurately describing the true lowest-cost development pathways. Additionally, estimates of the net market benefits of VRE and transmission infrastructure are likely to be inaccurate.

The concept of a social cost of carbon (SCC) has been described as the most crucial economic tool in assessing the impact on climate change of investment decisions, and organisational and governmental activities (Nordhaus, 2017). By factoring the externality of damage caused by carbon emissions into the development of policy and infrastructure, investments in renewable generation and transmission can be stimulated (IEA, 2020).

The 2022 ISP includes the Optimal Development Path (ODP) comprised of 22 different network investments in the NEM. Of these projects, AEMO used estimates for net market benefits to categorise 5 projects as 'actionable' to bring forward and support their development. The Regulatory Investment Test for Transmission (RIT-T) is used by transmission developers to identify the transmission investment option that maximises net economic benefits. The cost-benefit criteria of the RIT-T does not prescribe the SCC. Hence, estimates for the true net market benefits of the Actionable Transmission Projects (and all projects in the ODP) are likely to be inaccurate. Furthermore, the selection of projects from the ODP to be categorised as 'actionable' is likely to be misguided.

Research Questions

- Given a range of social costs of carbon, what are the true net market benefits of the Actionable Transmission Projects as listed in the 2022 ISP?
- What are the carbon costs of delaying the Actionable Transmission Projects beyond 2050?
- Considering the social cost of carbon, how do the social benefits of transmission change with location?

Method

To assess the emissions-related impacts of each Actionable Project, a long-term *Step Change* PLEXOS model was run through to 2050 with and without these network investments. Each scenario was computed with only one transmission project removed at a time. By analysing data on CO_2-eq emissions, generation, capacity mix, and curtailment, an overall picture was formed on how total emissions differ with and without these projects, and what causes these differences.

In considering the inconsistency between the likely real-world *Step Change* pathway for the NEM's future, and the nature by which carbon constraints have been included in AEMO's model; the carbon budget constraints were removed from the PLEXOS model for emissions analysis. For other research questions, and to explore the drivers of emissions in these scenarios, both types of models with and without the carbon constraints were still simulated.

There are considerable discrepancies between academic estimates of the SCC. In this analysis, for scenarios *without* a carbon budget constraint, GHG emissions were translated to a lower and upper estimate of social costs. For the lower estimate, emissions were indexed to the US Government's IWG calculations of the SCC, using a 3% discount rate. For the upper estimate of total social costs, emissions were translated with the published values of the SCC by Anthoff & Rennert (2022), and a 2% discount rate.

To assess the system cost benefits of the transmission projects *with* a carbon budget constraint, an annual system cost of emissions was derived by syncing yearly emissions to the average carbon shadow price. The difference between total system emissions cost of each scenario with a transmission line removed, and the BAU case, provided the emissions-related system cost benefits of each Actionable Transmission Project, given a carbon budget and price.

To investigate how carbon-related social benefits change with location, four concept transmission projects were implemented in addition to AEMO's Step Change model. A constant capacity of 3.29 GW was fixed across these projects, representing the average capacity of the Actionable Transmission Projects. To ascertain — at a high level — where additional transmission projects may have a considerable impact on emissions, NEM interconnector import and export behaviour over 2021 was analysed. Where there were frequent constraints or high VRE curtailment, a hypothetical interconnector was introduced.

Key Results

Table 1. Lower and upper estimates of the net present value of emissions-related social benefits of each Actionable Transmission Project, 2024-2050

Actionable Project	Emissions-related Social Savings (USD)	
	NPV Lower Estimate	NPV Upper Estimate
HumeLink	$45,614,786	$279,907,782
Sydney Ring	$111,360,541	$547,623,383
VNI West	$689,069,521	$3,114,800,101
New England	$1,254,279,789	$5,730,204,453
Marinus Link	$1,341,649,176	$6,065,502,279
All Actionable Projects	$3,546,128,464	$16,139,467,227

Given the inclusion of the SCC, the true net market benefits estimate of all Actionable Transmission Projects is roughly double what AEMO currently estimate in the 2022 ISP. This is in part attributable to the projects lowering the average VRE curtailment factor and avoiding the need to build excess gas capacity towards 2050.

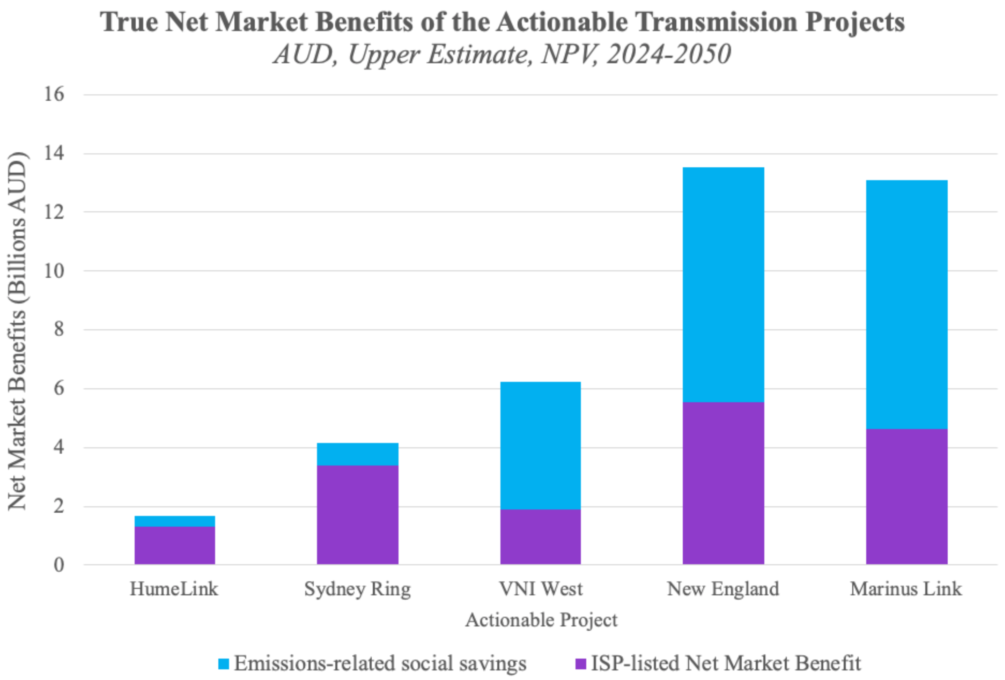

Figure 1. Upper estimates of the true market benefits of each Actionable Transmission Project

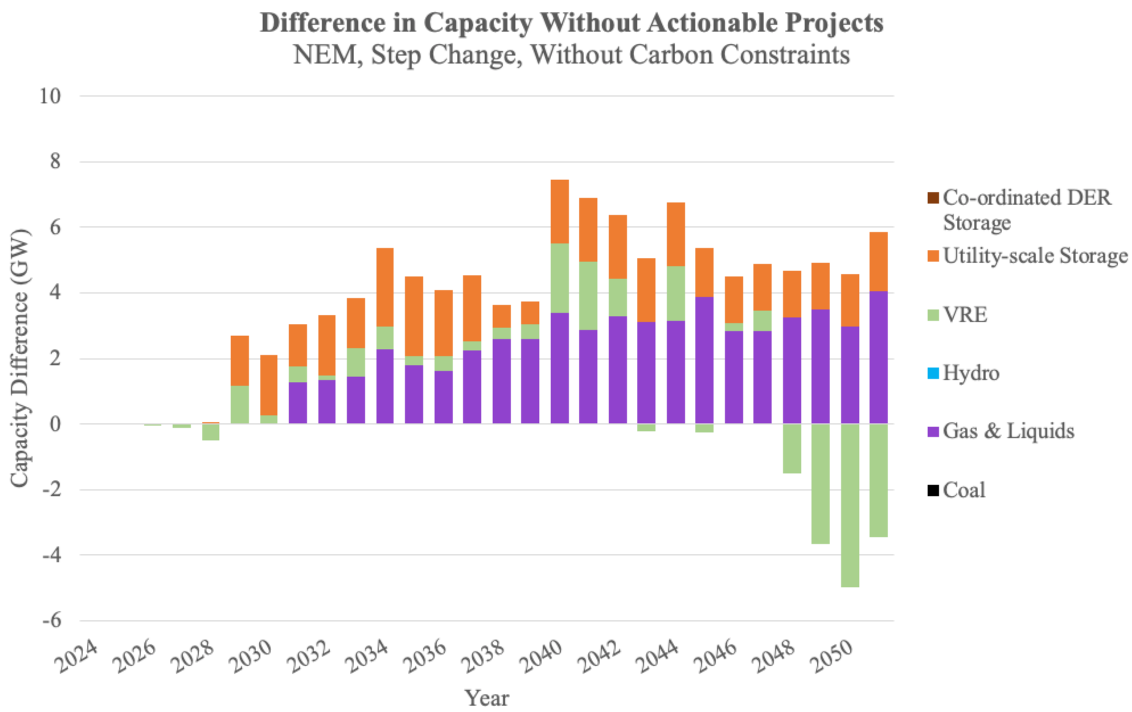

Figure 2. Difference in NEM capacity mix without the Actionable Transmission Projects, no carbon constraints

Given the inclusion of the carbon budget constraints, and hence a carbon price, the Actionable Transmission Projects reduce total emissions-related system costs by AUD$24.5 billion over 2024-2050. Additionally, the average VRE curtailment factor is reduced from 14.07% without the projects, to 10.45% over the same time period.

Table 2. Total NEM emissions and emissions cost without each Actionable Project, 2024-50, with carbon constraints

Scenario *(with carbon budget constraints)*	**Total NEM Emissions 2024-2050** (Mt CO2-eq)	**Emissions Cost 2024-2050** (Billions AUD)
BAU		**$55.2**
No HumeLink		$54.4
No Sydney Ring		$55.9
No VNI West	**890.8**	$58.5
No Marinus Link		$62.8
No New England		$64.0
No Actionable Projects		$79.7

The results showed that of the four conceptual projects considered, the difference in social benefits spanned USD$859 million. An additional 3.29 GW of transmission capacity between VIC and SNSW abated 4.08 Mt CO_2-eq through to 2050, whilst a line of equivalent capacity between SNSW and SA resulted in *additional* 0.56 Mt CO_2-eq.

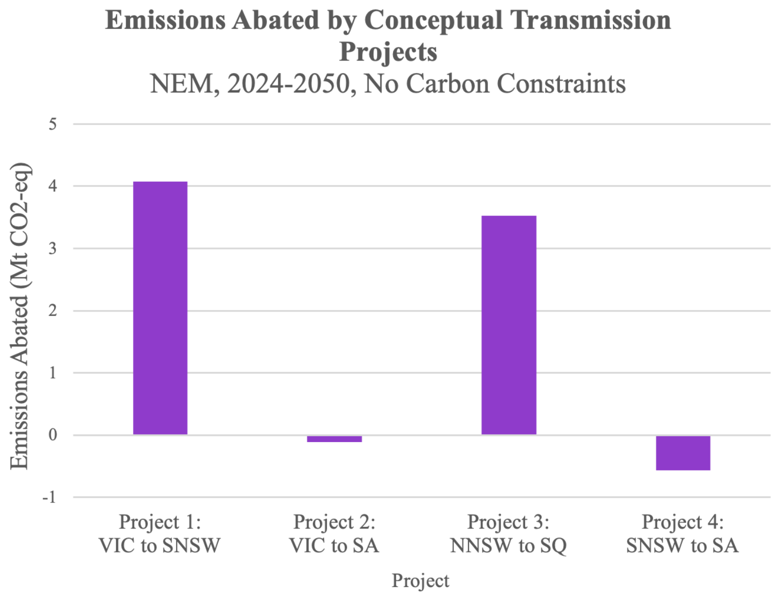

Figure 3. Emissions abated by each hypothetical 3.29GW transmission project concept, 2024-2050

By including the SCC in transmission project cost-benefit analyses, investment decision making can occur in economically efficient conditions, and the true least-cost pathway to decarbonising the grid can be uncovered. Without consideration of the social benefits of transmission, AEMO are unlikely to identify the most economically efficient transmission projects within the ODP. Moreover, with a mandated carbon shadow price in cost-benefit analyses, TNSPs would design and develop large-scale transmission in optimal alignment with decarbonisation goals. The results of this research call attention to the benefits of transmission in decarbonisation efforts and may prove useful in attaining social license for further network developments.

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