Submission to the 2019 Forecasting and Planning Consultation

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I welcome the opportunity to make a submission to the Australian Energy Market Operator's (AEMO) *2019 Forecasting and Planning Consultation* document (hence forth *consultation document*. In this submission I predominantly provide feedback on the emissions trajectories proposed, and the approach AEMO uses to model renewable energy resource traces.

The submission begins with a summary and key recommendations. Further details and analysis is provided in later sections. Please feel free to contact me if there are any questions or clarifications with respect to this submission[1].

Summary and key recommendations

The approach to emissions proposed by AEMO implicitly assumes Australia does not fulfill its commitments under the Paris Agreement. The emissions trajectories proposed would result in National Electricity Market emissions exceeding the budget allocated to it by well over 100% by 2050 in the two emissions scenarios considered. Expressed differently, the emissions budget for the NEM would be exhausted by 2028 or 2031 in the two scenarios respectively.

This approach amounts to planning for failure to meet our Paris Commitments. It seems both inappropriate and irresponsible for the market operator and planner to not actively consider even *one* scenario that would be consistent with meeting the Paris Agreement, the which the Federal Government of Australia is a signatory. The key recommendation from this submission is develop *at least one* scenario that would consider our commitments under the Paris Agreement.

The other recommendations relate to improving the development of renewable energy resource traces and improving data availability. The current approach to renewable energy trace development significantly undervalues the potential for some resources (and in particular, Concentrating Solar Thermal, CST).

> **Recommendation 1:** Develop scenarios that reflect emissions in the NEM being consistent with the Paris Agreement commitment. At an *absolute minimum*, this should limit emissions from the NEM to the budget derived by Climate Change Authority (CCA) in their electricity sector analysis.

> **Recommendation 2:** Develop a more sophisticated approach to resource trace development that allow the full capability, value and optimisation of different renewable energy resources to be explored.

> **Recommendation 3:** Make more of the input assumption data from the different scenarios available.

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1 Emission reduction assumptions

In 2014 The Climate Change Authority (CCA) prepared the *Targets and Progress Review* as part of it's legislative requirements, and recommended emissions reduction goals[2]. As part of this review, the Authority recommended a national emissions budget from 2013–2050 of 10,100 Mt CO_2-e. This was based on what was considered Australia's fair share of a global emissions budget that limited warming to 2°C.

Since then, the Paris Agreement was adopted (2015) and was ratified by enough countries for it to enter into force less than a year later. Under the Paris Agreement, countries have agreed (among other things) to a global goal to limit average temperature increase to well below 2°C above pre-industrial levels and pursue efforts to keep warming below 1.5°C. The Agreement entered into force for Australia 10 December 2016, and Australia's 'Nationally Determined Contribution' (NDC) as submitted to United Nations Framework Convention on Climate Change (UNFCCC) secretariat is based on cumulative abatement approach.[3].

Implications for the electricity sector

Achieving the objectives of the Paris Agreement will necessarily result in a significant change to the electricity sector. There are three inter-related reasons that necessitate this change[4]. Firstly, the electricity sector is a the largest single source of emissions in Australia, currently responsible for approximately 34% of our national emissions. Secondly, the cost reductions and advances in renewable energy technology mean significant reductions in electricity sector emissions are both technically feasible with currently known technologies, and more cost-effective than cuts in some other sectors. And finally (and related to the previous point), due to the relative difficulty of decarbonising other sectors of the economy, electrification of other sectors will be critical for Australia to meet its emissions objectives.

In 2016, the CCA published it's *Special Review electricity research report*[5]. This report was informed by modelling work completed by Jacobs. For this modelling work, the Authority specified a cumulative emissions constraint (an emissions budget) for the electricity sector, and each policy scenario to achieve the same cumulative emissions[6]. This set at a level consistent with Australia contributing to global action giving a likely chance (two-thirds) of limiting global average warming to no more than 2°C.

Importantly this is *not* the same (and results in higher emissions) than what would be consistent with the Paris Agreement commitment (which as above, is well below 2°C above pre-industrial levels and pursue efforts to keep warming below 1.5°C). In addition, the Jacobs analysis considered the entire electricity sector (not only the NEM).

The emissions budgets proposed in the consultation document are *well above* the budget specified by the Climate Change Authority. Figure 1 over page compares the cumulative emissions allocated to the

[2] Climate Change Authority, (2014). *Reducing Australia's greenhouse gas emissions: targets and progress review: final report.*

[3] Australia's *first* NDC is an *'Absolute economy-wide emissions reduction by 2030, to be developed into an emissions budget covering the period 2021-2030'.* See Australia's first NDC here: http://go.unimelb.edu.au/6rmx)

[4] See Climate Change Authority, (2016). *Special Review: electricity research report*, section 2.3 "The role of the electricity sector in Australia's emissions reduction goals" from page 19 on-wards.

[5] ibid.

[6] The regulated closures policy breaches the emissions budget by about 200 $MtCO_2$-e or 15%.

entire electricity sector from the Climate Change Authority to the cumulative emissions from the *NEM* in the AEMO scenarios. Table 1 illustrates both the degree to which the AEMO scenario (including *"the fast scenario"* which *"reflects more aggressive emissions reduction objectives"*[7]) over shoot the budget, and the year in which the over shoot would occur.

Year	28%-70% reduction	52%-90% reduction
2030	94.1%	80.7%
2050	218.9%	153.1%
Overshoot year	FY31	FY34

Table 1: This table shows the percentage of the CCA emissions budget for the *entire* electricity sector that was by exhausted by 2030 and 2025 in the two emissions reduction scenarios proposed in the consultation document. The year in which the budget is entirely exhausted is also shown.

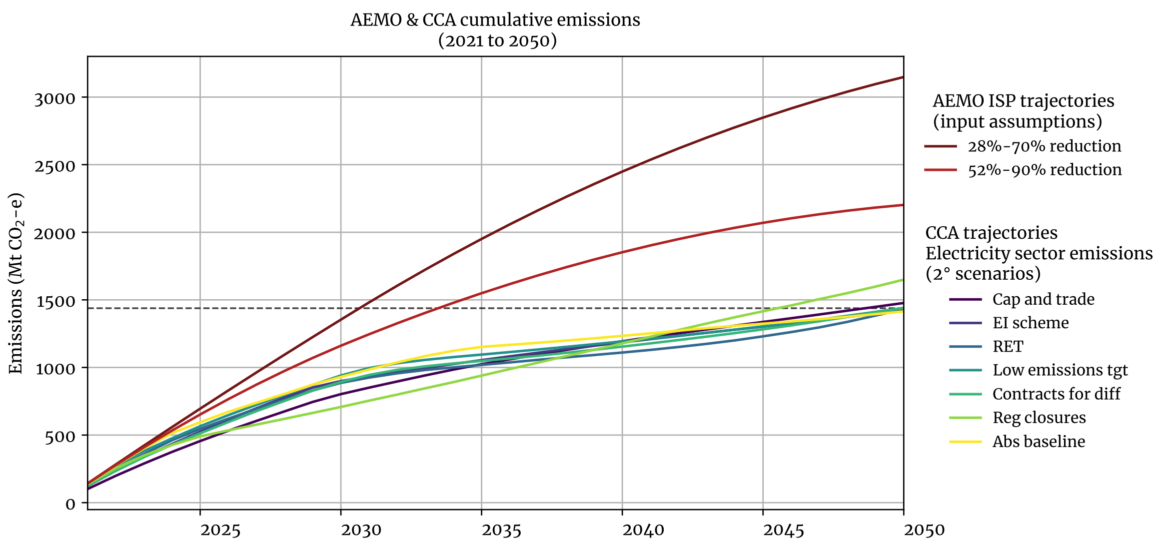


Figure 1: This figure illustrates compares the cumulative emissions in the entire electricity sector under the different scenarios modelled for the CCA with the cumulative emissions in the scenarios proposed by AEMO for the NEM. The Authority specified a cumulative emissions constraint (an emissions budget) for the electricity sector, and each policy scenario to achieve the same cumulative emissions which is, shown by the grey dashed line. The regulated closures policy breaches the emissions budget by about 200 $MtCO_2$-e or 15%.

[7] AEMO 2019, Planning and Forecasting Consultation Paper, Australian Energy Market Operator, page 18.

An estimate of the *NEM*'s budget can be determined by pro-rating the emissions allocated to the electricity sector to the NEM, based on the historic relative share of NEM emissions (relative to entire electricity sector emissions). This is equivalent to assuming the relative rate of electricity sector decarbonisation is equivalent across the non-NEM markets. Figure 2 and table 2 below make this (more fair) comparison. As can be seen, the current emissions trajectories proposed would result in the budget being exceeded by 2028 or 2031 in the *"fast scenario"*.

Year	28%-70% reduction	52%-90% reduction
2030	113.4%	97.3%
2050	263.7%	184.%
Overshoot year	FY29	FY31

Table 2: This table shows the percentage of the CCA emissions budget for the *entire* electricity sector that was by exhausted by 2030 and 2025 in the two emissions reduction scenarios proposed in the consultation document. The year in which the budget is entirely exhausted is also shown.

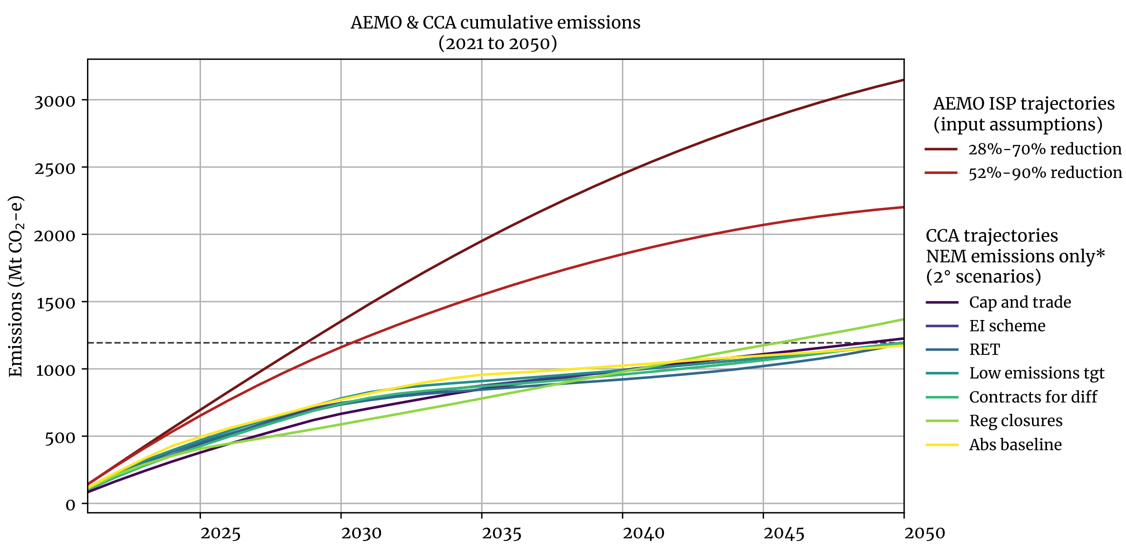


Figure 2: This figure illustrates compares the cumulative emissions in NEM under the different scenarios modelled for the CCA with the cumulative emissions in the scenarios proposed by AEMO for the NEM. The Authority specified a cumulative emissions constraint (an emissions budget) for the electricity sector, and each policy scenario to achieve the same cumulative emissions which is, shown by the grey dashed line. The regulated closures policy breaches the emissions budget by about 200 $MtCO_2$-e or 15%.

AEMO's approach and maximum budget

The CCA analysis and budget should be considered a *maximum, upper bound* when considering emissions reduction constraints. This is for several reasons, as a result of significant changes that have occurred since the CCA analysis was completed:

- **Paris Agreement:** The CCA budget was devised on the basis of a 2°C target rather then *"well below"* 2°C (and pursing efforts to keep warming below 1.5°C.)
- **Failure to reduce emissions:** The CCA budget of 10.1 MT was calculated from 2013-2050. Since 2013, Australia has failed to achieve emissions reductions (and emissions have increased in recent years). This means that we have *less* emissions budget remaining for the remaining years.
- **Renewable energy cost reductions:** The continued cost reductions of renewable energy (and in particular solar PV) means that electricity sector emissions are *even more* cost effective than considered in the initial CCA analysis.

In combination, these factors and the NDC ratcheting up process (described in the next section) suggest the emissions budget for the electricity sector will be much more stringent than the budget modelled by Jacobs for the CCA. While the consultation document correctly identifies that emissions trajectories are *"highly uncertain over the planning horizon"*, the same can not strictly be said of the emissions budget. There is essentially a fixed budget to achieve objective of limiting global warming to well below 2 degrees. In the case of the NEM, the CCA electricity sector emissions budget should be considered a maximum, upper bound limit for cumulative emissions reductions in the electricity sector at a minimum.

The consultation proposes that emissions outcome should be an output of the modelling process and changing resources mix. I agree with this approach, in so far as the particular emissions trajectory should be an endogenous output, which does not make presumptions about particular emissions policies. In addition, considering accelerated coal closures and/or increased investment in renewable energy generation seems like a reasonable approach, (given significant emissions reductions will necessarily require reductions in unmitigated coal generation and early retirement, and the increased cost-effectiveness of renewable energy). However the scenarios considered do not align with the required emissions reductions to achieve commitments made in the Paris Agreement.

To summarise, it would seem prudent for the market operator and planner to at least consider *one* scenario in which commitments that Federal Government have committed to are achieved. This scenario should (at a minimum) limit emissions from the NEM to the budget derived by Climate Change Authority (CCA) in their 2016 electricity sector analysis.

"Ratcheting up" the NDC's

It's widely understood that on a global level *current* climate policies will not achieve the aims of the agreement (keeping global temperature rise to "well below" 2°C). Critically, the ambition contained within each country's current NDC is not frozen in place. The Paris agreement contains provisions to increase ambition over time, through what is known as the "ratchet mechanism". Each countries NDC is to be updated over time, with the agreement stipulating that the efforts of each country will "represent a progression over time", and reflect its "highest possible ambition".

The next round of NDC's be submitted by 2020, the year that the agreement comes into force. Countries with 2030 targets, (like Australia) must "communicate or update" our NDC's by 2020. This updating process is set to happen every 5 years. As current commitments on global level are not sufficient to achieve the Paris Agreement objectives, NDC's are expected to ratchet up over time.

This includes Australia NDC, which is already lagging other countries ambitions and puts *"Australia at or near the bottom of the group of countries we generally compare ourselves with"*[8] (See the table below). In addition, we a currently on track to exceed the initial economy wide CCA budget of 10.1 in 2031, based on current projections. (See appendix).

	Change from 2005
UK	-61%
Switzerland	-51%
Germany	-45%
Norway	-44.5%
US	-35 to -39%
EU	-34%
Canada	-30%
New Zealand	-30%
Australia	-26 to 28%
Japan	-25%

Figure 3: Implied reductions in total emissions, 2005-2030 for comparable countries. (Japan's efforts and ambition to reduce emissions were effected by the Fukushima disaster) [Source: CCA, (2015). Statement by the chair]

[8]Climate Change Authority, (2015). *Statement by the chair: Some observations on Australia's post-2020 emission reduction target.*

2 Renewable energy resource traces and data availability

One-year renewable energy generator traces are currently used as inputs to the various planning and forecasting documents. Whilst this might provide a reasonable estimate for some technologies, at low renewable energy penetrations, it fails to accurately capture the real potential available from the different technologies.

This is most starkly illustrated in the case of Concentrating Solar Thermal (CST). The current approach uses a static generator trace, with no consideration of the chief value of CST (namely, the inherent storage). While the traces model a CST plant with 6 hour of storage, only the daily resource availability is considered, and not the how this technology and it's storage capabilities could operate.

The CST traces for a particular scenario and location are contrast below with the demand and rooftop solar in the figure 4 below. This highlights the issue problem for using a static resource trace for CST. Figure 5 over page provides an illustrative example of how a CST plant with 6hrs might operate more in both practice and an optimised system.

In the specific case of CST, the approach to modelling would be substantially similar to modelling storage technologies (for example batteries or pumped hydro). However for CST, the actual input to the storage technology would be dictated by the solar resource (not the grid).

Using generator traces (rather than resource traces) also has issues with other technologies like wind and solar PV. In the case of solar PV the use of a static generator trace assumes a particular orientation and elevation. As penetration increases, it might be expected that different elevation (to generate more during winter for example) might become more valuable to the system. Similarly with wind, different power curves might make sense for different locations and for optimal benefit to the system.

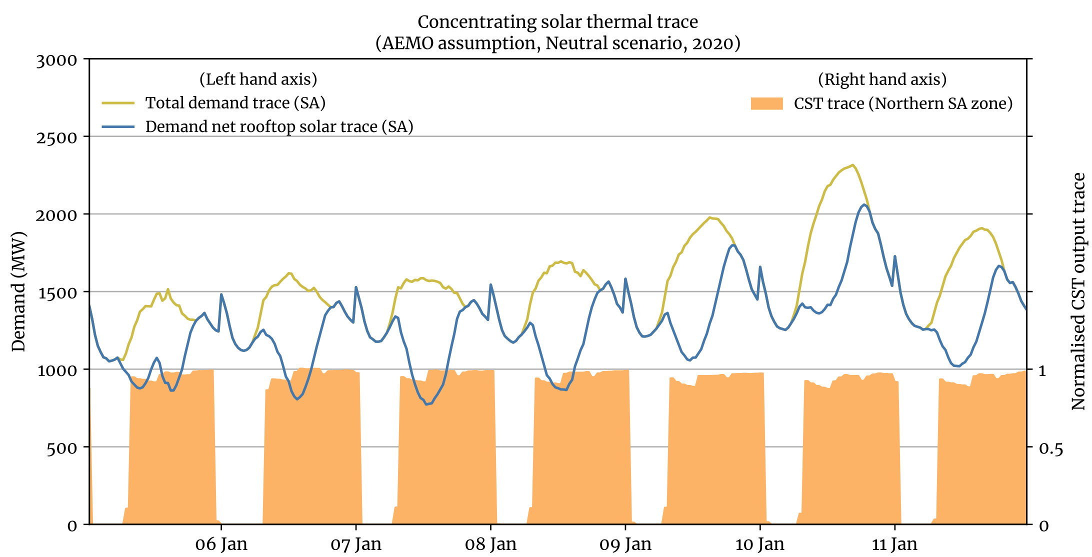


Figure 4: How CST is modelled in the previous approach. While taking into account resource availability, it doesn't take into account the storage capabilities, and temporal requirements of the system.

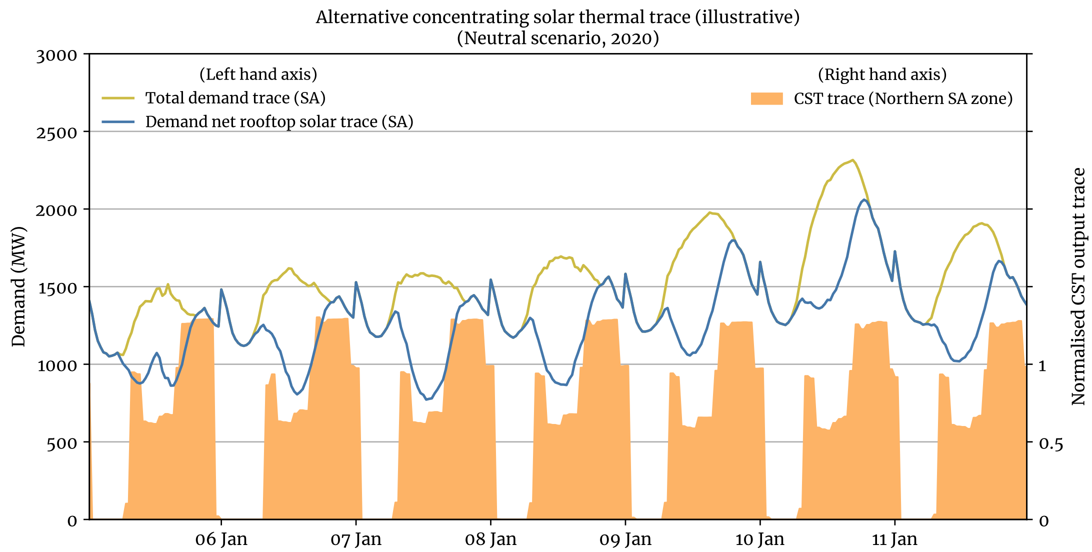


Figure 5: Stylised illustration of how CST might optimal be dispatched in the particular time period and scenario selected (this is *not* an optimised result). The energy delivered remains the same as in the previous figure.

Data availability

There are many well established benefits to increasing transparency and providing both open access data and using open source models. Openly available data and models facilitate higher quality science, greater productivity through less duplicated effort, and a more effective science-policy boundary[9]. On the flip side, black-box simulations can-not be verified, discussed or challenged, which is problematic for science, bad for the public and spreads distrust[10].

AEMO has an excellent track record of providing access to electricity market data, and is to be commended for this. Future analysis should continue in the this tradition and endeavour to make even more of the data (and modelling) open access or open source.

In particular it would be desirable to the full set of inputs (for example demand traces for particular scenarios), or assumed traces for electric vehicle charging to be made available in future releases.

[9] Pfenninger, S., DeCarolis, J., Hirth, L., Quoilin, S. & Staffell, I. *The importance of open data and software: Is energy research lagging behind?* **Energy Policy** 101, 211–215 (2017).

[10] Pfenninger, S. *Energy scientists must show their workings.* **Nature** 542, 393–393 (2017)

Addendum: Paris Agreement compatible carbon prices

In 2018 the Intergovernmental Panel on Climate Change (IPCC) prepared a special report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways[11]. This was prepared in response to an request contained in the Decision of the 21st Conference of Parties of the UNFCCC Change to adopt the Paris Agreement and includes comparison between global warming of 1.5°C and 2 °C above pre-industrial levels.

This report draws on mitigation pathways that were developed with detailed process-based integrated assessment models (IAMs). These models cover all sectors and regions over the 21st century to describe an internally consistent and calibrated (to historical trends) way to get from current developments to meeting long-term climate targets (such as 1.5°C).

In recent years there have been a large range of new studies that use different IAM that explore scenarios consistent with the Paris Agreement. These are more stringent than the lowest scenarios that were considered in the previous assessment reports that limit warming below 2°C (for example the IPCC's 5$^{\text{th}}$ Assessment Report, AR5) . For the IPCC special report a large number of these scenarios were collected in a scenario database.

Mitigation pathways were classified into classes that either kept surface temperature increases below a given threshold throughout the 21st century or returned to a value below 1.5°C above pre-industrial levels at some point before 2100 after temporarily exceeding that level earlier – referred to as an *"overshoot"*. Both groups were further separated based on the probability of being below the threshold and the degree of overshoot, respectively. These are shown in the table below[12].

Pathway group	Pathway Class	Pathway Selection Criteria and Description	Number of Scenarios	Number of Scenarios
1.5°C or 1.5°C-consistent**	Below-1.5°C	Pathways limiting peak warming to below 1.5°C during the entire 21st century with 50–66% likelihood*	9	90
	1.5°C-low-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a 50–67% probability of temporarily overshooting that level earlier, generally implying less than 0.1°C higher peak warming than Below-1.5°C pathways	44	
	1.5°C-high-OS	Pathways limiting median warming to below 1.5°C in 2100 and with a greater than 67% probability of temporarily overshooting that level earlier, generally implying 0.1–0.4°C higher peak warming than Below-1.5°C pathways	37	
2°C or 2°C-consistent	Lower-2°C	Pathways limiting peak warming to below 2°C during the entire 21st century with greater than 66% likelihood	74	132
	Higher-2°C	Pathways assessed to keep peak warming to below 2°C during the entire 21st century with 50–66% likelihood	58	

Figure 6: Pathway classification used for IPCC scenario database [**source: IPCC (2018)**]

[11]IPCC, 2018: *Global warming of 1.5° C. An IPCC Special Report on the impacts of global warming of 1.5° C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty* [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield (eds.)]. In Press.

[12]ibid. Chapter 2, Table 2.1, page 100

As previously mentioned (section 1, page 2), for the Climate Change Authority's special review on electricity, an emissions constraint was set at a level consistent with Australia's contribution to a likely chance (two-thirds) of limiting global average warming to no more than 2°C. For this, the CCA chose the median carbon price associated with an atmospheric concentration of 450ppm carbon dioxide equivalent observed in the database of global carbon prices in the IPCC's the 5^{th} assessment report, (AR5). Specifically, the median values from the analysis were converted from US dollars to Australian dollars and inflated to 2015 dollars. Uniform growth rates were calculated to interpolate the carbon price between 2020, 2030 and 2050.

A similar approach could be used for based on the data in the 1.5°C Special Report (SR1.5) database. The median price (in US dollars) across the Paris Agreement consistent pathway groups described in Figure 6 on the previous page are show in the table below. The two figures (Figure 7 and 8 show the carbon price range in the pathway classes with in each pathway group, and the median.

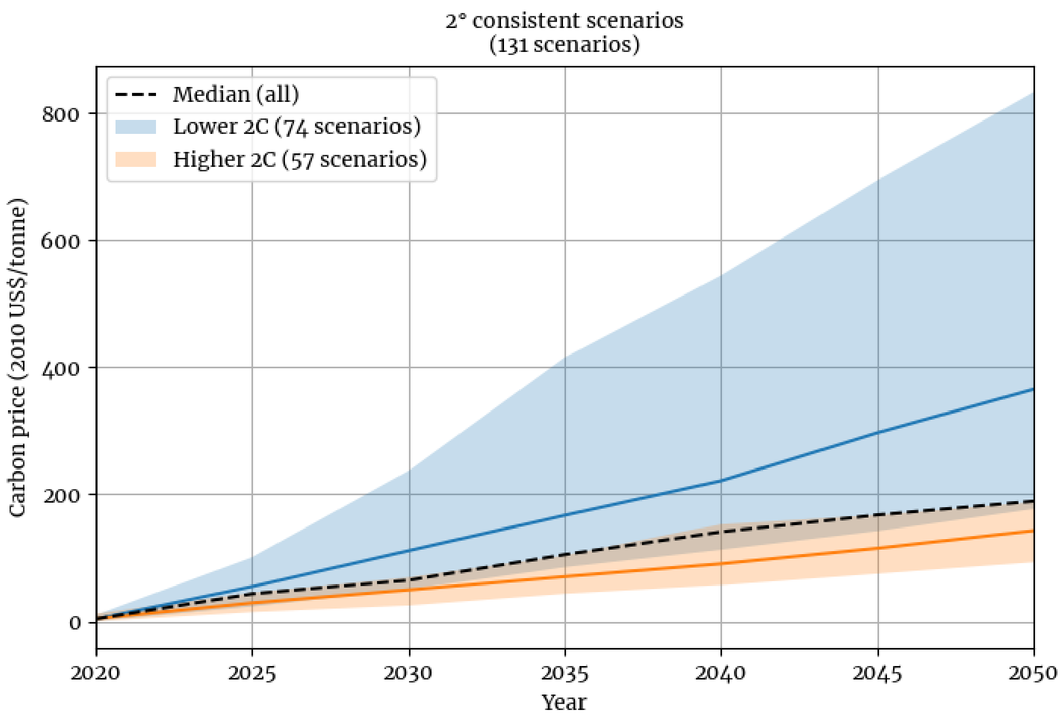


Figure 7: Carbon price trajectories , ranges (50% quantile) and median the two pathway classes ('*Lower 2° C*' and '*Higher 2° C*' in the 2°C pathway group. The median across the whole group is shown with a dashed line.

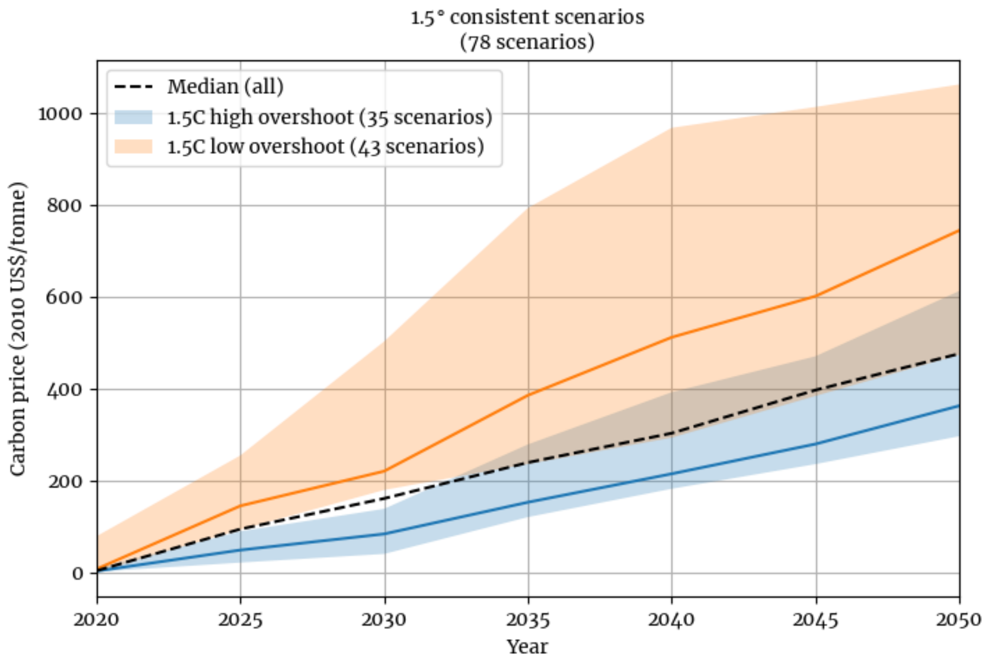


Figure 8: Carbon price trajectories, ranges (50% quantile) and median for the two pathway classes ('*1.5° C high overshoot*' and '*1.5° C low overshoot*' in the 1.5°pathway group. The median across the whole group is shown with a dashed line.

Year	2°C	1.5°C
2020	4.13	3.11
2025	43.47	98.91
2030	64.97	179.18
2035	105.16	244.82
2040	140.80	316.31
2045	167.58	402.08
2050	189.22	479.44

Table 3: The median carbon price (in US dollars per tonne) across the Paris Agreement consistent 1.5°and 2°pathway groups

Appendix

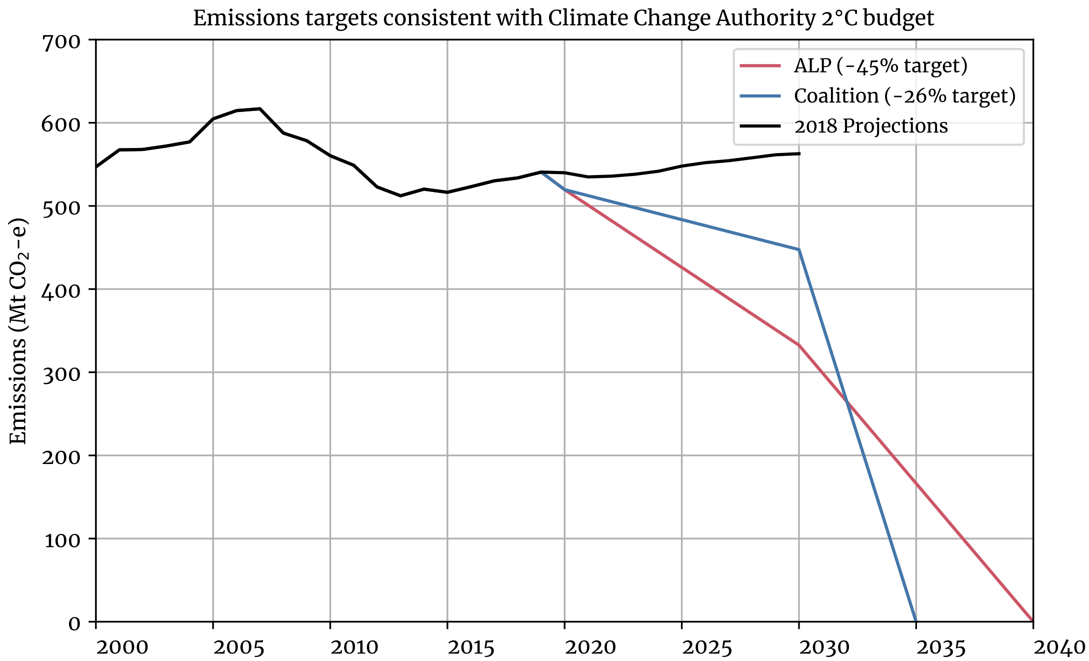


Figure 9: This figure illustrates the latest emissions projection from the Department of the Environment. On current projections, the 10.1Mt emissions budget determined by the CCA would be exhausted in 2031. Trajectories based on the current ALP and Coalition commitments and also consistent with the 10.1Mt budget are also illustrated.

Appendix: 1.5°C update

On Wednesday, 3 April 2019 Professor Garnaut delivered the first of several lectures, as part of an update to his previous works on climate policy in Australia, at the University of Melbourne[13]. As part of this seminar, he presented an update to both the international emissions budget, and the Australian emissions budget. Figure 10 shows the change in change in trajectory between 2010 and 2017, for the global 1.5°C and 2 °C budgets respectively. Figure 11 shows the change in the Australian budget for the 1.5°C, derived using the same approach used by the Climate Change Authority, when the aforementioned 10.1 MT budget was derived.

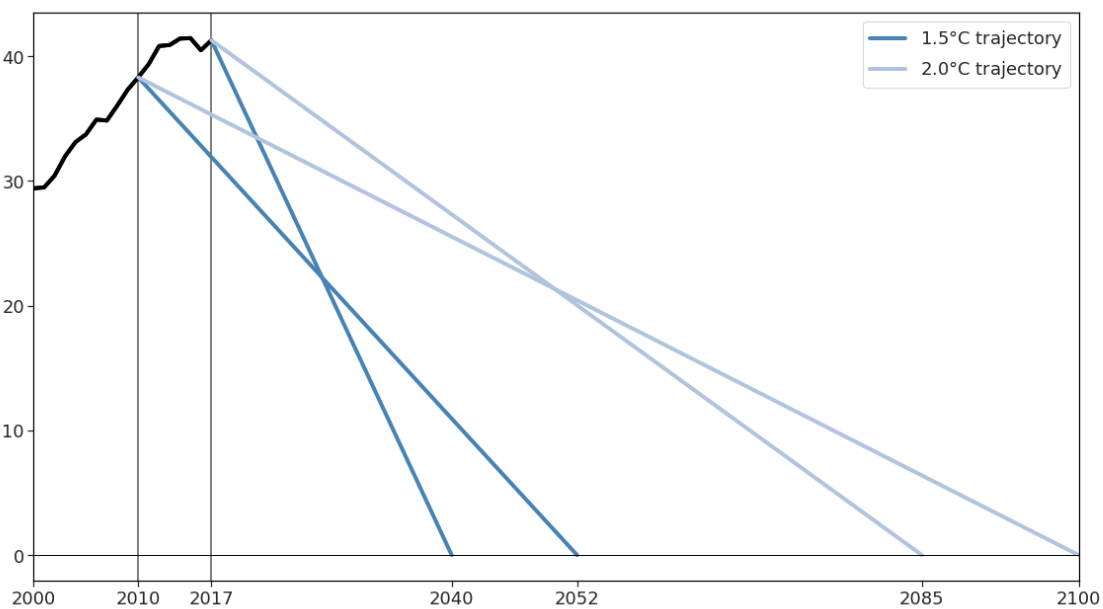
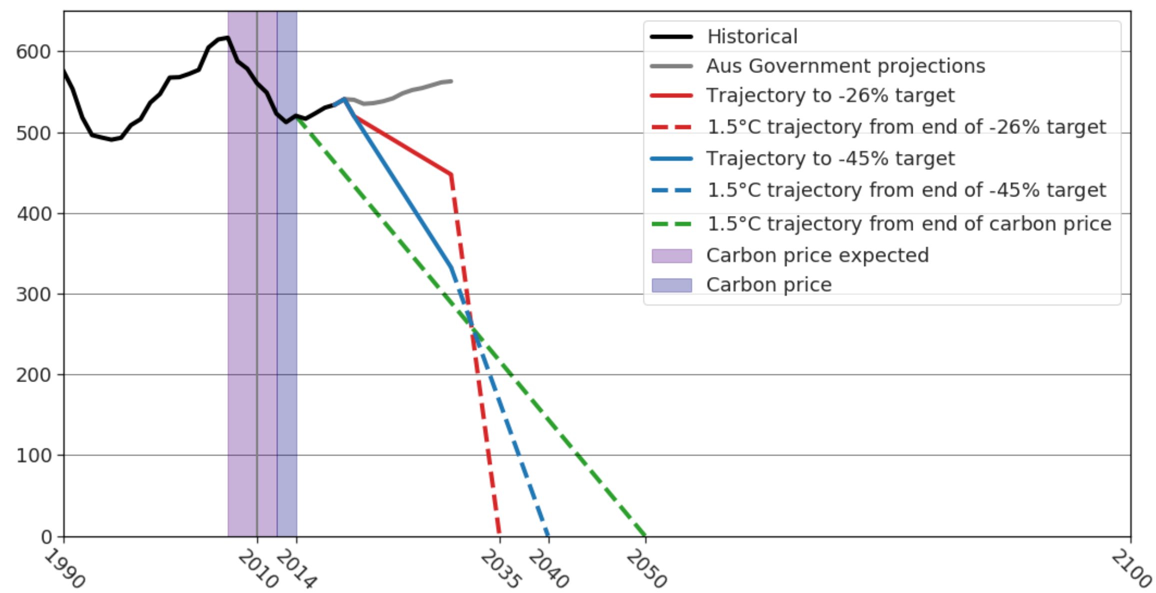


Figure 10: Change to international emissions trajectories between 2010 and 2017, for the 1.5°C and 2°C budgets[source: Garnaut (2019)]

[13]Professor Ross Garnaut (2019), *Lecture Series - Lecture 1: Exorcising the Diabolical Policy Problem*, Energy Transition Hub and University of Melbourne , Wednesday, 3 April 2019 - 6:30pm to 7:30pm, Public Seminar



Note: Australia's share of carbon budget calculated with modified contraction and convergence approach, see Garnaut 2008 and CCA 2014.
Source: Department of the Environment and Energy, accessed 29 March 2019.

Figure 11: Australia's updated 1.5°C budget, derived using the same approach used by the Climate Change Authority [source: Garnaut (2019)]